


Book of Abstracts

27th International Conference on the Application of Accelerators in Research & Industry (CAARI) and 55th Symposium of Northeastern Accelerator Personnel (SNEAP)

July 21 through 26, 2024
Worthington Renaissance Hotel
Fort Worth, Texas, USA

CAARI-SNEAP 2024

July 21 - 26, 2024 *Fort Worth, TX*
www.caari-sneap.com

Welcome to the 27th International Conference on the Application of Accelerators in Research and Industry (CAARI) and the 55th Symposium of Northeastern Accelerator Personnel (SNEAP)

The CAARI-SNEAP 2024 conference is being hosted by the University of North Texas (UNT), Sandia National Laboratories (SNL), and Los Alamos National Laboratory (LANL). The conference is also being supported by several other commercial companies involved with accelerator technology.

Our conference series brings together researchers from all over the world who use particle accelerators in both research and industrial applications. Each year the Topic Areas are reviewed and updated to reflect current research interests.

This year's CAARI is the 27th international conference in the biennial series that began in 1968 as a *Conference on the Use of Small Accelerators for Teaching and Research* by Jerry Duggan while he was a staff member at Oak Ridge Associated Universities. When Jerry moved to Denton, TX, and joined UNT in 1974, he continued the conference series and held the meeting on the UNT campus. At this time, Jerry invited Lon Morgan to join him as a co-chair. Lon Morgan brought in the industrial accelerator applications of CAARI and it became known as the *International Conference on the Application of Accelerators in Research and Industry (CAARI)*. CAARI was held in Denton for 30 years. In 2004, Jerry Duggan asked Floyd "Del" McDaniel and Barney Doyle to be co-chairs of the CAARI Conference Series. In 2004, Barney and Del moved the conference to Fort Worth, Texas, where it was held biennially from 2004-2012. In 2012, Yongqiang Wang and Gary Glass were invited to become co-chairs and the conference was held in San Antonio, TX. For the 2016 Conference, Arlyn Antolak joined as a co-chair and the conference returned to Fort Worth, Texas. Our 2020 conference was cancelled due to the Covid pandemic.

The Symposium of Northeastern Accelerator Personnel (SNEAP) is an international community of personnel involved with electrostatic particle accelerators and their use. Founded in 1968 by accelerator engineers/technicians from Chalk River Nuclear Laboratories, McMaster University, and the University of Montreal, the organization has gathered annually to discuss and exchange information on ion sources, electrostatic and rf accelerators, telemetry and control systems, cryogenic systems, safety issues and many other topics relevant to the operation of small-to-medium-sized electrostatic accelerator laboratories.

We hope that you enjoy the conference, find it intellectually stimulating, and use it as a segway to connecting with others. The conference schedule provides several opportunities to renew friendships and engage in productive discussions of current and future accelerator research, technologies, and applications. We also want to highlight the *Book of Abstracts* found at CAARI-SNEAP.com which contains the published abstracts submitted to the conference as well as providing a synopsis of the conference.

If there is anything we can do to make your conference experience and stay in Fort Worth, Texas, more enjoyable, just ask Gary, Yong, Barney, Arlyn, Mark, Holly, Carley or Shari. We are very happy you have joined us and hope you have a memorable time!

Gary Glass[a] Yongqiang Wang[b] Barney Doyle[c]
Arlyn J. Antolak[c] Mark Roberts[d]

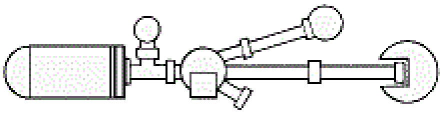
[a]University of North Texas [b]Los Alamos National Laboratory [c]Sandia National Laboratories [d]Woods Hole Oceanographic Institution
1155 Union Circle, # 311427 * Denton, Texas 76203-5017 USA Email: CAARI.SNEAP@outlook.com

Local Committees

Arlyn Antolak	Co-Chair, Sandia National Laboratories
Barney L. Doyle	Co-Chair, Sandia National Laboratories
Gary A. Glass	Co-Chair, University of North Texas
Mark L Roberts	Co-Chair, Woods Hole Oceanographic Institution
Yongqiang Wang	Co-Chair, Los Alamos National Laboratory
Holly Decker	Conference Coordinator, UNT Contractor
Shari McAnally	Conference Coordinator, UNT Contractor
Carley Parriott	Conference Coordinator, SNL
Zdenek Nejedly	Web Services, AnZ Solutions & Meeting247

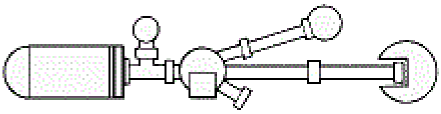
Topic Editors

Arlyn Antolak	Sandia National Laboratories
R. Mark Bradley	Colorado State University
Jim Browning	Oak Ridge National Laboratory
Martin Bues	Mayo Clinic in Arizona
Barney L. Doyle	Sandia National Lab
Jonathan Farr	Advanced Oncotherapy
Alfredo Galindo-Uribarri	Oak Ridge National Laboratory
Gary A Glass	University of North Texas
Lyudmila Goncharova	Western University
Khalid Hattar	University of Tennessee, Knoxville
Qing Ji	Lawrence Berkeley National Laboratory
Ming Xiong Liu	Los Alamos National Laboratory
Daniel Keith Marble	Tarleton State University
Sylwia Ptasinska	University of Notre Dame
Jani Reijonen	SLB
Feng Ren	Wuhan University
Mark Roberts	Woods Hole Oceanographic Institution
Jefferson L Shinpaugh	East Carolina University
Theva Thevuthasan	Pacific Northwest National Laboratory
Yongqiang Wang	Los Alamos National Laboratory
Yanwen Zhang	Queen's University



