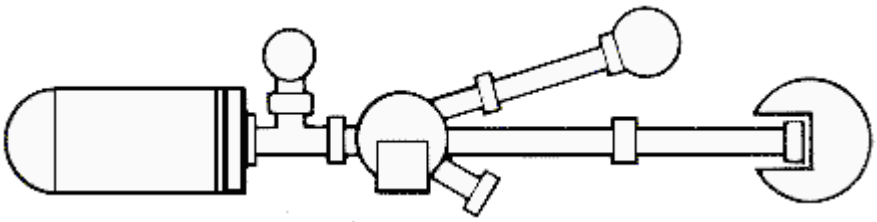
Book of Abstracts

21st International Conference on the Application of Accelerators in Research and Industry (CAARI 2010)



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This listing contains information about each presentation including all of the authors and their affiliations. If one wants to find out when Barney Doyle's talk is to be given, just look up his name in the index at the end of this book:

Doyle, Barney L. MON-AT03-1

Then go to the "PRESENTATIONS" listing to find

MON (i.e. the Monday presentations)
AT03 (the session codes are listed alphabetical, in this case AT is Accelerator Technology)
1 (the first talk of this session)

The details in this PRESENTATION listing includes the Presentation Number: #82
The type of presentation: Invited Talk
The day and time Session AT01 starts: Monday 1:00 PM
The location: The Bur Oak room

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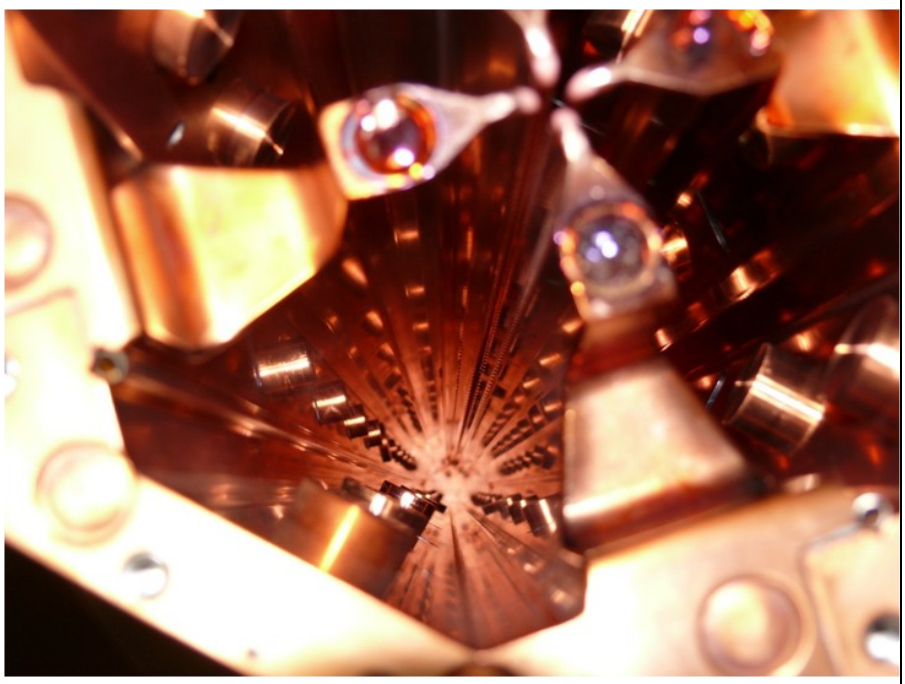

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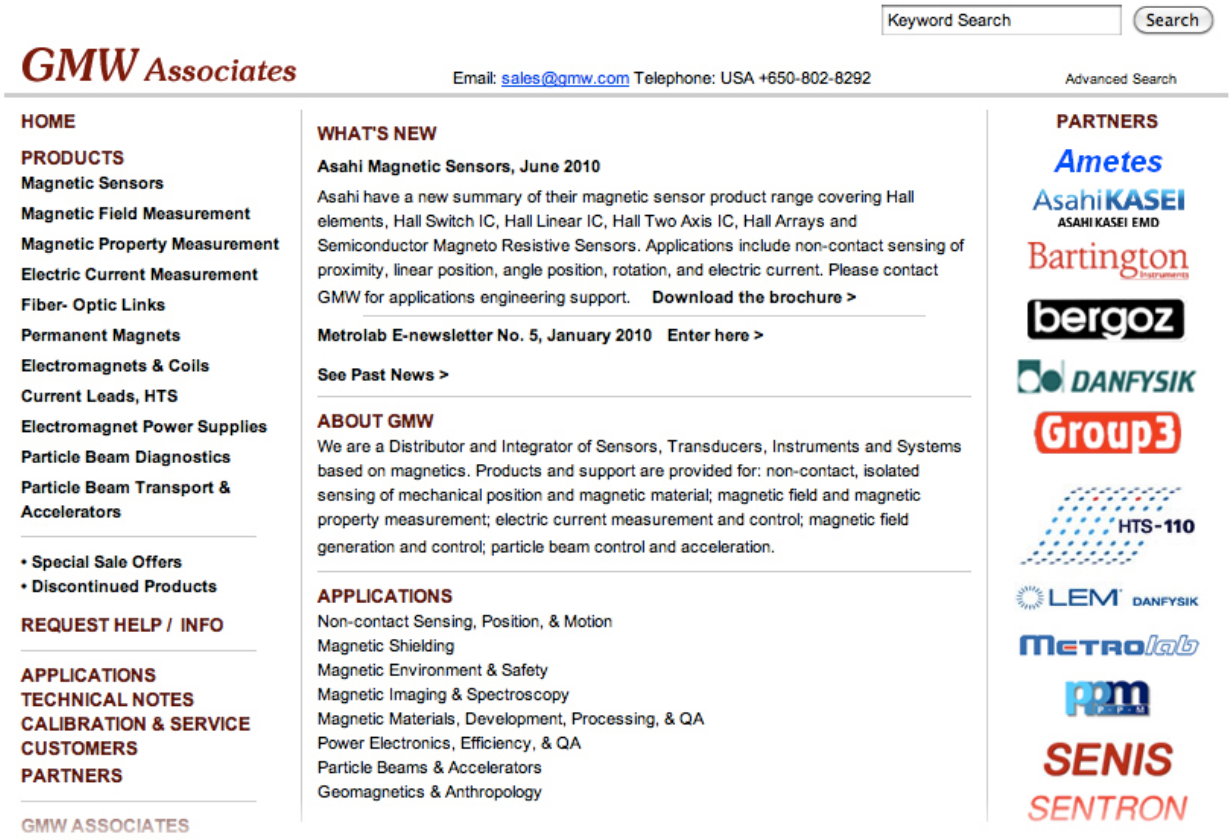

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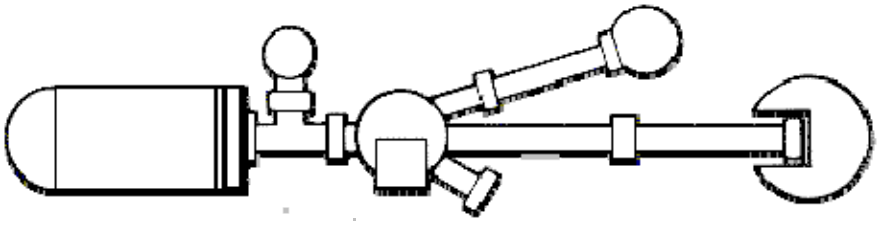

PRESENTATIONS

PLENARY, INVITED, CONTRIBUTED TALKS AND POSTERS

In Order by Day of the Week

MON-AP01-1 #156 - Invited Talk - Monday 1:00 PM - Elm Fork

Properties of multiply-charged actinide ions from Rydberg ion spectroscopy

Stephen R Lundeen
Physics, Colorado State University, 200 W. Lake St., Fort Collins CO 80523-1875, United States

The chemistry of actinide elements plays an important role in many issues of high national priority. Central to the chemistry is the actinide elements themselves, which normally occur in high ionization states. Yet these ions themselves are highly relativistic multi-electron systems that severely challenge a-priori theoretical methods, and of which very few experimental measurements are available. Spectroscopy of Rydberg ions consisting of a single highly excited electron bound to the actinide ion of interest can check the adequacy of theoretical methods by measuring specific properties of the actinide ion that control its long-range interactions, properties such as polarizabilities and permanent moments. Recent studies of this type begin with accelerated beams of actinide ions obtained from an ECR ion source. Rydberg ions are formed by charge transfer in a dense Rb Rydberg target, and the spectroscopy of high-L Rydberg levels is explored using the resonant excitation Stark ionization spectroscopy (RESIS) method. A Doppler-tuned CO2 laser excites selected Rydberg levels to a very high n state that can be easily Stark ionized. The resulting ion, collected and counted, shows that excitation has occurred. The laser excitation has sufficient frequency resolution to reveal the pattern of fine structure in the high-L levels that arises from the long-range interactions between the Rydberg electron and the actinide ion core that are present in addition to the dominant Coulomb attraction. Results to date and future prospects will be described

MON-AP01-2 #182 - Invited Talk - Monday 1:00 PM - Elm Fork

Atomic-orbital close-coupling calculations of electron capture from hydrogen atoms into highly excited Rydberg states of multiply charged ions

Katharina Igenbergs[1], Markus Wallerberger[1], Josef Schweinzer[2], Friedrich Aumayr[1]
[(1)]*Institute of Applied Physics - EURATOM-ÖAW, Vienna University of Technology, Wiedener Hauptstr.8-10/134, Vienna 1040, Austria*
[(2)]*Max-Planck-Institut für Plasmaphysik, EURATOM Assoziation, Max-Planck-Gesellschaft, Boltzmannstr. 2, Garching 85748, Germany*

Collisions of neutral hydrogen atoms with multiply charged ions have been studied in the past using various approaches [1]. Among these, the semi-classical atomic-orbital close-coupling algorithm offers an elaborate way of calculating total and state-resolved ion-impact cross sections. The wavefunction of the active electron in the target and the projectile potentials is expanded into basis states [2]. Convergence is achieved by applying a sufficient number of basis states on each center [3]. The advent of supercomputers and parallel programming facilities now allow treating collisional systems that could not be calculated before, because much larger basis sets involving much higher quantum numbers are now feasible. We want to present calculations of several collisional systems comparing lighter and heavier ion impacts. In our talk, we will focus on impact energies that are of interest in neutral beam diagnostics of hot nuclear fusion plasmas, i.e. roughly between 10 and 100 keV/amu [4]. In this energy regime the close-coupling formalism faces great challenges especially when treating heavy, highly charges ions such as Ar^{q+}. Below and above this region, we introduced non-coupling channels on the hydrogen center that allow to easily include a large number of excitation and ionization channels. In the intermediate energy region, these channels interact significantly with the basis states on the ion center. Therefore such an approximation cannot be made here.

Furthermore we will outline the used numerical algorithms as well as address issues concerning stability, runtime, memory needs, and parallelization schemes.

[1] Bransden B.H. & McDowell M.R.C. (1992) *Charge-Exchange and the Theory of Ion-Atom Collisions* (Internat. Series Monographs on Phys. **82**) (Clarendon: Oxford)

[2] Fritsch W. & Lin C.D. , Phys. Rep. **202** (1991) 1-97

[3] Igenbergs K. et al., J. Phys. B **42** (2009) 235206

[4] Isler R.C., Plasma Phys. Contr. Fusion **36** (1994) 171-208

MON-AP01-3 #226 - Invited Talk - Monday 1:00 PM - Elm Fork

Recent developments in the computational study of ion-atom collisions

David Robert Schultz
Physics Division, Oak Ridge National Laboratory, Bldg. 6010, MS 6372, Oak Ridge TN 37831-6372, United States

Contemporary computational methods to treat ion-atom/molecule collisions have opened opportunities to study them at a new level of detail and to uncover unexpected phenomena. Such interactions within gaseous, plasma, and even material environments are fundamental to such diverse phenomena as low temperature plasma processing of semiconductors, collapsing giant molecular clouds forming stars, fluorescent lighting, cold atom condensates, radiation treatment of disease, and the chemistry of earth's atmosphere. I will illustrate progress using examples from recent work treating very simple systems, for which our knowledge has been both subtly refined and significantly changed. In particular, using a novel computational approach, we have elucidated the origin of unexpected vortices in atomic collisions. Vortices are usually associated with systems containing large numbers of particles, however, we show the existence of those formed within atomic-scale wavefunctions and observable at macroscopic distance in collisions of protons with atomic hydrogen. We show how vortices appear in this system, rotate around the nuclei, and interact, thereby transferring angular momentum from nuclear to electronic motions, casting new light on how angular momentum is transferred in atomic-scale interactions.

MON-AP01-4 #283 - Invited Talk - Monday 1:00 PM - Elm Fork

Imaging slow dissociation of molecular-ion beams in strong fields produced by ultrashort laser pulses

Itzik Ben-Itzhak, Bishwanath Gaire, Mohammad Zohrabi, Jarlath McKenna, Nora G. Johnson, A. Max Sayler, Kevin D. Carnes, Fatima Anis, J. J. Hua, Brett D. Esry
J.R. Macdonald Laboratory, Department of Physics , Kansas State University, 116 Cardwell HALL, KSU, Manhattan Kansas 66506, United States

We have experimentally explored laser-induced dissociation of molecular ions, such as the benchmark H_2^+, HD^+, and H_3^+ molecules, using coincidence 3D momentum imaging. In this experimental technique a molecular-ion beam (few keV) is crossed by an ultrafast intense laser beam (typical pulses 7-50 fs, 10^{13}-10^{16} W/cm^2 at 790 nm). The resulting fragments, including neutral fragments, are recorded in coincidence by a time- and position-sensitive detector. Complete angular and kinetic energy release distributions are reconstructed from the measured momentum vectors of the fragments, and from this detailed information insight is gained into the dynamics of the dissociation process induced by the swift strong field. The focus of this study is on very slow dissociation processes, for which the kinetic energy release approaches zero. Explicitly, we will present clear evidence for zero-photon dissociation (ZPD) of H_2^+ - that is the dissociation driven by the strong field with the apparent absorption of zero photons. In addition, the fragmentation of the simplest polyatomic molecule, H_3^+, and the most likely dissociation pathways will be discussed.

*Supported by the Chemical Sciences, Geosciences, and Biosciences Division, Office of Basic Energy Sciences, Office of Science, U.S. Department of Energy.

MON-AP01-P1 #15 - Poster - Monday 5:30 PM - Rio Grande

M sub-shell x-ray production cross sections for 75-300 keV proton impact on W, Pt, and Pb

Sam J. Cipolla
Physics, Creighton University, 2500 California Plaza, Omaha NE 68178, United States

M x-rays from 75-300 keV protons impacting thick foils of W, Pt, and Pb were analyzed using a high-resolution Si(Li) detector equipped with an ultra-thin entrance window. X-ray production cross sections were derived and compared with the ECPSSR theory using different sets of transition rates, Coster-Kronig yields and fluorescence yields that are available in the literature.

MON-AP01-P2 #168 - Poster - Monday 5:30 PM - Rio Grande

Spectroscopy of high-L Rydberg levels of Fr-like Th using the RESIS technique

Mark E. Hanni[1], Julie A. Keele[1], Stephen R. Lundeen[1], Charles W. Fehrenbach[2]
[(1)]Deparment of Physics, Colorado State University, Fort Collins CO 80523, United States
[(2)]Deparment of Physics, Kansas State University, Manhattan KS 66506, United States

High-L Rydberg levels of Fr-like Th^{3+} have been studied using the Resonant Excitation Stark Ionization Spectroscopy (RESIS) technique. A beam of Rn-like Th^{4+}, obtained from a 14 GHz permanent magnet ECR source at Kansas State University, capture a single electron from a dense Rb Rydberg target, becoming a beam of Fr-like Th^{3+} in very highly excited states, n ~ 37. These Rydberg states are selectively excited to much higher levels, using a Doppler-tuned CO_2 laser, partially resolving the fine structure of the lower Rydberg level. Analysis of the spectrum with the long-range polarization model can be used to determine the polarizability of the Rn-like ion core.

This work supported by the Chemical Sciences, Geosciences, and Biosciences Division of the Office of Basic Energy Science, U.S. Department of Energy.

MON-AP01-P3 #483 - Poster - Monday 5:30 PM - Rio Grande

Thorium and Uranium M-shell x-ray production cross sections by bombardment with 4.5 - 10 MeV Carbon and 4.5 - 11.25 MeV Oxygen ions

L C Phinney[1], G Lapicki[2], D L Weathers[1], J L Duggan[1], F D McDaniel[1]
[(1)]Department of Physics, University of North Texas, 1155 Union Circle #311427, Denton TX 76203, United States
[(2)]Department of Physics, East Carolina University, Greenville NC 27858, United States

Total M-shell x-ray production cross sections have been determined for thorium and uranium for bombardment with 4.5 - 10 MeV carbon ions and 4.5 - 11 MeV oxygen ions. These results are compared to the theoretical values of the Plane Wave Born Approximation with the added electron capture cross sections provided by the Oppenheimer, Brinkman, and Kramers approximation of Nikolaev (PWBA+OBKN) [1,2], and the ECUSAR (DI+EC) theory [3,4,5]. The theoretical calculations use the recent atomic parameters of Chauhan and Puri [6]. The charge state dependence of the cross section will also be shown.

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MON-AT02-1 #169 - Invited Talk - Monday 3:30 PM - Bur Oak

New developments in highly charged ECR ion sources

Hongwei Zhao

Accelerator division, Institute of Modern Physics, Chinese Academy of Sciences, Nanchang Road No.509, Lanzhou Gansu Province 730000, China

Advancement of nuclear physics and high power heavy ion accelerator is always a driving force for persistent development of highly charged ECR (Electron Cyclotron Resonance) ion source. Increasing demands for more intense and higher charge state heavy ion beams have dramatically promoted development of ECR ion source technology and physics. In the past twenty years, beam intensities for highly charged heavy ions produced by ECR ion source have been increased by a factor 10-100 for different ion beams. This talk will provide an overview of new developments in intense highly charged ECR ion sources in the last few years. The key technologies, challenges and main issues related to construction and operation of high performance highly charged ECR ion source will be reviewed. Beam quality study and transmission of intense highly charged ion beams are also reviewed, which are important to achieve high injection efficiency for heavy ion accelerator. Future development and the next generation highly charged ECR ion source will be discussed.

MON-AT02-2 #381 - Invited Talk - Monday 3:30 PM - Bur Oak

Pushing the Beam Power Frontier with the SNS High Duty Factor H- Ion Source

Baoxi Han, Martin P. Stockli, Robert F. Welton, Syd N. Murray, Terry R. Pennisi, Manuel Santana
Spallation Neutron Source, Oak Ridge National Laboratory, P.O. Box 2008, MS 6461, Oak Ridge TN 37831, United States

The Spallation Neutron Source (SNS) ramped up the beam power from ~10 kW in 2006 to 1 MW in 2010 for the routine production of neutrons. This was accomplished by increasing the duty factor from ~0.1% to ~6%, which required significant modifications of the low-energy beam transport system to restore its availability to >99%. Due to the low duty factor, no source maintenance was required for the first two multi-month runs. In 2007, at 0.8% duty factor, a source failure led to the implementation of a two-week service cycle. This cycle was expanded to three weeks in 2008 and to four weeks in 2009 without any resulting downtime.

Most challenging was the simultaneous ramp up of the pulse length and the beam current, because the average beam current tended to decrease when the pulse length was increased. Learning to tune the RF for long pulses increased the beam current from ~13 mA to the initially-required 20 mA, but not to the 30-50 mA that had been obtained for short pulses. Enhancing the surface production of H- ions with an improved Cs-collar outlet aperture increased beam current by >50%. Improving the low-energy beam transport yielded another 15% gain until we reached the 38 mA linac beam current required for 1.0 to 1.4 MW operations.

Methodical engineering and procedural improvements and implementation of best practices in source preparation and startup led to fairly consistent performances (±10%) and to the well-established persistence of the beam current.

We continue to push the limits of our H- ion sources. On one occasion, a record beam current of 56 mA was demonstrated for ~20 minutes before the source was replaced at the end of its service cycle. This beam current is close to the 59 mA linac beam current required for 3 MW operations.

MON-AT02-3 #545 - Invited Talk - Monday 3:30 PM - Bur Oak

The New BNL EBIS Injector: Simultaneously Serving Multiple Requirements

E. N. Beebe, J. G. Alessi, M. Okamura, A. I. Pikin, D. Raparia
Collider-Accelerator, Brookhaven National Laboratory, 16 Fifth Street, Upton NY 11973, United States

A new heavy ion preinjector is currently being commissioned at BNL, which will provide beams for the Relativistic Heavy Ion Collider (RHIC) and the National Aeronautics and Space Administration Space Radiation Laboratory (NSRL). The preinjector consists of an Electron Beam Ion Source (EBIS), a 300keV/amu RFQ, and 2MeV/amu Linac. The

preinjector is designed to deliver milliampere currents of any ion species in ~10-40 microsec pulses, to allow single or few turn injection into the Booster ring. RHIC operations require that the EBIS delivers ions such as Au32+ with intensity ~3.0E9 particles/pulse for 10-40 microsecs pulses at 5Hz. In addition, the NSRL experimental program requires EBIS beams such as He2+, C6+, O8+, Si14+, Ti18+, Fe21+ and Cu22+ in ~2-3mA, 10 microsecs pulses.

Species are introduced into the EBIS at laboratory ground potential by either gas injection or low-charged ion injection from an external source, such as a hollow cathode ion source (HCIS). Ions are successively ionized to high charge state in the 1.5m long EBIS trap by a nominal 10A, 20keV electron beam, confined by a 5T superconducting solenoid. The entire EBIS and power supplies reside on an isolated platform, which is pulsed up to ~100 kV during ion extraction in less than 200 microsecs. This provides ion beams ~17 keV/amu for any ion species at q/m>1/ 6, in order to meet the entrance velocity requirement of the RFQ.

Total ion current measurement is made using both Faraday cups and non-destructive current transformers. Charge state analysis is made using a TOF spectrometer. EBIS design, operation and initial commissioning results will be presented.

*This work is performed under the auspices of the U.S. Department of Energy and the National Aeronautics and Space Administration

MON-AT02-4 #294 - Contributed Talk - Monday 3:30 PM - Bur Oak

Maximizing Persistent H- Beam Currents by Nano-Managing Stable, Fractional Mono-Layers of Cesium

Martin Peter Stockli, Baoxi Han, Syd N. Murray, Terry R. Pennisi, Manuel Santana, Robert F. Welton
Spallation Neutron Source, Oak Ridge National Laboratory, P.O. Box 2008, Bethel Valley Rd, Bldg 8600, MS 6461, Oak Ridge TN 37831, United States

The routine 1 MW beam power on the target of the Spallation Neutron Source originates from the ion source delivering 60 Hz, ~1-ms long, ~50 mA H- beam pulses. At ~6% duty factor, these high beam currents depend on a strong augmentation from H- ions produced on the cesiated Molybdenum ion converter surface which surrounds the ion source outlet. After proper plasma conditioning and an initial injection of <5 mg Cesium, the SNS source outputs a constant H- beam current without a steady flux of Cs, contrary to other cesiated H- sources.

Upgrading the beam power to 2-3 MW will require increasing the 38 mA linac peak current to 59 mA, of which 56 mA have been demonstrated. To routinely produce ~60 mA requires the optimization of all source parameters. The most intriguing optimization is obtaining the Cs mono-layer fraction that yields the maximum H- beam. Ion scattering data and numerous models suggest that the maximum occurs near 0.6 mono-layers, which corresponds to a minimum in the work function. This, however, has to be subject to experimentation to accommodate the technical variances intrinsic to the configuration required for a high-current H- source.

Experiments are now being conducted to determine the maximum beam current during gradual build ups of nearly-complete mono-layers of Cs on a cold, sputter-cleaned converter surface, which requires less than 200 ng Cs. Mono-layers that are too dense can be gradually reduced through either thermal emission or mass-selective sputtering to restore the optimal fraction.

In addition we will discuss the physics and diagnostics of our Cs system, which has allowed for reducing the initial Cs injection from ~30 mg down to < 5 mg, drastically reducing the arcing and any associated downtime and at the same time accelerating the successful startup of the ion sources.

MON-AT02-5 #133 - Contributed Talk - Monday 3:30 PM - Bur Oak

Ion source optimisation of the Van De Graaff accelerator at iThemba LABS

M E. M Eisa[1,4], J L Conradie[3], P J Celliers[3], J L G Delsink[3], D T Fourie[3], J G de Villiers[3], K A Springhorn[3,4], C A Pineda-Vargas[2,4]
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[(4)]*MRD Group, iThemba LABS, P.O. Box 722, Somerset West 7129, South Africa*

The operating principles of the two duoplasmatron ion sources and the PIG source available for the Van de Graaff accelerator have been determined qualitatively, mainly by studying the extensive literature on ion sources. The main characteristics of the three sources have therefore been determined experimentally on an ion source test bench. Important parameters of the sources such as the pressure and temperature in different regions of the sources not measured, because of space limitations. However, in spite of these limitations in quantitative understanding of the sources, sufficient information to continue with the study of the beam transport through the Van de Graaff accelerator and its beamlines could be obtained from these measurements. With regard to beam intensity, life-time and gas consumption the measurements showed that the hot-cathode duoplasmatron is at present by far the most suitable source for the van de Graaff accelerator.

The emittance of the ion source was measured with two slits, 90 mm apart, and a Faraday cup in the ion source test bench at an arc voltage of 83 V, an arc current of 1 Amp, a filament voltage of 24 V and an extraction voltage of 5 kV. The measured emittance for 90 % of the beam intensity is 48 mm mrad. This figure will be used to calculate the beam transmission through the Van de Graaf accelerator. Different computer programs have been used for these calculations from the ion source through the terminal section, the accelerator and beam line up to the Nuclear Microprobe (NMP) for beam quality.

MON-AT02-P1 #380 - Poster - Monday 5:30 PM - Rio Grande

ECR SOURCE BASED LOW ENERGY ION ACCELERATOR IN TIFR: DEVELOPMENT AND PERFORMANCE

Aditya N Agnihotri[1], Bhoopender Kumar[1], Siddharth Kasthurirangan[2], K V Thulasiram,[1], C A Desai[1], W A Fernandes[1], Lokesh C Tribedi
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[(2)]*Institute of chemical Technilogy, Matunga, Mumbai Maharashtra, India*

Electron Cyclotron Resonance (ECR) ion sources produce low energy, highly charged ions[1]. A wide variety of experiments involving the collisions at low velocities can be done using ECR ion-source. A new facility of ECR-based low energy ion-accelerator has been developed in TIFR, Mumbai. The ion-source [2,3] involves the plasma-chamber surrounded by all permanent magnets providing a suitable magnetic field (~1 T) for confinement. The plasma is powered by a 500 Watt, 14.5 GHz microwave supply. Charge states of ions produced are analyzed by a 900 analyzing magnet. The entire assembly including ion-source and the analyzing magnet is mounted on a high voltage deck. A new switching magnet will be installed to increase the number of beamlines. A LabVIEW based command and control system has been developed including wireless communication to operate the machine on high voltage. Charge state distribution of several gaseous-ions (He, N2, O2, Ne, Ar, Xe) have been measured. For Ar and Xe the maximum charge states measured were 16+ and 29+, respectively. A direct X-ray measurement for plasma diagnostics is carried out as a function of MW power and gas pressure. Typical electron temperature was found to be about 30-50 keV. Several experiments on fragmentation of bio-molecules, nano-dot formations on surfaces, ion-implantation, ion-beam mixing are initiated. Typical currents for some selected ions produced by the ECR ion-source and transported near the target position are the following: Ne(3+ and 10+)~4400nA and 15 nA; Ar(4+ and 16+)~10000nA and 10 nA; Xe(29+)~2 nA.

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MON-AT03-1 #82 - Invited Talk - Monday 1:00 PM - Bur Oak

The New Ion Beam Laboratory at Sandia National Laboratories

Barney L. Doyle
Radiation Solid Interactions, Sandia National Laboratories, PO Box 5800, MS 1056, Albuquerque NM 87185, United States

The US Department of Energy approved the construction of a new building at Sandia-Albuquerque in December, 2007. The building has now been completed and is called the Ion Beam Lab. The IBL has 20,000 square feet of high bay lab space and 7,000 square feet of office space. This new building houses the existing accelerators in the Radiation Solid Interactions (Physics) Department that can acceleration virtually any ion from energies ranging from 1 eV to almost 400,000,000 eV. Two new accelerators have been purchased as part of the project, including a 3 MV single-ended Pelletron installed in June and a multi-species focused ion beam (FIB) system manufactured in Japan by A&D that we are calling a NanoImplanter which is to be installed in December 2010. In this talk, the new facility will be described, and existing and anticipated research programs in the IBL will be discussed.

Sandia National Laboratories is a multi-program laboratory operated by Sandia Corporation, a wholly-owned subsidiary of Lockheed Martin company, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

MON-AT03-2 #482 - Contributed Talk - Monday 1:00 PM - Bur Oak

A Nuclear Microprobe Concept - From Physics Lab to a User Facility

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The Ion Beam Modification and Analysis Laboratory of the University of North Texas is currently developing a master plan including a major upgrade of its capabilities in the field of ion microprobe analysis and materials modification. The main part of this project is the creation of an innovative infrastructure for ion beam microscopy: A user friendly automated Quantitative Ion Beam Microscope (QIBMi) with focus on high sample throughput. The dedicated facility is designed to provide easy access for users, intuitive handling with a minimum of training needed, and remote control and monitoring options for off-site users.

The need for such an instrument becomes obvious when biomedical research has to take into account concentrations or distributions of particular elements in the investigated systems (e.g. metals in neurodegenerative diseases, altered elemental status in e.g. cancer cells or in arteriosclerotic lesions). But also materials research will gain from the improved performance of the microprobe technology. Standard ion beam analytical techniques will be brought into the sub-micron realm.

The presentation will give an overview on the state-of-the-art microprobe systems available worldwide with selected applications on the edge of the technology, and it will discuss the proposed microprobe system at UNT.

MON-AT03-3 #23 - Invited Talk - Monday 1:00 PM - Bur Oak

Present Trends in the Configurations and Applications of Electrostatic Accelerator Systems

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Despite the worldwide economic meltdown during the past two years and preceding any stimulus program projects, the market for electrostatic accelerators has increased on three fronts: new applications developed in an expanding range of fields; technical enhancements that increase the range, precision, and sensitivity of existing systems; and new accelerator projects in a growing number of developing countries. From the single application of basic nuclear structure research from the 1930's into the 1970's, the continued expansion of new applications and the technical improvements in electrostatic accelerators have dramatically affected the configurations and capabilities of accelerator systems to meet new requirements. This paper describes examples of recent developments in cosmology, exotic materials, high resolution RBS, compact AMS, dust acceleration, ion implantation, etc.

MON-AT03-4 #395 - Invited Talk - Monday 1:00 PM - Bur Oak

Assessed performance of the new NEC high resolution RBS system at CIM-AAMURI

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In February 2010 our 5SDH-2 Pelletron accelerator received a high resolution RBS detection system upgrade from National Electrostatics Corp. The system consists on a single focusing 90 deg magnet with an angle defining aperture at the entrance and a 100 mm wide position sensitive microchannel plate detector at the exit. The system is installed on the modified original RC43 chamber, with two positions to connect, for forward and back scattering geometries, with the whole assembly seated on a rail track, for easy maneuverability between the two positions. This arrangement is complementary to the original RBS setup using a SSB detector with an 18 keV resolution for the 2 MeV He+ beam. The new system's resolution should be able to reach 1 keV for 400 keV He+ beams. We tested the system with various energy He+ beams around 400 keV and various target samples from uniform, single crystal 6H silicon carbide, to highly oriented pyrolytic carbon, graphene sheets on various substrates, and nanolayered multi-sandwich structures for our thermoelectrics convertors program. We are going to discuss the performance of the system as a function of beam energy, position, sample type and condition.

MON-AT03-5 #341 - Invited Talk - Monday 1:00 PM - Bur Oak

Channeling facility with low temperature capability in Texas Center for Superconductivity at University of Houston

Dharshana Nayanajith Wijesundera, Xuemei Wang, Ki Bui Ma, Quark Chen, Buddhi Tilakaratne, Nirosha Kandegedara, Wei-Kan Chu
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Ion beam analysis and processing facilities in the Texas Center for Superconductivity at University of Houston is centered on a 1.7 MV NEC tandem accelerator. Via charge exchange, this accelerator is capable of producing up to 3.4 MeV protons, 5.1 MeV He ions, and over 10 MeV heavy ions. The beam line is fed by a SNICS source which can source upto 80 species and clusters of selected species, and an RF He ion source. The highlight of the talk will be the low temperature RBS/PIXE/NRA-channeling facility that can be used for channeling studies in the temperature range from 30K to 320K. The system can also be used for channeling implantation of different species and in-situ channeling studies. Sample manipulation and data acquisition is automated and software controlled. The manipulation system is embedded with geometric correction software for handling geometric distortion during channeling studies. The facility also includes software for common processing of channeling data.

MON-AT03-6 #298 - Contributed Talk - Monday 1:00 PM - Bur Oak

Can-AMS: The new accelerator mass spectrometry facility at the University of Ottawa

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The Canadian Centre for Accelerator Mass Spectrometry (AMS) at the University of Ottawa will consist of a new, 3 MV tandem accelerator with peripheral equipment for the analysis of elements ranging from tritium to the actinides. This facility, along with a wide array of support instrumentation recently funded by the Canada Foundation for Innovation, will be located in a new science building on the downtown campus of the University of Ottawa. In addition to providing the standard AMS measurements on ^{14}C, ^{10}Be, ^{26}Al, ^{36}Cl and ^{129}I for earth, environmental and biomedical sciences, this facility will incorporate, through agreements with the University of Toronto, and Health Canada, the new technologies of anion isobar separation at low energies using RFQ chemical reaction cells for ^{36}Cl and new heavy element applications, integrated sample combustion and gas ion source for biomedical and environmental ^{14}C analysis and the use of novel target matrices for expanding the range of applicable elements and simplifying sample preparation, all currently being developed at IsoTrace. An overview of the new facility will be presented and details of the new AMS technologies, in particular the Isobar Separator for Anions, will be discussed.

MON-AT03-7 #246 - Contributed Talk - Monday 1:00 PM - Bur Oak

High Beam Power Tandetron Accelerator Systems from HVEE

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In the last years High Voltage Engineering Europa (HVEE) has developed a new product line, the Very High Current Tandetron systems. Based on the current product line of tandem accelerators, with terminal voltages ranging between 1 and 6 MV, this product line is designed to deliver high beam power of up to 4 kW to target. Future extensions will cover 10 kW beam power capability. In this work we discuss the developments introduced to support beams with high current and high power. We focus on the results obtained on a 3 MV Tandetron accelerator with a beam power up to 3 kW. The system will be commissioned in 2011 by the "Saha Institute for Nuclear Research", Kolkata, India. The research activities that will be performed with this accelerator system include nuclear reactions in stellar interiors and pulsed beams research with nanosecond resolution and a repetition frequency of up to 4 MHz.To ensure failure-safe transport of the beams with kW intensity special emphasis has been paid to various beam line components like apertures, slits, Faraday cups. In addition, a software extension package for component protection against beam damage has been developed in-house and incorporated into the machine control software. Along with the high beam power requirements, the application also asks for high energy stability, in the 10^{-5} regime. Extra measures (advanced software/hardware control) have been taken to control for energy stability and beam positioning at target. Two ion sources will be discussed, the SO-120 for H^- / D^- and the SO-130 for He with output currents of 4 mA H^- respectively 50 μA He^-.

MON-AT03-P1 #115 - Poster - Monday 5:30 PM - Rio Grande

Automation and Optimization of a Mass Spectrometry Process

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Ion implantation is a materials engineering process by which ion species can be implanted into another material, thereby changing their physical properties. In order to obtain the implantation of a chosen isotope or to prevent the existence of more than one element on the target, the mass spectrometry is fundamental. The mass spectrum is registered in a plotter, after deflecting the ion beam with a magnetic field controlled by the operator through the current source.

In this work we present and discuss a fully automatic mass selection system. The system uses a PC to control and display the mass spectrum. Besides the computer, a data acquisition I/O board composed by multifunction input/output board NI

USB-6251 from National Instruments and four electronic modules using optic fiber control are used. The operator interacts with the I/O board that interfaces the computer and the ion implanter by a LabVIEW code. Some experimental results will be shown and the capabilities of the system discussed.

MON-AT03-P2 #141 - Poster - Monday 5:30 PM - Rio Grande

A new upcoming single-stage AMS facility at CAIS

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Accelerator mass spectrometry (AMS) of radiocarbon is widely being used

by researchers working in geology, archaeology and biomedicine and others.

The center for Applied Isotope Studies (CAIS) at University of Georgia

has been serving these research communities all over the world by providing

radiocarbon AMS services. The 0.5MV tandem accelerator built by NEC has been the work horse for over a decade continues to provide quality data

to the researchers.

As the sample throughput is approaching the capabilities of the machine,

there is a need for a second AMS sprectrometer to cater to the ever growing

demand of 14C AMS users. We have decided to acquire a second machine

and order has already been placed with NEC for a new single-stage AMS system. This system is proposed to be used mainly for 14C measurements of

natural products and also for biomedical applications. Details of the new system and proposed applications will be discussed.

MON-ECHT06-1 #447 - Contributed Talk - Monday 3:30 PM - Trinity Central

Tailored Positron Beams from Trapped Single-Component Plasmas

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There are a number of important uses of antiparticle beams (e.g., positron beams), including fundamental studies of antihydrogen, high energy particle accelerators, and the characterization of materials and material surfaces. However, antimatter's rare and violatile nature places serious limitations on source quality. Here, we present a new technique to create high quality positron beams having tailored width, energy spread, and brightness from positron plasmas in a Penning-Malmberg (PM) trap in a 5 tesla magnetic field [1]. By carefully lowering the confining trap potential on one end, beam pulses (< 10 microseconds) emerge from near the plasma center with radii as small as 50 micrometers, and energy spreads of 25 meV. A simple nonlinear model is used to derive the radial beam profile, number of extracted particles, and energy distribution function for a wide range of extraction parameters [1, 2]. Experiments with electron plasmas have verified the theoretical predictions over a wide range of plasma parameters. General trends in the beam characteristics as a function of

the plasma and extraction parameters will be discussed. Extraction of more than 50 % of a trapped plasma into a train of nearly identical beams is demonstrated. In some situations, an electrostatic beam (i.e., one in magnetic field free region) is more useful than a magnetically guided one. An experiment to create such a beam from a plasma in a PM trap, and then focus it electrostatically by a factor of five in radius, will be discussed. Emittance limits and prospects for future applications will also be discussed.

This work was done in collaboration with J. R. Danielson and C. M. Surko and supported by the NSF, grant No. PHY 07-13958.

1 T. R. Weber et al., Phys. Plasmas 15, 012106 (2008).

2 T. R. Weber et al., Phys. Plasmas 16, 057105 (2009).

MON-ECHT06-2 #201 - Contributed Talk - Monday 3:30 PM - Trinity Central

Measurement of Gas Electron Multiplier (GEM) Detector Characteristics Using Cosmic rays and Radio Active Sources

Seongtae Park, Edwin Baldelomar, Kwangjune Park, Mark Sosebee, Andy White, Jaehoon Yu
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The High Energy Physics group of the University of Texas at Arlington physics department has been developing gas electron multiplier (GEM) detectors to use them as sensitive gap detectors in digital hadron calorimeters (DHCAL) for the International Linear Collider, a particle accelerator. In this study, two kinds of prototype GEM detectors have been tested. One has 30x30 cm^2 active area double GEM structure with a 3 mm drift gap, a 1 mm transfer gap and a 1 mm induction gap. The other one has two 2x2 cm^2 GEM foils in the amplifier stage with a 5 mm drift gap, a 2 mm transfer gap and a 1 mm induction gap. The detectors' characteristics to high energy charged particles and other radiations have been tested by measuring the cosmic rays and 106Ru and 55Fe radioactive sources. From the 55Fe tests, we observed two well separated X-ray emission peaks and confirmed that the detectors work well. We also measured chamber gains which is measured to be over 6500 with a high voltage of 395 V across each GEM electrode. In both measurements of the cosmic run and the 106Ru run, we observed spectra which fit well to Landau distributions as expected from minimum ionizing particles.

MON-ECHT06-3 #266 - Contributed Talk - Monday 3:30 PM - Trinity Central

EIGENVALUE SOLUTIONS OF THE SEXTIC AND THE EIGHTIC OSCILLATOR

Sait Inan[1], Nureddin Turkan[2]
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In the past, there has been many attemps to solve the fourth order termed hamiltonian equation and the bell shaped potentials have been presented and encountered in the study of clustering pheomena. So, energy eigenvalues of the Hamiltonian in which the potential is in the form of power series expansion was examined. This hamiltonian has been considered as a perturbed harmonic oscilator and eigenvalues are solved under the assumption of fourth order terms. They showed that similar considerations can be used to gain insight into the collective model of nuclear structure. Moreover, there are also very few studies trying to solve sextic oscillator problem. In this study, it was tried to construct a brief solution for eigenvalue problem covering sextic and eightic orders. The first and second order perturbation theories are used as a solution method.

MON-ECHT07-1 #238 - Invited Talk - Monday 3:30 PM - West Fork

Neutron simulated damage in structural metals by ion beam irradiation

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This presentation will highlight recent advancements made at Sandia National Laboratories* into the simulation of neutron damage in cladding metals using ion beam irradiation. The renewed efforts to develop future generations of nuclear reactors combined with the continuing attempt to extend the lifetime and efficiency of current reactors requires a better understanding of neutron damage and the resulting changes in the mechanical properties of reactor components, particularly cladding materials. Due to the long lifetimes of a nuclear reactor and the low flux rates of current neutron testing facilities, many years are needed to reproduce the extent of damage seen over the lifetime of a reactor. The creation of this damage level can be condensed into a single day by self-ion irradiation using an EN tandem Van de Graaff/Pelletron accelerator, allowing for the evaluation of new material systems for cladding in nuclear reactors. Unfortunately, ion irradiation is limited to significantly smaller volumes; a limitation overcome by implementing small-scale mechanical testing. The microstructural rearrangements caused by ion irradiation are analyzed using EBSD and analytical TEM. A direct comparison of the microstructure formed by ion irradiation to that found in the literature to the same damage level is used to validate the neutron simulation technique taken. This approach permits rapid evaluation of the rate and extent of ion damage on current cladding metals, as well as the investigation of new engineered materials. The results of the ion irradiation studies, as well as small-scale mechanical property testing will be compared to molecular dynamics simulations of irradiation damage and published results of the mechanical properties and structures of neutron irradiated structural metals.

*Sandia National Laboratories is a multi-program laboratory operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin company, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

MON-ECHT07-2 #257 - Contributed Talk - Monday 3:30 PM - West Fork

Optical Properties of Ion Beam Induced Luminescent Materials

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The ability of luminescent materials to maintain their optical properties during and after radiation bombardment is important for a variety of applications, e.g. radiation detection and radiation effects microscopy. The luminescent spectra, decay time, and radiation tolerance are critical parameters for these applications. Changes in the emission intensity or spectrum of a scintillating material with radiation damage limits its' efficiency and usable lifetime. Typical well-studied luminescent materials include plastic scintillators, single-crystal semiconductors, and lanthanide-doped ceramics. Each of these material families offers exceptional performance for a specific parameter: plastic scintillators tend to have very fast decay times, ceramics have very high efficiencies, and semiconductors can produce uncommon wavelengths and be formed as transparent single-crystals. However, each of these benefits also comes with a significant limitation that can hinder the materials inclusion into these advanced applications. Materials from all of these groups have been studied for application in ion photon emission microscopy, which is a technique developed at Sandia National Laboratories for radiation effects studies. The materials investigated include Bicron BC400, Bicron BC430 , GaN of various doping levels, GaN/InGaN quantum wells of various structures, P47 (Y_2SiO_5:Ce), Y_2O_3:Eu^{3+}, $KGdTa_2O_7$:Eu^{3+}, $Y_4Al_2O_9$:Eu^{3+} and $Y_3Al_5O_{12}$:Ce. Ion-luminescent characterization studies have been carried out on these materials, including ion beam induced luminescence spectra, decay time measurements, and radiation tolerance studies. The results of these studies will be presented, as well as a discussion on the effects these results had on the material selection process for the IPEM application.

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MON-ECHT07-3 #222 - Contributed Talk - Monday 3:30 PM - West Fork

Activation of glassy carbon electrode using gold ion bombardment

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Glassy polymeric carbon (GPC) is a material commonly used for making electrodes for cyclic voltammetric and amperometric measurements.

One important step during the electrode fabrication is the activation of the carbon atoms. Polishing is the most common method for it. In addition, gold modified GPC electrode can yield greater sensitivity and selectivity over intrinsic glassy carbon electrodes. In this work, we used high energy gold (Au) ions to activate the surface of a GPC electrode made at Alabama A&M University.

Raman spectroscopy, atomic force microscopy (AFM), and X-ray photoelectron spectroscopy (XPS) were performed to compare the changes in surface morphology and structure before and after ion bombardment.

MON-ECHT07-4 #351 - Contributed Talk - Monday 3:30 PM - West Fork

Ion irradiation damage behavior of delta-Sc4Ti3O12

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Polycrystalline delta phase Sc4Ti3O12 was irradiated with light and heavy ions at cryogenic temperature, in order to examine the possible susceptibility of this compound to amorphization. Irradiated samples were characterized using grazing incidence X-ray diffraction (GIXRD) and cross-sectional transmission electron microscopy (TEM). We observed no amorphization transformation in our delta-Sc4Ti3O12 compounds, to a peak displacement damage dose of ~50 displacements per atom. However, we did observe an order-to-disorder (O-D) structural transformation, from an ordered delta-phase to a disordered fluorite phase by this dose. The resistance of delta-Sc4Ti3O12 to amorphization is remarkable because all titanate compounds examined to date, that possess fluorite derivative crystal structures, have been shown to be susceptible to radiation-induced amorphization (see, e.g., a review paper by K. Trachenko, J. Phys.: Condens. Matter 16 (2004) R1491). We will discuss our results within the framework of two considerations: (1) crystal structure; and (2) the Sc2O3 - TiO2 phase diagram.

MON-ECHT07-5 #516 - Contributed Talk - Monday 3:30 PM - West Fork

STUDY OF DEPTH-DOSE DISTRIBUTIONS FOR HIGH ENERGY BEAMS IN TISSUE LIKE MEDIA USING GEANT4

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We study the energy deposition by high energy beams in tissue-like media for the possible application in hadrontherapy. The depth-dose distributions for light particles like 12C, 14Si as well as for heavy particles like 56Fe, 58Ni beams will be presented by using Monte Carlo model based on the GEANT4 simulation software. These distributions are compared with each other. These studies will be very much interested for the purpose of hadrontherapy as well as for the study of radiation

dosimetry from high energy cosmic rays. The findings of Bragg's peak will be the main objective for these high energy beams at various energies available at the existing accelerator facilities like HIMAC, Japan, BNL, USA etc.

MON-ECHT07-6 #457 - Contributed Talk - Monday 3:30 PM - West Fork

The Characterization of Photocathodes and Secondary Electron Emitters for Use in Large Area Photo-Detectors

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The Large-Area Picosecond Photo-Detector Collaboration (LAPPD) unites a group of researchers from The University of Chicago, The University of Hawaii, Washington University, Stanford University, Argonne and Fermi National Laboratories, and the Space Science Laboratory, who are interested in the development of large-area systems to measure the time-of-arrival of relativistic particles with (ultimately) 1 pico-second resolution, and for signals typical of Positron-Emission Tomography (PET), a resolution of about 30 pico-seconds. Our contribution in this project is to help with identification and efficient fabrication of novel materials with properties optimized for use in such detectors. This encompasses both photocathodes for photon-to-electron conversion and secondary electron emitters for electron amplification. We have assembled several characterization techniques into a single ultra-high vacuum chamber in order to enable characterization of both photocathode and secondary electron emission (SEE) materials. This apparatus will examine how photocathode quantum efficiency and SEE material electron yield correlate to surface chemical composition, state, and band structure. The techniques employed in this undertaking are x-ray photoelectron spectroscopy (XPS) for surface chemical composition, ultraviolet photoelectron spectroscopy (UPS) for the determination of band structure and work function, as well surface cleaning techniques such as argon-ion sputtering. To determine secondary electron emission yields and quantum efficiencies of detector materials, we use a dedicated set of hemispherical electrodes that efficiently collect emitted electrons. As we gain a stronger insight into the detailed mechanisms of electron emission from photocathodes and SEE materials, we will be able to lay a foundation for the larger collaborative effort to design the next generation of large-area photo-detectors.

This work is supported by UChicago Argonne, LLC, under contract No. DE-AC02-06CH11357. Large-Area Picosecond Photo-Detector Collaboration (LAPPD) website: http://psec.uchicago.edu

MON-ECHT07-P1 #242 - Poster - Monday 5:30 PM - Rio Grande

Structural modifications and mechanical degradation of ion irradiated glassy polymer carbon

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The TRISO fuel that is planned to be used in some of the Generation IV nuclear reactor designs consists of a fuel kernel of UOx coated in several layers of materials with different functions. Here we are looking at the ion irradiation induced structural modifications of the glassy polymeric carbon (GPC) microstructure and their effect on the mechanical and physical properties. GPC is one of the materials considered as a potential replacement for the pyrolytic carbon coatings, with a function of diffusion barrier for the fission products. The material has to be able to withstand a high level of radiation damage without a significant loss of its qualities. For this work we irradiated GPC samples with 1 MeV protons, 5 MeV Ag and 5 MeV Au ions. We chose protons to simulate the effects of neutrons. Also, during the nuclear fission of 235U, the fission fragment mass distribution has two maxima around mass 98 and 137 that would best fit Rb and Cs,

respectively. However, both ions are hard to produce from our SNICS source at the accelerator, therefore we chose Ag (107 amu) and Au (197 amu) as best replacements. In this study, scanning electron microscopy (SEM), transmission electron spectroscopy (TEM), nano-indentation, and X-ray diffraction (XRD) were used for characterization. We were able to correlate the results with SRIM simulations of ion range and distribution, energy loss, and damage to the GPC material.

MON-FIBN01-1 #481 - Invited Talk - Monday 1:00 PM - Post Oak

Irradiation effects in nanostructured materials

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Nanostructured materials have been shown to exhibit a range of mechanical, electrical, magnetic and chemical properties, in some cases drastically improved compared to conventional structures. This is largely due to the large fraction of interfaces in these materials and to their metastability. Consequently, these novel structures are considered for a wide range of applications in extreme environments. Among these extreme environments, irradiation with energetic particles is an attractive option for obtaining irradiation resistant materials for a range of applications in fission and fusion reactor technology. The basic idea, that the point defects formed in the initial collision events (cascade) annihilate in the interfaces, i.e. grain and phase boundaries, has been proven correct for several nanostructured materials, including Pd and some ordered intermetallic compounds. This annihilation process is only possible if the structural dimensions, i.e. distance to the interfaces, are smaller than the typical diffusion lengths required for defect agglomeration. This agglomeration leads in conventional materials to the formation of defect clusters, and as a consequence irradiation damage. The inherent instability of nanostructured materials leads typically to rapid coarsening and loss of the improved properties. Therefore, the methods of stabilization of the desired nanostructures both by thermodynamic and kinetic approaches will be considered.

MON-FIBN01-2 #47 - Invited Talk - Monday 1:00 PM - Post Oak

Lateral diffusion in nanostructures fabricated by focused ion beams

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Ion implantation plays a very important role in semiconductor industry, especially microelectronics. Different kinds of ions are introduced into semiconductors by implantation in order to form n-type and p-type semiconductors. Nanoscale doped structures are required to be fabricated, usually by a focused ion beam (FIB), for applications in nanoelectronics. However, how closely these structures could be fabricated for an effective device performance would be determined by the limitation imposed by the lateral diffusion of the implanted species. For ion implantation, lateral straggling of the ion beam also produces defects surrounding the implanted region. This would produce radiation enhanced lateral diffusion. It is important to understand the lateral diffusion in FIB-fabricated nanostructures. We present a method based on photoemission electron microscopy (PEEM) for the determination of lateral diffusion coefficient in nanostructures. As an example, we present the investigation of lateral diffusion of Ga in FIB-fabricated structures of Ga-implanted n-type Si.

MON-FIBN01-3 #480 - Invited Talk - Monday 1:00 PM - Post Oak

Ion Beam Engineering of Advanced Diamond Devices

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Recent advances in diamond synthesis technologies have seen the emergence of diamond as front runner for practical, room temperature quantum information processing devices and for a new generation of ultrasensitive probes capable of measuring single spins in biological systems. These applications call for the development of a nanotechnology toolkit for diamond.

Ion beam techniques are of central importance in this toolkit. We employ a combination of MeV ion beams and focused ion milling to carve optical and mechanical structures into single crystal and ion implantation to create single colour centres which are used either as qubits or as single photon sources. This talk will review the interaction of ion beams with diamond and show how the ion beam induced phase transition from diamond to graphite can be used to sculpt mechanical and optical structures in diamond single crystals.

MON-FIBN01-4 #75 - Invited Talk - Monday 1:00 PM - Post Oak

Swift heavy ion induced conducting track formation in fullerene (C60 and C 70) thin films

Ambuj Tripathi
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We have shown the possibility of creating arrays of perfectly parallel conducting carbon nanowires, in fullerene (C60and C70) thin films. The passage of swift heavy ion results in an electronic energy loss induced increase in conductivity around ion path. The fullerene thin films, which have a conductivity comparable to insulators, turn into amorphous carbon around the ion track core and get polymerized along the ion track halo. Conducting tracks are studied after irradiation with 55MeV Ti, 120 MeV Au and 200 MeV Ag ion beams in C60 films and with and 100 MeV Ag ion beam in C 70 films. It is shown that the unirradiated films have a semiconducting nature of I¡VV characteristic, which shows an increased ohmic behavior with increasing fluence and increased conductivity with increasing electronic energy loss. The typical diameter of the conducting wires is observed to be about 50¡V200 nm for both C60and C70 films. The technique provides a simple control over the length, average spacing and angle from the surface by controlling the film thickness, ion beam fluence and the angle of irradiation. The conducting tracks in C60 film show excellent field emission properties. Irradiation with 120 Mev Au ions at a fluence of 5x109 ions/cm2 showed a reduction in threshold field to 9 V/?Ým from a high breakdown voltage of 51 V/?Ým for the as-deposited films

MON-FIBN01-P1 #228 - Poster - Monday 5:30 PM - Rio Grande

Thermoelectric Properties of Si/Si+Sb Nanolayered Thin Films Modified by MeV Si Ions Beam

R. Parker[1], S. Budak[1], C. Smith[2,3], J. Chacha[1], M. Pugh[1], K. Ogbara[3], K. Heidary[1], R. B. Johnson[3], C. Muntele[2], D. ILA[2]
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Thermoelectric power generators convert thermal gradients to electricity. The efficiency of thermoelectric devices is limited by the properties of n- and p-type (semi)conductors. Effective thermoelectric materials have a low thermal conductivity and a high electrical conductivity. The performance of the thermoelectric materials and devices is shown by a dimensionless figure of merit, ZT = S2sT/k, where S is the Seebeck coefficient, s is the electrical conductivity, T is the absolute temperature and k is the thermal conductivity. ZT can be increased by increasing S, increasing s, or decreasing k. We have prepared a thermoelectric device of 100 bilayers (Si/Si+Sb), superlattice films, using ion beam assisted deposition (IBAD). In order to determine the stoichiometry of the elements and the thickness of the grown multi-layer film, Rutherford Backscattering Spectrometry (RBS) and RUMP simulation have been used. The 5 MeV Si ion bombardments have been performed using the AAMU Pelletron ion beam accelerator, to make quantum clusters in the multi-layer superlattice thin films to decrease the cross plane thermal conductivity, increase the cross plane Seebeck coefficient and increase the cross plane electrical conductivity.

MON-FIBN01-P2 #231 - Poster - Monday 5:30 PM - Rio Grande

Thermoelectric Generator From SiO2/SiO2+Ag Multi-Nanolayered Films Effected by MeV Si Ions

C. Smith[1], S. Budak[2], J. Chacha[2], M. Pugh[2], K. Heidary[2], R. B. Johnson[3], Y. Yang[4], C. Muntele[1], D. ILA[1]
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We prepared 100 bilayers of SiO2/AgSiO2 with Au deposited on both sides as metal contacts. The deposited films have a periodic structure consisting of alternating layers where each layer is about 3.4 nm thick. The purpose of this research is to generate nanolayers of nanoclusters of Ag with SiO2 as host and as buffer layer, using a combination of co-deposition and MeV ion bombardment. The electrical and thermal properties of the layered structures were studied before and after 5 MeV Si ions bombardment at different fluences to form nanocrystals in layers of SiO2 containing few percent of Ag. Rutherford Backscattering Spectrometry (RBS) and RUMP simulation were used to monitor the stoichiometry before and after MeV bombardments and calculate the thickness of the deposited thin films. In addition to thermoelectric properties, the some optical properties of the SiO2/SiO2+Ag films have been measured.

MON-FIBN01-P3 #232 - Poster - Monday 5:30 PM - Rio Grande

Thermoelectric Properties of SiO2/SiO2+Au Nano-layered Superlattices Modified by MeV Si ions beam

S. Budak[1], C. Smith[3], J. Chacha[1], M. Pugh[1], K. Ogbara[3], K. Heidary[1], R. B. Johnson[2], C. Muntele[3], D. ILA[3]
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The efficiency of thermoelectric devices and materials is limited by the properties of n- and p-type (semi)conductors. Effective thermoelectric materials have a low thermal conductivity and a high electrical conductivity. The performance of thermoelectric materials and devices is shown by a dimensionless figure of merit, ZT = S2sT/k, where S is the Seebeck coefficient, s is the electrical conductivity, T is the absolute temperature and k is the thermal conductivity. ZT can be increased by increasing S, increasing s, or decreasing k. In this study we have prepared a thermoelectric generator from 100 alternating layers of SiO2/SiO2+Au superlattice films using ion beam assisted deposition (IBAD). In order to determine the stoichiometry of SiO2 and Au in the grown multilayer films and the thickness of the grown multi-layer films, Rutherford Backscattering Spectrometry (RBS) and RUMP simulation software package were used. The 5 MeV Si ion bombardment was performed using the CIM Pelletron ion beam accelerator to make nanoclusters in the multi-layer superlattice thin films to decrease the cross plane thermal conductivity, increase the cross plane Seebeck coefficient and increase the cross plane electrical conductivity.

MON-FIBN01-P4 #235 - Poster - Monday 5:30 PM - Rio Grande

MeV Si Ions Bombardment Effects on SiO2/SiO2+Cu Nanolayered Multilayer Film Thermoelectric Generator

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Thermoelectric devices could be categorized into two main groups, based on the direction of energy conversion: thermoelectric cooler (TEC), converting electricity to thermal energy, and thermoelectric generator (TEG), converting heat into electricity. Effective thermoelectric materials have a low thermal conductivity and a high electrical conductivity. The performance of the thermoelectric materials and devices is shown by a dimensionless figure of merit, ZT = S2sT/k, where S is the Seebeck coefficient, s is the electrical conductivity, T is the absolute temperature and k is the thermal conductivity. ZT can be increased by increasing S, increasing s, or decreasing k. We have prepared a TEG device from 100 alternating layers of SiO2/SiO2+Cu superlattice films using ion beam assisted deposition (IBAD). Rutherford Backscattering Spectrometry (RBS) and RUMP simulation software were used to determine the stoichiometry of SiO2, Cu in the multilayer films and the thickness of the grown multi-layer films. The 5 MeV Si ions bombardment was performed using

the AAMU Pelletron ion beam accelerator, to make quantum clusters in the multi-layer superlattice thin films, to decrease the cross plane thermal conductivity, increase the cross plane Seebeck coefficient and cross plane electrical conductivity.

MON-FIBN01-P5 #538 - Poster - Monday 5:30 PM - Rio Grande

Characterization of GeO2 nanocrystals prepared by microwave annealing

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GeOx films have been deposited on silicon substrate using RF magnetron sputtering. The as deposited samples were annealed at 9000C using microwave annealing. All the samples were subsequently characterized by X-ray diffraction (XRD) to observe the GeO2 nanocrystal formation. Raman spectroscopy and Transmission electron microscopy (TEM) measurements were also carried out to confirm the presence of the nanocrystals. The film topography was studied by atomic force microscopy (AFM).

MON-FIBN04-1 #12 - Invited Talk - Monday 3:30 PM - Post Oak

Crystalline Ge surface nanopatterns by erosion with heavy Bi-dimer and trimer ions

Bischoff Lothar, Heinig Karl-Heinz, Schmidt Bernd, Facsko Stefan, Pilz Wolfgang
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Two features of our heavy-ion-irradiation-induced surface patterns differ drastically from patterns formed on Ge with ions so far: The surface remains crystalline as proven by Raman measurements, and the dots and ripples heights equal their wavelengths (aspect ratio ~1).
The self-organisation of these very regular, high-amplitude dot and ripple patterns on (001)Ge has been found under bombardment with heavy ions of bismuth dimers and trimers. The Bi_2^+, Bi_3^+ and Bi_3^{++} ions are formed in a Liquid Metal Ion Source, they were accelerated, focused and scanned by a Focused Ion Beam system. 30 kV acceleration voltage and up to 10^{17} ions/cm^2 have been used.
In the ion impact angle range from normal to ~30° incidence, hexagonal patterns of dots with ~30 nm diameter and ~40 nm height are found. Using a Bi monomer ion beam having the same atomic energy and fluence like the dimer and trimer beams, an amorphous Ge nanosponge is found. In the incidence range from 30° to 60° Bi_3^{++} ions smoothen the Ge surface, whereas we found for 60° to 80° and more grazing incidence ripples and shingles perpendicular to the beam, respectively. The Bi_3^{++} ions are 16 times heavier than Ar^+ ions, and still 5 times heavier than Xe^+ ions. This high ion mass leads to a patterning mechanism different from the Bradley-Harper model, which becomes strikingly apparent by the crystalline Ge surface. An identified threshold of this new patterning mode could help to understand the mechanism: The ion-impact-induced deposition of energy per volume (as estimated by SRIM) must exceed a value which coincides with the energy needed for melting. Thus, Bi segregation during melt pool resolidification and the 5% volume difference between molten and solid Ge can cause the observed Bi separation and Ge patterning, respectively. A consistent, qualitative model will be discussed.

MON-FIBN04-2 #58 - Invited Talk - Monday 3:30 PM - Post Oak

Ion-induced Nanoscale Ripple Patterns on Si Surfaces

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Broad beam ion sputtering is a versatile tool commonly employed in many industrial processes, e.g. for surface cleaning and etching. Under certain experimental conditions, however, periodic nanoscale ripple patterns may form spontaneously by self-organization on the eroded surface. The formation of the ripple patterns can be explained in the framework of the Bradley-Harper model as resulting from the interplay between curvature dependent roughening due to ion sputtering and diffusional smoothing.

Periodic ripple patterns have been observed on a large variety of different materials including metals, semiconductors, and insulators and their periodicity can be tuned in the range from around ten up to several hundred nanometers by adjusting the experimental conditions. Thus, ion sputtering is a promising technique for the fabrication of large area nanopatterns with possible applications in microelectronics and thin film growth.

This talk will provide an overview of ion-induced pattern formation and present recent experimental results on the formation and evolution of nanoscale ripple patterns on silicon surfaces during low energy ion sputtering. In addition, promising applications of nanorippled Si substrates will be discussed.

MON-FIBN04-3 #143 - Contributed Talk - Monday 3:30 PM - Post Oak

Light-emitting Si nanostructures formed in silica layers within the tracks of swift heavy ions.

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Due to the quantum-size confinements Si nanocrystals are able to emit intense visible light, making them a promising candidate for the Si-based optoelectronics. Here we report the synthesis of Si nanostructures by the swift heavy ion (SHI) irradiation of the silica layers. The layers were fabricated by the plasma co-deposition of SiO2 and Si on the silicon substrates. The composition of the layers may be changed from ~100% of Si to a stoichiometric SiO2. 130 and 167 MeV Xe ions were used for irradiation with the doses of 3x1012 -3x1014 cm-2. The stopping power of such ions in the layers nearly completely (>99.8 %) consisted of the electronic losses. The spectroscopy of the photoluminescence (PL) and of the X-ray photoelectrons (XPS), and high-resolution electron microscopy were used for the characterizations. It was established, that even after the lowest dose electron microscopy revealed an appearance of 3-4 nm size dark spots. The XPS spectra demonstrated a decrease in number of Si-O4 bonds and growth in number of Si-coordinated Si atoms. Wide visible PL bands were observed after the irradiation. The spectra changed quite in compliance with the ion dose and the augmentation of Si content. The increase of the dose led to the growth of PL intensity followed with saturation after ~3x1013cm-2. For the lowest Si excess irradiation invoked formation of the PL band peaking at ~600 nm. But an increase in Si content made the long-wavelength emission dominating and peaking at ~780 nm. The emission in the 750-800 nm range is typical of the quantum-size Si nanocrystals. PL at about 600 nm is ascribed to the tiny Si nanoprecipitates. The results obtained are interpreted as the formation of Si nanostructures within the tracks of SHI. The contribution of the ionization and of the heating to the processes is discussed.

MON-FIBN04-P1 #221 - Poster - Monday 5:30 PM - Rio Grande

Modification of nanostructured materials by high-power ion beam irradiation

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The influence of high power proton-carbon ion beam treatment on nanostructure materials (por-Si, nanoporous SiO_2, carbon films) was investigated by and scanning electron and atom force microscopies. The melting of nanoporous Si and SiO_2 under high-power ion beam irradiation of nanosecond duration was observed. The sizes of ellipsoidal particles formed in Si and those of holes formed in SiO_2 under irradiation were determined. The possible origin of these morphology features was discussed. The influence of high power ion beam treatment on surface morphology and resistance of carbon films synthesized by PE CVD was investigated also. The possible mechanism of these surface morphology changes and increasing of carbon film resistance after irradiation was discussed.

MON-FIBN04-P2 #224 - Poster - Monday 5:30 PM - Rio Grande

Formation of periodical structures on the surface of the magnesium under high-power ion beam treatment

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Physics Department, Omsk State University, Pr. Mira 55a, Omsk 644077, Russia

The influence of high power ion beam treatment on surface morphology of the magnesium under high-power ion beam irradiation was

investigated by scanning electron microscopy. The formation of periodical structure and of the micro-and nanoparticles on the surface of the magnesium was observed. The spatial period of this structure and sizes of the micro- and nanoparticles formed on surface under irradiation high-power ion beam were determined. The possible mechanism of the formation of periodical structures and the particles on the surface of magnesium was discussed.

MON-IBA01-1 #356 - Invited Talk - Monday 3:30 PM - Brazos I

Recent progress in data analysis of Rutherford backscattering spectrometry and modeling of beam dispersion and dechanneling

Lin Shao
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In this talk, we summarize our recent activities in data analysis and modeling of Rutherford backscattering spectrometry: (1) A mathematical formula is given to describe a smooth transition from single scattering to multiple scattering in describing dechanneling of analyzing beams as a function of displacements; (2) a mathematical approach based on iterative improvement is given to extract dechanneling component without using any of predetermined dechanneling cross sections; (3) an approximation method is proposed to estimate beam dispersion through a compound layer; and (4) a Pearson VII distribution function is provided for fast calculation of dechanneling and angular dispersion of beams. These novel approaches are expected to increase accuracy and computational efficiency in channeling RBS analysis.

MON-IBA01-2 #157 - Invited Talk - Monday 3:30 PM - Brazos I

Applying Geometrically Adjusted Channeling Maps for Polarity Determination of Non-centrosymmetric Crystals

Dharshana Nayanajith Wijesundera[1,2], Ki Bui Ma[1,2], Xuemei Wang[1,2], Quark Chen[1,2,3], Paritosh Wadekar[1,2], Buddhi Tilakaratne[1,2], Nirosha Kandegedara[1,2], Wei Kan Chu[1,2]
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Ion channeling is a powerful analytical tool that can be used to study crystalline materials and crystalline thin films. Analysis by channeling is often linked with goniometry that defines geometric setting and manipulation of the crystal with respect to the analyzing ion beam and detectors. Depending on the geometric setting, distortions may be introduced to channeling maps that make data interpretation and experimental procedure difficult. A simple method for handling such mapping distortions in channeling crystallography will be discussed. Such a correction scheme is useful in analyzing complex and inherently asymmetric crystals. An application of such Geometrically Adjusted Channeling Maps (GACM) in determination of surface polarity of non-centrosymetric wuritzite structured ZnO, supported by simulation, will be presented.

MON-IBA01-3 #299 - Contributed Talk - Monday 3:30 PM - Brazos I

Strain Profiling with Simple Harmonic Planar Channeling

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The profile of strain in layered materials is frequently of interest in a study of these materials. One commonly used method to measure this profile is by ion channeling. More often than not, the angular scans are conducted along a planar channel at an axial channeling direction. The strain profile is then obtained from these angular scans by simulation. Here, we examine the alternative of conducting these scans across a planar channel at a direction off any major axis. If we adopt the simple harmonic potential description of planar channeling, the results could be interpreted more easily and the strain profiles can be recovered in a straightforward manner without resorting to simulation as a necessary step. We will demonstrate this approach with the analysis of strain on a number of superlattice systems with MeV alpha or proton ion beams.

MON-IBA01-4 #389 - Contributed Talk - Monday 3:30 PM - Brazos I

TOWARDS A TOF-BASED SOLUTION FOR BEAM ENERGY MEASUREMENTS AT LIEGE CYCLOTRON FACILITY - CONCEPTION AND PRELIMINARY RESULTS

Grégoire Chêne, Thomas Dupuis, François Mathis, André Marchal, Mathieu Clar, Henri-Pierre Garnir, David Strivay
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The AVF (Azimutal Varying Field) cyclotron of Liege can produce pulsed beams of positively charged particles (1H+ and 4He ++ essentially but also 2H+, 3He++) in a wide range of energies (from 3 to 24 MeV for protons or 5 to 24 MeV for alphas) which allows deeper probing of materials and access to rarely practiced nuclear reactions.

Among the first achievements towards the development of depth sensitive techniques at higher energies, optimization of beam optics and building of a new magnetically analyzed beam line has led to a satisfactory reduction by a factor of 20 of our cyclotron's "naturally poor" energy resolution. To fully profit of high-energy beams for analysis purposes, we now need to extend the Nuclear databases, and we intend to measure Non-Rutherford cross-sections for energies greater than 8 MeV, to allow correct interpretation of diffused particle spectrums. Accordingly we are developing adapted and dedicated set ups and methodologies for these measurements of prior importance for IBA users, namely with the recent mounting of the new "STANDARD de Liège" scattering chamber.

But to meet the accuracy and repeatability requirements for the monitoring of the mean energy of the incident beams used during these Non-Rutherford cross-section measurement procedures, and thus, at each energy step and over these unusual and wide energy-particle conjunctions and ranges, a Time-Of-Flight (TOF) based solution seems an interesting alternative to multiple and time-consuming, classic energy scanning of nuclear resonant events.

Taking full advantage of latest progress in MCP detectors and electronic chains time resolutions, an adapted set-up has been designed and will be mounted on the new High Energy-High Resolution beam line. First steps of its conception and first results obtained with this new TOF system dedicated to the energy measurements of the beam will be here presented.

MON-IBA01-5 #471 - Contributed Talk - Monday 3:30 PM - Brazos I

Multi-element Resonance Ionization Mass Spectrometry analysis of Genesis Solar Wind collectors

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A new generation of Laser Post-Ionization (LPI) Secondary Neutral Mass Spectrometers (SNMS) has been developed and constructed during at Argonne National Laboratory in order to enable trace-level quantitative elemental and isotopic analyses of samples having limited number of atoms of interest. One important class of such samples is formed by shallow ultra-low fluence ion implants represented by the Solar Wind (SW) collectors of the NASA Genesis spacecraft. These particular samples present significant challenges for analytical techniques, in part due to severe terrestrial contamination during the crash landing of the spacecraft, in part due to the low concentrations of SW implants (ppm to ppt) that peak at about 10-15 nm under the surface. In this work we will describe our efforts aiming at accurate and precise determination by

Resonance Ionization Mass Spectrometry (RIMS) of the fluences of Solar Wind Mg, Ca and Cr in the Genesis collectors. To this end, we developed and implemented new resonant photoionization schemes (using 422.78nm, 369.63nm and 285.30nm light), that allow simultaneous detection of Mg, Ca and Cr, using only three tunable lasers, and conducted a series of sputter depth profiling measurements by a sequence of alternating sessions of sputtering, using a raster scanned DC primary Ar+ ion beam, and TOF MS analysis, using the same ion beam in the pulsed (analysis) mode. We have tried and compared several different depth profiling arrangements aiming at identifying the optimal approach. At the Meeting we will summarize the results of these comparative studies. This work is supported by UChicago Argonne, LLC, under contract No. DE-AC02-06CH11357 and NASA through grants NNH08AH761 and NNH09AM48I.

MON-IBA01-P1 #124 - Poster - Monday 5:30 PM - Rio Grande

Stopping power of He, C and O in InN and GaN

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Group III nitrides such as InN and GaN and their alloys are very important materials in the field of optoelectronic and electronic devices such as high-brightness blue and white LEDs, multi-junction solar cells, high-frequency transistors, THz emitters and chemical sensors. The presence of unintentional impurities is one of the factors that can strongly affect the electronic properties of these materials, and thus ion beam analysis techniques can play a fundamental role, in particular heavy ion elastic recoil detection analysis. However, stopping powers in InN and GaN have not yet been measured, and data analysis relies on using the Bragg rule, which is often inaccurate. We have used a bulk method, previously developed by us and applied successfully to other systems, to determine experimentally the stopping power of several ions in InN and GaN. The results of our measurements and bulk method analysis are presented.

MON-IBA01-P2 #383 - Poster - Monday 5:30 PM - Rio Grande

Towards X-ray production and Non-Rutherford cross-sections measurements for 6-20 MeV alpha particles : latest developments on the dedicated « STANDARD » vacuum chamber and first results.

Thomas Dupuis[1], Grégoire Chêne[2], François Mathis[2], Michael Philippe[2], André Marchal[2], Mathieu Clar[2], Henri-Pierre Garnir[2], David Strivay[2]
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The IPNAS laboratory and the Centre Européen d'Archéométrie are partly focused on material analysis by means of IBA techniques. Using a CGR-520 AVF (Azimutal Varying Field) cyclotron allows us to produce high energy beams up to 22 MeV for both proton and alpha particles. The recent mounting of a new magnetically analyzed beam line is now providing an energy resolution of the probing beam comparable to that of classic electrostatic accelerators. Therefore, it allows investigating the benefits of combining and implementing particle-detection based and PIXE techniques with alpha particle beams and thus at High-Energy energies. Databases for both Non-Rutherford and X-Ray production cross-sections at energies greater than 8 MeV need to be extended.

A new "STANDARD de Liège" scattering vacuum chamber especially designed and optimised for cross-sections measurements has been installed on this "High Energy-High Resolution" beam line.

The set-up comprises five detectors (4 PIPS, 1 Si(Li)) and allows use of both thin and thick targets with accurate fluence control thus to perform simultaneously Non-Rutherford cross-sections measurements at four selected detection angles (150°, 165°, 170°, 177°) and X-ray production cross-sections under a well-established geometry.

The latest improvements, adaptations and optimisations in terms of geometry, calibration of beam fluence monitoring devices, electronic acquisition chains, will be described here.

Concerning X-ray production cross-sections measurements, we will focus on the 6-12 MeV energy range for light elements ($10 < Z < 27$).

Then, preliminary experiments performed to evaluate the accuracy attainable by the set-up for Non-Rutherford cross-sections and to select both appropriate Nitrogen targets (composition, surface roughness, effective thickness) and adapted as well acquisition procedures will be presented here.

MON-IBM01-1 #357 - Invited Talk - Monday 1:00 PM - Pecos II

Ion beam modification of carbon nanotubes

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Many traditional concepts in ion-solid interaction theory do not work at the nanoscale at all or require substantial modification. One such example is carbon nanotube. Challenges in scientific understanding exist at almost each stage of defect development, namely, damage cascade formation, thermal spike formation, defect recombination, defect clustering, and structural reconstructions in carbon nanotubes (CNTs). In this talk, we summarize the challenges in scientific understanding of radiation damage in CNTs and report our recent finding that ion irradiation can enhance thermal diffusivity of CNTs. Upon high energy proton irradiation, thermal diffusivity of carbon buckypapers first increases, then decreases with increasing fluences. The peak enhancement is a factor of 3 in comparison with a pristine sample. We believe inter-plane defects in CNTs increase the number of paths for energy dissipation, thus increasing thermal diffusivities. But at higher fluencies, scattering of thermal carriers becomes dominant and thermal diffusivity is reduced. Further tuning is possible by adjusting ion species and energies.

MON-IBM01-2 #241 - Contributed Talk - Monday 1:00 PM - Pecos II

Ion Beam Effects on Graphene's Electrical and Mechanical Properties

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Graphene is a one atom thick planar sheet of sp2-bonded carbon atoms, and has great potential as an electronic material. It is an atomic sheet of the same material that comprises carbon nanotubes and graphite. There are three types of graphene - theoretical, exfoliated, and epitaxial. Epitaxial graphene is the form studied in our lab. Epitaxial graphene is grown by starting with silicon carbide (SiC). When SiC is heated under certain conditions, silicon evaporates leaving behind carbon that reorganizes into layers of graphene. We focus our efforts in developing recipes for fabrication and characterization of epitaxial graphene on SiC and other non-conductive substrates. We are particularly interested in using accelerated ion beams to induce defects, in a controlled manner, in graphene sheets, develop the techniques to characterize such defects, and study the effects that these defects have on the mechanical and electrical properties of epitaxial graphene.

MON-IBM01-3 #445 - Contributed Talk - Monday 1:00 PM - Pecos II

Synthesis and characterization of nanostructures formed via implantation of carbon into silicon and silica

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We present a systematic study of the formation of β-SiC nanostructures by carbon ion (C^-) implantation into Si followed by high temperature annealing. The effects of the small variation in annealing time in the formation of β-SiC structures at an optimum annealing temperature has been studied. The quantitative analysis in the formation of β-SiC nanostructures has been performed by the implantation of various carbon ion fluences in the range of 1×10^{17} - 8×10^{17} atoms /cm^2 at ion energy of 65 keV into Si. It is observed that the average size of β-SiC crystals decreases whereas the amount of β-SiC increases with the increase in the implanted fluences when the samples were annealed at 1100°C for 1 hr. The amount of β-SiC increases only up to the fluences of 5×10^{17} atoms /cm^2. It appeared to saturate above this fluence.

Additionally, we present the formation and characterization of carbon nanoclusters in silica. The carbon nanoclusters were formed by the implantation of 70 keV carbon ions (C^-) at a fluence of 5×10^{17} atoms /cm^2 into a thermally grown silicon dioxide layer (~500 nm thick) on a Si (100) wafer. The implanted samples were annealed at 1100°C for different time periods of 10 min., 30 min., 60 min., 90 min., and 120 min., in the mixture of argon and hydrogen gas (96 % Ar + 4% H_2).
Low temperature Photoluminescence results to UV to visible emission (2.0 eV - 3.3 eV) from the samples pointing to carbon clusters, defects, and Si nanostructures at the Si-SiO_2 interface as the possible origin of luminescence. Luminescence at 3.3 eV disappears at room temperature measurements. A detail mechanism of the photoluminescence and its possible origin are discussed. Infrared spectroscopy, Raman spectroscopy, XRD, X-ray photoelectron spectroscopy, Photoluminescence spectroscopy, and Transmission electron microscopy were used to characterize the samples.

MON-IBM01-4 #375 - Invited Talk - Monday 1:00 PM - Pecos II

Neural Cell Attachment Studies on Ion Implanted Biodegradable Polymers

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In this work, our motivativation is to prepare neuronal growth stimulation on the biodegradable polymeric surfaces for artificial neural networks. We used metal-gas ion implantation to determine the best condition for neural guidance on biodegradable surfaces. As a polymer, we used lactide derivative Poly L-Lactide (PL), Poly -DL- Lactide Glycolide (PDLG), Poly Caprolactone (PCL) polymers and chitosan. Au and C ion implantations have been realized by using Metal-Vapour Vacuum Arc (MEVVA) ion implantation technique. Samples were implanted with a fluence range of 10^14 -10^17 ion/cm2 and extraction voltage of 20 kV. XPS, Fourier Transform Infra Red and Raman Spectroscopy techniques were used for surface studies. In vitro neural cell culture studies have been carried out with model cell lines (PC12 and Kelly) to demonstrate that Au and C ion implantation can stimulate the neural growth on biodegredable polymeric surfaces for biomedical and bioelectronics applications. Scanning electron microscopy (SEM) was used to demonstrate the cell attachments on the surfaces.

MON-IBM01-5 #116 - Contributed Talk - Monday 1:00 PM - Pecos II

Ion Beam Induced Bending and Alignment of Semiconductor Nanowires

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In recent years semiconductor nanowires (NW) have attracted much interest and a large variety of devices using NW have been presented. However, control of the nanowires is difficult and often a lot of work is necessary to position and align a single nanowire. Recently, it has been found that ion beam irradiation can be used to bend, realign, or reshape nanowires after growth, offering in principle a parallel method capable of manipulating large numbers of nanowires simultaneously.

We have irradiated nanowire ensembles using conventional ion beam systems and show that realignment of the nanowires is possible. In order to get a better understanding of the bending mechanism, single nanowires were irradiated using a two beam FIB, which allows in situ observation of the bending process using the integrated SEM. Furthermore, TRIM-like computer simulations of the ion beam irradiation of nanowires are presented, indicating that the ion induced defects play a major role in the bending.

MON-IBM01-P1 #416 - Poster - Monday 5:30 PM - Rio Grande

Water and Gas Permeability of Ion Implanted Electrospun Biodegradable Polymers

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Diffusional limitations of mass transport have adverse effects on biomaterials for tissue engineering that normally have high vascularity and cellularity. The current electrospinning method is not always successful to create micropores to encourage cell infiltration within the scaffold, especially when relatively large-sized pores are required. In this study, electrospun biodegradable polymers ion implanted with different range of energies and doses then its effects on porosity and permeability properties were examined.

MON-IBM02-1 #57 - Invited Talk - Monday 3:30 PM - Pecos II

The JANNUS Saclay multi-ion irradiation platform: Capabilities, performances and first application examples

Sandrine Miro[1], Patrick Trocellier[1], Yves Serruys[1], Eric Bordas[1], Hervé Martin[1], Nihed Chaabane[2], Stéphanie Pellegrino[2], Sylvain Vaubaillon[2], Jean-Paul Gallien[3]
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The multi-ion irradiation platform JANNUS (Joint Accelerators for Nanosciences and NUclear Simulation) is devoted to simulate the effects of neutron bombardment in nuclear materials based on single-, dual- or triple-beam experiments. Using the ion beams delivered by the accelerators of JANNUS, it is possible to study the combined effects of target damaging, ion implantation effects, helium and hydrogen production, and the occurrence of nuclear reactions.
Three electrostatic accelerators have been coupled in the JANNUS facility:
- a 3 MV Pelletron? from NEC, installed in December 2006. It is equipped with an ECR multi-charged ion source Nanogan? from PANTECHNIK, able to produce almost any ion beam from hydrogen to bismuth.
- a 2.5 MV single ended HVEE Van de Graaff used for research and teaching purposes able to supply proton, deuteron, helium-3 and helium-4 ion beams.
- a 2 MV Pelletron tandem from NEC installed in November 2009. It is implemented with a cesium sputtering charge exchange ion source, able to produce almost any ion beam except rare gazes.
Damage dose up to 100 dpa can be reached in 10 hours irradiation with heavy ion beams

Three beam lines (one from each accelerator) converge in a dedicated vacuum chamber implemented with a multi-Faraday cup device for dose monitoring and energy degraders. The sample holder allows irradiation to be carried on from - 150 °C to 800 °C. The first triple beam irradiation has been performed in March 2010.