Session Chairs

Arlyn Antolak	Sandia National Laboratories
Mauricio Ayllon Unzueta	NASA GSFC/ Catholic University of America
Dan Bardayan	University of Notre Dame
Alex Belianinov	Sandia National Laboratories
Joseph Bendahan	Lawrence Livermore National Laboratory
Anissa Bey	Washington University in St. Louis
Iva Bogdanovic Radovic	Ruder Boskovic Institute
R. Mark Bradley	Colorado State University
Martin Bues	Mayo Clinic in Arizona
David Button	ANSTO
Sergey Chemerisov	Argonne National Laboratory
Nerine Cherepy	Lawrence Livermore National Laboratory
Yasser Corrales Morales	MIT
Matthew David Coventry	Starfire Industries
Jay Theodore Cremer	Adelphi Technology, Inc.
MIGUEL L. CRESPILLO	University of Tennessee
Cathy Sue Cutler	Brookhaven National Laboratory
Cameron Dean	MIT
Naresh T. Deoli	Columbia University
Matthew J Devlin	Los Alamos National Laboratory
Jason Dugger	Sandia National Laboratories
Osman El Atwani	Pacific Northwest National Laboratory
Patrick Feng	Sandia National Laboratories
Leo Fifield	Pacific Northwest National Laboratory
Alfredo Galindo-Uribarri	Oak Ridge National Laboratory
Lyudmila Goncharova	Western University
Charles Hirst	University of Wisconsin-Madison
Fuhao Ji	SLAC National Laboratory
Karen L Kavanagh	Simon Fraser University
Robert David Kolasinski	Sandia National Laboratories
Lukasz Kurpaska	National Center for Nuclear Research
Sergey V Kutsaev	RadiaBeam Technologies, LLC
Jakub Kvapil	Los Alamos National Laboratory
Mikko Laitinen	University of Jyväskylä
Xuan Li	Los Alamos National Laboratory
Peter Linardakis	Australian National University
David Lunt	UK Atomic Energy Authority
Gennady Miloshevsky	Virginia Commonwealth University
Anand Prakash Pathak	University of Hyderabad
Graham F Peaslee	University of Notre Dame
Sylwia Ptasinska	University of Notre Dame
Jani Reijonen	SLB
Feng Ren	Wuhan University
Mark Roberts	Woods Hole Oceanographic Institution
Andy Roberts	Minnesota State University Mankato
Bibhudutta Rout	University of North Texas
Alexander Scheinker	Los Alamos National Laboratory
Franziska Schmidt	Los Alamos National Laboratory
John M Screech	Agilent Technologies Inc
Vaithiyalingam Shutthanandan	Pacific Northwest National Laboratory
Andy Smith	University of Manchester
Edward Stech	University of Notre Dame
Dannie Steski	Brookhaven National Laboratory
Yang Tan	Shandong University
Michael Titze	Sandia National Laboratories
Thomas Tunningley	Australian National University
Yongqiang Wang	Los Alamos National Laboratory
Hanyu Wang	Oak Ridge National Laboratory
Chris R Westerfeldt	Duke University
You Zhang	UT Southwestern Medical Center



Sponsors and Supporters

Sponsors

UNT University of North Texas

Sandia National Laboratories

Los Alamos National Laboratory

Exhibitors

Dean Technology

Anest Iwata

Buckley Systems Ingenious at work

ScandiNova

National Electrostatics Corp.

RadiaBeam

beamNetUS accelerating beam-based research

-Pace

Applied Diamond, Inc WWW.USAPPLIEDDIAMOND.COM

Amsterdam Scientific Instruments

Supporters

Agilent

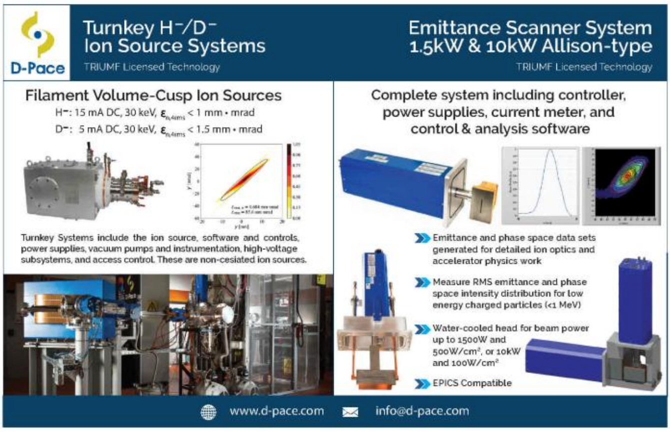
Endorsements

AVS Endorsed Topical Conference www.avs.org


Applied Diamond, Inc
USAppliedDiamond.com
Diamond Parts & Assemblies
Detectors, Windows, Filters, Brazed Parts, Plates
Your custom solutions partner – prototypes to production
(302) 999-1132
services@usapplieddiamond.com


Applied Diamond, Inc
DIAMOND DETECTORS
• Fully Customizable
• Metallization, Connectors, PCB, Packaging
• Single Crystal
• Polycrystalline
• Diamond Plates to Fully Packaged Assemblies
Applied Diamond, Inc
AD-1
+1 (302) 999-1132
www.USAppliedDiamond.com
3825 Lancaster Pike, Wilmington, DE 19805 USA


HVCA.COM



D-Pace
Turnkey H⁻/D⁻ Ion Source Systems
TRIUMF Licensed Technology
Emittance Scanner System 1.5kW & 10kW Allison-type
TRIUMF Licensed Technology
Filament Volume-Cusp Ion Sources
H^-: 15 mA DC, 30 keV, $\varepsilon_{n,4rms}$ < 1 mm • mrad
D^-: 5 mA DC, 30 keV, $\varepsilon_{n,4rms}$ < 1.5 mm • mrad
Turnkey Systems include the ion source, software and controls, power supplies, vacuum pumps and instrumentation, high-voltage subsystems, and access control. These are non-cesiated ion sources.
Complete system including controller, power supplies, current meter, and control & analysis software
Emittance and phase space data sets generated for detailed ion optics and accelerator physics work
Measure RMS emittance and phase space intensity distribution for low energy charged particles (<1 MeV)
Water-cooled head for beam power up to 1500W and 500W/cm², or 10kW and 100W/cm²
EPICS Compatible
www.d-pace.com
info@d-pace.com

ASI stands at the forefront of innovation in developing advanced scientific detectors for research in chemistry, physics, material science, and biology. Our mission is to develop detection systems that inspire the scientific community and open the doors for breakthrough discoveries. Embracing the revolutionary Timepix3 technology from CERN, our portfolio includes solutions for electrons, ions, photons, X-rays, and more. With a commitment to user-friendly, reliable, and configurable designs, ASI is dedicated to empowering researchers worldwide. Our participation in Nanotech 2024 marks a significant stride towards collaborating with international experts, furthering our vision of transforming scientific research through cutting-edge detection technology, and paradigm-shifting instrumentation.

https://amscins.com/

Presenters

The latest assignment of your particular session, location, and time is available in your CAARI-SNEAP account at https://www.meeting247.com/caari-sneap/. To see it please sign in with the account of the owner of the presentation abstract (account that was used to submit the abstract to the CAARI-SNEAP conference).

During the conference the Book of Abstracts is also available as a web app via https://www.meeting247.com/caari-sneap/ (filter the talks by day, location, topic, …)

The live schedule of all sessions is available organized by topics and sessions at https://meeting247.com/caari-sneap/pub/session-category-list.action
No account / sign-in is required for the session schedule.

The Guidelines for Presenters are available at https://caari-sneap.com/presentation-guidelines.

PDF-formatted Session and Speaker Schedules

Note: Changes happen and we republish the PDF files to capture the latest updates. If you are a presenter, please, also check your CAARI-SNEAP account to see the latest session assignment.

A single-page **session** schedule is available at https://caari-sneap.com/session_schedule

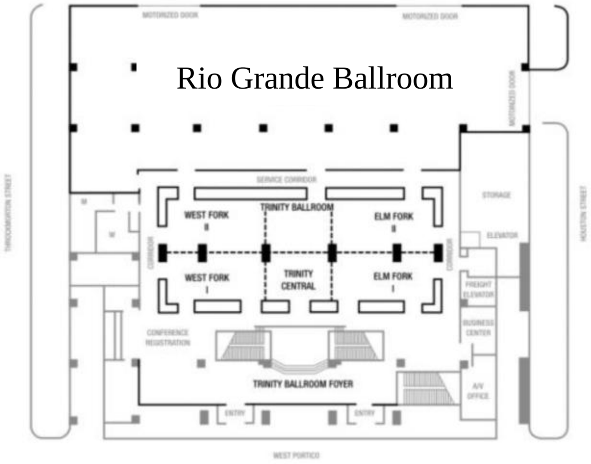
A detailed **speaker** schedule (along with the presentation time and location) is available at https://caari-sneap.com/speakerschedule

The summary of the **event** schedule is available at
https://caari-sneap.com/event-schedule

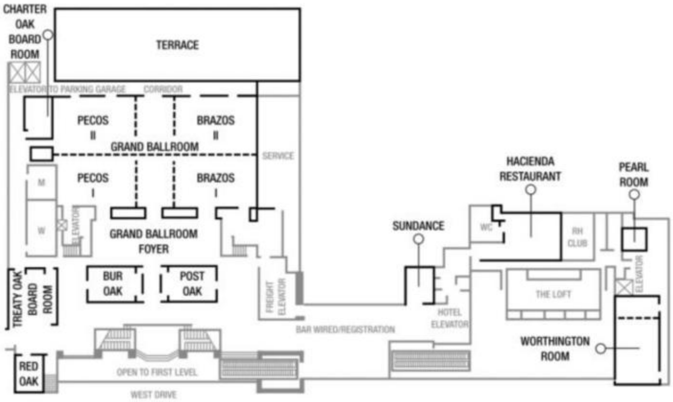
Worthington Renaissance Hotel

Floor maps of the CAARI-SNEAP conference rooms

STREET LEVEL



MEZZANINE LEVEL



Using this Book of Abstracts

This Abstract Book contains:

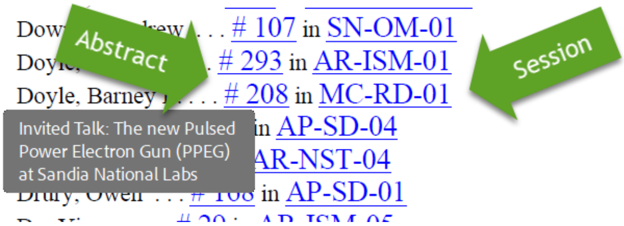
1. the session summary,
2. full text of accepted abstracts, and
3. the index of authors and co-authors.