First, we describe the experimental facility. Then, we will develop the different research topics conducted around JANNUS such as irradiation behaviour of structural materials for actual fission reactors, future reactors, and fusion machines, nuclear fuel developments and nuclear waste management. In the last part, we will illustrate some recent studies concerning advanced nuclear materials developed for Generation IV or fusion applications.

MON-IBM02-2 #73 - Invited Talk - Monday 3:30 PM - Pecos II

Simulating high energy neutron damage using ion irradiation

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Ion irradiation can be used to simulate displacement damage from high energy neutrons in thin samples. Both produce atomic displacement cascades of vacancies and interstitials. Two issues which arise are: a) damage similarity, ie. the extent

of defect clustering, and b) dose equivalence, ie. how many defects are produced per incident particle. Similarity of the damage can be assessed through atomistic simulations of displacement cascades, or through the primary collision energy distribution. Selection of the ion energy and mass allows some control over this. Damage can be quantified experimentally, for example using the minority carrier lifetime in a semiconductor or residual resistivity of a metal. Alternatively the damage may be quantified through simulations of primary collision events and ensuing displacement cascades. These issues will be discussed in the context of two recent studies. In one study, displacement damage in tungsten from fusion neutrons was simulated using 12 MeV silicon ions. The International Thermonuclear Experimental Reactor (ITER), is expected to produce enough fusion neutrons to cause nearly one displacement per atom in tungsten plasma-facing components. The concern is that that tritium injected from the fusion plasma will be trapped at displacement damage, thereby increasing in-vessel tritium inventory above allowed limits. This study showed that tritium retention by this mechanism is unlikely to be large enough to significantly impact operation of ITER. In the second example, silicon ion irradiation was used to simulate displacement damage from fission neutrons in silicon bipolar junction transistors. The concern here is that resulting lattice defects increase minority carrier recombination which degrades the gain of transistors and the efficiency of solar cells and photodiodes. In this case, defect clustering influences carrier recombination. The extent of defect clustering was found to be similar for damage from fission neutrons and end-of-range damage from silicon ion irradiation.

MON-IBM02-3 #22 - Invited Talk - Monday 3:30 PM - Pecos II

Conducting well-controlled ion irradiations to understand neutron irradiation effects in materials

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A firm understanding of the effect of radiation on materials is required in order to develop predictive models of materials behavior in-reactor and to provide a foundation for creating new, more radiation-tolerant materials. Ion irradiation can be used to understand the effect of neutron irradiation in nuclear reactor components and is becoming a key element of materials development for advanced nuclear reactors. Ion irradiations are rapid, low cost, and can be conducted with great control over temperature, dose rate, dose uniformity and total dose. In this presentation, the fundamentals of well-controlled ion irradiations as conducted at the University of Michigan will be described.

The ion beam is provided by a 1.7-MV tandem accelerator and raster-scanned over the samples. The samples are mounted on a specially designed end station (stage) that allows precise control of the temperature, current density uniformity, total current and current integration. Heat from the ion beam is conducted to a Cu-block that acts as a heat sink via a liquid metal layer between the back surface of the samples and the copper block. The temperature of the front surface of the samples is measured with a 2D thermal imager and controlled by either adjusting the beam current or the heat sink temperature. To achieve a uniform current density over the samples, a double slit aperture system is placed in front of the samples. The stage is electrically isolated from the aperture system and the rest of the beamline. Sample temperatures and beam currents are stored with a user selected frequency in an output file.

Post-irradiation analysis of beta radiation levels and microhardness are performed to verify the dose uniformity delivered to the samples. A final consideration is the importance of sample preparation.

MON-IBM02-4 #286 - Contributed Talk - Monday 3:30 PM - Pecos II

Medium energy ion irradiation capability for studies of radiation damage effects over a wide temperature range.

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Degradation of nuclear fuel and cladding materials properties in a nuclear reactor environment may be attributed to a combined effect of radiation damage accumulation and elevated operating temperature. A major cause of radiation damage in nuclear reactor fuels is the stopping of fast neutrons, fission fragments, high energy alpha particles and recoil nuclei formed following alpha decay. In this report we present, a medium energy (up to ~ 20 MeV) ion irradiation set up, which we developed to simulate a nuclear fuel radiation environment. Details of ion fluence accuracy and uniformity, sample

temperature control and measurement are described. The emphasis of this report will be irradiations in the temperature range from 400 to 1500 C, which are characteristic to a nuclear fuel pellet. Under normal operating conditions, typical temperatures at the fuel pellet surface and at the pellet centerline are within this range. Effects induced by irradiation with 10 MeV Au ions in a wide temperature and fluence range in multi-layered structures composed of HfO2 and MgO thin films will be presented. This multi-layer structure represents an idealized, CERCER (ceramic-ceramic) composite fuel form. The MgO is intended to represent a non-fissile component, while the HfO2 is a surrogate for a phase containing fissile species (U, Pu, etc.). Microstructural changes were examined using transmission electron microscopy (TEM) and grazing incidence X-ray diffraction (GIXRD). Inter-mixing between the composite layers was analyzed using Rutherford backscattering spectrometry (RBS) and scanning-TEM (STEM) elemental mapping.

MON-MAR01-1 #543 - Invited Talk - Monday 1:00 PM - Pecos I

Radiobiology of Particles: Introduction and Overview

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The CAARI 2010 Medical Applications and Radioisotopes (MAR) program will cover several important current issues in Hadron therapy. The Radiobiology of Particles Session MAR01 will focus on charged particles (protons and carbon ions) and neutrons.

The Session will open with a discussion of the status of theoretical modeling of biological effects of proton and carbon ion beams for particle therapy treatment planning with the Local Effect Model (LEM) by Thilo Elsaesser of Siemens.

This will be followed by presentation of a plan by Stephen Guetersloh to create a Center for Advanced Biomedical Imaging and Cancer Research at Texas A & M University (TAMU), College Station, Texas to establish an interdisciplinary center for biomedical imaging science and charged particle therapy research.

Neutrons are a secondary radiation produced in high-energy accelerators and must be considered in particle therapy for both the safety and treatment planning of the patient. Masashi Takada will report on recent neutron studies from the NASBEE (Neutron exposure Accelerator System for Biological Effect Experiments) at the NIRS in Chiba, Japan.

In cell biology, there are several modes of cell death. Autophagy, or autophagocytosis, is a catabolic process involving the degradation of a cell's own components through the lysosomal machinery. Linda Yasui of Northern Illinois University, DeKalb, Illinois will describe her work evaluating how fast neutron-induced autophagy can lead to necrosis in human glioblastoma multiforme brain tumor cells.

Finally we have a poster in this session describing a novel, agent-based model of proton treatment for murine eye melanoma that will be presented by Paolo Rossi and colleagues from the University of Padua, INFN, and IOV in Italy.

Supported by the Department of Energy under Contract # DE-AC02-05CH11231.

MON-MAR01-2 #392 - Invited Talk - Monday 1:00 PM - Pecos I

Biological Modelling for Particle Therapy Treatment Planning

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In recent years, particles like protons and carbon ions gained in importance for tumor therapy due to the beneficial dose distribution exhibiting the highest dose in the Bragg peak. Additionally, for the heavier particles the advantageous biological effectiveness offers a high potential for treatment with excellent tumor conformity.

Treatment planning for particle therapy needs to consider the relative biological effectiveness (RBE) in order to include the biological effects related to the irradiation with ions. The RBE quantifies these specific effects and must be determined at each position in the irradiation field. It depends on the energy of the primary beam and all its fragments, the irradiated tissue and the dose level.

The Local Effect Model (LEM) developed at GSI is currently the only model used for treatment planning taking these dependences into account. It calculates the RBE of ions for cell lines or tissues exploiting experimental/clinical photon data and an amorphous track structure model. For that purpose, the LEM simulates the distribution of double strand breaks (DSB) in the cell nucleus and analyzes it in terms of their spatial arrangement.

The LEM is used to investigate the RBE dependence of carbon ions on the linear-quadratic parameters of the corresponding photon survival curve, the ions' energy and the ion species, and it is compared to experimental cell inactivation data. Moreover, the applicability of the LEM is demonstrated by in-vivo experiments measuring the radiation tolerance of the rat spinal cord. Finally, the LEM is used to calculate the RBE-weighted dose for a typical treatment geometry for protons and carbon ions. The calculated cell survival is compared to recent measurements performed at HIT. Besides the benefit of carbon ions due to lower cell survival in the target volume relative to protons, the comparison demonstrates the applicability of LEM for both particle types.

MON-MAR01-3 #386 - Invited Talk - Monday 1:00 PM - Pecos I

TAMU Center for Advanced Biomedical Imaging and Cancer Research

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Texas A&M University, the oldest public institution in the State of Texas, has become a world leader in research and education. It is one of the few institutions in the nation that can boldly boast its holding of land-grant, sea-grant as well as space-grant designations. Texas A&M University is certainly one of the largest universities in the country not served by either a core imaging or an external particle therapy facility. Combining the two into one project provides unique and critical capabilities to both. The leading edge of advanced biomedical imaging research in the next few decades will be in personalized medicine, primarily molecular imaging. Teaming with a charged particle synchrotron facility will provide unique expertise and equipment to support the development new functionalized agents for advanced molecular imaging with PET and PET/MR. Similarly, the development of advanced tumor treatment technology will be greatly enhanced by the availability of real-time feedback through the imaging facilities. The two centers are synergistic and will provide Texas A&M with a unique research environment on both fronts. The recent development of the Texas Institute for Preclinical Studies (TIPS) and the Texas Institute for Genomic Medicine (TIGM) provides a unique environment and much of the collaborative and infrastructural support needed to provide a core imaging and cancer research facility to the TAMU campus. To this end, we are actively working toward the creation of the Center for Advanced Biomedical Imaging and Cancer Research that will expand the TIPS capabilities and establish an interdisciplinary center for biomedical imaging science and charged particle cancer therapy research.

MON-MAR01-4 #209 - Contributed Talk - Monday 1:00 PM - Pecos I

Neutron exposure Accelerator System for Biological Effect Experiments (NASBEE)

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Biological studies for neutrons have been performed using the Neutron exposure Accelerator System for Biological Effect Experiments (NASBEE) in National Institute of Radiological Sciences (NIRS), Chiba, Japan. Neutron biological data are necessary for radiation protections around high-energy accelerators, particle therapy and in aircraft. NIRS have focused to obtain the relative biological effects (RBEs) of several cancers of mice and rats. NASBEE provides the neutron beams produced from the d(4 MeV)-Be reactions at 500 micro-A on the target, cooled by flowing water. The neutron energy spectrum is measured from thermal energy up to 9 MeV and has a shoulder around 2 MeV. Two irradiation rooms can be used: one is normal neutron irradiation rooms for cell and physical irradiation and the other is for specific pathogen-free irradiation. We characterized the neutron irradiation field by measuring absorbed doses using neutron ion chambers, microdosimetric lineal energy distribution using low pressure proportional counters, energy spectra and spatial distributions. The neutron dose rates were measured to be 7.62 mGy/hr. The microdosimetric distributions are closely related to the biological effects of radiations and provides neutron RBEs, 3.5. Photon absorbed doses are contaminated to be 18% in the neutron beams. The neutron doses are within +-5% in the 120 mm in diameter. We are making neutron irradiation system to observe local neutron effect of rats (rat lungs).

MON-MAR01-5 #442 - Invited Talk - Monday 1:00 PM - Pecos I

Fast neutron induced autophagy leading to necrosis in glioblastoma multiforme cells

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Fast neutron irradiation kills human brain cancer, glioblastoma multiforme (GBM) cell lines. Clonogenic survival indicates that fast neutrons are more effective at killing GBM cells compared to gamma irradiation. The relative biological effectiveness (RBE) of fast neutron irradiation equals 2.4 . The majority of cells exhibit features of cell death with autophagy after irradiation with 2 Gy fast neutrons. The radiation-induced autophagy markers found in GBM cells were the appearance of autophagocytic vesicles by acridine orange staining and transmission electron microscopy and the increasing appearance of the lipidated, membrane bound protein called LC3-II. However, some cross talk between autophagy and another form of programmed cell death called necrosis is evident in images of irradiated cell samples. At several days after fast neutron irradiation, a small fraction of the irradiated GBM cells exhibit morphological evidence of necrosis. The number of necrotic cells increases with increasing dose and time after fast neutron irradiation. In contrast, the proportion of necrotic GBM cells does not similarly increase with increasing time after gamma irradiation. Our results suggest that necrosis induction by fast neutron irradiation is dose and time dependent, indicating we now have the means to specifically "turn on" necrosis in GBM cells. This ability to produce necrotic cells from autophagic, fast neutron irradiated GBM cells will allow us to investigate the necessary molecular parameters for the cell's choice towards cell death by necrosis in GBM cells. Understanding the role of necrosis in fast neutron induced cell death has significant clinical implications since necrosis induces an inflammation response. Avoidance of the inflammation response may provide a means of avoiding the lethal side effect of radiation induced gliosis.

MON-MAR01-P1 #376 - Poster - Monday 5:30 PM - Rio Grande

An Agent-Based Model of the Murine Eye Melanoma

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Human eye melanoma is today cured by radio therapy employing protons of intermediate energy (60 MeV). These particles feature a 27 mm penetration and a spatial spread of a few mm. An even better aim might be obtained with novel techniques, today under study, able to bring a lower energy radiation closer to the melanoma through a needle. This accuracy should reduce the damage to the retina and the loss of visual power that proton therapy currently implies. This paper is concerned with the importance of spatial resolution and hence the new aiming techniques. In view of future experimentation, we have modeled a mouse eye injected with a melanoma cell line and studied this latter's propagation through the different surrounding tissues, pinpointing the preferred transmission path and the most effective irradiation area, presuming a sub millimeter resolution. The modeling employs an open source multi-agent software platform (Swarm Simulation System) that is used to describe complex, dynamic and adaptive systems. We simulate a group of interacting cells, each one

represented by an agent, and include the crucial aspects of their behavior, such as the proliferation and the reaction to radiotherapy. Different kinds of proton therapy and their spatial accuracy are assessed.

MON-MAR02-1 #549 - Invited Talk - Monday 3:30 PM - Pecos I

Cell irradiation - from bench to bedside

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Cell irradiation studies provide important information about the way in which living cells respond to x-ray and particle beam irradiation. In this paper we describe the history of cell irradiation experiments and discuss the applications of ion microbeams for cell irradiation studies. Recent advances in cell irradiation are discussed along with the use of multi-scale mathematical models which allow experimental results to be translated into the clinical environment.

MON-MAR02-2 #77 - Invited Talk - Monday 3:30 PM - Pecos I

Ion, X-ray, UV and Neutron Microbeam Systems for Cell Irradiation

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The array of microbeam cell-irradiation systems is expanding for users at the Radiological Research Accelerator Facility (RARAF), Center for Radiological Research, Columbia University. The HVE 5MV Singletron particle accelerator at the facility provides particles to two focused ion microbeam lines: the sub-micron microbeam II and the permanent magnetic microbeam (PMM). Both the electrostatic quadrupole lenses on the microbeam II system and the magnetic quadrupole lenses on the PMM system are arranged as compound lenses consisting of two quadrupole triplets with "Russian" symmetry. Also, the RARAF accelerator is a source for a proton-induced X-ray microbeam (undergoing testing) and is projected to supply protons to a neutron microbeam based on the ^{7}Li(p,n)^{7}Be nuclear reaction (under development). Leveraging from the multiphoton microscope technology integrated within the microbeam II endstation, a UV microspot irradiator - based on multiphoton excitation - is available for facility users. Highlights from radiation-biology experiments on single living mammalian cells and on small animals are included in this review of microbeam systems for cell irradiation at RARAF.

Supported by the National Institute of Biomedical Imaging and Bioengineering under Grant: NIBIB 2 P41 EB002033-14.

MON-MAR02-3 #139 - Invited Talk - Monday 3:30 PM - Pecos I

Ion beam radiobiology and chemotherapy for high-grade brain tumour

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High-grade gliomas are the commonest form of primary brain tumours. Glioblastoma (GBM), the major and most aggressive type of glioma, has an extremely poor prognosis. For many years, the conventional treatment has been maximal surgical resection followed by radiotherapy, with a median survival time of less than 10 months.

Recently, a randomized phase III trial has confirmed the benefit of temozolomide (TMZ) chemotherapy, given during and after radiotherapy, and has defined a new standard of care for the treatment of patients with high-grade brain tumours.

Although TMZ represents a significant advance in neuro-oncology, the combined treatment of TMZ and radiotherapy is still unlikely to be curative.

Alternative strategies are needed to further improve outcome for patients with GBM.

High linear-energy transfer (LET) ions offer several potential advantages over conventional radiotherapy. Their superior dose profile permits increased energy deposition on the target without increasing the severe side effects on the normal tissue, and make them attractive for treating radioresistant tumours like GBM.

The objectives of this work were to assess the potential role of TMZ and to explore its synergistic contribution in addition to X-rays, and low energy protons and alpha-particles (< 7 MeV) on a panel of four glioma cell lines.

This study suggests that proton and alpha-particle irradiation can induce cell death in glioma cells more effectively than photons reporting an increased relative biological efficiency (RBE). TMZ causes additive cytotoxicity when combined with X-rays, protons and alpha-particles.

Our results need further evaluations in real clinical studies that incorporate both chemotherapy and particle therapy.

MON-MAR02-4 #354 - Invited Talk - Monday 3:30 PM - Pecos I

Optimization of radiation treatment of cancer patients with severe tumors by cellular and molecular studies on different ions

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Aim: This project aims to investigate the cellular and molecular responses to radiation of different ions.

Material and methods: Tumor cell lines with different human origin (melanoma, lung, prostate and head and neck) and with different gene status have been exposed to accelerated ions (boron, carbon, nitrogen, argon and iron) and low linear energy (LET) -rays. Dose response curves for clonogenic cell death have been established at different LET (13-200 keV/µm) to achieve the D10 dose. Cell samples have been collected at different post-irradiation times (a few minutes up to several days) for the D10 and the SF2 dose. Analyses of different types of cell inactivation (apoptosis, necrosis, senescence, cell cycle alterations etc) have been performed as well as investigations on up and down regulations of different proteins.

Results: Depending on the origin but also on the gene status of the cells the responses differed for cell inactivation. The data also shows a LET and ion species dependence, where the induction of different modes of cell death, cell cycle alterations as well as protein expression also varied.

Conclusions: Accelerated ions are significantly better to use than photons in treatment of radiation resistant tumors since a total higher cell kill can be achieved in the tumor but also because the normal surrounding tissue can be speared from damage. In addition, depending on ion and LET, elevated levels of apoptosis can be induced in p53 mutated tumor cells that normally are insensitive to low LET induced apoptosis.

MON-MAR02-P1 #398 - Poster - Monday 5:30 PM - Rio Grande

Fast highly charged carbon ion interaction with Uracil: ionization and fragmentation

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Fast charged particle induced multiple ionization and fragmentation can provide crucial input data for numerical track structure codes used to quantify radiation damages. The fast highly charged ions passing through the biological tissues can induce severe damage to the DNA and such damage is produced by primary ions as well as secondary electrons. We have studied ionization and fragmentation of Uracil by fast C and O ions of energy (2-5 MeV/u). The ions were obtained by a 14 MV Pelletron tandem accelerator facility. The experimental setup consists of a recoil-ion time-of-flight mass spectrometer. The Uracil gaseous target is produced by evaporation from a powder sample in a resistively heated oven. Heating up to 1750 C was enough to obtain sufficient target density without thermal dissociation of molecule.

The tof spectrum obtained shows single ionization of Uracil and mainly the fragments having m/q of 69, 43 and 28 . The spectrum which is similar to that for photo-ionization and e-impact ionization spectrum. The relative cross sections derived form the peak intensity of single ionization and fragments were plotted as a function of charge states of the ions. The charge state dependence of single ionization yields is found to be linear which is in contrast to the expected q2-dependence as used normally in modeling of the DNA damage. The yield of singly ionized Uracil decreases sharply with energy. Such a decrease is expected based on a CTMC type calculation as shown in [3] for proton. Such a calculation is in progress which will be the first such comparison between theory and experiment for large bio-molecules.

References

[1] Schlathölter et al. Int.J.Mass Spectr. 233 (2004) 173.

[2] de Vries et al. PRL 91 (2003) 053401.

[3] Lekadir et al. PRA 79 (2009) 062710.

MON-NBA01- #52 - Invited Talk - Monday 3:30 PM - Brazos II

Edward´s sword? - a study of ancient weaponry using photon activation analysis; a reprise

Christian R. Segebade
Idaho Accelerator Center, Idaho State University, 921 South 8th Ave., Stop 8106, Pocatello Idaho 83209-8106, United States

An ancient long sword was studied using high energy photon activation analysis (PAA) and other non-destructive investigation techniques. The aim of this study was the search for indication of forgery or any alterations eventually made after the estimated time of production (about middle of the 14th century), e.g. later replacement of parts of the weapon. The blade material was studied using non-destructive PAA; the decorative gold applications were analysed by radiochemical PAA. Photon radiation (X- and gamma ray) measurements were performed by standard spectroscopy techniques. The experimental results including analytical as well as metallographic investigations did not yield any evidence of non-authenticity. This stands in agreement with a thorough stylistic study and a weapon-historical assessment, both performed by an expert specialised in the respective scientific areas.

MON-NBA01-1 #490 - Invited Talk - Monday 3:30 PM - Brazos II

An Overview of Activation Analysis Techniques and Applications

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Activation analysis, being the only analytical method that is based upon nuclear interaction, can be performed using three different techniques, namely: Activation with neutrons (NAA), high energy photons (PAA) and charged particles (CPAA). The different features of these versions will be discussed in this presentation, including their respective advantages and drawbacks, the different types of nuclear reactions, the instrumentation required, basic operation procedures, radiation safety issues and other aspects. Basically, any kind of material can be studied. The analysis can be carried out frequently instrumentally (without radiochemical separation steps), in favourable cases non-destructively. This feature is of particular relevance in several applications, e.g. studies of precious goods and antiques. Several typical application cases will be discussed.

MON-NBA01-2 #415 - Invited Talk - Monday 3:30 PM - Brazos II

Photon Activation Analysis on Dust Particles

Philip Cole, Mayir Maimaitimin, Christian Segebade
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Instrumental analytical methods are preferable in studying the expected milligram quantities of airborne particulates collected in dust filters. The multi-step analytical procedure used in treating samples chemically is complicated. Moreover, due to the expected small masses of the "dust particles" collected on filters, such a chemical treatment can easily lead to significant contamination levels. Radioanalytical techniques, and in particular, activation analysis methods offer a far cleaner alternative. Activation methods require minimal sample preparation and provide sufficient sensitivity for detecting the vast majority of the elements throughout the periodic table. While neutron activation (NAA) has historically been the more standard technique, in this paper we shall discuss the technique of activating the dust particles with 10 to 30 MeV photons by means of photon activation analysis (PAA). The samples are imbedded in dust collection filters and are irradiated "as is" by these photons. The radioactivity of the photonuclear reaction products are measured with appropriate spectrometers and the respective analytes are quantified using multi-component reference materials. The special advantages and drawbacks of this technique are outlined in this paper.

MON-NBA01-3 #479 - Contributed Talk - Monday 3:30 PM - Brazos II

Using Photon Activation Analysis to Determine Concentrations of Unknown Component in Reference Materials

Jaromy Green[1], Zaijing Sun[1], Doug Wells[3], Buck Benson[2], Herb Maschner[2]
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Using certified multi-element reference materials for instrumental analyses one frequently is confronted with the embarrassing fact that the concentration of some desired elements are not given in the respective certificate, nonetheless are detectable, e.g. by photon activation analysis (PAA). However, these elements might be determinable with sufficient quality of the results using scaling parameters and the well-known quantities of a reference element within the reference material itself. Scaling parameters include: activation threshold energy, Giant Dipole Resonace (GDR) peak and endpoint energy of the bremsstrahlung continuum; integrated photo-nuclear cross sections for the isotopes of the reference element; bremsstrahlung continuum integral; target thickness; photon flux density. Photo-nuclear cross sections from the unreferenced elements must be known, too. With these quantities, the integral was obtained for both the known and unknown elements resulting in an inference of the concentration of the unreported element based upon the reported value, thus also the concentration of the unreferenced element in the reference material. A similar method to determine elements using the basic nuclear and experimental data has been developed for thermal neutron activation analysis some time ago (k0 Method).

MON-NBA01-4 #489 - Contributed Talk - Monday 3:30 PM - Brazos II

Practical and Analytical Aspects of the Production of Cu-67 using the Photon Activation Method

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Production aspects of Cu-67 using the photon activation technique with a linear electron accelerator are under investigation. Various radiochemical separation techniques can be used for the separation of copper from irradiated zinc target. Selection of optimal target materials and geometry are the focus of our research. Beam parameters are also key factors in the production of medical isotopes in any accelerator facility. In this study; analysis and optimization of the photon activation method for the production of Cu-67 via flux distribution in the target, activity in the target, dose distribution during the runs and associated physics have been investigated.

MON-NBA01-5 #122 - Contributed Talk - Monday 3:30 PM - Brazos II

Standardizing Activation Analysis: New Software for Photon Activation Analysis

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Photon Activation Analysis (PAA) of environmental, archaeological and industrial samples requires extensive data analysis that is susceptible to error. For the purpose of saving time, manpower and minimizing error, a computer program was designed, built and implemented using SQL, Access 2007 and asp.net technology to automate this process. Based on the peak information of the spectrum and assisted by its PAA library, the program automatically identifies elements in the samples and calculates their concentrations and respective uncertainties. The software also could be operated in browser/server mode, which gives the possibility to use it anywhere the internet is accessible. By switching the nuclide library and the related formula behind, the new software can be easily expanded to neutron activation analysis (NAA), charged particle activation analysis (CPAA) or proton-induced X-ray emission (PIXE). Implementation of this would standardize the analysis of nuclear activation data. Results from this software were compared to standard PAA analysis with excellent agreement. With minimum input from the user, the software has proven to be fast, user-friendly and reliable.

MON-NBA01-6 #56 - Contributed Talk - Monday 3:30 PM - Brazos II

Photon activation analysis of light elements using "Non-Gamma" radiation spectroscopy

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Unlike metal determinations the analysis of light elements (e.g., carbon, oxygen, phosphorus) is frequently problematic, in particular if analysed instrumentally. In photon activation analysis (PAA) the respective activation products do not emit gamma radiation in the most cases. Usually, annihilation quanta counting and subsequent decay curve analysis have been used for determinations of C, N, O, and F. However, radiochemical separation of the respective radioisotopes mostly is indispensable. For several reasons, some of the light elements cannot be analysed following this procedure, e.g. phosphorus. In this contribution the instrumental PAA of phosphorus in organic matrix by activation with bremsstrahlung of an electron linear accelerator and subsequent beta spectroscopy is described. The accuracy of the results was excellent as obtained by analysis of a BCR Reference Material.

MON-NP01-1 #350 - Invited Talk - Monday 1:00 PM - Trinity Central

RHIC status, upgrades and future plans

Thomas Roser
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RHIC is the first hadron accelerator and collider consisting of two independent superconducting rings and has operated with a wide range of beam energies and particle species. After a brief review of the achieved performance the presentation will give an overview of the plans, challenges and status of machine upgrades, that range from a new heavy ion pre-injector and beam cooling at 100 GeV to a high luminosity electron-ion collider.

MON-NP01-2 #51 - Invited Talk - Monday 1:00 PM - Trinity Central

Relativistic Heavy Ion Nuclear Physics at the LHC and RHIC

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The Large Hadron Collider (LHC) at CERN has now begun its p+p collision program and Pb+Pb collisions are expected to commence later this year. The first decade of research at the Relativistic Heavy Ion Collider (RHIC) at BNL produced many surprising discoveries and began to quantify the intriguing properties of the hot dense matter produced in high-energy heavy-ion collisions. In the first three years of RHIC operations

(2000-2003) the observed hadron suppression and jet quenching in Au+Au collisions at 200 GeV was confirmed (by comparison with d+Au results) to be a final-state effect. The top science news story of 2005 was the announcement that the hot dense matter (and by implication the early

universe) behaved not like an expected weakly-coupled expanding gas, but rather like a strongly-coupled plasma that flows like a nearly-perfect fluid. These and many other surprises from the RHIC program lay the basis for our expectations for exciting complementary results from the LHC.

Early results from the LHC p+p data and expections for the Pb+Pb program will be presented in the context of what we have learned so far at RHIC.

MON-NP01-3 #219 - Invited Talk - Monday 1:00 PM - Trinity Central

J-PARC status, Nuclear and Particle Physics.

Susumu Sato
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In J-PARC, three experimental facilities are in operation; materials and life science facility (MLF), neutrino facility, and hadron physics facility. Since November 2006, beam commissioning of the accelerator has been performed, and then productions of neutrons, muons, kaons, and neutrinos were performed in May, September 2008, February, and April 2009, respectively.

Currently (as of the 9th program advisory committee for nuclear and particle experiments, held in January 2010), nine experiments are approved in the hadron physics facility, and one experiment (T2K experiment, for neutrino oscillation) is approved in the neutrino facility. After the 1st stage approval (where scientific merit is high), the 2nd stage approval is given as a green light for each of these ten experiments to proceed, based on the technical achievability, the reliability of cost estimate, and the other various aspects of feasibility. The nine in the hadron physics facility include, penta-quark search in $\pi^-p \rightarrow K^-X$, search for deeply-bound kaonic nuclear states by in-flight $^3He(K^-,n)$ reaction, measurement of X-rays from Ξ^- atom, spectroscopic study of Ξ-hypernucleus via $^{12}C(K^-,K^+)$ reaction, $K_L \rightarrow \pi^0\nu\nu$-bar experiment, and so on.

In February 2010, the T2K began to observe neutrino at Super-Kamiokande, and hyper nucleus experiments observed Σ^- through $p(\pi^-,K^+)\Sigma^-$ reaction.
In this talk, progress of accelerator commissioning and status of experiments in nuclear and particle physics are presented.

MON-NP01-4 #513 - Invited Talk - Monday 1:00 PM - Trinity Central

A new Facility for Rare Isotope Beams (FRIB) at Michigan State University

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The 2007 Long Range Plan for Nuclear Science had as one of its highest recommendations the "construction of a Facility for Rare Isotope Beams (FRIB) a world-leading facility for the study of nuclear structure, reactions, and astrophysics. Experiments with the new isotopes produced at FRIB will lead to a comprehensive description of nuclei, elucidate the origin of the elements in the cosmos, provide an understanding of matter in the crust of neutron stars, and establish the

scientific foundation for innovative applications of nuclear science to society." A superconducting, heavy-ion, driver linac will be used to provide stable beams of >200 MeV/u at beam powers up to 400 kW that will be used to produce rare isotopes. Experiments can be done with rare isotope beams at velocities similar the driver linac beam, at near zero velocities after stopping in a gas cell, or at intermediate velocities through reacceleration. An overview of the envisaged science program and the design for the FRIB DOE national users facility on the campus of Michigan State University will be presented.

Work supported by DOE CA DE-SC0000661 and Michigan State University.

MON-NP01-5 #263 - Invited Talk - Monday 1:00 PM - Trinity Central

Synthesis of a New Element with Atomic Number Z=117

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An international team (1) has identified a new chemical element with atomic number Z=117 in fusion reactions between a Ca-48 ion beam and a Bk-249 target (2). The Bk was produced at Oak Ridge National Laboratory* by intense neutron irradiation of Am/Cm targets in the High Flux Isotope Reactor followed by chemical separation and purification at the Radiochemical Engineering Development Center. The resulting Bk material was coated on titanium foils at the Research Institute of Atomic Reactors in Dimitrovgrad, Russia, and irradiated for five months with an intense Ca-48 beam at the U400 heavy ion cyclotron at the Joint Institute for Nuclear Research in Dubna, Russia. A total of six atoms of element 117 (including both the A=293 and 294 isotopes) were detected using the Dubna gas-filled recoil separator. Nine new heaviest known isotopes were observed in subsequent decay chains. The measured decay properties demonstrate a strong rise in stability for heavier isotopes, providing experimental evidence for the long sought island of enhanced stability for superheavy elements.

(1) Joint Institute for Nuclear Research (Dubna, Russia), Oak Ridge National Laboratory (Oak Ridge, Tennessee), Lawrence Livermore National Laboratory (Livermore, California), Vanderbilt University (Nashville, Tennessee), University of Nevada-Las Vegas (Las Vegas, Nevada), and Research Institute of Atomic Reactors (Dimitrovgrad, Russia)

(2) Yu. Ts. Oganessian et al., Phys. Rev. Lett. 104, 142502 (2010)

*Oak Ridge National Laboratory is managed by UT-Battelle, LLC, for the Department of Energy.

MON-NP01-P1 #322 - Poster - Monday 5:30 PM - Rio Grande

Design Feature of K=200 cyclotron for ISOL

JIN AH PARK, Khaled Mohamed Mohamed Gad, Byeong-No Lee, Yong-Seok Lee, Hyun-Wook Kim, Ho-Seung Song, Jong-Seo Chai
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Korean National project ,KoRIA, was launched on April, 2010. In KoRIA facility we will produce the radioisotope beam for the basic science research. K=200 sector separated cyclotron was designed in conceptual. It has 6 separated sector magnets. 2 of SF cyclotrons will be used as injectors for this main cyclotron. RF frequency is 46 MHz, 6th harmonics. In this paper we have calculated and simulated 200MeV cyclotron's magnet by OPERA 3D (TOSCA) code. Ion beam dynamics calculations have been doing using particle studio code to prove the focusing properties of the designed magnet.

MON-PL01-1 #262 - Invited Talk - Monday 8:30 AM - Pecos I & II

ITER a Fusion Energy Source

Michael A Ulrickson
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Deuterium/tritium fusion has a peak cross section at about 110 keV. An alpha particle with 3.5 MeV and a neutron with 14 MeV are produced by the reaction. A plasma temperature of 100 million degrees and a density of 10^14 /cc can create up to 2 W/cc of fusion energy. Alpha particles are magnetically confined to the plasma and maintain the temperature and the neutron breeds new tritium while being stopped in a blanket where steam or hot Helium gas is produced. Electricity can be generated from the hot gas using known methods. ITER will be the first fusion device to enter the burning plasma regime where the reaction will continue as long a fuel is added to the reactor. ITER is a collaboration among Europe, Japan, Russia, USA, Korea, China, and India. Construction has started at the host site in France and various other locations where components are being fabricated by the partners. ITER is expected to generate up to 10 times more energy than needed to generate the plasma. Super conducting coils will allow pulse lengths up to 3000 sec. The energetic fusion particles can generate many plasma instabilities. The advances of the past decade have involved control of the instabilities and better energy confinement. The interaction of the hot plasma with the walls of the device is one of the greatest challenges facing the ITER design team. Advances in materials and plasma facing component technology are one of the reasons the International community agreed to pursue the aggressive ITER device. In a region only a few cm thick, the plasma cools from 10M degrees to room temperature, neutralizes, and recycles from the wall. Plasma materials interactions have a strong influence on core plasma performance. Accelerators are one of the tools used to diagnose plasma wall interactions.

MON-PL02-1 #40 - Invited Talk - Monday 9:15 AM - Pecos I & II

A Rapier, not a Broad Sword: Accelerator-based Analyses of Aerosols for Global Climate Research

Thomas A Cahill
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Global climate research is in a critical condition, and needs our help. The growing understanding that aerosols play the dominant (~ 80%) role in global climate model (GCM) uncertainties poses enormous problems for developing causal, as opposed to associative, relationships. Unlike gasses, which are pretty well understood, knowledge of aerosols requires the simultaneous information on particle size and composition as a function of time. Particle, size, because light scattering changes by an order of magnitude between 0.1 and 1.0 micrometer diameter, particle composition because light scattering and absorption are critically dependent on composition and albedo, and time because meteorology rules, both in term of sources and transport. Now add the requirement that this information must be known over much of the globe and for at least 9 levels vertically in the atmosphere, and you see the depth of the problem. The enormous advantage of focused energy beams is that by using momentum and focusing capabilities, accelerator-based laboratories, even the smallest, can do global climate research simply unavailable to standard optical and filter based techniques. I will also discuss the reasons why the global climate community is so loathe to accept this conclusion. I will develop these themes, and show recent data from our Greenland site and elsewhere. I will end by discussing the role of accelerator based analyses for health and welfare, which for different reasons has similar difficulties, and offers similar opportunities. In both these areas, I will present an proposal to assist the CAARI community to meet these challenges.

MON-PL03-1 #281 - Invited Talk - Monday 10:00 AM - Pecos I & II

Industrial Applications of Accelerators

Robert W. Hamm
R&M Technical Enterprises, Inc., 4725 Arlene Place, Pleasanton CA 94566, United States

Particle accelerators, originally developed for basic science research, are now manufactured predominantly for medical treatment or industrial applications, with the number of accelerators in use for industrial applications exceeding the number in use for medical treatment. This Conference, which covers all three of these accelerator applications, became one of the earliest conferences to include industrial accelerator applications when Lon Morgan joined Jerry Duggan as co-chairman in 1974. At that time many of the industrial applications were in the early stages of their development. Since then the

industrial applications of accelerators have grown tremendously, with more than 18,000 built over the last 50 years. The production of these industrial accelerators is itself a worldwide business conducted by more than 65 companies and institutes. Collectively these entities ship more than 1000 systems per year and have annual revenues in excess of $2 billion. While the manufacture and sale of industrial accelerators is itself a big business, the finished goods and materials produced or processed by the accelerators make an even more significant contribution to the world wide economy with an estimated annual sales value of ~ $500 billion. The numerous industrial applications cover a broad range of business segments from low energy electron beam systems for welding, machining, and product irradiation to high energy cyclotrons and synchrotrons for radioisotope production and synchrotron radiation production. This talk is a review of these business segments and their impact on people's lives. It will also cover new accelerator technology under development and the predicted growth in the various business segments.

MON-PL04-1 #493 - Invited Talk - Monday 10:45 AM - Pecos I & II

The Future of Accelerators: A DOE Symposium and the Stakeholders' View

Walter F Henning
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In October 2009, the Department of Energy's Office of High Energy Physics sponsored a symposium and workshop on accelerators to elicit views and opinions of a wide range of stakeholders (www.acceleratorsamerica.org). Its purpose was to identify and discuss challenges and opportunities for developing and deploying accelerators to help meet society's needs for the 21st Century. Some 300 accelerator users and developers attended the one-day symposium and poster session. In the two-day workshop that followed, 120 users of accelerator technology, from small business owners to well-known researchers, formed five working groups in Energy and Environment, Industry, Medicine, National Security, and Discovery Science. Their charge was to give us a perspective on needs, challenges and areas of greatest promise; and to provide guidance on bridging the gap between accelerator research and technical deployment. For two days the working groups discussed, disagreed and eventually converged on results. The groups' reports varied in scope, approach and level of technical detail. Sometimes their findings conflicted. The workshop was designed as an inclusive, broad-spectrum effort to learn from stakeholders with boots on the ground in fields that depends on accelerator science and technology. This talk attempts to capture what they told us. A DOE report about the results is presently in preparation for print.

MON-RE01-1 #305 - Invited Talk - Monday 1:00 PM - West Fork

Particle beam studies of radiation effects in nuclear energy materials at LANL - a multiscale endeavor

Mark Andrew Bourke
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Los Alamos National Laboratory is currently engaged in the definition of a signature facility called MaRIE (Matter-Radiation Interactions in Extremes). It is predicated on the use of the LANSCE (1mA 800 MeV proton accelerator), a fast neutron spallation source and a source of extreme intensity X-rays (probably a free electron laser). High level goals for the facility include unique in situ characterization of materials properties under radiation or dynamic extreme conditions. This talk will describe the current scope of radiation effects studies at LANL, focusing on the LANSCE accelerator. It will then speculate on decadal materials challenges in radiation extremes and discuss how they have lead to the definition of the MARIE facility.

MON-RE01-2 #313 - Invited Talk - Monday 1:00 PM - West Fork

Multi-ion Beam Facilities and their Application to Nuclear Energy

Michael Fluss
Physics and Life Sciences, Lawrence Livermore National Laboratory, 9700 East Avenue, Livermore CA 94550, United States

Nuclear energy faces challenges today and into the future with regards to our ability to accurately predict materials performance. Relevant issues include life extension of the existing reactor fleet, development of advanced fast reactors with design lifetimes of ~100 years, high burn-up fuels, and fusion energy materials. Ion-beam studies of materials has played an important role in the continued development of nuclear energy materials. With the new interest in nuclear energy

the need for much more intensive research focused on key mechanisms that can inform multi-scale models becomes paramount. Single and multi-ion beam facilities provide flexible platforms for investigating the underlying physics of radiation tolerance and actinide fuel evolution. We will review the various facilities currently in operation around the world, point out a few important experiments that have been conducted, and indicate where the US programs in nuclear energy might benefit from a coordinated and intensive initiative in ion beam research for nuclear energy materials. This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. This work was funded by the Laboratory Directed Research and Development Program at LLNL as part of project 09-SI-003.

MON-RE01-3 #91 - Invited Talk - Monday 1:00 PM - West Fork

Damage and analysis: the role of ion accelerators in plasma-surface interaction research

Graham M Wright, Dennis G Whyte, Harold S Barnard, Peter W Stahle, Regina M Sullivan, Kevin B Woller
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The material requirements for plasma-facing components in a nuclear fusion reactor are some of the strictest and most challenging facing us today. These materials are simultaneously exposed to extreme heat loads (20 MW/m^2 steady-state, 1 GW/m^2 in millisecond transients) and particle fluxes ($>10^{24}$ $m^{-2}s^{-1}$) while also undergoing high neutron irradiation (10^{18} neutrons/m^2s). Exposure to plasma can also result in net erosion of the material, net deposition, and significant material transport from one location in the tokamak to another resulting in material mixing. Plasma exposure also results in high rates of ion implantation, specifically deuterium and tritium ions, which can lead to wall activation concerns, significant fuel retention in the walls, and surface morphology changes of the plasma-facing materials. Ion accelerators are an invaluable tool in assessing the evolution and performance of materials in this harsh and complex environment. The elemental and isotope discrimination available in ion beam analysis techniques are commonly used to investigate and quantify many of the concerns and challenges facing the plasma-surface interaction (PSI) community. More recently, ion accelerators have also been used to simulate neutron damage through heavy ion irradiation to investigate PSI properties in damaged materials as we prepare for future fusion experiments where the materials will experience significant neutron damage. This talk will present PSI issues of high importance in the nuclear fusion community and give specific examples of ion beam analysis and ion accelerator use that are used by the PSI Science Center at MIT and other PSI research teams from around the world to investigate and clarify these issues.

TUE-AP02-1 #186 - Invited Talk - Tuesday 8:30 AM - Elm Fork

Three-Body Dynamics in Ionization of Atomic Hydrogen by 75 keV Proton Impact

Michael Schulz
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We have measured and calculated double differential cross sections for ionization of atomic hydrogen by 75 keV proton impact for fixed projectile energy losses as a function of scattering angle. This collision system represents a pure three-body system and thus offers an accurate test of the theoretical description of the few-body dynamics without any complications presented by electron correlation in many-electron targets. Comparison between experiment and several theoretical models reveals that the projectile - target nucleus interaction is best described by the operator of a second order term of the transition amplitude. Higher-order contributions in the projectile - electron interaction, on the other hand, are more appropriately accounted for in the final-state wavefunction.

TUE-AP02-2 #177 - Invited Talk - Tuesday 8:30 AM - Elm Fork

Charge-changing Processes in the Multiple Ionization of Noble Gases by C3+ Ions

Geraldo Monteiro Sigaud[1], Antonio Carlos Fontes dos Santos[2], Marcelo Martins Sant'Anna[2], Wilson Souza Melo[3], Eduardo Chaves Montenegro[2]
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Absolute charge-state-correlated cross sections for projectile electron loss, electron capture, and target multiple ionization in collisions between triply-charged C ions and noble gases have been measured for energies between 1.3 and 3.5 MeV. The data have been compared with other similar absolute cross sections existent in the literature for several projectiles. Calculations for the single-loss accompanied by the multiple target ionization channel have been performed for the screening mode using both an extended version of the classical-impulse free-collision model and the plane wave Born approximation (PWBA), and for the antiscreening mode within the PWBA. The energy-dependence of the average number of active electrons for the antiscreening has been described by means of a simple function, which is "universal" for noble gases but, in principle, projectile-dependent. A method has been developed to obtain the number of active electrons for each target subshell in the high-velocity regime, which presented physically reasonable results. The analysis of the dependence of the single-capture and transfer-ionization (SC and TI, respectively) processes on the projectile charge states showed that, for He, equally-charged bare and dressed projectiles have very similar cross sections, the latter thus acting as structureless point charges. A similar behavior as in the SC has been observed for the pure single ionization of He by projectiles with different charge states and of the other noble gases by singly-charged projectiles. It has been shown that the dependence of the single ionization cross sections with the square of the projectile charge, predicted by first-order models, is only valid for high collision velocities. For slower collisions, the electron capture process becomes more relevant and competes with the single ionization channel, a feature which is more important as the projectile charge state increases.

TUE-AP02-3 #337 - Invited Talk - Tuesday 8:30 AM - Elm Fork

Origin, Evolution, and Imaging of Vortices in Atomic Processes

Joseph H Macek
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Calculations of the time-dependent wave function for proton impact on atomic hydrogen carried out using the Lattice-Time-Dependent-Schr\\"{o}digner-Equation (LTDSE) method have been able to follow the evolution of the wave function from microscopic to macroscopic times. Isolated zeros, now identified as vortices, appear when the target and projectile nuclei are separated by a few atomic units. Such structure has apparently been observed frequently in {\\it ab. initio.} calculations. Our work shows that such structures persist to macroscopic distances and appear as "holes" in electron momentum distributions. They can, in principle, be observed in reaction microscope studies. Such observation is formally justified by the "imaging theorem", which can be derived from first principles. A general derivation applicable to all time-dependent wave functions will be given.

Similarly, two-electron momentum distributions as observed, {\\it e. g.} in (e,2e) coincidence measurements may show isolated zeros. Calculations using correlated wave functions support the interpretation that a minima in (e,2e) for helium targets corresponds to a vortex. In this case the "imaging theorem" can be applied to argue that there must be vortices in the two-electron wave function. A general discussion of vortices in quantum mechanics will be presented. The general discussion will be illustrated using exact LTDSE calculations, and, for interpretive purposes, the time-dependent first Born approximation. These calculations show that the plane wave B1 amplitudes have no vortices, but the time-dependent B1 amplitudes do. It will be further shown that angular momentum transfer is the key to forming vortices in the time-dependent theory.

TUE-AP02-4 #28 - Contributed Talk - Tuesday 8:30 AM - Elm Fork

Multiple ionization of Ne, Ar, Kr and Xe by different ions

Claudia Carmen Montanari[1], Jorge Esteban Miraglia[1], Eduardo Montenegro[2]

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We present theoretical single to quintuple ionization cross sections for Ne, Ar, Kr, and Xe bombarded by H+ and He+. Post-collisional contributions due to Auger-like processes are taken into account by using recent photoionization data. Present CDW-EIS and first Born approximation results are compared with the experimental data available in the range of energies (50-10000) keV for H+ in Ne and Ar, and (50-1000) keV/amu for the other cases. In general, the combination of the CDW-EIS with the post-collisional branching ratios describes well the multiple ionization data above 300 keV/amu, showing a clear tendency to coalesce with first Born approximation for high energies. The surprising result of this work is the good performance of the first Born approximation which describes very well the experimental data of double and triple ionization, even in the intermediate energy range (50-300) keV/amu, where direct ionization is the main contribution.

TUE-AP02-5 #102 - Invited Talk - Tuesday 8:30 AM - Elm Fork

TRANSMISSION OF FAST HIGHLY CHARGED IONS THROUGH A SINGLE GLASS MACROCAPILLARY

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The interaction of slow (keV energies) highly charged ions (HCIs) with several kinds of insulating capillaries has been studied recently experimentally and theoretically [1]. The studies with nanocapillary foils suggest that the guiding effect due to charge build up should also occur in single glass capillaries of macroscopic dimensions and this has been seen for slow ions [2]. In the present work much faster 16 MeV O^{5+} and 3 MeV proton beams obtained from the 6-MV tandem Van de Graaff accelerator at Western Michigan University were used to study the ion transmission through a single cylindrically-shaped glass macrocapillary. The sample was mounted on a goniometer to permit precise positioning with respect to the incident beam direction. A collimated beam ~1.5 mm in diameter struck the sample for tilt angles ranging from about -1^o to $+1^o$ (the beam was nearly parallel to the capillary), and the transmitted ions were magnetically analyzed to separate the emerging charge states. A movable silicon surface-barrier detector was used to measure the intensities vs. magnetically analyzed position of the transmitted ions. The intensities were normalized to the current incident on the sample. For incident O^{5+}, ions were transmitted through the macrocapillary with considerable energy losses, and the transmitted spectra show single electron capture and multiple electron loss. Protons showed transmission without energy loss. Analysis of these data is ongoing.

This work was supported in part by an award from Research Corporation

[1] T. Ikeda et al., J. Phys. Conf. Ser. 88, 012031 (2007)

[2] R. J. Bereczky et al., J. Phys. Conf. Ser. 194, 132019 (2009)

TUE-AP03-1 #264 - Invited Talk - Tuesday 1:00 PM - Elm Fork

A Nonperturbative Quantum-mechanical Approach to Ion-molecule Collisions

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A nonperturbative quantum-mechanical approach to ion collisions from molecular targets is presented. Its key ingredients are an expansion of the initially populated molecular orbitals in terms of a single-center basis and a spectral representation of the molecular Hamiltonian. Effectively, the approach amounts to a separation of molecular geometry and collision dynamics and offers the possibility to use well-established ion-atom methods with relatively minor modifications.

We have extended our basis generator method to deal with the collision dynamics and address ionization and fragmentation of water molecules by ion impact in the few-keV to few-MeV regime. We consider different geometries and study the variation of the results with respect to the orientation of the molecule.

In order to compare the results with experimental data and other calculations we have performed a (partial) average of the orientation-dependent cross sections. The results for net electron transfer and ionization in proton-water-molecule collisions are in remarkably good agreement with measurements. Furthermore, fragmentation cross sections will be presented. They are calculated by multiplying partial cross sections for electron removal from given molecular orbitals by branching ratios obtained from photoionization experiments. The results indicate a stronger dependence on the molecular geometry than found in the case of the net ionization and transfer cross sections.

TUE-AP03-2 #36 - Invited Talk - Tuesday 1:00 PM - Elm Fork

Radiative double electron capture observed during O^{8+} + C collisions at 38 MeV

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Radiative double electron capture (RDEC) is a one-step process for which two free (or quasifree) target electrons are captured into bound states of the projectile, e.g. into an empty K-shell, and the energy excess is released as a single photon. Due to electron-electron interaction, transitions of two target electrons into the projectile bound states occur with an emission of one photon with the energy two times greater than that of a single REC photon. This process can be considered as a time reverse of double photoionization. However, since bare ions are used during the experiment, RDEC does not have a background from other electrons, that makes the correlation effects difficult to observe during double photoionization experiments. Thus, RDEC may be the simplest, clean tool for investigation of electron-electron interaction in the presence of electromagnetic fields generated during ion-atom collision. Investigation of the RDEC process can provide crucial information necessary for a proper description of electron correlations within atomic systems and provide data required to define the wave function of two correlated electrons in the projectile continuum.

Recently, an experiment dedicated to the RDEC process with 38 MeV O^{8+} ions collided with carbon foil, was conducted at Western Michigan University using the tandem Van de Graaff accelerator. This experiment confirmed that the observation of such process is possible and allowed for estimation of the RDEC cross section of 3.8(1.9) b, which is significantly greater than the the theoretically predicted value of 0.15 b. The talk will cover the results of the experiment and possible explanations of the difference between the experimental and theoretical value of the cross section.

This work was supported by the Polish research Grant No. PB 1044/B/H03/2010/38

TUE-AP03-3 #150 - Contributed Talk - Tuesday 1:00 PM - Elm Fork

State Selective Charge Exchange from Na(3s) and Na*(3p) by Highly-Charged Ions

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State selective charge exchange cross sections and momentum spectra are calculated for collisions of Xe18+, Xe24+ and Xe54+ ions with Na(3s) and Na*(3p) over the energy range of 0.1 to 10.0 keV/amu. The CTMC method is used which includes all two-body interactions. The n-level cross sections are found to be rather insensitive to collision energy below 1 keV/amu. In contrast, the transverse momentum cross sections for specific n-levels change rapidly with energy. However,

this latter variation in energy is found to be in general agreement with simple scaling rules. Experimental state-selective data are available for Xe18+ and Xe24+ over a limited energy range; they are found to be in reasonable accord with the calculations.

TUE-AP03-4 #254 - Invited Talk - Tuesday 1:00 PM - Elm Fork

GUIDING OF SLOW HIGHLY CHARGED IONS THROUGH A SINGLE MESOSCOPIC GLASS CAPILLARY

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The transmission of charged particles through various types of capillaries has been recently attracted significant interest.

The guiding effect [1] is known to be caused by the formation of charge-patches at the inner wall of the glass tube due to the impact of the incident ions, which add up and finally cause a guiding electric field. So the slow highly charged ions are able to pass through the capillary, keeping their initial charge states even though the capillary axis is tilted with large angles compared to the direction of the incident beam. Recently, we were able to show that this guiding effect occurs even for macroscopic dimensions of straight glass capillaries [2, 3].

In this work we present first temperature dependent transmission measurements of highly charged ions through a single, straight Pyrex glass capillary with a high aspect ratio (length 11.8 mm, diameter 0.14 mm). The outer surface of the capillary has been covered with graphite. The sample was bombarded by 4.5 keV Ar9+ ions produced by the Vienna 14.5 GHz electron cyclotron resonance ion source applying a recently developed and built temperature regulated sample holder.

By changing the temperature of the glass capillary we are able to manipulate the electrical conductivity of the Pyrex by several orders of magnitude and thereby the effect of conductivity on the build-up and removal of charge patches in the capillary can be studied. We found a large influence of the glass temperature (i.e. conductivity) on the transmission of ions which can be compensated by adjusting the incident ion flux.

[1] N. Stolterfoht et al, Phys. Rev. Lett. 88, 133201 (2002)

[2] R. J. Bereczky et al, Nucl. Instr. and Meth. Phys. B 267, 317 (2009)

[3] G. Kowarik et al, Nucl. Instr. and Meth. Phys. B 267, 2277 (2009)

TUE-AP04-1 #196 - Invited Talk - Tuesday 3:30 PM - Elm Fork

Solar Wind Charge Exchange Studies of Bare and H- like Ions on Atomic Hydrogen

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Accurate studies of charge exchange (CX) are critical to understand the underlying soft X-ray radiation processes in the heliosphere, solar corona, the interaction of solar wind with cometary comas, planetary atmospheres, interstellar neutral gases, etc. Particularly important are the CX data for bare, H-like, and He-like ions of C, N, O and Ne, which are the dominant charge states for the heavier elements in the solar wind [McCammon, ApJ , **576**, 188 (2002)]. Absolute total cross sections for single electron capture by H-like ions of C, N, O and fully-stripped O ions from atomic hydrogen have been measured in an expanded range of relative collision energies (0.01 keV/u -20 keV/u). Measurements are performed using a

merged-beams technique [Havener, PRA, **39**, 1725 (1989)] with intense highly charged ion beams extracted from a 14.5 GHz ECR ion source installed on a high voltage platform (qx250 kV) at the Oak Ridge National Laboratory. For the collision energy range of 0.3 keV/u - 3.3 keV/u which corresponds to typical ion velocities in the solar wind, the new measurements are in good agreement with previous H-oven easurements [Meyer, PRA, **32**, 3310 (1985).]. The experimental results are discussed in detail and compared with different theoretical calculations. With the installation of an X-ray quantum calorimeter [McCammon, J Low Temp Phys, **151**, 715 (2008)] we plan to record the CX produced X-ray spectra in range 0.3 keV - 2 keV with high spectral resolution (up to 6 eV FWHM). Relative line intensities will be used to estimate the state selective CX cross sections for a detailed comparison with theory.

Research supported by the NASA Solar & Heliospheric Physics Program NNH07ZDA001N, the U.S DOE Office of Fusion Energy Sciences and the Office of Basic Energy Sciences under contract DE-AC05-00OR22725 with UT-Battelle, LLC.

TUE-AP04-2 #373 - Invited Talk - Tuesday 3:30 PM - Elm Fork

Fast-ion interaction with molecules and clusters

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The electron and recoil-ion spectroscopy are commonly used to investigate the underlying processes which govern the ion-atom collision mechanisms. For heavy-ion collisions with small or large molecules or clusters the ionization process is influenced by more completed mechanisms. Recently observed Young type interference is one of such example in case of ionization of homo-nuclear diatomic molecules [1-2]. The ionizations of a many-body system like C60 are largely governed by the collective excitation, known as Giant Plasmon Resonance (GPE). Several measurements on the emitted x-rays, recoil-ions and now low energy electrons from a free C60 molecule have indicated the large influence of the GPE [3-6]. The linear dependence on the projectile charge state (q) of the recoil-ion yields produced in single and double ionizations could be explained by a plasmon-based model. The experiments were carried out using 2-5 MeV/u C, O, F and Si ions with q between 3+ and 14+. A similar linear charge-state dependence is also observed for other large molecules, such as, Uracil. A direct observation of this process in low energy electron spectrum was awaited. We have now measured such an e-DDCS spectrum from C60 in collisions with fast bare F-ions. First, a direct evidence of the GDPR characteristic peak has been obtained through electron channel. Secondly, the angular distribution indicates that the dipole oscillations induced along the projectile beam direction. The experimental data on fullerenes as well as large bio-molecules will be discussed.

References:

[1] Stolterfoht et al. PRL. 87, 023201 (2001).

[2] Misra et al. PRL. 92, 153201 (2004).

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[4] Kadhane et al. PRA 75, 041201 (R) (2007).

[5] Kelkar et al. JPB 40, 2481 (2007).

[6] Kadhane et al. Phys. Rev. Letts., 90, 093401 (2003).

TUE-AP04-3 #530 - Invited Talk - Tuesday 3:30 PM - Elm Fork

Precision studies of fundamental atomic structure with high-Z few-electron ions.

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One- and two-electron ions traditionally serve as an important testing ground for fundamental atomic structure theories and of the eff
ects QED, relativity and electron correlation. In the domain of high nuclear charges, new opportunities open up for precise testing and consolidating of the present understanding of the atomic structure in the regime of extreme electromagnetic fields.

The improvements in experimental precision for structure investigations in H- and He-like heavy systems are accompanied by an increase of accuracy in theoretical predictions by evaluating higher-order QED contributions. In this review, the current progress in experimental investigations of the heaviest H- and He-like systems at GSI Darmstadt is presented. In addition, the planned future experimental studies and developments devoted in particular to high-resolution spectroscopy of excited states in heavy few-electron ions as well as of the 1s state in hydrogen-like systems, are reviewed.

TUE-AP04-4 #464 - Invited Talk - Tuesday 3:30 PM - Elm Fork

Electron emission from amorphous solid water induced by fast ion impact

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The pattern of energy deposition by ionizing radiation in biologic systems can be a critical factor in determining the biological response. Clustered radiation damage in DNA can challenge repair systems and lead to genomic instability and cell mutations. Models of the spatial patterns of radiation damage by ionizing radiation are generally obtained from Monte Carlo simulation of the production and transport of secondary electrons in liquid water, the medium of cells. The accuracy of these track structure simulations rely on theoretical and empirically derived interaction cross sections that have increasing uncertainty as the electron energy decreases below a few hundred electron volts. It is in this low-energy range, at the end of the electron track, where damage is most prominent. In order to test the accuracy of electron transport in track structure simulations, we have measured low-energy electron emission yields from amorphous solid water (a surrogate for liquid water) following fast ion transmission. Thin films of amorphous solid water were frozen on a one-micron-thick copper foil held at 40 Kelvin. Doubly differential electron yields were measured as a function of electron energy and emission angle following the transmission of 6 MeV protons and 1 MeV/u fluorine ions. These data are presented, along with comparisons to simulations from the Monte Carlo PARTRAC track structure code.

This work is supported in part by the National Institutes of Health, National Cancer Institute, and by the Chemical Sciences, Geosciences, and Biosciences Division, Office of Basic Energy Sciences, Office of Science, U.S. Department of Energy.

TUE-AP04-5 #63 - Contributed Talk - Tuesday 3:30 PM - Elm Fork

ELECTRON TRANSMISSION THROUGH A SINGLE GLASS MACROCAPILLARY

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The transmission of electrons through insulating nanocapillary foils consisting of millions of channels has been the focal point of recent experiments. The collective effect of all the capillaries needs to be considered when studying the transmission process, making the problem complex. Using a simpler geometry, electron transmission through a single

cylindrically-shaped glass capillary was investigated for 300-1000 eV electrons. The experiment was conducted for Borosilicate glass capillaries of diameter ~0.2 mm and length ~15.0 mm. The transmitted intensities revealed two regions with dissimilar transmission characteristics. For sample tilt angles $\psi < 2.5°$, direct transmission with no interaction between the incident beam and inner wall falls faster than for $\psi > 2.5°$, the indirect region in which the beam interacts with inner wall. The characteristic angle, ψ_c, at which the transmission intensity falls to 1/e, was found to be the same for all energies in the direct region, whereas a minimum in ψ_c for 500 eV was observed for the indirect. Rutherford cross section predictions revealed that lower energy electrons (< 500 eV) show remarkable agreement with the theory, but deviate from predictions with increasing projectile electron energy suggesting the co-existence of another transmission mechanism. Time evolution studies have shown that the second mechanism[1] is charge deposition causing Coulombic repulsion. The resulting field distribution on the inner surface elastically deflects incoming electrons away from the charging area towards the exit of capillary. The transmission intensity shows an oscillatory behavior in the indirect region at equilibrium suggesting a sudden discharge of the capillary followed by slower recovery, which again goes toward equilibrium.

This work was supported by an award from Research Corporation.

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TUE-AP04-P1 #421 - Poster - Tuesday 5:30 PM - Rio Grande

Interference in electron emission in fast ion and fast electron collisions with H2: A comparative study

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The ionization induced electron emission spectrum from H2 shows an oscillation in the electron double differential spectrum. The oscillation is due to the Young type electron interference phenomenon since the two H-atoms are indistinguishable and coherent sources of electrons. Such oscillations have been revealed in charged particle collisions with H2 [1-8]. We have now made new measurements using fast (5 MeV/u) ion beams of bare F. In addition we have also measured the similar spectrum using 8 keV electron colliding with H2 using a hemi-spherical electrostatic analyzer. The derived DDCS ratios of molecular-to-atomic H exhibit Cohen-Fano type oscillatory structure. The angular dependence of the derived frequency parameter of such oscillations, for a wide range of angles is measured which shows a dip at 900. Also the frequency in the backward angles is almost a factor of 2.0 larger than that for the forward angles. The observed trends [5] are different than to that predicted theoretically but similar to that observed earlier for a completely different collision system, such as, GeV energy heavier ions [1,3]. The spectrum of the forward backward angular asymmetry parameter shows a clear signature of the oscillation. In case of heavy-ion collision the oscillation is built on a line having a slope due to the two-center effect whereas for electron collision the oscillation is observed about a horizontal axis. A comparative study will be presented.

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TUE-AT04-1 #60 - Invited Talk - Tuesday 1:00 PM - Bur Oak

A Short History of Dust Accelerator Research

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Beginning in the late 1950's, the space-science community has adapted nuclear accelerator techniques to achieve hypervelocity acceleration (> 1 km/s) of macroscopic dust particles (~ 1 um diameter). The primary scientific objective has been to characterize the impact phenomena of micrometeoroids on satellite-born instruments and equipment, for both basic science purposes and for the safety of humans and equipment. More recent studies of micrometeoroids (cosmic dust) has focused on their origin, composition, and other properties, from which inferences can be made about the history and conditions of the solar system and beyond. As satellite-borne micrometeoroid diagnostic instruments have become more powerful, so have the requirements on accurate calibration techniques using dust accelerators. Additionally, dust accelerators have been used as material injectors and diagnostic probes of high-temperature plasmas. Here we present a short history and technical introduction to hypervelocity dust accelerators in their most common form, the electrostatic linear charged-particle accelerator. We review the critical technical developments which have enabled increased performance and diagnosis, and discuss the present state of modern dust acceleration facilities.

TUE-AT04-2 #121 - Invited Talk - Tuesday 1:00 PM - Bur Oak

Dust accelerators and their applications in high-temperature plasmas

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The perennial presence of dust in high-temperature plasmas and fusion devices has been firmly established. Dust inventory must be controlled, in particular in the next-generation steady-state fusion machines like ITER, as it can pose significant safety hazards and potentially interfere with fusion energy production. Much effort has been devoted to getting rid of the dust nuisance. We have recognized a number of dust-accelerator applications in magnetic fusion, including in plasma diagnostics, in studying dust-plasma interaction, and more recently in edge localized mode (ELM)'s pacing. With the applications in mind, we will compare various acceleration methods, including electrostatic, gas-drag, and plasma-drag acceleration. We will also describe some laboratory experiments and results on dust acceleration.

TUE-AT04-3 #118 - Invited Talk - Tuesday 1:00 PM - Bur Oak

The High Velocity Dust Particle Accelerator at Concordia College in Moorhead, MN

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In 1975, Concordia College in Moorhead, Minnesota acquired a 2MeV dust particle accelerator from NASA's Goddard Space Flight Center. The accelerator is still fully functioning and has undergone some updates in the past decade. Improvements to the electronic detection system have been made. We have designed a means to detect and record the charge and velocity of the dust particles with a computer system. Prior to these modifications, we had no means of correlating a particle's properties with the time the particles were detected. Improvements to the vacuum system have also been made. The diffusion pump on the beam line has been replaced with a turbomolecular pump.

Our traditional projectile material is 1-5 micron carbonyl iron. With this dust source, particles acquire velocities up to 14 km/sec. In addition, we have successfully used 70nm copper dust resulting in particles with speeds of 22km/sec and possibly higher. Over the past few years, our dust accelerator has been used to test a variety of instruments and materials including a prototype space flight dust particle detector, piezoelectric pins, ultra-high temperature ceramics, aerogel, and several thin films. The results of these experiments will be summarized.

TUE-AT04-4 #205 - Contributed Talk - Tuesday 1:00 PM - Bur Oak

Advancements in Dust Accelerators at the Colorado Center for Lunar Dust and Atmospheric Science

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At the Colorado Center for Lunar Dust and Atmospheric Science (CCLDAS) we are in the process of assembling a 3MV accelerator for macroscopic (~1um) dust particles. The acceleration unit is being made by the National Electrostatics Corporation (NEC). The accelerator consists of a Pelletron HV generator and potential rings encased in an enclosure held at 6 atm of SF6. A pulsed dust source is used to charge and then inject particles into the accelerator. Objectives of the system include precise control of the dust source, tight focusing of the dust "beam", and individual selection of dust particles based on their mass and charge. For control of the dust source and telemetry of the HV terminal, we have designed a fiber control and readout system. We have used a series of SIMION simulations to incorporate an Einzel lens for beam focusing. The individual selection of particles permitted through an electrostatic "gate" to reach the target chamber is made complicated due to the wide range of charge and mass values of the particles launched from the dust head. To solve this problem, we are designing a particle selection unit based on field programmable gate arrays (FPGAs). This will consist of real time digital signal filtering, triggering, and timing programmed onto a single FPGA chip. The implementation and design of these advancements will be presented.

TUE-AT05-1 #59 - Invited Talk - Tuesday 3:30 PM - Bur Oak

A Review of Industrial Beamline Technologies and Approaches

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This paper provides a review of industrial charged particle beamline technologies and design approaches. Sectors covered include radioisotope production, ion implantation, and electron beam processing. In the area of radioisotope production there have been a number of innovations in injection line technologies for commercial cyclotrons in recent years, as well as developments in the high energy beamlines both for Cyclotron and Linac accelerator solutions. Ion implantation beamlines have been adapted for ever larger beamspots over the years as well as higher energies and very particular uniformity and purity requirements. Electron beam processing has myriad ways of delivering beams in a large variety of industries. New componment technologies shall be discussed, as well as areas where better component solutions are required in future.

TUE-AT05-2 #303 - Invited Talk - Tuesday 3:30 PM - Bur Oak

Semiconductor Ion Implanters

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In 1953 the Raytheon CK722 transistor was priced at $7.60. Based upon this, an Intel Xeon Quad Core processor containing 820,000,000 transistors should list at $6.2 billion! Particle accelerator technology plays an important part in the remarkable story of why that Intel product can be purchased today for a few hundred dollars. Most people of the mid

twentieth century would be astonished at the ubiquity of semiconductors in the products we now buy and use every day. Though relatively expensive in the nineteen fifties they now exist in a wide range of items from high-end multicore microprocessors like the Intel product to disposable items containing 'only' hundreds or thousands like RFID chips and talking greeting cards. This historical development has been fueled by continuous advancement of the several individual technologies involved in the production of semiconductor devices including Ion Implantation and the charged particle beamlines at the heart of implant machines. In the course of its 40 year development, the worldwide implanter industry has reached annual sales levels in excess of $1B, installed thousands of dedicated machines and directly employs thousands of workers. It represents in all these measures, as much and possibly more than any other industrial application of particle accelerator technology. This presentation will briefly discuss the history of implanter development, touch on some of the people involved and and on some of the developmental changes and challenges imposed as the requirements of the semiconductor industry evolved.

TUE-AT05-3 #14 - Invited Talk - Tuesday 3:30 PM - Bur Oak

Uniform Beam Distributions of Charged Particle Beams

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The use of third order beam optics was originally suggested [1] to transform a transverse Gaussian distribution of a charged particle beam into a uniform beam distribution having rectangular cross section. The first experimental realization of this concept was materialized at the Radiation Effects Facility (REF) of the Brookhaven National Laboratory (BNL) [2] where the transverse Gaussian distribution of a 200MeV proton beam was transformed into a rectangular uniform distribution. Later, the beam line of the NASA Space Radiation Laboratory (NSRL) facility [3] built at BNL was specifically designed to accommodate octupole magnetic elements to generate uniform beams distributions with rectangular cross sections, in both, the horizontal and vertical directions, at the location of the target. The NSRL facility generates uniform beam distributions of various nuclear species, which may vary in energy, and also vary in size of the beam distribution. We will present an overview of the method to generate uniform beam distributions, and some results of uniform beam distributions collected from the NSRL facility will also be presented. We will suggest other possibilities on generating uniform beam distributions.

[1] P. Meads "A Nonlinear Lens System to smooth the Intensity Distribution of a Gaussian Beam" IEEE Transactions on Nuclear Science, Vol. NS-30, No. 4, August 1983

[2] N. Tsoupas et al. "Uniform beam Distributions Using Octupoles" Proc. 14th Particle Accelerator Conf., San Francisco, California, May 6-9, 1991, p. 1695.

[3] N. Tsoupas et al. "Uniform beam distributions at the NASA Space Radiation Laboratory" Phys. Rev. ST Accel. Beams 10, 024701 (2007)

TUE-AT05-4 #65 - Invited Talk - Tuesday 3:30 PM - Bur Oak

Beamlines for Improving Reliability in High Current PET Radionuclide Production

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State of the art liquid water targets used in the production of Fluorine-18 for clinical PET imaging are designed for an operating beam current of approximately one hundred microamperes. This operating level is fairly consistent over a number of cyclotron and target systems ranging in incident proton energy from 10 to 19 MeV. Conventional target systems typically consist of a target port or short beamline (less than 0.5 meters in length) connected to the cyclotron vacuum tank and housed inside of the cyclotron surface shield. The target port typically provides mating hardware for the target and houses a graphite collimator. If the demand for F-18 increases significantly over the next decade, regional production centers operating targets at several hundred microamperes would be economically viable. To implement this technology effectively, a robust beamline system would be of great utility. While target design methodology can be extended to systems with considerably higher operating power levels, substantial operating margin can be gained by effective beam transport. The most siginificant gains can be realized by reducing localized peaking within the beam intensity distribution. Additionally, "spilled" or "stray" beam incident upon the target body rather than the target medium is responsible for

localized heating of target materials and can lead to premature failure of seals and other components. Another barrier to a high power production modality is shielding of the target components. Utilizing a beamline would both provide improved control over the size, shape, and distribution of the beam and allow the target station to be located at a distance from the cyclotron sufficient to allow localized shielding.

TUE-AT05-5 #171 - Invited Talk - Tuesday 3:30 PM - Bur Oak

Double-Helix Magnets a Breakthrough in Magnet Technology for Particle Beam Lines

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Solenoid coils with sinusoidal modulations, called "Double-Helix" magnets, offer significant advantages for charged particle beam optics. Double-Helix coils generate almost pure multipole fields, enable straight and bent combined function magnets, as well as twisted and funnel-shaped coils. Such coils can be manufactured cost effectively on standard machining centers, resulting in small random field errors. The technology is applicable to different conductor shapes, including round, square and rectangular wires and cables, as well as superconducting tapes. Unique conductor cooling in normal conducting magnets enable current densities well above 100 A/mm2, and unlike superconductors can be achieved with AC operation of several hundred Hertz. In a novel implementation of the technology, complete coils are "directly" fabricated from conductive cylinders, which allows for unprecedented miniaturization and enables the use of conducting materials that are problematic for wire manufacturing. A general overview of the Double-Helix technology will be presented together with its applications.

TUE-AT05-6 #240 - Contributed Talk - Tuesday 3:30 PM - Bur Oak

Graphene-based Stripper Foils for Next Generation Rare Isotope Beam Facility

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[(2)]*Physics Division, Argonne Nantional Laboratory, 9700 South Cass Av., Bldg. 203, Argonne IL 60439, United States*
[(3)]*ARC Centre of Excellence for Electromaterials Science, University of Wollongong, Squires Way, Fairy Meadow NSW 2519, Australia*
[(4)]*Applied Nanotech, Inc., 2006 Longhorn Blvd, Suite 107, Austin TX 78750, United States*

The US DOE new Facility for Rare Isotope Beams (FRIB) to be constructed at Michigan State University promises to vastly expand our understanding of nuclear astrophysics and nuclear structure. The driver linac of FRIB is specified to deliver beams of heavy ions up to uranium with beam power of 400 kW. This linac requires a charge stripper to decrease the accelerator cost. One of the possible stripper mechanisms comprises a large area rotating carbon foil to strip electrons from energetic ions passing through the foil. The foils for this next generation accelerator must be able to handle high beam power density in the foil (about 1kW with beam diameters about 1 mm). Amorphous carbon foils are often used as strippers, but are fragile, expensive to make and have poor electrical and thermal conductivity. Graphene, a form of carbon that consists of a layer of atoms arranged in a honeycomb lattice having superlative mechanical and thermal properties , is being evaluated as a candidate for these high power strippers. In this work we have investigated free-standing foils of graphene paper with mass density 0.5 - 1.0 mg/cm^2 for stripper foil applications. Foils of 5 cm diameter were made by filtering dispersions of graphene. The size and thickness of the paper can be adjusted easily by changing the size of the filter and the loading and volume of the dispersion. We tested these foils using an alpha probe and found these foils to have mass-density uniformity as good as or better than benchmark amorphous carbon foils. Uniformity across the foils appears to also be very good. We further characterized these foils using an energetic electron beam and observed that the thermal conductivity of the foil was higher than amorphous carbon. The results of the characterization experiments will be reported.

TUE-AT05-P1 #321 - Poster - Tuesday 5:30 PM - Rio Grande

Design Study of Cyclotron Magnet With Permanent Magnet

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After the development of Positron emission tomography (PET), small cyclotrons have been wanted for the production of radio-isotopes such as F18. Korea Institute of Radiological & Medical Sciences (KIRAMS) developed a 13 MeV medical cyclotron ?KIRAMS-13' for PET in 2001. In the small cyclotron magnet design, an increase of magnetic field between the poles is needed to make a smaller size of magnet. The Permanent magnet can do this work without additional power consumption in the cyclotron magnet. In this paper the study of cyclotron magnet design using permanent magnet is shown and also the comparison between normal magnet and designed magnet using permanent magnet is shown. All field calculations had been performed by OPERA-3D TOSCA.

TUE-AT06-1 #498 - Invited Talk - Tuesday 8:30 AM - Bur Oak

Advanced Accelerator Techniques and Their Applications

James Benjamin Rosenzweig
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For the last 25 years, there has been a concerted effort to "reinvent" the accelerator, driven in large part by the need to find a new, more credible path to the ultra-high energy discovery frontier. These new techniques attempt to utilize the extremely large fields that enabled by use of lasers, intense charged particle beam wakfefields, and plasmas. Such high energy density scenarios imply dramatically smaller, shorter wavelength systems, in which one may encounter time scales at the level of fs or below. Recent years have brought rapid progress in advanced accelerator research, yielding some mature approaches that are ripe for application e.g. in novel photon sources, medicine and defense. We review the most important of these concepts and their likely applications.

TUE-AT06-2 #285 - Invited Talk - Tuesday 8:30 AM - Bur Oak

Plasma Wakefield Accelerators: Near-Term Applications

Mike Downer
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The idea of accelerating charged particles to high energy by surfing them on plasma waves in the wake of intense laser pulses, first proposed over 30 years ago, was originally envisioned as a future compact technology for high-energy physics. Now that compact laser wakefield accelerators (LWFAs) producing collimated, nearly mono-energetic electron bunches up to 1 GeV energy are a reality, a range of near-term applications relevant to medicine, biological research, and materials science is emerging. Because of their micron-scale accelerating buckets, LWFAs naturally produce ~ 10 fs duration electron bunches, much shorter than conventional rf accelerators, that are perfectly synchronized with the fs drive laser pulse. This opens the possibility of novel laser-electron pump-probe pairs for fs-time-resolved experiments. In addition, such short, high peak current bunches can efficiently produce ultrashort, coherent x-ray pulses upon propagating through a meter-scale undulator or upon Thomson/Compton scatter by a counter-propagating laser pulse. These pulses can potentially rival those available from much larger-scale synchrotron radiation sources in peak brilliance, yet are achievable in small-scale laboratories. At the opposite end of the spectrum, ultrashort electron bunches from LWFAs produce efficient THz transition radiation upon passing through dielectric boundaries. In addition, the extremely nonlinear evolution of the drive laser pulse during laser-wakefield acceleration produces millijoule-energy, ultrashort mid-infrared radiation useful for molecular vibrational spectroscopy. LWFA electron bunches can also be very low emittance, enabling tight focusing. They can therefore provide point-like gamma-ray sources useful for high-resolution radiography upon conversion to bremsstrahlung radiation in a dense material. Quasi-monoenergetic LWFA electrons can efficiently initiate gamma-n photonuclear reactions, raising the prospect of compact, on-stie production of short-lived radioisotopes used in positron emission tomographic medical imaging. I will review these and other emerging near-term applications of LWFAs.

TUE-AT06-3 #494 - Invited Talk - Tuesday 8:30 AM - Bur Oak

High Gradient Microwave Accelerators--Limits and Prospects

Tor O. Raubenheimer
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Normal conducting microwave-powered accelerators form the overwhelming majority of accelerators in research, medicine, and industry due in large part to their demonstrated reliability, efficiency, and compactness. Advances in power sources, accelerator structures, and material science have produced enourmous improvement in the achievable energy gain per unit distance, resulting in significantly more compact accelerators. We will discuss the physical and technical issues that limit microwave accelerator performance, and outline present state-of-the-art as well as prospects for further improvement. Implications for broader capability and applications of accelerators will be discussed.

TUE-AT06-4 #450 - Invited Talk - Tuesday 8:30 AM - Bur Oak

Accelerator Innovations for Hadron Therapy

David S Robin
Advanced Light Source, Lawrence Berkeley National Laboratory, 1 Cyclotron Rd. MS:80R0114, Berkeley CA 94720, United States

Radiation therapy is a form of radiation therapy where radiation is used to kill cancer tumor cells. At present X-rays are the most common form of radiation therapy. However the interest in Hadron Therapy, which is the use ion beams, is rapidly increasing. This is due to some distinct advantages that ion beam have in minimizing dose to normal tissue which in turn can minimize both the treatment time as well as toxicity, local control, and survival. As a result there are a growing number of proton beam and other ion beam (such as carbon) facilities ion in operation or under construction. However, as compared with X-ray facilities, hadron beam facilities are more complex and expensive to operate. Advances in sources, acceleration, beam delivery and detection are making ion beam more affordable as well being able to exploit the intrinsic advantages of ions. In this talk I will discuss some of the recent advances and thoughts in sources, accelerators, beam delivery systems, and detectors for improving hadron therapy.

TUE-AT06-P1 #158 - Poster - Tuesday 5:30 PM - Rio Grande

Compact AMS system at Yamagata-University

Fuyuki Tokanai[1], Minoru Anshita[1], Kazuhiro Kato[1], Akihiro Izumi[1], Tsugio Saito[2]
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A new compact Accelerator Mass Spectrometry (AMS) system has been installed in research institute at Yamagata University. The AMS system is based on a 0.5 MeV Pelletron accelerator developed by National Electrostatics Corp. The performance of the system were investigated using the C series samples (C1-C8), standard samples (OXII, SRM4990C), and reagent graphite without any chemical treatment. The precisions of measurements for the standard samples are typically better than 0.3%. The ratio of 14C to 12C is less than 7x10-16 for the reagent graphite. In this paper, we present the performance of the new compact AMS system as well as fully automated 20-reactor graphite lines equipped at the research institute.