The Abstract Book can be downloaded from the conference website at https://caari-sneap.com/ and is available in several formats. All formats feature mutual hypertext links between the schedule, abstracts, and the author index.

- Laptop or desktop users: the Microsoft Word version offers popup hints - to see them, please, hover the mouse over the hyperlink. Alternatively, a PDF version is also available.

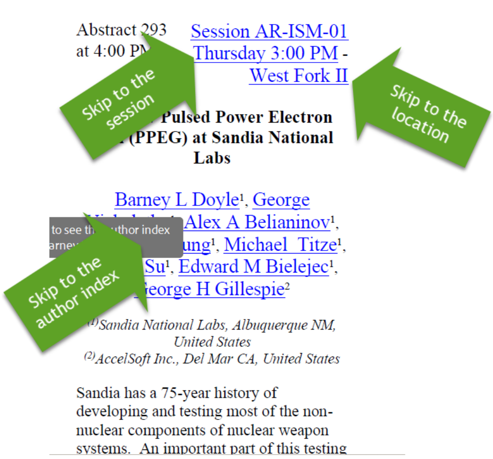
- Users of small mobile devices (tablets or smartphones): While you can certainly use the desktop Word and PDF versions if your device supports them, we have re-sized the Abstract Book to about 4" width so that if you are viewing the book you do not need to shift the screen horizontally. The mobile version of the Adobe Reader can be downloaded from the corresponding app stores, for example, from Google Play for Android.

Depending on the type of software you chose to view this Book of Abstracts, you may be able to search for keywords in the abstracts, add your own notes, or add bookmarks.



The Book of Abstracts contains information about each presentation including all of the authors and their affiliations. If you wish to find out, for example, when

Barney Doyle's talk is to be given, just look up his name in the author index at the end of this book:



Then click on the abstract number to read the full abstract or the session code to view other presentations in the same session.

When you are viewing the abstract click on the author's name to skip to the author index again or click on the session time and location to see all other presentations in this session.

In the example on the left, the abstract header lists the session code (ISM-01), session start time (3 PM), session location/room (West Fork II), abstract number (293) and the time when the talk starts (4 PM).

Hypertext content of this Abstract Book was facilitated by the Meeting247 service

Session Summary

Please note: the presentations marked (Poster session) in the listing below will be presented during the poster sessions only. They are listed at the end of each talk session only to provide the session context.

Disclaimer: Last minute changes happen. The session times and locations listed here may not reflect these latest changes. Before coming to the session always verify the current speaker and session schedules posted at the conference website at https://caari-sneap.com/

PS-PS-01: Monday Plenary Session
Chaired by: Yangyang Wang
Monday at 9:00 AM in Rio Grande Ballroom

92 (9:00 AM) Novel approaches for in situ interrogation of irradiated materials *by Blas Pedro Uberuaga*

AA-NBAT-02: In Situ and Operando Neutron Scattering Techniques for Materials Research
Chaired by: Hanyu Wang
Monday at 10:00 AM in Post Oak

71 (10:00 AM) Time-resolved SANS study of deformation-induced demixing in polymer blends *by Yangyang Wang*
170 (10:30 AM) Tagged neutron technique for in-situ soil composition determination *by Aleksandr Kavetskiy*
86 (11:00 AM) Unraveling the Molecular Mechanisms of Ion-selective Redox-mediated Electrosorption by In Situ Neutron Reflectometry *by Shao Wei Tsai*
169 (Poster session) Advancements in field measurement of soil composition: Introducing the tagged neutron technique mobile system *by Galina Yakubova*

AC-AF-02: Machine Learning for Particle Accelerators I
Chaired by: Alexander Scheinker
Monday at 10:00 AM in Elm Fork II

33 (10:00 AM) Adaptive Physics Constrained ML for Autonomous Particle Accelerators *by Alexander Scheinker*
128 (10:20 AM) Leveraging Distance-Aware Uncertainty Estimation for Machine Learning and Advanced Controls in Particle Accelerators *by Malachi Schram*
36 (10:40 AM) Latent autoregressive recurrent approach for generation and forecasting spatiotemporal beam dynamics *by Mahindra Rautela*
117 (11:00 AM) Errant Beam Prognostics with Machine Leaning at SNS Accelerator *by Kishansingh Rajput*
64 (11:15 AM) Safe Extremum Seeking in Accelerators and Machine Learning *by Alan Williams*
47 (Poster session) Suppression of X-ray radiation from a 2 MV electrostatic ion accelerator *by Ihor Hennadievich Ihnatiev*

AR-NST-04: Surface Science with Charged Particle Beams
Chaired by: Michael Titze, Alex Belianinov
Monday at 10:00 AM in West Fork II

265 (10:00 AM) Ultra-low kV Ion Implantation Depths Analyzed by Atom Probe Tomography *by Joanthan D Poplawsky*
286 (10:30 AM) Pseudo-Epitaxial and Aligned Growth of Transition Metal Dichalcogenide Heterostack *by Ludwig Bartels*
98 (11:00 AM) Coincidence Doppler broadening spectroscopy of single layer graphene on copper using a variable energy positron beam *by V. A. Chirayath*
58 (11:15 AM) Measuring the chemical composition of the topmost atomic layer of clean and adsorbate covered metal surfaces using a low energy positron beam *by Hany Mahdy*

AR-RE-07: Irradiation Effects in the Nuclear Extremes, II
Chaired by: Osman El Atwani
Monday at 10:00 AM in Elm Fork I

77 (10:00 AM) Functionally Graded Joints from Tungsten to Ferritic/Martensitic Steels Fabricated using Laser - Directed Energy Deposition as Plasma Facing Components *by Deniz Ebeperi*
139 (10:30 AM) On the application of an engineered ferritic/martensitic alloy for fusion environments *by Hyosim Kim*
99 (11:00 AM) Revealing radiation-induced defects and defect-phonon scattering in ThO_2 *by Mia Jin*

SN-OM-01: Facility Updates I
Chaired by: Mark Roberts
Monday at 10:00 AM in Trinity Central

85 (10:00 AM) Status report for the Australian National University's Heavy Ion Accelerator Facility (HIAF) *by Peter Linardakis*
107 (10:20 AM) ANSTO Centre for Accelerator Science Lab Report for 2024 *by David Button*
149 (10:40 AM) Status report for the Columbia Radiological Research Accelerator Facility *by Naresh T. Deoli*
191 (11:00 AM) Facilities at the UK National Ion Beam Centre *by Luke Antwis*

AA-IBTM-04: Ion and Micro Beam Analysis
Chaired by: Karen L Kavanagh
Monday at 1:00 PM in Post Oak

248 (1:00 PM) Status of the Scanning Light Ion Microprobe at the University of North Texas *by Todd A Byers*
203 (1:15 PM) The fabrication and design of a liquid target holder for Ion Beam Analysis. *by Jorden Matty*
249 (1:30 PM) Trace Element Analysis of Air Dust Samples using Particle-Induced X-ray Emission Spectroscopy *by Darshpreet Kaur Saini*
76 (1:45 PM) Imaging Seeds for Archaeology *by Karen L Kavanagh*
145 (Poster session) Low energy ion-solid interactions: a quantitative experimental verification of binary collision approximation simulations *by Felix Junge*

AP-SD-03: Neutron and Gamma Technologies for Security and Defense
Chaired by: Matthew David Coventry
Monday at 1:00 PM in West Fork II

201 (1:00 PM) Development towards a field-portable tagged neutron interrogation system for imaging and chemical analysis *by Brian Bucher*
275 (1:30 PM) Associated Particle Imaging for security and defense applications *by Mauricio Ayllon Unzueta*
241 (2:00 PM) Uranium Detection using Photon Active Interrogation based on Delayed Neutron Analysis *by Mairead E. Montague*
278 (2:15 PM) Testing and evaluation of an associated particle imaging neutron generator *by Matthew D Coventry*
223 (Poster session) Comparison of Neutron Generator Output Estimate Using a $LaBr_3$ and an Organic Scintillator *by Caryanne R. Wilson*

AR-NP-09: Neutron and Fundamental Symmetries, I
Chaired by: Matthew J Devlin
Monday at 1:00 PM in West Fork I

51 (1:00 PM) Measurement of 14 MeV tD neutron production from the reaction-in-flight of dD fusion *by Sean W Finch*
87 (1:30 PM) Differential neutron scattering measurements on U-238 using monoenergetic beams *by Richard Hughes*
46 (2:00 PM) Neutron reaction experiments in inverse kinematics with the Neutron Target Demonstrator and Low-Energy Heavy Ion Source at LANSCE *by Andrew Leland Cooper*

AR-RE-06: Irradiation Effects in the Nuclear Extremes, I
Chaired by: Osman El Atwani
Monday at 1:00 PM in Elm Fork I

290 (1:00 PM) Processing and Characterization of Refractory High Entropy Alloys as Candidates for Fusion Reactor Materials *by Mitra L. Taheri*
218 (1:30 PM) Novel Refractory High Entropy Alloys for Applications in Extreme Environments *by Osman El Atwani*
105 (2:00 PM) Rapid Selection and Elastic Property Determination of Novel High-Entropy Alloys using Resonant Ultrasound Spectroscopy *by Boris Maiorov*
221 (Poster session) Temperature range of deuterium retention from ferritic-martensitic steel implanted deuterium at 100K and 300K *by V. I. Zhurba*

SN-OM-02: Facility Updates II
Chaired by: David Button
Monday at 1:00 PM in Trinity Central

72 (1:00 PM) CASPAR Underground Accelerator Facility Update and Planning *by Daniel Robertson*
234 (1:20 PM) Status Report for Edwards Accelerator Laboratory at Ohio University *by Gregory Michael Leblanc*
73 (1:40 PM) Lab Status Report for Notre Dame's Nuclear Science Laboratory *by Edward Stech*
80 (2:00 PM) Status Report for Michigan Ion Beam Laboratory *by Prashanta Niraula*

AA-IBTM-01: In-situ and In-Operando Materials Analysis Using Ion Beams
Chaired by: Robert David Kolasinski
Monday at 3:00 PM in Post Oak