TUE-AT06-P2 #259 - Poster - Tuesday 5:30 PM - Rio Grande

EVIDENCE OF HEAVY-ION REACTIONS FROM INTENSE PULSED WARM, DENSE PLASMAS

J W Schumer, F C Young, B V Weber, S L Jackson, C N Boyer, D Mosher
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Nuclear reactions in pulsed-power ion-diodes are usually induced by proton- or deuteron-projectiles accelerated to high energy by the voltage across the anode-cathode gap. Reactions for which the incident projectile has a larger atomic number ($Z > 2$) are inhibited by the Coulomb barrier and are not usually detected. This work documents the detection of several heavy-ion nuclear reactions in the operation of a plasma-filled rod-pinch (PFRP) diode on the 2-MV Gamble II generator. By injecting a cable-gun plasma between an anode-cathode gap, this PFRP diode has been shown to concentrate a 500-kA, 2-MeV, 60-ns electron beam onto the pointed end of a 1-mm diameter tapered tungsten rod, generating a warm-dense tungsten plasma ($Z \sim +12$, ~20 g/cm^3, 25 eV, and 2.4 MJ/cm^3 at the time of maximum thermal

energy density.) To utilize the PFRP diode as a source of highly-charged ions, high-intensity electron beams impinge upon a ~1-mm diameter Al anode rod charged to high voltage. After an experimental discharge, anode material debris is collected in a 3-in diameter Al cup (at ground potential) and gamma-ray emissions are measured using a high-purity Ge spectroscopy system over several days. By measuring the gamma-ray energies and half-lives, the production of a variety of radioisotopes were identified, including ^{38}K, ^{34m}Cl, ^{43}Sc, ^{44m}Sc, ^{48}V, and ^{52}Mn (up to 10^8 per discharge). Weak evidence for ^{24}Na, ^{69}Ge, and ^{79}As was also observed. Proposed heavy-ion nuclear reactions with Q-values exceeding the accelerating potential of the diode suggest a novel acceleration mechanism. Although it is not surprising to find production of these isotopes in sub-10-MeV accelerators (the heavy-ion reaction ^{27}Al(^{12}C,α+n)^{34m}Cl was previously identified in an ion-diode experiment on the Aurora pulsed power generator operating at a peak diode voltage of 5 MV, this is the first demonstration of production using a PFRP diode.

TUE-ECHT02-1 #474 - Contributed Talk - Tuesday 8:30 AM - Post Oak

Development of an ion microbeam system with an old Van de Graaff accelerator for education and industrial application

Venkata C. Kummari, Mangal S. Dhoubhadel, Lucas C. Phinney, Bibhudutta Rout, Tilo Reinert, Jerome L. Duggan, Floyd D. McDaniel

Ion Beam Modification and Analysis Laboratory, Department of Physics, University of North Texas, 210 Avenue A, Denton Texas 76203, United States

Recent advances in accelerator technology, ion optics theory, focusing magnet systems, and system control software have led to the development of the high energy focused ion beam (HEFIB) microscope with a few nanometers resolution . In addition to new ways to utilize these probes as analytical tools, recently progress has been made in the area of synthesis of high-aspect ratio nanostructures in materials. Dedicated high performance HEFIB microprobe systems are often built around new single ended accelerators, which utilize protons or helium ion beams in the energy range of 1-4 MeV for multi-dimensional compositional, elemental and charge analysis, and fabrication of micro-structures in materials. While there is a strong need for HEFIB nanoprobes, there are still plenty of analytical applications using 2-3 micron diameter ion microbeams. Recently, we have developed an ion microprobe system along a beamline of a 50 year old, 2.5 MV Model AN, Van de Graaff accelerator using a recently developed simpler magnetic quadrupole doublet lens system. We will report the use of this microprobe for research and education of undergraduate and graduate students as well as analytical applications for industry.

TUE-ECHT02-2 #197 - Contributed Talk - Tuesday 8:30 AM - Post Oak

High energy heavy ion assisted wet etch of silicon

Jack Manuel[1], Bibhudutta Rout[2], Gary Glass[1]

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High energy (MeV) heavy ions can cause significant near-surface damage to the crystal structure of silicon, creating a thin amorphous layer which is very resistant to chemical wet etch. In this study, a 900 keV Au ion beam is used to irradiate selected areas of various silicon substrates and followed by a KOH wet chemical etch to create microstructures. The KOH etching process is a generally anisotropic process with the etch rate dependent on the temperature and KOH concentration, but there is also a dependence on the orientation of the crystal planes relative to the surface. Empirical data shows that etch rates of the {100} and {110} planes vary by only a factor of two while the intrinsically etch resistant {111} plane etches approximately two orders of magnitude slower. In this study a focused proton beam was used to direct write patterns in 40 micrometers thick coatings of SU-8 photoresist on Si {100} and {110} substrates and the developed SU-8 patterns served as masks for the Au ion irradiation of the Si substrates. Once the SU-8 masks were removed, the Au-irradiated substrates were wet-etched in 2M KOH at a temperature of 75 degree C to produce 10 micrometers deep 3D structures, with sidewall geometry exhibiting the etch rate differences between the {111} and {100} planes

TUE-ECHT02-3 #134 - Contributed Talk - Tuesday 8:30 AM - Post Oak

Theoretical Approach of the Reduction of Chromatic and Spherical Aberrations in an Acceleration Lens System for gas-FIB to Form Gaseous Nanobeam

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The focused gaseous ion beam (gas-FIB) system composed of a series of electrostatic lenses, called "acceleration lens system", has been developed to form nanobeams using gaseous ions generated from a plasma ion source. Ion beams are accelerated and focused simultaneously by a pair of electrodes. A beam diameter of 160 nm has been so far obtained with 46 keV hydrogen molecule ion beam focused by the compact acceleration lens system of 300 mm length. A new all-in-one compact acceleration system including an acceleration tube is now under development to form 300 keV ion nanobeam. Chromatic and spherical aberrations are, however, hindrance to form nanobeams with their smaller sizes in diameter. A defocusing lens was theoretically introduced to one of the acceleration lenses to reduce the aberrations. Those aberrations can be corrected by a combination of focusing lenses and defocusing lenses and then a deceleration lens which performs like a defocusing lens was introduced to downstream of the acceleration lens system. Ion beam optics simulations were carried out to show that the aberration correction technique is effective to reduce chromatic and spherical aberrations in the acceleration lens system. As a result, the deceleration energy of 15 keV enabled us to reduce the chromatic aberration coefficient by 26 % and the spherical aberration coefficient by 17 %, and a beam diameter is expected to become 109 nm. In case of using a 300 kV electrostatic acceleration tube with 100 mm length, the final beam diameter of 103 nm at 300 keV is obtained by the all-in-one system with the total acceleration length of only 650 mm.

TUE-FIBN02-1 #273 - Invited Talk - Tuesday 1:00 PM - Post Oak

A Review of the Helium Ion Microscope and Its Emerging Applications

William B Thompson, John Notte, Lewis Stern, Larry Scipioni, Chuong Huynh, David Ferranti, Mohan Ananth, Sybren Sijbrandij, Colin Sanford
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The scanning helium ion microscope (HIM) is now a mature commercial product with an expanding installed base and a growing range of unique applications. The current generation is capable of 0.35 nm beam size and long working distance, top-down, imaging. It can be operated in two main imaging modes; ion induced secondary electron (SE) mode and Rutherford backscatter imaging (RBI) mode. A helium ion microscope SE mode image differs from an SEM SE image in that it provides sub-nanometer, surface sensitive resolution, on either conductive or insulating samples without the need for any conductive coating of the sample. When used in scanning RBI mode, HIM images contain considerable material and channeling contrast that arises from the strong dependence of the backscattered ion yield on the target atomic number and crystal grain orientation. To provide still greater material analysis information, a Rutherford Backscatter Spectrometer (RBS) has recently been added to the system. The RBS spectrometer has proven to be useful in thin film analysis and particle identification. A gas injection system (GIS) was also recently added to the microscope for users interested in ion induced deposition and etching studies. We will provide a system overview and report on some novel applications areas, including nanofabrication and ion beam lithography, now being explored by our customers and our internal R&D team.

TUE-FIBN02-2 #448 - Invited Talk - Tuesday 1:00 PM - Post Oak

Fabrication of plasmonic nano antennae on scanning probe tips via Focused Ion Beam Machine as new generation near field probes.

Alexander Frank Weber-Bargioni, Peter James Schuck, David Frank Ogletree, Stefano Cabrini
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In this work we present the reproducible engineering of coupled Au plasmonic nano antennae on scanning probe tips. The novel concept of optical antennae enables the manipulation of light at the nm scale, confining optical near fields into the gap between two opposing Au nano structures down to the single digit nm scale while enhancing the fields two orders of magnitude. For the successful implementation of these antennae onto e.g. scanning probe microscopy (SPM) tips, flexible as well as topographically independent high-resolution fabrication techniques are necessary. We were able to employ Focused Ion Beam Machine milling to engineer optical Au antennae on SiN SPM tips with resolutions between 8 and 12 nm using a Cr protection layer to reduce the Ga contamination while increasing the lateral resolution. To demonstrate the

functionality of these next generation Near Field Scanning Microscopy tips we imaged Carbon Nano Tubes optically with a 20nm resolution - well below the diffraction limit.

TUE-FIBN02-3 #368 - Invited Talk - Tuesday 1:00 PM - Post Oak

First Results From a Multi-Ion Beam Lithography and Processing System at the University of Florida

Brent P Gila[1], Bill R Appleton[1], Joel Fridmann[2], Paul Mazarov[3], Jason E Sanabia[2], S Bauerdick[3], Lars Bruchhaus[3], Ryo Mimura[3], Ralf Jede[3]

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[(2)]Raith USA, Inc, Ronkonkoma NY 11779, United States
[(3)]Raith GmbH, 44263, Dortmund, Germany

The University of Florida (UF) have collaborated with Raith to develop a version of the Raith ionLiNE IBL system that has the capability to deliver multi-ion species in addition to the Ga ions normally available. The UF system is currently equipped with a AuSi liquid metal alloy ion source (LMAIS) and ExB filter making it capable of delivering Au and Si ions and ion clusters for ion beam processing. Other LMAIS systems could be developed in the future to deliver other ion species. This system is capable of high performance ion beam lithography, sputter profiling, maskless ion implantation, ion beam mixing, and spatial and temporal ion beam assisted writing and processing over large areas (100 mm2) - all with selected ion species at voltages from 15 - 40 kV and nanometer precision.

This presentation will discuss the performance of the system with the AuSi LMAIS source and ExB mass separator. We will report on initial results from the basic system characterization, ion beam lithography, as well as for basic ion-solid interactions. The use of some or all of Au+, Au++, Au3++, Au2+, Si+, and Si++ for a variety of accelerating voltages and target substrates will be studied.

The investigations will include sputtering yields, angle dependence, re-deposition; ion induced secondary electron imaging; and damage effects. Investigations reported will concentrate on interactions and alterations that exploit the ability of the system to control the spatial, temporal, and dose-rate of the ion beam; and the nanometer-precision patterning and direct-write capabilities. Effects associated with post annealing of ion implanted samples will be explored where appropriate, and studies of ion beam lithography combined with maskless ion implantation doping to fabricate nanoelectronic devices will be reported.

TUE-FIBN02-4 #152 - Contributed Talk - Tuesday 1:00 PM - Post Oak

Comparison of electromagnetic, electrostatic and permanent magnet quadrupole lens probe-forming systems for high energy ions

Alexander D. Dymnikov, Gary A. Glass

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The focusing system is an essential part in a nuclear microprobe. Focusing ion beams of MeV energy is generally accomplished by quadrupole lenses. There are three types of quadrupole lenses: electromagnetic, electrostatic and permanent magnetic. All these lenses have different advantages and disadvantages. Most microprobes employ electromagnetic quadrupoles for focusing, however electrostatic lenses have several advantages with respect to electromagnetic lenses. They can be made much smaller than electromagnetic lenses, which require space for windings. The compactness of the lens liberates more space for the specimen chamber. Electrostatic lenses do not suffer from hysteresis effects, negligible current is drawn from the power supply, and stable voltage is more readily achieved than stable current in electromagnetic systems. The field strength required for focusing the beam onto the target is independent of ion mass, thus ideally suited for heavy-ion beams. Another advantage is that electrostatic lenses can be constracted from industrial-grade material that facilitates reproductions. The main advantage of the permanent magnetic lens is that it does not require the power supply. The cost of operation of this lens can be minimum. The electromagnetic lens is the most expensive quadrupole lens. The short probe-forming systems comprised from all these types of quadrupole lenses in Lafayette Accelerator Center (LAC) are compared. The smallest beam spot size and appropriate optimal parameters of these probe-forming systems have been found.

TUE-FIBN02-5 #378 - Contributed Talk - Tuesday 1:00 PM - Post Oak

Investigation of multi-resolution support for MeV ion microscopy imaging

Harry J. Whitlow[1], Minqin Ren[2], Jeroen van Kan[2], Thomas Osipowicz[2], Frank Watt[2]
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In order to minimize the dose applied to the specimens during imaging in an MeV ion microbeam we have investigated new scanning concepts that allow collection of images with multi-resolution support. The underlying idea is to rapidly image suitable fields of view with low fluence then subsequently collect high-resolution images in a similar way to the multi-resolution capability of the JPEG-2000 image compression scheme.

To test the concept, a set of reference PIXE microbeam images with well-characterised noise were segmented. This was done by a pixel-addressing and summing scheme to obtain a set of test data with multi-resolution support. Subsequently, wavelet reconstruction was used to obtain different resolution images. Comparison with the original images showed the procedure to be very faithful and essentially loss-less. The image segmentation scheme can be easily implemented using a modern MeV focused ion microbeam or a system for programmable aperture lithography.

TUE-FIBN02-6 #426 - Contributed Talk - Tuesday 1:00 PM - Post Oak

Carbon microbeam IBIC studies of diamond detectors with planar and buried intredigitated electrodes

Milko Jaksic[1], Paolo Olivero[2], Zeljko Pastuovic[1], Federico Picolo[2], Natko Skukan[1], Ettore Vittone[2]
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After its recent upgrade, the Zagreb ion microprobe facility is able to focus wider range of heavier ions from either 6.0 MV or 1.0 MV tandem accelerators. Carbon ions ranging from hundreds of keV to tens of MeV energy can be focussed to a submicrometer spot size which is in particular suitable for studies of diamond.

Here we present two recent and related applications of carbon microbeams. The first one is DIBL (Deep Ion Beam Lithography) fabrication of buried conductive channels in diamond (1). These channels have been created after carbon microbeam irradiation and subsequent thermal annealing of high defect density regions. A comb like arrangement of conductive graphitic channels - electrodes formed at the end of the ion range were connected to the external electronic circuit and tested using IBIC (Ion Beam Induced Charge) technique. Higher collection efficiency has been obtained for IBIC measurements using ions having deeper range than the ions used for DIBL. IBIC has shown to be an appropriate tool for the microscopic depth profiling of charge collection efficiency in such structures.

Radiation hardness of diamond has been the subject of the other carbon microbeam application. We have performed controlled irradiation of the spectroscopic quality diamond detector using simultaneous IBIC monitoring of charge transport degradation. Small areas of diamond detector have been irradiated to monitor a kinematics of damage creation process, to establish a limit on diamond radiation hardness and to estimate the importance of polarization observed in higher count rate regimes.

Ref.1. P. Olivero, G. Amato, F. Bellotti, O. Budnyk, E. Colombo, M. Jak?iæ, C.Manfredotti, ?. Pastuoviæ, F. Picollo, N. Skukan, M. Vannoni, E. Vittone, Diamond Relat. Mater. 18 (2009) 870.

TUE-IBA02-1 #280 - Invited Talk - Tuesday 8:30 AM - Brazos I

Surface, Adatom and Nanostructure Electronic Properties Measured by Low Energy Ion-Surface Charge Exchange

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Low energy ion scattering (0.5-5 keV) has traditionally been used to obtain atomic scale compositional and structural information about the surface of a material. The charge exchange that occurs during the scattering of low energy alkali ions from solids can, however, also provide a unique probe of surface electronic properties that complements the information available from other tools. This ability results from electrons that resonantly tunnel between the projectile ionization level and overlapping states in the material. The talk will use examples to illustrate the basic physics of the process and demonstrate the variety of problems that can be addressed. These include mapping out inhomogeneous potentials at the surfaces of oxide materials and in the presence of adsorbates, as well as measuring the presence of quantum states in nanomaterials. Nanomaterials were produced for these experiments by deposition onto oxide surfaces and by sputtering thin metal films. Furthermore, the use of novel projectiles with low ionization energies, such as Si, P or Ga, increases the sensitivity to different regions of the electronic structure. In addition, we have shown that alkaline earth ions can probe correlated electron behavior at metal surfaces. The spin of the single valence electron of such an ion behaves as a magnetic impurity that interacts with the continuum of many-body excitations in the metal, resulting in Kondo and mixed valence resonances near the Fermi energy that lead to a marked temperature dependence of the neutralization.

TUE-IBA02-2 #399 - Invited Talk - Tuesday 8:30 AM - Brazos I

Combined RBS/Channeling and LEIS studies of epitaxial metal-metal interface structures

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The structures thin Ag and Ti films grown on Al(001) surfaces at room temperature are characterized using a combination of RBS/channeling, LEIS, and LEED. These two thin-film systems are particularly interesting in that thicker films with adatom coverage greater than one monolayer grow epitaxially on the Al(100) substrate, yet they exhibit quite different behavior for sub-monolayer coverage. The channeling results demonstrate the utility of RBS/c in characterizing epitaxial growth of thin films. However, the growth of a double domain (5x1) incommensurate Ag film for the first Ag monolayer, and the formation of a Ti-Al surface alloy with a c(2x2) structure for the first Ti monolayer, are difficult to analyze with RBS/c alone. In these cases, LEIS and LEED measurements are used to resolve the interface evolution at low coverage, showing the benefits of multiple ion scattering and diffraction techniques to determine the overall interface and epitaxial film structure.

TUE-IBA02-3 #137 - Contributed Talk - Tuesday 8:30 AM - Brazos I

CLASSICAL AND QUANTUM RAINBOW SCATTERING FROM SURFACES

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Recently, we observed pronounced diffraction effects for grazing scattering of fast atoms with energies up to some keV und axial surface channeling. The rich diffraction patterns provide information on the interatomic spacings between axial channels and on the corrugation of the interaction potential. The latter effect can be used to study the structure of surfaces with fast atoms with interferometric sensitivity. The new method shows some similarities to thermal He atom scattering (HAS), but has a number of advantages as simple tuning of the projectile energy (de Broglie wavelength) and, in particular, an orders of magnitude more efficient detection of scattered projectiles.. As examples, we will present studies on the accurate positions of adsorbed O and S atoms on Fe(110) and Ni(110) surfaces. Specific features of surface channeling are important prerequisites for preserving quantum coherence in the scattering process.

TUE-IBA02-4 #352 - Contributed Talk - Tuesday 8:30 AM - Brazos I

Characterization of H adsorption on surfaces using LEIS

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How hydrogen interacts with metal surfaces is relevant to a wide range of applications, including hydrogen storage, hydrogen energy infrastructure, and plasma/surface interactions in magnetic fusion devices. Low energy ion scattering (LEIS) and direct recoil spectroscopy (DRS) can provide fundamental information about the configuration of adsorbed hydrogen on single crystal systems and are an ideal way to validate the predictions of first-principles models. In this study, we have used low energy (<3 keV) He+ and Ne+ ion beams to examine the W(100)+H and Al(111)+H systems. The measurements were performed using an angle-resolved ion energy spectrometer (ARIES) which included a heated tungsten capillary doser for studies where atomic hydrogen was required. Using this system enables us to collect scattered and recoiled ions over a wide range of sample orientations, making it possible to construct "maps" which reveal complex focusing effects along the surface. These effects can be exploited to provide information on the adsorbate binding site. Thermal desorption profiles of surface-adsorbed hydrogen are also discussed.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000.

TUE-IBA02-5 #74 - Invited Talk - Tuesday 8:30 AM - Brazos I

Applications of MEIS to Advanced Electronic Materials

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Development of gate dielectrics for CMOS logic has advanced beyond simple HfO2/SiO2 structures. We are now faced with understanding complex systems where interdiffusion and silicate formation play an important role in determining film structure.

Dielectrics with permittivities greater than HfO2 have prompted numerous investigations into alternative metal-oxides. Rare earth scandates are of particular interest, since these materials may allow us to combine a high dielectric constant with an amorphous structure. Silicate formation is a concern, resulting in phase separation with largely unknown electrical effects. We will examine thermal stability of rare earth scandates, and discuss strategies to minimize decomposition.

Efforts to find a successor to traditional CMOS have spurred widespread investigations of graphene-based devices. Since large-scale substrates are now available, it is possible to study Gr/SiC growth and processing with ion beam techniques. We will discuss profiling of Gr/SiC using MEIS, looking at attempts to electronically decouple Gr from the substrate by insertion of a thin SiO2 layer. Despite the challenges presented by the small stopping power of a two-dimensional sheet of carbon, we are able to provide useful characterization of this exciting system.

TUE-IBA02-6 #140 - Contributed Talk - Tuesday 8:30 AM - Brazos I

Using a lithium beam to analize organic samples

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A 13 MeV ^{6}Li ion beam can be used to irradiate an evaporated organic liquid sample and determine its concentrations of H, C, N, O, Na and Cl simultaneously. The detection of protons produced in the ^{1}H(^{6}Li,^{1}H)^{6}Li reaction at forward angles allows the H characterization while the C, N, O, Na and Cl concentrations can be obtained by detecting elastically scattered ^{6}Li ions. A study of proton counting rates vs sample dilution with distilled water shows a linear dependence existing between H concentration and sample dilution. The effect of diluting amniotic liquid samples on the improvement of energy resolution is observed confirming previous reports. A combination of a counter telescope and a single detector, set up at the same polar angle on the opposite side of the beam, provides adequate particle identification and spectrum energy resolution simultaneously.

TUE-IBA02-P1 #331 - Poster - Tuesday 5:30 PM - Rio Grande

New Possibilities in High Sensitivity Low Energy Ion Scattering (LEIS) for Probing the Outermost Atomic Layer

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Low Energy Ion Scattering (LEIS) is an extremely surface sensitive analytical technique for the characterization and quantification of the composition of the outermost atomic layer. This information is required to understand material properties like catalytic performance or the nucleation and initial growth modes of ultra-thin films, e. g. in nanoelectronics.

The Qtac100 is a high sensitivity and high resolution LEIS instrument with innovative capabilities making a wide range of new applications available.

LEIS gains from the choice of different noble gas ions available on the Qtac100. Helium is used for non-destructive depth profiling and light element surface characterization. For the analysis of higher-mass elements, heavier primary ions can be chosen, which provides superior mass resolution. The higher energy range of the primary ion source of up to 8 keV, also improves the mass resolution. For example, it is now possible to separate Au and Pt or Ag and Pd, which are both relevant to the field of catalysis.

In addition, a time-of-flight (ToF) filter dramatically improves the detection limits by suppressing the signal arising from sputtered ions while allowing the scattered ions to reach the detection system. Our results show that quantification is feasible for real-world samples with coverages of a few 10 ppm of one monolayer, utilising the high primary ion energy and ToF filtering of the Qtac100.

Further possibilities such as localized analysis and depth profiling (both traditional sputter profiling, as well as non-destructive (static) profiling) will be also discussed.

TUE-IBA03-1 #84 - Invited Talk - Tuesday 1:00 PM - Brazos I

Irradiation-induced magnetic phase transition in granular magnetite films

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Magnetic nanomaterials are expected to play a critical role in developing or advancing the understanding of dramatic irradiation effects. Thin magnetic films are attracting considerable attention in recent years because of new science and interesting properties. However, very few studies, if any, have been conducted to date for granular films whose magnetic properties could be very susceptible to nuclear radiation due to a large surface area. Cubic phase Fe3O4 nanoparticles were deposited onto a Si substrate at room temperature using a state-of-the-art cluster-beam source and a high-transmission mass selector. The average size of the crystallites was ~3 nm with a narrow particle size distribution. The nanostructured film was irradiated with 5.5 MeV Si2+ ions to a fluence of 1E16 ions/cm2 near room temperature. The magnetic properties have been measured before and after the irradiation. It has been found that the material undergoes a superparamagnetic to ferromagnetic transition. The remanence of the film at room temperature changes from 0.00 to 9.36 emu/g. Subsequent hysteresis measurement at room temperature shows that the saturation magnetization and coercivity for the irradiated sample are 45.64 emu/g and 250 Oe, respectively. X-ray diffraction study indicates that the crystallite size increases from 3 to 23 nm as a result of the irradiation. A dramatic change in the microstructure is also observed using a high-resolution helium ion microscope. The changes in the magnetic properties have been attributed to the increase in particle size and an alteration of the interatomic and electronic configurations at the particle surface and interface, which lead to possible formation of multi-domain particles that contain a number of crystallites, domain wall movement, magnetic moment rotation, and occurrence of magnetic anisotropy in the film. A detailed discussion will be provided during the presentation.

TUE-IBA03-2 #521 - Invited Talk - Tuesday 1:00 PM - Brazos I

Thermal Stability and Interface Structure of ZrO2 films

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Zirconia (ZrO2) is an important material with a potential for a wide range of technological applications. The outstanding chemical stability, electrical and mechanical properties, high dielectric constant, and wide band gap of ZrO2 make it suitable for several industrial applications in the field of electronics, magnetoelectronics, and optoelectronics. However, it is well known that the electrical and optical properties of ZrO2 thin films are highly dependent on the film-substrate interface structure, morphology, and chemistry, which are in turn controlled by the film-fabrication technique, growth conditions, and post-deposition processes. The present investigation has been performed to understand the thermal stability and interface structure ZrO2 films grown on n-type Si (100) substrates. High-energy ion-beam analysis coupled with spectroscopic ellipsometry (SE) has been employed to understand the effect of temperature on the structure and stability of the ZrO2/Si system. Ion-beam analysis indicates an increase in the interfacial layer (IL) thickness with increasing temperature and also with the time of annealing, which is due to the oxidation of the ZrO2/Si interface. Interestingly, a two-step behavior with the growth rates divided into slow and fast. The spectroscopic ellipsometry also indicates the similar behavior in addition to confirming the changes in the electronic structure. The results of ion-beam analysis and ellipsometry will be presented to discuss the temperature stability and interface structure of the ZrO2-Si system.

TUE-IBA03-3 #369 - Invited Talk - Tuesday 1:00 PM - Brazos I

Ion beam damage studies of ultrananocrystalline diamond (UNCD)

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Investigations into the effects of high energy ion bombardment of ultrananocrystalline diamond (UNCD) thin film was performed using 3 and 6 MeV protons and 24 MeV flourine with the dose of 2.123 x 1017 ions/cm2, 2.94 x 1017 ions/cm2, and 6.715 x 1015 ions/cm2 respectively. Objective of the research is to investigate the effect of structural damage on the physical properties of the material. Pre and post damage samples were analyzed by ion beam analysis measurements, Raman Spectroscopy, AFM and SEM. Ion beam analysis (IBA) measurements including Rutherford Backscattering Spectrometry (RBS), Non-Rutherford Backscattering Spectrometry (NRBS) and Elastic Recoil Detection Analysis (ERDA) was used to determine elemental concentration of pre and post damage samples. Visible Raman spectra corresponding to 3 and 6 MeV ion energy did not show much variation but for 24 MeV, significant changes are observed, particularly loss of shoulder at 1179 cm-1 and sharpening of G peak at around 1532 cm-1 indicating significant changes at the grain boundary and increase in graphitic phase. AFM measurements show reduction in RMS roughness after bombardment possibly due to the graphitization of the UNCD surface. The results of IBA measurements did not show any change in the elemental concentration or interface region.

TUE-IBA03-4 #227 - Invited Talk - Tuesday 1:00 PM - Brazos I

Hydrogen Compatibility of Piezoelectrics

Kyle J Alvine[1], Shuttha V Shutthanandan[1], Stan G Pitman[1], Daniel C Skorski[1], Michael E Dahl[1], Wendy Bennett[1], Madhusudan Tyagi[2], Craig Brown[2], Terry Udovick[2]
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Direct Injection hydrogen internal combustion engines (H2ICE) have the potential to deliver high power density very efficiently with near zero emissions utilizing mature ICE technology. A critical materials science challenge facing existing technology is that of rapid "fouling" (degradation) of the piezoelectric material used in the hydrogen injector when exposed to high pressure H2, presumably due to hydrogen absorption. Similar detrimental effects occur at low pressure during hydrogen passivation of ferroelectric RAM. We present high pressure hydrogen absorption data based on Elastic Recoil Detection Analysis (ERDA) and diffusion data from Quasi-elastic Neutron Scattering (QENS) for PZT and BaTiO3 piezoelectric materials.

TUE-IBA03-5 #522 - Contributed Talk - Tuesday 1:00 PM - Brazos I

Low-Energy Ion Irradiation Induced Reduction Behavior and Metallic Tungsten Formation of WO3 films

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Tungsten oxide (WO3) is a wide band gap semiconductor (~ 3.2 eV), which exhibits excellent properties suitable for the development of integrated chemical sensors and electrochromics. N-type conductivity coupled with selectivity and sensitivity to certain type of chemicals make WO3 thin films interesting for NOx and H2S sensors. The present work was performed to understand the effect of low-energy Ar+ ion irradiation on the microstructure WO3 thin films. WO3 thin films were produced by the RF magnetron sputtering. The films were grown at various temperatures (30-500 oC) and reactive gas pressures (2.3 - 5.6mTorr). The X-ray photoelectron spectroscopic has been employed to study the electronic structure of WO3 films under low-energy Ar+ ion-irradiation. The analysis revealed that for the W6+ component determined from an ion-irradiated WO3 surface, the parameter ΔE(O 1s-W 4f7/2) is very close to that of pristine WO3 film. The surface layer becomes amorphous and the chemical environment of W6+ ions in the amorphous layer similar to that in pristine WO3. The Ar+ ion irradiation of WO3 films in the transition of most of the W6+ ions into lower chemical valence states, metallic state predominantly. The formation of lower chemical states of transition metal ions in turn results in the formation of localized electronic states that appear at the top of valence band. These localized states usually lower the activation energy and hence an increase in the surface conductivity. The results will be presented and discussed in detail.

TUE-IBA04-1 #324 - Invited Talk - Tuesday 3:30 PM - Brazos I

Artificial neural networks in accelerator based data analysis

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Advances in accelerator technology have led to a strong decrease in data acquisition time in accelerator based analysis. This encouraged the development of in situ acquisition which naturally results in large batches of valuable data. Presently the time-consuming factor in research no longer appears to be data acquisition, but has rather become data analysis. Real-time Rutherford backscattering spectrometry (RBS) for example probes the full evolution of the compositional depth profile in situ upon annealing. Although very valuable insights can be gained by this technique, the required time-consuming analysis of the vast amount of spectra has discouraged its widespread use.

Recently, groundbreaking progress in the analysis of real-time RBS data has been achieved: artificial neural networks (ANNs) have been applied for an instantaneous and accurate fully quantitative analysis of large batches of real-time RBS data. This approach is based on pattern recognition for which an ANN is trained to automatically link acquired RBS spectra to the quantitative information of interest, e.g. layer thickness, elemental composition, etc. With this method, huge RBS datasets can be analyzed quantitatively without a reduction in accuracy, enabling on-line analysis and dedicated systematic real-time studies.

The use of ANNs in data analysis is however not restricted to backscattering spectra. In this contribution we will show the major progress achieved in the analysis of synchrotron nuclear resonant scattering data and real-time elastic recoil detection thanks to our experience with ANNs for real-time RBS. We will review the construction, training and analyzing skills of ANNs and demonstrate that this method can be directly expanded to the analysis of any type of data for which simulation software is available. Hence, ANNs prelude a solution to the analysis of large data sets and thus allow applying the in situ real-time approach to techniques which would otherwise require an intensive time-consuming analysis.

TUE-IBA04-2 #5 - Invited Talk - Tuesday 3:30 PM - Brazos I

Simulating and Fitting High Resolution RBS Spectra

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High resolution Rutherford Backscattering Spectrometry (HR-RBS) can be performed by using an electrostatic analyzer (ESA) for energy detection instead of a conventional solid state detector. Our ESA setup provides a depth resolution of about 1 nm, which is particularly interesting to investigate concentration gradients on the nanometer scale. For simulating and fitting experimental RBS spectra, a variety of ion beam analysis software is available. However, the ESA spectra exhibit various differences compared to conventional RBS spectra, for example, the energy resolution ΔE scales with the energy E and the different charge states of the backscattered ions affect the detection. These differences provide the motivation to develop a new code for the simulation of ESA spectra. Furthermore, we implemented a Monte Carlo fit algorithm, which is suitable for fitting concentration gradients. The fit routine imitates a diffusion mechanism in the virtual sample, in order to find a concentration profile matching the measured spectrum. We discuss the advantages and drawbacks of this diffusion-like fit approach and demonstrate the functionality of the program on different applications, i.e. metal-carbon multilayer thin films prepared by mass selected ion beam deposition and the analysis of concentration gradients in Gd/Ni bilayers.

TUE-IBA04-3 #17 - Contributed Talk - Tuesday 3:30 PM - Brazos I

IBIXFIT a tool for the analysis of microcalorimeter PIXE spectra

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PIXE analysis software has been for long mainly tuned to the needs of Si(Li) detector based spectra analysis and quantification methods based on Kα or Lα X-ray lines. Still, recent evidences related to the study of relative line intensities and new developments in detection equipment, namely the emergence of commercial microcalorimeter based X-ray detectors, have brought up the possibility that in the near future PIXE will become more than just major lines quantification. A main issue that became evident as a consequence of this, was the need to be able to fit PIXE spectra without prior knowledge of relative line intensities. Considering new developments it may be necessary to generalise PIXE to a wider notion of ion beam induced X-ray (IBIX) emission, to include the quantification of processes such as Radiative Auger Emission. In order to answer to this need, the IBIXFIT code was created based much on the Bayesian Inference and Simulated Annealing routines implemented in the Datafurnace code [1]. In this presentation, the IBIXFIT code will be described coupled to a brief overview on microcalorimeter spectra fitting and a discussion on cases where X-ray lines intensity can be left free and cases where fixed line ratios are needed. The usefulness of the IBIXFIT code when high resolution spectra from a microcalorimeter detector are at stake, will thus be shown.

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TUE-IBA04-4 #250 - Contributed Talk - Tuesday 3:30 PM - Brazos I

Stopping and straggling of ions in solids within the shellwise local plasma approximation

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We present a theoretical study on the energy loss of ions in solids, stopping power and straggling. The formalism employed is the shellwise local plasma approximation (SLPA) which works within the dielectric formalism and describes the response of bound electrons as that of an inhomogeneous free electron gas. This formalism, proposed by Lindhard [1] many years ago, has evolved in the last years by considering independent shell response and including the ionization thresholds explicitly.

We will review in this talk the SLPA results for ions in solids like Al, Zn or Cu [2-4], but also recent results on very heavy targets such as Au, Pb, Bi or W [5-6], showing the comparison of the ab-initio theoretical calculation with the experimental data and the SRIM curves. We will also present in this opportunity results for the stopping number using the Lindhard scaling and theoretical values for the mean excitation energy.

The SLPA has the advantage of dealing with very heavy targets, like Au with 79 electrons, with the same degree of complexity of much simpler ones like He, C or Ne. On the other hand. the same formalism is employed to describe bound electrons of solid or gas targets. The only inputs for the SLPA are the density of each shell of electrons and its binding energies. Nor parameters are included.

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TUE-IBA04-5 #113 - Contributed Talk - Tuesday 3:30 PM - Brazos I

Integration of SIMS into a general purpose IBA data analysis code

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IBA techniques such as RBS, ERDA, NRA, or PIXE are highly complementary of each other, and are often used in conjunction. In particular, they have different sensitivities to different elements and probe different depth scales. The same is true for secondary ion mass spectrometry (SIMS), that can have much lower detection limits for many species.

The data analysis of IBA normally relies on assuming a given sample description, producing a theoretical spectrum based on well known physics and well known quantities such as stopping powers and scattering cross sections, and then comparing it to the data. The assumed sample structure is then changed until good agreement is reached. This is what NDF, a standard IBA data analysis code, does for RBS, ERDA, resonant and non-resonant NRA, and PIXE.

On the contrary, sputter rates and secondary ion yields are experimental quantities that depend on the sample composition and on the concentration of the element being studied. Quantification of SIMS data normally requires careful calibration of the exact system being studied, and often the results are only semi-quantitative.

Nevertheless, when SIMS is used together with other IBA techniques, it would be highly desirable to integrate the data analysis. We developed a routine to analyse SIMS data, and implemented it in NDF. Details of this new routine are presented in this work.

We tested the new code by studying deuterium retention in carbon samples subject to plasma irradiation in the JET tokamak. We used SIMS and IBA techniques extensively for the analysis of wall components removed from JET. Lateral microbeam PIXE was performed on some samples, obtaining depth profiles that probe as deep as SIMS. We also obtained RBS, ERDA, and NRA data from the same samples. All the data are analysed simultaneously, with the same depth profile, ensuring self-consistency between all results.

TUE-IBA04-P1 #114 - Poster - Tuesday 5:30 PM - Rio Grande

A double scattering analytical model for elastic recoil detection analysis

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We present an analytical model for calculation of double scattering in ERDA spectra. Only events involving the beam particle and the recoil are considered, i.e. 1) ion scatters off a target element then produces a recoil, and 2) ion produces a recoil which then scatters off a target element. Events involving intermediate recoils are not considered, i.e. when the primary ion produces a recoil which then produces a second recoil. If the recoil element is also present in the absorbing foil, recoil events in the absorbing foil are also calculated. We show that, given the grazing angle geometries employed in ERDA, events with small scattering angle must be taken into account, as long as they lead to paths that are significantly different from the corresponding single scattering event. We included the model in the standard code for IBA data analysis NDF, and applied it to the measurement of hydrogen in indium nitride.

TUE-IBM03-1 #93 - Invited Talk - Tuesday 8:30 AM - Pecos II

Structure and composition of high-k materials on novel substrates

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Medium Energy Ion Scattering (MEIS) has been very successfully applied to the study of oxidation and interface structure of silicon. This topic was of central importance for understanding the performance of microelectronic devices as silicon oxide is used as an insulator in such circuits. As the size of these devices was scaled down, these insulating SiO2 layers became too thin, and the focus for the microelectronics industry is therefore changing to materials with higher dielectric constant ("high-k") that could be made thicker. MEIS results have made major contributions in making high-k materials a commercial reality. In the ever increasing push towards even smaller devices, this community is now directing its attention in part to substrate materials with better performance (higher channel mobilities) than Si, such as Ge, GaAs and InGaAs. The removal of native oxides and the growth an ideal dielectric layer on these materials remain serious challenges. It is known that chemical cleaning and subsequent passivation of the interface prior to dielectric deposition can greatly reduce the interface state density (Dit). We have used atomic layer deposition (ALD) to obtain detailed structural and chemical information about the interface and reduction processes when high-k materials are deposited on GaAs and Ge. We have determined depth profiles of the elements with an integrated tool that enables ALD growth with in situ characterization by MEIS. Films were also analyzed by x-ray photoelectron spectroscopy (XPS). Our results show the existence of a preferential interface reduction of native oxides (especially AsO), which helps create a higher capacitance, lower interface defect density CMOS gate stack.

TUE-IBM03-2 #18 - Invited Talk - Tuesday 8:30 AM - Pecos II

Ion beam irradiation effects in elemental and compound semiconductors: modifications and characterizations

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Synthesis and modification of semiconductor nanostructures using low and high energy ion beams will be discussed and our recent results will be presented. The materials used are elemental (Ge, Si) as well compound (GaAs and GaN based) semiconductors. The single layers as well as multi quantum wells were treated by atoms as well as ion beams in low energy region in sputtering and ion implantation mode. These were finally irradiated with Swift Heavy Ions (SHI) and in some cases subjected to Rapid Thermal Annealing (RTA), to produce nanostructures. The characterizations were carried out by RBS/Channeling, HRXRD, Raman and PL. Some interesting effects of SHI irradiation and the underlying mechanisms will be discussed

TUE-IBM03-3 #64 - Invited Talk - Tuesday 8:30 AM - Pecos II

Synthesis and Characterization of transparent diluted ferromagnetic semiconductors induced by Ni+2 ion implantation in ZnO films

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Research on nanoscale magnetic semiconductors is under significant focus in materials science because of their promising applications in spin-mediated devices. The upcoming technologies where these materials are going to be used are, spintronics, opto-spintronics, data storage and sensors. Improved performance of these devices depends on proper synthesis of these materials and engineering their properties. Ion implantation has been established as a promising route to synthesise

magnetic semiconductor having phase transition temperature around room temperature. The challenges in this research are to obtain robust ferromagnetism at room temperature, tuning the ferromagnetic (FM) properties and optimize the FM strength. In this talk we first address some of the important issues related to transition metal implanted wide band gap semiconductor materials as ferromagnetic semiconductor. After this, detailed results on 200 keV Ni+2 ion implanted ZnO thin films grown by pulsed laser deposition and vapor phase transport method will be discussed. These results include fluence dependent variation of FM strength, tuning FM properties by varying film microstructure, combination of room temperature ferromagnetism and high optical transmittance. Temperature dependent electrical transport is studied in detail and correlated with ferromagnetic properties. The results PLD grown and VPT grown ZnO Ni implanted films are explained on the basis of carrier mediated exchange interaction of localized magnetic moments of Ni and bound magnetic polaron (BMP) models.

Relevant References:

1. B. Pandey, S. Ghosh et al. J. App. Physics 107, 023901 (2010)

2. B. Pandey, S. Ghosh et al. J. App. Physics 105, 033909 (2009)

3. S. Ghosh, D. Kanjilal et al. Rad. Eff. Def. Sol. 163 (2008) 215

4. S. J. Pearton, D. P. Norton et al. IEEE Transactions on Electronic Devices 54, 1040 (2007).

TUE-IBM03-4 #37 - Invited Talk - Tuesday 8:30 AM - Pecos II

Ion beam studies of semiconductor nanoparticles for the integration of optoelectronic devices

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Radiation hardened microelectronics compatible and tunable light emitting devices are essential for the integration of electronic and optoelectronic devices. Integration of optoelectronic devices requires band-gap tuning because different optoelectronic devices demand different band-gaps. Porous or nano-crystalline silicon seems to be a promising material for accomplishing this task. Ion beam patterned structures of light emitting silicon nanoparticles can be used for achieving multiple wavelength emission. A complete understanding of the ion beam modification of emission parameters is critical for achieving controlled tunability. Radiation damage studies are important because these devices are expected to be operated in space and nuclear electronics.

A detailed study on the influence of gamma and ion irradiation on the anodization process of silicon and radiation damage investigations of light emitting porous silicon will be presented. The influence of energetic ions and gamma radiation on the stability of surface passivation bonds (like Si-H and Si-O) will also be discussed. This information is useful for understanding the global nature of Si-H bonds in semiconductors and for improving the long-term reliability of electronic devices.

Similarly, ion beam synthesis and modification of various kinds of semiconductor nanoparticles of elemental as well as III-V semiconductors will also be presented. The techniques used are sputtering and ion implantation. The emphasis is on direct band-gap semiconductors and other optoelectronic materials. New results will be presented along with a detailed review on ion beam nano-structuring of optoelectronic materials.

TUE-IBM03-5 #367 - Contributed Talk - Tuesday 8:30 AM - Pecos II

Boron behavior affected by ion irradiation in SiC

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Recent studies show that post-irradiation will affect the behavior of interstitials and vacancies in crystalline SiC. A p-type SiC layer formed in the region from 200 to 400 nm was induced by the combination of 180, 140 and 110 keV B ion implantation of 4H-SiC at room temperature. Then, they were irradiated with 550 keV Si ion at room temperature. So vacancies and energy deposition were induced advisedly in the p-type layer. The microstructure and electrical properties of SiC thin film were investigated respectively by RBS/C, GIXRD and Hall measurements. The results show that the hole concentration was enhanced by post-irradiation and Boron nano-crystal particles were formed in SiC.

TUE-IBM03-6 #19 - Contributed Talk - Tuesday 8:30 AM - Pecos II

SHI effects on Ge+SiO2 composite films prepared by RF sputtering

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We have deposited Germanium and Silicon dioxide composite films by using RF magnetron sputtering. The irradiation was performed at room temperature (RT) using 150 MeV Ag ions with fluences ranging from 5 x 1012 to 5 x 1013 ions/cm2. These samples have been characterized by Rutherford back scattering spectrometry (RBS), X-ray diffraction (XRD), and transmission electron microscopy (TEM). RBS was used to quantify the concentration of Ge in the SiO2 matrix. Structure of the irradiated films was evaluated by XRD. Size of the crystallites was calculated using TEM. Surface morphology of these films is studied using atomic force microscopy (AFM). Swift heavy ion irradiation (SHI) induced crystallization in these films has been discussed in detail.

TUE-IBM03-P1 #233 - Poster - Tuesday 5:30 PM - Rio Grande

SiO2/SiO2+CoSb Thermoelectric Generator Superlattice of Skutterudite Nanolayered Films Modified by MeV Si Ions

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Thermoelectric materials of skutterudite structure, which have a body-centered cubic (bcc) structure and AB3 formula like CoSb3, have been reported of having promising thermoelectric properties. Since we have reached efficient thermoelectric materials when we prepare our superlattice thin films of SiO2/SiO2+M (M=Ag, Au), we decided to combine our good results from skutterudite and superlattice sides by preparing the thermoelectric device from SiO2/SiO2+CoSb superlattice skutterudite nanolayered films. As shown in the literature, the performance of the thermoelectric devices and materials is shown by a dimensionless figure of merit, ZT = S2sT/k, where S is the Seebeck coefficient, s is the electrical conductivity, T is the absolute temperature and k is the thermal conductivity. ZT can be increased by increasing S, increasing s, or decreasing k. We have prepared a thermoelectric generator from 100 alternating layers of SiO2/SiO2+CoSb superlattice thin films using ion beam assisted deposition (IBAD). Rutherford Backscattering Spectrometry (RBS) and RUMP simulation have been used to determine the stoichiometry of the elements of Si, Co and Sb in the multilayer thin films and the thickness of the grown multi-layer films. The 5 MeV Si ions bombardment was performed using the AAMU Pelletron ion beam accelerator to make quantum clusters in the nanolayered superlattice films to decrease the cross plane thermal conductivity, increase the cross plane Seebeck coefficient and cross plane electrical conductivity.

TUE-IBM03-P2 #236 - Poster - Tuesday 5:30 PM - Rio Grande

SiO2/SiO2+Ge Nanolayered Thin Film Thermoelectric Generator Modified by MeV Si Ions

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Thermoelectric materials are important due to their application in both thermoelectric power generation and microelectronics cooling. Thermoelectric power generators convert heat to electricity. The efficiency of thermoelectric devices is limited by the properties of n-and p-type semiconductors. Effective thermoelectric materials have a low thermal conductivity and a high electrical conductivity. The performance of thermoelectric materials and devices is shown by a dimensionless figure of merit, ZT = S2sT/k, where S is the Seebeck coefficient, s is the electrical conductivity, T is the absolute temperature, and k is the thermal conductivity. ZT can be increased by increasing S, increasing s, or decreasing k. We prepared a thermoelectric generator device from 100 alternating layers of SiO2/SiO2+Ge superlattice films using ion beam assisted deposition (IBAD). Rutherford Backscattering Spectrometry (RBS) and RUMP simulation software package were used to determine the stoichiometry of Si and Ge in the grown multilayer films, and the thickness of the grown multi-layer films. The 5 MeV Si ion bombardments was performed using the AAMU Pelletron ion beam accelerator to make quantum clusters in the multi-layer superlattice thin films to decrease the cross plane thermal conductivity, increase the cross plane Seebeck coefficient and cross plane electrical conductivity.

TUE-IBM03-P3 #237 - Poster - Tuesday 5:30 PM - Rio Grande

MeV Si Ions Modifications on Si/Si+Ge Superlattice Nanolayered Film Thermoelectric Generators

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Thermoelectric devices have no moving parts and, therefore, need substantially less maintenance. The direction of heat-pumping in a thermoelectric system is fully reversible. Changing the polarity of the DC power supply causes heat to be pumped in the opposite direction - a cooler can then become a heater. The performance of thermoelectric devices is shown by a dimensionless figure of merit, ZT = S2sT/k, where S is the Seebeck coefficient, s is the electrical conductivity, T is the absolute temperature and k is the thermal conductivity. ZT can be increased by increasing S, increasing s, or decreasing k. We prepared a thermoelectric generator device from 100 alternating layers of Si/Si+Ge superlattice films using ion beam assisted deposition (IBAD). To determine the stoichiometry of Si and Ge in the grown multilayer films and the thickness of the grown multi-layer films Rutherford Backscattering Spectrometry (RBS) and RUMP simulation were used. The 5 MeV Si ions bombardment was performed using the AAMU Pelletron ion beam accelerator to make quantum clusters in the nanolayered superlattice films to decrease the cross plane thermal conductivity, increase the cross plane Seebeck coefficient and cross plane electrical conductivity. In addition to thermoelectric properties, some optical properties of the Si/Si+Ge multi-layer superlattice films have been measured.

TUE-IBM03-P4 #382 - Poster - Tuesday 5:30 PM - Rio Grande

Effects of MeV ion bombardment on the performanmce of Pd based gas sensors

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Non-linear electronics devices (MOSFET, metal-semiconductor, or p-n junctions) are promising candidates for hydrogen detection schemes if used in conjunction with a platinum group catalyst. For the past decade, the emphasis was mostly on using silicon carbide devices for high temperature applications in the automotive (hydrogen-fueled engines) and in the aerospace industry (jet engines), but now the focus is broadening to include auxiliary systems such as storage tanks, fuel lines, fuel production systems, all operating in a wide range of temperatures, all the way down to cryogenic levels. The

purpose of this work is to develop a sensor capable of operating in the ppm-ppb range detecting hydrogen-based aerosols at room temperature. Here we are investigating how the type, energy, and fluence of accelerated ions affect the sensor performance at ambiental temperatures. We used e-beam deposition and ion implantation for preparing our samples on silicon substrates, and 1 to 5 MeV Si and Au ions to modify the sensors' active area. Rutherford backscattering spectrometry, Raman spectroscopy, and atomic force microscopy will show the structural alterations of the device, while controlled-atmosphere electrical measurements will monitor the effect on performance.

TUE-MAR03-1 #385 - Invited Talk - Tuesday 8:30 AM - Pecos I

Current Status of New Accelerators in Charged Particle Radiotherapy

George Coutrakon
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The past decade has experienced a large growth in proton and light ion facilities for cancer therapy. The properties of the depth dose distributions for charged particles allow greater dose sparing of healthy tissue than X-ray beams. In the United States alone, there are now seven operational proton facilities and several others in construction. Five light ion facilities in Europe and three in Japan are in various stages of operation or construction to treat with proton, helium and carbon ions. Three facilities are actively treating with carbon ion beams. The growth has led to new innovations in accelerator designs. In this talk, the basic requirements of therapeutic medical accelerators are presented. As a result of an increased need for lower cost and more compact particle accelerators in cancer treatment, new technologies are being developed in order to make this treatment modality more widely available. A glimpse of what future accelerators may look like and their characteristics will be discussed.

TUE-MAR03-2 #306 - Invited Talk - Tuesday 8:30 AM - Pecos I

Status of the Dielectric Wall Accelerator for Proton Therapy

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The Dielectric Wall Accelerator (DWA) offers the potential to produce a high gradient linear accelerator for proton therapy and other applications. The current status of the DWA for proton therapy will be reviewed. Recent progress in SiC photoconductive switch development will be presented. There are serious beam transport challenges in the DWA arising from short pulse excitation of the wall. Solutions to these transport difficulties will be discussed.

*This work performed under the auspices of the U.S. Department Of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. Patents Pending.

TUE-MAR03-3 #355 - Contributed Talk - Tuesday 8:30 AM - Pecos I

Optimizing Proton Therapy: A Two-Stage, Dual CW Accelerator System

Carol Joanne Johnstone
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A two-stage accelerator approach optimizes the efficiency and throughput of patients in a proton therapy facility by exploiting the natural division in the treatment energy of the different types of cancers. Lung, breast, central nervous system, pediatric, neck and several other forms of cancer which represent approximately 50% of the patients are treated with proton beams in the energy range 70-170 MeV (with lower energies obtained by plastic range shifters placed close to

the skin). Prostate patients comprise the remaining cases and are treated predominately with high-energy proton beams from ~180-250 MeV. This fits nicely with a dual energy accelerator system where E<170 MeV represents the first accelerator stage and associated treatments, but, in addition, feeds a second stage of acceleration which raises the energy to the range required for prostrate treatment. A two-stage, CW, variable-energy, fixed-field accelerator system has been designed which supplies simultaneous proton beams of different energies to different treatment rooms thereby increasing the projected efficiency relative to a single-accelerator facility with minor impact on civil, equipment and operational costs.

TUE-MAR03-4 #526 - Invited Talk - Tuesday 8:30 AM - Pecos I

Proton Therapy at Siteman Cancer Center: The State of the Art

Charles Bloch
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Barnes-Jewish Hospital is on the verge of offering proton radiation therapy to its patients. Those treatments will be delivered from the first Monarch 250, a state-of-the-art cyclotron produced by Still River Systems, Inc., Littleton, MA. The accelerator is the world's first superconducting synchrocyclotron, with a field-strength of 9 tesla, providing the smallest accelerator for high-energy protons currently available. On May 14 it was announced that the first production unit had successfully extracted 250 MeV protons. That unit is scheduled for delivery to the Siteman Cancer Center, an NCI designated Comprehensive Cancer Center at Washington University School of Medicine. At a weight of 20 tons and with a diameter of less than 2 meters the compact cyclotron will be mounted on a gantry, another first for proton therapy systems. The single-energy system includes 3 contoured scatterers and 14 different range modulators to provide 24 distinct beam delivery configurations. This allows proton fields up to 25cm in diameter, with maximum range from 5.5 to 32 cm and spread-out-Bragg-peak extent up to 20cm. Monte Carlo simulations have been run using MCNPX to simulate the clinical beam properties. Those calculations have been used to commission a commercial treatment planning system prior to final clinical measurements. MCNPX was also used to calculate the neutron background generated by protons in the scattering system and patient. Additional details of the facility and current status will be presented.

TUE-MAR03-P1 #78 - Poster - Tuesday 5:30 PM - Rio Grande

Compact Electronic Gamma Source for Radiotherapy

Allan Xi Chen, Arlyn Antolak, Ka Ngo Leung, Thomas Raber, Daniel Morse
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A novel mono-energetic gamma source for medical applications that utilizes the 9Be(D,ng)10B nuclear reaction is being developed. The compact source makes use of LiTaO3 pyroelectric crystals to accelerate D+ ions towards a beryllium reaction target at energies above 100 keV to produce primary gammas at 718 keV and 1.03 MeV. The required acceleration potential is developed between the crystal polar faces through thermal distortion of the lattice. Thermal management of the accelerator is achieved by convective fluid flow around the entire pyroelectric crystal. This approach has the advantages of (1) better temperature uniformity along the crystal polar axis and (2) higher dielectric strength to suppress voltage breakdowns between the polar faces. The D+ ions are injected into the pyroelectric system from a separate RF-driven ion source, allowing independent control of the current and energy of the D+ ion beam. The design and operational performance of the pyroelectric gamma generator, experimental results of gamma production, and some applications to radiotherapy are presented.

Sandia National Laboratories is a multi-program laboratory operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Company, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

TUE-MAR03-P2 #265 - Poster - Tuesday 5:30 PM - Rio Grande

A Novel Linear Accelerator for Image Guided Radiation Therapy

Xiaodong Ding, Salime Boucher
RadiaBeam Technologies, Berkeley California 94705, United States

RadiaBeam is developing a novel linear accelerator which produces both kilovoltage (~100 keV) X-rays for imaging, and megavoltage (6 to 20MeV) X-rays for therapy. We call this system the DEXITron: Dual Energy X-ray source for Imaging and Therapy.

The Dexitron is enabled by an innovation in the electromagnetic design of the linac, which allows the output energy to be rapidly switched from high energy to low energy. In brief, the method involves switching the phase of the radiofrequency (RF) power by 180 degrees at some point in the linac such that, after that point, the linac deccelerates the beam, rather than accelerating it. The Dexitron will have comparable cost to other linacs, and avoids the problems associated with current IGRT equipment.

TUE-MAR03-P3 #268 - Poster - Tuesday 5:30 PM - Rio Grande

Design of an X-band Medical Linear Accelerator

Xiaodong Ding, Salime Boucher
RadiaBeam Technologies, Berkeley California 94705, United States

Microwave linear accelerators have been used as the the X-ray source for radiation therapy machines for many decades. The majority of the radiation therapy machines are based on S-band frequency (~3 GHz) microwave sources and linac technologies. X-band frequency (~9 GHz) structures will significantly reduce the size and weight of the radiation source and is preferable for modern radiation therapy. Some X-band machines, such as the Cyberknife, have already been developed and commercialized. However, there are still many areas in which the X-band linac needs improvement. For instance, the length of the state-of-the-art X-band 6 MeV radiation therapy linac is over 60 cm. In most cases, this is too long to fit into a circular gantry for straight through X-ray radiation without a bending magnet.

In this paper, an new 6 MeV X-band linac is described. The total length of the linac is only 30 cm. It will easily fit into a rotating gantry and will allow for many kinds of treatment. It also has the potential to replace radioactive isotopes (such as Cobalt-60) as the radiation source in the Gamma Knife, which uses hundreds of Cobalt-60 sources located in a ring around a central treatment point. The new X-band linac will have broad applications in modern radiation therapy.

TUE-MAR04-1 #309 - Invited Talk - Tuesday 1:00 PM - Pecos I

The Production and Clinical Applications of High Specific Activity Sn-117m

Nigel Raymond Stevenson
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Sn-117m is a 14 day half-life gamma (159 keV) and conversion electron (130 keV) isotope that has historically been produced in a reactor at low (up to 20 Ci/g) specific activities and used for bone pain palliation studies. Recently, this isotope has also found application in the investigative efforts to image (and potentially treat) vulnerable plaque. The specific targeting mechanism for this modality requires high (carrier-free) specific activity Sn-117m that can only be produced with accelerators. Initial development work in Russia with an antimony target and a 140 MeV proton beam successfully produced small quantities of ~1000 Ci/g material but this production route was eventually abandoned due to the perceived need for having a reliable long-term domestic source of the isotope. An alternate commercial production method was then explored at the University of Washington MC50 cyclotron with a 47 MeV alpha beam striking a Cd-116 target and using the (p,3n) reaction. Resulting yields were found to be significantly higher (~0.15 mCi/μAh) and undesirable by-products were reduced by orders of magnitude compared with the Sb method. Standard electroplated targets are irradiated and processed in a straightforward manner resulting in a very pure high specific activity (~20,000 Ci/g) product. This isotope has subsequently been attached to biological targeting molecules and used in pre-clinical and clinical studies to image vulnerable plaque.

TUE-MAR04-2 #215 - Invited Talk - Tuesday 1:00 PM - Pecos I

[13N] Ammonia Cardiac Program at West Virginia University Health Sciences

John M Armbruster
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[13N] Ammonia Cardiac Program at West Virginia University Health Sciences

Due to the shortage of the more traditional cardiac imagining isotopes, specifically, Technicium-99, the Cardiologists at WVU have had to look to alternative imagining techniques such as PET. This has led to a dramatic increase in the use of [13N] Ammonia PET scans at the Health Sciences Center. The patient load has gone from one to two patients one day a week to typically two to three patients, two days a week, with occasional add-on in-house patients; each patient typically requiring two target irradiations. In this paper, we will discuss the process that is being used to meet this increased demand from the production of the isotope through the final result.

TUE-MAR04-2 #38 - Invited Talk - Tuesday 1:00 PM - Pecos I

Sn-117m Annexin for Vulnerable Plaque

Jaime Simon[1], Jason A Rogers[1], R Keith Frank[1], George M St. George[1], David W Mueller[2], Nigel R Stevenson[2]
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Vulnerable plaque is responsible for over 60% of heart related deaths. Unlike normal plaque, it cannot be diagnosed by any technique including measuring the thickness of blood vessels. In this paper we report the synthesis and evaluation of Sn-117m Annexin for the detection and potential treatment of vulnerable plaque. The isotope is prepared using a cyclotron followed by a purification step to obtain Sn-117m of high radiochemical purity and specific activity. Sn-117m is chelated to a bifuctional chelating agent and excess chelating agent is purified using an HPLC procedure. Attachment of the chelate to annexin was acomplished by preparing the isothiocyanate version of the chelate and reacting it with lysine residues on the annexin. The final product was analyzed by electrophoresis, size exclusion chromatography and a cell assay for potentcy. The results show that high purity Sn-117m-annexin was produced which gave positive images in a rabbit model for vulnerable plaque. The first in-man clinical trials are planned for second quarter of 2010.

TUE-MAR04-3 #485 - Invited Talk - Tuesday 1:00 PM - Pecos I

F-18 labeled PET agents for imaging Alzheimer's plaques

Padmakar V. Kulkarni[1], Neil Vasdev[2], Guiyang Hao[1], Veera Arora[1], Michael Long[1], Nikolai Slavine[1], Srinivas Chiguru[1], Bao Xi Qu[1], Xiankai Sun[1], Michael Bennett[1], Peter P Antich[1], Frederick J. Bonte[1]
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Amyloid plaques and neurofibrillary tangles are hall marks of Alzheimer's disease (AD). Advances in development of imaging agents have focused on targeting amyloid plaques. Notable success has been the development of C-11 labeled PIB (Pittsburgh Compound) and a number of studies have demonstrated the utility of this agent. However, the short half life of C-11 (t1/2: 20 min), is a limitation, thus has prompted the development of F-18 labeled agents. Most of these agents are derivatives of amyloid binding dyes; Congo Red and Thioflavin. Some of these agents are in clinical trials with encouraging results. We have been exploring new class of agents based on 8-hydroxy quinoline, a weak metal chelator, targeting elevated levels of metals in plaques. Radio iodine labeled clioquinol showed affinity for amyloid plaques, however, had limited brain uptake thus not successful in imaging in intact animals and humans. We have been successful in synthesizing F-18 labeled 8-hydroxy quinoline. Small animal PET/CT imaging studies with this agent showed high (7-10% ID/g), rapid brain uptake and fast washout of the agent from normal mice brains and delayed washout from transgenic Alzheimer's mice. These promising results encouraged us in further evaluation of this class of compounds for imaging AD plaques.

Supported by NIH, NIA Grant Number: 1RCAG036308-01

TUE-MAR04-5 #310 - Invited Talk - Tuesday 1:00 PM - Pecos I

Accelerator-Driven Production of Mo-99 in a Sub-Critical LEU Solution Reactor

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Recent acute shortages in Mo-99, the most commonly employed radioisotope in nuclear medicine, has resulted in a flurry of concepts and proposals for alternate production methods. Most of these methods either suffer from low yields and/or low specific activity or require expensive highly regulated operations that will take many years to be realized as commercially viable systems. An alternate approach is the AMIC-University of Missouri method which involves the following steps: An electron accelerator is used to produce photons from a W (or similar) target. The photons produced enter a reaction vessel containing LEU salts dissolved in heavy water where they dissociate the D2O releasing neutrons. These neutrons are slowed down in the same medium and contained therein with suitable reflector materials lining the reaction vessel wall. The thermalized neutrons cause the fission of U-235 atoms dissolved in the solution thereby adding neutrons for future interactions. The Mo-99 (6 per 100 fissions) produced remains dissolved in the solution and can be either extracted during the irradiation process (on-line) or at the end of a typical 6-day irradiation (batch) by passing the solution through an alumina or similar column. Prototype experiments have been undertaken and further ones are planned for this year. These experiments confirm our calculations that indicate that this system is self-limiting and cannot go critical and that it can also be quickly shut down by simply switching off the electron beam - both major advantages over conventional reactor production methods. Specific activity, purity and by-product profiles are comparable to existing commercially available Mo-99. MCNPX calculations predict yields of up to 3000 six-day Ci/week per device. Because of its small-footprint/lower cost it is conceivable to have one or more of these systems operational and capable of delivering a significant fraction of the US domestic need within a few years.

TUE-MAR04-6 #528 - Contributed Talk - Tuesday 1:00 PM - Pecos I

Experimental Activities Supporting Comercial U.S. Accelerator Production of Mo-99

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^{99m}Tc is the most commonly used radioisotope for nuclear medicine in the United States, used in over 18 million medical procedures in the US each year. ^{99m}Tc, the metastable state of ^{99}Tc, has a 6-hour half life and decays by the emission of a 143 keV internal transition (IT) photon. The longer-lived parent isotope ^{99}Mo, with a 66-hour half life, is currently produced as a fission fragment (6% yield) from uranium targets irradiated in specialized nuclear reactors. The entirety of the U.S. supply of ^{99}Mo for nuclear medicine is produced in ageing foreign reactors using highly enriched uranium (HEU) targets. Maintenance and repair shutdowns of these reactors have significantly disrupted the supply of ^{99}Mo, and hence ^{99m}Tc imaging agents, in the last year.
The National Nuclear Security Administration's (NNSA) Global Threat Reduction Initiative (GTRI), in partnership with commercial entities and the national laboratories, is working to address the need for a reliable domestic supply of ^{99}Mo for nuclear medicine while also minimizing the civilian use of HEU. Los Alamos National Laboratory (LANL) and Argonne National Laboratory (ANL) are performing experiments to demonstrate accelerator production of ^{99}Mo. The process under investigation uses the ^{100}Mo(γ,n)^{99}Mo reaction in an enriched ^{99}Mo target. Experiments are being performed at ANL using a high-power electron accelerator to produce the required flux of high energy photons through bremsstrahlung. To date, two scaled low-power production tests with natural Mo targets have been performed at 20 MeV producing a total of 613 µCi of ^{99}Mo. A test with an enriched Mo target is scheduled for the middle of July. Current results will be discussed.

TUE-MAR04-P1 #346 - Poster - Tuesday 5:30 PM - Rio Grande

"Continued Development of a 2.5-MeV RFI Linac System"

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A 2.5-MeV, 20-mA, Cw Linac System is nearing completion at Linac Systems, LLC. The intended application is to produce abundant quantities of epithermal neutrons for the BNCT medical application. The operating frequency is 200 MHz. The linac structure consist of a radial strut RFQ linac section to an energy of 0.75 MeV and an RFI linac section to the final energy of 2.5 MeV. The two linac structures are resonantly coupled by a quarter-wave-stub resonant coupler, which locks the relative phases and relative field amplitudes of the two structures. The rf power is loop-coupled to the RFQ section, and the power required for the RFI section is transmitted through the resonant coupler. The ion source is an ECR microwave type, operated at 25 keV. The LEBT includes dual magnetic solenoid focusing lenses and independent x and y steering magnets. The final amplifier of the rf power system is a cavity-based amplifier with 6 CPI/Eimac YC-300A power tubes in parallel. The peak and average power output is 180 kW cw. The current status of the system will be described.

TUE-MAR04-P2 #353 - Poster - Tuesday 5:30 PM - Rio Grande

Accelerator Production of Ac-225 for Alpha-immunotherapy

Francois Meiring Nortier, Hong T. Bach, Kevin D. John, Aaron J. Couture, John L. Ullmann, Michael E. Fassbender, George S. Goff, Wayne A. Taylor, Frank Valdez, Laura E. Wolfsberg, Michael Cisneros, Donald Dry, Michael Gallegos, Russel E. Gritzo, Leo J. Bitteker, Steve Wender, Roy S. Baty, John W. Weidner
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Actinium-225 has tremendous potential for the treatment of metastatic cancer due to the four alpha particles emitted during its decay to stable ^{209}Bi. Additionally, it is one of the few alpha emitters being considered for clinical trials. The anticipated ^{225}Ac demand for these trials is expected to far exceed the annual international supply of approximately 1,000 mCi/yr. Consequently, the DOE Office of Science has funded investigations into accelerator-based production of ^{225}Ac. Theoretical models of the ^{232}Th(p,x)^{225}Ac cross section indicate that approximately 450 mCi/day of ^{225}Ac could be created by bombarding a thick target of natural thorium with 100 MeV protons. To verify these predictions, experiments are underway at the Los Alamos Neutron Science Center to measure the ^{232}Th(p,x)^{225}Ac production cross sections for proton energies ranging from 40 MeV - 200 MeV, and at 800 MeV. Preliminary results indicate that the ^{225}Ac production cross section using 800 MeV protons is 10 mb. Experiments to measure the ^{232}Th(p,x)^{225}Ac production cross sections at proton energies below 200 MeV are planned for the last half of calendar year 2010. These experiments will also attempt to quantify the production of parent radioisotopes of interest, such as ^{225}Ra and ^{229}Th, and of impurities such as ^{227}Ac. When complete, this data will be the most comprehensive set of ^{225}Ac production cross sections ever measured.

TUE-MAR04-P3 #553 - Poster - Tuesday 5:30 PM - Rio Grande

DDesign Feature of Microfluidic reactor for [18F]FDG radiopharmaceutical synthesis

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Microfluidic reactor exhibits great advantage for radiopharmaceutical synthesis. Microfluidic chips can reduce the time for radiosynthesis using tiny quantities of chemical compounds. It also has good heat transfer performance and provides a view for an integrated total system including synthesis, separation, and purification. This advantage make FDG produces easily in point of view Half-life of 18F(T 1/2 = 109.7 min). So we designed a Microreactor chip included whole chemical processing as like water evaporation, solvent exchange, radiofluorination and so on. We have designed it using commercial 3D CAD modeling CATIA V5, analyzed heat transfer performance by ANSYS, and analyzed fluid performance by FLUENT. This paper described how to design FDG synthesis system on a Microchip related location of their parts and analysis efficiency about heat and fluid performance.

TUE-MAR05-1 #496 - Invited Talk - Tuesday 3:30 PM - Pecos I

Laser as particle accelerators in medicine: from laser-driven proton to imaging with Thomson sources

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We report the recent progress in using a high-power picosecond CO2 laser for Thomson scattering and ion acceleration experiments. These experiments capitalize on certain advantages of long-wavelength CO2 lasers, such as: higher number of photons per energy unit and beneficial wavelength scaling of the electron's ponderomotive energy and critical plasma frequency.

High X-ray fluxes produced in interaction of counter-propagating laser and electron beams have been successfully used for producing single-shot high-contrast images of biological objects.

Focused on a hydrogen jet, the laser generated a monoenergetic ~1 MeV proton beam via the radiation pressure mechanism. The energy of protons produced by this method scales linearly with the laser intensity. We present a plan for scaling the process into the 100 MeV proton energy range via the CO2 laser upgrade. This development will enable an advance in the laser-driven proton cancer therapy.

TUE-MAR05-2 #107 - Invited Talk - Tuesday 3:30 PM - Pecos I

X Rays Compton Detectors for Biomedical Application

Paolo Rossi[1], Giuseppe Baldazzi[2,3], Andrea Battistella[4], Michele Bello[4], Dante Bollini[3], Valter Bonvicini[5], Cristiano Lino Fontana[1], Gisella Gennaro[6], Giuliano Moschini[1], Francesco Navarria[2,3], Alexander Rashevsky[5], Nikolay Uzunov[4,7], Gianluigi Zampa[5], Nicola Zampa[5], Andrea Vacchi[5]
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Collimators are usually needed to image sources emitting X-rays that cannot be focused. Alternately, one may employ a Compton Camera (CC) and measure the direction of the incident X-ray by letting it interact with a thin solid, liquid or gaseous material (Tracker) and determine the scattering angle. With respect to collimated cameras, CCs allow higher gamma-ray efficiency in spite of lighter geometry, and may feature comparable spatial resolution. CCs are better when X-rays energy is high and small setups are required.

We review current applications of CCs to Gamma Rays Astronomy and Biomedical systems stressing advantages and drawbacks.

As an example, we focus on a particular CC we are developing, which is designed to image small animals administered with marked pharmaceuticals, and assess the bio-distribution and targeting capability of these latter. This camera has to address some requirements: relatively high activities of the imaged objects; detection of gamma-rays of different energies that may range from 140keV (Tc99m) to 511 keV; presence of gamma and beta radiation with energies up to 2MeV in case of 188Re. The camera consists of a thin position-sensitive Silicon Drift Detector as Tracker, and a further downstream position-sensitive system employing scintillating crystals and a multi-anode photo-multiplier (Calorimeter). The choice of crystal, pixel size, and detector geometry has been driven by measurements and simulations with the tracking code GEANT4. Spatial resolution, efficiency and scope are discussed.

TUE-MAR05-3 #315 - Invited Talk - Tuesday 3:30 PM - Pecos I

PET online in hadrontherapy

Francesca Attanasi, Nicola Belcari, Sascha Moehrs, Valeria Rosso, Alberto Del Guerra

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A possibility for monitoring the dose delivery to the patient in the hadron tumor therapy is the utilization of secondary radiation resulting from nuclear interactions of the primary ions along their path in tissue. This includes both prompt emission or photons or secondary particles like protons or neutrons and delayed emission of radiation from the decay of unstable nuclei formed in the target.

The interest towards the beta+ induced radioactivity for in situ range monitoring has become widespread in the last years and several research groups worldwide are currently investigating the optimal strategy for implementing PET monitoring in the clinical centers. The geometrical detector arrangement and the counting statistics are the most crucial points affecting the quality of the PET images together with the rather low density of the induced activity which demands highest detection sensitivity. The in beam solution, although restricted by the limited angle detectors with a lower efficiency compared to that of off-line full ring tomograph, seems to be preferable because it also allows detection of the shorter-lived isotopes, minimizing isotope washout and avoiding alignment errors due to the patient movements.

At the University of Pisa, in collaboration with the Italian Institute of Nuclear Physics (INFN, Pisa), we have proposed the design and the development of an ad hoc dual-head PET detector to enable application-optimized imaging for dose monitoring in hadron therapy. The small prototype has been intended to be easy to scale-up, compact and with the resolution and sensitivity, as required for monitoring purposes at low count levels, that are competitive with commercial performance of a state of art clinical PET. We will report our experience and the results we obtained by measuring the beta+ activation induced in several homogeneous and inhomogeneous phantoms by 62 Mev proton beams, at the CATANA facility (INFN-LNS, Catania, IT).

TUE-MAR05-4 #271 - Invited Talk - Tuesday 3:30 PM - Pecos I

Prompt gamma ray emission during proton radiotherapy for assessing treatment delivery and patient response

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Purpose: Future advancements in radiation therapy will require the development of patient specific treatment techniques that tailor and adapt dose delivery based upon the specific biological response of each patient over the course of treatment. Such techniques will require methods to verify dose delivery and quantify the response irradiated tissues. The purpose of this work is to study the use of "prompt" gamma rays emitted from tissues during proton beam irradiation for verifying treatment delivery as well as imaging physical responses (compositional and density changes) of irradiated tissues as a means of assessing patient response and treatment efficacy.

Methods and Materials: We preformed preliminary measurements and Monte Carlo calculations of the "prompt" gamma ray spectra emitted from tissue during proton beam irradiation. The emission spectra from several types of tissue where characterized according to the emission lines from the individual elemental constituents of the target tissue. Next, we studied the individual emission lines from the tissues as a function of elemental concentration and density.

Results: These results show that the prompt gamma emission is strongly correlated to the delivery of dose within the patient. Also, emission lines from the major elemental components can be identified in the measured and calculated spectra. The intensities of these emission lines were found to be a function of concentration of each element and the physical density of the tissue, indicating it may be possible to identify tissue type by measuring the prompt gamma ray spectra emitted during proton radiotherapy.

Conclusion: Based on the results of these preliminary studies, we conclude that it may be possible to verify treatment dose delivery, as well as, determine the type of tissues irradiated by measuring and imaging the prompt gamma ray spectra emitted during proton treatment delivery.

TUE-MAR05-5 #332 - Contributed Talk - Tuesday 3:30 PM - Pecos I

ProSPECTus: SPECT imaging using semiconductor detectors with future MRI capabilites

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Single Photon Emission Computed Tomography (SPECT) is an established functional imaging technique which is used for medical diagnostic applications. A radioisotope which decays along a single photon pathway such as Tc-99m (141keV) readily accumulates in specific areas of the patient and subsequently decays away. These decays are detected and an image is generated. In the case of cancers, functional imaging has to be registered with anatomical structure as its precise location has major implications in how the disease is treated.

Current SPECT systems employ a gamma camera to locate the distribution of the administered radiotracer. The gamma camera system is typically constructed from heavy metal collimators placed in front of scintillator detectors attached to photomultiplier tubes. The limitations of the current systems are that;

1) The use of collimators for spatial resolution results in a lack of efficiency as only a small fraction of emitted gamma rays are detected. It also limits the energy that can be imaged.

2) They cannot work in a magnetic field so co-registry with anatomical Magnetic Resonance Imaging (MRI) is impossible.

3) To image a radioactive distribution the gamma camera has to be rotated around the patient.

ProSPECTus is an interdisciplinary project based at the University of Liverpool which is investigating the use of semiconductors in Compton camera mode which can be deployed in magnetic fields for SPECT/MRI multimodality imaging. The spatial resolution is provided by using highly electronically segmented detectors which removes the necessity of mechanical collimation. Compton kinematics and cone beam reconstruction are used to locate the distribution of the radioactive substance.

Initial results from tests of the performance of Germanium detectors in a 1.5T field along with images generated from a Compton camera constructed from two segmented High Purity Germanium (HPGe) detectors will be presented.

TUE-MAR05-6 #128 - Contributed Talk - Tuesday 3:30 PM - Pecos I

Proton Beam Simulation with MCNPX: Germanium Metal Activation Estimates Below 30 MeV Relevant to the Bulk Production of Arsenic Radioisotopes

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Metal targets containing Ge metal encapsulated in Nb shells were irradiated in a 30 MeV proton beam for the production of As-71,73,74. Proton and secondary neutron beam fluences as well as radionuclide activity formation were modeled using MCNP-X in combination with CINDER90. Irradiated targets were chemically processed; radioarsenic was recovered using distillation and anion exchange. Good agreement between measured radiochemical yields and MCNPX/CINDER estimates was observed. An [As-74]Cl5 deposition target for (n,gamma) neutron capture studies was prepared.

TUE-NBA02-1 #29 - Invited Talk - Tuesday 8:30 AM - Brazos II

Nuclear Tools for Oilfield Logging-While-Drilling Applications

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Schlumberger is a global oilfield service company with nearly 80,000 employees of 140 nationalities, operating globally in 80 countries. As a market leader in oilfield services, Schlumberger has developed a suite of technologies to assess the downhole environment, including, among others, electromagnetic, seismic, chemical, and nuclear measurements. In the past 10 years there has been a radical shift in the oilfield service industry from traditional wireline measurements to logging-while-drilling (LWD) analysis. For LWD measurements, the analysis is performed and the instruments are operated while the borehole is being drilled. The high temperature, high shock, and extreme vibration environment of LWD imposes stringent requirements for the devices used in these applications. This has a significant impact on the design of the components and subcomponents of a downhole tool.

Another significant change in the past few years for nuclear-based oilwell logging tools is the desire to replace the sealed radioisotope sources with active, electronic ones. These active radiation sources provide great benefits compared to the isotopic sources, ranging from handling and safety to nonproliferation and well contamination issues. The challenge is to develop electronic generators that have high degree of reliability for the entire lifetime of a downhole tool.

In this presentation, LWD tool testing and operations are highlighted with particular emphasis on electronic radiation sources and on nuclear detectors for the downhole environment.

TUE-NBA02-2 #61 - Invited Talk - Tuesday 8:30 AM - Brazos II

Can accelerator-based radiation sources replace the chemical-based sources commonly used in geophysical exploration?

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In geophysical exploration, the most commonly used radiation sources are Cesium (137Cs) and Americium (241Am). Concerns on security, safety, and toxicity have prompted the search for other radiation sources. Currently the only accelerator-based radiation sources that are (marginally) capable of producing a statistically significant radiation are neutron generators based on Deuterium-Tritium tubes. The use of neutron generators in geophysical exploration was driven by the development of special analyses; measurements such as neutron die-away, carbon/oxygen activation, and prompt-neutron logging were facilitated by the capabilities of neutron generators.

Development of accelerator-based sources is highly constrained in geophysical exploration by limited geometric forms and environments. Also, critical constraints such as power consumption, radiation output flux, shock and temperature have limited the current technology. For the very long-lived Cesium and Americium, the measurement paradigms use the near-constant output flux (on a day-to-day basis) in the calibration of the measurement. Constant output from accelerator-based systems will require development of more exact regulation and monitoring of performance to be an effective replacement.

The primary application of Americium is mixed with beryllium to produce a neutron source, switching to use a neutron generator in this analysis is fairly straightforward. Cesium is used as a gamma-ray source in densitometers by measurement

of the electron density via Compton scattering. Replacement of the cesium gamma-ray source with a neutron generator is more problematic; discussion of several new techniques for measuring the density using neutron generators is presented.

The scope of the presentation is not to promote a specific technology or alternative analysis paradigm, rather it is a survey of the current capabilities and development needs for geophysical exploration. A discussion of the constraints and typical values for temperature, shock, power consumption, output flux, radiation types and energies is presented as a framework for future development.

TUE-NBA02-3 #119 - Invited Talk - Tuesday 8:30 AM - Brazos II

Calibration of a 14 MeV Neutron Generator with Reference to NBS-1

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NBS-1 is the US national neutron reference source. It has a neutron emission rate of 1.234E6 n/s with an uncertainty of 0.85%. All neutron emission-rate calibrations performed at the National Institute of Standards and Technology (NIST) are made in comparison to this source, either directly or indirectly. To calibrate a commercial 14 MeV neutron generator, NIST performed a set of comparison measurements to evaluate its neutron output relative to NBS-1. The comparison process involves comparing activation produced by the generator against activation produced by NBS-1 in identical geometries. Due to the low-energy and uncertain neutron spectrum of NBS-1, a Cf-252 source which had been calibrated relative to NBS-1 was used as an intermediary. Calibration issues involved positioning, uncertainties in the reaction cross sections between fission and monoenergetic activation, the production of interfering activation due to the low-energy component of the Cf-252 spectrum and the low neutron output of the generator. The reaction Al-27(n,alpha)Na-24 proved to be useful for this comparison. A 4-inch diameter aluminum collar was fabricated and activated sequentially with the CF-252 and 14 MeV neutron sources. The neutron output of the generator was determined to an accuracy of about 7%. The 15-hour half-life of the reaction product also makes possible off-site measurements.

TUE-NBA02-4 #438 - Contributed Talk - Tuesday 8:30 AM - Brazos II

HIGH-FIELD DEUTERIUM ION SOURCES FOR NEUTRON GENERATORS

B. Bargsten Johnson[1], I Solano[1], C E Holland[2], P R Schowoebel[1,2], K L Hertz[3], P Resnick[4], D L Chichester[5]
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It is generally accepted that active neutron interrogation is a reliable means of detecting the presence of shielded special nuclear material, in particular highly enriched uranium. We are facilitating the deployment of portable active neutron interrogation systems for field detection applications by developing a new atomic deuterium ion source for compact, accelerator-driven neutron generators. This ion source uses high electric fields at the surfaces of microfabricated tip arrays to produce atomic deuterium ions.

Deuterium ion production from microfabricated tip arrays has been demonstrated using field desorption of atomic deuterium, field evaporation of titanium hydride, and field ionization of molecular deuterium. Field ionization currents to date have achieved 50nA per square mm of tip array area. These currents are presently limited by the voltage that can be applied to the array before electrical breakdown is initiated. Measured neutron production rates with the deuterium-deuterium reaction at ion energies of ~90keV/u are consistent with the measured ion currents.

This program has evolved microfabricated tip arrays to the point where they operate with applied voltages of roughly 1000V and produce fields of ~ 20V/nm - over ten times their typical operating conditions in the electron emission mode for which they were first invented. Further array design enhancements should allow for operation in the ~ 40V/nm range, yielding deuterium ion sources that will generate 108 neutrons/(s?cm2) of tip array area in the field ionization mode, 109 neutrons/(s?cm2) of tip array area in the field desorption mode, and single pulses of ~1010 neutrons/(s?cm2) of tip array area when field evaporating titanium deuteride - all with tritiated targets. Scalability of the neutron yield by the fabrication of larger arrays or tiling of smaller arrays should be straightforward.