284 (3:00 PM) Revealing Radiation Response in Atomically-Thin Transition Metal Sulfides (MoS_2, WS_2) through In-Situ Ion Irradiation Experiments *by Christopher Smyth*
143 (3:30 PM) Quantifying radiolysis effects for in-situ RBS and electrochemical impedance spectrometry (EIS) *by Lyudmila V Goncharova*
245 (3:45 PM) Ion and neutral time-of-flight spectroscopy as an in-situ diagnostic for probing plasma-exposed surfaces *by Robert D Kolasinski*
256 (4:00 PM) Investigating the in-situ radiation damage in optical sensors using ion beam-induced charge microscopy *by Mohin Sharma*
184 (4:15 PM) An attempt to predict oligomer sputtering using binary collision approximation simulations *by Patrick Kirscht*
108 (Poster session) Homogenous and Robust Gypsum-Based Standard Materials for Trace Element Analysis by PIGE/PIXE *by Anthony M Miller*

AP-IA-02: Industrial and Medical X-ray, Gamma-ray and UV Systems and Applications
Chaired by: Sergey V Kutsaev
Monday at 3:00 PM in West Fork I

229 (3:00 PM) Development of Pre-Clinical Electron FLASH LINACS with X-Ray Capability *by Marcos Ruelas*
212 (3:30 PM) Design efforts to upgrade beam power of a 10 MeV S-band e-beam system from 15 kW to 25 kW *by Anthony Tylenda*
152 (4:00 PM) Development of deuteron nuclear reaction database and its applications: from compact to large scale neutron sources *by Shinsuke Nakayama*

AR-ISM-02: Synthesis and Modification of Metal-Halide inspired Materials
Chaired by: Bibhudutta Rout
Monday at 3:00 PM in Elm Fork I

274 (3:00 PM) Metal Halide Perovskite Solar Cells for Emerging Space Applications *by Ian R Sellers*
207 (3:25 PM) Effects of Electronic Energy Loss on Ion-Beam Modification of Oxide Perovskites *by William J. Weber*
273 (3:50 PM) Observation of Superconducting Transition at ~ 25 K in Ag Implanted Au Thin Film *by Manas Kumar Dalai*
216 (4:10 PM) Study of the Elemental Diffusion and Radiation Tolerance of Metal Halide Perovskite Solar Cells *by Mritunjaya Parashar*

AR-NST-01: Nanoscale Pattern Formation

Produced by Ion Bombardment of Solid Surfaces I
Chaired by: R. Mark Bradley
Monday at 3:00 PM in Elm Fork II

69 (3:00 PM) Investigation of Ar/Si Ion Beam Nanopatterning Near the Critical Angle *by Karl Ludwig*
259 (3:30 PM) Large area periodically modulated plasmonic and 2D Transition Metal Dichalcogenide layers featuring flat-optics light harvesting *by Matteo Barelli*
132 (4:00 PM) Some Advancements in the Continuum Modeling of Ion-Induced Nanopattern Formation *by Scott A Norris*
82 (Poster session) Real-time In-situ and Post-facto Study of the Mechanisms of Ion Beam Nanopatterning: Angle Dependence and Stress Behavior *by Benli Jiang*

SN-OM-03: Operations and Maintenance
Chaired by: Peter Linardakis, Chris R Westerfeldt
Monday at 3:00 PM in Trinity Central

198 (3:00 PM) Safety Review of the BNL Tandem Facility *by Dannie Steski*
220 (3:20 PM) Update on ANSTO's New BPM Interface and Measurement System *by David Button*
84 (3:40 PM) Rejuvenation of the 14UD at ANU *by Thomas Tunningley*
226 (4:00 PM) Accident in the JYFL Accelerator Laboratory - Lessons Learned *by Mikko Laitinen*
299 (4:20 PM) The 2 low energy Van de Graaf Accelerators AN2000 and CN maintenances and operation of Legnaro National Laboratories (Italy) *by Luca Maran*

PS-VR-01: Tuesday Vendor Roadshow
Chaired by: Gary A Glass
Tuesday at 9:00 AM in Rio Grande Ballroom

308 (9:00 AM) Tuesday Vendor Roadshow *by Gary Glass*

AP-SD-05: Space-Based Security & Defense Applications
Chaired by: Gennady Miloshevsky
Tuesday at 10:00 AM in Post Oak

111 (10:00 AM) Applications of laser-produced plasmas in the fields of space security and nuclear non-proliferation *by Sivanandan S. Harilal*
127 (10:35 AM) Plasma ablation and shock generation to study the effect of laser impulse *by Farhat Beg*
120 (11:10 AM) MIRDIC computer code for predictive modeling of electrostatic discharge induced

by space radiation in dielectric and insulating materials of spacecrafts *by Gennady Miloshevsky*

AR-ISM-04: Mechanical Properties of Ion-Irradiated Complex Alloys
Chaired by: Lukasz Kurpaska
Tuesday at 10:00 AM in Elm Fork I

195 (10:00 AM) Coupling Ion Accelerators to Small-scale Mechanical Testing and Analytical Tools for Rapid Screening of Complex Material Systems *by Khalid Hattar*
166 (10:30 AM) Development of ODS steels for fusion and other harsh environments *by Malgorzata Lewandowska*
172 (11:00 AM) Irradiation-Induced Defect Characteristics and Hardening Behaviour of Oxide-dispersion Strengthened Concentrated Solid Solution Alloys *by Sri Tapaswi Nori*
251 (11:15 AM) In-situ Transmission Electron Microscopy study of irradiation-induced crystallization in advanced amorphous ceramic coatings *by Andrea Stinchelli*