This work was supported by the US DOE through the NNSA Office of Nonproliferation Research and Development (NA-22).

TUE-NBA02-5 #401 - Contributed Talk - Tuesday 8:30 AM - Brazos II

A permanent magnet microwave ion source for a compact high-yield neutron generator

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We present recent work on the development of a microwave ion source that will be used in a high-yield compact neutron generator for active interrogation applications. The sealed tube generator will be capable of producing a high neutron yield, 10^{10} n/s for D-D and 5×10^{11} n/s for D-T reactions while still being transportable. We constructed a microwave ion source (2.45 GHz) with permanent magnets to obtain magnetic field strength of 87.5 mT that is needed for electron cyclotron resonance (ECR) condition. Microwave ion sources produce high extracted beam currents at the low gas pressures required in a sealed tube and at lower power levels than previously used RF-driven ion sources. A 100 mA deuterium/tritium beam is extracted through a large slit (60×6 mm^2) to spread the beam power over a larger target area. The beam-loaded target consists of a titanium layer on a water-cooled molybdenum backing arranged in a V-shape formation. Preliminary results from ion source testing will be presented and incorporation into the neutron generator will be discussed.

TUE-NBA02-6 #194 - Contributed Talk - Tuesday 8:30 AM - Brazos II

Field Ionization Studies for Compact Neutron Sources

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To be able to replace radioactive sources with a compact neutron generator we investigate the use of direct field ionization as well as surface conversion effects to create positive and negative deuterium ions. To achieve high fields different nano-structures possessing sharp tips such as aligned carbon nano-tubes (CNT) or CNT arrays, self aligned metal-pillars as well as GaAs nano-needles are being explored. We present preliminary results of first neutron yields from ionizing deuterium and creating neutrons in a D-D reaction after accelerating the ions to energies of 50-80 keV. Experiments using field emission of electrons are used to characterize the emitter properties such as the local field enhancement factor. We will discuss the optimization of the emitter geometry to maximize neutron production. To further understand the emission geometry and effects of variations in the emitter ensembles (e.g. height and shape) computer simulations results will be shown.

Work performed under the auspices of the US Department of Energy, NNSA Office of Nonproliferation Research and Engineering (NA-22) by Lawrence Berkeley National Laboratory under Contract DE-AC02-05CH11231.

TUE-NBA02-7 #13 - Contributed Talk - Tuesday 8:30 AM - Brazos II

Directed Neutron Beams from Inverse Kinematic Reactions

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Medical imaging and contraband interrogation require uni-directional neutron beams. Commonly used neutron source reactions produce a spray in all directions. Many neutrons are wasted because forming a beam requires absorption of all neutrons not traveling in the desired direction. Large radiation fields occur in the vicinity of the production target which are hazardous to workers and limit the compactness of the source. Kinematic focusing by use of inverse-kinematic reactions can provide a nearly-complete utilization of the neutron yield and provide a safer environment. We examine the merit of various production reactions and consider the practicalities of producing and propagating the neutron beam. Preliminary results of measurements at the NSWC-Carderock Positive Ion Accelerator Facility are presented.

TUE-NBA02-P1 #129 - Poster - Tuesday 5:30 PM - Rio Grande

Measurement of the Neutron Spectrum of a DD Electronic Neutron Generator

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This paper will present recent work in our laboratory to evaluate the energy spectrum of neutrons from a deuterium-deuterium (DD) electronic neutron generator (ENG) using a Cuttler-Shalev (C-S) helium-3 proportional counter. To improve the analysis of results from the C-S detector digital pulse shape analysis techniques have been used to eliminate neutron recoil artifacts in the recorded data. Data was collected with the detector axis perpendicular to the direction of ions in the ENG, in a plane 0.5-m to the side of the ENG, measuring neutrons emitted at an angle of 90-degrees with respect to the path of ions in the ENG. Preliminary results indicate the detector system demonstrated an energy resolution of approximately 30 keV. This paper will present the measured neutron energy spectrum and further analysis of the energy distribution of the ENG's near-monoenergetic DD fusion neutrons.

TUE-NBA02-P2 #253 - Poster - Tuesday 5:30 PM - Rio Grande

Multi-frame thermal neutron camera for energy-selective neutron radiography in pulsed spallation-neutron beams

Benjamin Bromberger[1], Elbio Calzada[2], Volker Dangendorf[1], Burkhard Schillinger[2], Doron Bar[3], Mark Benjamin Goldberg[3], Ilan Mor[3], Kai Tittelmeier[1], David Vartsky[3], Mathias Weierganz[1]
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Short-pulsed spallation neutron sources can be employed to perform energy-resolved thermal neutron radiography using Time-Of-Flight (TOF) techniques. In many such applications, transmission images at several neutron energies must be acquired simultaneously. However, even with the most powerful accelerator-based sources, the flux within individual energy windows in a single pulse is too small to obtain useful image information. Thus, for stationary or slowly-scanned inspected objects, the image statistics can be substantially improved by superimposing the images of many beam pulses for a given TOF window.

We present here a neutron imaging system capable of simultaneously acquiring and integrating up to 8 different energy frames over thousands of beam pulses. Its central component is an 8-fold segmented image intensifier, commonly used in commercial ultra-high speed cameras. By selecting the delay and width of the gate pulses, eight different neutron energy windows can be independently defined at high-speed (< 100 ns) by high-voltage pulses. The corresponding images are recorded by a cooled CCD camera.

The setup has been tested in the continuous thermal neutron beam of the ANTARES imaging facility at the FRM II reactor near Munich. Since pulsed beams were not available there, the method was demonstrated via phase-locked multi-frame stroboscopy of a rotating fan with a Cd marker attached to one of its fan blades.

TUE-NBA02-P3 #410 - Poster - Tuesday 5:30 PM - Rio Grande

Compact Permanent Magnet Microwave-driven Neutron Generator

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Compact permanent magnet microwave-driven neutron generators have been developed at Lawrence Berkeley National Laboratory. The 2.45 GHz microwave signal is directly coupled into the plasma chamber via a microwave window. Plasma is confined in an axial magnetic field produced by the permanent magnets surrounding the microwave cavity, which also serves as the plasma chamber. The fabrication and assembly of an ion source with a round plasma chamber have been completed. The source chamber is made of aluminum with a diameter of 4 cm and length of 5 cm. A stack of five aluminum discs, which are 3 cm in diameter and total length of 3 cm, work as microwave window. Three permanent ring magnets are used to generate the axial magnetic field required for the microwave ion source. Both hydrogen and deuterium plasma have been successfully ignited. With 330W of microwave power, source chamber pressure of 5 mTorr, and an extraction aperture of 2 mm in diameter, the deuterium ion beam measured on the target was approximately 3 mA. Approximately 85% of the ions are atomic. With the ion source at ground potential and titanium target at -40 kV, the analysis of the activated gold foil indicated that roughly 10^7 n/s of DD neutrons have been produced. The DD neutron yield can be easily scaled up to 10^8 n/s when the titanium target is biased at -100 kV. More measurements are still in progress and the results will be presented in the conference.

TUE-NBA02-P4 #422 - Poster - Tuesday 5:30 PM - Rio Grande

Ion Beam Collimation for Improved Resolution in Associated Particle Imaging

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Improvements in field-portable associated particle imaging (API) systems for active interrogation are constantly being pursued. Current commercially-available neutron generators for API employ Penning ion sources [1] and are characterized by 2 mm diameter ion beams on target that limit the spatial resolution of neutron emission sites. Radio-frequency driven ion sources have been developed for use with API [2] and have achieved beam spot sizes of less than 1 mm, but these sources require higher power and relatively high operating pressures that are not desirable for field-operable units.

This work focuses on improving the beam spot size on target without additional focusing lenses for a Penning ion source in API systems. Initial beam spot measurements for extraction voltages of 20 kV indicate the presence of a beam halo, which results from the energy spread of ions generated in the Penning discharge. The presence of a beam halo and core suggests that smaller beam spot sizes can be achieved through collimation of the large-angle extracted ion beams. This collimation will be achieved through adjustment of the extraction aperture and utilization of long extraction channels. Beam energies as high as 120 keV will be used to take full advantage of the majority molecular ions in the beam without sacrificing neutron yield due to reduced ion beam currents. Extracting molecular ions with energies of 120 keV will increase the power efficiency of the neutron generator, as molecular ions dissociating upon target impact will result in atoms with sufficient energy to induce the yields required for API. Results will be presented and discussed in the conference.

[1] D.L. Chichester et al., Nucl. Instr. and Meth. in Phys. Res. B 241 (2005) 753-758

[2] Y. Wu et al., Rev. Sci. Instrum. 81, 02B908 (2010)

TUE-NBA02-P5 #428 - Poster - Tuesday 5:30 PM - Rio Grande

X-ray Output Measurements of a Thermo Scientific P385 DD Neutron Generator

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Idaho National Laboratory is experimenting with electrical neutron generators, as potential replacements for californium-252 radioisotopic neutron sources in its PINS prompt gamma-ray neutron activation analysis (PGNAA) system for the identification of military chemical warfare agents and explosives. In addition to neutron output, we have recently measured the x-ray output of the Thermo Scientific P385 deuterium-deuterium neutron generator. X-rays from a neutron generator, of course, can interfere with gamma rays from the object under test, increase gamma-spectrometer dead time, and reduce PGNAA system throughput.

The P385 x-ray energy spectrum was measured with a high-purity germanium (HPGe) detector, and a broad peak is evident at about 70 keV. To identify the source of the x-rays within the neutron generator assembly, it was scanned by collimated scintillation detectors along its long axis. At the strongest x-ray emission points, the generator also was rotated 60° between measurements. The scans show the primary source of x-ray emission from the P385 neutron generator is an area 60 mm from the neutron production target, in the vicinity of the ion source. Rotation of the neutron generator did not significantly alter the x-ray count rate, and the x-ray emission appears to be axially symmetric within the neutron generator.

As a temporary measure, we have shielded the neutron generator with a 3.2-mm (1/8-inch) thick lead sheet, and we have successfully carried out PGNAA tests of the generator, the lead having reduced the x-rays to negligible levels.

TUE-NBA03-1 #370 - Invited Talk - Tuesday 1:00 PM - Brazos II

Delayed Neutron Group Parameters from Photofission

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Delayed neutron group parameters from photofission have been measured for 232Th, 238U, and 239Pu. The photofission reactions were induced with a pulsed bremsstrahlung beam produced from a 25 MeV nominal energy linear electron accelerator. The resulting delayed neutron emissions were recorded and characterized based on the traditional six-group scheme. The fractional group yields, á, and corresponding group decay constants, ë, were determined for each isotope with a 15 MeV endpoint energy bremsstrahlung beam and suggest significant discrepancies in the individual isotopes' decay characteristics. The energy-dependence of the 238U group parameters was also examined with bremsstrahlung endpoint energies of 8, 12, 15, and 18 MeV. Although some energy-dependence was evident, overall decay rates were comparable.

TUE-NBA03-2 #404 - Contributed Talk - Tuesday 1:00 PM - Brazos II

Testing a High-Energy Prompt Neutron Fission Signature at Low Beam Energies

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Recent work at the Idaho Accelerator Center has developed a fissionable material detection method that exploits high-energy neutrons emitted on prompt timescales following bremsstrahlung irradiation. This technique relies upon the fact that non-fission photoneutron emissions have distinct maximum energies that are dependent upon both incident and binding particle energies. A beam energy-dependent threshold is chosen such that an elevated neutron detection rate above this threshold indicates the presence of fissionable material. At low enough beam energies, this high-energy region encompasses all neutron emissions, thus eliminating the necessity for complicated energy discrimination techniques. Measurements were performed at a bremsstrahlung endpoint energy of 6 MeV, demonstrating the viability of this fission signature under several conditions using simple neutron counting equipment.

TUE-NBA03-3 #436 - Contributed Talk - Tuesday 1:00 PM - Brazos II

Discrete γ-Rays from Photofission for Use in Nuclear Forensics Applications

Edward T.E. Reedy[1,2], Heather A. Seipel[1,2], Edna S. Cardenas[1,2], Bruce H Failor[3], Alan W. Hunt[1,2]
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[(3)]ATG-Pulse Sciences, L3 Communications, San Leandro CA 94588, United States

Prompt and delayed emissions from induced fission events have proven useful in nondestructive assay techniques for nuclear forensics applications. Several of these techniques focus on broad spectrum yields of neutrons or γ-rays from fission with some emphasis on the timescales of these emissions. This research looks specifically at short lived discrete β-delayed γ-rays from photofission as a method to detect, identify and quantify fissionable materials. A 25 MeV pulsed linear electron accelerator was used to produce a bremmstrahlung photon beam to interrogate several aqueous solutions containing varied concentrations of ^{238}U and ^{232}Th as well as nonfissionable materials. The resulting γ-ray energy spectra were then time and energy analyzed to isolate unique signatures of fission. Buried within these spectra are discrete γ-rays from short lived fission fragments that are unique to the fissioning isotope. By treating a section of these energy spectra as a unique vector, an orthogonal basis set can be formed. One can then utilize this basis set to deconvolute an energy spectrum containing contributions from multiple fissionable sources.

TUE-NBA03-4 #472 - Contributed Talk - Tuesday 1:00 PM - Brazos II

Parametric Study of Induced Fissions from 10-60 MeV Bremsstrahlung Inspections of Shielded Uranium

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A parametric study of the induced fissions response in a shielded nuclear material from 10 to 60-MeV bremsstrahlung interrogations is presented. The selected nuclear material consists of a 5-kg sphere of uranium (depleted and enriched [20% and 93%] in U-235) surrounded by air and/or various thicknesses of polyethylene, iron, or lead. The bremsstrahlung is produced using a fixed thickness, tungsten converter thickness for all inspection energies studied. Any electrofission contribution is eliminated by the numerical removal of all transmitted electrons from the electron/photon process in the converter. For each selected bremsstrahlung energy, this study presents an unshielded, baseline response for the induced fissions for each uranium composition and then compares it to the induced fissions (i.e., photofissions and neutron-fissions) produced with increasing shield thicknesses (up to 20 cm). While many other parameters will also be important in the design of a bremsstrahlung-based inspection system, these induced fission results will assist in identifying an optimal bremsstrahlung inspection energy for a given inspection objective.

TUE-NBA03-5 #487 - Contributed Talk - Tuesday 1:00 PM - Brazos II

Photofission of Actinides with Linearly Polarized Photons

Valeriia Starovoitova, Phil Cole, Dan Dale, Tony Forest, Oleksiy Kosinov, Jasen Swensen, Roman Shapovalov
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Idaho State University and the Idaho Accelerator Center are developing a polarized photon facility using the off axis bremsstrahlung technique. Initial tests have been performed using the high analyzing power of the photodisintegration of the deuteron to measure the beam polarization. A program is currently underway to measure the potential angular

asymmetries of fission neutrons which are a consequence of the angular distribution of the fission fragments from photofission with linearly polarized photons. In this talk, we will describe the Idaho State University Polarized Photon facility, present the results of commissioning runs, and describe potential application of polarized photofission in detecting actinides for nuclear safeguards applications.

TUE-NBA06-1 #407 - Invited Talk - Tuesday 3:30 PM - Brazos II

The Free Electron Laser: A Unique Tool for Materials Processing R&D

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A free electron laser driven by an energy-recovering linac provides a unique light source to explore and develop laser-based processes. The FEL addresses much of the vast "white space", especially wavelengths, between the output of conventional lasers. The greatest success of conventional lasers is in delivering great energy intensity for ever-shorter pulse duration with increasing average power. Effectively functioning as precision heat sources, they find expanding applications for metals processing especially.

In contrast, the inherent tunability of the FEL provides opportunity for channeling energy into specific pathways in a material to achieve desired effects. Organic materials offer a significant example, attracting as they do growing attention for next-generation photonics and electronics, with some applications already commercialized. Present fabrication techniques based on solvents or evaporation set limits on materials selection. Tuning the FEL to an IR absorption band offers a path to molecularly-selective energy deposition, enabling pulsed laser deposition of otherwise intractable materials. Other examples are available.

How extensively FEL-based processes will ultimately move downstream into production remains to be seen. Certainly, however, they offer great immediate value as a versatile tool for materials and processes cannot otherwise be explored.

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TUE-NBA06-2 #360 - Contributed Talk - Tuesday 3:30 PM - Brazos II

X-ray Production: Past, Present and Future Trends

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Since Rontgen's discovery, X-rays have proven to be an invaluable tool in medical imaging, industrial inspection, homeland security and a myriad of other applications. From the Coolidge tube to the modern synchrotron radiation source there are many ways to produce X-rays. This paper will review, in a somewhat subjective manner, different X-ray production techniques, pointing to major technical innovations enabling advances in this important field. The evolution of the bremstraahlung radiation based X-ray sources reached the present day modern, X-ray tubes used in CT scanners or the Dual Axis Radiographic Hydrodynamic Test facility (DAHRT) in Los Alamos. From the first observation of the synchrotron radiation in 1946 at GE by Langmuir and collaborators, to the fourth generation light sources like the Linac Coherent Light Source (LCLS) in Stanford, the accelerator physicist played a leading role in enabling many new investigation techniques, contributing to more than 25 Nobel prizes in Physics, Chemistry and Medicine. X-ray sources based on Inverse Compton Scattering are getting close to the point when they will leave the research laboratories and enter in the field of everyday applications. Besides the conventional methods of producing X-rays, the paper will present some more exotic methods using atomic or nuclear reactions, pyroelectric accelerator based X-ray sources, or peeling sticky tape in vacuum. Finally,

the efforts toward miniaturization will be reviewed with the goal to produce chip based X-ray source or a tabletop synchrotron radiation source based on laser wakefield acceleration.

TUE-NBA06-3 #476 - Contributed Talk - Tuesday 3:30 PM - Brazos II

Particle physics using a Free Electron Laser

Oliver K. Baker[1], Andrei Afanasev[2], Kevin B. Beard[4], George Biallas[3], James Boyce[3], Minarni Minarni[5], Roopchan Ramdon[2], Michelle Shinn[3], Penny Slocum[1]

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If the Standard Model of particle physics is part of a more fundamental theory which has some new mass scale, then new dynamics and particles could appear that serve to signal the new physics associated with it. This physics may be accessible at high energy colliders at the TeV energy scale, and also at the sub-eV energy scale using lasers and microwave sources, for example. I will present results of searches for new particles and new forces using Jefferson Lab's Free Electron Laser. I will also show the consequences of our new limits on Dark Matter searches, in astrophysical studies, and on theories that are Beyond the Standard Model of particle physics.

TUE-NP02-1 #24 - Invited Talk - Tuesday 8:30 AM - Trinity Central

Cyclotron Gas Stopper: Simulations and Predicted Performance

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Projectile fragmentation followed by in-flight separation provides fast, chemistry-independent access to a wide range of beta-unstable nuclei. To optimize their use, these exotic beams should be available at energies from rest to several MeV per nucleon. This can be achieved by stopping fast beams in a volume of helium, extracting the stopped ions, and reaccelerating them to the desired energy. A "cyclotron gas stopper" has been proposed to overcome the limitations of current and proposed linear gas stoppers. Details of the NSCL cyclotron gas stopper and the simulation package developed to predict its performance will be presented along with typical results of these simulations.

TUE-NP02-2 #81 - Invited Talk - Tuesday 8:30 AM - Trinity Central

Prompt Gamma-ray Activation Analysis with Neutron Beams

Zsolt Revay

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Prompt Gamma Activation Analysis (PGAA) has been used in a large number of cement factories and also in mining insustry for monitoring the elemental composition of raw materials. These industrial facilities use accelerator-based neutron generators or isotopic neutron sources and scintillator detectors. Many PGAA instruments have been installed in large neutron centers of world: at research reactors and spallation sources. The highest-performance laboratory devices use guided cold neutron beams and Compton-suppressed high-purity germanium (HPGe) detectors together with high-resolution spectrometers. PGAA in principle can be used for the analysis of each isotopes of every chemical elements. In practice it is mainly used for major-component analyses of a large variety of materials. It is especially useful for the analysis of light elements, like hydrogen down to ppm level, or boron as a trace element.

Thanks to the deep penetration of both neutrons and gamma photons, PGAA can be used for the investigation of samples placed in closed containers, or for monitoring the chemical composition inside chemical reactors (in situ PGAA).

A spectroscopic data library has been compiled and maintained at the Institute of Isotopes, Budapest, Hungary, based on the systematic series of measurements performed at the Budapest Research Reactor. Besides nuclear analysis, the spectroscopic data can be used in the field of nuclear physics, investigation of nuclear materials etc.

Thanks to the new data, PGAA has been successfully used in material sciences, archaeometry, catalysis, mineralogy, nuclear safety etc.

TUE-NP02-3 #71 - Invited Talk - Tuesday 8:30 AM - Trinity Central

Elemental analysis with prompt and delayed gamma-rays using guided neutron beams, neutron generators, and cosmic rays

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We have measured prompt and delayed gamma ray production cross sections from neutron capture on all stable elemental targets using thermal neutron beams at the Budapest Reactor. These data have been evaluated and published in the IAEA/LBNL Evaluated Gamma-ray Activation File (EGAF). The EGAF database is the first comprehensive reference source for Prompt and Delayed Neutron Activation Analysis (PGAA/NAA). Our research using the EGAF database has included the analysis of deep sea vents, the determination of impurities in chemical reagents, and the discovery of the Younger Dryas impact boundary layer that is associated with the disappearance of the Mammoths and other megafauna. Further studies of fissile material analysis were performed with 2.5 MeV neutrons from the high intensity LBNL D+D neutron generator. In addition we investigated the historical cosmic ray flux impacting the atmosphere, as recorded by the 14N(n,p)14C reaction in the radiocarbon record, which led to the discovery of four prehistoric supernovae that exploded <250 pc from Earth during the past 50,000 years.

TUE-NP02-4 #108 - Invited Talk - Tuesday 8:30 AM - Trinity Central

New Tools for Nuclear Astrophysics at Notre Dame

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Two new tools will dramatically enhance the capabilities of the Nuclear Science Laboratory at the University of Notre Dame. The Recoil Mass Separator, ST. GEORGE, is designed to study alpha radiative capture reactions in inverse kinematics utilizing its angular acceptance of ± 40 mrad, energy acceptance of ±7.5% and a mass resolving power M/DM=100. The design and motivation as well as the current status of the installation and commissioning process will be presented. In addition, the accelerator feeding ST. GEORGE is scheduled to be replaced in early 2011 by a new 5MV Pelletron with an ECR source in the terminal. The design and motivations for this will also be discussed.

TUE-NP02-5 #244 - Invited Talk - Tuesday 8:30 AM - Trinity Central

Forward Drift Chamber for the GlueX experiment at the12 GeV CEBAF machine

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The GlueX experiment will search for exotic mesons produced by 9 GeV linearly polarized photon beams from the upgraded CEBAF machine. It is critical to detect and measure the four-momenta of all the charged particles and photons resulting from the decays of the mesons. The solenoid-based detector system includes tracking detectors and calorimeters. The Forward Drift Chamber, FDC, consists of 24 circular planar drift chambers of 1m diameter. Additional cathode readout is required to achieve efficient pattern recognition. The detection of relatively low energy photons by the e.m. calorimeters imposes severe constraints on the amount of the material used in the FDC. The specific features of the detector and the readout electronics will be described. Results from the tests of the full scale prototype will be presented, as well.

TUE-NP03-1 #434 - Invited Talk - Tuesday 1:00 PM - Trinity Central

The SNS External-Antenna H- Ion Source

Robert F Welton[1], Nandish J Desai[2], Baoxi X Han[1], Syd N Murray[1], Terry Pennisi[1], Kerry G Potter[1], Bonnie Lang[1], Manny Santana[1], Martin P Stockli[1]
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The Spallation Neutron Source (SNS) now operates routinely near 1 MW with a highly- persistent 38 mA peak current in the linac and with an availability of >85%. The ~1 ms-long, 60 Hz, ~50 mA H- beam pulses originate from the Cs-enhanced, multi-cusp baseline ion source. The plasma is generated by ~550 A pk-pk current circulating through a 2.5-turn antenna, which requires ~55 kW of 2 MHz power. The plasma-immersed antenna fails ~once per ~20-week run, which limits the source availability to ~99.8%.

To increase source availability to >99.9%, we are developing an H- ion source with an antenna external to a water-cooled, ceramic aluminum nitride (AlN) plasma chamber. An earlier version of this source has briefly delivered up to 42 mA on the SNS front end, and unanalyzed beam currents of up to ~100 mA have been recorded on the test stand at a 6% duty factor. Early in 2009 the source was implemented on the Frontend, where it routinely produced the required ~35 mA, although it normally required raising the RF power by ~20% over the first week. After 5 source failures within eight weeks, the external antenna sources were taken out of service due to an unacceptable availability of 96.6%.

To achieve the desired >99.9% availability, the designs the of plasma chamber cooling jacket, the ferrite-backed antenna structure, and the water-cooled magnetic confinement were improved. In addition, an RF-plasma gun was designed to replace the DC-plasma gun which is suspected to be the cause of the ~20% loss of efficiency during the first week of operation. This report discusses the status of these efforts and the results of initial testing of the redesigned source.

TUE-NP03-2 #488 - Invited Talk - Tuesday 1:00 PM - Trinity Central

Application of HIRFL in Research and Ion Therapy

Hongwie Zhao, HIRFL group
Institute of Modern Physics (IMP), Chinese Academy of Sciences (CAS), PO Box 31, Lanzhou 730000, China

HIRFL (Heavy Ion Research Facility in Lanzhou) accelerator complex consists of ECR ion sources, Sector Focus Cyclotron (SFC), Separated Sector Cyclotron (SSC) and cooling storage rings. The maximum beam energy of HIRFL is 1.0 GeV/u for carbon beam and 500 MeV/u for uranium beam. HIRFL has been operated for nuclear physics research and heavy ion application such as ion therapy, irradiation material science and so on. This talk will present a brief review on HIRFL operation status, highlights of nuclear research and ion therapy of patient treatment at HIRFL.

TUE-NP03-3 #135 - Contributed Talk - Tuesday 1:00 PM - Trinity Central

NEUTRON REFERENCE FIELDS AT THE PTB ION ACCELERATOR FACILITY AND THEIR POTENTIALS TO INVESTIGATE NEUTRON INDUCED REACTIONS

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At the ion accelerator facility PIAF of the Physikalisch-Technische Bundesanstalt (PTB) two accelerators are used to produce neutron fields by nuclear reactions induced by light ions. The Van-de-Graaff (VdG) accelerator with high voltages between 0.1 MV and 3.75 MV accelerates protons, deuterons and alpha-particles. The second accelerator is an energy variable cyclotron of the type TCC CV28. The energy range covered by the cyclotron is 2 MeV to 19 MeV for protons, 3 MeV to 13.5 MeV for deuterons and 6 MeV to 26 MeV for alpha particles. The ion beams are used for the measurement of cross sections of nuclear reactions induced by neutrons and light ions, for the calibration of particle detectors and the

production of neutron and photon radiation fields. Both accelerators can be operated in pulsed mode, hence the time-of-flight method can be employed for the measurement of neutron energies.

The proper selection of the primary ion, ion energy and target permits to produce almost monoenergetic neutron fields from 24 keV up to 19 MeV via nuclear reactions. Since the measured fluence of monoenergetic neutrons is traceable to the primary standard for neutron fluence at PTB, these neutron fields are reference fields according to international standards (ISO).

In addition to these monoenergetic fields, intensive neutron beams with broad energy distributions and neutron beams with a monoenergetic component and a low-energy break-up continuum are made available. The PTB time-of-flight spectrometer installed at the cyclotron is especially designed for the measurement of differential neutron scattering and double differential neutron emission cross sections in the neutron energy range from 6 MeV to 15 MeV where truly monoenergetic neutron sources are unavailable. In addition to the measurements of neutron scattering cross sections, the time-of-flight spectrometer can also be used for the measurement of neutron activation cross sections.

TUE-NP03-4 #379 - Contributed Talk - Tuesday 1:00 PM - Trinity Central

Low cost, low intensity 7Be radioactive beam

Natko Skukan[1], Matko Milin[2], Zdravko Siketic[1], Milko Jaksic[1]
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Feasibility study on production of low cost, low intensity 7Be beam at 6 MV tandem accelerator has been performed. The aim was to produce the 7Be enriched cathodes and to insert them into the negative Cs-sputter source.

The 7Be production by the 7Li(p,n)7Be reaction was measured for energies between 2 and 9 MeV. The produced 7Be activity was measured by counting the 429 and 478 keV gamma ray emission - the first one corresponding to the decay of the 1st excited 7Be state and the second one coming from the beta decay of 7Be to 7Li(T1/2= 52 days).

As a 2nd step, a sputter cathode filled with LiO powder was prepared (in order to avoid any hot chemistry) and then activated with proton beam. The activated cathode was transported in the sputtering source and 7LiO- and 7BeO- molecular beams were extracted and injected to the accelerator. 7Be was separated from 7Li by addition of a stripper foil on high energy side of the accelerator. Several problems were encountered; the most important one being the fact that the beam was contaminated with scattered 7Li and 16O of high intensity. In addition, a comparison of activation per ion was done for another reaction, 6Li(d,n)7Be.

As a conclusion, the possibility to produce 7Be beams of intensities of 10^5 to 10^6 pps was demonstrated. Addition of a Wien filter is desirable to produce a cleaner 7Be beam.

TUE-NP03-5 #144 - Contributed Talk - Tuesday 1:00 PM - Trinity Central

A HIGH INTENSITY POSITRON SOURCE AT SACLAY: THE HUNT FOR POSITRONS ON THE SOPHI PROJECT

Jean-Michel G Rey, Michael Carty, Gilles Coulloux, Pascal Debu, Pierre Dupre, Laszlo Liszkay, Tomoko Muranaka, Patrice Perez, Jean-Yves Rousse, Paul Lotrus, Nicolas Ruiz, Yves Sacquin
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In order to produce a high intensity low energy positrons beam, IRFU has developed and build a positron source based on a small 5 MeV electron linac (1). It aims at the production of 1010 e+/s via pair production on a tungsten target. This facility named SOPHI (2) has been started in 2009 and its commissioning is still on the way. Several tungsten targets of various geometries have been tested to optimize production and identification of the positron signal in the high background of secondary electrons. The detection of positron signals in the noisy RF environment of an industrial linac will be presented, and first positron production rate measurements reported.

TUE-NP04-1 #345 - Invited Talk - Tuesday 3:30 PM - Trinity Central

Are beta-decay half-lives affected by external conditions?

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A series of publications in the past two years have claimed to observe that the half-lives of radioactive isotopes decaying by α, β^-, β^+ and electron-capture show significant differences - up to 6% - depending on whether the radioactive parent is placed in an insulating or conducting host material, and whether the latter is at room temperature or cooled to 12K. The authors have also proposed a theoretical explanation of their observations based on quasi-free electrons causing an enhanced screening effect in metallic hosts. This would lead to a smooth dependence of half-life on temperature in a metal. These claims have attracted considerable popular interest, not least because, if confirmed, they could possibly lead to the improved disposal of radioactive waste.

There has also been a recent claim that radioactive half-lives have been observed to vary as a function of the earth-to-sun distance at the time of measurement. These authors speculate that this could arise from a terrestrial modulation in the fine-structure constant caused by a scalar field from the sun, or because the terrestrial radioactive nuclei are interacting in some way with the neutrino flux from the sun.

We have investigated the claims of temperature dependence for two types of decay - β^- and electron-capture - by measuring the decay over 10 half-lives of ^{198}Au ($t_{1/2}$ = 2.7d) and ^{97}Ru ($t_{1/2}$ = 2.8 d) at room temperature and at 19K. We have also measured the ^{198}Au half-life at seven different earth-sun distances. We are able to set limits on possible half-life changes that are well below the claimed observations and, in fact, well below any previously set limits.

TUE-NP04-2 #320 - Invited Talk - Tuesday 3:30 PM - Trinity Central

Study of the dynamics of halo nuclei collisions at Coulomb barrier energies

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During the last ten years we have carried out a number of experiments related with the study of radioactive nuclei. One of the fields where we have centred our research programme is the scattering of halo nuclei at energies around the Coulomb barrier. As part of this study, we present in this work a review of the obtained results from the scattering of ^{6}He, ^{11}Be and ^{11}Li. The presence of a "halo" in these exotic nuclei makes the dynamics of the reactions where these are involved the main interest, and convert them in good candidates to test the nuclear interactions in extreme conditions.

TUE-NP04-3 #274 - Contributed Talk - Tuesday 3:30 PM - Trinity Central

Use of the BigSol Time of Flight Spectrometer in the Study of Superheavy Elements Production

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A time of flight spectrometer with the BigSol superconducting solenoid at Texas A&M was used to investigate the possibility to produce heavy and superheavy nuclei in two body reactions. In particular, the 7.5 AMeV 197Au + 232Th reaction was studied. Theoretical calculations suggest that this reaction could be used as an alternative method to produce

superheavy elements (SHEs). In fact, during the short interaction time, giant systems of interacting nucleons are formed and, due to strong energy dissipation, a large number of nucleons can be transferred. Moreover shell effects may help in the formation of heavy nuclei in the region of the predicted island of stability.

Reaction products emitted in an angular range from 6 to 16 degrees were collected at the entrance of the BigSol superconducting solenoid and detected at the focal plane using a segmented ionization chamber (IC). Four position sensitive PPAC detectors placed along the flight path were used to track the product trajectories and measure the times of flight.

The atomic number identification of the reaction products is performed using the time of flight and energy loss information in the eight segments of the IC. Consequently, the energy and time calibration of the detectors is a crucial task. A preliminary experimental study of the stopping powers of heavy ions in the detector materials was therefore performed. A new parameterization of the stopping powers in the energy range of interest for the experiment was developed and used to extrapolate the stopping powers of SHEs. The energy calibration and the ion identification procedures will be discussed in detail. Another important task in this kind of experiment is the pileup rejection. Different filtering procedures that were applied to the experimental data will be discussed in detail. Results for the yields of heavy nuclei will be presented.

TUE-NP04-4 #336 - Invited Talk - Tuesday 3:30 PM - Trinity Central

Investigation of exotic shapes, correlations, and isomers in nuclei with Large Compton Suppressed Clover Array

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A large array of Compton suppressed clover detectors is used to study the structure and dynamics of atomic nuclei through different nuclear reactions. The array is a joined facility of TIFR, IUAC, IUC-DAE-CSR, SINP, BARC, VECC and universities within India and rotates between the three Indian accelerator facilities.

The array is designed for 24 compton suppressed clover detectors providing around 5$\\%$ photopeak efficiency. Recent reseach results from the array will be presented which highlights our experimental effort in improving the understanding of the interplay between single-particle, vibrational and rotational degrees of excitation modes of nuclei generating a rich variety of nuclear structure phenomena. Among the topics covered will be the effects due of triaxial deformations in A ~ 130 region, collective shape evolution in f-p-g nuclei and single particle states near the shell closure. Future possibilities of exploring the non-yrast states in nuclei by taking the low-fold coincidence data using the new digital data acquisition system and particle-detectors will be discussed.

TUE-NP04-5 #335 - Invited Talk - Tuesday 3:30 PM - Trinity Central

Status and performance of the Advanced Gamma Tracking Array (AGATA)

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Each major technical advance in gamma-ray detection devices has resulted in significant new insights into the structure of atomic nuclei. The next major step in gamma-ray spectroscopy involves achieving the goal of a 4pi ball of Germanium detectors by using the technique of gamma-ray energy tracking in electrically segmented Germanium crystals. The resulting spectrometer will have an unparalleled level of detection power for nuclear electromagnetic radiation [1]. Collaborations have been established in Europe (AGATA) [2] and the USA (GRETA/GRETINA) to build gamma-ray tracking spectrometers [3].

The Physics Campaign of the AGATA demonstrator commenced at Legnaro National Laboratory (LNL) in Italy in February 2010.This presentation will discuss the status of the AGATA (Advanced GAmma Tracking Array) spectrometer, including examples of results from the early experiments. The performance of the asymmetric production detectors that have been tested at the University of Liverpool will also be summarised. The use of a fully digital data acquisition system has allowed detector charge pulse shapes (from a selection of well defined photon interaction positions) to be analysed yielding important information on the position sensitivity of the detectors. The differences between experimental and theoretical "basis" data sets will be discussed in the context of the overall performance of the device.

[1] J. Simpson, J. Phys. G 31 (2005) S1801-S1806.

[2] J. Simpson, Acta Phys. Pol. B36 1383 (2005)

[3] M.A. Delaplanque, NIM A 430 (1999) 292

TUE-RE02-1 #10 - Invited Talk - Tuesday 8:30 AM - West Fork

Opportunities for Ion Beams in the Study of Radiation Damage in Extreme Environments

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Ion irradiation provides a low cost, rapid and well-controlled means of studying irradiation effects in materials. Target and beamline systems can be constructed to provide excellent temperature control and accurate tracking of dose and dose rate using a monoenergetic beam of ions. The degree of achievable control of the key irradiation parameters make ion irradiation the ideal tool for studying radiation effects in materials. Furthermore, the results are transferable to radiation damage in a reactor environment by accounting for the differences in dose rate and damage morphology. The development of advanced characterization techniques (such as atom probe tomography) requiring exceptionally small volumes have extended the range of applicability of the technique to understand the irradiated microstructure. Ion beams also enjoy great promise in capturing multiple components of the reactor environment, such as high temperature, high dose, stress and an aggressive environment. Dynamic deformation under irradiation (tensile or creep) can be conducted in real-time experiments that can also probe very low dose behavior as well as sensitivity to irradiation parameters such as dose rate, stress or temperature within a single experiment. The opportunity also exists to conduct experiments in aggressive chemical environments such as high temperature, high pressure water or liquid metal. In-situ diagnostic techniques are becoming available to provide information on corrosion under irradiation in real time. This paper will focus on the control of irradiation parameters in ion irradiation studies and the opportunities to extend ion beam-based irradiation damage to include one or more elements of the extreme environment of nuclear reactor core materials.

TUE-RE02-2 #275 - Contributed Talk - Tuesday 8:30 AM - West Fork

Measurement of Thermal Contact Resistance for Engineering Interfaces of Relevance to Ion Beam Applications

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Irradiation studies performed using an ion beam to induce damage in materials of interest to research and engineering applications requires accurate knowledge of the thermal properties of all materials within the system. The incident beam will result in volumetric heating of the sample which must then be evacuated through the mounting assembly and into the heat sink. A variety of mounting techniques are often employed to hold samples in place during irradiation. While the thermophysical properties of familiar materials are well known, the thermal contact resistance resulting from two materials being placed in either contact under pressure or with a mounting aid to increase thermal transport is generally unknown and must be estimated. Estimation of this quantity or worse, assumption of zero contact resistance, introduces significant uncertainty in the temperature of irradiated samples and requires more conservative operating conditions if specific temperature ceilings cannot be exceeded.

Evaluation of thermal contact resistance for systems of interest to ion beam applications is possible using multilayer flash diffusivity techniques. Typical mounting configurations such as malleable graphite, silver paste, indium foil, and bare interfaces have been examined from room temperature to 500°C. The impacts of contact pressure applied through fastener torque as well as material surface roughness are also investigated. The result is thermal contact resistance values for many familiar mounting techniques that will enhance the accuracy of heating calculations performed to estimate the temperature of samples being irradiated or heat transfer through any comparable system.

TUE-RE02-3 #249 - Invited Talk - Tuesday 8:30 AM - West Fork

Helium behavior at Cu-Nb interfaces

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An atomistic modeling effort to understand the trapping, diffusion, and clustering of He introduced at heterophase interfaces by ion implantation will be presented. This study uses the Cu-Nb interface as a model system. The impact of He on interface shear resistance and cohesive strength will be discussed.

This work is supported by the Los Alamos LDRD program.

TUE-RE02-4 #131 - Invited Talk - Tuesday 8:30 AM - West Fork

Mechanical Properties of Ion Irradiated Nanoscale Cu/Nb Multilayers

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A series of helium (He) ion irradiations with different energies and doses were performed at room temperature to produce a near constant He concentration of 7 ± 1 at% over a depth of 1 μm in Cu-Nb multilayers with individual layer thicknesses ranging from 2.5 nm to 50 nm. Transmission electron microscopy shows He bubbles, approximately 1 nm in diameter, throughout the multilayered films, but the average helium bubble density, swelling and lattice expansion reduce with decreasing bilayer period. Focused-ion-beam machined micropillar specimens were used to obtain compressive stress-strain curves for Cu/Nb multilayers before and after ion irradiation. Consistent with the reduction in damage with reducing layer thickness, the magnitude of radiation hardening decreases significantly with decreasing layer thickness, without any measurable loss in deformability. Radiation hardening in nanoscale multilayers is discussed in terms of the influence of He bubbles on different unit processes that become active with decreasing layer thickness such as confined layer slip and interface crossing of single dislocations.

TUE-RE02-5 #431 - Contributed Talk - Tuesday 8:30 AM - West Fork

Simulation of ion implantation into nuclear materials and comparison with experiment

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Radiation defects generated in various nuclear materials such as Mo and CeO_2 as a surrogate material for UO_2, formed by sub-MeV Xe and Kr ion implantation were studied via TRIM and MD codes and the results were compared with defect distributions in CeO_2 crystals obtained from experiments by implantation of these ions at the doses of $1x10^{17}$ ions/cm^2 at several temperatures. A combination of in situ TEM (Transmission Electron Microscopy) and ex situ TEM experiments

were used to study the evolution of defect clusters during implantation of Xe and Kr ions at energies of 150-700 keV, depending on the experimental conditions. The simulation and irradiation were performed on thin film single crystal materials. The formation of dislocation loops, voids or bubbles, solid state precipitates and dislocation networks due to radiation were studied by simulation and compared to experiment. The irradiation damage caused the formation of complex microstructures with dislocation loops, voids or bubbles, and dislocation networks at higher doses. The void and bubble formation rates are estimated based on a new mesoscale approach that combined experiment with the kinetic models validated by atomistic and Ab-initio simulations, that show its dependence on irradiation dose and irradiation temperature. Various sets of quantitative experimental results were obtained to characterize the dose and temperature effects of irradiation. These experimental results include size and size distributions of dislocation loops, voids and gas bubble structures created by irradiation. More importantly, this systematic experimental work has provided key insights into the understanding of the mechanisms of defect evolution in the materials investigated.

TUE-RE02-P1 #413 - Poster - Tuesday 5:30 PM - Rio Grande

Angular Distribution of Bi Sputtered by 25 keV Ar^+

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The angular distribution of neutral atoms sputtered from the surface of solid Bi by normally incident 25 keV Ar^+ has been measured. The sputtered atoms were collected on aluminum foils under ultrahigh vacuum conditions, and the collector foils were subsequently analyzed using heavy ion Rutherford backscattering spectroscopy. The resulting differential angular sputtering yield was fit by a function of the form $dY/d\theta = A\cos^B \theta$ where A = 4.1 atoms/ion and B = 2.3 for 25 keV Ar^+ projectiles. The corresponding total sputtering yield is Y = 7.7±0.6 atoms/ion, which is consistent with published values of the Bi sputtering yield at other Ar energies. Details of the measurements and data analysis are presented.

TUE-RE03-1 #519 - Invited Talk - Tuesday 1:00 PM - West Fork

Reliability Impact of radiation in advanced commercial CMOS technology

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The once-ephemeral, radiation-induced soft error has become a key threat to advanced commercial electronic components and systems. Whether in a cluster of workstations, a router hub, or an automotive control system, left unchallenged, soft errors have the potential for inducing the highest failure rate of all other reliability mechanisms combined. We briefly review the types of failure modes for soft errors, and the dominant terrestrial radiation mechanisms. The soft error sensitivity as a function of technology scaling for various memory and logic components is also presented with a consideration of which applications are most likely to require soft-error mitigation. We briefly discuss the types of characterizations possible in accelerator facilities and how data obtained from these tests are used to extrapolate product reliability. Finally, we look ahead and consider challenges for future commercial semiconductor technology.

TUE-RE03-2 #225 - Contributed Talk - Tuesday 1:00 PM - West Fork

High-Reliability Computing for the Smarter Planet

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The geometric rate of improvement of transistor size and integrated circuit performance known as Moore's Law has been an engine of growth for our economy, enabling new products and services, creating new value and wealth, increasing safety, and removing menial tasks from our daily lives. Affordable, highly integrated components have enabled both life-saving technologies and rich entertainment applications. Anti-lock brakes, insulin monitors, and GPS-enabled emergency response systems save lives. Cell phones, internet appliances, virtual worlds, realistic video games, and mp3 players enrich our lives and connect us together. Over the past 40 years of silicon scaling, the increasing capabilities of inexpensive computation have transformed our society through automation and ubiquitous communications.

Looking forward, increasing unpredictability threatens our ability to continue scaling integrated circuits at Moore's Law rates. As the transistors, wires, and other components that make up integrated circuits become smaller, they display both greater differences in behavior among devices designed to be identical and greater vulnerability to transient and permanent faults. While there a number of reliability problems with these highly-scaled devices, radiation-induced upsets due to naturally occurring neutrons are becoming increasingly problematic, as computation becomes more pervasive. In this talk, we will present an analysis of electronics testing performed at the Los Alamos Neutron Science Center and its implication for cars and avionic systems.

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TUE-RE03-3 #541 - Invited Talk - Tuesday 1:00 PM - West Fork

An Overview of Single-Event Effects Testing: Qualifying Modern IC's for the Space Radiation Environment

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In space, particle bombardment of electronics can cause a variety of disruptions, e.g. bit upsets or device latchups; these are known collectively as single-event effects (SEE's). Ground-based testing to measure either these effects directly or the effectiveness of SEE mitigation schemes is accomplished using particle accelerators to simulate cosmic rays, as well as solar and trapped particles. The concept of effective linear energy transfer (LET) is used to project accelerator data into expected on-orbit SEE rates. This paper gives an overview of the difficulties that SEE testers face in obtaining useful data, including both the increasing fundamental problems with the models as integrated circuits (IC's) scale and some logistical issues arising from statistical issues and newer packages .

TUE-RE03-4 #518 - Invited Talk - Tuesday 1:00 PM - West Fork

Applications of Monte Carlo Radiation Transport Simulations Techniques for Predicting Single Event Effects in Microelectronics

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MRED (Monte Carlo Radiative Energy Deposition) is Vanderbilt University's Geant4 application for simulating radiation events in semiconductors. Geant4 is comprised of the best available computational physics models for the transport of radiation through matter. Geant4 is a library of c++ routines for describing radiation interaction with matter assembled by a large and diverse international collaboration. MRED includes a model developed by researchers at Vanderbilt University for screened Coulomb scattering of ions (currently available in the latest Geant4 release), tetrahedral geometric objects, a cross section biasing and track weighting technique for variance reduction, and a number of additional features relevant to semiconductor device applications. The Geant4 libraries contain alternative models for many physical processes, which differ in levels of detail and accuracy. Generally, MRED is structured so that all physics relevant for radiation effects applications are available and selectable at run time.

The underlying physical mechanisms for Single Event Effect (SEE) response are: 1) ionizing radiation-induced energy deposition within the device, 2) initial electron-hole pair generation 3) the transport of the charge carriers through the semiconductor device and 4) the response of the device and circuit to the electron-hole pair distribution and subsequent transport. Each of these occur on a different time scale and they are often assumed to be sequential, i.e., energy deposition determines the initial electron-hole pair generation, which in-turn impacts device and circuit response. In this paper we

discuss the current application of MRED that are intended to address emerging technology issues as they relate to the mechanisms listed above.

TUE-RE03-5 #256 - Invited Talk - Tuesday 1:00 PM - West Fork

Heavy Ion Radiation Effects Studies with Ion Photon Emission Microscopy

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The development of a new radiation effects microscopy (REM) technique is crucial as emerging semiconductor technologies demonstrate smaller feature sizes and thicker back end of line (BEOL) layers. To penetrate these materials and still deposit sufficient energy into the device to induce single event effects, high energy heavy ions are required. Ion photon emission microscopy (IPEM) is a technique that utilizes coincident photons, which are emitted from the location of each ion impact to map out regions of radiation sensitivity in integrated circuits and devices, circumventing the obstacle of focusing high-energy heavy ions. Several versions of the IPEM have been developed and implemented at Sandia National Laboratories (SNL). One such instrument has been utilized on the microbeam line of the 6 MV tandem accelerator at SNL. Another IPEM was designed for ex-vacu use at the 88" cyclotron at Lawrence Berkeley National Laboratory (LBNL). Extensive engineering is involved in the development of these IPEM systems, including resolving issues with electronics, event timing, optics, phosphor selection, and mechanics. The various versions of the IPEM and the obstacles, as well as benefits associated with each will be presented. In addition, the current stage of IPEM development as a user instrument will be discussed in the context of recent results.

*Sandia National Laboratories is a multi-program laboratory operated by Sandia Corporation, a wholly-owned subsidiary of Lockheed Martin company, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

TUE-RE03-6 #185 - Contributed Talk - Tuesday 1:00 PM - West Fork

Refreshable Decrease in Peak Height of Ion Beam Induced Transient Current from Silicon Carbide Metal-Oxide-Semiconductor Capacitors

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Metal-Oxide-Semiconductor (MOS) capacitors were fabricated on n-type 4H- and 6H-SiC epitaxial layers, and transient currents induced in SiC MOS capacitors by ion incidence were investigated. The samples used in this study were 4H- and 6H-SiC MOS capacitors fabricated on n-type epitaxial layers grown on Si-face n-type 4H and 6H-SiC substrates (CREE), respectively. The gate oxide at a thickness of 24 nm (4H-SiC) / 39 nm (6H-SiC) was formed using dry oxidation at 1180 C for 80/120 min. After the oxidation, re-oxidation at 800 C in a pyrogenic condition (H2: O2 = 1:1) for 15 min was carried out. Circular electrodes with 200 um diameter were formed using Al evaporation and a lift-off technique. Transient Ion Beam Induced Current (TIBIC) measurements were performed using 9 or 15 MeV oxygen ions. As a result, the TIBIC peak height decreased with increasing number of incident ions. For example, in the case of 15 MeV-O ions, the TIBIC signal peak for a 4H-SiC MOS capacitor at a reverse bias of 15 V was 0.18 mA at the beginning. The peak decreased to be 0.10 mA after 1800 ion irradiation. After that, the forward bias of 1 V was applied to the MOS capacitor and the TIBIC measurements were carried out under the same conditions. As a result, the peak height was recovered to be 0.18 mA. In general, the response of charge de-trapping by deep levels in wide bandgap semiconductors is very slow and they act as fixed charge. Since dense electron-hole pairs are generated by ion incident and holes move to the SiO2/SiC interface by the electric field (applied reverse bias). Therefore, the decrease in TIBIC signal peak can be interpreted in terms of the recombination of negatively charged acceptor type deep levels with ion induced holes.

TUE-RE03-7 #520 - Invited Talk - Tuesday 1:00 PM - West Fork

Radiation Effects in Space*

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Protecting space missions from severe exposures from radiation, in general, and long duration/ deep space human missions, in particular, is a critical design driver, and could be a limiting factor. The space radiation environment consists of galactic cosmic rays (GCR), solar particle events (SPE), trapped radiation, and includes ions of all the known elements over a very broad energy range. These ions penetrate spacecraft materials producing nuclear fragments and secondary particles that damage biological tissues and microelectronic devices. One is required to know how every element (and all isotopes of each element) in the periodic table interacts and fragments on every other element in the same table as a function of kinetic energy ranging over many decades. In addition, the accuracy of the input information and database, in general and nuclear data in particular, impacts radiation exposure health assessments and payload penalty. After a brief review of effects of space radiation on materials and electronics, the discussion would focus on human space missions with some examples.

*Invited Talk

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TUE-RE03-P1 #391 - Poster - Tuesday 5:30 PM - Rio Grande

Modeling the ion induced quantum dot structure formation from multiperiod alternated nanolayer films

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We use high energy ion beams to modify co deposited nanolayer films of alternated materials (insulator and metal, semiconductor 1 and semiconductor 2, or more complex mixtures), to form nanodots (quantum dots or metallic nanoclusters) through localized nucleation. Our particular application is for high efficiency thermoelectric conversion systems. Since the ion beam contribution is based on the energy deposited through the contribution of electronic stopping power of the ion-target system, we constantly need to assess the energy and fluence of a given type of ion necessary to induce the desired size nanodots. The type of ion is generally dictated by the type of device or substrate material, such that no parasitic chemical interference is generated. An important parameter to assess is the nanodot size and distribution variation with the thickness of the device (number of alternated nanolayers), as this will affect the performance. The performance of a thermoelectric converter is generally given by the figure of merit, ZT, which is a function of the Seebeck coefficient, electrical conductivity, and thermal conductivity. A performant device would have a maximized electrical conductivity and a minimized thermal conductivity (maximum electron transport, minimal phonon transport). The current models of electron and phonon transportation through 1D, 2D, 3D quantum regimented structures assume an infinitely repetitive perfect structural "cell", without a fuzziness factor given by the tructural imperfections caused by the fabrication

process, and therefore the theoretically predicted performance is far superior to the experimental results. Our focus is to resolve the contribution of the structural imperfections factor to this discrepancy.

TUE-RE03-P2 #499 - Poster - Tuesday 5:30 PM - Rio Grande

A broad, uniform flux alpha-particle beam for accelerated SEU testing

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The use of radioactive alpha particle sources (e.g. Am-241, Th-228) of several micro Curie activity for the single event upset (SEU) testing of memory devices is common practice. However, the fixed energy nature of these sources and the distributed angle of incidence resulting from their isotropic emission, making it impossible to determine the angle of incidence causing a given SEU, result in SEU data that is of limited research or predictive use. The University of North Texas (UNT) Ion Beam Modification and Analysis Laboratory (IBMAL) has developed an SEU testing system that uses a broad beam of collimated alpha particles with uniform density over an area of at least 1.5" diameter. These alpha particles can be produced at energies from 1 to 9 MeV, and at fluxes ranging from 10^2 to 10^5 (alpha/cm^2)/s. This flux can uniformly irradiate a 512 Mbit SRAM memory array and four PIN diodes that surround the array, which measure fluence (alpha/cm^2) coincident with upsets. Measured SEU/fluence rates of the 512 Mbit arrays using 5.5 MeV alphas in the broad-beam testing chamber agree with rates measured using a 10uCi Am-241 source. Additional results of SEU testing of the 512 Mbit arrays at various energies of alphas and Si ions will be shared. Further discussion of the use of the 3MV tandem accelerator and SNICSII ion source of IBMAL to produce multi-MeV beams of Mg and other SEU relevant ions at low intensity and broad area uniformity will also be presented.

TUE-RE04-1 #189 - Invited Talk - Tuesday 3:30 PM - West Fork

An Overview of the Role of Crystal Structure and Microstructure on the Radiation Tolerance (or Radiation Susceptibility) of Ceramic Oxides

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In this presentation, I will present an overview of the radiation damage response of oxides made from single metal constituents (general formula MxOy) and multiple metal constituents (general formula AxByOz). I will compare and contrast the radiation tolerance of various oxides with respect to several considerations: (1) cation valence; (2) cation coordination; (2) cation size; (3) crystalline atomic patterning; (4) propensity for cation disorder; (5) deviations from ideal compound stoichiometry; (6) ionic versus covalent bonding; and (7) themodynamic phase diagrams. I will consider the possibility to establish "universal" concepts for radiation damage response of oxides and discuss future research challenges relating to the search for advanced radiation resistant ceramic materials.

TUE-RE04-2 #53 - Invited Talk - Tuesday 3:30 PM - West Fork

Role of Grain Boundaries on Defect Creation and Defect Processes in SiC

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The reduction of grain size down to the nanometer regime has opened new and fascinating avenues for studying several aspects of materials science, including high hardness, high fracture toughness, and super-plastic behavior, as well as high tolerance to irradiation damage.

Large-scale molecular dynamics simulations have been employed to study defect generation and primary damage state in nano crystalline (NC) SiC of average grain diameters from 5 to 21 nm. Primary knock-on atoms (PKAs) with kinetic energies of 10-20 keV are initially simulated because higher-energy cascade simulation (up to 50 keV) yields multiple branches with energies on the order of 10 keV in a bulk SiC. It is found that the local stresses near the grain boundaries (GBs) strongly affect the behavior of the PKA and secondary recoil atoms (SRAs), and the GBs act as sinks for deposition of kinetic energy. A striking feature is that the PKA and SRAs preferentially deposit energy along the GBs for grains with

average sizes of less than 12 nm, which results in atomic displacements primarily within the GBs, which are amorphous. For larger grain sizes, most defects are produced within the grains. The mechanisms of defect generation in nanocrystalline SiC are found to be different from those observed in metals. However, for average grain diameters larger than 20 nm, it is interesting to note that most defects are produced within nano grains, rather than inside the grain boundaries in NC SiC. The defect production within grains generally increases with increasing grain size, which is manifested in switching from grain boundary damage to grain damage. The present simulations provide important insights into how nanostructures influence the radiation response or tolerance of ceramics.

TUE-RE04-3 #117 - Invited Talk - Tuesday 3:30 PM - West Fork

Radiation response of nanocrystalline pyrochlore and zirconia

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Atomic-level understanding of radiation interactions with surfaces and interfaces, including grain boundaries and precipitate-matrix interfaces, is crucial for the development of advanced nuclear materials that can withstand the extreme radiation environments in reactors, accelerators, and even geologic repositories. Materials design at the nanoscale will play a key role in mitigating radiation damage and for developing radiation tolerant materials. In this talk, we will highlight recent progresses in understanding of response of nanostructured ceramics under extreme radiation environments by focusing on radiation-induced amorphization and phase transition process among different polymorphs. The nanostructured ceramics under investigation include fluorite-related structure such as pyrohclore and zirconia, potential host phases for actinides incorporation. Systematic ion beam irradiation studies suggest that nanostructured materials are not inherently radiation tolerant and there is a critical length scale (size) at which nanostructured materials are optimally radiation tolerant. For nanocrystalline pyrochlores, the interplay of among composition, crystal size, bond nature and degree of disordering defines the structural deviation and defect energetics that may essentially control phase stability of materials upon radiation damage. The correlation among the tendency of phase transformation, crystal size and structure, defect production and dynamic annealing, and the thermodynamic properties for nanostructured zirconia will also be discussed.

TUE-RE04-4 #69 - Invited Talk - Tuesday 3:30 PM - West Fork

Transmission electron microscopy study on radiation-induced structures in GaN

Manabu Ishimaru
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Atomistic structures of high-energy ion irradiated GaN have been examined using transmission electron microscopy (TEM). Single crystalline GaN substrates were irradiated at cryogenic temperature with 2 MeV Au²⁺ ions to a fluence of 7.35x10¹⁵ Au/cm². Cross-sectional TEM observations revealed that ion-beam-induced damaged regions possess a layered structure consisting of amorphous/nanocrystalline and defective crystalline GaN. The ion-beam-induced layer contained bubbles due to N₂ gas. The N₂ bubbles became large at the buried damaged layer and prominent phase segregation occured accordingly. Atomic radial distribution function analyses revealed that the atomistic structures of amorphous/nanocrystalline phases retain GaN tetrahedral configuration as the primary structural unit of crystalline GaN, but Ga-Ga bonds, which do not exist in the crystalline state, are observed. The formation of the self-bonded Ga atoms was attributed to the phase segregation during irradiation. It was found that the ratio of heteronuclear-to-homonuclear bonds, i.e., the degree of chemical disorder is different between the surface and buried damaged layers. That is, chemical disorder becomes more pronounced at the buried damaged layer, as compared with the surface damaged layer. This is associated with prominent phase segregation due to the formation of large bubbles.

I appreciate Drs. William J. Weber and Yanwen Zhang (Pacific Nortwest National Laboratory) for providing ion irradiated GaN. This work was partially supported by the Division of Materials Science & Engineering, Office of Basic Energy Sciences, U.S. Department of Energy, and a portion of the research was performed using EMSL, a national scientific user facility sponsored by the Department of Energy's Office of Biological and Environmental Research and located at Pacific Northwest National Laboratory.

TUE-RE04-5 #443 - Contributed Talk - Tuesday 3:30 PM - West Fork

Fluence-Dependent Surface Modification of YSZ Single Crystals Due to Ion Implantation Studied by SPM

Marilyn E. Hawley, Igor O. Usov, Maulik K. Patel, Jonghan Won, James A. Valdez, Yong Q. Wang, Kurt E. Sickafus
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Yittria stabilized zirconia (YSZ) has long been of interest for nuclear energy applications. YSZ is the cubic form of zirconium oxide stabilized at room temperature by the addition of yttria. Previous studies of radiation damage in YSZ focused primarily on microstructural changes in the bulk or near surface layer whereas irradiation induced changes on the surface have received little attention. Here we use scanning probe microscopy, SPM, to study the fluence-dependent generation of surface modifications to YSZ due to Argon and Xenon ion implantation at high fluences. The microstructural changes in the near surface region have previously been investigated by Rutherford backscattering spectrometry in channeling geometry (RBS/C). Further, we investigated implantation as a function of crystal orientation, (100), (110), and (111) oriented single crystals of YSZ, to explore differences in crystal orientation sensitivity to damage to ion implantation. At the highest fluence, large, densely packed round surface hillocks were observed for all three orientation. The hillocks appear to be due to surface bubble formation. To the best of our knowledge, this is first observation of these structures on the surface of YSZ. The ion induced surface modifications revealed by AFM differ slightly from the bulk lattice damage measured by RBS, although both indicate that under the implantation conditions used in this study, the (110) oriented crystal shows the most radiation damage resistance. The mean size of the hillocks, which in the case of the (100) crystal, approach a micron scaled with concentration of implanted Ar atoms.

TUE-RE04-P1 #544 - Poster - Tuesday 5:30 PM - Rio Grande

Radiolysis of Lithium Hydride by Proton Induced X-rays (U)

A.R. Webster, C. L. Haertling, J.R. Tesmer, R.R. Greco, Y.Q. Wang
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Lithium hydride (LiH) is a highly reactive solid that may be used in radiation environments, where present ionizing radiation can disrupt the structure of a material. This disruption creates defects and can produce gases, most obviously H2 gas; irradiation of LiH corrosion products may produce further gases. We have performed introductory experiments to determine the effects of radiolysis on LiH and its ubiquitous hydrolysis product, LiOH. Our experiments focus on irradiation with X-rays. We have used a particle accelerator in the Ion Beam Materials Laboratory to produce characteristic x-rays at desired energies from selective metal targets. During irradiation, evolved gases were measured, particularly H2, and quantified. Our data allows prediction of concentrations that could be released over time.

TUE-SSCD01-1 #72 - Invited Talk - Tuesday 1:00 PM - Pecos II

When Physics Strikes: Realities of Actively Interrogating Cargo

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Ensuring the security of cargo containers is an important international objective that has been elevated to unprecedented levels in recent years. An array of technology has already been deployed to the field, most notably radiographic inspection systems and information technology designed to track and assess the threat of individual containers. While these technologies have proven valuable, they have not adequately met the cargo-scanning challenge. An array of technologies exploiting nuclear interactions has been and continues to be developed. These active interrogation methods can in principle detect the presence of illicit material at very high levels of confidence. Challenges posed by the cargo container geometry, operational constraints, and the ability of adversaries to engineer shielding have the potential to significantly diminish

system effectiveness. The purpose of this presentation is to provide an overview of the cargo scanning problem and to provide a foundation upon which the feasibility of potential active interrogation technologies can assessed.

TUE-SSCD01-2 #44 - Invited Talk - Tuesday 1:00 PM - Pecos II

Low Energy Electron Linacs and Their Applcation in Cargo Inspection Systems

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Low energy electron linacs are the main x-ray sources for cargo inspection, which normally use magnetrons as their rf power source. Several kinds of linacs have been developed in Tsinghua University, amoung them, the dual energy linacs for material identification will be introduced in detail in this paper.

TUE-SSCD01-3 #203 - Invited Talk - Tuesday 1:00 PM - Pecos II

Combined Neutron and X Ray Cargo Interrogation System

Tsahi Gozani, Timothy Shaw, John Stevenson, Michael J. King, Mashal Elsalim, Craig Brown, Cathie Condron
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Effective cargo inspection systems for nuclear material detection require: good penetration of the interrogation radiation, generation of a sufficient number of fissions, and strong and penetrating signatures. Cargo content and density vary considerably. The inspection system therefore needs to be sensitive for highly-hydrogenous cargo, where neutron attenuation is a major limitation, as well as for dense metallic cargo where x-ray penetration is low. A system that combines both neutrons and x-rays as probing radiations can therefore potentially achieve high performance over the widest range of cargos. Moreover, utilizing the strong prompt-neutron (approximately 3/fission) and delayed-gamma (approximately 7/fission) signatures further strengthens the detection sensitivity across all cargos. The complementarity of x-rays and neutrons, utilized as both probing radiations and detection signatures, alleviates the need to employ exceedingly strong sources, which is required to provide adequate performance with the most difficult cargo if only one particle type is utilized.

We have developed and designed a system founded on the above principles. The system is based on a commercially-available 9 MV linac. Neutrons are produced simultaneously with x-rays by the photonuclear interaction of the x-ray beam with a suitable converter. Average neutron yields of the order of 1e11n/s are achieved with a 100 microamp, 9 MV linac.

If fissionable material is present, fissions are produced by the high-energy x-ray beam as well as by the photoneutrons. Photon-and neutron-induced fissions dominate in hydrogenous and metallic cargos, respectively. Neutron-capture gamma rays provide information on the cargo composition.

The fission prompt neutrons are detected in two independent detectors: our high efficiency Differential Die Away Analysis (DDAA) detectors and by a direct detection of >3 MeV neutrons using a novel Fission Detector (FD). This FD also simultaneously detects the fission delayed-gamma rays.

Principles and experimental verification of the new sensitive and cost-effective system will be discussed.

TUE-SSCD01-4 #435 - Contributed Talk - Tuesday 1:00 PM - Pecos II

A neutron based interrogation system for SNM in cargo

Steven Ze Kane, David Stanley Koltick
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A study will be presented on the detection of special nuclear materials (SNM) in cargo containers through the observation of multi-detector, multi-gamma coincidences due to prompt gamma-rays from both 14-MeV and thermal neutron-induced fissions. The scanner utilizes an associated particle neutron generator with active focusing and features a built-in ZnO:Ga alpha detector with nanosecond scintillation decay time and sub-nanosecond time resolution. The detection of shielded SNM can be accomplished in a reasonable time using less than the maximal neutron yield, 1e9 neutrons/s. The system design, decision hyperspace, and methods of detection are discussed. A variation of the associated particle imaging (API) technique, which delivers enhanced background reduction beyond the traditional approach will be presented. This new approach allows neutron interrogation at production rates beyond the approximate1e7 neutron/s limit faced by the traditional method of API.

TUE-SSCD01-5 #145 - Contributed Talk - Tuesday 1:00 PM - Pecos II

FIELD USE OF THE EURITRACK TAGGED NEUTRON INSPECTION SYSTEM

Giuseppe VIESTI[1], Daniela FABRIS[2], Marcello Lunardon[1], Sandra Moretto[1], Giancarlo Nebbia[2], Silvia Pesente[1]
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The tagged neutron inspection system EURITRACK [1] has been in operation in seaport of Rijeka since March 2007. The core of the system is the EADS-SODERN sealed tube neutron generator with the embedded 64 pixel alpha particle detector from INFN-Padova and the CAEN VME data acquisition system [2]. Sub-systems were delivered at beginning of 2006 for the first laboratory tests. Consequently the equipment is in use since 4 years, with the last 3 being spent in a seaport. About 150 cargo containers have been inspected by using an average neutron flux of 107 neutron/s, the tagged neutrons being about 1% of the total [3,4]. Data on the field use of the tagged neutron inspection system are presented with particular attention to the alpha particle detector behavior. The associated particle technique allows the reconstruction of the interaction point of the neutron inside the container by determining the flight path and the time of emission of each neutron. When more than one alpha particle are present in a given event it is rather difficult to reconstruct the point of emission of the produced gamma ray. Double-alpha particle events induce consequently a loss of information. The lessons learned from the EURITRACK tagged neutron system are discussed to define requirements for future systems as far as the alpha particle detector and the front-end electronics it concerns.

1) B. Perot et al., Nucl. Instr. Meth. B 261 (2007) 295-298

2) M. Lunardon et al., Nucl. Instr. Meth. B 261 (2007) 391-395

3) C. Carasco et al., Nucl. Instr. Meth. A 588 (2008) 397-405

4) J. Obhodas et al., Nucl. Instr. Meth. A in press.

TUE-SSCD01-6 #2 - Contributed Talk - Tuesday 1:00 PM - Pecos II

L-3 CAARS (Cargo Advanced Automated Radiography System) - system and results

david perticone
L3 communications Security and detection systems, 10 commerce way, woburn ma 01801, United States

The L-3 Communications CAARS (Cargo Advanced Automated Radiography System) is a state of the art active interrogation system for cargo. It features excellent image quality, penetration, material discrimination and automated detection of high Z (Z>72) objects. The project was begun in fall 2006 and testing of the prototype began in winter 2010. The primary funding was from DNDO and included a direct contribution from L-3. This presentation summarizes the goals, approach and some results from the program.

TUE-SSCD01-7 #200 - Contributed Talk - Tuesday 1:00 PM - Pecos II

Adapting a human-portable explosive detection system with SNM detection using the Differential Die-Away technique

Dan A. Strellis, Tsahi Gozani
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At the CAARI 2006 meeting, we reported on our development of a human-portable threat detection system based on 14-MeV neutron interrogation with funding from the DOD Counternarcotics Office for the U.S. Coast Guard. We summarized our methodology for detecting threat materials such as narcotics, C4, and mustard gas in the myriad of backgrounds present in the maritime environment. On this foundation, we are expanding our mission for the Domestic Nuclear Detection Office to detect Special Nuclear Material (SNM) by employing a new detector array enabling the Differential Die-Away Analysis technique (DDAA).

The DDAA technique measures the time-dependence of the fast and epi-thermal neutron population using a Cd-covered array of moderated ^{3}He (or other thermal neutron) detectors. When no fissile material is present in the inspected object, the detector signal represents the intrinsic time response ("neutron die away") of the detector plus the natural background. If fissile material is present, the detector shows, in addition, a signal decaying much more slowly with the die-away time of the inspected medium. This represents the fission induced by the thermalized source neutrons in the SNM Previous investigations using this technique for land/sea container inspection have shown considerable sensitivity, but with long measurement times, using COTS electronic neutron generators (ENGs) with 10^{8} neutrons/sec output. Initial simulations and experimental measurements using a human-portable configuration will be presented along with improved detection methodologies for explosives, narcotics, and chemical weapons.

TUE-SSCD01-8 #347 - Contributed Talk - Tuesday 1:00 PM - Pecos II

A shielding study comparison of delayed neutron and delayed gamma-ray signatures for nuclear material detection

Heather A. Seipel[1,2], Maxwell Ankrah[1,2], Edward T.E. Reedy[1,2], Edna S. Cardenas[1,2], Bruce H. Failor[3], Alan W. Hunt[1,2]
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The application of active inspection techniques to nondestructive detection and identification of nuclear materials has risen greatly in the past decade. Delayed neutrons and delayed γ-rays are emitted following β-decay and are often used as signatures of fissionable materials. In these experiments, we examine the efficacy of these signatures by measuring the minimal detectable mass for various shielding scenarios in a cargo screening like environment. A variable energy linear electron accelerator was used to produce an uncollimated bremsstrahlung beam for target interrogation. Bismuth germinate was selected as a scintillator since high energy resolution was not required, and ^{3}He detectors were utilized for neutron detection. Target shielding studies were performed for low-Z material (0"-12") and high-Z material (0"-8") for both large mass (~1kg) fissionable targets and low-mass (~60 g) ^{232}Th and ^{238}U aqueous targets. Lastly, the benefits of each signature and their complimentary nature will be discussed.

TUE-SSCD02-1 #439 - Contributed Talk - Tuesday 3:30 PM - Pecos II

A Comparison of Experimental Measured Efficiency of HPGe Using an Extended Source and Simulations Over the Energy Range 787-keV to 10.8-MeV

David S Koltick
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An absolute measurement of the photopeak efficiency as a function of energy has been made using a 1-liter cylindrical source of gamma rays. The source is excited using a 14-MeV neutron generator both directly and moderated by a hydrocarbon-lead neutron guide. 22 gamma rays lines between 787-keV and 10.8-MeV are used to measure the photopeak efficiency has a function of energy for 8 different coaxial HPGe detectors. The HPGe detectors have measured detection efficiencies at 1.33-MeV between 22.3% and 97%. The first escape photopeaks are also measured so that the ratio between the photopeak and first escape is found. These experimental measurements are compared to MCNP simulations.

TUE-SSCD02-2 #311 - Invited Talk - Tuesday 3:30 PM - Pecos II

Reactor Monitoring with Antineutrino Detectors

Adam Bernstein
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Over the last two decades, groups in Russia and the United States have developed cubic meter scale antineutrino detectors that can be placed tens of meters from reactor cores, outside of containment, and provide timely information about the thermal power and fissile isotopic content of the reactor core. Such information is useful for the International Atomic Energy Agency's safeguards regime. A key element of the Treaty on Nonproliferation of Nuclear Weapons, the goal of this international regime is to track flows of fissile materials in the global civil nuclear fuel cycle, to verify that plutonium and uranium are not diverted into weapons programs. In the last five years, numerous groups worldwide have worked to demonstrate this capability with simple and practical detectors. I will summarize the state of the art and discuss recent innovations by our Livermore Sandia collaboration, which is a world leader in the burgeoning field of applied antineutrino physics.

TUE-SSCD02-3 #217 - Contributed Talk - Tuesday 3:30 PM - Pecos II

Initial studies towards a high-spatial resolution, resonant-response γ-ray detector for Gamma Resonance Absorption (GRA) in ^{14}N

Michal Brandis[1], David Vartsky[1], Eliahu Friedman[3], Igor Kreslo[2], Israel Mardor[1], Volker Dangendorf[4], Shaul Levi[1], Doron Bar[1], Ilan Mor[1], Mark Benjamin Goldberg[1]
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[(3)]Racah Institute of Physics, The Hebrew University of Jerusalem, 91904, Jerusalem, Israel
[(4)]Physikalisch-Technische Bundesanstalt (PTB), 38116, Braunschweig, Germany

This paper introduces the concept and initial studies towards a novel resonant detector with mm spatial resolution, for the Gamma Resonance Absorption (GRA) method, based on a micrometric glass capillary array filled with liquid scintillator. GRA is an automatic-decision radiographic screening technique that combines high radiation penetration with excellent sensitivity and specificity to nitrogenous explosives. The high spatial resolution imaging is required for detecting small quantities of thin-sheet explosives in the inspected object.

A detailed simulation of the response of the detector to electrons and protons generated by the 9.17 MeV γ-rays was followed by a proof-of principle experiment at Bern University using a mixed γ-ray and neutron source. Towards this, a prototype capillary detector was assembled, including the associated filling and readout systems. Both the experimental results and detailed subsequent simulations show that proton tracks are distinguishable from electron tracks at relevant energies, on the basis of an event-identification criterion that combines track length and light intensity per unit length.

TUE-SSCD02-4 #149 - Invited Talk - Tuesday 3:30 PM - Pecos II

Recent developments in field of radiation detection for homeland security

Vitaliy Ziskin
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The new generation of active interrogation and stand-off detection systems for illicit materials (explosives, narcotics, etc.) and Special Nuclear Materials (SNM) presents new challenges and opportunities for the radiation detection technologies. A review of recent developments to meet these challenges will be presented.

TUE-SSCD02-5 #25 - Invited Talk - Tuesday 3:30 PM - Pecos II

Polaris 3-D CdZnTe Semiconductor Gamma-Ray Array Systems

Zhong He
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The performance and capability of the first three-dimensional position sensitive CdZnTe semiconductor gamma-ray detector array systems (Polaris) will be reported. Each Polaris system consists of eighteen 2x2x1.5 cm^3 modular CdZnTe detectors with a total detection volume of 108 cm^3 and an energy resolution of close to 1% FWHM at 662 keV. The Polaris system can provide the energy deposition and position in 3-D of each individual radiation interaction, enabling real-time gamma-ray imaging capability based on photon scattering kinematics if gamma rays undergo Compton scattering within the detector volume. Since the signatures of radiation interactions with detector material are recorded, it is possible to recognize different types of gamma-ray interactions, such as photoelectric absorption, Compton scattering and pair production. The current development effort on Polaris systems will be summarized.

TUE-SSCD02-6 #462 - Invited Talk - Tuesday 3:30 PM - Pecos II

A Look Forward at the Research Needs for Active Interrogation Radiation Safety

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The increase in the interest to build systems which probe luggage, vehicles, containers and even transportation systems for illicit materials, has spawned a growth in research needs to support these emerging technologies. Such "active interrogation systems" utilize energetic beams of particulate radiation to either image or probe objects in order to stimulate characteristic signatures. These technologies are of particular interest in national security applications, specifically homeland security and the countering of weapons of mass of destruction, where adversaries may use sophisticated means to mask the movement of such materials. A consequence of utilizing these systems are the inherent risks (many radiation safety related) associated with their operation and use in certain scenarios, such as in pseudo public venues as well as military operational environments. This paper will address a study of the radiation safety needs of some possible active interrogation technologies. Utilizing research from both military and homeland security programs, examples of some of the areas where breakthroughs are needed in not only scientific and technical capabilities but also policy and legal instruments will be discussed. Data from recent research will be used to provide some insight as to areas where future research activities may nominally need to go.

TUE-SSCD02-7 #130 - Invited Talk - Tuesday 3:30 PM - Pecos II

Radiation Safety for Active Interrogation Systems for Security Screening of Cargo, Energies Up to 100 MeV

Siraj Mujtaba Khan[1], George Vourvopoulos[2]
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This paper describes a standard which establishes radiation safety policies and procedures for the safe use of active interrogation systems in applications involving the detection of weapons of mass destruction (WMD) and other contraband in trucks and cargo containers. The intent and purpose of this standard is to ensure that the workers and members of the general public (including stowaways) are protected from excessive exposure to ionizing radiation (such as high-energy photons, neutrons and charged particles), and that the radiation exposures to these individuals are maintained well within the regulatory limits as established by Nuclear Regulatory Commission (NRC), Occupational Safety and Health Administration (OSHA), and other Federal and State regulatory agencies. This document also contains a number of annexes containing useful information to provide guidance in the implementation of this standard.

WED-AP05-1 #106 - Invited Talk - Wednesday 8:30 AM - Elm Fork

Relativistic high-order harmonic generation and other effects with highly charged ions and strong laser fields

Karen Z Hatsagortsyan, Markus C Kohler, Antonino Di Piazza, Christoph H Keitel
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We discuss several nonperturbative strong field effects with highly charged ions in strong laser fields. The first problem is the realization of high-order harmonic generation (HHG) in the relativistic regime employing highly charged ions and the harmonic energy exceeding tens of keV. The relativistic HHG is driven either by counterpropagating attosecond pulse trains or via assisting the infrared strong laser field with a weak beam of XUV photons. We propose methods to compensate the phase mismatch caused by a large free electron background. In this way coherent hard x-rays and extremely short pulses can be feasible [1].

In extremely strong laser fields vacuum polarization can play a role. Thus, in the collision of a high-energy ion beam and a strong laser field, merging of laser photons can occur due to the polarization of vacuum [2]. This non-perturbative vacuum-polarization effects can be experimentally measured by combining the next-generation of table-top petawatt lasers with presently available accelerators.

Further, we consider the electron-positron pair production problem. We investigate a setup in which a strong laser field and a weak gamma-ray beam collide head-on with a relativistic nucleus [3]. We also consider pair production by counterpropagating laser beams taking into account explicitly the spatial dependence and magnetic component of the laser field [4].

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[2] A. Di Piazza, K. Z. Hatsagortsyan, and C. H. Keitel, Phys. Rev. Lett. 100, 010403 (2008).
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WED-AP05-2 #176 - Invited Talk - Wednesday 8:30 AM - Elm Fork

Interaction of highly charged ions with nano- to micrometer sized droplets from a cryogenically cooled liquid target beam source

Nikolaos Petridis, Robert Evaristo Grisenti
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At storage rings, atomic and nuclear processes with small cross-sections can only be studied efficiently by employing high-density targets. State-of-the-art internal targets, realized by expanding a gas through a tiny orifice into vacuum, provide target densities that are generally too low for many present and future nuclear and atomic physics experiments, such as those planned at the future facility FAIR. Recently, considerable progress with regard to this fundamental topic has been made with the development of a novel cryogenically cooled liquid droplet beam source, with which significantly higher target densities are achieved by expanding the liquid at cryogenic temperature [1]. In order to characterize the interaction of large liquid droplets with highly charged ions, we have carried preliminary investigations on ion beam heating and losses of relativistic hydrogen- and lithium-like uranium ions. Here, we will present the experimental data that hints to non-trivial, so far unexplored collision phenomena, and which, in some respect, can be compared to that occurring in intense laser-cluster interactions.

WED-AP05-3 #455 - Invited Talk - Wednesday 8:30 AM - Elm Fork

Excitation of K-shell transitions in highly charged uranium ions

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Electron- and proton-impact excitation (EIE and PIE) of bound electrons are among some of the most fundamental spectral line formation processes in the universe. In highly charged high-Z ions these two processes are in principle similar (a coulomb field excites the electron), except that EIE is characterized by a sharp threshold, which is not present in PIE because of the much larger momentum transfer possible between a proton and an electron. Furthermore, QED is predicted to affect the EIE process while the PIE process is left untouched. Previously, there have been no EIE measurements done at heavy ion storage rings and so all previous experiments were either carried out at electron beam ion trap facilities or fusion plasma facilities. I will present some recent experiments in which a large collaboration used the experimental storage ring (ESR) to study EIE and PIE of K-shell transitions in stored highly charged uranium ions during collisions with neutral gas atoms.

WED-AP05-4 #126 - Invited Talk - Wednesday 8:30 AM - Elm Fork

Polarization of the high-energy end of the electron-nucleus bremsstrahlung in electron-atom collisions

Renate Märtin[1,2], Roman Barday[3], Weidong Chen[2], Robert D. DuBois[2], Joachim Enders[3], Alexandre Gumberidze[2], Siegbert Hagmann[2], Mayk Hegewald[2], Sebastian Hess[2], Yuliya Poltoratska[3], Uwe Spillmann[2], Andrey Surzhykov[1,2], Daniel Thorn[2], Sergiy Trotsenko[2], Günter Weber[1,2], Danyal F.A. Winters[1,2], Thomas Stöhlker[1,2]
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Owing to recent progress in the development of highly segmented solid state detectors, novel type Compton polarimeters for the hard x-ray regime have become available. Thus two-dimensional position sensitive x-ray detectors applied for Compton polarimetry now allow for precise and efficient measurements of photon polarization properties in the energy region between 50 and a few 100 keV.

First measurements have been performed at the ESR storage ring at GSI, Darmstadt and at the spin polarized electron source SPIN at the TU Darmstadt. In the present talk, emphasis is given on the study of the linear photon polarization as a possible diagnostic tool for spin polarized collision systems, e. g. for stored beams of polarized ions as they are proposed within the frame of the atomic physics collaboration SPARC at the future FAIR facility. In a proof of principle experiment the bremsstrahlung emitted by polarized electrons of different spin orientations impinging on gold and carbon targets was investigated with respect to a predicted rotation of the photon polarization ellipse depending on the degree of electron spin polarization. Although detailed analysis is still ongoing, various preliminary results will be presented.

WED-AP05-5 #252 - Invited Talk - Wednesday 8:30 AM - Elm Fork

Electron Spectroscopy in Heavy-Ion Storage Rings: Resonant and Non-Resonant Electron Transfer Processes

S Hagmann[1,2], Th Stoehlker[2,3], Ch Kozhuharov[2], V Shabayev[4], I Tupitsyn[4], Y Kozhedub[4], H Rothard[5], U Spillmann[2], R Reuschl[2,6], S Trotsenko[2], F Bosch[2], D Liesen[2], D Winters[2], J Ullrich[7], R Doerner[1], R Moshammer[7], P-M Hillenbrand[2], D Jakubassa-Amundsen[8], A Voitkiv[7], A Surzhykov[7], E DeFilippo[9], X Wang[10], B Wei[10]
[(1)]Inst. f. Kernphysik, Univ. Frankfurt, Frankfurt, Germany
[(2)] GSI, H Helmholtz Zentrum, Darmstadt, Germany
[(3)]Dep of Physics, H Helmholtz Institut, Jena, Germany
[(4)]Dep of Physics, St Petersburg State Univ., St Petersburg, Russia
[(5)]CIMAO-CIRIL, GANIL, CAEN, France
[(6)]Dep of Physics, Univ. P.M. Curie Paris VI, Paris, France
[(7)]Dep of Physics, Max Planck Inst f. Kernphysik, Heidelberg, Germany
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[(9)]Dep of Physics, LNLS, Catania, Italy
[(10)]Dep of Physics, Fudan University, Shanghai, China

Storage rings for heavy ions all the way up to Uranium, like the present ESR and the future NESR storage ring within the FAIR project, provide the user with a wide range of unique and unrivalled tools for spectroscopy as well as for the investigation of the dynamics of ion-atom and electron-ion collisions. The electron continua and Auger lines emitted in said collisions have been identified as messengers of supreme usefulness with their bountiful and prolific information on the nature of the interaction.

For studies pertaining to resonant and non-resonant charge transfer we have designed and built a variety of imaging electron spectrometers: a) an imaging 00-electron spectrometer in the ESR target zone for forward Cusp electron spectroscopy (vevproj); b) we have designed for the longitudinal reaction microscope in the ESR a new magnetic toroidal electron sector which permits to simultaneously image electrons which are emitted with low to intermediate energies into the forward hemisphere, onto 2D position sensitive electron detectors.

Upon completion, the toroidal sector permits for the first time to investigate the impact parameter (b) dependence of the resonant 1s to 1s charge transfer probability P(b) via the electron branch in heavy symmetric systems like Xe53+ + Xe, opening up a unique spectroscopy of quasimolecular orbitals for αZ>1.

WED-AP06-1 #184 - Invited Talk - Wednesday 1:00 PM - Elm Fork

Exploring Low Energy Molecular Ion Reactions with Merged Beams

C. C. Havener[1], I. N. Draganic[1], H. Kreckel[2], B. J. McCall[2], V. M. Andrianarijaona[3]
[(1)]Physics Division, Oak Ridge National Laboratory, Oak Ridge TN 37831, United States
[(2)]Departments of Chemistry and Astronomy, University of Illinois at Urbana-Champaign, Urbana IL 61801-3792, United States
[(3)]Department of Physics, Pacific Union College, Angwin CA 94508, United States

Charge transfer (CT) in molecular ion-neutral interactions can proceed through dynamically coupled electronic, vibrational, and rotational degrees of freedom. Using the upgraded Oak Ridge National Laboratory ion-atom merged-beams apparatus (Havener *et al.*, NIM B 2007), absolute charge transfer is explored from keV/u collision energies where the collision is considered "ro-vibrationally frozen" to sub-eV/u collision energies where collision times are long enough to sample vibrational and rotational modes. Our first molecular ion measurements (Andrianarijaona *et al.*, J. Phys. Conf. Ser. 2010) with the merged-beams apparatus have been performed for D_2^+ + H and are used to benchmark high energy theory (Errea *et al.*, NIM B 2005) and vibrationally specific adiabatic theory (Krstic, PRA 2002) for the $(H_2\text{-}H)^+$ complex, the most fundamental ion-
molecule two-electron system. CT measurements have also been performed for D_3^+ + H from 2 eV/u to 2 keV/u. A threshold is observed around 4 eV with structure at higher energies where vibrationally excited states are thought to be important. With straightforward improvements to the apparatus, we plan to extend our measurements to key "destructive" rate coefficients for H_2^+ and CH^+ with H at temperatures relevant to the interstellar medium.

Research supported by the U.S Department of Energy Office of Fusion Energy Sciences and the Office of Basic Energy Sciences under contract DE-AC05-00OR22725 with UT-Battelle, LLC.

WED-AP06-2 #327 - Invited Talk - Wednesday 1:00 PM - Elm Fork

Full two-electron calculations of antiproton collisions with molecular hydrogen

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[(2)]*Department of Physics, Humboldt University Berlin, Berlin 12489, Germany*

Total cross sections for single ionization and excitation of molecular hydrogen by antiproton impact are presented over a wide range of impact energies from 1 keV to 6.5 MeV. A nonperturbative time-dependent close-coupling method is applied to fully treat the correlated dynamics of the electrons. Good agreement is obtained between the present calculations and experimental measurements of single-ionization cross sections at high energies, whereas some discrepancies with the experiment are found around the maximum. The importance of the molecular geometry and a full two-electron description is demonstrated. The present findings provide benchmark results which might be useful for the development of molecular models.

WED-AP06-3 #292 - Invited Talk - Wednesday 1:00 PM - Elm Fork

Target Ionization due to Close-encounter Collisions with Few-keV Molecular Ions

K. D. Carnes[1], Nora G. Johnson[1], Wania Wolff[2], Ben Berry[1], A. Max Sayler[1], I. Ben-Itzhak[1]
[(1)]*J. R. Macdonald Laboratory, Kansas State University, Department of Physics, Manhattan KS 66506, United States*
[(2)]*Instituto de Fisica, Universidade Federal do Rio de Janeiro, Rio de Janeiro RJ 21945-970, Brazil*

Even after decades of study, there is still new information to be gleaned from collisions between few-keV molecular ions and target atoms. Our 3D molecular imaging system allows us to reconstruct momentum and angular distributions for all beam fragments and recoil ions. We can therefore study collision induced dissociation with and without target ionization, *e.g.* $H_2^+ + Ar \rightarrow H + H^+ + Ar^+ + e^-$, $H + H^+ + Ar$, and non-dissociative target ionization, *e.g.* $H_2^+ + Ar \rightarrow H2^+ + Ar^+ + e^-$. Electrons and neutral recoils are not detected in our system. Our focus is on close encounter collisions, defined as those with large transverse momentum transfer. We will discuss possible mechanisms for target ionization and present preliminary results on the effect of molecular alignment and orientation.

This work is supported by the Chemical Sciences, Geosciences, and Biosciences Division, Office of Basic Energy Sciences, Office of Science, U.S. Department of Energy.

WED-AP06-4 #387 - Invited Talk - Wednesday 1:00 PM - Elm Fork

Isotope and laser effects on the charge transfer into the n=1, 2, and 3 shells of He2+ in collisions with H and T

Remigio Cabrera-Trujillo[1], N. Stolterfoht[2], P S Krsti´c[4], R Hoekstra[3], Y Öhrn[5], E Deumens[5], J. R. Sabin[5]
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[(2)]*Helmholtz-Zentrum Berlin, Glienickerstraße 100, Berlin D-14109, Germany*
[(3)]*KVI Atomic Physics, University of Groningen, Groningen NL 9747 AA, Netherlands*
[(4)]*Physics Division, Oak Ridge National Laboratory, Oak Ridge TN 37831, United States*
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Charge transfer processes are fundamental to the understanding of matter neutralization in atomic and molecular processes. Due to the polarizability of the material, charge transfer can be enhanced or suppressed during the interaction with electromagnetic radiation. Furthermore, charge transfer has different contributions arising from the radial and rotational regions of the potential interaction in the collision which depend on the mass of the target and projectile. Since these effects

appear in a very short time (femtoseconds), the dynamics must be carried out outside the Born-Oppenheimer approximation.

In this work, we present charge transfer results for He2+ ions colliding with atomic H and T atoms for collision energies from 30 eV/amu up to 10 eV/amu assisted by a fast, short laser pulse of intensity 3.5 e+12 W/cm2, FWHM of 6 fs and wave length of 790 nm. Probabilities and cross sections for electron capture into different shells of the projectile were calculated using an ab-initio approach which solves the time-dependent Schrödinger equation as well as by a finite difference approach. The probabilities exhibit strong Stueckelberg oscillations for charge transfer into the shells with the principal quantum numbers n=2 and 3 due to radial coupling mechanisms in specific ranges of the impact parameter. The total cross sections for charge transfer, evaluated for a given shell, differ by orders of magnitude as different isotopes are used in the collisions. The isotope effect increases significantly for decreasing n=3, 2, and 1. This finding is attributed to the influence of the rotational coupling mechanism that is strongly affected by the distance of closest approach between the collision partner. In the presence of the laser pulse, the isotope effect is negligible and the charge transfer cross section is enhanced up to three orders of magnitude in the low energy region.

WED-AP06-5 #340 - Invited Talk - Wednesday 1:00 PM - Elm Fork

Quantum Models of the Fermi Shuttle

James B. Sternberg
Department of Physics and Astronomy, University of Tennessee, 1408 Circle Drive, Knoxville Tennessee 37919, United States

The Fermi Shuttle is a process in which an electron or multiple electrons in an ion-atom collision are accelerated through multiple collisions with the target and projectile nuclei. The mechanical analog to the Fermi Shuttle is the "gravity assist" method which is used to accelerate spacecraft to the outer reaches of the solar system. In the case of the Fermi Shuttle, the forces are purely electro-magnetic rather than gravitational, however. The Fermi mechanism was originally proposed as an explanation for high energy cosmic radiation and it is still of practical interest for the role it might play in radiation damage of biological tissue. The Fermi Shuttle has a very clear classical explanation, and in fact almost all calculations of this mechanism are either purely classical or use a semi-classical approach. Atoms exist in the realm of quantum mechanics, however, and such an effect should be predictable by purely quantum methods. In this talk we will explore several quantum mechanical models for ion-atom collisions and look for evidence for the Fermi Shuttle in them.

WED-AP06-6 #427 - Invited Talk - Wednesday 1:00 PM - Elm Fork

Physical methods for control, localization and recognition of biomolecules

Predrag S Krstic
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Synthetic nanopores provide a tight confinement constriction which localize and control the motion of biomolecules, submerged in aqueous electrolytic environment. The electric current of ions passing simultaneously with the molecule through the pore, or the electron tunneling current measured accross the molecule depend on the structural properties of the molecule, which enable nondestructive physical recognition of single molecule. This approach has been recently recognized as a prospective for development of a cheap and fast method for the DNA sequencing [1].

A possible recognition or sequencing device has to resolve three main challenges: (1) single-molecule or in case of DNA single-base resolution, in presence of thermal and other sources of the uncertainties, (2) electric reader matching of the speed of the molecule translocation through the pore, and (3) massive fabrication of robust and simple reading devices.

We are developing, in collaboration with the researchers form the Yale University, a nanoscale quadrupole Paul trap in aqueous environment. A molecule is stabilized by a combined action of a radio-frequency (RF) multipolar trapping electric fields, drag forces in the electrolytic solvent, and lateral electric filed which control its translocation through the device. The main advantage of the Paul trap is relaxation of critical dimension control, which eliminates the effects of channel walls. A single-base resolution is predicted by using transverse electron tunneling from N-functionalized CNT electrodes.

In collaboration with researchers from Arizona State and Columbia Universities we are also developing a control of translocation of a DNA segment using single-walled carbon nanotubes which here play the role of nanopores. Unexpected results were obtained in the measured translocation currents of electrolyte and biomolecules through the nanotube and these have recently theoretically explained [2].

[1] D. Branton et al, Nature Biotechnology 26, 1146 (2008).

[2] H. Liu et al, Science 327, 64 (2010).

WED-AP06-P1 #153 - Poster - Wednesday 5:30 PM - Rio Grande

COLLISION INDUCED DISSOCIATION OF HD2+ MOLECULAR ION IN H2

Alfonso Guerrero, Juan Carlos Poveda, Ignacio Alvarez Torres, Carmen Cisneros
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The collisional dissociation of HD2+ on H2 has been studied for collision energies in the range 1.5 to 5 keV. The angular distribution of the dissociation fragments: H+, D+, HD+, and D2+ were measured at six energies in this range. In addition, the velocity distribution for each dissociation product has been determined for collision energy 3.75 keV. The results are discussed in terms of scaling laws. By replotting the angular distributions in terms of reduced variables, the excitation process which produced the dissociation could be inferred. Particularly in the case of D+ fragments, the data suggest that the background distribution, which is monatomic in the reduced angular variable, is produced by electronic excitation at a level crossing, while the single peak in the angular distributions is due to a non-localized electronic excitation with substantial excitation energy. The dissociation energies corresponding to the structures in the angular distributions are found to be in good agreement with those obtained from the velocity distribution data. Substantial differences were observed between the angular distributions of the D+ and H+ fragments suggesting strong isotope effect.

Acknowledgments: The research has been partially supported by joint grants of CONACYT and DGAPA-UNAM

WED-AT01-1 #183 - Invited Talk - Wednesday 3:30 PM - Bur Oak

Recent innovations in the field of ion linear accelerators

Peter N Ostroumov
Physics, Argonne National Laboratory, 9700 S. Cass Av, Argonne IL 60439, United States

Linear ion accelerators have found wide application in research and industry. Ongoing development continues to create more cost-effective accelerating and focusing structures for ion linacs. In most applications, ion linacs are operated in a pulsed mode and based on normal conducting (NC) accelerating structures. Superconducting (SC) accelerating structures are also used for ion beam acceleration. Superconducting radiofrequency (SRF) technology is especially superior to NC technology for c.w. accelerators due to its significantly reduced operational cost and higher accelerating gradients. As was recently demonstrated at the Spallation Neutron Source (SNS), SC technology can be efficiently used in pulsed high-power linacs. Thanks to superior technology used in the beta=1 elliptical accelerating structures developed for the International Linear Collider (ILC), multi-GeV proton (H-minus) linacs have became more cost-efficient than NC linacs. In the past decade, aggressive research and development work for SC structures in the low- and medium-velocity ranges has resulted

in construction projects for several light- and heavy-ion SC linacs. Modern SC accelerating cavities offer higher accelerating gradients than NC structures. However, there is a very interesting niche for NC structures operating at 3-5 GHz frequency range, which can provide extremely high accelerating gradients (~40 MV/m) in a low-duty cycle linac at energies above 100 MeV/u. This application could be a significant breakthrough for low-cost carbon therapy facilities.

This work was supported by the U.S. Department of Energy, Office of Nuclear Physics, under Contract No. DE-AC02-06CH11357.

WED-AT01-2 #245 - Invited Talk - Wednesday 3:30 PM - Bur Oak

Advances in High-Brightness Electron Beams

Bruce Carlsten
High-Power Electrodynamics, Los Alamos National Laboratory, Los Alamos NM 87545, United States

Over the recent couple of years, there have been extraordinary advances in high-brightness and high-average current electron beams. For example, the generation and preservation of high-brightness electron beams have led to the remarkable success of the 8-keV X-ray Free-Electron Laser at the SLAC National Accelerator Center. Additional insights into the underlying physics of high-brightness beams have led to new technologies for manipulating high-brightness beams, such as the Flat-Beam Transform and the Emittance Exchanger. Also, significant advances in high-average current electron injectors are taking place, with recent preliminary testing of a cw photoinjector at LANL and design work of ampere-class photoinjectors at both LBNL and BNL.

WED-AT01-2 #245 - Invited Talk - Wednesday 3:30 PM - Bur Oak

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WED-AT01-3 #173 - Invited Talk - Wednesday 3:30 PM - Bur Oak

Features of the J-PARC Linac

Tetsuya Kobayashi
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Japan Proton Accelerator Research Complex (J-PARC) will be one of the highest intensity proton accelerators in the world aiming to realize 1 MW class of the beam power. This is the joint project between High Energy Accelerator Research Organization (KEK) and Japan Atomic Energy Agency (JAEA). The J-PARC consists of a 400-MeV linac, a 3-GeV rapid-cycling synchrotron (RCS) and a main ring synchrotron (MR), and the accelerated beam is applied to several experimental facilities.

The linac accelerates negative hydrogen (H-) ion beam from an ion source up to 191 MeV with cavity modules of an RFQ, three DTL's (drift tube linac) and sixteen SDTL's (separated-type DTL) driven by 324-MHz RF Systems in the first half section, and up to 400 MeV with twenty-one ACS cavity modules driven by 927-MHz RF systems in the second half section.

The error in the accelerating field should be within +/- 1% in amplitude and +/- 1 degree in phase because the momentum spread of the RCS injection beam is required to be within 0.1%. In order to realize the required cavity stability, a high stable optical signal distribution system is used as the RF reference, and sophisticated digital feedback and feed-forward techniques are working well in the low level RF control system. Consequently the providing beam to the RCS is very stable, and the beam commissioning and the experiments of the application facilities have been progressed steadily since the linac beam operation was started in November 2006.

In this conference, the main features of the J-PARC Linac equipments and the present status will be presented.

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WED-AT01-4 #188 - Invited Talk - Wednesday 3:30 PM - Bur Oak

Novel Linac Structures for Low-Beta Ions and for Muons

Sergey S. Kurennoy
AOT-ABS, Los Alamos National Laboratory, P.O. Box 1663, MS H817, Los Alamos NM 87545, United States

Development of two innovative linacs will be discussed.

1. High-efficiency normal-conducting accelerating structures for ions with beam velocities in the range of a few percent of the speed of light. Two existing accelerator technologies - the H-mode resonator cavities and transverse beam focusing by permanent-magnet quadrupoles (PMQ) - are merged to create efficient and practical structures for light-ion beams of considerable currents. The inter-digital H-mode accelerator with PMQ focusing (IH-PMQ) has the shunt impedance 10-20 times higher than the standard drift-tube linac. Results of the combined 3-D modeling for an IH-PMQ accelerator tank - electromagnetic computations, beam-dynamics simulations, and thermal-stress analysis - will be presented. H-PMQ structures following a short RFQ accelerator can be used in the front end of ion linacs or in stand-alone applications like a compact mobile deuteron-beam accelerator up to a few MeV.

2. A large-acceptance high-gradient linac for accelerating low-energy muons in a strong solenoidal magnetic field. When a proton beam hits a target, many low-energy pions are produced almost isotropically, in addition to a small number of high-energy pions in the forward direction. We propose to collect and accelerate copious muons created as the low-energy pions decay. The acceleration should bring muons to a kinetic energy of ~200 MeV in about 10 m, where both an ionization cooling of the muon beam and its further acceleration in a superconducting linac become feasible. One potential solution is a normal-conducting linac consisting of independently fed 0-mode RF cavities with wide apertures closed by thin metal windows or grids. The guiding magnetic field is provided by external superconducting solenoids. The cavity choice, overall linac design considerations, and simulation results of muon acceleration will be presented. Potential applications range from basic research to homeland defense to industry and medicine.

WED-AT01-5 #466 - Contributed Talk - Wednesday 3:30 PM - Bur Oak

A High Repetition Rate Multi-Energy LINAC for Non Intrusive Inspection

Pedro E. Frigola, Salime M. Boucher, Xiodong Ding, Luigi Faillace, Alex Murokh
RadiaBeam Technologies, 1717 Stewart Street, Santa Monica CA 90404, United States

RadiaBeam Technologies is developing a high repetition rate (1kHz) multi-energy linac for high throughput, non-intrusive inspection (NII). This new high repetition rate linac, which we call the Rapitron, is envisioned to be a drop-in replacement for today's state-of-the art linac systems. We have designed the linac guide for multi-energy operation (3, 6, and 9 MeV), and with enhanced thermal handling capability. We have manufactured a Proof-of-Principle cell to verify the thermal handling capability. In this paper we present an updated design, simulations, and experimental results of the PoP cell.

WED-AT01-P1 #358 - Poster - Wednesday 5:30 PM - Rio Grande

A Versatile DDS-Based Low Level RF Source for Linear Accelerator Applications

James M. Potter
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The Low Level RF (LLRF) system is the source of all of the rf signals required for an rf linear accelerator. These signals are amplified to drive accelerator and buncher cavities. It can even provide the synchronizing signal for the rf power for a synchrotron. The use of Direct Digital Synthesis (DDS) techniques results in a versatile system that can provide multiple coherent signals at the same or different frequencies with adjustable amplitudes and phase relations. Pulsing the DDS allows rf switching with an essentially infinite on/off ratio. The LLRF system includes a versatile phase detector that allows phase-locking the rf frequency to a cavity at any phase angle over the full 360° range. With the use of stepper-motor-driven slug tuners multiple cavity resonant frequencies can be phase locked to the rf source frequency. No external phase shifters are required and there is no feedback loop phase setup required. All that is needed is to turn the frequency feedback on. The use of Digital Signal Processing (DSP) allows amplitude and phase control over the entire rf pulse. This paper describes the basic principles of a LLRF system that has been used for both proton accelerators and electron accelerators, including multiple tank accelerators, sub-harmonic and fundamental bunchers, and synchrotrons.

WED-AT01-P2 #458 - Poster - Wednesday 5:30 PM - Rio Grande

Compact, inexpensive, low-energy linacs for radiography and self-contained irradiators

Xiaodong Ding, Salime Boucher, Alex Murokh, Luigi Faillace
1717 Stewart Street, RadiaBeam Technologies, 1717 Stewart Street, Santa Monica CA 90404, United States

RadiaBeam Technologies is developing a compact, low-cost linear accelerator - the MicroLinac - for use in portable industrial radiography and self-contained irradiators. The innovation of the design is to utilized a low-power, inexpensive X-band RF power system. The MicroLinac was originally developed at SLAC, and the first prototype reached 500 keV. RadiaBeam is currently developing a 1 MeV, 20 µA system for radiography (as a replacement for Ir-192), and a 2 MeV, 70 µA version for use in self-contained irradiators (as a replacement for Cs-137). This paper describes the new designs, the applications, and our future development plans.

WED-ECHT03-1 #452 - Contributed Talk - Wednesday 1:00 PM - Brazos I

Ion Beam Analysis of Silicone-Based Intraocular Implants and Correlation with Surface Energy Measurements

Qian Xing[1], N. Herbots,[1,3,4], M. Hart[1], D. A. Sell[1], J. D. Bradley[1,3], B. J. Wilkens[1], Clive H. Sell[2], Henry Mark Kwong, Jr[2], R. J. Culbertson[1], S. D. Sheridan[1], S. D. Whaley[1]
[(1)]Physics/LeRoy Eyring Center of Solid State Science/IBeAM (Ion Beam Analysis of Materials), Arizona Retinal Research Foundation, P.O. Box 1504, Tempe AZ 85287-1504, United States
[(2)]Vitro-Retinal Surgery Research, Arizona Retinal Research Foundation, 7600 N. 15th Street Suite 155 , Phoenix AZ 85020, United States
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The hydroaffinity of Si-based surfaces is measured to predict surface energy and the resulting hydrophobic or hydrophilic behavior of silicone, silicates, and silicon. Surface defect density, topography and electrical carrier concentration are discussed.

4.265 ± 0.035 MeV 12C(alpha, alpha;)12C , 3.05 ± 0.005 16O(alpha, alpha)16O MeV Nuclear Resonance and 2.8 MeV Hydrogen Recoil Detection are used for high resolution compositional depth profiling. Tapping Mode Atomic Force Microscopy (TMAFM)

provides statistical analysis of the topography of these Si-based surfaces at a length scale ranging from a few nm to several µm. Extended atomic terraces with low edges and defects density on Si(100) and crystalline silicates such as beta-cristobalite and alpha-quartz render an insulating surface hydrophobic, while small scale roughness and surface defects makes it more hydrophilic. The water affinity and energy of these surfaces are measured using the Sessile Drop method and the Young-Dupré analysis and correlated with topographical, compositional and micro-structural surface analysis

using TMAFM, IBA combined with ion channeling and X-ray diffraction respectively. This correlation explains the behavior of water condensation at the liquid/air interface of intraocular implants during vitro-retinal surgery after cataract extraction and intraocular lens (IOL) implantation.

Polymer adsorption on surfaces alters their hydroaffinity, can control condensation on silicone IOL's [1] and enable for hermetic bonding in silica-based sensors in medical electronic implants [2]

[1] US Patent pending: "Molecular films for controlling hydrophobic, hydrophilic, optical, condensation and geometric properties of silicone implants surfaces, including intraoccular lenses used in cataract surgeries." Inventor(s): N. Herbots, J. D. Bradley, M. Hart, D. A. Sell, S. Whaley, Q. Bradley (November 09, 2009)

[2] US Patent Pending: "Methods for Wafer Bonding, and for Nucleating Bonding Nanophases". Inventor(s): N. Herbots, J. D. Bradley, M. Hart, D. A. Sell, S. Whaley, R. J. Culbertson (April 30, 2010)

WED-ECHT03-2 #425 - Contributed Talk - Wednesday 1:00 PM - Brazos I

Detection of metals in particulate matter in air using PIXE

Jack Manuel, James Deaton, Gobind Basnet, Gary Glass
Louisiana Accelerator Center / Physics Dept., University of Louisiana at Lafayette, P.O. Box 42410, Lafayette LA 70504, United States

It is known that fine particulate matter having a diameter less than 2.5 microns can penetrate deep into human lung tissue causing significant health effects, and these effects can be worse if metals or metal oxides are attached to the particles. Although the state of Louisiana has a network to regularly monitor ozone, sulfur and nitrous oxides in air particles there is presently no analysis of metal content of the particulates. A preliminary study was initiated to detect metal content of 2.5 micron air particles using PIXE analysis. Weekly samples were obtained using a sequential self-loading air sampling pump by flowing ambient air through a Teflon filter for 24 hours to collect particles. To perform PIXE analysis the filter substrates were removed, secured in an aluminum frame and three separate areas were then irradiated with a 3 MeV proton beam. GUPIX was used to analyze the resulting PIXE spectra to determine which metals were present and provide an estimate of the concentrations. Varying concentrations of K, Ca, Fe, Co, and Zn were found to be present.

WED-ECHT03-3 #400 - Contributed Talk - Wednesday 1:00 PM - Brazos I

Tomography Back-Projection Algorithm for "Incomplete" Compton X-rays Detectors

Cristiano Lino Fontana[1], Giuseppe Baldazzi[2], Andrea Battistella[3], Michele Bello[3], Dante Bollini[4], Giuliano Moschini[1,3], Gianluigi Zampa[5], Nicola Zampa[5], Paolo Rossi[1]
[(1)]Department of Physics, University and INFN, via Marzolo 8, Padua 35131, Italy
[(2)]Department of Physics, University and INFN, Bologna, Italy
[(3)]National Laboratories of Legnaro, INFN, Legnaro (Padua), Italy
[(4)]INFN, Bologna, Italy
[(5)]INFN, Trieste, Italy

A "Compton" detector finds the direction of an X-ray by letting it interact with a gaseous, liquid or thin solid material (Tracker) and employing no collimators. This paper takes into account the case of an "incomplete" solid Tracker where the recoiling electron travels only a few dozen microns and cannot be followed. However, impact positions and incoming and outgoing energies are measured. In this situation, exploiting the Compton Scattering formula, one is only able to identify a cone whose surface the X-ray belongs to. On the other hand, Compton tomography luckily requires fewer views (for example rotating the apparatus in just four positions around the subject), as the "electronic collimation" that takes place in each position already extracts X-rays coming from many directions. A back-projection algorithm that combines the reconstructed "cones" in space, weighted according to the Klein-Nishina formula, has been applied to the special case of small animal SPECT (Single Photon Emission Computed Tomography). Here source is close to detector, every imaged point in space is calculated from many rays that are emitted at different angles, and the algorithm totally differs from that of the Compton imaging in Astronomy. Tomography reconstruction has been validated employing simulated data, generated

using GEANT4 that includes the Doppler Broadening in the energies of scattered photons, which is due to moving non-free electrons. Space resolution has been assessed.

WED-ECHT03-4 #388 - Contributed Talk - Wednesday 1:00 PM - Brazos I

Particle Induced X-ray Emission Spectroscopy (PIXE) as a Tool for Determination of Localization and Accumulation of Lanthanide-labeled Drug in Biological Tissues: Aspects of Specimen Preparation

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PIXE is the sole investigative technique that offers elemental quantification at parts-per-million sensitivity, with high accuracy at spatial resolutions less than cellular dimensions, and is thus advantageous for microanalysis of samples of complex heterogeneity, including neural tissue. Optimal microanalysis of biological materials requires preservation of both in vivo cell and tissue structure and subcellular elemental distribution, which are achieved by means of appropriate specimen preparation and handling. Our overall research goal is utilize PIXE to localize and quantify brain uptake of europium-labeled therapeutic compounds that target signaling pathways for medulloblastoma in transgenic mice that exhibit 100% incidence of tumor development. To achieve this aim, we developed a specimen preparation protocol that incorporated the sequence of techniques: plunge-cryofixation, freeze-substitution, and ultramicrotomy. In order to prevent formation of ice crystals and consequent structural damage, small pieces of the cerebellum were immediately cryo-fixed after dissection and removal from the cranium by rapid plunging into isopentane at -1500C. During subsequent freeze substitution, frozen amorphous water in brain tissue was replaced by tetrahydrofuran at -850C. Brain tissue samples were then infiltrated and embedded in Lowicryl HM20 resin at -500C, which was polymerized by UV light. Three micron-thick sections were cut from resin-embedded samples on an ultramicrotome by using diamond knife, and collected on mylar foils for analysis by PIXE. PIXE analysis of specimens prepared by this method is expected to yield reliable information on the efficacy of drug delivery via an intracerebroventricular route of administration.

WED-ECHT03-5 #216 - Contributed Talk - Wednesday 1:00 PM - Brazos I

Hydrogen Absorption and Desorption Studies for Thin Hydrogenated Diamond-Like Carbon Films

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Hydrogen Absorption and Desorption Studies for Thin

Hydrogenated Diamond-Like Carbon Films

G. Tecos, A. Moore, E. Garratt, S. AlFaify, A. Dissanayake, R. Taibu, M.I. Nandasiri, and A. Kayani

Department of Physics, Western Michigan University, Kalamazoo, MI 49008, USA

Hydrogen diffusion kinetics has been studied for unbalanced magnetron sputtered deposited of C-H thin films. Argon was used as a sputtering gas and formed the majority of the gas in the plasma. Hydrogenation of the films was carried out during the growth process by diluting argon with hydrogen. The effect of hydrogenation on the final concentration of trapped elements and their thermal stability with respect to hydrogen content is studied using ion beam analysis (IBA) techniques. The elemental concentrations of the films were measured in samples deposited on silicon substrates by performing Rutherford Backscattering Spectrometry (RBS), Non-Rutherford backscattering Spectrometry (NRBS) and Elastic Recoil Detection Analysis (ERDA). In-situ desorption and absorption measurements of hydrogen in the samples were performed by heating in vacuum using a non-gassy button heater. Hydrogen was found to be decreasing around 400o

C, however, absorption at different partial pressure of hydrogen at 400o C resulted in only 3 at% gain in hydrogen concentration.

WED-ECHT03-6 #206 - Contributed Talk - Wednesday 1:00 PM - Brazos I

Fish gelatin thin film standards for biological applications of PIXE

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Results of recent investigations to develop PIXE standards for detection of trace elements in tissue using a protein matrix will be presented. These standards use fish gelatin as a base because the gelatin provides a protein matrix, it is water soluble, and it is fluid at room temperature. Production of sample standards uses small volumes of aqueous solution to introduce known concentrations of trace elements, typically to a small mass of wet gelatin. This gelatin is then spin-coated onto a Teflon substrate and the resultant film is dried, retaining 45% of its mass after drying to produce films of thicknesses 30-40 micrometers. These films have proven to be resistant to beam damage and can be stored for relatively long periods without degradation. Results from standards made using water soluble metal salts, including copper sulfate, europium chloride, and sodium chloride will be presented.

WED-ECHT03-7 #181 - Contributed Talk - Wednesday 1:00 PM - Brazos I

Measurement of hydrogen capacities and stability in thin films of AlH deposited by magnetron sputtering

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Thin, hydrogenated Aluminum hydride films were deposited on silicon substrates using unbalanced magnetron (UBM) sputtering of an Aluminum target under electrically grounded conditions. Argon was used as sputtering gas and hydrogenation was carried out by bleeding it during the growth the process. The effect of hydrogen partial pressure on the final concentration of trapped hydrogen has been studied. Moreover, in-situ thermal stability of trapped hydrogen in the films was carried out using Rutherford backscattering spectrometry (RBS), Nuclear Reaction analysis (NRA) and Elastic Recoil detection analysis (ERDA). Hydrogen content in the thin films was found decreasing as the films were heated in vacuum.

WED-ECHT03-P1 #372 - Poster - Wednesday 5:30 PM - Rio Grande

RUTHERFORD BACKSCATTERING SPECTROMETRY OF InN THIN FILMS

Ion Burducea[1,2], Mariana Braic[3], Viorel Braic[3], Liviu Stefan Craciun[1,2], Dorin Dudu[1], Cristina Ionescu[1,2], Mihai Straticiuc[1,2], Ion Vata[1], Catalin Nicolae Zoita[3], Petru Mihai Racolta[1]
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The ion beam analysis (IBA) technique of Rutherford Backscattering Spectrometry (RBS) has been used to quantitatively determine the elemental composition of indium nitride (InN) thin films, deposited on yttria-stabilized zirconia (YSZ), by reactive magnetron sputtering in pure nitrogen atmosphere. The substrate temperature during InN film growth was varied in

the range of 350-550^{0}C. As expected, RBS analysis indicated that the thin films are In_xN_{1-x} type, with no oxygen in the composition, as also confirmed by X-ray diffraction measurements. The obtained results indicate the stoichiometry of the hexagonal InN thin films is influenced by the deposition temperature, the measured N/In ratios being in the range 0.33 - 0.81. The highest value was obtained for the samples deposited at 450^{0}C, probably due to the dissociation process and nitrogen loss which takes place in InN films for substrate temperatures higher 500^{0}C.

WED-ECHT03-P2 #437 - Poster - Wednesday 5:30 PM - Rio Grande

Structural Evolution of the Doped Metal-Fullerene Composites

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The widespread research activity of the nano- to micro-structured materials has been fueled by the great potential of their applicability. Because such materials can also often be synthesized by a spontaneous self-organization, a considerable endeavor has been put into the understanding of their formation and into the controllable manipulation of their structures, as well. Composites consisting of both organic and in-organic (or metallic) components are complex materials that often show higher-level patterning. One of the important issues in the research of the self-organized hybrid materials is (how) to control their assembling towards forms that exhibit new functional capabilities. In the present paper, fabrication and structural development of the metal-fullerene systems doped with suitable highly mobile dopants (e.g., Li, I, etc.) have been studied. The thin films of the hybrids were prepared either by vapor co-deposition or alternating deposition of components; doping of the dopants was performed either in vacuum or from gas phases. After doping, the specimens were gradually annealed (in vacuum) in order to trigger in-diffusion of the incorporated dopants and (at higher temperatures) to induce re-arrangement of the specimens' structure matrices. The effect of annealing on the structural modification and mobility of dopants was monitored by ion and neutron beam methods (i.e., Rutherford Backscattering and Neutron Depth Profiling) and some other techniques (micro-Raman Spectroscopy and Scanning Electron Microscopy). The results showed that (i) the dopants can selectively in-diffuse into the hybrids and decorate their structural variations, and (ii) the hybrids exhibit (under high fluence ion irradiation and heating at certain temperatures) a specific phase transformation that can result in their interesting self-arrangement.

The work was supported by the Academy of Sciences of the Czech Republic (Grant Nos. KAN400480701, IAA400320901) and Ministry of Education of the Czech Republic (Research program No. LC 06041).

WED-ECHT05-1 #461 - Invited Talk - Wednesday 3:30 PM - Brazos II

Elemental Analysis of Volcanic Material from the Alaska Peninsula: A Comparative Evaluation of Photon Activation Analysis

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In an attempt to advance the utility of Photon Activation Analysis (PAA) in the field of Archaeology, a blind test was performed on fifty fragments of culturally modified stone collected from five village sites across the Alaska Peninsula region. In order to test the capabilities of PAA the materials were also analyzed using four additional geochemical techniques including; Time-of-Flight Laser Ablation ICP-MS (TOF-LA-ICP-MS), Neutron Activation Analysis (NAA), Quadrupole Laser Ablation ICP-MS (LA-ICP-MS), and handheld x-ray fluorescence (XRF). Using the four additional techniques as a comparative baseline, we found that PAA showed statistically similar results in comparative geochemical group discrimination. Based on these analyses, we find that PAA demonstrates real potential as a source of isotopic data capable of contributing data required for understanding prehistoric cultural behaviors.

WED-ECHT05-2 #424 - Contributed Talk - Wednesday 3:30 PM - Brazos II

The Effect of Pileup on the 10.8 MeV Nitrogen Photopeak

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Portable D-T neutron generators producing 14 MeV neutrons for elemental analysis operate in two modes, pulsed to measure thermal capture reactions and continuous to measure inelastic neutron scattering reactions. The region above 10 MeV is important due to the 10.8 MeV gammas that occur as a product of thermal neutron capture on nitrogen. Rapid decision making about the presence of energetic materials requires a complete understanding of the 10.8 MeV photopeak's background in order to minimize data collection time. It is shown that the background in pulsed mode is entirely caused by pileup events independent of the environment being studied, while in continuous mode single gamma rays events and pileup events contribute equally to the background at the detector's highest rates. In both generator operating modes, the background in the region above 10 MeV can be found as a function of the detector's counting rate, live time, and the resolving time.

WED-ECHT05-3 #146 - Contributed Talk - Wednesday 3:30 PM - Brazos II

A new facility for Non-Destructive Assay with a time-tagged fission source

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A new facility for Non-Destructive Assay is now in operation, based on a time-tagged 252Cf source. The system is designed to analyze samples having dimension on the order of 20 x 20 cm2, the material recognition being obtained by measuring simultaneously transmission of neutrons and gamma rays from a spontaneous fission source. The characterization of a given material is based on the dependence of the atomic number on the ratio R between the absorption coefficients for neutrons and gamma rays. In addition, direct signatures to identify light elements such as C,N,O in the sample are obtained by using the measured transmission versus neutron time of flight obtaining direct information about the neutron cross section. This allows to determine the relevant elemental ratios (C/O and C/N) that are normally used to identify threat organic materials.

On the heavy element side, the discrimination is optimized by implementing the measurement of the average absorption coefficient for gamma rays as a function of the energy taking over the wide energy range of the fission gamma rays.

The present system employs a set of 8 ultra-fast plastic scintillators for time-of-flight measurements by using a 100 cm flight path. Those detector provides a first 2D reconstruction of the average Z inside the sample by measuring the ratio of the energy-integrated attenuation between gamma rays and neutrons. In a second time, for well defined positions in the 2D image, the neutron and gamma ray attenuation as a function of the energy are measured, yielding more precise information on the material. Results obtained in the calibration and with phantoms are presented and possible applications discussed also using small accelerators.

WED-ECHT05-4 #478 - Contributed Talk - Wednesday 3:30 PM - Brazos II

Establishing equilibrium of natural decay series in earth science samples using alternative isotope combinations

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The activity equilibrium in samples of geological or geomorphological interest is often established using isotope combinations, such as Pb-210/Ra-226 or Th-228/Ra-228, which require Germanium detectors with thin windows and good

energy resolution in order to effectively detect low energy gamma-rays. This research explores alternative isotope combinations, such as Bi-214/Ra-226, Bi-214/Pa-234m, Pb-212/Ac-228, which can effectively be quantified without the use of a thin detector entrance window. The samples studied are relevant in the context of stratigraphical dating of sedimentary rocks at Lake George in Eastern Australia and may shed light on prehistoric climate changes. Following retrieval on site, samples were prepared conventionally by sieving and compression into thin disks in airtight standard containers which ensure reproducible detection geometry. The sample geometry and thickness were chosen to minimize self-absorption in the sample. Detector and sample were housed in a cylindrical castle made from low radiation lead and including a Cd-shield for neutrons. Measurement times typically extended over several days. The lines considered are sufficiently separated from background contributions that even deteriorated Ge-detectors with poor energy resolution can be employed to quantify them. Initial work has shown that the Bi-214/Ra-226 and Pb-212/Ac-228 ratios can provide sufficient accuracy to establish equilibrium, whereas the interpretation of the Bi-214/Pa-234m ratio can only give tentative confirmation. An outlook on future work with this approach will also be given.

WED-ECHT05-P1 #371 - Poster - Wednesday 5:30 PM - Rio Grande

CDBS AND AFM STUDY IN POLYURETHANE NANOFIBERS - SILVER NANOPARTICLES MATRIX

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Despite the general use of positron annihilation lifetime spectroscopy (PAL) in polymer studies we present a new approach in probing the chemical environment of the free volume holes in polymers by the use of the Doppler broadened annihilation energy line. Coincidence Doppler Broadening Spectroscopy (CDBS) measurements were performed on gamma-irradiated polyurethanes nanostructure samples with and without the silver ions in the nanofibers matrix. It is shown that, after a certain gamma irradiation, the momentum density distributions of annihilation electrons have changes for the high dose irradiated polyurethane, but no significant changes have been observed for the low dose irradiated polyurethane. The irradiation procedure consisted in using gamma radiation at 30-35 kGy/h exposure fluency, up to 100 kGy absorption dose, and temperature at 25°C. In this work we used Atomic Force Microscopy (AFM) technique to investigate the morphology of polyurethane nanofibers irradiated with ^{60}Co gamma rays. The results obtained show that, with respect to other microscopy techniques, AFM can give some additional information regarding the modification induced by γ-irradiation on surface morphology. Three dimensional surface topological images of the surfaces have been obtained by AFM for both unirradiated and irradiated samples. The CDBS results show a peculiar behavior of the silver ions in modifying the chemical environment of the free volumes.

WED-ED01-1 #167 - Invited Talk - Wednesday 8:30 AM - Bur Oak

Teaching and training tools for the undergraduate: Experience with a rebuilt AN-400 accelerator

Andrew D. Roberts

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There is an increasingly recognized need for people trained in a broad range of applied nuclear science techniques, indicated by reports from the American Physical Society and elsewhere. Anecdotal evidence suggests that opportunities for hands-on training with small particle accelerators have diminished significantly in the US, as programs established in the 1960's and 1970's have been decommissioned over recent decades. Despite the reduced interest in the use of low energy accelerators in fundamental research, these machines can offer a powerful platform for bringing unique training opportunities to the undergraduate curriculum in nuclear physics, engineering and technology. We report here on the 4-year experience establishing the MSU Applied Nuclear Science Lab, centered around the rebuild of an AN400 electrostatic accelerator. This machine is run entirely by undergraduate students under faculty supervision, allowing a great deal of freedom in its use without restrictions from graduate or external project demands. Undergraduate work in machine engineering, beam characterization, high sensitivity mass identification and applied radioisotope production will be discussed.

WED-ED01-2 #344 - Invited Talk - Wednesday 8:30 AM - Bur Oak

Materials Analysis Using PIXE and a Pelletron Particle Accelerator in Undergraduate Physics

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Union College, an undergraduate liberal arts college in Schenectady, NY, houses a 1.0-Megavolt tandem electrostatic Pelletron particle accelerator that is used to teach and do research in the field of environmental materials analysis. The ion beam analysis technique of proton induced x-rays emission spectroscopy, or PIXE, provides a simple to use pedagogical tool to facilitate the introduction of our students to the field of materials analysis and is routinely seen in introductory and upper-level physics courses at Union College. Each year, 3 - 4 students are offered the opportunity to further explore PIXE as a research tool and to work on a research project, often of the student's own design, involving the analysis of environmental materials. Our undergraduate students are fully trained to operate the accelerator and in this talk I will provide a brief introduction to the Pelletron and to the method of PIXE. I will discuss two situations in which our students are introduced to PIXE in the classroom, one from an introductory physics course and one from an advanced physics course. Then two research projects that are currently being investigated by our undergraduate ion beam analysis team will be presented. These projects are a PIXE analysis on the aerosol emissions from a crematorium and an elemental analysis of the variation in the composition and concentration of liquid precipitation samples collected from around New York State.

WED-ED01-3 #260 - Invited Talk - Wednesday 8:30 AM - Bur Oak

Educational Activities at the Nuclear Engineering Teaching Laboratory

Tracy N Tipping
Nuclear Engineering Teaching Laboratory, The University of Texas at Austin, 1 University Station, R9000, Austin TX 78712, United States

The Nuclear Engineering Teaching Laboratory (NETL) at the University of Texas at Austin performs a wide variety of educational activities for various levels of students. Regular on-site courses in the areas of health physics, radiochemistry, and reactor operations are offered for university credit. Along with on-site courses, off-site access to the reactor facility via a remote console connection allows students in an off-site classroom to conduct experiments via a "virtual" control console. In addition to the regularly scheduled courses, other programs, such as the Summer Nuclear Engineering Institute and partnerships with Historically Black Colleges and Universities, provide access to the facility for students from other universities both domestic and foreign. And NETL hosts professional development programs such as training programs for Nuclear Regulatory Commission and International Atomic Energy Agency personnel.

WED-ED01-4 #300 - Contributed Talk - Wednesday 8:30 AM - Bur Oak

Pyroelectric Crystal Accelerator in the Department of Physics and Nuclear Engineering at West Point

Don Gillich[1], Mike Shannon[2], Andrew Kovanen[1], Tom Anderson[1], Kevin Bright[1], Ronald Edwards[1], Yaron Danon[3], Brian Moretti[1], Jeffrey Musk[2]
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The Nuclear Science and Engineering Research Center (NSERC), a Defense Threat Reduction Agency (DTRA) office located at the United States Military Academy (USMA), sponsors and manages cadet and faculty research in support of DTRA objectives. The NSERC has created an experimental pyroelectric crystal accelerator program to enhance undergraduate education at USMA in the Department of Physics and Nuclear Engineering. This program provides cadets with hands-on experience in designing their own experiments using an inexpensive tabletop accelerator. This device uses pyroelectric crystals to ionize and accelerate gas ions to energies of ~100 keV. Within the next year, cadets and faculty at USMA will use this device to create neutrons through the deuterium-deuterium (D-D) fusion process, effectively creating a compact, portable neutron generator. The new double crystal pyroelectric accelerator will also be used by students to investigate neutron, x-ray, and ion spectroscopy.

WED-ED01-5 #329 - Invited Talk - Wednesday 8:30 AM - Bur Oak

Enhancing the Undergraduate Experience: Measuring film thicknesses using a Helium ion beam

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Students performed RBS experiments using 1.5 MeV helium ion (+1) beam from a Van de Graaff accelerator. The ion beam was incident normally on target samples located in a scattering chamber. The samples were single and multilayered thin films on substrate, prepared using a vacuum evaporator. The scattered ions were measured using a particle detector located at 150° from incident beam direction. The elastically scattered particle energies were predicted from kinematical scattering factor (derived using conservation of energy and momentum) and experimentally verified. Using samples of known elemental thicknesses, the data was normalized and thicknesses of layers in unknown samples determined. For multilayer samples, the scattered particle spectra were analyzed for particle yield per ion, energy shift in the centroid and energy at the leading edge for the elemental peak. The Rutherford scattering formula and the kinematical scattering factor together with the energy loss of the helium ion through the various layers were used to identify elemental layers, their positions and thicknesses. The multilayer films were identified as gold-tungsten-tin (Au-W-Sn). The normalization procedure allowed the thicknesses to be determined with uncertainties of a few percent.

WED-ED01-P1 #284 - Poster - Wednesday 5:30 PM - Rio Grande

"The Identification, Recruitment, and Training of Accelerator Technologists"

Nathan Jones
Customer Service Training, Siemens Healthcare Molecular Imaging, 810 Innovation Drive, Knoxville TN 37932, United States

As the use of small accelerators continues to grow, the maintenance of these devices becomes vital to both owners and vendors. Once the realm of scientists and research engineers, these devices are now often considered to be appliances, and their service has at times fallen to the hands of technicians unschooled in their theory of operation. We offer experience gained by one manufacture of over 200 cyclotrons and their efforts to identify, recruit, and train the "accelerist".

In the 1980's the CTI corporation in Knoxville, Tennessee, USA had a vision of making Positron Emission Tomography a clinical reality. To guarantee the availability of positron emitting radionuclides for compounding biomarkers, the company acquired "The Cyclotron Corporation" and its designs. Through the years and various acquisitions/sales/mergers, etc., cyclotron production and service is now conducted by Siemens.

International training for cyclotron service engineers is conducted in the factory in Knoxville, Tennessee USA. A production cyclotron, equipped as specified by the instructors, is utilized for hands-on training of maintenance personnel and operators.

The identification of potential successful personnel for these service tasks has long been a problem. Suggestions based on successful recruitment, training, and performance of personnel with selected traits is discussed.

Recruitment of new personnel to a field that not many understand or are aware of is difficult. Sources and suggestions for these candidates is discussed, as well as some success stories.

The training of personnel, although recognized as vitally important yet too often neglected, is discussed from the viewpoint of an instructor with 21 years of accelerator experience prior to 9 years in the role of instructor. Suggestions are made for both large-scale vendor and smaller institutional training programs. Details of a training program development and progression, adjustments, continuing improvements, and results are presented.

WED-ED01-P2 #301 - Poster - Wednesday 5:30 PM - Rio Grande

Preliminary Results Using the Pyroelectric Crystal Accelerator at West Point

Tom Anderson[1], R J Edwards[1], Kevin Bright[1], Andrew Kovanen[1], Yaron Danon[3], Brian Moretti[1], Jeffrey Musk[2], Mike Shannon[2], Don Gillich[1]
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The Nuclear Science and Engineering Research Center (NSERC), a Defense Threat Reduction Agency (DTRA) office located at the United States Military Academy (USMA), sponsors and manages cadet and faculty research in support of DTRA objectives. Cadets in the Department of Physics and Nuclear Engineering at USMA are using pyroelectric crystals to ionize and accelerate residual gas in a vacuum system. A system using two lithium tantalate crystals with associated diagnostics was designed and is now operational. X-ray energies of approximately 100 keV have been achieved. Future work will focus on developing a portable neutron generator using the D-D nuclear fusion process.

WED-ED02-1 #148 - Invited Talk - Wednesday 1:00 PM - Bur Oak

Nuclear Physics Experiments below the Coulomb Barrier

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In 1932, Cockcroft and Walton showed that (p,alpha) reactions with lithium were possible at energies below 100 keV. We report an undergraduate laboratory experiment with 90 keV protons colliding with a thick lithium target. The experiment allows students to observe the products of two reactions, determine the masses of the products of the reaction, and to learn techniques for deconvolving experimental spectra profiles.

WED-ED02-2 #199 - Invited Talk - Wednesday 1:00 PM - Bur Oak

Undergraduate Measurements for Fission Reactor Applications

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Undergraduate students at the University of Dallas (UD) complete research as part of a program to investigate neutron elastic and inelastic scattering cross sections on structural materials important for criticality considerations in nuclear fission processes. Neutrons scattered from 23Na and NatFe are detected using neutron time-of-flight techniques at the University of Kentucky (UK) Low-Energy Nuclear Accelerator Facility. These measurements are part of an effort to increase the efficiency of power generation from fission reactors and part of the Department of Energy's Nuclear Energy University Program.

In this research program, students learn how to operate the Model CN Van de Graaff generator at the laboratory at UK, setup detectors and electronics, participate in data acquisition, and they are currently analyzing the angular dependence of the scattered neutrons from 23Na and NatFe for incident neutron energies of 3.0 and 3.5 MeV. In addition to providing valuable information on basic nuclear physics and for reactor technology, the measurements allow students to investigate energy and momentum conservation in a very fundamental way. Most students participating in the project will use the

research experience as the material for their undergraduate research thesis required of all Bachelor of Science students at the University of Dallas. An overview of their participation in this investigation and preliminary results will be presented.

WED-ED02-3 #492 - Invited Talk - Wednesday 1:00 PM - Bur Oak

The Scanning Electron Microscope as an Accelerator for the Undergraduate Advanced Physics Laboratory

Randolph S. Peterson[1,2], Karl K. Berggren[2], Mark Mondol[2]
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Few universities or colleges have an accelerator for use with advanced physics laboratories, but many of these institutions have a scanning electron microscope (SEM) on site, most likely in the biology department. This SEM can be used as an accelerator for the advanced physics laboratory. To emphasize the accelerator features of the SEM, the names of some controls should be relabeled for the devices they control rather than for the image effects that result. Examples of experiments that highlight the use of the SEM as an accelerator include measurement of the beam current and determination of the beam spot size. The SEM is a superb instrument for measuring the physical effects of electrons interacting with matter and for the detection of electrons and photons from those events. Students can use a variety of detectors and use them to explore the meaning of and to create an image of the target.

If SEM imaging is a reading of the target, then an SEM can also write, that is, it can be used for electron-beam lithography. For the simplest pattern in the shape and size of the field of view, all that is needed is a piece of silicon wafer coated with Poly(methyl methacrylate) (PMMA) resist. After beam exposure the PMMA is quickly developed and imaged with the SEM. Some SEMs have beam blanking features or raster control of the sweep of the electron beam, allowing basic, micron-sized lithographic features to be written in the PMMA.

As an accelerator for the undergraduate, advanced physics laboratory, the SEM is an excellent substitute for an ion accelerator. Although there are no nuclear physics experiments that can be performed with a typical 30 kV SEM, there is an opportunity for experimental work on accelerator physics, atomic physics, electron-solid interactions and the basics of modern lithography.

WED-ED02-4 #100 - Invited Talk - Wednesday 1:00 PM - Bur Oak

Undergraduate Research and the MoNA Collaboration at the National Superconducting Cyclotron Laboratory

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MoNA, (the Modular Neutron Array), is a large-area high efficiency neutron detector housed at the National Superconducting Cyclotron Laboratory, NSCL, at Michigan State University. It is used to study the structure of exotic neutron-rich nuclei produced with the Coupled Cyclotron Facility at the NSCL. The detector was designed and built by the MoNA collaboration of 10 colleges and universities in conjunction with the NSCL with support from the National Science Foundation. The bulk of the construction and testing was done by undergraduates at the collaboration institutions. The

MoNA Collaboration undergraduates are currently constructing a second detector system LISA that will be used in conjunction with MoNA. Undergraduates have not only been involved in the construction of the detectors but play a vital rule in their operation and the analysis and publication of the data taken with them using rare isotopes beams at the NSCL.

The talk will describe the MoNA and LISA detectors and the role of undergraduates in their construction and use. Techniques and practices such as regular videoconferencing and shared quality-control documentation that have been successful in supporting and integrating undergraduate participation in nuclear physics research at a large user facility will also be discussed.

WED-ED02-5 #214 - Contributed Talk - Wednesday 1:00 PM - Bur Oak

Materials Science and Engineering Research and Education at the Center for Irradiation of Materials of Alabama A&M University

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The Center for Irradiation of Materials was established in 1990 to serve the Alabama A&M University in its research, education, and to serve the need of the local community and industry. CIM capabilities are oriented around two tandem ion accelerators with beam lines providing high resolution Rutherford backscattering spectrometry (RBS), MeV focused beams, implantation and irradiation damage studies, particle induced x-ray and gamma-ray emission (PIXE, PIGE), and nuclear reaction analysis in addition to fully automated ion channeling. The CIM facility is well equipped with a variety of surface analysis systems, such as SEM, ESCA, as well as scanning micro-Raman analysis, UV-VIS Spectrometry, luminescence spectroscopy, nanoscale thermal conductivity, electrical conductivity, IV/CV systems, mechanical test systems, AFM, FTIR, voltammetry analysis as well as low energy implanters, Ion Beam Assisted Deposition and MBE systems. In this presentation we will demonstrate how the facility provides education and training services to schools, industries and how highlight few of the recent inventions at CIM. Example of research, services and training by CIM are: A) pure & fundamental research, B) applied research in materials modification (ion Implantation, Radiation effects?), forensics, materials characterization (RBS, NRA, PIXE, PIGE, micro-beam, ion channeling), device prototyping (such as sensors, detectors, thermoelectric, filters, HT carbon-composites, bio-materials, and nano-pore devices), C) education through special topics courses (3-6 Credit hours), summer training, REU, IGART, exchange student and visiting scientist/scholar programs, D) services such as small business innovative research, small business tech transfer, ion beam analysis, ion beam modification and innovative forensics projects. As a result of this training program at CIM, as of 2009 we have produced 17 Ph. D. dissertations, 13 Master degree theses, over 75 undergraduates funded, 4 high school research scholars and over 100 summer/visiting scholars.

WED-ED02-6 #165 - Contributed Talk - Wednesday 1:00 PM - Bur Oak

An apparatus for student projects using in-air PIXE and PIGE

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We have recently installed a simple endstation at the Naval Academy Tandem Accelerator Laboratory to support student projects based on in-air PIXE and PIGE. The endstation consists of a short, carbon-lined beamline extension with a 7.5-micrometer-thick kapton window, an interlocked acrylic box that surrounds the target, Si(Li) and HPGe detectors for x- and gamma-ray detection, provision for flooding the target with helium gas, easily-changed x-ray absorbers, and a compact video camera for monitoring the position of the beam spot on the target. We have used this system to measure the elemental composition of colonial-era architectural materials, principally bricks and mortar, from James Madison's Montpelier, the reconstructed Virginia estate of the fourth President of the United States. In this talk, we will describe the design and construction of the system, relate some of our experiences using it, and present some preliminary data from our investigations.

WED-FIBN05-1 #27 - Invited Talk - Wednesday 8:30 AM - Post Oak

Deterministic doping for nanoscale electronic devices

Jeffrey C McCallum[2], David N Jamieson[2], Changyi Yang[2], Andrew D Alves[2], Brett C Johnson[2], Jessica A van Donkelaar[2], Samuel C Thompson[2], Andrew S Dzurak[1], Laurens H Willems van Beveren[1], Andrea Morello[1], Eric Gauja[1]
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Deterministic doping of Si via single ion implantation is being utilised in the construction of a range of devices that are of interest for development of a solid-state quantum computer (SSQC). A range of metal-oxide semiconductor (MOS) SSQC-related devices are currently being fabricated within the Centre for Quantum Computer Technology (CQCT) in Australia include devices where charge transfer occurs between quantum dots and isolated donors or between individual donors or even between small clusters of donors. Electrically detected magnetic resonance devices where spin-dependent transport is measured are also under development. FinFET devices are also being investigated for single ion implantation as part of the Atomic Functionalities in Si Devices (AFSiD) project of the EU seventh framework. For single ion implantation of MOS devices our Centre has developed a technique whereby the electron-hole pairs generated as each íon comes to rest in the substrate are detected. For the FinFET devices changes in the current-voltage characteristics due to the damage arising from passage of ions through the device is being developed as a detection methodology. In this presentation, a brief overview of the solid-state quantum computer device programs of the CQCT will be given and our single íon detection methodologies will be discussed, including strengths and challenges. Future directions for improvements in methods and implementations will also be addressed.

WED-FIBN05-2 #62 - Invited Talk - Wednesday 8:30 AM - Post Oak

Performance evaluation of transistors with discrete dopants by single-ion doping method

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A key challenge for scaling semiconductor devices towards 10 nm with reduced variation in device performance is the ability to a more accurate placement of dopants in active device areas [1]. Single-ion implantation technique is one of major options to achieved deposit a specified number of desired dopant ions, and fabricated ordered dopant arrays in active channel region to reduce the RDF [2]. The key of SII method is precise single dopant detection by measuring such as secondary electrons and changes in transistor current [3-4]. In this work, in order to investigate electron transport properties of the devices with asymmetrically ordered dopant array, phosphorus ions are asymmetrically implanted into one-side of channels with ordered dopant array by single-ion implanter.

The results showed that the drain current in drain-side distributed device with ordered dopant array is higher than that in source-side distributed device, and is higher than that in drain-side distributed device with random dopant distribution [5]. We believe that this increase in drain current is caused by the suppression of injection velocity degradation in the source-side [6] and the reduction of the Coulomb scattering in the uniform potential distribution of ordered dopant array. It is clear that positioning of the dopant atoms significantly influences carrier distribution. Therefore, single-dopant control could pave way to the novel device development beneficial for extensibility of bulk planner CMOS device technologies including single-dopant device.

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WED-FIBN05-3 #486 - Invited Talk - Wednesday 8:30 AM - Post Oak

Addressing and optical inspection of NV color centers with high lateral resolution.

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Coupling of electron spins of nitrogen vacancies is a promising approach for magnetic sensors or quantum registers. The fabrication of these devices using the well known technique of ion implantation is already established [1]. We have shown that the implantation of a focused nitrogen beam enables us to create pairs of quantum mechanics couplet NV-centers [2]. However, these NVs fabricated by MeV beams and their position are limited by the ion beam straggling to a few hundred nanometer only. To address NV with high lateral resolution low energy implantation is necessary. Here we will present a method that allows the creation of an ensemble of shallow NVs with a resolution of 25 nm in diameter. The shallow NVs are further optical inspect using the STED microscopy technique.

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WED-FIBN05-4 #94 - Invited Talk - Wednesday 8:30 AM - Post Oak

Single Ion Detection for Donor Devices

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We present experimental results and fabrication details of an effort at Sandia National Laboratories (SNL) to develop single ion implanted donor devices for quantum information processing. This program involves development along three parallel tracks - development of single ion detection capability using avalanche photodiodes (APD) detectors, integration with a nanostructured platform and the development of a focused nano-beam for spatially controlled implantation. The use of single ion Geiger mode avalanche diode (SIGMA) detectors leads to two critical challenges - the high number of dark counts and the lateral sensitively of the detectors. We have addressed the source of dark counts (thermally generated e-h pairs) by lowering the operational temperature to 77K which drops the dark count rate by three orders of magnitude and we have determined the lateral sensing capability by using ion beam induced current (IBIC) to map out the sensitivity of the device. We estimate an upper bound of the sensitivity to be ~600 e-h pairs 75 μm from the center of the device. This greatly increases the flexibility of device fabrication allowing for future integration of single donor devices with additional

nanostructures such as double quantum dots. We also present details of the new nano-beamline that has been developed at SNL using an existing 400 keV HVEE implanter. To date the new beamline has demonstrated a sub-micron beam spot for a variety of ion species including H+ and Sb+. We are currently installing a series of improvements expected to dramatically decrease the spot size.

This work was supported in full by the National Security Agency Laboratory for Physical Sciences under contract number EAO-09-0000049393. Sandia National Laboratories is a multi-program laboratory operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin company, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000

WED-FIBN05-5 #39 - Invited Talk - Wednesday 8:30 AM - Post Oak

Deterministic Ultracold Ion Source Targeting the Heisenberg Limit

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The major challenges to fabricate solid state quantum processors and future nano-solid-state devices are material modification techniques with nanometer resolution and suppression of statistical fluctuations of dopants or qubit carriers. Based on a segmented ion trap with mK laser-cooled ions, we have realized a deterministic single-ion source, which could operate with a huge range of sympathetically cooled ion species, isotopes or ionic molecules [1]. By using an electrostatic einzel-lens, we focus down an ion beam consisting of single Ca+ ions by a factor of 12 [2]. Due to the small beam divergence and narrow velocity distribution of our ion source, chromatic and spherical aberration at the einzel-lens is vastly reduced, presenting a promising starting point for focusing single ions on their way to a substrate. Numerical simulations predict, that if the ions are cooled to the motional ground state (Heisenberg limit), nanometer spatial resolution can be achieved [2,3]. This technique can e.g. be applied to generate color centers in diamond or to implant P into Si. Both systems provide a possible way for the realization of a solid state quantum computer [4,5]. Another challenge is to circumvent the breakdown of Moore's law due to Poissonian dopant fluctuations in nanometer scaled semiconductor devices, where the deterministic implantation of single ions can greatly enhance the electrical properties [6].

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WED-FIBN05-6 #211 - Invited Talk - Wednesday 8:30 AM - Post Oak

Progress in Single Ion implantation for qubit integration in Silicon and Diamond

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Spins of donors in silicon and of color centers in diamond are promising quantum bit candidates due to their long coherence times. Ion implantation is an established method for controlled doping of materials. Integration of ion beams with scanning probes for imaging and alignment and the development of single ion detection methods can enable the formation of integrated qubit devices. Challenges for reliable single atom placement by single ion implantation will be discussed

together with progress towards single donor spin readout in silicon and steps towards device integration of color centers, such as nitrogen-vacancy centers, in diamond.

WED-FIBN06-1 #289 - Invited Talk - Wednesday 1:00 PM - Post Oak

Principles of nanofabrication with focused helium ion beams

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A single atom is the probe source of the helium ion microscope. This new type of microscope offers imaging and chemical analysis with sub-nanometer resolution and high surface sensitivity, also for non-conducting specimens. Apart from these unique imaging and analytical qualities, an atomic size helium ion beam is also being regarded as a new tool for nanofabrication.

In this talk I will review the physical principles of this new microscope, with emphasis on its use as a nanofabrication tool. In particular, I will discuss direct ion bean milling, helium ion beam induced deposition or etching, and scanning helium ion beam lithography. Quantitative comparisons with the conventional, competing technologies will be made as well as comparison with Monte Carlo simulations. These comparisons show that on various important aspects, such as resolution and proximity effects, the helium ion microscope surpasses the conventional tools.

WED-FIBN06-2 #460 - Invited Talk - Wednesday 1:00 PM - Post Oak

Advances in cutting and patterning of graphene with helium ions

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Helium ion microscopy is a recently developed high-resolution imaging technology useful for a variety of materials applications, such as materials that would normally charge under an electron beam and especially imaging of carbon nanostructures. Being a charged ion beam instrument, it is also

possible to perform milling and sputtering, as commonly done with a focused ion beam (FIB) system. Advantages of helium ion lithography (HIL) compared to FIB include its ability to mill and sputter soft and fragile materials at low rates and its small probe size (<0.5 nm). Graphene is a two-dimensional hexagonal lattice of carbon atoms with thickness of one or a few atomic layers.

Due to its material stability and strength, absence of defects, and unique electronic band-structure, graphene holds considerable promise for a number of applications in nanoscale electronics, optoelectronics, and mechanics, as well as being of fundamental interest in condensed matter physics. Many potential applications, such as high-speed field-effect transistors, require graphene to be patterned at the nanoscale. Unlike comparable structures made from carbon nanotubes, patterned graphene can form complex extended geometries and can be readily contacted electrically, yielding a well controlled connection between micron-scale and nanometerscale systems and devices.

WED-FIBN06-3 #290 - Invited Talk - Wednesday 1:00 PM - Post Oak

Nanofabrication with the Helium Ion Microscope at TNO VLL

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In 2006 the Helium Ion Microscope (HIM) was introduced in the market. Since then, the sub-nanometer-sized probe of the HIM is used for mostly imaging and some analysis. To explore the capabilities of the Orion plus

helium ion microscope (HIM) as a nanofabrication tool, the HIM at the TNO Van Leeuwenhoek Laboratory (VLL) is equipped with a pattern generator and a gas injection system. HIM nanofabrication research at TNO focuses on: lithography, direct write and Helium Ion Beam Induced Processing (HIBIP). A limitation of imaging and nanofabrication helium is bubble formation in some substrate materials at extremely high ion doses.

Lithography with helium ions in negative and positive resists is studied to obtain ultimate resolution in dense patterns. The helium ions interact very locally with the resist. As a result, (almost) no proximity effects are observed, not even at pattern densities of 50% and line widths well below 10 nm.

The most simple direct write option is to sputter material with the helium ions. At TNO VLL, Au- and Pt-rods have been sliced to obtain small incisions.

HIBIP is a direct write technology involving the local activation of adsorbed precursor molecules with the helium ion beam. HIBIP is performed using the following precursors: $(CH_3)_3Pt(C_pCH_3)$, TEOS and XeF_2. The Pt precursor is used to illustrate the possibilities of depositing conductive 3D nanostructures with dimensions down to approximately 15 nm. Similar objectives are investigated for TEOS precursors to fabricate non-conducting objects. XeF_2 is tested for etching materials (SiO_2 on Si, quartz, some metals) with high precision.

In conclusion, the helium ion microscope equipped with a gas injection system and a pattern generator is an agile new nanofabrication tool. It allows the user to modify and inspect samples on the nanometer scale within the same instrument, thus accelerating the nanofabrication design cycle.

WED-FIBN06-4 #393 - Invited Talk - Wednesday 1:00 PM - Post Oak

Biological and Material Applications of the Helium Ion Microscope

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The Helium Ion Microscope (HIM) is a new imaging technology based on a high brightness and stable Gas Field Ion Source (GFIS). The GFIS employed exhibits a low energy spread (<1 eV) and a high brightness > 4 x 10^9 A/cm^2.sr. This, in conjunction with the shallow escape depth (<1 nm) of the secondary electrons generated by the incident 30 keV helium ions, contribute to the HIM's primary advantage in the imaging of solid samples: its high spatial resolution (0.25 nm). We have applied this novel technology across a broad spectrum of multidisciplinary applications (from basic materials science to the biological sciences) to assess its utility and possible advantages over alternative techniques.

One area where our investigations have gained significant traction is in the imaging of biological specimens. The utility of this instrument here is due in part to the HIM's high spatial resolution. However, in the context of biological specimens, it is the ability to image non-conductive samples without the application of a metal (or other conductive) overcoat and without the need of a background gas (both of which degrade resolution and surface details), which has proven to be a distinguishing attribute. This opens up a range of biological problems that can be solved with less risk of artifacts.

An equally compelling application is in the field of graphene nano-structuring. The focused helium ions can directly modify the sample surface under a high ion flux (via surface sputtering). This enables the direct patterning of graphene structures in the sub-10 nm range. It also provides a mechanism for high resolution patterning on nonconventional substrates (such as suspended graphene membranes), where resist-based lithographic techniques are not feasible. We have observed sub-10 nm pattern transfer on both supported (Si bulk, 300 nm Si02) and suspended structures, with graphene nanoribbons of 5 nm width.

WED-FIBN07-1 #31 - Invited Talk - Wednesday 3:30 PM - Post Oak

Ion Beam synthesis of Nano-crystals for Electronics and Photonics

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One of the main goals of materials research using ion beams is to synthesize nanostructures, for example semiconducting or metallic nanocrystals (NCs) in insulating films. A great effort is currently devoted to NC fabrication for micro- and optoelectronics by ion beam synthesis (IBS), because this method is compatible with modern CMOS technology.
The present contribution addresses the Si NC formation by conventional ion implantation into the gate oxide and by a non-conventional IBS approach of ion beam mixing of SiO_2/Si interfaces in thin gate oxides, with special emphasis on well-controlled size and position tailoring. The two approaches will be compared and related technological challenges discussed. Compared to conventional Si NC synthesis by Si^+ ion implantation into the gate oxide, we take advantage of the self-alignment ion beam mixing process, i.e., the Si NCs are formed in SiO_2 at a well-controlled small distance of 2-3 nm from the Si/SiO_2 interfaces.
The technical applications in non-volatile nanocrystal memories and in light emitting field-effect transistors (LEFET) are demonstrated.
The Si NC MOSFETs were fabricated as nMOSFET devices in a standard 0.6 µm CMOS process line. Their electrical characteristics have been evaluated in terms of write/erase voltage, duration of the programming time, endurance and retention for different ion irradiation and annealing conditions.
For the investigation of the light-emitting characteristics of the same nMOSFETs, an AC voltage was applied to the gate in order to inject charges of both polarities into the NCs. AC voltage and frequency dependent electroluminescence spectra in the wavelength region of 400-1000 nm were recorded for different annealing conditions.
The performance of the Si NC memories and LEFETs with further possibilities of optimization of efficient charge storage and light emission properties will be discussed.

WED-FIBN07-2 #104 - Invited Talk - Wednesday 3:30 PM - Post Oak

Modeling the Ion Beam Synthesis of Nanocrystals

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Ion beam synthesis of nanoclusters is studied via both kinetic Monte Carlo simulations and the self-consistent mean-field solution to a set of coupled rate equations. Both approaches predict that under the steady-state implantation conditions typically employed, the nanocluster-size distributions reach a steady state. The shape of the steady-state cluster-size distribution depends only on a characteristic length determined by the effective diffusion coefficient, the ion solubility, and the volumetric ion flux. The average cluster size in the steady-state regime is determined by the implanted species/matrix interface energy. Comparison of theoretical predictions to experimental results enables measurement of the characteristic length, and thereby the product of the effective diffusivity and solubility. The theory is also used to identify non-steady-state processing routes that can potentially lead to narrower size distributions. The results of experiments aimed at testing these predictions are also presented. This research is supported by the Directorate, Office of Science, Office of Basic Energy Sciences of the U. S. Department of Energy under Contract No. DE-AC02-05CH11231.

WED-FIBN07-3 #55 - Invited Talk - Wednesday 3:30 PM - Post Oak

Ion beam formation and modification of embedded metal nanoparticles

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Metal nanoparticles can be readily formed in a variety of host matrices by ion implantation and thermal annealing, processes compatible with semiconductor device fabrication protocols. Thereafter, the nanoparticle size, shape, orientation and/or phase can be modified for device-specific applications using ion irradiation. Here we report on ion beam formation and modification of elemental metal nanoparticles in silica focusing on the application of the synchrotron-based techniques X-ray Absorption Spectroscopy and Small-Angle X-Ray Scattering. Finite-size effects were readily apparent in the

nanoparticle structural properties including increased disorder and surface tension coupled with decreased coordination number and bondlength relative to bulk material. The nanoparticle vibrational properties were also perturbed with the smallest nanoparticles exhibiting reduced Einstein temperatures relative to bulk material as attributed to a greater influence of loosely-bonded, under-coordinated surface atoms compared to the effect of capillary pressure generated by surface curvature. Ion irradiation in the nuclear stopping regime induced a crystalline-to-amorphous phase transformation in Co and Cu nanoparticles. Though bulk elemental metals are typically insensitive to ion irradiation, we suggest nanoparticles can be amorphised due to their greater inherent disorder and the stabilizing influence of the surrounding amorphous matrix. Conversely, ion irradiation in the electronic stopping regime yielded a spherical to rod-like shape transformation for all elemental metal nanoparticles examined. Spherical nanoparticles below a critical diameter did not elongate but instead were dissolved in the matrix while larger nanoparticles became progressively more rod-like. For the latter, the major dimension was aligned with the incident ion-beam direction while the minor dimension saturated at a value comparable to the critical diameter for transformation. This saturation was correlated with the metal melting temperature and was confined by the molten ion track formed in the silica matrix.

WED-FIBN07-4 #213 - Contributed Talk - Wednesday 3:30 PM - Post Oak

Pseudo-crystals in MeV Ion Beam Track

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For the past fifteen years, we have formed nanostructures in the MeV ion beam track in order to fabricate pseudo-crystals consisting of nanostructures. The focus of our work is based on the energy deposited due to ionization in order to produce quantum dots or nano-structures resulting in production of pseudo-crystals consisting of nanostructures with applications in optical devices as well as with applications in highly efficient thermoelectric materials. The interacting nanostructures enhance the electrical conductivity, reduce thermal conductivity and increase the Seebeck coefficient, in order to produce highly efficient thermoelectric materials. Theoretically, the regimented quantum dot superlattice / pseudo-crystal consisting of nanostructures of any materials produces new physical properties such as new electrical band structure, phonon mini-bands, as well as improved mechanical properties. A proper choice of nanostructure, host and buffer layer results in production of a highly efficient thermoelectric system* with a figure of merit as high as 4.0. In addition, such systems are in a unique position to be used both as electrical generators from heat, as well as Peltier coolers.

The high efficiency is attributed to the interaction of nanostructures resulting in a) phonon mini-band formation reducing the thermal conductivity, and b) increasing the electrical conductivity. We review a series of materials selected for investigation, some operating at temperatures near 300 K and some near 1000 K.

Supported in part by the Center for Irradiation of Materials, Alabama A&M University and by the AAMURI Center for Advanced Propulsion Materials under the contract number NAG8-1933 from NASA, and by National Science Foundation under Grant No. EPS-0814103. * Patent by AAMURI

WED-FIBN07-P1 #261 - Poster - Wednesday 5:30 PM - Rio Grande

Ion Beam Analysis of Nitrogen Incorporated Ultrananocrystalline Diamond (UNCD) Thin Films

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Determination of the elemental composition is important to correlate the properties of nitrogen doped Ultrananocrystalline Diamond (UNCD) thin films with the growth conditions. Films were deposited by CVD deposition technology and nitrogen doping was introduced by diluting the growth plasma with the nitrogen gas. Deposition of these thin films was carried out on tungsten coated Si substrates with varying concentrations of nitrogen diluted to the plasma mixture. Raman spectroscopy is used to confirm the dominant sp3 bonding, which is a characteristic of UNCD structure with 3-5 nm grains size. Deposited films were smooth on submicron scale with the RMS value of 4-5 nm. To obtain the elemental composition of the UNCD thin films, Rutherford Backscattering Spectrometry (RBS), Non-Rutherford Backscattering Spectrometry (NRBS), Elastic Recoil Detection Analysis (ERDA) and Nuclear Reaction Analysis (NRA) were performed on the films. Helium beam was used for RBS and ERDA and protons were used for NRBS measurements. Exploiting the nuclear

reaction of deuterons with C, O and N, 1.1 MeV D+ beam was used to quantitatively measure the concentration of these elements. Our results show that UNCD films contain less than 3 at% of hydrogen and nitrogen content incorporated in the film was estimated to be lower than 1 at%. The intermixing region between the substrate and the film was found to be negligible. Moreover, disorder phase as determined by Raman analysis was found increasing for the samples deposited with increasing nitrogen dilution in the plasma mixture.

WED-IBA05-1 #220 - Invited Talk - Wednesday 8:30 AM - Brazos I

The analysis of ultra-thin films with HRBS-30

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In the development of thin films, simple analysis techniques with fast turnover times are indispensable. We have evaluated the advanced capabilities of a low energy magnetic spectrometer in combination with conventional RBS. The High Resolution Rutherford Backscattering Spectrometer with radius 30 cm (HRBS-30) and a magnetic field up to 1.1 Tesla, installed around a 6SDH-1 Pelletron, is composed of a 90 degree dipole magnet and a position sensitive detector. The magnet has inclined boundaries (26.6 degrees) for two dimensional focusing. The detector is an 8 by 3 cm2 MCP combined with a resistive anode. An energy filter in front of the MCP has been installed to reduce the intrinsic noise of the detector.

Most of the data presented were acquired with 600 to 1000 keV He+ incident beams. The detection energy window is limited to max. 10% of the beam energy and requires for the case of high-K material two or more separate spectra, In this set-up, simultaneous data acquisition with conventional RBS are used to normalize and catenate different spectra. The 3 axes UHV goniometer has been equipped with automated rotating random routines to avoid channeling during the measurement.

The magnetic spectrometer delivers energy-profiles with nm resolution (for heavy and medium mass target atoms. The performances of the spectrometer will be demonstrated with the analysis of a 1 nm HfO, 6 nm HfSiO, 10 nm LaAlO and a 4 nm SiO2 sample and a channeling measurement of a 5 nm Si cap layer on top of a SiGe layer. Moreover, spectrum broadening of a 1 nm HfO, under glancing conditions has been evaluated with CORTEO. The above experiments prove that a magnetic spectrometer in combination with a standard tandem accelerator is perfectly suited for state of the art thin film analysis.

WED-IBA05-2 #105 - Invited Talk - Wednesday 8:30 AM - Brazos I

Data analysis software for ion beam analysis

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The first edition of the Handbook of modern IBA did not have a chapter on data analysis software. However, with the increasing complexity of materials and systems, IBA techniques are faced with a double challenge: on the one hand, to develop new experimental methods to tackle the new problems, and on the other hand, to be able to extract the desired information from the data. This is not trivial, as effects such as plural and multiple scattering, sample roughness and three dimensional structures, and many others that were previously often overlooked or dismissed as not importat, now need to be included in the data analysis in order to obtain meaningful results.

The new chapter on data analysis software, included in the second edition of the Handbook, deals mainly with the data analysis software of particle-particle ion beam analysis (IBA) techniques: Rutherford backscattering spectrometry (RBS), elastic recoil detection analysis (ERDA), and nuclear reaction analysis (NRA).

We discuss the types of codes that exist and their capabilities, from first generation codes such as RUMP to second generation codes such as SIMNRA and NDF. We will also discuss the accuracy of codes, and, in general, their applicability

to different problems. Finally, we stress that software is an aid to data analysis and does not replace the judgment of the analyst, and show that software that is not correctly used, or that is used outside its scope of application, leads to wrong data analysis.

WED-IBA05-3 #151 - Contributed Talk - Wednesday 8:30 AM - Brazos I

Enhanced High Resolution RBS System

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Abstract. Improvements in full spectrum resolution with the second NEC high resolution RBS system are summarized. Results for 20Å TiN/HfO films on Si yielding energy resolution on the order of 1KeV are also presented. Detector enhancements include improved pulse processing electronics, upgraded shielding for the MCP/RAE detector, and reduced noise generated from pumping. Energy resolution measurements on spectra front edge coupled with calculations using 0.4mStr solid angle show that beam energy spread at 400KeV from the Pelletron(R) accelerator is less than 40eV. To improve user throughput, magnet control has been added to the automatic data collection. Depth profiles derived from experimental data are discussed. For the thin films profiled, depth resolutions were on the Angstrom level with the non-linear energy/channel conversions ranging from 100 to 200eV.

WED-IBA05-4 #403 - Contributed Talk - Wednesday 8:30 AM - Brazos I

Calibration of Space and Atmospheric Detectors Using Ion Beam Analysis Techniques

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The energetic particle subsystem (called ZEP) of the Space and Atmospheric Burst Reporting System (SABRS) is a satellite-based sensor suite deployed in collaboration with the United States Air Force to verify the Limited Test Ban Treaty and provide space weather data to national customers. The ZEP subsystem measures energetic electrons and protons in the space environment at a geostationary orbit. In this report, we present the ZEP proton response using energetic proton particles generated at the Ion Beam Material Laboratory (IBML) in Los Alamos. To simulate low radiation flux in the space, the proton beam from the IBML's 3.0 MV Pelletron tandem accelerator cannot be directly used for this calibration. We have devised an experiment that uses a very thin (~50 nm) free-standing gold foil to scatter the Tandem's proton beam into the ZEP subsystem. The direct Rutherford backscattering from the gold foil produces proton particles that have tunable energies of 0.5 - 6.0 MeV with a desired counting rate of <1 kHz. To extend the proton particle energy beyond the Tandem's limit of 6 MeV, a nuclear reaction, 2H + 3He --> p + 4He + 18.352 MeV, was used. This reaction allows us to obtain as high as 26 MeV proton particles, more than 4 times as high as the accelerator's maximum proton beam energy, and has greatly extended our proton energy range for this calibration activity. Results of the ZEP subsystem response to these proton particles are presented.