AR-NP-10: Neutron and Fundamental Symmetries, II
Chaired by: Matthew J Devlin
Tuesday at 10:00 AM in West Fork I

19 (10:00 AM) Neutron capture cross sections measured with DANCE *by Ingrid Knapova*
83 (10:25 AM) Fundamental Physics using Pulsed Neutron Sources: Using Compound Nuclear (Resonance) States to Search for Exotic Beyond the Standard Model Physics *by Danielle Schaper*
13 (10:50 AM) Development of a high-resolution fast-neutron detector *by Thomas Baumann*
202 (11:15 AM) Recent High-precision Prompt Fission Neutron Spectra Measurements for Fast Neutron-induced Fission at LANSCE *by Matthew Devlin*

AR-NST-05: Quantum Information Sciences
Chaired by: Alex Belianinov, Michael Titze
Tuesday at 10:00 AM in West Fork II

176 (10:00 AM) The tin-vacancy qubit in diamond: an emerging platform for quantum technologies *by Eric Irving Rosenthal*
193 (10:30 AM) Synthesis of optically active solid-state spin qubits via ion implantation and irradiation *by Yeghishe Tsaturyan*
254 (11:00 AM) Quantum business opportunities *by Vignesh Chandrasekaran*

179 (Poster session) Single Ion Multispecies Positioning at Low Energy for Fabrication of Quantum Technologies *by Ella Schneider*

AR-RE-10: Irradiation Effects in the Nuclear Extremes, III
Chaired by: Osman El Atwani
Tuesday at 10:00 AM in Elm Fork II

288 (10:00 AM) Beam-On Irradiation Effects for Faster Down-Selection of Fusion Reactor Material Candidates *by Michael P Short*
222 (10:30 AM) Surface near Helium damage in materials studied with a high throughput implantation method *by Peter Hosemann*
60 (11:00 AM) Avalanche Energy: The development of the Orbitron, a micro-fusion reactor for clean, mobile and distributed energy applications *by Daniel Velazquez*

SN-OM-04: Ion Sources
Chaired by: Dannie Steski
Tuesday at 10:00 AM in Trinity Central

156 (10:00 AM) Heavy ions for radiobiological work at the Columbia Radiological Research Accelerator Facility *by Naresh T. Deoli*
211 (10:20 AM) Current status of the Triton source at Florida State University *by Ashton B. Morelock*
287 (10:40 AM) Development and performance of sub-nanoamp beam diagnostics at National Electrostatics Corp. *by Eric Alderson*
130 (11:00 AM) Analytic Model for Filament Degradation in Filament-Driven DC Ion Sources *by Mark Harrison*

AC-AF-03: Machine Learning for Particle Accelerators II
Chaired by: Alexander Scheinker
Tuesday at 1:00 PM in Elm Fork II

34 (1:00 PM) Multi-Objective Bayesian Active Learning for MeV-ultrafast electron diffraction *by Fuhao Ji*
38 (1:30 PM) Machine Learning to improve the Spallation Neutrons Source Accelerator and Target performance *by Willem Blokland*
39 (1:50 PM) Report on accelerator-physics-related machine learning studies from FRIB theory group *by Xilin Zhang*
65 (2:05 PM) Particle Beam Focus Optimization using Stochastic Swarm Technique *by Peter Norgard*

56 (2:20 PM) Physics-constrained machine learning for electrodynamics based on Fourier transformed Maxwell's equations *by Christopher Anders Leon*

AP-SD-04: Detectors for Accelerator-Based Systems
Chaired by: Nerine Cherepy
Tuesday at 1:00 PM in West Fork II

155 (1:00 PM) Scintillation response of gallium oxide to charged particle and gamma radiation produced by radioisotope and accelerator sources *by John Derek Demaree*
67 (1:20 PM) Detectors for MeV X-ray and Neutron Imaging *by Nerine Cherepy*
43 (1:40 PM) Investigating Ce and Tb Concentrations in Translucent Rare-Earth Aluminum Garnet Ceramic Scintillators *by Nathan Gillespie*
57 (2:00 PM) Radiation Hardness of New Inorganic Halide Single Crystal Scintillators *by Kimberly Pestovich*

AR-RE-01: Irradiation Effects in Semiconductor and Applications
Chaired by: Feng Ren
Tuesday at 1:00 PM in Elm Fork I

151 (1:00 PM) Displacement Damage and Total Ionizing Dose Response of Ga_2O_3 MOSFETs *by Michael Titze*
88 (1:25 PM) Radiation Testing for Electronic Devices in Space at the ANU Heavy Ion Accelerator Facility *by Lauren T Bezzina*
100 (1:40 PM) Radiation-induced crystalline defects in $Al_xGa_{1-x}N$ *by Mia Jin*
235 (2:05 PM) Radiation defect engineering in hexagonal boron nitride *by S. O. Kucheyev*
148 (2:20 PM) Defect generation mechanisms in silica under intense electronic excitation by ion beams below 100 K: Interplay between radiative emissions *by MIGUEL L. CRESPILLO*
103 (Poster session) High energy ion implantation for photoconducting terahertz switches *by Vitalij Kovalevskij*
283 (Poster session) Synthesis of topological surface and superconductivity via implantation of Sn into InSb crystal *by Soumya Srotaswini Sahoo*
300 (Poster session) Measurements of radiation tolerance of Superlattice (Al)GaAs by Positron Annihilation Spectroscopy *by Thai hang Chung*