WED-IBA05-5 #175 - Contributed Talk - Wednesday 8:30 AM - Brazos I

Novel Surface Hydrogen Analysis using Three-Dimensional Medium-Energy Ion Scattering

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Three-dimensional medium-energy ion scattering (3D-MEIS) was developed for structural and chemical compositional analysis of nanomaterials. Recently we have found for the first time that it is feasible to have a high sensitive for detecting

surface hydrogen using 3D-MEIS. In 3D-MEIS, a pulsed He+ ion beam with a pulse width of 2 ns at a medium energy of 100 keV is used, and scattered particles and desorbed ions stimulated by He+ ion beam are detected using a two-dimensional position-sensitive and time-resolving microchannel plate (three-dimensional) detector [1-3]. The system of 3D-MEIS consists of a He+ ion source combined with a 100 keV accelerator, a beam chopping system, a sample on a goniometer and 3D detectors.

In this study, neither highly charged ion nor the principle elastic recoil detection analysis is utilized for the novel surface hydrogen analysis. We consider that the surface hydrogen detection using 3D-MEIS is due to the mechanism similar to electron stimulated desorption. The amount of absorbed hydrogens on Si(001) and on Si(111) were analyzed as a function of time after flushing at a temperature of 1200 degreeC. It was found that the hydrogen content on Si(001) increased 10 times more quickly as compared with the Si(111) case.

[1] S.Shimoda, T.Kobayashi, Nucl. Instrum. Methods Phys. Res. B 219-220, 573 (2004). [2] S.Shimoda, T.Kobayashi, J. Appl. Phys. 96, 3550 (2004). [3] T.Kobayashi, Phys. Rev. B 75, 125401 (2007).

WED-IBA05-6 #396 - Contributed Talk - Wednesday 8:30 AM - Brazos I

Combinatorial PCT measurement of Mg-Ni hydrogen storage alloy by using ambient micro-beam nuclear reaction analysis

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We recently developed a micro-beam-line of nuclear reaction analysis (NRA), in Tandem accelerator facility in University of Tokyo, for hydrogen analysis using 6 MeV 15N ion. The minimum beam size on sample was observed as 20 x 30 micron. The beam can be extracted into the atmosphere by using a SiN barrier membrane, which has the thickness of 100 nm. We applied this system to research the hydrogen storage alloys. To find an alloy composition, which has a good property of hydrogen storage, it becomes important to take pressure-concentration-isothermals (PCT curves). In general, the data acquisition of the PCT curve by changing the alloy composition is time-consuming. Our idea is that the micro-beam NRA in ambient condition realizes the combinatorial method for PCT measurement of the hydrogen storage alloys. In particular we prepared a one-dimensional combinatorial thin films of Mg-Ni with the dimension of the 3 x 15 mm and thickness of 100 nm capped by 5 nm thick Pd layer, and made the NRA measurements in 100 mbar hydrogen atmosphere. We succeeded to determine the hydrogen concentrations in the film by changing the beam position on the sample. The alloy composition (Mg-Ni ratio) at the beam spot was also determined at the same time by taking Rutherford back scattering. In near future we will take complete PCT curves on various Mg-Ni ratio by changing the pressure of the hydrogen atmosphere and also temperature. This method is very powerful to develop the useful and practical hydrogen storage alloys.

WED-IBA05-7 #440 - Contributed Talk - Wednesday 8:30 AM - Brazos I

Fabrication of Buried Self-Organized Stripes

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The preparation of well-defined structures in atomic, mesoscopic and microscopic scales is of central interest to material scientists in order to perform (i) basic studies on the sub-micro-structural systems and, based on the obtained data, (ii) to develop functional materials (devices) with specified properties (functions). In the present paper, an attempt to prepare hybrid materials, based on the synthesis of fullerenes and transition metals, have been realized. In experiments, the thin film systems (mixtures, multilayers and their combinations) of the transition metals (Ni, Ti, etc.) and fullerenes (C60) were deposited on the selected monocrystal substrates (e.g., MgO, Al2O3, etc.). The systems were prepared by co-evaporation

and/or alternating deposition of the metallic and fullerene components under following deposition kinetics: a) deposition rates ~ 0.05 nm/s, b) thickness of the deposited layers ~ 300 nm, c) temperature of the substrate during deposition either 500°C (buffer Ni) or 120°C (other layers). As a result, complex multilayer sequences, structurally stressed (due to immiscibility of both components), were prepared. The synthesized films were then ion-irradiated and/or annealed in the inert atmosphere in order to induce step-by-step re-arrangement of their structures. The process of structural modification was monitored by ion beam nuclear analytical techniques including Rutherford Backscattering / Channeling, and some other relevant methods (e.g., micro-Raman spectroscopy and Scanning Electron Microscopy). The results showed that during thermal and ion beam processing the unstable multilayer architecture degraded (C60 molecules decayed to amorphous carbon, a-C, or out-diffused). Surprisingly, however, the degradation of the system was accompanied by unusual constructive effects - spontaneous formation of the buried metal/a-C nanoscopic stripes. The paper discusses possible mechanisms of the pattern formation.

The work was supported by the Academy of Sciences of the Czech Republic (Grant Nos. KAN400480701, IAA400320901) and Ministry of Education of the Czech Republic (Research program No. LC 06041).

WED-IBA05-P1 #111 - Poster - Wednesday 5:30 PM - Rio Grande

Hydrogen in group-III nitrides: an ion beam analysis study

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InN and related group-III-nitride alloys are key materials for contemporary and future optoelectronic and electronic devices such as high-brightness blue and white LEDs, multi-junction solar cells, high-frequency transistors, THz emitters and chemical sensors. The doping mechanisms of InN are however still not well understood, and the origin of the unintentional n-type conductivity in InN is strongly debated. Unintentionally introduced hydrogen is a possible source of doping but until very recently it was believed that the amount of H in high-quality undoped InN films is insufficient to explain the observed free electron concentrations.

We measured a series of state-of-the-art InN samples grown by molecular beam epitaxy with 2 MeV 4He-ERDA and with RBS, showing the presence of relatively high amounts of hydrogen not only at the surface, but also in the bulk. Strong depletion of hydrogen due to the analysing beam was observed and taken into account in the analysis. Heavy ion ERDA experiments with a 35 MeV 35Cl beam were made in selected samples, in order to determine the content of other light impurities and to provide an independent measurement of the hydrogen. Here, we report on the details of the analysis and show how the results correlate with the free-electron concentrations of the samples.

WED-IBA05-P2 #390 - Poster - Wednesday 5:30 PM - Rio Grande

Ion Beam Study of Hydrogen Diffusion in Coating Layers on Zirconium Surface

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Hydrogenation of zirconium which is a common structural material in nuclear reactors leads to the formation of cracks in zirconium parts thus limiting their durability. Various coatings are applied to protect zirconium parts from hydrogenation. The diffusion coefficient of hydrogen in the coating layers of different composition was investigated in this work using accelerated ion beams.

The coating layers were loaded with hydrogen using ion implantation. The initial hydrogen peaks thus created then dispersed as diffusion proceeded at certain elevated temperatures. PIGE and NRA were used for hydrogen depth profiling, with ^{1}H and ^{2}H isotopes being implanted respectively. The ions energy was selected to be 600 keV for ^{1}H and 735 keV for ^{2}H so as to create the initial hydrogen peaks at approximately same depth.

Hydrogen depth profiling was made using $^{1}H(^{19}F,\alpha\gamma)^{16}O$ reaction. A scintillation spectrometer with NaI(Tl) crystal was used to register gamma rays with E_{γ} exceeding 6 MeV. In order to provide the analysis of relatively thick coating layers (up to 5 μm) the beam energy varied over a wide range from 6.4 to 22 MeV. Since the $^{1}H(^{19}F,\alpha\gamma)^{16}O$ excitation function has several resonances in this energy region a special algorithm was used to convert the gamma ray yield into the hydrogen concentration profile. Deuterium depth profile was derived from the spectra of protons produced in the reaction $^{2}H(d,p)^{3}H$ at 1.05 MeV deuteron beam energy. Similar hydrogen profiles were obtained when different techniques were applied. Details of the methodology and the obtained results for hydrogen diffusion in the coating layers are presented.

WED-IBA06-1 #49 - Invited Talk - Wednesday 3:30 PM - Brazos I

From 2 to 2k detectors in 20 years - development of particle detector systems for IBA

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Ion Beam Analysis has a tradition of using single detector systems, where the experimentalist focus on an as good energy resolution as possible. The traditional techniques PIXE, RBS and also PIGE are all based on this concept. In parallel, during the last decades both the nuclear and particle physics experiments have moved to detector systems with higher and higher granularity. This allow experiments with higher multiplicities but also at the same time give the experimentalist much more specific information about each particle and each nuclear interaction

In this presentation, I will try to describe the advantage of using more than one detector for IBA purposes. I will use the development of the IBA facility in Lund, going from 2 to 2000 detector elements in 20 years, to emphasiate this. The presentation will devide in three parts, the early years with the introduction of fast timing for IBA purposes, via the development of array detectors in steps via 2, 4 and 8 detectors to the present system of 32*64 overlapping detectors. The different steps going to higher granularity will be motivated and illustrated by different IBA applications both from Lund and other laboratories and finally the present status and future plans and opportunities of the 2k particle detector will be discussed in more detail.

WED-IBA06-2 #101 - Invited Talk - Wednesday 3:30 PM - Brazos I

Radiation hard gas ionization detectors for IBA

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The energy resolution of gas ionization detectors for low energy ions has been dramatically improved in the past few years by the use of thin and homogeneous entrance windows and low noise electronics. In the low MeV region, their energy resolution outperforms the one of silicon charged particle detectors for ions heavier than Li and is only slightly worse for He and protons.

A big advantage of gas ionization chambers is their high radiation hardness and consequently their durability and long life-span with unreduced performance. Therefore, they are not only attractive for detecting heavy ions but can also be used in light ion measurements at high particle fluence, such as STIM, where permanence of detector response is an issue.

Recently, we have drastically reduced the size of gas detectors and designed models that withstand a pressure difference of at least 1 bar and thus can be used both in vacuum and at ambient pressure. With this type of detector no change in response can be observed under STIM conditions even after a fluence of 1E7 particles per square micron of the entrance window.

An overview of the present status and potential of the technology will be given with special emphasis on small detectors with optimized count-rate and long life-time.

WED-IBA06-3 #429 - Contributed Talk - Wednesday 3:30 PM - Brazos I

A New High Performance TOF-ERDA Spectrometer For Thin Film Analysis

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A new TOF-ERDA spectrometer has been designed and commissioned at the beam line of the 1.7 MV Pelletron accelerator in Jyväskylä, Finland, The main application of the spectrometer is the analysis of all elements in very thin films, down to a thickness of less than ten nanometers. This spectrometer has two timing detectors and a solid state energy detector at recoil angle of 41 degrees. The flight path between the timing detectors is 633 mm. The first timing gate is designed to be position sensitive in order to make kinematic correction for recoil energies. The solid state energy detector can later be replaced with gas ionization detector with a thin silicon nitride entrance window. A low-cost but very efficient list mode data collection system for a maximum eight ADCs with 25 ns resolution time stamping for each event was realized by means of LabVIEW and Field-programmable gate array (FPGA) card.

The performance figures for the detector telescope are good: the detection efficiency is 70% for 0.1 MeV and 35% for 0.5 MeV H ions, respectively, and better than 99% for C ions. The timing resolution of the timing detector pair is 155 ps (FWHM) measured for 4.8 MeV He ions scattered from a thin Au film. In this paper the detector telescope is presented and its performance highlighted in the analysis of sputter deposited CN films and atomic layer deposited Al2O3 and Ru films on Si substrate, all with thickness of less than 10 nm.

WED-IBA06-4 #97 - Contributed Talk - Wednesday 3:30 PM - Brazos I

Biological Material Analysis with Swift Heavy Ions:A Proposal of "Wet SIMS"

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Biological material analisys is of interest because of the complexity of the structure and chemical composition in living organisms. Much progress has been made in the analisys of biological samples. For instant, PIXE have been utilized to visualize elemental distribution in biological materials. Because most of biological molecules have similar chemical composition, such as H, C, O and P, molecular structural and chemical state information is extremely important and invaluable. Energetic ion irradiation also leads to the emission of atomic and molecular ions from the sample surface, and molecular ions represent the chemical composition of biological materials.

We have developed a molecular imaging technique with secondary molecular ions emitted by swift heavy ions[1]. Swift heavy ions (of the order of MeV energy) produce secondary molecular ions at much higher yields than monomer ions with energy of a few tens keV, owing to their larger energy deposition near surfaces. Therefore, swift heavy ions are practical for biological material analisys. A single animal cell and rat tissues were clearly imaged with lateral resolution of around 5 ?Ým. Moreover, the high transmission capability of the swift heavy ions through an ambient allows the use of this beam at low vacuum. A novel SIMS system equipped with orthogonal ToF has been developed to analyze biological materials

containing volatile molecules. Analysis of biological samples containing water can be realized with this new system, which can operate at 2000 Pa. We call this new technique ¡§wet-SIMS¡¨.

Recent progress in the development of this novel technique will be presented and discussed with some examples for biological material analysis.

This work is partially supported by JST, CREST.

[1] Y. Nakata, Y. Honda, S. Ninomiya, T. Seki, T. Aoki and J. Matsuo, "Matrix-free high-resolution imaging mass spectrometry with high-energy ion projectiles", Journal of Mass Spectrometry, 44 (2009) 128.

WED-IBM04-1 #70 - Invited Talk - Wednesday 1:00 PM - Pecos I

Construction of Complex Two- and Three-Dimensional Molecular Devices: Combined Time-of-Flight Secondary Ion Mass Spectrometry and Electron Microscopy Studies

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Methods for the chemically selective deposition of metals, semiconductors, biomolecules and other compounds have been studied and applied to the construction of complex multilayer structures. This work has important applications in molecular and organic electronics, sensing, biotechnology, photonics and other technologies. To illustrate the analytical methods employed we discuss three applications: electron beam lithography of self-assembled monolayers (SAMs) on GaAs and Au, selective electroless nickel deposition on functionalized SAMs and the construction of three dimensional-nanostructures via layer-by-layer assembly using covalent interactions.

WED-IBM04-2 #251 - Invited Talk - Wednesday 1:00 PM - Pecos I

Recent developments in cluster primary ion sputtering in SIMS - from theory to practice

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Cluster ion sputtering has revolutionised the utility of secondary ion mass spectrometry (SIMS) to study organic materials. For cluster ion bombardment there is a non-linear enhancement of the sputtering yield, which is well described using a thermal spike model. This leads to a significant enhancement in the molecular secondary ion yield (MSIY) leading to dramatic improvements in molecular imaging. The damage cross-section does not increase as strongly so that the efficiency (the ratio of intensity to damage cross-section) is higher for cluster primary ions. For large primary ion clusters such as C_{60} and Ar_{1000} the ion range is shallow and the sputtering yield high so that most of the damaged material is sputtered away leaving a relatively undamaged surface. This opened the possibility for SIMS to profile the molecular composition of organic layers. The simple extension to dual beam analysis for high resolution imaging whilst profiling, allows the 3 dimensional molecular chemistry to be mapped in exquisite detail.

NPL is developing the measurement infrastructure to help analysts optimise the use of cluster primary ions and to understand the many effects that occur. Here, we show how the MSIY is related to the total sputtering yield(1) and how the effectiveness of the many choices of cluster primary ions compare. We show how the mass spectrum from cluster primary ions may be understood in terms of the product of spectra for an atomic primary ion and two further spectra that relate directly to physically meaningful properties (2). We also show our recent developments in the fundamental understanding of organic depth profiling using the NPL-VAMAS molecular delta layer, including recent results for Ar1000 cluster primary ions (3,4).

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2.J. Phys. Chem. C, 114 (2010) 5351.
3.J. Phys. Chem. B, 112 (2008) 2596.

WED-IBM04-3 #88 - Invited Talk - Wednesday 1:00 PM - Pecos I

The Potential of Cluster SIMS Ion Beams in Biological Applications

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Cluster ion beams in secondary ion mass spectrometry (SIMS) have become commonplace for analyzing a range of organic materials, with a considerable emphasis on biomaterials and biological cells/tissue. These ion beams range from small trimeric species such as Bi3+ and Au3+ to intermediate small clusters such as SF5+ and C60+. The premise of using cluster ion beams for SIMS imaging and spectral analysis of biological targets stems from 1) larger sputter yields and ion signals from biomolecules, and 2) less overall damage of the delicate biomaterials during and after ion bombardment. However, despite the advances in ion beam technology, there are other areas to be maximized in order for the cluster ion beams to reach full potential in cell/tissue characterization. An overview will be provided for what biological questions can potentially be answered with cluster ion beam SIMS, and which questions may be difficult to study with the technique.

WED-IBM04-4 #154 - Invited Talk - Wednesday 1:00 PM - Pecos I

Time-of-Flight Secondary Ion Mass Spectrometry: Surface Analysis with Cluster Ion Beams

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In Time-of-Flight Secondary Ion Mass Spectrometry (ToF-SIMS), a sample surface is bombarded with a high energy pulsed primary ion beam causing atomic and molecular ions to be emitted from the outer layers. These ions can be then analyzed in a time-of-flight mass spectrometer. Thus the chemical composition of a surface can be probed with a sensitivity down to sub-ppm concentrations. In scanning and sample erosion modes, it is also possible to determine the lateral and vertical distribution of species in a sample. By combining imaging and depth profiling even the 3D chemical composition of a sample can be visualized.

In recent years, cluster primary ions have been successfully applied for analysis. Compared to monoatomic primary ion bombardment, the use of clusters leads to a considerable enhancement of the secondary ion efficiency, especially of molecular ions, by up to several orders of magnitude. In particular, a Bi-liquid metal ion gun combines the fundamental benefits of cluster ion bombardment with a high brightness source to provide high lateral resolution image analysis down to less then 100 nm.

It has also been shown, that it is possible to depth profile many organic systems by using cluster primary ion beams like C60 for sputter erosion in contrast to traditional depth profiling with a monoatomic sputter beam. In the latter case, depth profiling of organic samples has often suffered from the fact that high-mass molecular information is rapidly lost under high-dose sputtering conditions.

In this contribution, we will present the latest developments in cluster ToF-SIMS and discuss various applications, which are now possible.

WED-IBM04-5 #96 - Invited Talk - Wednesday 1:00 PM - Pecos I

Large Size Cluster Ion Beams:from Fundamental Aspects to Industrial Applications

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Ion beam are widely used in material processing and analysis techniques for inorganic materials, such as metals, ceramics and semiconductors. However, very few techniques are available for soft material processing or analysis. There are essential subjects for ion beam processing for soft materials, such as organic or biological materials. One is how to diminish surface damages during irradiation, because binding energy of soft materials is low. Cluster ion beam, which are equivalently low energy beam, is expected to overcome this issue. The other subject is how to evaluate surface damage of soft materials. Most of analysis techniques for organic materials have less sensitivity to surfaces.

Cluster ion beam process has been developed for shallow junction formation, surface smoothing, nano-fabrication and thin-film formation. "Non-Linear phenomena" plays an import role in these novel nano-process. Both experiments and MD simulations show that damage layer thickness decrease dramatically, when the cluster size is larger than certain size. Soft materials, such as polymer, organic semiconductor molecules and amino acids have been investigated in order to evaluate residual damage on the surface. Recently, cluster size dependence on sputtering have measured using size selected cluster ion beams.

Atomistic mechanism of energetic cluster impacts and prospect for this technique will be discussed in conjunction with possible applications.

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WED-IBM06-1 #85 - Invited Talk - Wednesday 3:30 PM - Pecos II

Amorphization in Ion-Irradiated Nano-Crystalline 3C-SiC

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Silicon carbide (SiC) has been considered as a prominent candidate for a variety of applications, including future nuclear energy systems and advanced electronic devices. Extensive research efforts have been devoted to the study of irradiation effects in SiC single crystals over the past decades. Recently, radiation effects in nanostructured materials have attracted significant attention because the material contains a large fraction of interfaces that could serve as strong sinks for mobile point defects produced during irradiation, and thus being potentially more resistant to irradiation-induced damage. There have been very few irradiation studies of nanocrystalline SiC to date. In this study, energetic ion beams are used for irradiation of nanocrystalline and single-crystalline 3C-SiC under the identical conditions for comparison. The nanocrystalline 3C-SiC specimens with an average crystallite size on the order of a few nanometers were prepared using pulsed laser deposition. The primary methods for material characterization include ion channeling, x-ray diffraction, and transmission electron microscopy. The results from this study show that for Au2+ ion irradiation at room temperature, nanostructured 3C-SiC, composed of nominally 4.6-nm crystallites in size, can be fully amorphized at a dose not higher than for bulk SiC at the same temperature. Full amorphization of 3C-SiC with particle sizes ranging from 2.0 - 3.8 nm irradiated with Si+ ions requires a lower dose than for single crystal 3C-SiC under the identical irradiation conditions at room temperature or 400 K; a significant effect on amorphization dose at 400 K is observed for particle sizes between 2.0 and 3.0 nm. This behavior has been attributed to the preferential amorphization at the interfaces. Further experiments for nanocrystalline 3C-SiC at temperatures close to and higher than the critical temperature for amorphization of single crystal 3C-SiC are currently undertaken and the results will be also presented and discussed.

WED-IBM06-2 #444 - Invited Talk - Wednesday 3:30 PM - Pecos II

Combination of Ion Beam, 3D Atom Probe and Scanning Transmission Electron Microscopy Analysis of Embedded Nanoclusters in Oxide Matrix

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The influence of embedded nanoclusters on the optical, magnetic and electrical properties of bulk and surface oxides has been an active area of investigation. In this study we report on Au-rich nanoclusters that have been embedded into MgO and TiO2 substrates. The effect of high temperature annealing on the properties of the matrix and the secondary phase (Au) are studied in detail. Electron microscopy analysis has shown that the embedded metal particles are often associated with various defects, which further contribute to property modification.

We report the first Local Electrode Atom Probe (LEAP®) analysis of bulk MgO and TiO2 implanted with 2 MeV Au ions using the accelerator facility at EMSL. Both as-implanted and annealed samples were critically analyzed using a combination of APT and high angular annular diffraction scanning transmission electron microscopy (HAADF STEM) imaging. High-resolution transmission electron microscopy (HRTEM) clearly resolves the Au-rich nanoclusters and allows observation of the pronounced vacancy clustering associated with these features. These Au-rich nanoclusters were also observed in the atom probe data with the average cluster size (~ 5 nm diameter) in good agreement with those seen using HRTEM. The APT technique, however, due to the high three-dimensional (3D) spatial resolution, is also able to detect the presence of finer-scale Au clusters. It can also directly measure residual Au composition within the MgO matrix and any MgO-Au mixing within the clusters. Besides variations in compositional microstructure, evolution of mass spectrum quality as a function of Au content is also observed. Efforts are ongoing in EMSL to confirm this observation and eliminate the possibility of any contribution from experimental artifacts. During the course of this presentation we will highlight the advantages of using 3D APT in combination with electron microscopy.

WED-IBM06-3 #95 - Invited Talk - Wednesday 3:30 PM - Pecos II

An Investigation of Performance of Cluster Primary Ions in Elemental Depth Profiling Using Time-of-Flight Secondary Ion Mass Spectrometry

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Time-of-flight secondary ion mass spectrometry (ToF-SIMS) has been used for elemental depth profiling for over three decades. Recent years, cluster primary ions have been widely used and they can greatly enhance signal intensity of molecular ions (10-1000 times) if compared to single atom primary ions. So how about the performance of cluster primary ions in traditional elemental depth profiling? To answer this question, large amounts of experimental data are needed. In this work, hydrogen and deuterium depth profiling using six different primary ions (25 keV Bi+, Bi3+, Bi5+, 50 keV Bi3++, 10 keV C60+ and 20 keV C60++) were compared. It is found that the cluster primary ions do enhance H- and D- yields, but the enhancement is only about 1.5-4.0 times if compared to the yields of single atom Bi+ ions. Presently, the highest available current of single atom primary ion beam is much stronger than the currents of cluster ion beams for most available commercial ToF-SIMS instruments. Therefore, the single atom ion beam is still the best choice for hydrogen and deuterium depth profiling due to relatively weak H- and D- signal intensity. In addition, relative yields of low abundance isotopes such as 18O, 30Si was also studied, and limited enhancement within a similar range (1.5-4.0 times) was also observed.

WED-IBM06-4 #441 - Contributed Talk - Wednesday 3:30 PM - Pecos II

Ion solid interaction and surface modification at rf breakdown in high-gradient linacs

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Ion solid interaction has been shown to be a new important mechanism of unipolar arc formation in high-gradient rf linear accelerators through surface self-sputtering by plasma ions, additionally to an intense surface field evaporation. A non-Debye plasma is formed in the close vicinity to the surface and it strongly affects surface atomic migration via intense bombardment by ions, strong electric field, and high surface temperature. Formation of various self-organized irregular and periodic structures such as ripples, cones, and bubbles were frequently observed on rf-cavity surfaces subjected to vacuum breakdown development, on the first wall on the Tokamak chamber, on the glass surfaces irradiated by laser beams, on the satellite surfaces bombarded with micro-meteorites; and they are subject of our detailed study via experiment and computer simulation. Scanning Electron Microscope (SEM) studies of copper surface of rf cavity were conducted that show craters

and arc pits and irregular and regular ripple structures with a characteristic length of 2 microns on the surface. Strong field enhancements are characteristics of the edges, corners and crack systems existing of the surfaces subjected to breakdown. These structures can function as field emitters that was shown by using atomistic and finite-element simulations. Such surface micron-scale geometries produce high enhancement factors that are consistent with experimental data. A new plasma model of the high-gradient breakdown in rf cavities was proposed that can explain most of the existing experimental data.

WED-IBM06-5 #16 - Contributed Talk - Wednesday 3:30 PM - Pecos II

Subwavelength Surface Textures for Silicon Antireflection by Ion Implantation

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As the semiconductor industry continues to show more interest in the photovoltaic market, cheaper and readily integrable methods of silicon solar cell production are desired. One of these methods?ion implantation?is well-developed and optimized in all commercial semiconductor fabrication facilities. Here we have developed a novel Si surface texturing technique predicated upon the phenomenon of surface blistering of H-implanted silicon, using only ion implantation and thermal annealing. It has previously been shown that when silicon is implanted with high doses of hydrogen (> 3e16/cm2), subsequent thermal annealing causes molecular hydrogen to form as gaseous bubbles near the implanted range, which in turn push against the Si surface and form shallow blisters. As this is found to have been facilitated by hydrogen accumulating in damaged regions caused by the implant, we have investigated the role of these damaged regions by using a second, heavier ion implant by Ar to create an amorphous region near the surface. We find that the surface blistering is markedly enhanced, causing large trenches that act as a surface texturing of c-Si. We have found that this method reduces total broadband Si reflectance from 35% to below 5%, and simplifies the texturing process in that it requires only ion implantation and furnace annealing, avoids chemical waste, and can be performed in-situ. In addition, we have used both Rutherford backscattering/channeling measurements and Transmission electron microscopy to investigate the effect of ion implantation on the crystallinity of the sample. The data suggests that implantation-induced lattice damage is recovered upon annealing, reproducing the original monocrystalline structure in the previously amorphized region, while at the same time retaining the textured surface.

WED-IBM06-P1 #451 - Poster - Wednesday 5:30 PM - Rio Grande

Laser-Assisted Atom Probe Tomography and Helium Ion Microscopy at EMSL: Nanoscale Analysis of Materials Impacting Energy and the Environment

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Increasing emphasis on materials with enhanced properties in various functional applications has provided an impetus to develop tools to further our understanding of material properties through imaging with increased spatial resolution, larger field-of-view and enhanced detector sensitivity. In principle, Laser-assisted atom probe tomography (APT) offers atomic scale analysis of materials with high compositional sensitivity. While this technique has been used for decades, the development of laser pulsing has extended the scope of applications from metals to semiconductors, and very recently to insulating materials such as metal oxides. The Environmental Molecular Sciences Laboratory (EMSL), a Department of Energy scientific user facility, is developing an APT and a He-ion microscopy (HIM) capability to provide solutions to problems of interest to energy and environmental studies at the nanoscale. This presentation examines the feasibility of using APT and HIM for challenging materials that have not been previously examined by this method.

One such material, intragrain ferrous phosphate, was obtained from the reductive biotransformation, by Shewanella oneidensis MR-1, of 6-line ferrihydrite located within nano-porous silica. Imaging and analysis of the biologically induced

Fe-Phosphate precipitates in porous silica was performed using HIM and APT. The distribution of the precipitates within a dissimilar matrix required a site-specific specimen preparation methodology to enable tomographic analysis.

We also report the first Local Electrode Atom Probe (LEAP®) and HIM analysis of bulk oxides which contain ion-beam-synthesized Au nanoclusters. Au cluster distributions, generated by the implantation of 2 MeV Au ions into MgO and TiO2 single crystal substrates and subsequent annealing for 10 hrs at 1000oC, were analyzed along with the host oxide matrices using a combination of APT, TEM and HIM. The results of these analyses will be discussed in detail.

WED-MAR06-1 #532 - Invited Talk - Wednesday 8:30 AM - Pecos I

Potential Non-Gantry Solutions for Isocentric Patient Irradiation with Heavier Ions

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As 3-D conformal irradiation of clinical patients with protons and heavier charged particles has become more widely accepted, technology has evolved to permit a greater variety of beam-entry angles, in a similar fashion to what has been possible for decades with mega-voltage X-ray therapy units. Although the initial particle-therapy units in national laboratory settings used fixed horizontal beam lines in concert with isocentric patient-positioning tables -- maintaining isocentricity of the target volume during angular rotations of the patient in pitch, yaw and roll -- the development of proton gantries in the early 1990's markedly facilitated such treatments by making beam-entry-angle selection akin to X-ray therapy. Although somewhat bulky and more expensive than fixed beam lines, proton gantries have become widely used, allowing easier treatment planning and delivery for many complexly shaped target volumes and anatomical locations, with the patient immobilized in supine position.

With the evolution of sophisticated beam-scanning technology and real-time beam adjustment to compensate for organ motion, the demands for gantry stability with increased equipment load have become even more exacting, as have the demands for mechanical stability of the peripheral equipment during gantry rotation.

Although heavier ions have significant potential relative-biological-effectiveness benefits for the treatment of radio-resistant tumors, the greater size and expense of gantry design for heavier ions has thus far been a show-stopper for many programs. Pending the development of less expensive and more compact gantry design, potential solutions can be found by combining isocentric patient-positioning tables with fixed horizontal, vertical and diagonal beams. This presentation describes the historical background of isocentric positioning tables, and the possibilities and limitations of beam-entry angle selection made possible by combining isocentric tables with vertical and diagonal fixed beams.

WED-MAR06-2 #288 - Invited Talk - Wednesday 8:30 AM - Pecos I

New developments in proton computed tomograpy

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Proton accelerators are becoming more widely used in the medical setting due to the dosimetry advantages of protons. The main advantage of protons compared to photons is that the distribution of dose can be controlled not only laterally but also in depth. In order to fully exploit this advantage, accurate prediction of the relative stopping power of the tissues along the

proton path is an important requirement. This was possible for the first time when x-ray CT was introduced in medical imaging during the 1970s. The entire development of 3D and, more recently, 4D imaging for radiation treatment planning has rested on the availability of high-quality x-ray CT images. Since the accuracy of range predictions of proton beams relies on the conversion of CT Hounsfield units to relative proton stopping power values and these quantities are not related uniquely, uncertainties in addition to other prevalent x-ray CT uncertainties and artifacts are of the order of a few millimeters in the brain and can be more than 1 cm in the trunk. For some clinical procedures where the proton beam is aimed at a critical structure this uncertainty is prohibitive. Proton computed tomography (pCT) has been shown, up to this point mostly by Monte Carlo simulations, to be capable of reconstructing relative stopping power of a patient through individual proton energy loss measurements. Various groups and laboratories world-wide are working on the technical realization of proton CT with modern particle tracking and data acquisition techniques mostly derived from high energy physics. This presentation will give an overview of the status of proton CT development within our pCT collaboration. Challenges both with respect to data acquisition and fast and efficient image reconstruction will be addressed.

WED-MAR06-3 #547 - Contributed Talk - Wednesday 8:30 AM - Pecos I

Pencil beam scanning system based on cyclotron

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Purpose: SHI has developed a new pencil beam scanning system for proton therapy. Taking advantage of continuous and high intensity beam from the cyclotron P235, the line scanning method is employed in order to realize continuous irradiation with high dose rate. 3D irradiation volume is formed by superposing layers in depth direction, where the energy of each layer is adjusted with the energy selection system (ESS) at the exit of cyclotron. The pencil beam scanning system is incorporated into either a dedicated scanning nozzle or a multi-purpose nozzle, which enables also the wobbling irradiation technique.

Method: Formation of 3D irradiation field requires a modulation of dose distribution in each layer. This is done by varying the scanning speed and keeping the beam current constant. Intensity at different layer is adjusted by either changing the beam current or changing the number of rescanning. The beam intensity is made constant by stabilizing the cyclotron extracted current in the range of 1 to 300nA with a feedback system.

Result: The test nozzle was installed in one gantry of National Cancer Center, Kashiwa. The scanning magnet is controlled with a time response of less than 1ms and the beam current from cyclotron is stabilized within +/- 1%. Irradiation tests have been conducted with at first a simple square uniform field, an intensity modulated 2D field and finally a 3D spherical field. The measured data are in good agreement with the result of simulation.

Conclusion: We developed the line scanning method for proton therapy utilizing the continuous beams from cyclotron. Performance of beam scanning and intensity control have been verified. The agreement of dose distribution between simulation and measurement for 3D spherical target is investigated.

WED-MAR06-4 #540 - Contributed Talk - Wednesday 8:30 AM - Pecos I

Dose Error Analysis for a Scanned Proton Beam Delivery System

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All particle beam scanning systems are subject to dose delivery errors due to errors in position, energy and intensity of the delivered beam. In addition, finite scan speeds, beam spill non-uniformities, and delays in detector, detector electronics and magnet responses will all contribute errors in delivery. In this paper, we present dose errors for an 8 x 10 x 8 cm target of uniform density with 8 cm spread out Bragg peak (SOBP). Beam energy errors and errors due to limitations of scanning system hardware have been included in the analysis. Although the beam properties and nozzle limitations are derived from measurements at Loma Linda using a prototype scanning system, the methods of analysis and some of the results will be applicable for many beam scanning systems. In this example, the rms dose errors have been calculated for all points in the target volume. A dose volume analysis is also presented to show the integral effects of dose errors. The results

show that with reasonable assumptions of random beam delivery errors and ion chamber and magnet response times, the spot scanning technique can be applied with an rms dose error less than 2 or 3 % throughout the target volume.

WED-MAR06-5 #533 - Invited Talk - Wednesday 8:30 AM - Pecos I

Target and Normal Tissue Delineation, Current Clinical Issues

Anita Mahajan
Radiation Oncology, MD Anderson Cancer Center, 1515 Holcombe Boulevard, Houston TX 77030, United States

As radiotherapy technology has advanced, dose can be delivered to very complex targets. The clinical benefit of this ability now relies on efficient and accurate delineation of target and avoidance structures. Every region of interest (ROI) determination requires assessment of all available anatomic, biologic and functional information which can be obtained from clinical assessment, diagnostic imaging.

CT, MRI and PET fusion is commonly used for ROI delineation. CT scans with and without contrast can give anatomic information for GTV delineation. There is little information regarding function or for CTV determination beyond organ definition. MRI scans are routinely used for CNS tumor delineation. The GTV is usually determined by assessment of the abnormal signal noted on the T1 contrast and/or T2/FLAIR series. Again our current ability to determine a precise CTV is somewhat limited. Diffusion tensor imaging (DTI) and perfusion MRI may be techniques to define the CTV better. DTI and functional MRI may allow better delineation of eloquent cortex and white matter tracts. FDG-PET/CT scan is used for RT planning for many extracranial tumors where there is hypermetabolism noted in the tumor; however, optimal isotopes for intracranial disease evaluation are not readily available.

Deformable image registration (DIR) is a technique that will allow greater efficiency and consistency in ROI delineation for both the target and normal tissue. DIR allows re-assessment of the GTV during RT for an adaptive approach. DIR using a standard template could be a tool to facilitate delineation normal ROI's consistently between radiation oncologists and efficiently to allow numerous ROI's to be evaluated.

Overall, RT planning and delivery technologies have advanced significantly over the last decade. The clinical benefit will even more apparent if the ability to define the GTV , CTV and normal structures better with the use of advanced imaging techniques.

WED-MAR06-P1 #255 - Poster - Wednesday 5:30 PM - Rio Grande

Evaluation of the dose deposited by MeV protons using the Fricke Xylenol Gel sensor

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In this work we studied the behavior of a Fricke Xylenol Gel (FXG) as a function of MeV proton fluence, and compared with theoretical profiles expected after irradiations. The FXG dosimeter is composed mainly of ferrous sulphate, xylenol orange corant (XO) and swine skin gelatin. It has been used for several types of radiation (beta, gamma, X) measurements especially for health applications. When irradiated, the Fe+2 ions are oxidated to Fe+3 and the [XO-Fe+3] complex is generated due to the radiolysis processes. It has the atomic effective number and density near to those of the soft tissue (7.75 and 1.05 g/cm3) what makes it a good simulator for irradiations in radiotherapy and radiology areas. The highest absorption peak is centered at 585 nm and the measurements in this wavelength, as a function of absorbed dose, has shown a linear behavior for all types of radiations and energies previously used. All proton irradiations were done in air, with the

proton beam from the CIM Pelletron ion accelerator extracted through an Al foil window. The samples were measured with an innovative method using a high resolution CCD camera and imaging software that has the pixel grayscale color calibrated into units of absorbed dose (microgray) and can be used to accurately determine the deposited dose as a function of depth from the surface. Results show not only a linear dependence, but also that the fluence profiles are in agreement with theoretical (TRIM) predictions.

WED-MAR07-1 #539 - Invited Talk - Wednesday 3:30 PM - Pecos I

THE ROLE OF PROTON THERAPY IN THE TREATMENT OF CANCERS OF THE HEAD AND NECK

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Protons are an attractive option in radiation therapy because of their physical properties. They have a sharp fall off in dose at the end of the track and therefore a much reduced dose to surrounding normal tissues. This physical property allows tumoricidal doses to be delivered to the tumor while providing the opportunity to keep adjacent critical structures, especially, the optic nerves, brainstem and temporal lobes of the brain, within tolerance limits.

This presentation will discuss: the selection of patients and disease sub-sites within the head and neck region for proton therapy, immobilization requirements and devices, simulation procedures, special attention to treatment planning and image-guided treatment delivery. In addition clinical examples will be presented to illustrate the underlying principles in the practice of proton therapy in head and neck cancers.

WED-MAR07-2 #534 - Invited Talk - Wednesday 3:30 PM - Pecos I

Proton Radiotherapy for Children

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Overall survival for childhood cancer has improved significantly over the past three decades. It is now apparent that the childhood cancer survivors are at great risk of developing late effects from their therapies including radiation. Organs that have received radiation are at risk of growth retardation, function loss and secondary malignancies.

Proton radiotherapy has potential to provide benefit to selected patients because of the reduction of the integral dose to the body. Because of the reduction of dose to organs distant and and adjacent to the tumor, pediatric patient may have the greatest benefit from proton therapy.

At this time, proton therapy is being used for different childhood malignancies including brain tumors, sarcoma, and retinoblastoma. In general, any patient who has a good chance of overall survival and who requires a significant radiation dose could be considered a candidate for radiotherapy.

Treating children with radiotherapy does require specific consideration. Developing tissues such as bone is at risk of asymmetric growth if treated with a non-uniform dose of radiation, which can be seen with proton therapy. In addition, the daily delivery for very young patients requires anesthesia support, which is not readily available in all situations. Dealing will young patients and their families requires time and patience which also needs to be considered when developing a robust pediatric proton therapy program.

Efforts are underway to establish the role of radiotherapy in these young patients. Single institution and cross institutional databases are being constructed to follow young patients for late toxicity evaluation. It is anticipated that there will be a reduction in late morbidities including secondary malignancies in the future in survivors of childhood cancer with the use of proton therapy.

WED-MAR07-3 #552 - Invited Talk - Wednesday 3:30 PM - Pecos I

Reirradiation With Protons

Markus Fitzer
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Local failure after irradiation of a tumor or the tumor bed can be a devastating event with few reasonable treatment options remaining. The previously irradiated tissues have reduced repair capacity, and severe complications from normal tissue failure are relatively frequent. Limitation of normal tissue exposure thus assumes even greater importance than under circumstances of primary treatment. Protons constitute a valuable addition to the radiotherapeutic armamentarium to re-treat local failures, and in many situations are preferable to conventional x-ray re-treatment. Due to their dose localization properties they are often the only available method to avoid excessive risk from repeated exposure of critical organs. This presentation will review the existing rational, the evidence, and the future potential of re-irradiation with protons in certain body locations, predominantly in the pelvic and head and neck areas.

WED-MAR07-4 #365 - Contributed Talk - Wednesday 3:30 PM - Pecos I

Development of multilayer double ring ionization chamber system for particle therapy

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In order to shorten the measurement time of the depth dose distribution in water, various types of multilayer ionization chamber (MLIC) has been developed. Mostly existing MLIC has a small size of ionization chamber because the purpose of its development is replacement for a water phantom measurement, which has a small detector and moves it step by step. However, the demand for Bragg curve measurement of pencil beam, which requires the larger area size of ionization chamber to cover all lateral profile, is increasing as the resent expansion of pencil beam scanning irradiation technique. Therefore we have been developing multilayer double ring ionization chamber; each layer has a small circular chamber and ring shaped chamber surrounding it. The distinctive feature of this is to measure Bragg curve of pencil beam using sum of circular and ring shaped chambers output and depth dose distribution of passive scattered or actively scanned beam by only small circular ones.

The measurement system consists of the MLIC, range shifter and control units. MLIC consists of 104 parallel-plate double ring ionization chambers and its measurement step is 4mm. Range shifter consists of 5 thin ABS slabs and they are moved individually into and out of the beam path with the control units to measure smaller step width.

Validity test of the measurement system has been successfully conducted using proton beam under collaboration work with University of Tsukuba. The measurement result of Bragg curve of pencil beam has a good agreement with that of reference data acquired by water phantom with large size chamber. Also depth dose distribution was measured and agreed with water phantom measurements within 0.5% at 6cm SOBP region. In both cases, measurement time was shorter than 1/10 of water phantom measurements. The detail result will be presented.

WED-MAR07-5 #535 - Invited Talk - Wednesday 3:30 PM - Pecos I

The new Skandion Clinic in Uppsala. Proton therapy with "Distributed competence"

Erik Blomquist
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The Skandion Clinic will be organized at one central proton treatment facility located at Uppsala University Hospital and about ten collaborating university or other major clinics (home clinics). The Centre will be financed and administrated under shared governance of the collaborating clinics. A core concept will be the distributed radiation oncology and medical physics competence within all participating hospitals supported by advanced information and telemedicine technology.

Every patient will be prepared for the proton therapy at their home clinic but will be discussed in regular distributed teleconferences before proton therapy is prescribed. The intention is that most of the patient treatments should be part of prospective clinical studies and thus treated according to approved clinical protocols. The planning information will be handled over a secured high capacity computer network. Patients will remain under full medical responsibility of the home clinic during and after the proton therapy course. There must be full competence at the Skandion Clinic, however, for taking care of any acute problems arising during the course of therapy

WED-MAR07-6 #537 - Invited Talk - Wednesday 3:30 PM - Pecos I

Particle therapy and medical evidence - the need for clinical trials

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Center for Proton Therapy, Paul Scherrer Institut and University of Zurich, Villigen PSI 5232, Switzerland

Hospital based particle therapy facilities are currently experiencing an exponential growth rate. Compared to conventional photon therapy, particle facilities will remain in the foreseeable future cost intensive. Most comparisons calculate at present a factor in the range of 1.77-2.4 as additional costs of protons compared to photons. There is increasing pressure to link the approval for particle therapy projects with the medical evidence of superior outcome. This presentation will review the present medical evidence on the use of proton therapy for various indications. Although several new facilities have gone online recently, the majority of medical evidence is still based on the few facilities worldwide, that have accumulated long-term outcomes data. The present medical evidence is primarily based on phase I / II prospective studies, prospective data collection or on retrospective data reviews. There is presently no Level I evidence available, i.e. results of a randomized trial comparing directly photon and proton therapy. One issue is the potential ethical conflicts of conducting a phase III trial. The importance of clinical trials as well as currently ongoing trials will be reviewed in detail.

WED-NBA04-1 #463 - Contributed Talk - Wednesday 8:30 AM - Brazos II

Studies of Oxidation and Thermal Reduction of the Cu(100) Surface Using Positron Annihilation Induced Auger Electron Spectroscopy

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The study of adsorption of oxygen on transition metal surface is important for the understanding of oxidation, heterogeneous catalysis, and metal corrosion. The structures formed on oxidized transition metal surfaces vary from simple adlayers of chemisorbed oxygen to more complex structures which result from the diffusion of oxygen into sub-surface regions. Changes in the surface of an oxidized Cu(100) single crystal resulting from vacuum annealing have been investigated using positron annihilation induced Auger electron spectroscopy (PAES). PAES measurements show a large increase in the intensity of the positron annihilation induced Cu M2,3VV Auger peak as the sample is subjected to a series

of isochronal anneals in vacuum up to annealing temperature 300 °C. The intensity then decreases monotonically as the annealing temperature is increased to ~600 °C [1]. In contrast, the O KLL PAES intensity is the lowest at 300 °C and it starts to increase again as the temperature is increased further. Experimental probabilities of annihilation of surface trapped positrons with Cu 3p and O 1s core-level electrons are estimated from the measured intensities of the positron annihilation induced Cu M2,3VV and O KLL Auger transitions. PAES results are analyzed by performing calculations of positron surface states and annihilation probabilities of surface-trapped positrons with relevant core electrons taking into account the charge redistribution at the surface, surface reconstructions, and changes of electronic properties of the surfaces with adsorbed oxygen. Possible explanation is proposed for the observed behavior of the intensity of positron annihilation induced Cu M2,3VV and O KLL Auger peaks and probabilities of annihilation of surface trapped positrons with Cu 3p and O 1s core-level electrons with changes of the annealing temperature.

[1] N.G. Fazleev, M.P. Nadesalingam, W. Maddox, S. Mukherjee, K. Rajeshwar, and A.H. Weiss, Surface Science 604 (2010) 32.

WED-NBA04-2 #423 - Contributed Talk - Wednesday 8:30 AM - Brazos II

Development of high intensity source of thermal positrons at 20 MeV electron linac.

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We wll present an update on positron-facility development at Argonne National Laboratory. We will discuss advantages of using low energy electron accelerator, present our latest results on slow positron production simulations, and plans for further development of the facility.

We have installed a new converter/moderator assembly that is appropriate for our electron energy and that allows increasing the yield about an order of magnitude. We have obtained a Penning trap and buncher from LLNL that we plan to install. We have simulated the relative yields of thermalized positrons as a function of incident positron energy on the moderator. We use these data to calculate positron yields that we compare with our experimental data as well as with available literature data. We will discuss the new design of the next generation positron front end utilizing reflection moderation geometry.

WED-NBA04-3 #523 - Invited Talk - Wednesday 8:30 AM - Brazos II

Oxygen-atom Defects in 6H Silicon Carbide Implanted Using 24 MeV O3+ Ions Measured Using Three-dimensional Positron Annihilation Spectroscopy System (3DPASS)

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Three dimensional electron-positron (e^--e^+) momentum distributions were measured for single crystal 6H silicon carbide (SiC), both virgin and having implanted oxygen-atom defects. 6H SiC samples were irradiated, bombarded with 24 MeV O^{3+} ions at 20 particle-nanoamps at the Sandia National Laboratory's Ion Beam Facility. O^{3+} ions were implanted 10.8 microns deep normal to the (0001) face of one side of the SiC samples. During positron annihilation measurements, the opposite face of the 254.0 μm thick SiC samples was exposed to positrons from a ^{22}Na source. This technique reduced the influence on the momentum measurements of vacancy-type defects resulting from knock-on damage by the O^{3+} ions. A three-dimensional positron annihilation spectroscopy system (3DPASS)[1] was used to measure e^--e^+ momentum distributions for 6H SiC as virgin crystal, O^{3+} irradiated crystal before annealing, and irradiated crystal following annealing. 3DPASS simultaneously measures coincident Doppler-broadening (DBAR) and angular correlation of annihilation radiation (ACAR) spectra. DBAR ratio plots and 2D ACAR spectra are presented. Changes in the momentum anisotropies relative to crystal orientation observed in 2D ACAR spectra for annealed O^{3+} ions irradiated SiC agreed with

computational predictions using Surface Integrated Molecular Orbital/Molecular Mechanics (SIMOMM) which showed that oxygen atoms insert between Si and C atoms, producing a bond slightly distorted (~15^{o}) from the linear Si-C bonding.

WED-NBA04-4 #501 - Contributed Talk - Wednesday 8:30 AM - Brazos II

Positron Annihilation and Electrical Conductivity Studies of Cu Substitution Effect in Li0.5-0.5xCuxFe2.5-0.5xO4 Spinel Ferrite

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Positron annihilation lifetime (PAL), infrared spectroscopy (IR) and electrical conductivity studies were carried out on a series of polycrystalline spinel ferrite with composition Li0.5-0.5xCuxFe2.5-0.5xO4 where (x = 0.2, 0.4, 0.6, 0.8, 1). The lattice parameter a , the radius of the tetrahedral A- sites (rA) and the radius of the octahedral B- sites (rB) were studied as a function of composition. The infrared spectra have been analyzed in the frequency range 200-1000 cm-1 and two bands were observed. The bands around 589 cm-1 (õA) and 400 cm-1 (õB) were assigned to the tetrahedral and octahedral complexes, respectively. For the samples with x= 0.2 and 0.4 the band õL near õB is observed which assigned to Li+-O2- bands on octahedral B-site. With the increase of copper concentration (x> 0.6), the Li+- O2- bands completely disappear. The observed band õV at x= 0.8 and 1.0 was attributed to the lattice vibration. The compositional dependence of the dc electrical conductivity ódc showed a maximum at x= 0.4 then decreases with increasing Cu2+ ions content. This behavior was explained on the basis of the hopping conduction mechanism.

For lifetime measurements, a conventional fast -fast coincidence system with a resolution of 220 ps was used. The recorded lifetime spectra were analyzed in terms of two lifetime components ô1 and ô2 with their relative intensities I1 and I2. The variation in lifetime value is relevant to defect type, while changes in the intensity reflect amount of defect concentration. The variations in positron lifetime parameters with Cu2+ ion substitution are attributed to positron trapping in tetrahedral and octahedral sites. Positrons initially get trapped in the vacancies in the octahedral sites. With doping by Cu2+ ions tetrahedral vacancies dominate as positron trapping sites. With further doping, some of the octahedral sites become vacancies and trap positrons.

WED-NBA04-P1 #333 - Poster - Wednesday 5:30 PM - Rio Grande

Production and characterization of tungsten based positron moderators

Oscar G de Lucio
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Experiments of interest in Atomic Physics require production of well-defined low-energy positron beams through a moderation process of high-energy positrons, which can be produced by either the use of a radioactive source or by accelerator based pair production process. Tungsten is one of the most commonly used moderator materials because of its reasonable efficiency, high work function and low cost. In this work we will present different methods to produce tungsten-based moderators in a variety of shapes. Results from characterizing these moderators by ion beam analysis (RBS, NRA), as well as microscopy techniques (AFM, SEM, EDS) will be presented too. This information along with positron conversion efficiency measurements will allow us to determine which of the methods for producing moderators we present here is the best.

WED-NBA05-1 #138 - Invited Talk - Wednesday 1:00 PM - Brazos II

Positron Annihilation Studies in Membranes and Polymeric Inorganic Nano-Composites

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[(2)]Department of Chemical and Bimolecular Engineering, The Ohio State University, 140 West 19th Ave., Columbus Ohio 43210, United States

Positron annihilation spectroscopy coupled with a variable mono-energy positron beam has been applied to study nano-scale polymeric and membrane systems in recent years. New information about multi-layer depth profiles and structures, glass transition temperatures, pore and free-volume properties has been obtained from the membranes with different substrates. Significant variations of Tg at interface were observed and compared with nanocomposite bulk Tg, which are dependent on strong or weak interactions between polymers and nano-scale substrate surface.

WED-NBA05-2 #272 - Invited Talk - Wednesday 1:00 PM - Brazos II

Vacancies and hydrogen in ZnO - How positrons and accelerators contribute

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Zinc oxide (ZnO) is a wide bandgap transparent semiconductor with tremendous potential in a broad range of applications. Following more than 6 decades of research the reliable production of p-type doped material remains elusive. Positron annihilation spectroscopies were applied to identify the presence of oxygen vacancies in ZnO, which turned red after annealing in Zn vapor hydrogen ambient. Under oxygen poor conditions (sometimes referred to as zinc rich) ZnO may turn red. Methods to indirectly detect positively charged oxygen vacancies and to manipulate the hydrogen content will be discussed. Optical measurements and positron annihilation spectroscopy were applied to ZnO annealed in a range of conditions and compared to 3 MeV proton and deuteron implantation experiments. A consistent, but controversial, picture emerges. Hydrogen occupying oxygen vacancies is the most likely responsible for the red color.

A brief introduction to the capabilities of positron annihilation techniques will be given.

WED-NBA05-3 #465 - Contributed Talk - Wednesday 1:00 PM - Brazos II

Positron annihilation induced Auger electron spectroscopic studies of reconstructed semiconductor surfaces

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Positron probes of semiconductor surfaces that play a fundamental role in modern science and technology are capable to non-destructively provide information that is both unique to the probe and complimentary to that extracted using other more standard techniques. In this talk, we discuss recent progress in studies of the reconstructed surfaces of GaAs and Ge using positron annihilation induced Auger electron spectroscopy (PAES). The positron annihilation induced Auger spectrum from GaAs(100) displays six As and three Ga Auger peaks corresponding to M4,5VV, M2M4V, M2,3M45M45 Auger transitions for As and M2,3M4,5M4,5 Auger transitions for Ga. The PAES spectra measured from Ge(100) and Ge(111) display several strong Auger peaks corresponding to M4,5N1N2,3, M2,3M4,5M4,5, M2,3M4,5V, and M1M4,5M4,5 Auger transitions. Unlike different surfaces of transition metals, the reconstructed (100) and (111) semiconductor surfaces show significantly different PAES intensities. The integrated Auger peak intensities have been used to obtain experimental annihilation probabilities of surface trapped positrons with relevant core electrons. Experimental PAES results are analyzed by performing calculations of positron surface states and annihilation probabilities of surface-trapped positrons with relevant core electrons taking into account the charge redistribution at the surface, surface reconstructions, and electron-positron correlations effects. The orientation-dependent variations of the atomic and electron densities associated with reconstructions are found to affect localization of the positron wave function at the reconstructed surface. Computed positron binding energies and annihilation characteristics demonstrate their sensitivity to crystal face, elemental content, atomic structure of the topmost layers of reconstructed surfaces, and approximations used to describe electron-positron correlations. The results of performed studies are compared with the ones obtained for the reconstructed Si(100)-(2x1) and Si(111)-(7x7) surfaces. The observed crystal face sensitivity of positron annihilation probabilities indicates that PAES could serve as an important surface diagnostic tool capable of distinguishing different surfaces and defining their state of reconstruction.

WED-NBA05-P1 #79 - Poster - Wednesday 5:30 PM - Rio Grande

Correlation of Ortho-Ps Intensity with Doppler Broadening for Rubber Above and Below the Glass Transition Temperature

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Previous research [K. Sato, et al., Phys. Rev. B71 (2005)012201; C. Quarles, et al., Nucl. Inst. Meth. Phys. Res. B 261(2007)875-878] has demonstrated a correlation between the Doppler broadening S parameter and the intensity of the ortho-positronium lifetime component in polymers which depends on the composition of the polymer. On the other hand, rubber polymers do not show this correlation and behave more like liquids for which the S parameter is essentially independent of the ortho-positronium intensity. The bubble model has been suggested as an explanation of the lack of correlation in analogy with liquids, but the bubble model applied to rubber is controversial. There are two important differences between the rubber and the polymers samples: first, the rubber samples at room temperature were all above the glass transition temperature (TG). Second, the rubber samples all contained sulfur and were vulcanized. These differences were investigated by first measuring the S parameter for seven rubber samples below TG where the bubble model would not be expected to work. Second, raw rubber samples, that did not contain any sulfur and were unvulcanized, were studied at room temperature. The results suggest that the lack of correlation is due to the inhibition of Ps formation by the sulfur in the vulcanized rubber samples rather than to the rubber being above TG.

REU student supported by NSF grant PHY-0851558

WED-NBA05-P2 #99 - Poster - Wednesday 5:30 PM - Rio Grande

Positron Annihilation Spectroscopy of High Performance Polymer Films under CO2 Pressure

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[(3)]*PSC, Idaho Falls ID, United States*

Positron annihilation Lifetime and Doppler broadening measurements are reported for six polymer films as a function of carbon dioxide absolute pressure ranging from 0 to 45 psi. The thin films investigated were: TPX (polymethylpentene from Mitsui Chemicals), Ultem 1000 (polyetherimide from GE plastics), Kapton (polyimide from Dupont), Pyre RC ML 5083 (polyimide structure from Industrial Summit Technology Co.), PBI (polybenzimidazole from PBI Performance Products, Inc.) and PBI-TMS (bis(trimethylsilylmethyl)-polybenzimidazole, fabricated at INL*). Since the polymer films were thin and did not absorb all positrons, corrections were made in the lifetime analysis for the absorption of positrons in the positron source and sample holder using the Monte Carlo transport code MCNP. Different polymers are found to behave differently. Some polymers studied form positronium and some, such as the polyimide structures, do not. For those samples that form positronium an interpretation in terms of free volume is possible; for those that don't form positronium, further work is needed to determine how best to describe the behavior in terms of the bulk positron annihilation parameters. Some polymers exhibit changes in positron lifetime and intensity under CO2 pressure which may be described by the Henry or Langmuir sorption models, while the positron response of other polymers is rather insensitive to the CO2 pressure. Results for some polymers depend on the history of the treatment of the sample, and this needs to be investigated further. The results demonstrate the usefulness of positron annihilation spectroscopy in investigating the sorption of CO2 into various polymers at pressures up to about 3 atm.

* Klaehn, J. R., C.J. Orme, T. A. Luther, M. G. Jones, A. K. Wertsching, and E. S. Peterson, 2007, "Soluble N-Substituted Organosilane Polybenzimidazoles," Macromolecules, Vol. 40, p. 7487.

WED-NBA05-P3 #497 - Poster - Wednesday 5:30 PM - Rio Grande

Positronium formation of Glycidyl methacrylic acid (GMA)/ styrene grafted on PVDF membrane for fuel cells

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Simultaneous gamma irradiation was used effectively for facilitation the grafting of glycidyl methacrylic acid and styrene onto polyvinylide fluoride (PVDF). Some factors affecting the grafting were studied such as exposure irradiation dose, dose rate, monomers ratio and different solvent as well. Grafting percent was 188 when monomers ratio are 30% styrene and 70 % glycidyl at 20 KGy and 1.22 Gy/sec. Characterization of the membrane was performed using FTIR, ion exchange capacity (IEC), water uptake and porosity. Mechanical behaviors as tensile strength and hardness beside thermal properties were also investigated using thermal gravimetric analysis (TGA) and differential scanning calorimetry (DSC). Morphological structure of the membrane was studied by scan electron microscope (SEM) while the positronium yield was measured by positron annihilation lifetime spectroscopy (PALS). The high probability of positronium formation enables the application of PALS to the study of free volume and the mechanism of gas permeation to the membrane under investigation. Durability approved the applicability of the membrane from the cost benefit point of view.

WED-NP05-1 #76 - Invited Talk - Wednesday 8:30 AM - Trinity Central

Calorimetry at Very High Energy Colliders

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The capability of hadron colliders has increased to where it will soon be possible to collide protons at center of mass energies of 14 TeV with the advent of the LHC. With increasing collision energy calorimeters become ever more essential components of a detector, and collaborations often choose very different technologies to optimize for their goals. From the perspective of a high energy particle and nuclear physicist, a survey is presented of the differences in design considerations and actual performance of the wide variety of calorimeters used in modern hadron colliders such as the Tevatron, RHIC, and LHC. The lessons learned and some ideas for future development of calorimetry will also be discussed.

WED-NP05-2 #92 - Invited Talk - Wednesday 8:30 AM - Trinity Central

Neutron capture reactions at DANCE

Todd Allen Bredeweg
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The Detector for Advanced Neutron Capture Experiments (DANCE) is a 4π BaF_2 array consisting of 160 active detector elements. The primary purpose of the array is to perform neutron capture cross section measurements on small and/or radioactive species. The measurements made possible with this array will be useful in answering outstanding questions in the areas of national security, threat reduction, nuclear astrophysics, advanced reactor design and accelerator transmutation of waste. Since the commissioning of DANCE we have performed neutron capture cross section measurements on a wide array of medium to heavy mass nuclides. Measurements to date include neutron capture cross sections for several astrophysics branch-point nuclei as well as neutron capture and neutron induced fission cross sections for several actinide isotopes. Results from several of these measurements will be presented to provide an overview of current successes, remaining challenges for future measurements and additional physics information that can be extracted from DANCE data including prompt γ-ray multiplicities and energy spectra as well as resonance spin assignments for certain nuclear species.

Work was performed under the auspices of the U.S. Department of Energy by Los Alamos National Security, LLC (contract DE-AC52-06NA25396) and Lawrence Livermore National Security, LLC (contract DE-AC52-07NA27344).

WED-NP05-3 #46 - Invited Talk - Wednesday 8:30 AM - Trinity Central

The neutron time-of-flight facility n_TOF at CERN

Frank Gunsing, for the n_TOF Collaboration
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Neutron induced reaction cross sections play an important role in a wide variety of research fields, ranging from stellar nucleosynthesis, symmetry breaking effects in compound nuclei, nuclear level density studies, to applications of nuclear technology, including the transmutation of nuclear waste, accelerator driven systems and nuclear fuel cycle investigations.

Neutron-induced reactions are studied at the neutron time-of-flight facility n_TOF at CERN. The facility uses a pulsed 20 GeV/c proton beam impinging on a lead spallation target. The large neutron energy range and the high instantaneous neutron flux combined with high resolution are among the key characteristics of the facility.

After a first phase of data taking during the period 2001-2004, the facility has been refurbished with an upgraded spallation target and cooling system for a second phase of data taking which started in 2009.

During the 2009-2010 winter shutdown the experimental area has been modified in order to meet the requirements for a work sector of type A. This will allow the extension of the physics program to include neutron-induced reactions on radioactive isotopes.

The status and technical characterstics of the facility, its instrumentation, and the foreseen experimental programme will be discussed.

WED-NP05-4 #142 - Contributed Talk - Wednesday 8:30 AM - Trinity Central

Using Quasi-Monoenergetic Photon Sources to Probe Photo-Fission Resonances

Micah S Johnson[1], James M Hall[1], Dennis P McNabb[1], Mohammed Ahmed[2], Sean Stave[2], Henry Weller[2]
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Quasi-monoenergetic photon sources are being developed to provide higher fluxes and lower bandwidths. These sources may be game-changers in the national security sector to detect special nuclear material (SNM) in various containers. Many efforts are underway to study the efficacy of using these sources with processes such as nuclear resonance fluorescence (NRF) to detect, map, and assay containers for isotopes of interest. LLNL is part of a large collaboration to study NRF. However, LLNL is also part of a collaboration to look at photo-fission signatures with very intense, low-bandwidth sources to detect SNM. One of the major benefits of using low bandwidth sources is noise reduction. Photo-fission is appealing because of its higher signal rate compared to NRF. We will present our efforts to exploit quasi-monoenergetic photon sources with photo-fission for SNM detection. We will discuss recent photo-fission measurements at the HIGS facility.

*This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344

WED-NP05-5 #229 - Invited Talk - Wednesday 8:30 AM - Trinity Central

Thermalization of projectile fragments at NSCL

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Gas stopping techniques have been developed and used to thermalizing high-energy beams of rare isotopes produced via projectile fragmentation and in-flight separation at the NSCL. The thermalized beams have been used to perform precision mass measurements of a wide range of chemical elements that are very difficult to obtain with ISOL techniques. The NSCL in constructing two beam lines to thermalize fast beams of short-lived rare isotopes in a linear gas cell for mass measurements, laser spectroscopic studies, and for reacceleration. The NSCL plan for the next generation devices includes two linear gas cells in the near term and the construction of a novel gas-filled reverse cyclotron in the longer term. The general layout and plans for the NSCL gas-stopping stations will be discussed.

WED-NP06-1 #269 - Invited Talk - Wednesday 1:00 PM - Trinity Central

Recent results on R&D of the SPES production target

Alberto andrighetto
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The SPES project at the Laboratori di Legnaro of INFN (Italy) is concentrating on the production of neutron-rich radioactive nuclei produced by the fission of uranium at a rate of 10E13 fission/s. The emphasis to neutron-rich isotopes is justified by the fact that this vast territory has been little explored, with the exception of some decay and in-beam spectroscopy following fission. The Rare Ion Beam (RIB) will be produced by the ISOL technique using proton-induced fission on a Direct Target of UCx. The most critical element of the SPES project is the Multi-Foil Direct Target. Currently, the proposed target represents an innovation in terms of capability to sustain irradiation with a high-power primary production beam. The design is carefully oriented to optimize the radiative cooling, taking advantage of the high operating temperature of 2000 C. During this talk the development of ISOL production targets for the SPES project will be presented including recent developments on the fabrication, characterization, and on-line testing of uranium carbide targets. Also, developments related to the ion-source activities using the surface ion source technique will be reported. Finally, results of the simulations of the thermal behavior of the target system dissipating 10 kW of power will be shown.

WED-NP06-2 #477 - Invited Talk - Wednesday 1:00 PM - Trinity Central

Radioactive Ion Beam Production Capabilities at the Holifield Radioactive Ion Beam Facility

James R Beene, Darryl T Dowling, Carl J Gross, Raymond C Juras, Yuan Liu, Martha J Meigs, Anthony J Mendez, Witek Nazarewicz, John W Sinclair, Daniel W Stracener, B Alan Tatum
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The Holifield Radioactive Ion Beam Facility (HRIBF) is a national user facility for research with radioactive ion beams (RIBs) that has been in routine operation since 1996. It is located at Oak Ridge National Laboratory (ORNL) and operated by the ORNL Physics Division. The principal mission of HRIBF is the production of high quality beams of short-lived radioactive isotopes to support research in nuclear structure physics and nuclear astrophysics. HRIBF is currently unique worldwide in its ability to provide neutron-rich fission fragment beams post-accelerated to energies above the Coulomb barrier for nuclear reactions.

HRIBF produces RIBs by the isotope separator on-line (ISOL) technique using a particle accelerator system that consists of the Oak Ridge Isochronous Cyclotron (ORIC) driver accelerator, one of the two Injectors for Radioactive Ion Species (IRIS1 or IRIS2) production systems, and the 25-MV tandem electrostatic accelerator that is used for RIB post-acceleration.

ORIC provides a light ion beam (proton, deuteron, or alpha) which is directed onto a thick target mounted in a target-ion source (TIS) assembly located on IRIS1 or IRIS2. Radioactive atoms that diffuse from the target material are ionized, accelerated, mass selected, and transported to the tandem accelerator where they are further accelerated to energies suitable for nuclear physics research. RIBs are transported through a beam line system to various experimental end stations including the Recoil Mass Spectrometer (RMS) for nuclear structure research, and the Daresbury Recoil Separator (DRS) for nuclear astrophysics research. HRIBF also includes two off-line ion source test facilities, one low-power on-line ISOL test facility (OLTF), and one high-power on-line ISOL test facility (HPTL).

This paper provides an overview and status update of HRIBF, describes the recently-completed $4.7M IRIS2 addition and incorporation of laser systems for beam production and purification, and discusses a proposed replacement of the ORIC driver accelerator.

WED-NP06-3 #277 - Invited Talk - Wednesday 1:00 PM - Trinity Central

Recent Developments in the Handling of Actinide Targets at ISOLDE

Richard Catherall
ISOLDE, CERN, Geneva, Switzerland

The On-Line Isotope Mass Separator ISOLDE is a facility dedicated to the production of a large variety of radioactive ion beams for a great number of different experiments, e.g. in the field of nuclear and atomic physics, solid-state physics, life sciences and material science. The facility is located at the Proton-Synchrotron Booster (PSB) of CERN, Geneva, Switzerland.

At ISOLDE, radioactive nuclides are produced in thick high-temperature targets via spallation, fission or fragmentation reactions. The targets are placed in the external proton beam of the PSB, which has an energy of either 1.0 or 1.4 GeV and an intensity of about 2 microA. The target and ion-source together represent a small chemical factory for converting the nuclear reaction products into a radioactive ion beam.

Uranium carbide as a target material represents up to 60% of all targets produced at ISOLDE throughout the operational period. Furthermore, the successful production rate of fission products from actinide targets continues to stimulate research and development in view of optimizing both target material properties and geometries.

In order to satisfy the legislative constraints and to ensure a safe working environment for the handling of actinide material as an open source, the ISOLDE facility has built a Class A type laboratory. This paper will draw upon the experiences gained through the production of uranium carbide targets in the Class A laboratory over the last 5 years and will give an insight into planned future developments as part of an upgrade of the target area and the conditioning of radioactive actinide material.

WED-NP06-4 #394 - Invited Talk - Wednesday 1:00 PM - Trinity Central

Production and Recovery of Heavy Isotope Target Material at Oak Ridge National Laboratory

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The High Flux Isotope Reactor (HFIR) and the Radiochemical Engineering Development Center (REDC) at Oak Ridge National Laboratory (ORNL) were built in the mid-1960's as integral parts of the National Heavy Element Program. From 1965 through 2004, the HFIR and the REDC (with the collaboration of the Savannah River Site) produced, recovered and

distributed virtually all the transplutonium isotopes (Am-243 through Fermium-257) used in the western world. The REDC mission changed to suppport USDOE fuel cycle efforts. A number of heavy element targets continued to be irradiated.The production and recovery of the Cf-252 presented an opportunity to recover Bk-249. Through lab-directed funding, the Bk-249 was made available to a Joint Institute for Nuclear Research (Russian Federation)-LLNL-ORNL collaboration to discover element 117.

The production and recovery of the Bk-249 used for this experiment will be reviewed. In addition, the opportunity for future Bk-249 campaigns, optimization of Bk-249 production and the potential for producing Cf-250, Cf-251 and Es-254 targets will be discussed.

WED-NP07-1 #475 - Invited Talk - Wednesday 3:30 PM - Trinity Central

The Fundamental Neutron Physics Program at the SNS

Paul R Huffman
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The Fundamental Neutron Physics Beamline (FnPB) at the SNS will be used to investigate fundamental symmetries such as parity and time reversal invariance and the manner in which they are violated. This facility is designed to accommodate two classes of experiments: cold neutron experiments that require intense, polychromatic beams and ultracold neutron experiments in which neutrons of ~1 meV are "down-converted" to near zero energy in superfluid liquid helium. The experiments proposed for the FnPB facility include precise measurements of the parameters describing neutron beta decay, studies of the quark-quark weak interaction, and the search for a neutron electric dipole moment. I will overview the current status of the commissioning of the beamline and provide an overview of the first experiments that will take data on the two beamlines.

WED-NP07-2 #4 - Contributed Talk - Wednesday 3:30 PM - Trinity Central

Neutron resonance spin determination using multi-segmented detector DANCE.

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A highly sensitive method to determine the spin of neutron resonances is introduced based on the statistical pattern recognition technique. The new method was used to assign the spins of *s*-wave resonances in ^{155}Gd and the generalization of the technique was tested on *s*- and *p*-wave resonances in ^{94}Mo and ^{95}Mo.

The experimental neutron capture data for these nuclei were measured with the DANCE calorimeter at the Los Alamos Neutron Science Center. The highly segmented calorimeter provided detailed multiplicity distributions of the capture γ-rays. Using this information, the spins of the neutron capture resonances were determined. The results were compared with previous resonance data. With these new spin assignments and resonance parameters, level spacings and neutron strength functions are determined separately for *s*-wave resonances with J = 1 and 2.

This work was supported in part by U.S. DOE grants No. DE-FG52-09NA29460
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U.S. DOE under contracts Nos. DE-AC52-07NA27344 and DE-AC52-06NA25396.

WED-NP07-3 #297 - Invited Talk - Wednesday 3:30 PM - Trinity Central

An Active Target-Time Projection Chamber for Reactions Induced by Rare Isotope Beams

Wolfgang Mittig
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The 1995, 2002 and 2007 Long Range Plans for nuclear physics identified opportunities at rare isotope beam facilities to determine the properties of nuclei and nuclear matter in the unexplored domain of extreme isospin asymmetry as priority research areas for the field. The knowledge of these properties will provide answers to questions concerning the nature of neutron stars and dense nuclear matter, the origin of the elements in the cosmos, and the nuclear reactions that drive stars and stellar explosions. Realizing these opportunities at present and future rare isotope facilities requires highly sensitive scientific instruments that can overcome low rare isotope beam intensities and low cross sections for the processes of interest.

We are developing an Active Target-Time Projection Chamber (AT-TPC) to be used to study reactions induced by rare isotope beams at the National Superconducting Cyclotron Facility (NSCL) and at the future Facility for Rare Isotope Beams (FRIB). As the name implies, the AT-TPC will operate in two different modes. In the active target mode, the AT-TPC counter gas acts as both a target and detector, allowing investigations of fusion, isobaric analog states, cluster structure of light nuclei and transfer reactions to be conducted without significant loss in resolution due to the thickness of the target. The high efficiency and low threshold of the AT-TPC will allow investigations of fission barriers and giant resonances with fast fragmentation rare isotope beams. Operating the AT-TPC in the detector mode, the reaction products created in collisions between isospin asymmetric heavy ions will uniquely allow the density dependence of the nuclear equation of state to be explored simultaneously both above and below saturation density.

The detector and its electronics are developed in an international collaboration. The layout of the detector together with some results with prototype electronics will be shown.

WED-NP07-4 #302 - Contributed Talk - Wednesday 3:30 PM - Trinity Central

Actinide Neutron-Induced Fission Cross Section Measurements at LANSCE

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Fission cross sections of a range of actinides have been measured at the Los Alamos Neutron Science Center (LANSCE) in support of the Fuel Cycle Research program (FC R&D). By combining measurements at two LANSCE facilities, the Lujan Center and the Weapons Neutron Research center (WNR), differential cross sections can be measured from sub-thermal energies up to 200 MeV. Incident neutron energies are determined using the time-of-flight method. Ratios of counting rates from investigated and reference targets in parallel-plate fission ionization chambers were used to measure fission cross sections relative to the ^{235}U standard. The actinide targets with thin, <200 μg/cm^2, actinide deposits were prepared at Idaho National Laboratory. Measurements include the ^{237}Np, ^{233,238}U, $^{239-242}$Pu and ^{243}Am neutron-induced fission cross sections. Data for ^{237}Np and ^{239}Pu were used as benchmarks to validate the employed method. It was concluded that a re-evaluation of the ^{243}Am fission cross section for the ENDF library is recommended to get more realistic energy dependence above 15 MeV. The experimental data for ^{237}Np has already been used in a new ENDF evaluation of the fission cross section in the fast region, where a large discrepancy between the ENDF and JENDL evaluations was resolved. The measured ^{241}Pu fission cross section is also discrepant with the current ENDF evaluation in the fast region, and a re-evaluation is recommended for this isotope as well.

This work has benefited from the use of the Los Alamos Neutron Science Center at the Los Alamos National Laboratory. This facility is funded by the US Department of Energy and operated by Los Alamos National Security, LLC under contract DE-AC52-06NA25396.

WED-NP07-5 #304 - Contributed Talk - Wednesday 3:30 PM - Trinity Central

Absolute np and pp Cross Section Determinations Aimed at Improving the Standard for Cross Section Measurements

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The *np* scattering cross section is used as a *primary* standard in measurements of neutron-induced nuclear reactions, which is why confidence in its evaluation is extremely important. The absolute cross sections for both *np* and *pp* scattering below 1000 MeV are determined based on partial-wave analysis (PWA) of nucleon-nucleon scattering data from the George Washington (GW) Data Analysis Center. Total cross sections are compared with the most recent ENDF and JENDL data files, and the Nijmegen PWA. Systematic deviations from the ENDF and JENDL evaluations are found to exist. In the energy region below 20 MeV, ENDF is systematically below GW PWA results with the deviation less then 1%, whereas the GW PWA and JENDL agree within 0.5%. Above 180 MeV, GW PWA *np* cross sections are larger than the JENDL/HE evaluation by up to 5%. Comparison of the *np* evaluation with the recent LANL total *np* cross section data in the energy range from 9 to 500 MeV, which was not used in the evaluated database, will be discussed. Excellent agreement within nearly 1% was found between the LANL measurement and PWA prediction.
This work was supported in part by the U.S. Department of Energy under grant DE-FG02-99ER41110.

R.A. Arndt Deceased.

WED-RE05-1 #456 - Invited Talk - Wednesday 8:30 AM - West Fork

Ion or electron irradiation effects of metallic glasses

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Metallic glasses are attracting increasing attention due to their excellent mechanical properties (e.g., high strength and large elasticity), good corrosion resistance and, in some cases, exceptional soft magnetic properties. This has facilitated the development of widespread applications, including medical and electronic devices, sporting goods or advanced defense and aerospace technologies. However, the absence of microstructure in monolithic bulk metallic glasses can cause marked strain localization and rapid shear-band propagation, which results in brittle fracture and catastrophic failure of such materials. The disappointingly poor ductility limits the extensive practical applications. Introducing nano- or micro-scale crystalline phases into the metallic glassy matrix which leads to the formation of multiple shear bands has been proposed to enhance ductility of bulk metallic glasses.

Recently, metallic glass alloys have been of great interest not only as structural and functional materials but also as precursors to obtain nanocrystalline composites. The nanocrystallization of the glassy phase can be realized by ion or electron irradiation, as well as some other methods such as heat treatment, electropulsing, high pressure, etc. In this paper, we will review the recent results on the nanocrystallization studies of the Cu-based, Zr-based and Fe-based metallic glassy alloys induced by ion or electron irradiation.

WED-RE05-2 #279 - Invited Talk - Wednesday 8:30 AM - West Fork

Kinetically evolving irradiation-induced point defects in UO2 from moledcular dynamics simulation

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The evolution of irradiation-induced point defects in UO2 is captured using a new molecular dynamics (MD) approach that circumvents the ballistic phase of the traditional collision-cascade MD simulation but rather focuses only on the kinetic evolution of point defects. The simulations reveal that in the absence of defects on the cation sublattice, the defects initially present on the anion sublattice recombine and annihilate completely during equilibration. In contrast, the defects initially present only on the cation sublattice do not recombine due to their high migration energies. Moreover, they further nucleate new anion point defects. However, in the simultaneous presence of defects on both sublattices, vacancy Schottky defects are formed, thereby sequestering the oxygen vacancies. The resulting excess oxygen interstitials form cuboctahedral clusters, whose existence has previously been identified experimentally but the generation mechanism has not been determined. It is concluded that the cation sublattice is primarily responsible for the radiation tolerance or intolerance of the material.

WED-RE05-3 #155 - Invited Talk - Wednesday 8:30 AM - West Fork

Computational Studies of Radiation Damage near Grain Boundaries in Copper

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We have used three atomistic modeling methods that span different time scales -- molecular dynamics, temperature accelerated dynamics, and molecular statics -- to investigate radiation-induced damage production and subsequent defect annealing near tilt grain boundaries in copper. The short-time (picoseconds) defect production is modeled by molecular dynamics simulations, and the resulting damaged structures are used as the input for long-time defect annealing studies via temperature accelerated dynamics simulations. Molecular statics calculations are used for calculating the thermodynamic properties of defects. We find that grain boundaries have a surprising "loading-unloading" effect. In the defect production stage, interstitials are loaded into the grain boundaries while vacancies remain trapped in the bulk. In the defect annealing stage, interstitials are unloaded from the grain boundaries and emitted back to the bulk to annihilate vacancies with relatively low barriers compared to conventional vacancy diffusion. The combination of this newly found interstitial emission mechanism and conventional vacancy diffusion help explain the different radiation tolerance of nanocrystalline and polycrystalline materials under different conditions.

WED-RE05-4 #343 - Invited Talk - Wednesday 8:30 AM - West Fork

Glass Ceramic Study for Advanced Waste Form Development

Ming Tang[1], Anna-Eden Kossoy-Simakov[1], Meng Zhou[1], James Vadlez[1], Gordon Jarvinen[1], Kurt Sickafus[1], Jarrod Crum[2], Laura Turo[2], Kevin Fox[3], Amanda Billings[3], Kyle Brinkman[3], James Marra[3]
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The safe and effective disposal and/or reuse and recycling of nuclear wastes has become a crucial issue in our increasingly globalized society. An important component of the United States Department of Energy (DOE) Fuel Cycle Research and Development (FCR&D) program involves the development of advanced nuclear waste. In this presentation, we report on a project to develop glass ceramic waste forms for fission products obtained from spent nuclear fuel. This is a collaborative project among Savannah River National Laboratory (SRNL), Pacific Northwest National Laboratory (PNNL), and Los Alamos National Laboratory (LANL).

For this project, we are using a borosilicate glass as matrix in which to incorporate fission products such as Cs/Sr (CS), lanthanides (LN) and transition metal (TM) elements. We are currently developing two glass ceramics: (1) a borosilicate glass matrix with crystalline precipitates of one phase (this is titanate phase incorporating either CS/LN or CS/LN/TM mixtures); (2) a borosilicate glass matrix with multiple precipitated crystalline phases (e.g., oxyapatite, pollucite, and celsian). We performed High-spatial resolution characterization of these glass ceramics using transmission electron microscopy (TEM) in order to relate to resultant microstructural characteristics (including crystallite size, composition, structure, and distribution in the glass matrix) with processing procedures. We will also discuss results of electron and light ion irradiation experiments, which we are using to test the stability and durability of these glass ceramic waste forms.

WED-RE05-5 #348 - Contributed Talk - Wednesday 8:30 AM - West Fork

Light ion irradiation effects on stuffed Lu2(Ti2-xLux)O7-x/2 (x=0, 0.61 and 0.67) structures

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We have recently synthesized "stuffed" (i.e., excess Lu) Lu2(Ti2-xLux)O7-x/2 (x=0, 0.61 and 0.67) compounds using conventional solid state synthesis methods. X-ray diffraction measurements indicate that stuffing more Lu3+ cations into the oxide structure leads eventually to an order-to-disorder transition, from an ordered pyrochlore to a disordered fluorite crystal structure. At the maximum deviation in stoichiometry (x=0.67), the Lu3+ and Ti4+ ions become completely randomized on the cation sublattices, and the oxygen "vacancies" are randomized on the anion sublattice. Lu2(Ti2 xLux)O7 x/2 (x=0, 0.61 and 0.67) samples were irradiated with 400keV Ne++ ions to fluences ranging from 2x1014 - 5x1015 ions/cm2 at cryogenic temperature (77K). Ion irradiation effects in these samples were examined using grazing incidence X-ray diffraction (GIXRD) and transmission electron microscopy (TEM). The results are discussed within the framework of two considerations: (1) crystalline structure; and (2) the Lu2O3-TiO2 phase diagram.

WED-RE05-P1 #192 - Poster - Wednesday 5:30 PM - Rio Grande

Radiation Effect on Gas Electron Multiplier Detector Performance

Kwang June Park, Seongtae Park, Jaehoon Yu, Andrew White
Physics, University of Texas at Arlington, 701 S. Nedderman Drive, Arlington TX 76019, United States

It has been well-known that polymer materials can be damaged by exposure to radiation. When they are used in a device or a measurement equipment as a component in a radiation environment, effects of radiation should be understood for safe operation of system. In this study, radiation effects were evaluated for some small double-GEM (Gas Electron Multiplier) detectors which are similar to the ones being developed at CERN (Conseil Europeen pour la Recherche Nucleaire) and at UT Arlington used in high energy particle detectors. The GEM foils in these detectors include a polymer material named as "Kapton (polyimide film)" for the electrical insulation between their electrodes. In this study, five small double-GEM detectors were constructed, and some performance tests, such as gain HV dependence, atmospheric pressure dependence and others, were carried out. And then the eight GEM foils in four detectors were irradiated together with the Kapton film samples in a gamma irradiation facility to the dosages of 10kGy, 100kGy, 1,000kGy and 10,000kG. The electronic signals of reassembled GEM detectors after irradiation of GEM foils were measured and analyzed periodically, and also the electrical and chemical properties of irradiated-Kapton films were analyzed by the four-point probe, FTIR spectrometer, etc. according to the elapsed time. Finally, the radiation effects were evaluated by comparing the analysis results of the irradiated GEM detectors and Kapton films with those of the detector with unirradiated GEM foils and Kapton films in electronic signal gain, electrical property and chemical structure.

WED-RE06-1 #54 - Invited Talk - Wednesday 1:00 PM - West Fork

Swift heavy ion irradiation of embedded metal nanoparticles

M C Ridgway[1], R Giulian[1], D J Sprouster[1], P Kluth[1], L L Araujo[1], D J Llewellyn[1], A P Byrne[1], F Kremer[2], P F Fichtner[2], G Rizza[3], H Amekura[4], M Toulemonde[5]
(1)Australian National University, Canberra, Australia
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Swift heavy ion irradiation of silica and a variety of other materials results in the formation of a molten ion track when the energy transferred to the lattice is sufficient to melt the matrix. Elemental metal nanoparticles embedded in a matrix of

silica undergo a spherical to rod-like shape transformation when irradiated with swift heavy ions, with the direction of elongation aligned to that of the incident ion beam. The transformation is cumulative, typically necessitating hundreds of ion-track overlaps. Large and once spherical nanoparticles become progressively more rod-like yet are subject to dissolution and fragmentation. Small nanoparticles below a critical diameter remain spherical and do not elongate but instead dissolve in the matrix. For this report, we combine transmission electron microscopy, x-ray absorption spectroscopy and small-angle x-ray scattering to examine the shape transformation for a variety of metals with the aim of achieving mechanistic insight into the transformation process. We identify subtle metal-specific differences. For example, the width of elongated nanoparticles saturates at a value comparable to the critical diameter for transformation and is well correlated with the metal melting temperature and energy required for vaporisation. Furthermore, we show the elongation process necessitates the formation of a molten ion track in the silica matrix. This track confines nanoparticle elongation and as a consequence the saturated nanoparticle width does not exceed the molten ion track diameter.

WED-RE06-1 #54 - Invited Talk - Wednesday 1:00 PM - West Fork

Swift heavy ion irradiation of embedded metal nanoparticles

M C Ridgway[1], R Giulian[1], D J Sprouster[1], P Kluth[1], L L Araujo[1], D J Llewellyn[1], A P Byrne[1], F Kremer[2], P F Fichtner[2], G Rizza[3], H Amekura[4], M Toulemonde[5]
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[(3)]*Ecole Polytechnique, Palaiseau, France*
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Swift heavy ion irradiation of silica and a variety of other materials results in the formation of a molten ion track when the energy transferred to the lattice is sufficient to melt the matrix. Elemental metal nanoparticles embedded in a matrix of silica undergo a spherical to rod-like shape transformation when irradiated with swift heavy ions, with the direction of elongation aligned to that of the incident ion beam. The transformation is cumulative, typically necessitating hundreds of ion-track overlaps. Large and once spherical nanoparticles become progressively more rod-like yet are subject to dissolution and fragmentation. Small nanoparticles below a critical diameter remain spherical and do not elongate but instead dissolve in the matrix. For this report, we combine transmission electron microscopy, x-ray absorption spectroscopy and small-angle x-ray scattering to examine the shape transformation for a variety of metals with the aim of achieving mechanistic insight into the transformation process. We identify subtle metal-specific differences. For example, the width of elongated nanoparticles saturates at a value comparable to the critical diameter for transformation and is well correlated with the metal melting temperature and energy required for vaporisation. Furthermore, we show the elongation process necessitates the formation of a molten ion track in the silica matrix. This track confines nanoparticle elongation and as a consequence the saturated nanoparticle width does not exceed the molten ion track diameter.

WED-RE06-2 #469 - Invited Talk - Wednesday 1:00 PM - West Fork

Swift Heavy Ion Beam Shaping of Au and Ge Nanoparticles in SiO_2

Bernd Schmidt[1], Karl-Heinz Heinig[1], Arndt Muecklich[1], Chavkat Akhmadaliev[1], Mark Ridgway[2], Patrick Kluth[2]
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Lasers can process materials at spatiotemporal μm and ps scales. Here it will be shown that swift heavy ions can be used for materials processing at even shorter length and time scales.
Swift-heavy-ion-induced deformation of spherical Au and Ge nanoclusters (NCs) embedded in SiO_2 was studied experimentally and theoretically. Ge NC shaping is size dependent under irradiation with 38 MeV iodine ions and with 89 and 185 MeV gold ions. Large NCs don't deform, smaller ones become discus-shaped, and very small ones show Ge loss at their equator. Small Au NCs deform into rods and wires, and, rather exotic, at critical NC size Au wires are squeezed out of the poles of the Au spheres.
Modeling and atomistic computer simulations identified the main driving forces: (i) The materials dependent electronic stopping power, (ii) the volume change upon melting, (iii) the asymmetric hydrodynamic flow due to stress field hysteresis, as well as (iv) far-from-equilibrium steady-state solubilities and strongly anisotropic diffusion. The latter one leads to "Ostwald ripening" of deformed NCs. The NC size distributions, shapes and anisotropies can be tailored by appropriate tuning of the driving forces.

Our model describes the ion-induced shape evolution of different elements for different ion species, energies and fluences even quantitatively, where only one fit parameter describes all experiments. It is based on classical thermodynamics and hydrodynamics only.
An even stronger proof is the shape change of nanospheres of critical size under swift heavy ion irradiation. For such particles, exclusively central ion impacts induce shaping, where Au is squeezed out of the poles. Using an unimodal size distributions and changing the ion impact angle during irradiation, tailoring of very exotic nanoparticle shapes become feasible.

WED-RE06-3 #172 - Invited Talk - Wednesday 1:00 PM - West Fork

Coupling High-pressure Cells with Large Ion Accelerators: solids at extreme conditions

Maik Lang[1], Beatrice Schuster[2], Fuxiang Zhang[1], Jiaming Zhang[1], Jianwei Wang[1], Christina Trautmann[2], Rodney C Ewing[1]
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Important progress has been achieved in utilizing temperature and pressure to manipulate the properties of materials. Ion-beam techniques provide a standard means to induce nanoscale phase transformations. Here, we describe a new strategy of combining high-pressure techniques with ion beams by injecting relativistic ions from one of the world's largest accelerator facilities (GSI - Helmholtz Centre for Heavy Ion Research - Darmstadt, Germany) through a mm-thick diamond anvil of a high-pressure cell into a pressurized target [1,2]. This provides the unique opportunity to investigate the behavior of materials at extreme conditions and opens up unprecedented possibilities for the synthesis of new materials. The combined use of advanced *in situ* (synchrotron X-ray diffraction and Raman spectroscopy) and *ex situ* (transmission electron microscopy) characterization techniques revealed that the ion irradiation (45-GeV uranium) of gadolinium-zirconate pyrochlore ($Gd_2Zr_2O_7$) under a pressure up to 40 GPa ions results in the stabilization of a new metastable high-pressure phase. This phase cannot be obtained by irradiation or pressure applied separately. Ion-beam exposure of zirconia (ZrO_2) at up to 60 GPa demonstrates that ion-induced energy depositions into highly compressed materials are able to induce transformations into high-pressure and high-temperature phases at unexpected low pressures and/or radiation fluence. A set of experiments have been completed for zircon ($ZrSiO_4$) that showed that the coupling of high-pressure cells and ion accelerators is a powerful tool to access a wide spectrum of geoscience applications from nanoscale simulations of fission-track formation under crustal conditions to phase transitions of radiation-damaged minerals resulting from meteorite impact.

[1] M. Lang, F.X. Zhang, J.M. Zhang, J.W. Wang, B. Schuster, C. Trautmann, R. Neumann, U. Becker, R.C. Ewing, Nature Materials 8 (2009) 793.

[2] M. Lang, F.X. Zhang, J. Lian, C. Trautmann, R. Neumann, and R.C. Ewing, J. Synchrotron Rad. 16 (2009) 773.

WED-RE06-4 #210 - Invited Talk - Wednesday 1:00 PM - West Fork

Molecular dynamics simulation of nanoscale phase transitions induced by swift heavy ions in ceramics

Ram Devanathan
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We have used massively parallel molecular dynamics simulations, using the thermal spike model, to examine the creation of swift heavy ion tracks in ceramics. The simulations examined energy deposition up to 15 keV/nm in zircon, forsterite, urania and pyrochlore. Our results show that there is a threshold energy loss below which tracks are not produced. This threshold depends on the material composition. The damage recovered efficiently in UO_2 and $Gd_2Zr_2O_7$ leaving behind a crystal with a few defects, while amorphous tracks were produced in Mg_2SiO_4, $ZrSiO_4$ and $Gd_2Ti_2O_7$. The track radius was not dependent on the initial thermal spike radius. The results provide atomic-level insights into track formation and will be discussed in light of experimental observations.

WED-RE06-5 #316 - Contributed Talk - Wednesday 1:00 PM - West Fork

Swift Ions Implanted Optical Waveguides in Chalcogenide Glass

Feng Qiu, Tadashi Narusawa
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Swift ion implantation is chosen to generate optical waveguides in amorphous materials, for the first time as far as we know. Ar^{4+} ions with energy of 60MeV and dose of 2×10^{12} ions/cm^2 are used to fabricate chalcogenide glass waveguides in this work. Compared with the standard implantation procedure, our implantation is much more efficient, because only very small dosages are required due to a large electronic energy cross section of swift heavy ions. Furthermore the range of ~13μm for Ar^{4+} ions is essential for the waveguides used in infrared wavelength region. The refractive index profiles of resultant waveguides have shown a "well + barrier" distribution, and non-leaky modes have been observed. These are evidences of well confined light propagation, and strongly suggest a possibility of channel waveguide fabrication by simply adding standard photolithographic procedures.

WED-RE07-1 #34 - Invited Talk - Wednesday 3:30 PM - West Fork

Review of in situ transmission electron microscopy investigation of radiation effects

Jonathan Andrew Hinks
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Transmission electron microscopy (TEM) allows the internal microstructure of materials to be imaged at a resolution not offered by any other type of instrument. When coupled to an ion accelerator, it is possible to explore the dynamic effects of ion irradiation whilst also maintaining experimental parameters such as temperature. This combination of TEM with in situ ion irradiation produces a powerful and unique technique enabling the formation and evolution of radiation damage to be studied as it occurs - rather than just the end-states offered by ex situ investigations. In this way, the fundamental atomistic processes at work in samples under irradiation can be explored.

There are currently around eleven TEMs with in situ ion irradiation in operation around the world with a range of capabilities. A brief history of the development of these instruments will be given along with a discussion of their key features and construction. An overview of the new facility recently established at the University of Salford will also be presented.

Applications include investigations into materials for use in fission and fusion reactors, radioactive waste storage, semiconductor processing and devices for deployment in, for example, extraterrestrial environments. Experimental results will be presented on a range of materials to illustrate the usefulness of the technique and as examples of some of the unique insights it can deliver into the responses of materials to ion irradiation.

WED-RE07-2 #68 - Invited Talk - Wednesday 3:30 PM - West Fork

In-situ RBS channelling studies of ion implanted semiconductors and insulators

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The experimental set-up at our institute allows the performance of Rutherford backscattering spectrometry (RBS) in channelling configuration at temperatures between 15 K and room temperature. The target chamber is connected to both a 3 MV Tandetron accellerator providing the analysing ions and a 400 kV implanter. Therefore, ion implantation and subsequent channelling analysis by RBS can be done without changing the environment or the temperature of the sample.

In this paper the set-up is described and advantages and possible problems are discussed. The capability of the set-up is demonstrated by various examples.

Doing RBS channelling studies at 15 K increases the sensitivity to defects, because the influence of lattice vibrations is reduced. Thus, the very early processes of ion induced damage formation can be studied and the cross section of damage formation per ion in virgin material can be determined. In AlAs, GaN, and ZnO this cross section can be used to estimate an upper level of the displacement energy for the heavier component, which were found to be in reasonable agreement with other experiments or theoretical calculations.

At 15 K ion-beam induced damage formation itself can be investigated, because the occurrence of thermal effects can be widely excluded. This gives the possibility to analyse the damage cross section as a function of various fundamental properties of the materials in order understand the origin of their different susceptibility to ion beam induced damaging. This is done for nine different III-V compound semiconductors.

Applying the computer code DICADA to calculate the depth distribution of displaced lattice atoms, indirect information about the type of defects produced during ion implantation at 15 K can be obtained. In some materials like GaN or ZnO the results indicate the formation of extended defects and thus suggest some kind of defect mobility even at 15 K.

WED-RE07-3 #433 - Invited Talk - Wednesday 3:30 PM - West Fork

Using Reflective High Energy Electron Diffraction to monitor in-situ ion irradiation effects in materials

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We have a developed a novel way to observe materials crystal structure changes (or lack thereof) in-situ while performing ion irradiations. To do this, we are using a reflection high electron diffraction (RHEED) instrument. In-situ ion irradiation monitoring techniques provide valuable information while performing ion irradiations of materials. By using in-situ monitoring techniques to track ion irradiation effects, the materials "live" irradiation response is seen real time, therefore allowing researchers to stop irradiating at precise fluences when phase transformations (order-disorder and amorphization) occur. After irradiation, microstructural changes produced in the samples observed using RHEED can be examined in detail with higher precision characterization techniques such as transmission electron microscopy (TEM) and grazing incidence X-ray diffraction (GIXRD), to fully assess the materials ion irradiation response. Preliminary results obtained from in-situ RHEED ion irradiation experiments at both cryogenic and room temperature on various materials (both single crystal and polycrystalline) will be discussed and compared with results obtained from ex-situ characterization techniques. Also discussed will be the experimental apparatus developed, sample requirements for these experiments, and the pros and cons in using RHEED in this fashion.

WED-RE07-4 #198 - Contributed Talk - Wednesday 3:30 PM - West Fork

Characterization of structural modifications caused by swift heavy ions using in-situ XRD (X-Ray Diffraction) in zircon and scheelite phases of ThGeO4

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We demonstrate the use of insitu X-ray diffraction to study the structural modifications in swift heavy ion irradiated materials. Structural modifications in the zircon and scheelite phases of ThGeO4 induced by swift heavy ions (93 MeV Ni7+) at different fluences as well as pressure quenching effects are reported. X-ray diffraction and Raman measurements at room temperature on the irradiated zircon phase of ThGeO4 indicate the occurrence of stresses that lead to a reduction of the cell volume up to 2% followed by its transformation to a mixture of nano-crystalline and amorphous scheelite phases.

Irradiation of the zircon phase at liquid nitrogen temperature induces amorphization at a lower fluence (7.5e1016 ions/m2), as compared to that at room temperature (6e1017 ions/m2). Scheelite type ThGeO4 irradiated at room temperature undergoes complete amorphization at a lower fluence of 7.5e1016 ions/m2 without any volume reduction. The track radii deduced from x-ray diffraction measurements on room temperature irradiated zircon, scheelite and low temperature irradiated zircon phases of ThGeO4 are, 3.9 nm, 3.5 nm and 4.5 nm, respectively. X-ray structural investigations on the zircon phase of ThGeO4 recovered after pressurization to about 3.5 and 9 GPa at ambient temperature show the coexistence of zircon and disordered scheelite phases with a larger fraction of scheelite phase occurring at 9 GPa. On the other hand, the scheelite phase quenched from 9 GPa shows crystalline scheelite phase pattern.

WED-SSCD03-1 #500 - Contributed Talk - Wednesday 8:30 AM - Pecos II

High Energy Protons for Remote Standoff Detection of SNM Utilizing a Compact Superconducting Cyclotron

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High energy protons can be a powerful probe for standoff detection of SNM. In particular, the use of protons of 500 MeV and up can be far more efficient in the production of fission neutrons than conventional bremmstrahlung based electron linacs. Proton beams can provide both the range and, more importantly, the sensitivity to fissile materials required for remote detection at distances of hundreds of meters or more. The practical application of this technique has been limited by the requirements of producing such high energy protons using conventional proton accelerators which are typically very large, fixed installations. The development at MIT of a new generation of very compact superconducting cyclotrons makes a compelling case for this approach for a practical standoff detection system where large numbers of neutrons can be produced in a target object using an accelerator with ~ 1 GeV energy and beam currents in the 10 to 100 microA. We will describe current work in the design of such an accelerator and make estimates of sensitivity to reasonable amounts of fissile material.

WED-SSCD03-2 #414 - Invited Talk - Wednesday 8:30 AM - Pecos II

Medium energy accelerators for Neutron generation and other applications

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In cooperation with major Israeli laboratories, the Physikalisch Technische Bundesanstalt Braunschweig and other cooperation partners RI is involved in a research and development program aimed at developing next-generation transmission-imaging systems that can detect standard and improvised explosives as well as special nuclear materials, concealed within items ranging in size from mail parcels and passenger bags to air-cargo containers, private and small-commercial vehicles. Such systems combine high-spatial resolution Fast-Neutron Resonance Radiography and Dual Discrete-Energy gamma-Radiography, in a single, concomitant screening sequence.
This system requires a medium energy accelerator as a radiation source for Neutron and gamma's. Within the presentation possible technical solutions will be discussed. The discussion will include aspects as availability, reliability and maintainability of those solutions, with view on its use in safety, security and contraband detection. As the development of such a system including required prototypes ask for substantial invest other applications requiring similar technical parameters will be addressed.

WED-SSCD03-3 #361 - Contributed Talk - Wednesday 8:30 AM - Pecos II

Nuclear-Reaction-Based Radiation Source for Explosives- and SNM-Detection in Massive Cargo

Michal Brandis[1,3], Volker Dandendorf[2], Ilan Mor[1], David Vartsky[1], Benjamin Bromberger[2], Israel Mardor[1], Eliahu Friedman[3], Kai Tittelmeier[2], Mathias Weierganz[2], Mark Benjamin Goldberg[1,2]
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An ion-accelerator/nuclear-reaction-based radiation source, for use in radiographic cargo inspection systems that will detect small, operationally-relevant quantities of explosives and special nuclear materials (SNM: ^{239}Pu and highly-enriched-^{235}U) as well as chemical explosives, is presented. Such systems would be cost-effective, employing largely-common hardware. Detection of all threat materials is performed simultaneously via the ^{11}B(d,n+γ) reaction on thick, isotopically-enriched targets. SNM-detection is primarily effected via Dual Discrete-Energy Radiography (DDER), the probes being the 15.11 and 4.43 MeV γ-rays. Explosives are primarily detected via Pulsed Fast Neutron Transmission Spectrometry (PFNTS), the probes being the broad-energy neutron spectra produced in the thick target.

As a first step towards optimizing conditions and sensitivities of an operational system, the 0° spectra and yields of both γ-rays and neutrons in the above reaction have been extended to cover a broad range of incident deuteron energies, from 2-12 MeV.

Contrary to previous expectations that deuteron beams of 3-4 MeV might be adequate, it is now clear that 5-7 MeV beams will give rise to significantly better system performance. Moreover, in the light of recent progress in developing compact, cost-effective ion-accelerators, the prospects for such systems seem appreciably brighter than they were several years ago.

WED-SSCD03-4 #307 - Invited Talk - Wednesday 8:30 AM - Pecos II

Status and Prospects of Vacuum Insulated Tandem Accelerator (VITA)

A. S. Kuznetsov, Yu. I. Belchenko, A. V. Burdakov, V. I. Davydenko, A. A. Ivanov, S. G. Konstantinov, K. I. Mekler, A. L. Sanin, I. N. Sorokin, Yu. S. Sulyaev, S. Yu. Taskaev
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The technique for explosives detection using gamma ray resonance absorption in nitrogen was studied by various researchers, see for example [1, 2]. The 9.17 MeV gamma rays required for this method are generated in ^{13}C(p,γ)^{14}N reaction and resonantly absorbed in nitrogen in the inverse reaction ^{14}N(γ,p)^{13}C. The is an interest to check experimentally the possibility to realize this method in a real device using the novel vacuum insulated tandem accelerator of protons at BINP with designed current up to 5 mA, proton energy up to 2.5 MeV and high energy stability ~0.7% [3].

To carry out the experiments we designed several kinds of graphite targets enriched with ^{13}C carbon. The experiments were carried out with proton beam current up to 2.8 mA. To increase the sensitivity and resolution of gamma registration system the detector with big BGO crystal of ø80×100 mm was used. The idea to use a non resonant spectral line to normalize the resonant attenuation has allowed us to get all necessary information using only one detector.

Results of experiments allow us to estimate, that parameters of the registration system and the proton beam reached already appear to be sufficient to detect the 5 kg melamine simulant in real time. The concept of moving target with radiation cooling, suitable for usage with a powerful proton beam is suggested. Tests with an explosive simulants are planned.

1. D.Vartsky, M.B.Goldberg, R.E.Morgado, et al. *The Total Width of the 9.17-MeV Level in 14N.* // Nuclear Physics A505 pp. 328-336 (1989).

2. T.J.T.Kwan, K.J.Bowers, et al. *Bulk explosives detection using nuclear resonant absorption technique.* // Plasma Science, p. 396, 2003.

3. B.Bayanov, A.Burdakov, et al. *First neutron generation in the BINP accelerator based neutron source.* // Applied Radiation and Isotopes, Volume 67, Issues 7-8, Supplement 1, pages S285-S287 (July 2009).

WED-SSCD03-5 #287 - Contributed Talk - Wednesday 8:30 AM - Pecos II

Performance Characteristics of an Intensity Modulated Advanced X-Ray Source (IMAXS) for Homeland Security Applications

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X-ray cargo inspection systems for the detection and verification of threats and contraband must address competing performance requirements. High X-ray intensity is needed to penetrate dense cargo, while low intensity is desirable to minimize the radiation footprint, i.e. the size of the controlled area, required shielding and the dose to personnel. In a collaborative effort between HESCO/PTSE Inc., Schonberg Research Corporation, XSCell Corp., Stangenes Industries, Inc. and Rapiscan Laboratories, Inc., an Intensity Modulated Advanced X-ray Source (IMAXS) was designed and produced. Cargo inspection systems utilizing such a source have been projected to achieve up to 2 inches greater penetration capability, while on average producing the same or smaller radiation footprint as present fixed-intensity sources. Alternatively, the design can be used to obtain the same penetration capability as with conventional sources, but reducing the radiation footprint by about a factor of three. The key idea is to anticipate the needed intensity for each x-ray pulse by evaluating signal strength in the cargo inspection system detector array for the previous pulse. The IMAXS is therefore capable of changing intensity from one pulse to the next by an electronic signal provided by electronics inside the cargo inspection system detector array, which determine the required source intensity for the next pulse. We report on the completion of a 9 MV S-band (2998 MHz) IMAXS source and comment on its performance.

This project was funded under a Phase II SBIR award from DHS/DNDO.

WED-SSCD03-6 #207 - Contributed Talk - Wednesday 8:30 AM - Pecos II

Intense Photoneutron Sources for Nuclear Material Detection

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Intense neutron sources are essential for cargo inspection for a broad range of threats from explosives, to contraband and nuclear material and especially SNM (Special Nuclear Materials).

To be effective over a wide range of cargo materials, in particular for hydrogenous cargo such as food, and to offer practical inspection times the neutron source must be very strong, typically >1e10 neutrons per second. Unfortunately there are currently no reasonably compact and economical neutron generators with the required intensities. The insufficiency and inadequacy of intense neutron sources is especially conspicuous at, or below the 2.5MeV energy range (low voltage (d,D) generator). This energy range is needed if the strong signature of prompt fission neutrons (approximately 3/fission) is to be detected and discerned from the numerous source neutrons.

The photonuclear reactions of x-rays from commercial linacs in appropriate converters with a low (gamma,n) energy threshold such as 1.67MeV for Be and 2.23MeV for D, can provide ample intensities of neutrons. The intense x-ray beams more than compensate for the relatively low (gamma,n) cross-sections (millibarns).

The choice of converter, its shape, dimensions and location relative to the x-ray source determine the neutron intensity per electron linac. For <10MeV linac both preferred converters, Be and D2O, are also very good neutron moderators. For example, increasing converters' thickness increases the neutron yield, but causes softening of the neutron spectrum, which in turn reduces the neutron penetrability especially in hydrogenous cargos.

Photoneutron sources can be optimized to meet specific needs such as maximum fission signals in range of cargo materials of interest. Efficient photoneutron sources with different spectra were designed. Conversion efficiency of about

2e-4 neutron per 9MeV electron (e.g. >1e11n/s average intensity for COTS 100microAmp linac) has been modeled and designed. The simulation was validated in laboratory experiments. These and other results will be discussed.

WED-SSCD03-7 #230 - Contributed Talk - Wednesday 8:30 AM - Pecos II

Simulation of a Photofission-Based Cargo Interrogation System

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Commercial high energy x-ray linacs (e.g. 9 MV) commonly used for radiographic inspection of cargo can also be a powerful tool for the detection of illicit nuclear materials. The intensity of the x-ray beams delivered by such machines combined with detection of the strongest fission signatures with novel efficient detectors compensates for the low photofission cross sections. Such a system is being designed.

A comprehensive model has been developed to characterize and optimize the detection of Bremsstrahlung x-ray induced fission signatures from nuclear materials hidden in cargo containers. An effective active interrogation system should not only induce a large number of fission events but also efficiently detect the fission signatures. The proposed scanning system utilizes a 9 MV commercially available linac and the detection of strong fission signals i.e. delayed gamma rays and prompt neutrons. Because the scanning system is complex and the cargo containers are large and often highly attenuating, the simulation method segments the model into several physical steps, representing each change of radiation particle. Each approximation is carried-out separately, resulting in a major reduction in computational time and a significant improvement in tally statistics.

The model investigates the effect on the fission rate and detection rate by various cargo types, densities and distributions. Hydrogenous and metallic cargos, homogeneous and heterogeneous, as well as various locations of the nuclear material inside the cargo container were studied. We will show that for the photofission-based interrogation system simulation, the final results are not only in good agreement with a full, single-step simulation but also with experimental results, further validating the full-system simulation.

WED-SSCD03-P1 #132 - Poster - Wednesday 5:30 PM - Rio Grande

Monte Carlo Simulations of the Response of Shielded SNM to a Pulsed Neutron Source

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Active interrogation (AI) has been used as a technique for the detection and identification of Special Nuclear Material (SNM) for both proposed and field-tested systems. Idaho National Laboratory (INL) has been studying this technique for systems ranging from small systems employing portable electronic neutron generators (ENGs)[1] to larger systems employing linear accelerators as high-energy photon sources for assessment of vehicles and cargo[2]. In order to assess the feasibility of new systems, INL has undertaken a campaign of Monte Carlo simulations of the response of a variety of masses of SNM in multiple shielding configurations to a pulsed neutron source using the MCNPX[3] code, with emphasis on the neutron and photon response of the system as a function of time after the initial neutron pulse. We present here some preliminary results from these calculations.

1. D.L. Chichester and E.H. Seabury, " Using Electronic Neutron Generators in Active Interrogation to Detect Shielded Nuclear Material," *IEEE Transactions on Nuclear Science* **56** (2009) pp 441-447.

2. J.L. Jones et al., "Photonuclear-based, nuclear material detection system for cargo containers," *Nuclear Instruments and Methods in Physics Research B* **241** (2005) pp 770-776.

3. D.B. Pelowitz, "MCNPX™ User's Manual version 2.6.0," Los Alamos National Laboratory Report LA-CP-07-1473 (2008).

WED-SSCD03-P2 #349 - Poster - Wednesday 5:30 PM - Rio Grande

Photon Probe Beam Diagnostics and Characterization for Detection of Special Nuclear Material

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Our goal is to detect special nuclear material (SNM) that could be used to form a nuclear explosive device. We are interested in both nonproliferation and forensics applications and have been investigating the use of bremsstrahlung photon beams to stimulate fissions in SNM. For either application, the confidence levels of the mass determination depend equally on (1) the uncertainty of the signature (neutron or gamma-ray) measurement and (2) the uncertainty of the fission-stimulating photon probe intensity. To date, the photon probe intensity has been calculated from the electron beam current measurement and the electron beam energy setting (as set by a bending magnet current). In experiments to date the calculated dose agreed with the measured dose in many cases, but in some the beam operation needed to be tuned up before agreement was achieved. The objective of the work described here is to develop a direct photon beam intensity measurement for real time photon beam monitoring. As a proof-of-principle test, we chose to use an available gated intensified charge-coupled device (ICCD) camera and a 2 mm thick fast plastic scintillator to actively monitor the photon beam for a forensics application. Useful measurements of the beam profile were obtained and during sample irradiations, the ICCD images confirmed sample alignment in real time. Due to the usefulness of the data obtained, we are currently investigating how to best implement the scintillator photon beam measurement on a routine basis and have identified radiation hardened scintillator materials that appear to be suitable for this application.

WED-SSCD03-P3 #459 - Poster - Wednesday 5:30 PM - Rio Grande

Inverse compton scattering gamma ray source for standoff detection of special nuclear materials

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Special Nuclear Materials (e.g. U-235, Pu-239) can be detected by active interrogation with gamma rays (>6 MeV) through photofission. For long-range detection (~1 km), an intense beam of gamma rays (~10^14 per second) is required

in order to produce a measurable signal of neutrons. The production of such fluxes of gamma rays, and in the pulse formats useful for detection, presents many technical challenges, and requires novel approaches to the accelerator and laser technology. RadiaBeam is currently designing a gamma ray source based on Inverse Compton Scattering (ICS) from a high-energy electron beam. To achieve this, improvements in photoinjector, linac, final focus, and laser system are planned. In this paper, we describe these improvements, as well as an ongoing project to demonstrate key aspects of the our design at the BNL ATF.

WED-SSCD04-1 #11 - Invited Talk - Wednesday 1:00 PM - Pecos II

Lessons Learned in Developing the VACIS Products

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SAIC's development of VACIS provides useful "lessons learned" in bridging the gap from an idea to a security or contraband detection product. From a gamma densitometer idea for solving a specific Customs Service (CS) requirement (detection of drugs in near-empty tanker trucks) in mid-1990's, SAIC developed a broad line of vehicle and cargo inspections systems (over 400 systems deployed to date) based on a gamma-ray radiographic imaging technique. This paper analyzes the reasons for the successful development of VACIS and attempts to identify "lessons learned" useful for future security and contraband detection product developments.

A prime reason that VACIS succeeded was that it addressed a high priority requirement of the customer: CS needed a more effective means of inspecting cargo entering the country. A summary of lessons learned is as follows:

? Insure that product idea addresses a real-world requirement

? Demonstrate performance meets user requirements

? Work closely with the user to adapt the product to the user's needs (for example, working with CS, VACIS' niche application for tanker truck inspection expanded to cargo containers, trucks, railcars, and cargo pallets

? Identify other users for the product (for example, VACIS is being used in Iran and Afghanistan by the military for force protection.)

? Identify potential challenges facing development as early as possible and address (e.g., ability of CS inspectors to safely handle ~ 1 Curie Co-60 source in VACIS was demonstrated as was ability of source container to withstand explosion for force protection application)

? Develop infrastructure to support product (for example, responsive maintenance service)

Paper provides examples from VACIS development illustrating these lessons learned.

WED-SSCD04-2 #166 - Invited Talk - Wednesday 1:00 PM - Pecos II

The Dummies Guide to High Tech Entrepreneurship

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A large number of high tech companies have been established to commercialize a new technology that has been developed by scientists at universities and research facilities. Some of them are successful, but many do not bridge the perilous gap from idea to useful product. While having a great idea for a technology-based product is necessary, it is by no means sufficient. This is particularly true for those scientists who have an entrepreneurial spirit and want to try to "do it on their own". This talk is based on the "real world" experiences and lessons learned from a number of successful companies that have "been there - done that" on this challenging path.

WED-SSCD04-3 #45 - Invited Talk - Wednesday 1:00 PM - Pecos II

Development and Commercialisation of a Fast-Neutron/X-ray Scanner for Air Cargo

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There is a pressing world-wide need for a technology that can rapidly scan air freight containers for a range of threats, including explosives, narcotics, CBRN materials and other contraband. The time-critical nature of air cargo and the large numbers of containers handled daily at major airports dictate scan times of a few minutes or less. The diverse range and small size, often <0.1% of total cargo mass, of threat items requires high resolution imaging and computer-assisted human image interpretation.

Starting in 2002, CSIRO developed the FNGR scanning concept that combines fast-neutron and high-energy gamma-ray or x-ray radiography. The scans can be processed to produce high-resolution radiographic images that show both areal density and composition. Compared to conventional dual-energy x-ray scanning, fast neutron radiography allows a much wider range of material classes to be identified.

The FNGR concept was demonstrated in the laboratory in 2003 and a full-scale system was constructed and used operationally in an extended field trial at Brisbane Airport, Australia during 2006-7. Critical to the success of the prototype were the use of commercially proven radiation sources and the development of low-cost, reliable radiation detectors.

Following the completion of the trial, a world-wide search was conducted for a suitable commercialisation partner and an agreement was signed with Nuctech Company Ltd, China early in 2008. The following year, a commercial prototype unit was demonstrated that combined neutron and x-ray technologies from the two partners to achieve significantly higher image quality and scanning speeds.

This paper reviews the scientific, technological and commercial developments that have been critical to the development of the Air Cargo Scanner. Future developments, particularly on the man-machine interface and the automation of the threat detection process are discussed.

WED-SSCD04-4 #204 - Invited Talk - Wednesday 1:00 PM - Pecos II

Bridging the Gap between Idea & Product-The VEDS story

Tsahi Gozani
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The distance between an idea and a product may be anything from a bridgeable gap to a real chasm. This space is precipitously affected by the process one goes through between the cause (be it the idea or the desired product) and the effect (be it a desired product or an idea which will lead to it).

A product, which is well defined and specified, with clear inputs from the potential customer, marketing specialists and technical experts, has a much better chance of seeing the light of day and being successful, than starting from a (possibly great) solution and looking for a problem to match it. The latter approach is often the approach taken wittingly or unwittingly by scientists, leading in many cases to a disappointing dead end. On the other hand, following the "proper" product development road map, prescribed in text books and lectured in corporate halls, though more efficient, does not guarantee the successful development of a product either. There are many real reasons (and excuses) for this situation. These can include the customer's (or their marketing interface's) inability to articulate what they want, changing specifications, raising expectations, insufficient R&D efforts, promising or accepting unattainable requirements and then failing in (often) adversarial acceptance tests etc. etc.

So a relevant question is: what are the necessary ingredients, in addition to luck, to transform an idea to a product, particularly in the inspection business?

We will take an, at times (and only in hindsight), amusing stroll through the history of our VEDS (Vehicular Explosive Detection System) product line as a concrete example or rather a metaphor for "Bridging the gap between idea and a product".

WED-SSCD04-5 #338 - Invited Talk - Wednesday 1:00 PM - Pecos II

Considerations in starting a high-tech business

Robert J Ledoux
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You have a great new idea for a product or service. Your prior background is as a scientist or engineer with little or no prior business experience. Should you start a company to commercialize your idea? What are the considerations that are important in this decision? The author's experiences of getting started in a new high-tech business venture will be discussed; forming a team, raising capital, and managing government and corporate relations. Some observations of the pros and cons of embarking on a new enterprise and thoughts on the personal implications of such a decision will be presented.

WED-SSCD04-6 #531 - Invited Talk - Wednesday 1:00 PM - Pecos II

Achieving Commercial Success in a Non-commercial Market

Mark John McCarthy
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The security business is not driven by traditional market forces alone, especially when it comes to the acquisition of technology-based capital equipment. The concepts of supply-and-demand and cost-to-benefit do not always apply in their conventional forms when government is a major stakeholder. To execute an effective strategy for achieving commercial success, providers of threat-detection solutions must consider the unique and shifting demands on decision-makers within government funding, test & evaluation, acquisition, and end-user groups. In this presentation, some guidelines for funding acquisition, product development, sales and marketing, and protection of intellectual property are proposed. We also examine some recent examples of product introductions, and suggest lessons to be learned by their success or failure.

THU-AP07-1 #293 - Invited Talk - Thursday 8:30 AM - Elm Fork

Projectile-Wave Diffraction in High-Energy Electron-Capture from Atomic and Molecular Targets

Reinhold Schuch[1], M. Gudmundsson[1], H. Cederquist[1], N. Haag[1], H.A.B. Johansson[1], D. Misra[1], P. Reinhed[1], H. T. Schmidt[1], K. Stockel[3], D. Fischer[2]
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The particle-wave duality, inherently fundamental to quantum mechanics, is often illustrated by double slit and diffraction experiments. The experiments reported here elucidate the quantum interference in the final projectile state after reactions necessarily involving one or two active electrons in a one- and two-center scatterer. We demonstrate, in particular, the interference effects arising after single and double electron capture of p and He++, respectively, from H2 or He [1-3]. With the molecular target, the interference phenomena reveal in a direct way the dominance of localized electron capture. The outgoing hydrogen waves of £f=25 fm[1] or He wave[3] are shown to be superpositions of contributions from the vicinities of either protons in H2. In capture by protons from an atomic target (He), we separate the kinematical (KTI) and Thomas transfer ionization processes by means of recoil-ion momentum spectroscopy at the gas-jet target in the storage ring CRYRING. The ratio ?ãKTI/(?ãSC+?ãTI), where ?ãTI and ?ãSC are the total transfer ionization and single-electron capture cross sections, respectively, decreases with the velocity and approaches the asymptotic limit of the double-to-single ionization ratio in (non-Compton) photoionization (1.66 %), and there ?ãTI as well ?ãSC scales, as predicted, as vE-11 [1]. We also discuss here additional features of single capture by protons from He: the width and shapes of the forward peaks in d?ãSC/d£[are independent of collision energy. It will be shown that this can be seen as diffraction of the de Broglie waves for the proton capturing an electron from He.

[1] H.T. Schmidt et al. Phys. Rev. Lett. 101, 083201 (2008)

[2] H.T. Schmidt et al. P. R. L. 89, 163201-1, 2002, D. Fischer et al. Phys. Rev. A81, 012714 (2010)

[3] D. Misra et al. P. R. L. 102, 153201 (2009)

THU-AP07-2 #174 - Invited Talk - Thursday 8:30 AM - Elm Fork

Characterization of the metastable D_2^- ion in storage ring experiments

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The metastable states of the D_2^- ion were studied using fast-beam single-molecule photofragment imaging. The recorded distributions of energy release allow conclusions on internuclear distance and rotational state of the strongly rotating anions. Time-resolved measurements on a stored ion beam allow to follow these properties for varying relative state populations.

The long-debated existence of metastable states
of anionic hydrogen molecules was recently confirmed
by Golser *et al.* [Phys. Rev. Lett. **94**, 223003 (2005)].
Apart from the fundamental interest in this simplest molecular anion,
the negative diatomic hydrogen system plays a crucial role in a
number of collision processes of importance in fields ranging from
astrophysics to nuclear fusion technology.

The metastable states, for which lifetimes in the microsecond range
have been measured [Phys. Rev. A **73** 060501(R) (2006)], are described theoretically as highly rotationally excited systems, where the centrifugal barrier shifts the potential energy minimum to large internuclear distances thus preventing fast autodetachment [Phys. Rev. A **75**, 012507 (2007)].

To characterize these exotic states experimentally, we have performed photodissociation studies on a keV beam of D_2^- using fragment and electron momentum imaging. The kinetic energy release of the emerging D atoms is composed to a large extent of rotational energy, therefore the experiments are sensitive to both the internuclear distance and the rotational state of the anions.

By storing the molecular ion beam in an electrostatic storage ring for variable times prior to initiating the photofragmentation process, ion ensembles with different rovibrational state compositions could be studied.
The results from the present experiment will be discussed in the light of available theoretical predictions and data from other types of experiments.

THU-AP07-3 #278 - Invited Talk - Thursday 8:30 AM - Elm Fork

Cold chemistry with fast ion and electron beams

Henrik Buhr[1,2], Claude Krantz[1], Mario B Mendes[1], Christian Nordhorn[1], Oldrich Novotný[1,3], Dmitry A Orlov[1], Dirk Schwalm[1,2], Julia Stützel[1], Annemieke Petrignani[1], Andrey Shornikov[1], Andreas Wolf[1]
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In storage ring experiments at the ion cooler ring TSR in Heidelberg, Germany, we study electron collisions with molecular ions in merged beams at relative velocities down to the meV (10 Kelvin) level. With diatomic as well as small polyatomic systems, the breaking of the molecular ions through the binding of an electron is investigated. Collisions are prepared at resolved energies by changing the relative speed between electron and ion beams, and individual reactions occurring in the merged beams interaction region are detected and kinematically analyzed by fast-beam coincidence fragment imaging. Experiments are reported from recently studied heavier diatomic and small polyatomic systems. The merged electron beams are produced with cryogenic GaAs photocathodes and were recently also shown to yield fast phase-space cooling of the heavy and correspondingly slow stored molecular ion beams. Multiparticle imaging is used to reconstruct the molecular fragmentation events. In CF+, a rich spectrum of capture resonances due to excited ionic cores is found, together with a rapid energy-dependent switching of the electronic state of the C fragment (3P or 1D). The HF+ ion, through an accidental quasi-degeneracy of the initial and the final levels, yields H(n = 2) + F+ fragments with kinetic energy releases as low as 5 meV, which reflect the rotational levels of HF+ and are resolved in the fragment imaging observations. For polyatomic ion fragmentation, the fragment imaging has been combined with individual fragment mass identification implementing an energy-sensitive multi-strip surface-barrier detector (EMU). It measures with near-unity efficiency the masses of all fragments together with their hit positions in multi-particle events. This device allows internal molecular excitations to be derived for individual chemical channels in polyatomic fragmentation. New results will be presented in particular on D3O+ and for the breakup of DCND+ into its isomeric fragment channels CND and DCN.

THU-AP07-4 #282 - Invited Talk - Thursday 8:30 AM - Elm Fork

Using the Paul Ion Trap for Trace Species Detection in Space flight

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Some of the most critical tasks for mass spectrometry are determining the major and trace components of a complex gas mixture, as well as accurate measurement of isotope ratios. Each of these tasks requires different levels of accuracy and sensitivity. A Paul Trap is used as the mass spectrometer of choice. Presented in this talk will be a compact gas chromatograph/Paul trap that can perform these tasks within a single portable unit. The different modes used to trap and eject the ions will be presented, and discussed in terms of the ion dynamics.

THU-AP07-5 #524 - Invited Talk - Thursday 8:30 AM - Elm Fork

Metallic Magnetic Calorimeters: New Developments and Applications

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Cryogenic particle detectors such as metallic magnetic calorimeters (MMCs) have rapidly advanced in their performance in recent years and are now applied in a wide range of experiments from high resolution x-ray detection to neutrino mass measurements. MMCs are composed by an energy absorber, optimized for the particles to be detected, in good thermal contact with a metallic paramagnetic sensor positioned in a weak magnetic field. A change in the sensor magnetisation follows the change of the detector temperature. High energy resolution can be obtained by using a low-noise, high-bandwidth DC-SQUID to measure the corresponding change of flux. Fully micro-fabricated MMC detectors operated below 100 mK are now available for x-ray detection with an energy resolution of 2.7 eV at 6 keV. We will discuss the basic principle of such detectors and their optimization for different applications. In particular, the status of development for MMCs arrays with multiplexed readout and MMC based position sensitive detectors will be presented. In addition, we will show the results of current applications of MMCs.

THU-AP07-P1 #296 - Poster - Thursday 3:00 PM - Rio Grande

Artificially Structured Boundary For Antihydrogen Studies

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Research associated with artificially structured boundaries is reported. An artificially structured boundary is defined at present as one that produces a spatially periodic static field, such that the spatial period and range of the field is much smaller than the dimensions of a cloud, plasma or beam of charged particles that is confined by the boundary. The possibility of developing an alternative to the nested Penning trap for producing antihydrogen from trapped antiprotons provides an underlying motivation for the research. Such an alternative should allow lower energy antihydrogen atoms to be formed. Antihydrogen is currently produced at the CERN Antiproton Decelerator using nested Penning traps. The antiproton kinetic energy associated with various drifts within the nested Penning traps may be too large for conducting studies such as CPT and gravity tests using antihydrogen synthesized from the antiprotons. However, it may be possible to trap non-drifting antiprotons using an artificially structured boundary. One configuration being studied is a modified Kingdon trap, which would employ an artificially structured boundary at the inner electrode. The artificially structured boundary would produce a multipole magnetic field that keeps particles from reaching the inner electrode. The magnetic field would be sufficiently short in range to affect the particle trajectories only in close proximity to the inner electrode. The conditions for producing such a magnetic field have been assessed. The results indicate that a magnetic field that is sufficiently short in range to affect the particle trajectories only in close proximity to the inner electrode must be an octupole or higher order field. A preliminary discussion of antihydrogen studies that may be possible with an artificially structured boundary is provided in: [C. A. Ordonez, Journal of Applied Physics 106 (2009) 024905.]

THU-AP07-P2 #453 - Poster - Thursday 3:00 PM - Rio Grande

Energy transfer between ions and electrons in a strong magnetic field

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An analytical model for strongly magnetized collisions is developed and applied to investigate the energy loss of ions interacting with cold and warm electrons under a strong magnetic field. In this model, the strong magnetization constrains the momentum transfer to one dimension (that which is parallel to the magnetic field). Thus, collisional energy transfer is dominated by short-range collisions. This result is remarkably different from the unmagnetized case, which has been studied elsewhere [1]. The theoretical expectations are compared with previous [2] and new computer simulations. The agreement reveals that the model captures important features of the interaction of electrical charges of disparate masses

(i.e., ions and electrons, antiprotons and electrons, etc). Furthermore, the analytical expressions derived using this model can be quickly calculated and thus, they may prove to be a good alternative to computer simulations when computing the energy loss rates of two species interacting under a strong magnetic field within the applicable parameter space. This research is motivated by experiments being conducted at CERN aimed at creating and confining antihydrogen [3,4]. In these experiments, energetic antiprotons are cooled by collisions with electrons within a strong magnetic field. Subsequently, these cold antiprotons are made to interact with positrons under a strong magnetic field leading to some recombination.

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3. M. C. Fujiwara, M. Amoretti, et. al. Phys. Rev. Lett. 101, 053401 (2008)

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THU-AP08-1 #408 - Invited Talk - Thursday 1:00 PM - Elm fork

Using Microcalorimeters to Study Highly Charged Ions

Eric Silver[1], John Gillaspy[2], Nancy Brickhouse[1], Ting Lin[1], Joseph Tan[2], Joshua Pomeroy[2], Martin Laming[3], Guo-Xin Chen[1], Elliot Kanter[4], Joseph McDonald[5], Dieter Schneider[6], Robert Dunford[4], Linda Young[4], Thomas Stöelker[7], Jeffrey Beeman[8]

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[(8)]Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley CA 94720, United States

High resolving power, a bandwidth that can span 0.1-120 keV and low internal background are the hallmarks of cryogenic X-ray microcalorimeters. Initially developed for future satellite-borne spectroscopy of cosmic X-ray and Gamma ray sources such as black holes, supernova remnants and clusters of galaxies, we are now using microcalorimeters for a wide range of applications on Earth. These include laboratory astrophysics studies of highly charged ions in an electron beam ion trap, measurements of the hydrogenic and helium -like heavy ions in storage rings, industrial applications where high resolution x-ray spectroscopy is important to materials and chemical analysis, and biological and medical science explorations of cell metabolism and structure. We will discuss the important features of our detector technology as they pertain to experiments with stored highly charged ions.

THU-AP08-2 #202 - Invited Talk - Thursday 1:00 PM - Elm fork

Ion neutralization energy as a tool for modifying electronic materials

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The "exotic" properties of HCIs have attracted an increased scientific audience since relatively small instruments, like the electron beam ion trap (EBIT), have enabled HCI production with relative ease and without the need for large accelerator facilities. HCIs trapped in the rest frame of the laboratory allow a wide range of spectroscopic activities with relevance to fusion power and laboratory astrophysics. These spectroscopy activities, in turn, motivate extracted HCI-matter interaction

studies as models for solar wind interactions with comets and asteroids that are observed to produce soft X-rays. Combining scanning probe, secondary electron/ion, X-ray and other studies of HCI-matter interactions paints a picture of an especially violent collision at the surface, where energy densities reach many times higher than the most energetic of swift heavy ion collisions. While most studies have been observational in nature, we have incorporated HCI-surface interactions as a method of fabricating and tuning electronic devices. Specifically, the neutralization energy of highly charged ions (HCIs) is used to modify the electrical integrity of thin insulating films used as a tunnel barrier in magnetic tunnel junctions (MTJ). Since the electrical performance of the MTJ is exponentially sensitive to the integrity of the insulating barrier, this method provides the ability to tune over a dynamic range of several orders of magnitude. Conversely, the exponential sensitivity of the tunnel junction also provides a novel scientific tool for probing the electronic nature of nano-features form

THU-AP08-3 #308 - Invited Talk - Thursday 1:00 PM - Elm fork

Interaction of very highly charged ions with surfaces

Nobuyuki NAKAMURA[1], Yuji NAWATA[1], Nobu OHKI[1], Akira YAMAZAKI[1], Hayato OHASHI[1], Chikashi YAMADA[2], Shunsuke OHTANI[1], Masahide TONA[4], Makoto SAKURAI[3]
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A highly charged ion has so huge potential energy that a single ion impact can induce drastic changes on a surface even if it has no kinetic energy at all. For example, it is known from previous studies that a nano-structure is created with a quantum efficiency of unity for various kinds of surfaces. The size and the shape of the structure are found to be strongly dependent on the charge state of the incident ion, the physical properties of the surface and so on, but the detailed mechanism is still unclear so that further studies are needed.

We have been using the Tokyo electron beam ion trap (Tokyo-EBIT) to study the interaction between slow, very highly charged ions and surfaces. Highly charged ions such as He-like Bi, whose potential energy reaches almost 600 keV, can be prepared as a projectile using the Tokyo-EBIT and the ion extraction system attached to the EBIT. In this paper, we present microscopic observations of the nano-structure and measurements of secondary particles (including photons) emitted from the surfaces.

THU-AP08-4 #163 - Invited Talk - Thursday 1:00 PM - Elm fork

Potential Medical Application of Ions from Light and Light from Ions

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The World Health Organization project that one in three people in the industrialized world will suffer from cancer at some point in their lives. Unfortunately, due to the limitations of current cancer treatments, this high incidence rate also leads to a high mortality rate - cancer is currently the second most common cause of death, and will soon overtake circulatory disease to become the most common if current trends continue. Around 50% of patients receive radiotherapy as part of their cancer treatment and it is second only to surgery in its ability to cure cancer. Improved survival rates owe a lot to improved accelerator and imaging technologies. However, the effectiveness of radiotherapy is limited by the need to minimize dose to surrounding healthy tissue to prevent late harmful effects of exposure. In the developing world incidence of cancer is growing faster than that of Aids so there is also a pressing need for low-cost, portable treatment solutions.

Gold nanoparticles can selectively be taken up by tumors. Due to their increased X-ray absorption in the 50 - 100 keV range, this then offers the potential for new forms of diagnosis and therapy. There are several candidates for the associated radiation generation including synchrotrons, filtered rotating anode tubes and the use of fluorescence from highly charged ions extracted from an electron beam ion trap. Modeling studies concerning the relative merits of these three types of radiation generation, along with measurements of biological effect in various systems will be presented.

Heavy ion therapy also provides the promise of improved outcome due to the dose-localization inherent in the Bragg peak. Results from an ongoing program (LIBRA) to produce suitable ions from high intensity laser beams will also be presented.

THU-AP08-5 #312 - Invited Talk - Thursday 1:00 PM - Elm fork

SPARC: Stored Particle Atomic Research Collaboration

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[(4)]*Atomic Physics, Fysikum, AlbaNova University Centre, Stockholm S-10691, Sweden*

An overview of the future Facility for Antiproton and Ion Research (FAIR) at GSI is presented whereby particular emphasis will be given to the envisioned physics program of the SPARC collaboration [1]. This program exploits almost all the key features of the future FAIR facility: Ions from rest up to the relativistic energy regime; various ion species from anti-protons up to bare uranium and radioactive nuclei; targets that range from intense photon fluxes to cold electrons and atoms up to nano-structures. These facilities together with new instrumentation offer a wide range of challenging opportunities for atomic physics and related fields [2]. Within SPARC we plan experiments at relativistic energies (SIS 100/300) to Doppler-boost laser photons for spectroscopy and laser-cooling and in the high-energy cave for collision studies. The cooler ring NESR will have optimized features and novel installations, an electron target, a gas-jet target, spectrometers, and COLTRIMS for studying properties of stable and unstable nuclei and collisions. Following NESR, the ions enter FLAIR where they can be slowed-down, stored and cooled and finally be trapped in the Penning ion trap facilities of HITRAP. There, high-accuracy experiments in the realm of atomic and nuclear physics will be possible.

REFERENCES

[1] http://www.gsi.de/sparc

[2] SPARC Technical Proposal: http://www.gsi.de/onTEAM/grafik/1068560945/sparc-technical-proposal_print.pdf

THU-AP08-6 #110 - Invited Talk - Thursday 1:00 PM - Elm fork

FEL photons on trapped ions in EBITs

Sascha W Epp[1,2], José R. Crespo López-Urrutia[1], Martin C Simon[1], Thomas Baumann[1], Günter Brenner[1,3], Rainer Ginzel[1], Volkhard Mäckel[1], Paul H. Mokler[1], Hiro Tawara[1], Joachim Ullrich[1]
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Accelerator based free-electron lasers (FELs) presently provide the unique possibility to extend the technique of laser spectroscopy, widely applied in physics and other natural sciences, into the soft X-ray spectral range and even beyond, up to the bound-bound transitions in highly charged ions (HCI), which naturally lie in the X-ray range and therefore remain out of reach for common laser sources. Since HCI are the predominant form of visible matter in vast regions of the universe, precise knowledge of their electromagnetic spectrum is indispensable for developing astrophysical and cosmological models. Moreover, HCI are ideal testing systems for advanced atomic structure theory, in particular strong-field quantum electrodynamics (QED). Here we report on our novel technique of combining an electron beam ion trap (EBIT) with the Free-electron LASer at Hamburg (FLASH) to measure resonant fluorescence by trapped HCI as a function of the wavelength. In this first demonstration of laser spectroscopy of multiply or highly charged ions at more than one

order of magnitude higher photon energies than hitherto reported we achieved instantaneously the resolution of sophisticated conventional soft and hard X-ray spectroscopy with obvious potential to push the current limits of accuracy by orders of magnitude.

THU-AT08-1 #529 - Invited Talk - Thursday 8:30 AM - Bur Oak

A brief history of Mevex's modular linac solutions for industry

David Brown
Accelerator Technology Development, Mevex Corporation, PO Box 1778, Stittsville ON K2S1B4, Canada

Alternate approaches to delivering high throughput, flexibility, reliability, and improved logistics for the market.

Until recently the philosophy for trying to satisfy these requirements was to design and build an irradiation facility around a single, large accelerator. The accelerator was the mystical power source within the irradiation "temple". This is similar to the philosophy of main-frame computing in the 60's, 70's, and 80's. Today, thousands of small computers are networked together to deliver overall IT solutions.

Mevex connects accelerator modules together in series or parallel to deliver the correct current and voltage for each application. Mevex can deliver energies from 1MeV to 40MeV using the modular approach. Each module uses readily available components and avoids expensive, single-purpose, long-lead devices.

The modular approach makes "mass customization" possible in the electron linac world

The technology in our machines is familiar to the thousands of linac engineers who are already trained to work in the cancer therapy field. This eliminates the "white coat" mentality and reduces the difficulty in finding technical support resources.

Every radiation application demands the following:

? The right penetration

? The right throughput

? The right reliability

? The right capital cost

? The right operating cost

? Rapid installation and deployment

Networks of electron accelerators can deliver outstanding results for business, science, and R&D.

Someday electron accelerators will be seen as just another piece of equipment on the factory floor.

THU-AT08-2 #208 - Invited Talk - Thursday 8:30 AM - Bur Oak

Electron Beam Irradiation of Microcrystalline Cellulose

Mark S Driscoll, Mellony S Manning, Arthur J Stipanovic, John P Hassett
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Cellulose is the major structural component of wood and plant fibers and is the most abundant polymer synthesized by nature. Despite this great abundance, cellulosic biomass has seen limited application outside of the paper industry. Its use as a feedstock for fuels and chemicals has been limited because of its highly crystalline structure, inaccessible morphology and limited solubility (recalcitrance). Any economic use of lignocellulosic resources for the production of ethanol will require a "pretreatment" technology to enhance the accessibility of the biomass to enzymes and/or chemical reagents. Electron beams (EB), X-rays or gamma rays produce ions in a material which can then initiate chemical reactions and cleavage of chemical bonds. Such ionizing radiation predominantly scissions and degrades or depolymerizes cellulose. Reduction in the molecular weight and crystallinity of cellulose has been shown to increase its rate of chemical and enzymatic hydrolysis. Microcrystalline cellulose (MCC) was irradiated using a 90 kW, 3 MeV Dynamitron? at IBA Industrial's Edgewood, NY facility. Four parameters were studied; available surface area, molecular weight, relative crystallinity and enzymatic hydrolysis. All tests showed that the recalcitrance of MCC was reduced as the dose was increased from 10 to 1000 kGy.

THU-AT08-3 #314 - Invited Talk - Thursday 8:30 AM - Bur Oak

Research Utilizing Electron Beams and X-Rays at the State University of New York College of Environmental Science and Forestry

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The State University of New York College of Environmental Science and Forestry (ESF) is a small, specialized, PhD granting institution located adjacent to Syracuse University in Syracuse, NY. The college was established in 1911 and has been engaged since then in research, teaching and public service in the areas of renewable resource development, management and conversion into useful products including fuels, chemicals and advanced materials. ESF has approximately 100 faculty members in eight academic departments including: chemistry, biology, wood products engineering, paper and bioprocess engineering, forest engineering, forestry (resources management), environmental studies, and landscape architecture. About fifteen years ago researchers at the college started conducting studies utilizing electron beams. Today ESF has ten faculty members conducting research in the areas of coatings, adhesives, composites, polymers, biochemistry, organic compounds, dosimetry and fundamental ions. This research is conducted with the help of both graduate and undergraduate students. This talk will present an overview of research conducted at the college that utilizes low and high energy electron beams, and x-rays.

THU-AT08-4 #295 - Invited Talk - Thursday 8:30 AM - Bur Oak

Performance Evaluation of an Irradiation Facility Using an Electron Accelerator.

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Irradiation parameters over a period of eight years have been evaluated for a radiation processing electron accelerator facility. The parameters monitored during this time were the electron beam energy, linearity of beam current, linearity of dose with the inverse value of the samples speed, and dose uniformity along the scanning area after a maintenance audit performed by the electron accelerator manufacturer.

The electron energy was determined from the depth-dose curve by using a two piece aluminum wedge and measuring the extrapolated range from the obtained curves. The linearity of beam current, of dose with cart conveyor inverse of the speed and dose uniformity along the scanning area of the electron beam were determined by measuring the dose under different beam current and cart conveyor speed conditions using film dosimetry. And the dose uniformity along the scanning direction of the electron beam was determined by measuring the dose in a strip of film dosimeter taped to the edges of the aluminum tray of the cart conveyor system and moving perpendicular to its length. A detailed description of how the measurements were carried out and the results obtained is included in the text.

The results of the experiments have shown that the energy in the range from 1 to 5 MeV has not changed by more than 5% from the High Voltage setting of the machine over the evaluation period, and dose linearity with beam current and cart conveyor speed has not changed. The dose uniformity along the scanning direction of the beam showed a dose uniformity of 90% or better for energies between 2 and 5 MeV, however for 1 MeV electrons this value was reduced to 80%. However, this can be improved by changing the beam optics settings in the control console of the accelerator.

THU-AT08-5 #330 - Invited Talk - Thursday 8:30 AM - Bur Oak

THE IBA EASY-E-BEAM INTEGRATED PROCESSING SYSTEM

Marshall R Cleland, Richard A Galloway
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IBA Industrial, Inc.(formerly known as Radiation Dynamics, Inc.) has been making high-voltage, direct-current electron accelerators for research and industrial applications for many years. Some typical applications are the crosslinking of polymeric materials and products, such as the insulation on electrical wires, cable jackets, heat-shrinkable plastic tubing and film, plastic foam, pipe and pellets, molded plastic parts, the partial curing of automobile tire components, and the sterilization of disposable medical devices. The curing of fiber-reinforced composite materials, the preservation of foods and the treatment of waste materials are attractive prospects for future applications. For electron energies above 1.0 MeV, the radiation protection for operating personnel is provided by surrounding the accelerator facility with thick concrete walls. For lower energies, the shielding usually consists of steel and lead panels, which can be substantially thinner and more compact than the equivalent concrete walls. IBA Industrial, Inc. has developed a series of electron processing systems called Easy-e-Beam(TM) for the medium energy range from 300 keV to 1000 keV. These systems include the shielding as an integral part of a complete radiation processing facility. The basic concepts, such as the electron accelerator, the radiation shielding, the product handling equipment, and typical performance capabilities are described in this paper.

THU-AT08-P1 #467 - Poster - Thursday 3:00 PM - Rio Grande

3D Conformal Proton Therapy in Dubna, Russia

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To irradiate neoformations located in the region of the head, neck and chest, the 3D conformal proton therapy of deep-lying tumours has been worked out and is applied at present at the Medico-Technical complex (MTC) in Dubna, Russia.

At real irradiation, the therapeutic proton beam is formed with an individual collimator made from the Wood's alloy. To make the dose distribution of the proton beam conformal on the target shape depth, bolus - range shifter of a complex form - are calculated and then manufactured to take into account the heterogeneous structure of the patient's tissue and organs that are located in the beam route.

The physical basis for the boluses application is in the fact that particles, while going through matter, lose their energy and thus, the length of their residual length decreases. As the bolus has a heterogeneous profile, i.e. not identical thickness in different points, the proton beams that passed through that bolus exit it with altered rates. Thus, these particles have a definite path length in the human tissue forming in this way the back border of the dose field.

Boluses are produced at the drilling-and milling unit with digital programme control on calculated parameters of the bolus profile as a result of the proton irradiation simulation. To produce the bolus according to this technique Machinable WAX is used for the unit treatment. The advantage of the application of this material is the simplicity of treatment and possibility to use it a second time that considerably decreases the cost of its production.

After a series of dosimetric experiments with the radiochrome film applied where the algorithm of the dose and profile calculation of the boluses, as well as the technology of their production are verified the method is used in clinical practice.

THU-ECHT04-1 #212 - Invited Talk - Thursday 8:30 AM - Pecos II

New Directions of the Ion Beam Modification of Materials

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Only relatively recently have high energy ion beams been used to modify and improve materials for applications in medicine and biology, as well as for nano-science and nanotechnology. Our team has been among a few pioneer research groups in the ion beam community who have studied the interaction of ion beam for nanoscience and nanotechnology. Specifically, the interaction of MeV ions in its track was used in a variety of materials for control cell adhesion, for improved surface properties of polymers used for heart-valve, for hip-joint implants, for fabrication of nanopores, for nanolithography, as well as for changing the surface properties of bio-compatible polymers for controlled drug/medication delivery, nanostructure formation, and fabrication of sensors and thermoelectric materials. This presentation will include examples of new trends in ion beam modification of polymers and metals for percutaneous devices and other implants, for fabrication of nanopores, and for surface modification of ceramics and semiconductors in order to fabricate sensors and devices for extreme environments, such as highly efficient thermoelectric materials. Since there is a separate session on nanolithography, we will slightly touch the most recent developments on ion beam application for nanolithography and projection ion beam.

THU-ECHT04-2 #417 - Contributed Talk - Thursday 8:30 AM - Pecos II

Ion beam irradiation induced changes of hydrophilicity on polystyrene surfaces

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Ion beam irradiation of polymer materials for improving hydrophilicity has created a great interest in biological cell patterning and attachment applications. When an ion beam bombards a polymer surface it undergoes a range of physical and chemical modifications depending on the energy of the beam and ion species. One significant change on the surface is the hydrophilicity, which is a determining criterion for cell attachment. Here we discuss the changes in molecular weight and hydrophilicity on polystyrene surfaces with Carbon ion beam energies ranging from 10keV to 3MeV. These changes were observed based on contact angle, X-ray photoelectron spectroscopy and gel permeation chromatography measurement techniques. Additionally, we will present the case of the growth of rat cells (PC12) on polystyrene surfaces to demonstrate how the cell attachment depends on the energy of the irradiating ion beam.

THU-ECHT04-3 #276 - Contributed Talk - Thursday 8:30 AM - Pecos II

Investigation of Phase Transitions of Implanted Silicon

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The optical diffraction method for fast measurement of current temperature and dynamic of recrystallization on the surface of implanted silicon at light pulse irradiation was suggest and realized.

On the sample surface two adjacent grating were formed: the amplitude grating with period of 50 μm and the phase grating with period of 4 μm. The phase grating is temperature sensor of the sample. The amplitude grating the structural-phase changes is used.

The current silicon temperature was determined by measuring the varying diffraction angle of the probing laser beam. The diffraction angle was varied over time because the period of the diffraction grating increased as a result of the dynamic thermal expansion of the crystal. The measured signal was recorded in the pair of symmetric fifth-order diffraction maxima.

The amplitude grating was formed by implantation with phosphorous ions by photolithography method. As a result of implantation, on the silicon surface amorphous cells (R=0.45 for wavelength 0.6328 μm) with size 40×40 μm enclosed by a net of single-crystal silicon were formed (R=0.37 for wavelength 0.6328 μm). The recrystallization of amorphous cells during pulse light heating changes the diffraction efficiency of grating. To register the diffraction efficiency the intensity change of first diffraction maximum was recorded.

Single-crystal silicon plates KDB-1 with (100) orientation and 400 μm thickness were chosen as a semiconductor substrate. The radiation beam of a He-Ne laser with wavelength 0.6328 μm was used as the probing beam. The pulsed heating of silicon samples was performed on a UOL.P-1 setup.

THU-ECHT04-4 #430 - Invited Talk - Thursday 8:30 AM - Pecos II

Optimizing Au nanoparticles formed by void trapping in Si

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Metal-void decoration is a very important phenomenon because it has potential to fabricate buried nano-structured devices. For example, drive-in diffusion of Au into Si with open volume defects can fabricate self-assembling Au nanoparticles, forming a novel optoelectronic device. In order to optimize size and density of nanoparticles, we studied Au trapping by voids in Si formed by He ion irradiation and annealing. The Au trapping efficiency under various conditions was compared. We found that Au trapping is more efficient if Au is introduced by ion implantation than surface deposition, and that trapping is more sensitive to Au implantation fluence and less sensitive to He implantation fluence. For surface deposition, penetration of Au is limited at lower temperature and at higher temperature, due to formation of stable Au-Si phase. For Au ion implantation, the amount of Au trapped in voids does not depend strongly on void size or density.

THU-ECHT04-5 #223 - Contributed Talk - Thursday 8:30 AM - Pecos II

Gold and proton beam effects on phenol-based composites reinforced with nanopowders

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In general, glassy polymeric carbon (GPC) ware produced at AAMU is used for making crucibles, heat exchangers, and, because of its biocompatibility and inertness, for prosthetic devices. In this work we have introduced small amount of silicon carbide (SiC), carbon nanotubes (CNT) and alumina (Al2O3) to the GPC precursor to enhance its physical properties. The composite were then pyrolyzed to 1000 C and irradiated with high energy proton and gold ions using a Pelletron accelerator. Surface analyses including microRaman spectroscopy, atomic force microscopy (AFM), X-ray

photoelectron spectroscopy (XPS) and secondary electron emission (SEM) were performed to observe the changes in surface morphology and structure before and after ions bombardment.

THU-ECHT04-P1 #159 - Poster - Thursday 3:00 PM - Rio Grande

Effect of C+H and C+H+Ar hybrid ion implantation on UHMWPE samples

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UHMWPE samples were C+H and C+H+Ar hybrid ion implanted by using MEVVA ion implantation technique. Samples were implanted with an extraction voltage of 30 kV and the fluence of 1017 ions/cm2. Surface characterization of implanted samples were compared to unimplanted ones. ATR- FTIR chemical characterisation analysis were used to see if any new chemical bonds formed at 2 microns deep at the surface. It was found that cis- and trans- geometric isomerism occurred and C-H bond concentration decreased after C+H and C+H+Ar implantation, which was thought to be caused by cross link formation on the surface. Alkyne triple bond characteristics were observed better with C+H implanted samples than C+H+Ar implanted samples. Contact angle measurements of all samples were done. Hydrophilicity of implanted samples was found decreased on comparison to unimplanted ones. Also SEM analyses showed that roughness of surface decreased by ion implantation. Consequently, considering biomedical area C+H+Ar hybrid ion implanted samples might be more useful by means of longevity and biocompatibility especially in hip joint applications.

THU-ECHT04-P2 #160 - Poster - Thursday 3:00 PM - Rio Grande

Chemical Surface Characterization of Ti+C Hybrid Ion Implanted UHMWPE Samples

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UHMWPE samples were Ti+C hybrid ion implanted by using MEVVA ion implantation technique. Samples were implanted with an extraction voltage of 30 kV and the fluence of 1017 ions/cm2. Samples was characterized of implanted samples with ATR- FTIR, UV-Vis-NIR and RBS were compared to unimplanted ones. In this study, Ti ions used for activation of polymer radical sides and C ions were used increasing of radical side of polymers. Transition metals are generally used to increase stability of chain of polymer. ATR-FTIR and UV-Vis-NIR equipments showed that Ti ions interacted by polymer chains. RBS equipment confirmed Ti and C ions distrubitýon on the surface of the implanted samples.

THU-ECHT04-P3 #218 - Poster - Thursday 3:00 PM - Rio Grande

An epitaxial layer sliced from the self-implanted silicon by HF etching

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In this work, Si (100) substrates were implanted with 1 MeV Si ions with fluences of $5x10^{14}$ to $1x10^{16}$ ions/cm^2 at room temperature. A buried amorphous layer was formed at a depth of about 1 μm below the surface. The implanted specimens were then etched with a 35% by volume HF solution for 35 h. Following the HF etching, a furnace annealing at 1000°C for 30 min was performed to recover the radiation damage region and to detach a thin layer from the substrate. The results showed that about 1 μm layer was successfully sliced from the substrate by using the HF etching method in the self-ion implanted silicon.

THU-ECHT04-P4 #397 - Poster - Thursday 3:00 PM - Rio Grande

Characterization of ZnO nanostructures synthesized by ion implantation

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Zinc oxide (ZnO), a wide band gap semiconductor, has been attracting considerable attention because of its possible application in high-performance optoelectronic devices. ZnO nanostructures were synthesized by the implantation of low energy (35 keV) ZnO molecular ions into thermally grown SiO_2. The implantation fluence was 5×10^{16} ions/cm^2. Implanted samples were thermally annealed in an oxygen environment at different temperatures. High resolution transmission electron microscopy (HRTEM) results showed that nanostructures with diameters ranging from 2 to 5 nm were formed. Energy dispersive x-ray spectroscopy (EDS) confirmed the presence of zinc. These nanostructures and the effect of thermal annealing were studied by using x-ray diffraction spectrometry (XRD), Raman spectroscopy and Fourier transform spectroscopy (FTIR).

THU-ECHT04-P5 #473 - Poster - Thursday 3:00 PM - Rio Grande

Synthesis and Characterization of Transitional Metal Nanosystems in Silicon

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In recent years a great deal of interest has been focused on the study of transition metallic nano-systems in silicon for their technological importance as well as for fundamental understanding of their atomic and electronic structures and optical properties. Inter-diffusion across metal-silicon interfaces, intermetallic compound formation and their thermal stability and kinetics of metal silicon interaction have also been the subject of numerous studies. Low energy (less than 100 keV) transition metal ions (Ag, Cu) were implanted into Si(100) to create buried metallic layers. The physical structure of the defects due to the various ion energies and fluencies has been studied. The evolution of defects clusters in the Si due to the implanted ion as well as the morphology of nano structures due to the irradiation were observed for various annealing parameters. The annealing temperature (~500 0C) was kept moderately low to study the diffusion of the implanted metal ions. The samples were characterized using Rutherford Back Scattering Spectrometry/ Ion Channeling, X-ray Diffraction, and Transmission Electron Microscopy.

THU-ECHT08-1 #267 - Contributed Talk - Thursday 1:00 PM - Bur Oak

A Scintillator Loaded with Fissionable Material for Neutron Flux Monitoring

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A novel type of neutron flux monitor, consisting of fissionable material loaded in a liquid scintillator, has been developed, characterized, and tested in the beam line at the Los Alamos Neutron Science Center. Its neutron sensitivity is significantly better than that of a conventional fission chamber. Related research on nanocomposite scintillators for gamma-ray detection suggests that it should be possible to extend this approach by synthesizing nanoparticles of a fissionable material and loading them into an organic scintillator. Calculations indicate that this technique will be capable of achieving up to three orders of magnitude higher loading than in typical fission chambers. This will result in a rugged, cost-efficient detector with high efficiency, a short signal rise time, and the ability to be used in low neutron-flux environments.

THU-ECHT08-2 #170 - Contributed Talk - Thursday 1:00 PM - Bur Oak

950 keV X-band Linac for material recognition using two-fold scintillator detector as a concept of dual-energy X-ray system

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One of the advantages applying X-band Linac is the compact size of the whole system. That leads to the possibility of application on-site such as airport for material recognition inside of luggage for custom inspection. We have developed X-band Linac system and achieved maximum 950 keV X-ray using the low power magnetron (250 kW) in 2 ìs pulse length. In addition, we developed two fold scintillator detector as dual energy X-ray concept which dose not need two times X-ray irradiaition but once. MCNP code (Monte carlo N-particle transport code) was used to make up the design of sensor part with two scintillators, CsI and CdWO4. We will show you the results of experiment which is performed with metal, aluminium, iron and lead in various condition.

THU-ECHT08-3 #83 - Contributed Talk - Thursday 1:00 PM - Bur Oak

Statistical Requirements for Pass-Fail Testing of Contraband Detection Systems

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Contraband detection systems for homeland security applications are typically tested for probability of detection (PD) and probability of false alarm (PFA) using pass-fail testing protocols. Test protocols usually require specified values for PD and PFA to be demonstrated at a specified level of statistical confidence CL. Based on a recent more theoretical treatment of this subject (1), this summary paper reviews the definition of CL and provides formulas and spreadsheet functions for constructing tables of general test requirements and for determining the minimum number of tests required.

(1) David Gilliam, Stefan Leigh, Andrew Rukhin, and William Strawderman, Pass-Fail Testing: Statistical Requirements and Interpretations, J. Res. Natl. Inst. Stand. Technol. 114, 195-199 (2009).

THU-EEA01-1 #87 - Invited Talk - Thursday 8:30 AM - Brazos II

A review on the measurement of light elements in atmospheric aerosol samples by IBA methods

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Ion Beam Analysis (IBA) techniques have proven to be a reliable tool to study the composition of atmospheric aerosols in a fast, non-destructive way. In particular, Particle Induced X-ray Emission (PIXE) is widely used to determine the aerosol elemental composition, simultaneously detecting elements from Na to Pb.

Up to 80% of the aerosol mass is anyhow composed by low-Z atoms like H, C, N and O. Other IBA techniques, like Elastic Backscattering Spectrometry (EBS) and Particle Elastic Scattering Analysis (PESA) - based on the detection of a proton beam elastically scattered by the target nuclei in the backward and in the forward directions, respectively - allows obtaining quantitative information about the concentration of these light elements in the sample. Thus, the application of both PIXE and EBS (for C, N, O measurement) and PESA (for H measurement) allows a complete reconstruction of the aerosol mass.

In this contribution a review on about 20 years of EBS/PESA measurements of light elements in atmospheric aerosol samples will be illustrated, highlighting advantages and limitations of such techniques using proton beams of different energies (from 2.5 up to 6 MeV), different kind of aerosol collection substrata (Teflon, Nuclepore, Mylar,?) and different data analysis procedures (comparison with standards or direct simulations of the elastic backscattering spectra).

As concern H (which can be used as a proxy for a major component of atmospheric aerosols, such as the organic fraction of particulate matter), it will be shown how this element can be easily measured by PESA also in a unenclosed external beam set-up.

The analytical possibilities opened by the use of other IBA techniques, such as Nuclear Reaction Analysis (NRA) with 1-3 MeV deuteron beams for the quantification of light elements will be discussed as well.

THU-EEA01-2 #50 - Invited Talk - Thursday 8:30 AM - Brazos II

Ion beam analyses of bark and wood in environmental studies

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A large number of wood and bark samples have been analysed utilizing particle-induced X-ray emission (PIXE) and particle-induced gamma-ray emission (PIGE) techniques. Samples of common tree species like Scots Pine, Norway Spruce and birch were collected from a large number of sites in Southern and Western Finland. Some of the samples were from heavily polluted areas in the vicinities of a copper-nickel smelter and a zinc metal plant. The samples were dry ashed at 550ºC for the removal of the organic matrix in order to increase the analytical sensitivity of the method. The sensitivity was enhanced by a factor of 50 for wood and slightly less for bark. The ashed samples were pressed into pellets and irradiated as thick targets with a millimetre-sized proton beam. By including the ashing procedure in the method, the statistical dispersion due to elemental heterogeneities in wood material could be reduced. As a by-product, information about the elemental composition of ashes was obtained. By comparing the concentration of an element in bark ash to the concentration in wood ash of the same tree useful information from environmental point of view was obtained. The obtained ratio of the ashes was used to distinguish between elemental contributions from anthropogenic atmospheric sources and natural geochemical sources, like soil and bedrock.

THU-EEA01-3 #20 - Invited Talk - Thursday 8:30 AM - Brazos II

PIXE and microPiXE analysis of atmospheric aerosols from Mexico City

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The origin of atmospheric aerosols in the Metropolitan Area of the Mexico Valley (MAMV) is not a fully understood problem. The complete identification of the emitting sources of soil-derived and other sulphur-containing particulate matter is still under discussion, as many areas have been suggested as the origin of the particles. A possible solution to this question is to correlate the elemental composition of aerosol samples with the simulation of transport of the pollutants from different sources during the sampling periods towards the studied site, as well as the use of receptor models.

With this in mind, a study was carried during the year 2009 in three representative sites in the MAMV, collecting PM10 samples with MiniVol samplers. In this work, the usual Particle Induced X-ray Emission (PIXE) analysis was complemented with a microPIXE characterization of a few representative samples, in an attempt to determine the emitting source. The results of the elemental analysis of the samples are presented, together with the application of multivariate statistical methods, such as the Positive Matrix Factorization (PMF).

THU-EEA01-4 #21 - Invited Talk - Thursday 8:30 AM - Brazos II

Long-term fine particulate matter, its composition and sources in Hanoi between 2001-08

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PM2.5 particulate matter has been collected on Teflon filters every Sunday and Wednesday at Hanoi, Vietnam for nearly eight years from April 2001 to December 2008. These filters have been analysed for over 21 different chemical species from hydrogen to lead by ion beam analysis (IBA) techniques. This is the first longterm PM2.5 dataset for this region. The average PM2.5 mass was (54+/-33) ug/m3, well above the current USEPA health goal of 15 ug/m3. The average PM2.5 composition was found to be (29+/-8)% ammonium sulfate, (8.9+/-3.3)% soil, (28+/-11)% organic matter, (0.6±1.4)% salt and (9.2+/-2.8)% black carbon. Positive matrix factorisation techniques identified the major source contributions to the fine mass as automobiles and transport (40+/-10)%, windblown soil (3.4+/-2)%, secondary sulfates (7.8+/-10)%, smoke from biomass burning (13+/-6)%, ferrous and cement industries (19+/-8)%, and coal combustion (17+/-7)% during the 8 year study period.

Furthermore back trajectories were used to identify long range transport into Hanoi for two of these sources, namely, windblown dust (Soil) from 12 major deserts in China and emissions from 33 coal fired power plants (Coal) in Vietnam and China. There were 28 days of extreme events with Soil concentrations greater than 6 ug/m3 and 25 days of extreme Coal with concentrations greater than 30 ug/m3 from a total of 748 sampling days. Through the use of back trajectories it was found that long range transport of soil from the Taklamakan and Gobi desert regions (more than 3,000 km to the north west) accounted for 76% of the extreme events for Soil. The three local Vietnamese power stations contributed to 15% of the extreme Coal events, while four Chinese power stations between 300 km and 1,700 km to the north-east of Hanoi contributed 50% of the total extreme Coal events measured at the Hanoi sampling site.

THU-EEA01-5 #41 - Contributed Talk - Thursday 8:30 AM - Brazos II

Accelerator based aerosol size and composition for health research

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Enormous benefits to public health have been achieved through decades of work through the US Clean Air Act (CAA). However, the EPA regulations derived from the CAA regarding ambient air quality and the standards for fine aerosol mass, PM2.5, do not reflect 40 years of advances in medicine and public health. Yet a strong statistical association of ambient fine particulate mass (PM2.5) to mortality has been well established over the past 15 years. These studies have been used by the US EPA to set sampling and analysis methodologies, the Federal Reference Method (FRM), measuring PM2.5 mass on filters over 24 hours every 3rd day. The problem is that progress in identifying what it is in the PM2.5 mass that is actually killing people has not kept pace with statistical identification of medical risk. Statistical studies require measurements extended in space and time, and routine FRM measurements do not provide enough information to identify the key causal factor behind the statistical data on health impacts. Further, research studies that record extensive information on particle size and composition with better time resolution than 24 hours for health impacts are very expensive and usually occur only over limited times and locations. An eminent research scientist, Mort Lippmann, MD, of New York University School of Medicine, recently published a review paper related to two major national meetings stating that "Furthermore, because of cost considerations, there is virtually no prospect for collecting the data needed by health researchers for more definitive analyses as long as there is continuing reliance on FRM sampling and analysis methodologies". We have shown in recent EPA funded studies that accelerator based techniques are almost the only way we can meet the needs of health professionals and obtain causal as opposed to statistical information of aerosols and health.

THU-EEA01-6 #164 - Contributed Talk - Thursday 8:30 AM - Brazos II

Analysis of atmospheric aerosols by PIXE, INAA, and ion chromatography

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PIXE, INAA, and other techniques enable one to perform multi-elemental analyses on atmospheric aerosol samples. Another common technique is ion chromatography (IC), which is used to measure water-soluble species, such as sulphate and alkali and alkali earth elements. Analysing samples by more than one technique allows

one to assess the reliability of the analyses. Furthermore, parallel analyses by IC and a non-destructive technique, which measures the total content of an element, such as PIXE or INAA, allow one to assess which fraction of the element is water-soluble (e.g., for Na, K, Ca) or which fraction of the element is associated with the species measured by IC (in the case of sulphate). By comparing PIXE S data with IC sulphate-S data it can, for example, be assessed which fraction of the S may be associated with organosulphates. Results are presented of several measurement campaigns at urban and forested sites in Europe, whereby PM10 or PM2.5 filter samples were taken (mostly on Nuclepore polycarbonate filters and occasionally on Teflon filters) and the samples were analysed by IC and PIXE and occasionally also INAA. From comparing the PIXE and INAA results, the extent of the matrix effects in PIXE (X-ray attenuation and particle size effects) was determined. From the PIXE and IC results for a 2003 summer campaign at the K-puszta site in Hungary, it was estimated that organosulphates could be responsible for 20% of the total sulfur concentration and 30% of the organic aerosol in PM10. The comparison of the IC and PIXE data for K and Ca for the various sites indicated that most of the Ca was water-soluble (the Ca was presumably mostly present as CaCO3); in contrast, for K, only half of it was typically water-soluble, indicating that it was to a large extent associated with insoluble mineral dust.

THU-EEA01-P1 #363 - Poster - Thursday 3:00 PM - Rio Grande

Application of Accelerator Mass Spectrometry to Archaeology, Geography and Environmental Science.

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Accelerator mass spectrometry (AMS) is an ultrasenstive method for the measurement of isotope ratios of a long lived radioisotope to a stable isotope (e.g. 14C/12C = 10 exp(-12)) with numerous applications in interdisciplinary research. The Erlangen AMS facility, based on an EN tandem accelerator and a hybrid sputter ion source for solid and gaseous samples, is well suited for age determination of carbonaceous materials for periods of up to 50.000 years. The application to geography and archaeology is demonstrated by the investigation of wood samples from historic monasteries, temples and secular buildings in Tibet and Nepal. Here the 14C measurements in combination with tree ring structure enable a highly resolved annual information about climatic variability in Tibet and the Himalayas in earlier times than that of the currently available dates. The knowledge of the exact age of these buildings could help to improve the understanding of the cultural and historical context of their development and their function. For applications concerning the origin of environmental compounds the 14C content can be used, since biogenic samples contain 14C in natural concentration whereas anthropogenic samples contain no 14C due to their formation via fossil materials. Since the concentration of environmental compounds in natural samples is very small, the amount of carbon for AMS measurements is in the microgram range where the background problem is critical. To minimize any carbon contamination a closed system has been developed from gas chromatograph, used for fraction separation, via EA and a fully automatic gas handling system to the sputter ion source and accelerator for AMS measurements. With this new method the 14C content of modern and old calibration samples of ethyl alcohol with carbon masses down to 10 µg have been measured with reasonable results.

THU-EEA01-P2 #548 - Poster - Thursday 3:00 PM - Rio Grande

Comparison of the Viability, Accuracy, and Precision Among XRF, ICP-MS, and PIXE on Trace Element Analyses of Small Water Samples

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The study aimed to compare the viability, precision, and accuracy among three popular instruments - X-ray Fluorescence (XRF), Inductively Coupled Plasma Mass Spectrometer (ICP-MS), and Particle-Induced X-ray Emission (PIXE) - used to analyze the trace elemental composition of small water samples. Ten-milliliter water samples from public tap water sources

in seven different localities in India (Bangalore, Cochin, Bhubaneswar, Cuttack, Puri, Hospeta, and Pipili) were prepared through filtration for proper analysis in the XRF and PIXE. Separate ten-milliliter samples were diluted (1:1000) with 1% Nitric Acid solution for proper analysis in the ICP-MS. The project speculates that the ICP-MS will give the most accurate and precise trace elemental analysis, followed by PIXE and XRF. XRF will be seen as a viable, portable, and affordable instrument that can analyze samples on-site while ICP-MS is viable, extremely accurate, and expensive option for off-site analyses. PIXE will be deemed to be too expensive and cumbersome for off-site analysis; however, laboratories with a PIXE accelerator can use the instrument to get accurate analyses without the need of an ICP-MS. The experiments were performed by two high school students in the laboratories of the University of North Texas; therefore, the study can be replicated in the future as a means to train undergraduate research students on the use and applications of ion accelerators.

THU-EEA02-1 #546 - Invited Talk - Thursday 1:00 PM - Brazos II

Introduction to the Role of Accelerators in Nuclear Power

Richard Sheffield
Los Alamos National Laboratory, Los Alamos NM, United States

Overview talk only

THU-EEA02-2 #536 - Invited Talk - Thursday 1:00 PM - Brazos II

Accelerator Driven Subcritical Systems and the Nuclear Energy Future

Jean-Pierre Revol
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Accelerator driven systems offer the possibility of making nuclear fission energy sustainable and acceptable to society. The Energy Amplifier proposed by Carlo Rubbia at CERN is used to illustrate the potential of ADS, and the resulting R&D activity wave it triggered in Europe and in the world is briefly discussed. ADS must be part of the strategy to provide clean, safe and abundant energy for a harmonious development of society.

THU-EEA02-3 #454 - Invited Talk - Thursday 1:00 PM - Brazos II

Transmutation Concepts of Minor Actinides in Accelerator Driven Systems

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The growth of the nuclear energy production, as a carbon free energy source in the United States of America, is tied to the national problem of disposing the current and the future spent nuclear fuel inventories. At present, USA has ~60,000 MT of spent nuclear fuel and this inventory is growing by ~2,000 MT per year with the present fleet of nuclear plants. A significant increase in this production rate is forecasted in the near future due to the planned increase in the deployment of new nuclear power plants. The transuranics content of the spent nuclear fuel is ~1% and these transuranics are responsible for a significant fraction of the spent fuel radio-toxicity. Accelerator driven systems consisting of one GeV proton accelerators with neutron spallation targets and subcritical blankets can be utilized for transmuting the transuranics, simultaneously generating carbon free energy, and significantly reducing the capacity of the required geological repository storage facility for the spent nuclear reactor fuels and the related radioactive waste. The required number of these systems is a function of the accelerator power, the operating life time and availability of the system, and the blanket fuel composition. The main parameter in the fuel composition is the plutonium fraction. It is possible to use a small fraction of the spent fuel plutonium in the accelerator driven system and the balance is used as MOX fuel for thermal power reactors or utilized in future fast power reactors.

In this paper, several ADS concepts are examined based on the use of conventional stationary solid and mobile fuels. The mobile fuel concepts use molten salts or liquid metals as fuel carrier. The fuel materials are dissolved or solid particles suspended in the fuel carrier. The system performance parameters are analyzed and the different concepts are compared.

THU-FIBN03-1 #432 - Invited Talk - Thursday 8:30 AM - Post Oak

Ion Beam Lithography - Status and Challenges

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In this review, we identify some areas of technology where the unique capabilities of ion beam processing appear to offer dramatic advantages for nano-fabrication at a commercially viable scale. One such area is that of advancing semiconductor processing to incorporate cleanly defined features having dimensions of only a few nanometers. We will discuss realistic criteria for acceptable pattern quality, such as low line edge roughness, low pattern granularity, freedom from proximity effects in resist layers, high aspect ratio features in developed resist, long range coherence of pattern, low incidence of defective features, and negligible irradiation damage to underlying device layers. Economic considerations critical for the commercial adoption of ion beam lithography will also be discussed, such as throughput, cost of masters, fault tolerance, and compatibility with established manufacturing protocols. All of these requirements can be addressed to some extent by exercising the considerable diversity of ion beam parameters and resources already available.

However, to compete successfully with older commercial approaches, ion beam lithography can greatly benefit from fresh, innovative ideas. We highlight a few exciting developing areas, such as guided self-assembly, multi-scale patterning, patterned IAD or RIE, maskless lithography, and perhaps customized structured polymers as ideal resist materials.

THU-FIBN03-2 #374 - Invited Talk - Thursday 8:30 AM - Post Oak

Scanning-helium-ion-beam lithography: exploring limits on resolution

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Resist-based ion-beam lithography is not nearly as prevalent as electron-beam lithography, in part due to destructive ion-sample interactions and in part due to lack of a source competitive with the Schottky field-emission electron gun in terms of brightness, energy spread, and source stability. Helium-ion-beam lithography may hold promise for higher resolution than electron-beam lithography for two reasons. First, scattering in resist and substrate should be reduced because the helium-ion mass is over three orders of magnitude higher than the electron mass. Second, the secondary-electron range should be reduced because the higher-mass helium ions generate lower-energy secondary electrons. Destructive sputtering and recoil-atom collision cascades, a problem with heavier ions such as Ga+, should not similarly limit the resolution of helium-ion lithography. Recently, a high-brightness gas phase field ionization source of helium ions has been commercialized as part of a sub-nm-spot-size scanning-helium-ion-beam microscope (Zeiss Orion). This system may enable an improvement in lithographic resolution relative to prior work with light (e.g. He+ , H2+) and "heavy" (e.g. Ga+) ion sources. We connected a helium-ion microscope to a commercially available pattern generator (Nabity NPGS) in order to evaluate the system's resolution potential relative to electron-beam lithography. Results show that sub-10-nm-pitch patterning is feasible using hydrogen silsesquioxane (HSQ) resist.

THU-FIBN03-3 #109 - Invited Talk - Thursday 8:30 AM - Post Oak

Fabrication of nanomechanical devices integrated in CMOS circuits by ion beam exposure of silicon

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In this communication, we present a novel approach for the fabrication of nanomechanical devices integrated in CMOS circuits. It is based on ion beam patterning by direct exposure of silicon and poly-silicon surfaces and standard silicon etching. The exposed areas sustain a chemical or reactive ion etching process, resulting in robust masks for defining nanomechanical devices with sub-micron resolution. We have studied the optimal processing condition in terms of selectivity and resolution (ion beam dose and patterning mode, reactive ion etching parameters) as well as the procedure to ensure that the CMOS circuits are not damaged by the ion beam exposure. As a result, nanomechanical devices have been successfully patterned. Ion beam based patterning by direct silicon exposure offers advantages compared to electron beam lithography: there is no need to deposit a resist on the non-flat CMOS substrate, it is a single step patterning method and it does not cause damage to the surrounding CMOS circuits.

THU-FIBN03-4 #127 - Invited Talk - Thursday 8:30 AM - Post Oak

Material Patterning by Masked Ion Beam Irradiation using Anodic Porous Alumina

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Material structures with micro- to nano-scale dimensions arranged in a well-defined pattern have a wide range of technological applications. A unique way of synthesizing ordered functional material structures, or an array with modulated physical or chemical properties, is by ion beam-based methods.

In this contribution we will discuss the formation of geometrically ordered nano-scale material structures using Masked Ion Beam Irradiation. In this technique the ion impact is restricted by a stencil mask or template, in order to ensure a localized material synthesis or modification. This enables a parallel and direct formation of embedded high-density arrays of well-defined structures having interesting material properties. The tailoring of e.g., nanoporous materials, catalyst surfaces, and magnetic patterns in a controlled way is thus possible.

The masks used as templates in the present work are primarily anodic porous alumina membranes consisting of a well-ordered array of nanopores. In order to transfer the pattern defined by the mask to a substrate, energetic heavy ions were applied. The resulting material structures are formed via the deposited ion energy or by the implanted ion species themselves. High-energy (a few tens of MeV) ions were used for ion track lithography, whereas low energy (tens of keV) ions were used for restricted ion implantation.

We will show examples of resulting regular micro- and nano-structures having interesting chemical, optical or magnetic properties in a variety of materials following ion irradiation through the anodic porous alumina mask. Advantages and disadvantages, different effects and problems occurring using the present technique will be discussed. Finally, examples of possible applications of the patterned material modifications will be given.

THU-FIBN08-1 #9 - Invited Talk - Thursday 1:00 PM - Post Oak

Ultra bright single photon emitters in diamond fabricated by ion implantation

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Quantum technologies require new platforms and paradigms for their efficient fabrication and use. Single photon sources exemplify this need with their development pushing the bounds of existing materials and fabrication techniques. Color centers in diamond are a leading candidate for single photon generation, provided a suitable fabrication method can be identified. Ion implantation techniques may pave the way in this regard, offering a scalable and controlled fabrication method for generating optical centers in diamond.

This work presents a comprehensive study of a new class of ultra bright diamond color centers fabricated through ion implantation. The new family of chromium color centers exhibit narrow photoluminescence in the near infra red with count rates of the order 3×10^6 counts/s, making them ideal candidates for application in quantum information processing, metrology, and cellular bio markers. Simulations of their performance in practical devices, e.g. quantum cryptography systems will be presented and discussed.

Finally, we will highlight future directions to optimize these sources and determine the local chemistry by employing co-implantation techniques. We will also show preliminary results of a "step and repeat" technology which would be of great benefit to large-scale integrated quantum devices.

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THU-FIBN08-2 #420 - Invited Talk - Thursday 1:00 PM - Post Oak

Structural and electrical characterization of buried graphitic micro-channels fabricated in single crystal diamond by deep ion beam lithography

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In the present work we report about the continuation of our studies on the micro-fabrication of buried conductive structures into synthetic single crystal diamond by DIBL (Deep Ion Beam Lithography) [1]. The DIBL process employs focused MeV ion-beams to cause the modification of the diamond lattice by inducing a transition to a conductive graphitic-like phase, which is completed after a suitable post-implantation thermal annealing processing. The control of the ions penetration depth is achieved by using a variable thickness mask; this technique has been significantly refined with respect to previous reports [1], thus guaranteeing a complete emersion of the buried channels at specific locations on the sample surface. The analyzed samples were implanted with different ion species, energies and fluences at room temperature. In particular, we employed 1.3 MeV He^+ at the AN2000 microbeam line of Legnaro National Laboratory, 6 MeV C^{+++} ions at the ion microbeam line of the LIBI laboratory at Ruđer Bo?ković Institute and 500 keV He^+ at the Pelletron accelerator of the University of Melbourne. The as-implanted channels were characterized in both their structural and electrical properties. In particular, by means of direct milling with a Focused Ion Beam (FIB) it was possible to obtain cross-sectional SEM and TEM images displaying the shape and depth of the buried channels, representing the first direct proof of their formation at variable depths. Moreover, extensive electrical characterization was performed at variable temperature with a novel microprobe setup developed at the University of Torino, allowing a detailed investigation of the nature of the conduction mechanisms in as implanted channels, as well as in channels subjected to subsequent thermal annealing treatments (200-1300 °C), thus allowing the characterization of the progressively graphitized channels.

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[1] P. Olivero et al., Diamond and Related Materials 18, 870-876 (2009)

THU-FIBN08-3 #405 - Invited Talk - Thursday 1:00 PM - Post Oak

Ion beam modification and thin film Diamond Like Carbon (DLC) coating of polymeric surfaces for neural tissue regeneration and fabrication of large neural patterning

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It has been shown in recent years that it is possible to use plasma-based and ion-beam-based material surface modification techniques to form surfaces that are enhanced for their biological characteristics in various ways. Thus for example, energetic ion implantation of negative silver ions, and alternatively and separately the plasma deposition of ultra-thin films of diamond-like carbon, have been used to form modified surfaces that are particularly "neuro-friendly" and on which neuron growth is selectively encouraged . We carry out a directed research and development program to explore the suitability of various kinds of ion implantation and of Vacuum Arc DLC(Diamond Like Carbon) plasma deposition for the selective, enhanced growth of neuronal cells on substrates that could be applied to human surgical/medical needs. A specific goal of the program is to develop short lengths of small - diameter polymer tubing, the inside surface of which is plasma/ion modified so as to selectively enhance the growth of nerve cells within the tube, thus serving as a vehicle for the regeneration and repair of broken elements of nervous system. As necessary components of the overall project, we also explored several other related fundamental and applied issues, including a quantitative survey of the suitability of specific plasma/ion-based surface modification parameters on biological cell growth, and the fabrication of large neural arrays or networks in experimenter-designed patterns.

Our program thus has both fundamental and applied aspects, and if fully successful would have broad impact to medical technology as well as to several other subfields of plasma and ion beam physics, materials science, and ion beam biotechnology. Our work consists of ; 1) Surface modification of polymeric samples (Chitosan, PDLG, PLA), 2) Cell study, in-vitro tests, on modified surfaces (C+ and C+ + N+ ion implanted and DLC coated) of Chitosan, PDLG, PLA samples.

THU-FIBN08-4 #342 - Invited Talk - Thursday 1:00 PM - Post Oak

Strategies for optimized color center formation in diamond by ion implantation

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Color centers in diamond, e. g. the nitrogen - vacancy center, the silicon - vacancy center and several nickel related centers, are promising candidates for single photon source development and for implementation of spin quantum bits. Ion implantation followed by thermal annealing is an established method for color center formation in diamond, but the efficiency of color center formation, i. e. the number of centers formed per implanted dopant atom is often much below 50%. In this talk, we will describe our efforts towards optimization of the efficiency of NV-center formation. Following low energy (<30 keV), low fluence (<10^11 cm-2) nitrogen ion (15^N) implantation, high purity diamond samples are implanted with other ion species to add vacancies that enhance NV-center formation during thermal annealing [1]. Status and prospects of this approach will be discussed.

[1] C. D. Weis, et al., J. Vac. Sci. Tech. 26, 2596 (2008)

THU-IBA07-1 #67 - Invited Talk - Thursday 8:30 AM - Brazos I

Recent Developments in Stopping Power for Positive Ions

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We discuss recent experimental results showing that stopping power for low energy protons, in metals and insulators, is not necessarily proportonal to velocity.

We show that there is no discrepancy between the mean ionization potential derived from optical data or from stopping power.

The problem of water stopping power in ICRU Report 73 has been resolved.

We discuss recent stopping measurements on liquid water jets.

We discuss the comparison between measurement and theory for the stopping of light ions in zinc.

We discuss measurement methods that yield stopping at many energies in a single run.

We discuss the reliability of stopping power programs and tables.

THU-IBA07-2 #411 - Invited Talk - Thursday 8:30 AM - Brazos I

Implementation of a new method for extraction of L-subshell ionization cross sections from only Lγ and Lα+Lβ cross sections

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Traditionaly, L-subshell cross sections are obtained from Lα, Lβ, Lγ peaks whose clear distinction is obstructed by their proximity and ambiguities in the x-ray background subtraction. Solutions of 3 equations for L subshells lead to very uncertain results and even negative cross sections. In a procedure we propose, σ_{L3}/σ_{L2} ratios of published ionization cross sections are expressed as a universal power function of the proton velocities scaled by the orbital velocity of L-shell electrons. They serve as a constraint with which the L-subshell ionization cross sections are extracted after suitable fits to the Lγ and Lα+Lβ data. The present method relies on only two cross sections deduced from two parts L x-ray spectra which are well resolved. They are due to Lγ and combined Lα+Lβ transitions involving distinct -- {L1, L2} and {L1, L2, L3}, respectively -- sets of L-subshell vacancies. This method is implemented with an updated database for the L x-ray production (XRP) and the L-subshell ionization by protons. Our update, which exceeds previous compilations [1-3] by 53%, consists of 1773 {Lα, Lβ, Lγ} x-ray production (XRP) and of 993 {L1, L2, L3} ionization cross sections reconverted to the XRP. Several choices of atomic parameters [4-8] are made to test their influence on the extracted ionization cross sections.

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[7] Puri S., Mehta R., Chand B., Singh N., and Trehan P.N. X-Ray Spectrom. 22 (1993) 358

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THU-IBA07-3 #8 - Invited Talk - Thursday 8:30 AM - Brazos I

New Developments in Ion Beam Analysis at Surrey and their Application in Forensic Science

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Ion beam analysis (IBA) techniques are used a great deal in archaeometry because of their non-destructive nature and traceability, together with their ability to determine the provenance of materials by capitalising on their sensitivity to trace elements. It is therefore rather surprising that ion beams have been rarely used in the analysis of samples from forensic investigations, since the requirements in archaeometry and forensics are similar. Our recent studies have shown that IBA methods are well suited to the study of trace evidence such as gunshot residues [1], glass fragments [2] and soils [3]. In this talk, new advances in IBA at Surrey will be discussed. For example, advances in data analysis are enabling greater discrimination of gunshot residues and glasses and a new IBA technique called MeV SIMS [4] is making a significant contribution to fingerprint chemistry.

[1] M J Bailey, K Kirkby and C Jeynes, Trace Element Profiling of Gunshot Residues by PIXE and SEM-EDS: a Feasibility Study, J. X Ray Spec, 38, 3, (2009) 190-194

[2] M Christopher, C Jeynes, N Ward and M J Bailey presented at Ion Beam Analysis 2009, Cambridge

[3] P Comini, R Morgan, P Bull and M J Bailey, manuscript in preparation

[4] M J Bailey, B N Jones and R P Webb, Depth Profiling of Fingerprints and Inks for Forensic Investigations, Accepted for publication in NIMB, in press

THU-IBA07-4 #362 - Invited Talk - Thursday 8:30 AM - Brazos I

Quantitative elemental mapping of biological tissue with micro-PIXE: from 2D mapping toward three-dimensional tomography

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Micro-PIXE elemental mapping of biological tissues has been evolved over the last years into the most demanded analytical method at JSI tandem accelerator laboratory.

To provide a complete service to the users from biomedical research, sample preparation consisting of cryo-fixation, cryo-sectioning and freeze-drying has been developed. In the case of tissue sections, on-off axis STIM spectra are recorded simultaneously with PIXE to determine the dry tissue thickness. Quantitative analysis is enabled by precise determination of the proton dose by an in-beam chopping device positioned next to the collimating slits [1].

Elemental concentrations of morphologically distinct regions are quantified by GupixWin program, taking into account the exit energy determined by STIM and known matrix composition. The elemental tissue maps in the case of overlapping spectral lines are formed by dynamic analysis algorithm. Among others, the results on plants surviving the soil rich in salt and on the plants grown on soil contaminated by heavy elements, will be presented.

To access the elemental distribution on the sub-cellular level, sample preparation via shock-freezing and freeze-drying of the tissue induces structural damage inside the cell membranes due to water removal. Important step further in the elemental mapping on the cellular and sub-cellular level will be a construction of a setup for measurements on frozen hydrated tissue, currently ongoing in the laboratory.

Polycapillary lens in front of the X-ray detector, aligned in confocal set-up, enables 3D tomography [2]. Recently, a dedicated confocal PIXE spectrometer, consisting of silicon drift X-ray detector, alignment mechanics and X-ray lens, has been put in operation at JSI.

International access to the instrumentation is provided upon a peer-reviewed project proposal within the SPIRIT project [3].

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[1] K. Vogel-Miku? et al, Plant Cell Environ. 31, 1484 (2008).

[2] M. ?itnik et al., J. Anal. At. Spectrom. 25, 28 (2010).

[3] www.spirit-ion.eu

THU-IBA07-5 #48 - Invited Talk - Thursday 8:30 AM - Brazos I

OVERVIEW OF RECENT CULTURAL HERITAGE APPLICATIONS ON BEAM LINES OF THE IPNAS CYCLOTRON OF LIEGE

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Improvements on the AVF (Azimutal Varying Field) cyclotron in Liège (Belgium) have provided an energy resolution comparable to that of classic electrostatic accelerators. Given the wide range of incident beam energies (3-20 MeV), a whole new perspective opens in terms of access to other nuclear reactions and deeper probing of materials with the possibility of analyzing thick layers such as corrosion or gilding layers often observed on cultural heritage artifacts.

This paper intends to illustrate that cyclotrons can offer a wide variety of analytical solutions for archaeometric purposes. We will here present the latest improvements on the PIXE (Particle Induced X-ray Emission), PIGE (Particle Induced Gamma-ray Emission) and IBIL (Ion Beam Induced Luminescence) techniques in use at the CEA-IPNAS cyclotron facility as well as the High-Energy High-Resolution beam lines and new set-ups developed accordingly. The benefits of the extended energy and particle range will be discussed and new applications both in the conventional and high energy will be commented.

An on-going study of gemstones, which profits of a synergic combination of PIXE and IBIL at 3 MeV, comprising the development of a new identification method of beryllium for treated minerals through NRA at higher energies, illustrates the potential of our new analytical skills in our traditional direct archaeometry beam line.

As for our recently mounted High-Energy High-Resolution beam line (HE-HR), the new developments on the extraction nozzle that allow in-air measurements, have been now upgraded with a new set-up allowing particle-detection in order to take full advantage of the increased probed thickness.

First results on the study of Roman gilding craftwork techniques by means of "high-energy" alpha backscattering spectrometry performed in-air and combined with PIXE will be also presented to stress the interest of higher energies and their implementation with depth-sensitive and particle-detection based techniques.

THU-IBA07-6 #125 - Contributed Talk - Thursday 8:30 AM - Brazos I

Analysis of early medieval glass beads: glass in the transition period

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Glass beads excavated from the early medieval graves in Slovenia (dated between 8th-10th c.) were analyzed by the combined PIXE-PIGE method in the air. PIXE was used for the elements heavier than silicon and PIGE for Na, Mg, and Al exploiting gamma rays induced by inelastic proton scattering. For normalization, the X-ray spectra were normalized according to the argon X-rays, and gamma spectra according to the proton dose measured by a thin wire mesh intersecting the beam. The matrix elements were considered in a procedure that evaluates concentrations from X-ray and gamma ray intensities simultaneously. From the concentrations of magnesium and potassium oxides, two types of glass were identified. One was a typical Roman glass using Egyptian natron as flux, and the other type was made of ash of halophytic plants. It is now commonly belied that the later type of glass gradually replaced natron glass between the 9th and 12th centuries. The new technology spread from the Byzantine or Islamic east. The glass beads included in our analysis originate from the archaeologically well defined context, so the belongings to particular graves allowed the reconstruction of necklaces. It was interesting to observe that particular necklaces contain beads of both glass types. Several types of beads were found in different sites of Europe where they were dispersed by commerce; such are beads with mosaic eyes and knuckled beads which are supposed to be of oriental origin. Our identification of the glass type confirms this hypothesis. The second result is construction of the dating schemes: dating of the graves has to be in agreement with the introduction of the new glass type.

THU-IBA08-1 #418 - Invited Talk - Thursday 1:00 PM - Brazos I

"Recent uses of PIXE in life sciences

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A survey of recent papers on the use of PIXE in life sciences published after CAARI2008 is given. The main topics like molecular and cell biology, medicine, plant and food analysis, characterisation of proteins, biosorption-uptake etc. are illustrated by selected examples. Trends and tendencies in this traditional PIXE territory are also discussed.

THU-IBA08-2 #32 - Invited Talk - Thursday 1:00 PM - Brazos I

BIOLOGICAL APPLICATIONS OF PIXE TECHNIQUE AND FUTURE PROSPECT

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Although 40 years have passed since the first PIXE (Particle Induced X-ray Emission) experiments carried out by Johansson, this technique is still being widely and successfully used in numerous research fields where biological studies stand out. The knowledge of the elemental composition of biological systems can be decisive to understand its function, and PIXE has shown itself to be a very reliable and versatile tool for its detection and quantification.

Opposite to the early PIXE applications achieving bulk sample elemental concentration with a broad beam, nowadays most of the work is carried out scanning a beam of micrometer dimensions on the specimen, delivering images of its elemental

distribution in addition to concentrations. The possibility of focusing ion beams and combining PIXE with other IBA techniques in compact set-ups, the so called nuclear microprobe, enables to extend the information about sample characteristics helping to unravel morphological and physiological features of tissues and individual cells. The evolution of PIXE in the biological and biomedical research move forward more and more small scale, which is fixed by sub-micrometer dimensions of the beam that can be currently reached.

In the present paper, PIXE biological applications whether using large or focused ion beam are shown emphasizing specific physiological aspects of organs, tissues and cells. Examples of studies carried out using bone, skin and pancreas will be presented and discussed.

THU-IBA08-3 #43 - Invited Talk - Thursday 1:00 PM - Brazos I

Recent developments in the use of PIXE for the analysis of materials

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Particle Induced X-Ray Emission, better known as PIXE, is one of the most recognized analytical methods based on the use of particle accelerators. Advantages such as its high-sensitivity and being a non-destructive technique has placed it, over the last decades, as a good choice in a variety of fields that require knowledge of elemental concentrations for a diversity of samples.

In this work we will present a review covering some of the currently-most relevant applications of PIXE, as well as some of the recent developments on this analytical technique, with emphasis in subjects related to the analysis of materials. We will also present possible future uses and applications of the PIXE analytical method.

THU-IBA08-4 #90 - Invited Talk - Thursday 1:00 PM - Brazos I

External beam PIXE and micro-PIXE analysis of environmental samples at LABEC, Florence

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At the 3 MV Tandetron accelerator of the LABEC laboratory of INFN (Florence, Italy) an external beam facility is fully dedicated to PIXE-PIGE measurements of elemental composition of atmospheric aerosols. Thanks to the capability of detecting all the crustal elements (Na, Mg, Al, Si, Ca?), PIXE-PIGE analyses are unrivalled in the study of mineral dust: as a consequence they are very effective in the study of natural aerosols, like, for example, mineral dust archived in polar ice cores (for environmental and paleoclimatic studies) and Saharan dust intrusions. Among detectable elements there are also important markers of anthropogenic sources, which allow effective source apportionment studies in polluted urban environments. Examples regarding recent monitoring campaigns, performed in urban and remote areas, both on a daily basis and with high time resolution (hourly samples), will be discussed.

Recently at the LABEC external scanning microbeam facility we started a study for PIXE analyses of ants (the "Crematogaster scutellaris", an ant species common throughout Mediterranean habitats) as bioindicators in environmental contamination assessment. Heavy metals are one of the major classes of contaminants in both terrestrial and aquatic environments and raise several concerns for their adverse effects on all the components of ecosystems, including humans. The combined use of the PIXE and the scanning microbeam made it possible to map element distributions in ants sampled from sites with different environmental metal availability with high spatial resolution and good sensitivity and to restrict quantitative analysis to specific organs/regions where such elements were detected, to better understand the behaviour of metals within living organisms and hence clarify their fate within ecosystems.

THU-IBA08-5 #377 - Contributed Talk - Thursday 1:00 PM - Brazos I

Development of PIXE measurement of Ca changes resulting from of disease processes in cells

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A significant number of elements such as Cu, Ca, Zn, Fe are present in small concentrations in living cells where they play an important role as structural elements in proteins or signal substances. Ca is of particular interest because it is both bound proteins, such as calmodulin and in hydroxyapatite, (the mineral content of bone), and as Ca2+ ions where acts as signal substance in apoptosis. PIXE is well suited to measure the total content of Ca because, unlike competing techniques, it is completely blind to chemical bonding effects.

Here we present work on the development of methods for measuring the Ca fluxes from infected HepG2 cells. The cells were infected with human pavovirus B19 carrying different DNA payloads.

Two different approaches have been developed. The first is where the cells are directly cultured using pioloform as a substrate; with the number of cells determined by counting the cell nuclei that were rendered visible using with Hoechst stain. In the second approach the cells are homogenised and the bound-Ca content in the debris and unbound-Ca in the wash solutions using an internal reference standard was measured. The results show that there is a difference in the Ca contents depending on the payload of the virus used to i nfect the cells.

THU-IBA08-6 #449 - Contributed Talk - Thursday 1:00 PM - Brazos I

Proton-Induced X-ray Emission (PIXE) of Silicate and Phosphosilicate Coatings on High Impact Resistance Polycarbonates

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Proton-Induced X-ray Emission (PIXE) analysis was employed to characterize silica-based surfaces. These results, combined with previous Rutherford Backscattering Spectrometry (RBS) results, were used to establish an electronic model to predict surface energy and the hydrophobic or hydrophilic behavior of silicates, phospho-silicates and other compounds used for high impact resistance vision wear coatings. Ultimately, the goal is to control condensation on such coated polymers for applications in sport eyewear used in hockey, skiing, football and other contact sports, swimming goggles, and diving masks.

Complementary surface characterization techniques used in this work include the 4.265 ± 0.035 MeV 12C(alpha, alpha)12C and the 3.05 ± 0.005 MeV 16O(alpha, alpha)16O MeV Oxygen Nuclear Resonance to increase light atoms detection and,2.8 MeV Hydrogen Elastic Recoil Detection for compositional analysis with depth profiling, and Tapping Mode Atomic Force Microscopy for surface topography. The water affinity of the solid surface is measured via contact angle using the Sessile Drop method and the Young-Dupré equation to compute the surface energy of the silicate surface. The surface energy is then correlated with statistical analysis of silicate surface topography Tapping Mode Atomic Force Microscopy and PIXE analysis to predict and determine the mechanism and kinectics driving water condensation. Polymer adsorption on these surfaces is used to alter the surface hydroaffinity and control condensation [1].

[1] US Patent pending "Molecular films for controlling hydrophobic, hydrophilic, optical, condensation and geometric properties of Si-based surfaces. Inventor(s): N. Herbots, J. D. Bradley, M. Hart, D. A. Sell, S. Whaley, Q. Bradley (filed: November 9, 2009)

THU-IBA08-P1 #98 - Poster - Thursday 3:00 PM - Rio Grande

Seasonal Variation and Trace Elemental Mapping of the Composition and Concentration of New York Rainwater Samples Using the Union College Pelletron Particle Accelerator and Proton Induced X-ray Emission Spectroscopy

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A 1-megavolt tandem electrostatic Pelletron particle accelerator housed at Union College was used to measure the elemental composition and concentration of rainwater and snow collected around New York State from June 2009 until June 2010. A beam of 2.0-MeV protons was directed at an approximately 12-micrometer thin Mylar film substrate onto which 0.5-mL of concentrated rainwater was dried. The interaction of the incident protons with the target material causes inner shell electrons to be ejected and these vacancies are filled through electronic transitions of higher orbital electrons with the production of an x-ray photon characteristic of the elemental composition of the target. This is the PIXE Method. Data on the energy and intensity of x-rays were collected using an Amptek silicon drift detector. Spectra of the number of x-rays collected as a function of energy were analyzed and the elemental composition was found to contain P, S, K, Cl, Ca, Mn, Al, Mg, & Ar and concentrations were determined using the analysis package GUPIX.

THU-IBM07-1 #33 - Invited Talk - Thursday 1:00 PM - Pecos II

Application of Ion Bombardment to Elastomers. Modification and functional consequences.

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Ion bombardment used to be applied mainly for modification of metals, ceramics and recently polymers. Despite the influence of energetic ions on composition and structure of engineering semicrystalline polymers seems to be well established, knowledge on effects possible to obtain for amorphous elastomers remains unexplored.

The paper discusses chemical modification, crosslinking and degradation of rubber macromolecules under ion beam treatment in terms of related changes to engineering and functional properties of the vulcanizates. Conventional vulcanizates based on: natural (NR), styrene-butadiene (SBR), butadiene-acrylonitrile (NBR) or chloroprene (CR) rubber, as well as special elastomers: polyurethane (PU), silicone (MQ), fluorine (FPM) and polyolefine thermoplastic (TPE) elastomers, were subjected to ion beam treatment of H+, He+, O+, F+ or Ar+ of energy 130 - 160 keV and range of 1xe11 - 1xe16 ions/cm2.

The effect of interaction between ion beam and rubber macromolecules seems to be mainly energetic. Chemical doping of the surface layer of elastomers is of less importance. Heavy ions results mainly in chain scission - producing macroradicals, whereas due to light ions dominates mechanism of ionization - manifesting itself by hydrogen release. Depending on molecular structure of rubber, its macromolecules exhibit tendency either to degradation (NR, CR) or to crosslinking (SBR, NBR). Free radicals, present in the surface layer of elastomers, react readily with atmospheric oxygen, modifying chemically the materials. Crosslinking of macromolecules makes the surface layer shrunk, what results in internal strain, finally producing cracks.

The reported above structural and chemical changes modify mechanical, tribological and biological properties of elastomers, as well as their wettability, ageing and chemical resistance. Application of right ion beam treatment makes possible to decrease friction and wear, improve adhesion, ageing and fuel resistance, biocompatibility and bacteriostaticity of the materials.

Functionalized nanoporous track-etched Membranes: synthesis and applications

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The irradiated Polymer group at LSI (Ecole Polytechnique, France) synthesises nanoporous polymer membranes using ion track technology. This synthesis is based on swift heavy ions irradiation of thin polymer films in collaboration with the GANIL (Caen, France). In the zone next to the ion-trajectory, a cloud of intersticial atoms, chain scissions and lacunes are formed. These zones of defects, energetically cylindrical, are called latent tracks. The latent tracks may be directly modified chemically by radio-induced grafting leading to grafted channels formation inside the polymer matrice.
The latent tracks may also be etched by chemical attack prior to grafting. Cylindrical pores, paralell ones to each others, of monodiperse diameter in 10 nm to few microns range depending etch conditions et the nature of the ion-projectile, are obtained (Figure below). The persistence of radicals after etching in a PVDF fluoropolymer membrane was recently proved in our group by EPR for diameter inferior to 500 nm. This property allows to graft, very locally, a hydrophilic polymer in a hydrophobic matrice from nanopore walls. A specific functionnalisation inside the nanopores is then possible. It has been proved by confocal laser microscopy after fluorescent labelling of the grafted polymer.

Main applications: proton-exchange membranes for fuel cell, templates for layer-by-layer electrodeposition of nanowires (GMR), nanosensors, protein translocation study.

Aliphatic Polymer ageing under swift heavy ion (SHI) irradiation in oxidative environment:effect of linear energy transfer, dose and dose rate

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There are practical situations where polymers are submitted to alpha or swift heavy ion irradiations. Extensive work has been done on polymer ageing in air during beta and gamma irradiations, but swift ion irradiation is still demanding work. These irradiations are characterized by a high Linear Energy Transfer (LET). The particles deposit energy inside a track where a high ionisation density and a high local dose rate are induced. This is very different from the way beta or gamma rays deposit their energy. In terms of LET, alpha irradiation can be conveniently simulated by ion beams heavier than He, for instance C or Ne, but at higher energies.

Polymers submitted to ionising radiations are modified by the creation of defects such as unsaturated bonds, chain scissions and crosslinks in the polymer backbone. The counterpart of these modifications is out gassing. Both groups of defects must be taken into account to understand the mechanisms underlying degradation.

The effect of ionising radiations on a polymer is quantified by using the radiation chemical yield (G). At low doses, G is generally constant, and the knowledge of the zero dose yield (G0) is sufficient. At higher doses (typically in the MGy range), G decreases and can even vanish for some defects. The polymers contaminated by alpha emitters are locally submitted to very high doses. Consequently, the understanding of the dose effect is essential. Elsewhere, under oxidative environment, G depends on the dose rate. As the LET is function of the beam characteristics, knowing its influence on the polymer degradation is of great importance.

We will focus on the influence of the irradiation dose and dose rate, at various LET, on in-chain defects creation in selected polyolefins. This study is a fundamental work with obvious technological concerns.

Chemical and refractive index depth profile in PDMS polymer due to ion irradiation

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The aim of this work was to determine the refractive index and the chemical changes in proton irradiated poly(dimethylsiloxane) (PDMS) as a function of penetration depth. It was assumed that the occurring changes at a given depth are proportional to the energy loss at that depth. To be able to measure the changes at a selected depth, it had to be brought close to the surface. This task can be done by varying the energy of the incident protons, so different energy losses are attainable on the surface of the samples. The energy of the protons reaching the samples ranged from 2.00 MeV - 170 keV.

To determine the chemical changes of the functional groups at the surface of the polymer, infrared spectroscopic measurements were carried out with an infrared spectrometer equipped with a universal Attenuated Total Reflectance (ATR) accessory. The data were collected and analysed using Spectrum ES 5.0 software.

The refractive indices of the irradiated PDMS samples were measured with spectroscopic ellipsometry. The measurements were performed with a rotating compensator ellipsometer in the 250 - 1000 nm range at 476 different wavelengths. Micro-spot optics was applied to assure that the data were collected from the irradiated area.

This work will underlie the future production of optical devices and other structures made by ion irradiation in polydimethylsiloxane.

THU-IBM07-5 #366 - Contributed Talk - Thursday 1:00 PM - Pecos II

Hydrogen loss from elastomers subjected to ion irradiation.

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Hydrogen release from various elastomers upon irradiation with H+, He+ and Ar+ ions having energy in 100 keV range has been studied by using Nuclear Reaction Analysis (NRA) method. Measurements of hydrogen content were made by using a resonant reaction 1H(15N, áã)12C at 6.385 MeV. A massive loss of hydrogen atoms upon irradiation has been noted, the results point to the saturation of hydrogen content at about 10 at.%. The analysis of the experimental data indicates that the hydrogen release from elastomers is controlled by inelastic collisions between ions and target electrons and may be scaled with the density of energy deposited in ionization processes.

THU-IBM07-P1 #6 - Poster - Thursday 3:00 PM - Rio Grande

A study of molecular structural change depth profile in PMMA due to MeV proton irradiation

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Although numerous reports have been published regarding to the chemical change of polymethyl methacrylate (PMMA) due to different kind of exposures (e.g. UV, , X-ray, plasma, etc.), but only few of them study the changes that occur not close to the surface. So farnone of these reports investigated the molecular structural changes due to energetic ions as a function of penetration depth of the protons.

In this work we determined the depth profile of the chemical change of MeV proton irradiated PMMA by infrared spectroscopic measurements. The measurements were carried out using a diamond head Perkin-Elmer Spectrum One type

Universal Attenuated Total Reflection Fourier Transform Infrared Spectrometer (UATR-FTIR) equipped with DTGS detector.

THU-IBM07-P2 #412 - Poster - Thursday 3:00 PM - Rio Grande

Silver Ion Release from Ion Implanted UHMWPE

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As a biomaterials, polymers provide low friction surfaces and some degree of shock absorption, on the other hand metals provide appropriate material properties such as high strength, ductility, fracture toughness, hardness, corrosion resistance, formability, and biocompatibility necessary for use in load-bearing roles required for prosthetic devices. Ion implantation is a good way to modify polymeric materials with metallic properties but, all metal alloy implants corrode in vivo. In general, the degradative process may reduce structural integrity of the implant, and the release of corrosion products is potentially toxic to the host. The corrosion resistance of implant alloys is primarily due to the formation of passive oxide films to prevent significant electrochemical dissolution from taking place. In this work we examined Ag ion release from Ag and Ag -N ion implanted UHMWPE. For this aim, implanted and unimplanted samples were placed into PBS and then solution was analyzed with Atomic Absorption Spectrometry. The results are exhibits comprehensive study for Ag ion release from Ag and Ag-N implanted UHMWPE.

THU-MAR08-1 #1 - Invited Talk - Thursday 8:30 AM - Pecos I

Carbon Ion Radiotherapy at NIRS-HIMAC

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Carbon ion radiotherapy (CIRT) is a unique radiotherapy, which possesses well localized, and superior depth dose distribution in addition to less repairable radiobiological effects. The use of CIRT for various diseases has been explored as clinical trials at the Heavy Ion Medical Accelerator in Chiba (HIMAC), Japan. Since 1994, when the first clinical study of cancer therapy with carbon ion beams was started, about 50 clinical studies have been completed safely and effectively. These studies revealed that intractable cancers such as inoperable bone and soft tissue sarcomas can be cured and so can be cancers in the prostate, head and neck, lung, and liver in a safe manner in a shorter overall treatment time. The number of patients receiving CIRT has reached 5,000 and the therapy was approved as a highly advanced medical technology in 2003.To make the treatment more affordable, a study was undertake in an effort to reduce the size and cost of the treatment facility. This study has been realizing a compact system that is about 1/3 of both the size and cost of the HIMAC at Gunma University in Japan. On the other hand, a basic technology study to develop scanning and rotating gantry irradiation adaptive to respiratory movement is underway with an attempt to make a next-generation carbon ion irradiation system. This project also aims to achieve great cost reduction that comes as a complete surprise.

THU-MAR08-2 #359 - Invited Talk - Thursday 8:30 AM - Pecos I

Current state of proton and carbon-ion radiotherapy at the Hyogo Ion Beam Medical Center (HIBMC)

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HIBMC is the world's first facility to be able to use both proton (PRT) and carbon-ion radiotherapy (CiRT). The medically dedicated synchrotron can accelerate protons up to 230 MeV and carbon-ions up to 320 MeV. From Apr 2001 to Mar 2010, 3275 patients were treated with PRT in 2487 patients or with CiRT in 788. Malignant tumor originated from the Head and Neck (502 patients), lung (330), liver (539), prostate (1283), and the bone & soft tissue (130) was a major subject. The clinical results are as follows. (1) H & N tumors: The 2 year overall survival (OS) rates of patients with olfactory neuroblastoma, mucoepidermoid ca., adenoid cystic ca., adenoca., squamous cell ca., and malignant melanoma was100%,

86%, 78%, 78%, 66%, 62%, respectively. (2) Lung cancer: For all 80 patients, the 3-year OS, and local control (LC) rates were 75% (IA: 74%; IB: 76%) and 82% (IA: 87%; IB: 77%), respectively. These results are comparable to those obtained by surgery. Grade 3 pulmonary toxicity was observed in only 1. Proton therapy and carbon-ion therapy are safe and effective for stage I lung cancer. (3) Liver cancer: The 5-year LC rate for 429 tumors was 90% and the 5 year OS rate for 364 patients was 38%. These results seem equivalent to those obtained by surgery or radiofrequency ablation. (4) Prostate cancer: Five patients died from other disease in the median follow-up period of 62 months. Biochemical disease free survival and OS rates at 5 years was 88.2% and 96.5%. Our proton radiotherapy showed excellent OS and biochemical disease free survival rates in patients with prostate cancer with minimum late morbidities. (6) PRT VS CiRT: It seems that there is no significant difference in controlling H&N tumors, cancers of the lung and the liver between PRT and CiRT.

THU-MAR08-3 #517 - Invited Talk - Thursday 8:30 AM - Pecos I

Current status of carbon ion radiotherapy at Gunma University

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Charged particle therapy with protons and carbon ions allows uniquely precise delivery of a high dose to the target volume while sparing the surrounding normal tissue. Additionally, carbon ion beams deliver a larger mean energy per unit length of trajectory in the body than protons and X-ray beams. This unique property includes a high biological effect when used in radiotherapy.
Carbon ion radiotherapy for the first patient at Gunma University was initiated in March of 2010. Our facility is the first university hospital-based facility in Japan, is supported by the Japanese and local governments, and is a compact prototype of a commercial design ready for distribution. The major specifications of the facility were determined based on the experience of clinical treatments at the National Institute of Radiological Sciences (NIRS). The main accelerator is a slow-cycling synchrotron with a diameter of 20m, and it accelerates carbon ions up to an energy range from 140 to 400 MeV per nucleon. A spiral wobbler system is adopted for the beam delivery system in order to improve the beam efficiency in a large irradiation field size. Among 4 treatment rooms, one has a fixed horizontal beam line, one has a fixed vertical beam line, one has both fixed horizontal and vertical beam lines, and the remaining one is prepared for future development of advanced irradiation techniques.
The carbon ion radiotherapy project was launched at Gunma University in 2001, and collaboration with NIRS was started in 2004. Based on the design and R&D studies at NIRS, the construction (size: 45m x 65m) and operation costs of the accelerator system were reduced to one-third of those at NIRS while maintaining its high performance. From the start of construction to treatment of the first patient took approximately 3 years.

THU-MAR08-4 #491 - Invited Talk - Thursday 8:30 AM - Pecos I

Heidelberg Ion Therapy Center: Initial Clinical Experience

Stephanie E Combs
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The Heidelberg Ion Therapy Center (HIT) started clinical operation in November 2009. In this report we present our initial clinical experience at HIT with patients treated with proton and carbon ion radiotherapy and describe patient selection, treatment planning and daily treatment for different indications.
Between November 15th, 2009 and May 2010, over 100 patients were treated at the Heidelberg Ion Therapy Center (HIT) with carbon ion and proton radiotherapy. Main treated indications consisted of skull base chordoma and chondrosarcoma, malignant salivary gland tumors, chordomas of the sacrum, low grade glioma, primary and recurrent malignant astrocytoma and glioblastoma and well as osteosarcoma.
All patients were treated using the intensity-modulated rasterscanning technique. 76 patients were treated with carbon ions (95%), and four patients were treated with protons. In all patients X-ray imaging was performed prior to each fraction. Treatment concepts were based on the initial experiences with carbon ion therapy at the Gesellschaft für Schwerionenforschung (GSI) including carbon-only treatments and carbon-boost treatments with photon-IMRT. The average time per fraction in the treatment room per patient was 29 minutes; for irradiation only, the mean time including all patients was 16 minutes. Position verification was performed prior to every treatment fraction with orthogonal X-ray imaging.

Particle therapy could be successfully included into the clinical routine at the Department of Radiation Oncology in Heidelberg. Numerous clinical trials will subsequently be initiated to precisely define the role of proton and carbon ion radiotherapy in radiation oncology.

THU-MAR08-5 #258 - Contributed Talk - Thursday 8:30 AM - Pecos I

Monte Carlo Simulations of the Dose Distributions from Carbon Microbeams Used in an Experimental Radiation Therapy Method

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Recent upgrades of the MCNPX Monte Carlo code include transport of heavy ions. We employed the new code to simulate the energy and dose distributions produced by carbon beams in rabbit's head in and around a brain tumor. The work was within our experimental technique of interlaced carbon microbeams, which uses two 90º arrays of parallel, thin planes of carbon beams (microbeams), which interlace to produce a solid beam at the target. A similar version of the method was earlier developed with synchrotron-generated x-ray microbeams [1].

We first simulated the Bragg peak in high density polyethylene and other materials, where we could compare the calculated carbon energy deposition to the measured data produced at the NASA Space Radiation Laboratory in BNL. The results showed that new MCNPX code gives a reasonable fit of the carbon beam up to ~200 MeV/nucleon. At higher beam energies, which were not relevant to our project, the model failed to reproduce the Bragg-peak's increasing nuclear breakup tail.

In our model calculations we determined the dose distribution along the beam path, including the angular straggling of the microbeams, and used the data for determining the optimal beam spacing in the array for producing adequate beam interlacing at the target. We also determined, for the purpose of Bragg-peak spreading at the target, the relative beam intensities of the consecutive exposures with stepwise lower beam energies and simulated the resulting dose distribution in the spread out Bragg-peak. The details of the simulation methods used and the results obtained will be presented.

This research was supported by Musella Brain Tumor Foundation, Voices against Brain Cancer, Targeted Research Opportunities of SUNY SB, and SB Research Foundation.

[1] F.A. Dilmanian et al., Proc. Nat'l Acad. Sci. USA 103(25):9709-9714.

THU-MAR09-1 #406 - Invited Talk - Thursday 1:00 PM - Pecos I

Session Overview: The Future of Particle Therapy in Medicine; The Next Likely Steps

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As conformal irradiation has become more widely accepted, treatment with protons and heavier charged particles has gained widespread use. All charged particles have intrinsic 3-D dose distribution properties, tightly conforming to targets with rapid dose fall-off in surrounding tissues. After three decades and 65,000 patients, protons and helium nuclei, with relatively low linear-energy-transfer (LET) properties similar to X-rays, have demonstrated good results for many tumor types. However, up to 20% of tumors have proven resistant to low-LET irradiation. For these tumors, treatment with heavier ions (e.g., carbon) offers great potential benefit. These high-LET particles have increased relative biological effectiveness (RBE) that reaches maximum effect within the Bragg peak at the target volume. Irradiation with heavier ions

offers the unique combination of excellent 3D-dose distribution and increased RBE at the target. Dose-fractionation studies have demonstrated that high-LET radiation can treat some tumors with fewer fractional doses than is safe with lower-LET particles.

More cost-efficient and compact design of proton systems will make treatment available to more patients. In parallel, heavier ion therapy provides further tools for treatment of radioresistant tumors, as well as for treatment with fewer fractions for many tumor types. Some cancers may be better treated with a combination of lower-LET particles for the clinical target volume, and high-LET particles to treat the gross tumor. The future of heavy charged particle therapy will be best realized by clinical trials with ready access to top-quality delivery of both protons and heavier ions, and which will permit randomized-trial comparison of various ions for different diseases. Optimal results will require: (1) sophisticated target delineation that integrates CT, MRI and PET imaging; (2) reliable RBE modeling algorithms; (3) efficient beam-scanning technology that compensates for organ movements; (4) online beam control proximal to and within the patient; and (5) better understanding of dose-fractionation parameters.

THU-MAR09-2 #542 - Invited Talk - Thursday 1:00 PM - Pecos I

Construction, Commissioning and First treatments at the ProCure Oklahoma City and Chicago Proton Therapy Facilities.

Niek Schreuder, Ben Harris, Ray Chevalier, John Henderson
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ProCure Treatment Centers, Inc., based in Bloomington, Ind., was founded in 2005 to improve the lives of patients with cancer by increasing access to proton therapy. ProCure collaborates with leading radiation oncology practices and hospitals and provides management leadership and a comprehensive approach for the design, construction, financing, staffing, training and day-to-day operations of world-class proton therapy centers. ProCure's solution reduces the time, cost and effort necessary to create a facility. ProCure has one proton treatment center in operation in Oklahoma City, treating patients and another under construction (Warrenville, Ill.) and four others in development (Seattle; Somerset, N.J.; South Florida; and Detroit, Mich.).

THU-NP08-1 #248 - Invited Talk - Thursday 8:30 AM - Trinity Central

Large-area fast-timing systems in STAR

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The STAR experiment at RHIC concentrates on the tracking of charged hadrons via ionization, and the detection of electrons and photons via calorimetry, in a wide and azimuthally complete acceptance. STAR's ability to directly identify charged hadrons was initially limited to low momenta. This has been addressed via the construction of a large-area Time-of-Flight (TOF) system based on small Multigap Resistive Plate Chambers (MRPCs). The installation of the STAR TOF system was completed last fall. The full system is presently running in RHIC Run 10. The operation of the system, and its performance for particle identification, during RHIC Runs 9 and 10 will be described. STAR's ability to identify muons is also extremely limited. Another large-area TOF system based on much larger MRPCs is envisioned. This system will be located outside the STAR magnet and is called the Muon Telescope Detector (MTD). Several different prototype MTD systems were operated in Runs 7 through 10, and a patch of near-final MTD detectors is under construction for use in Run 11. The performance of the MTD prototype detectors, and the design of the Run 11 installation and the full system, will be described.

THU-NP08-2 #86 - Invited Talk - Thursday 8:30 AM - Trinity Central

A FOrward CALorimeter upgrade for PHENIX

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Over the past few years, the PHENIX detector has undergone several upgrades in the forward region (1<|eta|<4). Initially covered only by the muon arms, the addition of the Forward Calorimeter (FOCAL) will expand on the physics capabilities. The focus of these upgrades is toward a better understanding of the Color-Glass Condensate and the interplay between the different components of the proton's spin valence/sea quark and and gluon contributions. This talk highlights the newly proposed forward calorimeter detector, FOCAL. FOCAL is a tungsten-silicon sampling calorimeter with high position and energy resolution, covering a pseudorapidity of 1<|eta|<3. This future detector aims to constrain the current view of gluon saturation at small x in the Color-Glass condensate framework, through isolation of direct photons at high-pT over a broad range of pseudorapidity.

THU-NP08-3 #123 - Invited Talk - Thursday 8:30 AM - Trinity Central

The GlueX electromagnetic barrel calorimeter and its novel readout photo-sensors

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The GlueX experiment, at the Thomas Jefferson National Accelerator Laboratory (JLab), will be housed in a new purpose-built experimental hall and will take advantage of the 12 GeV electron beam of the upgraded facility to deliver linearly polarized photons in the 8-9 GeV energy region onto a LH target. The initial scientific program of GlueX will be probing QCD confinement, with particular emphasis on the mapping of the nonets of hybrid and exotic hybrid mesons known as gluonic excitations. The extraction of the J, P and C quantum numbers of the reconstructed mesons, from their decay of neutral and charged products, will require partial wave analysis that, in turn, requires good four momentum resolution and hermetic detectors. One of the two calorimeters in GlueX is the electromagnetic barrel calorimeter (BCAL). BCAL is a sampling calorimeter with emphasis on photon four momentum reconstruction and it consists of a scintillating fiber and lead sheet matrix within a 2.2T field super-conducting solenoid. The high field strength at the location of the read-out precludes the use of vacuum photomultipliers unless they are removed to areas of reduced field. This results in loss of photoelectron statistics and presents technical problems. A novel solid state photo-sensor, known as silicon PMT's (SiPM), of large enough active area has been developed and tested and has been selected as the read-out of choice. The technical characteristics of the BCAL and its novel read-out, as well as beam test results, will be presented in this talk.

THU-NP08-4 #89 - Invited Talk - Thursday 8:30 AM - Trinity Central

The Vertex Upgrade Detectors for PHENIX

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The PHENIX detector at RHIC has been built with a strong heavy quark particles identification capability. These unique probes of matter are essential to adequately understand in-medium energy loss and to test the basic properties of QCD. The current PHENIX heavy flavor physics program suffers from a poor precision of collision vertex position determination. In order to improve PHENIX vertex measurement capabilities, a set of two independent silicon trackers is being developed as a part of detector upgrade program. First detector to be installed in FY2010 is central barrel Vertex Detector (VTX) - full azimuth coverage tracker around the mid-rapidity region consisting of several layers of strip-pixel and pixel silicon detectors. The main purpose of this device will be precision measurement of the primary collision vertex as well as tagging the off-vertex decays of the heavy quark mesons. Second detector to be installed in FY2011 is going to be the Forward Silicon Vertex Detector (FVTX) - silicon micro-strip tracker, covering the acceptance of the existing muon arm detectors ($1.2 < |y| < 2.4$). Installation of this subsystem will provide important information about the muon vertex to help disentangle the muons, originated from semi-leptonic decays of the heavy quark particles. The current status of the vertex upgrade detectors' construction and expectations for the physics signal extraction will be presented.

THU-NP08-5 #80 - Invited Talk - Thursday 8:30 AM - Trinity Central

STAR Heavy Flavor Tracker Upgrade --Status of PIXEL Detector

Leo Greiner[1], Hans Georg Ritter[1], Thorsten Stezelberger[1], Xiangming Sun[1], Michal Szelezniak[1], Jim Thomas[1], Chinh Vu[1], Flemming Videbaek[2], Howard Wieman[1], Nu Xu[1]

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The Heavy Flavor Tracker (HFT) is an upgrade project for the STAR detector at RHIC. It will allow the topological reconstruction of the heavy flavor hadrons via their hadronic decays . The HFT consists of three coaxial detectors: SSD(Silicon Strip Detector), IST(Intermediate Si-Tracker) and PIXEL(a pixel detector). The PIXEL is the inner-most and highest precision detector in HFT with two layers at 2.5 and 8 cm radius. The sensor chip we use to build PIXEL is developed in Monolithic Active Pixel Sensor(MAPS) technology. Each sensor has 1024X1188 pixels with 18.4 micron pitch and 50 micron thickness. The integration time is 200 us. Correlated double sampling (CDS) and digitization are performed on the sensor chip. The readout electronics is designed to handle 400 sensors which are grouped in 10 sectors. In this talk, we discuss the relation between the physics goals and sensor characteristics, such as pixel size, sensor thickness, integration time, radiation tolerance and power consumption. We introduce the on-chip electronics design to perform CDS and digitization. We also discuss the readout electronics designed to handle R&D tests and physics data acquisition. The PIXEL is expected to be fully installed in 2014 for RHIC Run14.

THU-NP09-1 #193 - Invited Talk - Thursday 1:00 PM - Trinity Central

CAESAR-A high-efficiency scintillator array for gamma-ray spectroscopy with fast beams of rare isotopes

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The high-efficiency scintillator array CAESAR was constructed and commissioned for in-beam gamma-ray spectroscopy with fast beams of rare isotopes at the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University (MSU). At the Coupled Cyclotron Facility of the NSCL, rare isotopes are produced by projectile fragmentation of stable beams at energies higher than 100 MeV per nucleon, separated in-flight, and delivered to experiments at velocities exceeding 30% the speed of light. In those experiments, gamma rays emitted from the fast moving nuclei are considerably Doppler shifted and a sufficient granularity of the detection system is needed to reconstruct the gamma-ray energy. High gamma-ray detection efficiency is needed to perform experiments in a reasonable amount of beam time for spectroscopy of rare isotopes at production rates of only a few particles per second.

CAESAR consists of 192 CsI(Na) crystals that surround the reaction target in a 4pi geometry. The granularity of CAESAR allows for an in-beam resolution better than 10% FWHM for 1MeV gamma rays. The total amount of 650 lbs of active scintillator material and a close to 4pi coverage yield an in-beam full-energy-peak efficiency exceeding 35% for 1MeV gamma-rays. The spectral quality of in-beam gamma-ray spectra measured with CAESAR allows the identification of gamma-ray transitions with several ten counts in the full-energy peak.

This work was supported by the US National Science Foundation under contracts PHY-0722822 and PHY-0606007.

THU-NP09-2 #334 - Contributed Talk - Thursday 1:00 PM - Trinity Central

Multi-Channel Integrated Circuits for Use in Research with Radioactive Ion Beams

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The Integrated Circuits Design Research Laboratory at Southern Illinois University Edwardsville (SIUE) has been collaborating over the past several years with the Nuclear Reactions Group at Washington University (WU) on the development of a family of custom, multi-channel integrated circuits (ICs). To date, the collaboration has successfully produced two micro-chips. The first was an analog shaped and peak sensing chip known as HINP16C (Heavy Ion Nuclear

Physics - 16 Channel). The second chip, christened PSD8C (Pulse Shape Discrimination - 8 Channel), was designed to logically complement (in terms of detector types) the HINP16C chip.

The HINP16C chip, for use with solid-state detectors, produces sparsified analog pulse trains for both linear (pulse height) and timing (relative to an external reference) signals. A shaper and peak detector are implemented in the linear branch, and a pseudo constant-fraction discriminator and time-to-voltage converter (TVC) are implemented in the logic/timing branch. The internal and external gain options make the chip suitable for use in a wide variety of applications.

PSD8C greatly simplifies the pulse-processing electronics needed for large arrays of scintillation detectors. Because PSD8C employs user-controlled, multi-region charge integration; particle identification is inherent in the design. Each of the three pulse-height sub-channels consists of a gated integrator with eight programmable charging rates and an externally programmable gate generator that defines the start (with 4 time ranges) and the width (with 4 time ranges) of the gate, relative to an external discriminator signal. Each channel on the chip also contains a TVC.

This presentation describes the design, capabilities, and features of the HINP16C and PSD8C ICs along with experimental results obtained using the ICs. The presentation will also discuss modifications and enhancements which have been made to both chips and their associated prototypical systems in order to improve ease of use, increase performance, and expand capabilities

THU-NP09-3 #323 - Invited Talk - Thursday 1:00 PM - Trinity Central

A Pulse Shape Analysis Technique for the MAJORANA Experiment

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The first experimental phase of the MAJORANA neutrinoless double beta decay project is currently under way, designing and constructing a demonstrator module consisting of ~60 kg of High Purity Germanium (HPGe) detectors. These detectors, ~30 kg of which will be enriched to 86% in Ge-76, are based on a P-type Point Contact (PPC) geometry, providing optimum performance in terms of both energy resolution and background rejection efficacy. This novel detector technology will be introduced and the characteristics of these devices discussed within the context of the MAJORANA experiment.

In order to achieve background count rates sufficiently low as to allow the observation of rare event such as neutrinoless double beta decay, background suppression techniques are routinely employed. Details of a novel Pulse Shape Analysis technique which allows single-site events of interest (such as neutrinoless double beta decay) to be distinguished from multi-site background events will then be discussed.

The PSA algorithm, which is based on the event-by-event chi-squared fitting of experimental signals to a basis data set of unique single-site pulse shapes, has been developed through simulation studies and tested experimentally using a Broad Energy Germanium (BEGe) detector.

It is found experimentally that the technique is able to successfully identify and reject 99% of multi-site events in the single escape peak associated with the gamma decay of Tl-208, whilst maintaining a survival probability of 98% for neutrinoless double beta decay like double escape peak events.

THU-NP09-4 #66 - Contributed Talk - Thursday 1:00 PM - Trinity Central

Digital electronics for the Versatile Array of Neutron Detectors at Low Energies

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The proposed Versatile Array of Neutron Detectors at Low Energies (VANDLE) will consist of a modular array of 164 plastic scintillator bars to measure the

neutron energy using time of flight technique (TOF). The expected large neutron energy dynamic range, from 100 keV to 10 MeV, and its modular design will give

the flexibility

necessary to use the detector in experiments with requirements as different as beta decay of neutron rich elements to (d,n) reaction experiments.

VANDLE will be equipped with a high channel density, low threshold data acquisition with sub-nanosecond

timing resolution. It is proposed to use a digital data acquisition. Its simplicity and low noise makes it an attractive choice for VANDLE.

A series of tests have been made to study the feasibility of using of-the-shelf Pixie16 100 MSPS digital electronics. The main challenge is its intrinsic

digitization period of

10 ns, slower than the required resolution. Both the analysis of controlled pulser

experiments and data from the VANDLE prototype indicate that it is possible to achieve sub-nanosecond resolution with proven digital filtering. Preliminary

results with Pixie16 digital electronics and the VANDLE prototype have shown a time resolution comparable to that of analog electronics.

THU-NP09-5 #328 - Invited Talk - Thursday 1:00 PM - Trinity Central

Compton Imaging with Semiconductor Detectors

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Single Photon Emission Computed Tomography (SPECT) is an established functional imaging technique which is used for medical diagnostic applications. A radioisotope which decays along a single photon pathway such as Tc-99m (141keV) readily accumulates in specific areas of the patient and subsequently decays away. These decays are detected and an image is generated. In the case of cancers, functional imaging has to be registered with anatomical structure as its precise location has major implications in how the disease is treated.

Current SPECT systems employ a gamma camera to locate the distribution of the administered radiotracer. The gamma camera system is typically constructed from heavy metal collimators placed in front of scintillator detectors attached to photomultiplier tubes. The limitations of the current systems are that;

1) The use of collimators for spatial resolution results in a lack of efficiency as only a small fraction of emitted gamma rays are detected. It also limits the energy that can be imaged.

2) They cannot work in a magnetic field so co-registry with anatomical Magnetic Resonance Imaging (MRI) is impossible.

3) To image a radioactive distribution the gamma camera has to be rotated around the patient.

ProSPECTus is an interdisciplinary project based at the University of Liverpool which is investigating the use of semiconductors in Compton camera mode which can be deployed in large magnetic fields for SPECT/MRI multimodality imaging. The spatial resolution is provided by using highly electronically segmented detectors which removes the necessity of mechanical collimation. Compton kinematics and cone beam reconstruction are used to locate the distribution of the radioactive substance.

Results for semiconductor detectors originally designed for deployment in nuclear structure physics experiments will be presented which will include Compton images along with data collected in a 1.5T field.

THU-RE08-1 #187 - Invited Talk - Thursday 8:30 AM - West Fork

Nanoparticles for Scintillation Detection of Nuclear Radiation

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Inorganic scintillators are commonly used for measuring radiation from nuclear materials, and normally are a single crystal often doped with a rare earth (RE) ion that controls the wavelength and intensity of radioluminescence. Scintillating nanoparticles have the potential to replace the expensive, limited volume single crystal detectors. A variety of detector materials have been grown as nanoparticles, including $Gd_2O_3:Eu^{3+}$, $GdVO_4:Eu^{3+}$ (GVO), $Gd_2SiO_5:Ce^{3+}$ (GSO) and self-

activated $Bi_4Ge_3O_{12}$ (BGO) using a variety of synthesis methods, such as sol gel, solution precipitation, polyol and hot solution growth. Some of these nanoparticles with dimensions as small as ~5 nm self-assembled into more complex architectures, such as nanoplatelets, nano and micro rods, and complex hierarchical structures that were flower-like or coral-like; these will be illustrated and discussed. In addition to the above ?core' nanostructures, we have grown core/shell and core/shell/shell nanostructures to (i) reduce non-radiative surface states created by dangling bonds (e.g. $Gd_2O_3:Eu^{3+}/Y_2O_3$), and (ii) increase the absorption of radiation with high-Z cores and scintillator shells (e.g. $Bi_2O_3/Gd_2O_3:Eu^{3+}$). Reduced non-radiative surface states and higher absorption by the core result in higher quantum yields, and therefore better sensitivities. However the nanostructure size must match the attenuation distances of the radiation and hot charge carrier, as will be illustrated. Enhanced energy harvesting by the shell and transfer to the RE activator ion leading to increased luminance will be illustrated. Scintillation data will be compared to photoluminescence data. We conclude that core/shell nanostructured materials are especially promising scintillators for radiation detection.

THU-RE08-2 #136 - Invited Talk - Thursday 8:30 AM - West Fork

Characterization of Al_2O_3:C optically stimulated luminescence detectors (OSLD) for dose and LET measurements of therapeutic proton beams

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Proton therapy is increasingly becoming popular for the treatment of cancer patients. Precise dosimetry of therapeutic proton beams is vital for achieving the best possible therapeutic outcome. Measurement of dose in proton beams can be challenging because protons produce very high ionization density in the vicinity of their tracks, which in turn may affect the response of most of the commonly used detectors. Thus, it is important to explore the use of novel detectors and characterize their response to therapeutic proton beams, and develop protocols that minimize uncertainties in the delivered doses. It is also important to develop experimental techniques to measure linear energy transfer (LET) of therapeutic proton beams because LET is a required parameter to determine biological effective doses. In the past decade, OSLDs have been widely used in radiation dosimetry. Recently, these detectors have also been investigated for medical dosimetry applications. Most of the OSLDs are based on Al_2O_3:C. The OSL technique has many favorable features for use in clinical dosimetry including the high sensitivity of Al_2O_3:C to ionizing radiation, small detector size, no need for cables, simple preparation procedure (bleaching by light exposure), simple and fast optical readout process, possibility of re-evaluation (re-reading) and potential for real-time in-vivo applications. The objective of this work is to present a detailed characterization of the response of Al_2O_3:C based OSLD for dose and LET measurements of therapeutic proton beams.

THU-RE08-3 #446 - Invited Talk - Thursday 8:30 AM - West Fork

Thermal Neutron Scintillators Grown by MOCVD

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A new type of neutron detector has been developed using a novel scintillator crystal growth technique, Metal Organic Chemical Vapor Deposition (MOCVD). MOCVD has the unique capability of growing uniform, oriented, single crystal scintillators from a number of novel materials. This crystal growth method has the unique capability of growing thin scintillators with very precise control over thickness (less than 10 nm control), dopant levels, and alloying concentrations. Two promising materials, zinc oxide (ZnO) and gallium nitride (GaN) have been grown by the authors and constructed neutron detectors. These high crystalline quality (XRD FWHM of 390 arc seconds) scintillators have ultra-fast decay times with rise times for ZnO of 35 pS and decay times of 0.65 µs. Crystals can be grown in relative high volume with diameters up to six inches. Current scintillators are grown in two inch diameters with growth rates of up to four microns per hour. These scintillators have been conformally coated with 6LiF as well as doped interstitially with lithium. Gadolinium doped GaN is the other promising material. Gadolinium is both doped interstitially as well as conformally coated with gadolinium metal. These materials were tested in reference neutron fields. The doped ZnO scintillators perform superior to 3He tubes

in a number of categories including pulse height rise and fall times, absolute efficiency, and intrinsic efficiency. These scintillators also possess good neutron versus gamma discrimination capabilities equal to those of ^{3}He tubes. Using the fine control over crystalline thickness, engineered crystals can be created minimizing the gamma ray response, and producing large stacks of the scintillator crystals. Results from neutron, gamma, and XRD spectra will be presented. Neutron efficiency and gamma ray rejection results will be compared to standard reference thermal neutron detectors including ^{3}He, $10BF_3$, and ^{10}B lined tubes, and lithiated glass scintillators.

THU-RE08-4 #402 - Invited Talk - Thursday 8:30 AM - West Fork

LET Spectrum Measurements in CR-39 PNTD with AFM

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Energetic protons, neutrons, and heavy ions undergoing collisions with target nuclei of varying Z can produce residual heavy recoil fragments via intra-nuclear cascade/evaporation reactions. The particles produced in these non-elastic collisions generally have such extremely short range ($\sim< 10$ μm) that they cannot be directly observed by conventional detection methods including CR-39 plastic nuclear track detector (PNTD) that has been chemically etched for analysis by standard visible light microscopy. However, high-LET recoil fragments having range on the order of several cell diameters can be produced in tissue during radiotherapy using proton and carbon beams.

We have developed a method to analyze short-range, high-LET tracks in CR-39 plastic nuclear track detector (PNTD) using short duration chemical etching ($\sim< 1$ μm) following by automated atomic force microscope (AFM) scanning. The post-scan data processing used in this work was based on semi-automated matrix analysis opposed to traditional grey-scale image analysis. This method takes advantage of the 3-D data obtained via AFM to achieve robust discrimination of nuclear tracks from other features. Through automation of AFM scanning, sufficient AFM scan frames were obtained to attain an LET spectrum spanning the LET range from 200-1500 keV/μm. The results of our experiments are generally in good agreement with simulations carried out with the Monte Carlo transport code, FLUKA.

To demonstrate this method, CR-39 PNTD was exposed to the proton therapy beam at Loma Linda University Medical Center (LLUMC) at 60 and 230 MeV. Additionally, detectors were exposed to 1 GeV protons at the NASA Space Radiation Laboratory (NSRL) at Brookhaven National Laboratory (BNL). For these exposures CR-39 PNTD, Al and Cu target foils were used between detector layers.

THU-RE08-5 #384 - Contributed Talk - Thursday 8:30 AM - West Fork

Rapid Development of Dosimetric Materials with Nanophosphors

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Nanotechnology and nano-scale materials are areas of intense research and exciting results for many disciplines of science. Much of the interest has centered on the unique properties of quantum dots caused by the quantum confinement of electrons. More recently, the properties of insulating nanophosphors have been explored where the effects of reduced dimensionality are not as dramatic (no quantum confinement of the electrons), but nanophosphors may have other advantages over single crystal materials.

The reduced dimensionality of nanophosphors appears to have little affect on Thermally Stimulated Luminescence (TSL) and Optically Stimulated Luminescence (OSL), two common dosimetric techniques. However, these techniques are very sensitive to changes in material properties that are either intentional (e.g., rare-earth doping) or unintentional (e.g., impurity inclusion) that can lead to the creation, alteration, or annihilation of trapping levels within the material. Since single crystal growth procedures are typically time and labor intensive, exploring these effects by altering growth conditions or doping schemes is difficult. On the other hand, nanophosphor production techniques such as Solution Combustion Synthesis (SCS) can rapidly produce large quantities of materials where the type and concentration of dopant can be easily and systematically varied. This procedure then allows us to quickly and efficiently produce potential dosimetric materials by varying the dopant levels and synthesis parameters and tailor these properties to particular applications such as radiation dosimetry at accelerators.

In this presentation, we will review some TL and OSL results from SCS produced nanophosphors. We will concentrate on the basic radiation dosimetry properties of these materials and how these properties are affected by varying the conditions of nanophosphor production.

THU-RE08-6 #527 - Contributed Talk - Thursday 8:30 AM - West Fork

Optical Characterization of Molecular Scintillation Materials

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Ideal scintillators exhibit short emission lifetimes, high light yields, minimal self-absorption and high effective Z. Information obtained from radiation-scintillator interactions includes energy, position and duration of the incident radiation. The reliable acquisition and interpretation of this information is critical for radiation detection scenarios.

CeBr3 is a recently discovered scintillator that outperforms most known scintillators, having a faster lifetime, better energy resolution and stronger emission. The optical properties of molecular scintillators will be sensitive to the local environment around the Ce3+. Systematic changes to the solvate can be used to manipulate the energy levels to obtain materials suitable for specific applications. Adducts of interest include tetrahydrofuran (THF) and pyridine among others.

This presentation will review the photoluminescence and optical lifetime properties of CeBr3 in different adducts. Because of the ideal properties of these materials they will have applications as scintillators and for use as radiation detectors.

THU-RE09-1 #161 - Invited Talk - Thursday 1:00 PM - West Fork

Stochastic Simulation of Ion Beam Radiolysis of Aqueous Systems

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Stochastic calculations, employing track simulations and independent reaction times diffusion-kinetic modelling, have been used to elucidate the chemistry of aqueous systems containing hydrated electron, hydroxyl radical and hydrogen atom scavengers. Simulation results were compared with experimental measurements, and used to obtain information about the underlying nonhomogeneous radiation chemical mechanisms and radical kinetics. There is a significant effect of radiation

quality on the radiation chemical yields that can be explained interms of the radiation track structure: The scavengable yields of the hydrated electron and the hydroxyl radical decrease with LET, while the yields of the molecular (damage) products, hydrogen and hydrogen peroxide, increase with LET. The tracks of different ions with the same LET show different chemistry and are found to have very different structures.

THU-RE09-2 #162 - Invited Talk - Thursday 1:00 PM - West Fork

The Photoprotective Properties of Adenine: Femtosecond Time-resolved Photoelectron Spectroscopy at Different UV Excitation Wavelengths

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The UV photostability of biomolecules is determined by their excited state electronic relaxation mechanisms. To be effective, these mechanisms must operate on ultrafast timescales in order to dominate over competing photochemical processes that potentially lead to destruction of the biomolecule. Femtosecond time-resolved photoelectron spectroscopy (TRPES) provides unique capabilities for studying photoinduced processes in small polyatomic molecules. Changes in the PES, observed as the delay between the pump and probe pulses is scanned, can be associated with electronic configurational changes during the relaxation process. Analysis based on ionization correlations allows us to extract the electronic character of the excited states in addition to their lifetimes.

Details of the experimental setup and technique will be presented in this talk as well as our results on the deactivation pathways in the DNA base adenine following excitation by wavelengths between 200-266 nm.

THU-RE09-4 #419 - Invited Talk - Thursday 1:00 PM - West Fork

The Center for Ion Modified Materials Research: A New Highly Charged Ion-Based User Facility at Clemson University

Chad E Sosolik
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In this talk, I will give an overview of a newly funded facility centered on the production and extraction of highly charged ions (HCIs) at Clemson University. Specifically, I will discuss first the electron beam ion trap source, which is used to produce HCIs in a controlled laboratory setting. Additionally, I will outline our designs for an HCI beamline and its associated target and sample preparatory stations. My purpose is to introduce our facility as a project "in-progress" and to solicit useful ideas from participants as to how this can best be configured and utilized as a user facility. Targeted areas for this new facility include the following: electronic materials and devices, biologically-relevant targets, fusion reactor wall materials, and laboratory astrophysics.

THU-RE09-5 #3 - Contributed Talk - Thursday 1:00 PM - West Fork

Production and Recoil-Implantation of Multiple Radioisotopes towards the Tracing of Prosthetic Joint Wear Particles

Jacob Alan Warner[1], Laura G Gladkis[1], Heiko Timmers[1,2]
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Worldwide, 600,000 knee replacement surgeries are performed every year. The most preferred design used combines a CoCrMo femoral component and an ultra-high molecular weight polyethylene (UHMWPE) tibial insert on a CoCrMo tibial component. The articulation of this metal-on-polymer-on-metal system creates problematic UHMWPE wear debris particles. The UHMWPE debris can lead to harmful immunological responses, eventually causing osteolytic bone resorption and necessitating revision surgery.

In order to map the pathways of the UHMWPE debris particles, a new radioisotope tracing technique has been trialed, as an alternative to the established ^{7}Be technique. The new technique takes advantage of the complementary information from three different tracers with different atomic and chemical properties. Furthermore, these tracers have relatively short half-lives on the order of 3 days, which in comparison with ^{7}Be with a half-life of 53 days, gives more sensitivity for the same implanted fluence.

The radioisotope tracers ^{97}Ru, ^{100}Pd, and ^{101m}Rh were produced via fusion evaporation reactions using a 70 MeV ^{12}C beam incident on a ^{92}Zr target. The reaction products recoiled into UHMWPE samples placed at forward angles. The implantation depth profiles are predicted by TRIM to be relatively uniform, extending from the surface to a maximum depth of 5.4 μm. The tracers were detected via characteristic gamma-rays. The efficacy of the new technique has been confirmed with sliding wear studies using a polyethylene-on-steel system. It has been found that particle dispersion into the lubricant depends on load, surface roughness and sliding mode. The new technique can be applied to wear studies of commercial knee prostheses in efforts to map the transport pathways of the problematic UHMWPE particles.

THU-RE09-P1 #239 - Poster - Thursday 3:00 PM - Rio Grande

Control of Cell Growth on Glassy Polymeric Carbon (GPC)

Tabitha Lewis, Patrice Coleman, Lynn Bowman, Malek Abunaemeh, Claudiu I. Muntele, Robert L. Zimmerman, Daryush ILA

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We have succeeded in enhancing the properties of the glassy polymeric carbon (GPC) used for the moving parts of replacement human heart valves by MeV ion implantation of silver. Potentially dangerous accumulation of natural cells attached to the valve after installation has been eliminated. These results appear in previous MRS publications. Although it has been proved satisfactorily that the total amount of silver implanted in the heart valve poses no toxic effects, an unanswered question remains: will the beneficial effects of the silver diminish as silver leaches out? To determine the leach rate, we have immersed a GPC sample implanted with silver in a bath of physiological solution at the beginning of June 2009. We have developed a cyclic voltammetry technique that detects the absolute concentration of silver ions to parts per billion in aqueous solutions. The bath has been quantitatively analyzed periodically by cyclic voltammetry to determine the out diffusion of silver ions from the near surface of GPC. With assurance that ion beam implanted silver in GPC is stable, we are justified in initiating en vivo tests to show that silver implanted GPC remains free of cell growth in the blood stream.

FRI-PL05-1 #550 - Invited Talk - Friday 8:30 AM - Pecos I & II

Brief Overview of the Standard Model for Experimentalists

Konstantin Toms

University of New Mexico/CERN, 1 rue du Bordeau, Saint Genis-Pouilly 01630, France

The Standard Model (SM) of Particle/High Energy Physics provides the modern understanding of all of the interactions of elementary particles, except gravity. The theory combines strong, weak and electromagnetic interactions in the united theoretical framework, using the language of quantum field theory. The Higgs boson, is the only elementary particle predicted by SM but not yet observed in experiment. Some SM theoretical problems and some ways to extend the SM are reviewed such as the supersymmetry, 4th generation of quark/leptons, Dark Matter, TeV scale gravity, Extra Dimensions.

FRI-PL06-1 #551 - Invited Talk - Friday 9:00 AM - Pecos I & II

The Development of Experiments on the LHC

Konstantin Toms

University of New Mexico/CERN, 1 rue du Bordeau, Saint Genis-Pouilly 01630, France

The Large Hadron Collider is the largest and highest-energy particle accelerator ever built. Since March 30th 2010 its experiments collect data of proton-proton collisions at 7TeV center-of-mass energy. The main challenge for the LHC and its experiments is the search for the Higgs boson, the last not yet observed particle of the Standard Model, and the search for the Physics Beyond the Standard Model. Four main experiments of the LHC to be reviewed (ATLAS, ALICE, CMS, LHCb) with their scientific programs, main advantages and specializations, schedules and plans.

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