MC-VAC-01: Vacuum Class I
Chaired by: John M Screech, Yongqiang Wang
Tuesday at 1:00 PM in Post Oak

280 (1:00 PM) Ultra-High Vacuum Seminar: Part 1 of 2 Session Series *by John Screech*

SN-OM-05: Open Discussion
Chaired by: Edward Stech
Tuesday at 1:00 PM in Trinity Central

74 (1:00 PM) SNEAP Communications and Web Based Presence *by Daniel Robertson*

AP-IA-03: Compact Accelerator-Based Systems for Geo-Physical Applications
Chaired by: Jani Reijonen
Tuesday at 3:00 PM in West Fork II

255 (3:00 PM) geochemistry and Saturation Applications Utilizing A New Slim Pulsed Neutron Technology *by Weijun Guo*
15 (3:30 PM) "Compact" Accelerators in Geological Probing, Petroleum to Climate Mitigation-State of Technology *by Ahmed Badruzzaman*
90 (4:00 PM) Quantification of Mercury Contamination using a Compact Cadmium Zinc Telluride Imaging Spectrometer and Neutron Generator. *by Christopher Meert*
301 (Poster session) Compensated Neutron Logging with nGen® D-D Neutron Source *by John E Tolar*

AR-ISM-05: Ionization Enhanced Synthesis, Modifications and Analysis
Chaired by: Vaithiyalingam Shutthanandan
Tuesday at 3:00 PM in Elm Fork I

29 (3:00 PM) Nanoscale hydrogen detection using time-of-flight secondary ion mass spectrometry *by Zihua Zhu*
79 (3:20 PM) Radiant Precision: Exploring Material Radiation with the Helium Ion Microscope *by Vaithiyalingam Shutthanandan*
157 (3:40 PM) Effects of Electronic Energy Loss on Amorphization Behavior in Pyrochlore Oxides *by William J. Weber*
53 (4:00 PM) Ionization Effects on Nanostructured Materials Subjected to Ion Irradiation *by Yanwen Zhang*

AR-NP-13: Precision Measurements, Amo-Nuclear Techniques, I
Chaired by: Alfredo Galindo-Uribarri
Tuesday at 3:00 PM in West Fork I

59 (3:00 PM) Precision spectroscopy of heavy molecular ions using quantum logic scheme *by Yan Zhou*

177 (3:20 PM) Probing physics beyond the Standard Model with molecular ion $^{227}ThF^{+}$ *by Kia Boon Ng*
188 (3:40 PM) Precision Measurement Techniques for Isotope Shifts of Unstable Atoms *by Alex Brinson*
138 (4:00 PM) Expanding Experimental Opportunities at TRIUMF with TITAN EBIT *by Jaime Damiany Cardona*
294 (4:15 PM) Advancing EDM searches with ultracold radioactive molecules at FRIB *by Xing Wu*
298 (4:30 PM) Precision Measurements with Cavity QED and Molecules for Fundamental Physics *by Edwin Pedrozo-Penafiel*
306 (Poster session) Background Characterization Efforts for Future Neutrino Experiments at H *by D. Martínez-Montiel*
307 (Poster session) Sensitivity to 144Pr-Antineutrino Production with the PROSPECT Expe *by F. Silva-Garcia*

AR-NST-02: Nanoscale Pattern Formation Produced by Ion Bombardment of Solid Surfaces II
Chaired by: R. Mark Bradley
Tuesday at 3:00 PM in Elm Fork II

50 (3:00 PM) Ion Bombardment of Carbon Targets and Beyond: Bridging Molecular Dynamics Simulations and Reduced-order Models *by Huck Beng Chew*
30 (3:30 PM) Insights on silicon nanopatterning induced by low-energy surface bombardment *by Alvaro Lopez-Cazalilla*
48 (4:00 PM) A Simple Dynamical Model that Leads to Sputter Cone Formation *by R. Mark Bradley*

MC-RD-01: Radiation Damage: Fundamentals and Applications
Chaired by: Yongqiang Wang
Tuesday at 3:00 PM in Post Oak

276 (3:00 PM) Accelerator-based radiation materials science for nuclear engineering *by Lin Shao*
208 (3:45 PM) Using ion beam irradiation as a surrogate for neutron displacement damage in microelectronics: Simple theory and equivalency considerations *by Joshua Michael Young*

PS-PS-02: Wednesday Plenary Session
Chaired by: Barney L. Doyle
Wednesday at 9:00 AM in Rio Grande Ballroom

91 (9:00 AM) Diagnostic development in MIT accelerator lab in support of advances in Inertial Confinement Fusion, including Ignition *by Maria Gatu Johnson*

AC-AF-01: Accelerator Facilities I
Chaired by: Fuhao Ji
Wednesday at 10:00 AM in Elm Fork II

81 (10:00 AM) Recent Developments and Scientific Highlights at the FRIB Facility *by Mauricio Portillo*
192 (10:25 AM) Pioneering research in accelerator and beam physics: recent highlights and initiatives at Jefferson Lab's CASA *by Amy Sy*
122 (10:50 AM) An overview of ongoing and prospective R&D activities at HiRES to advance MeV-UED instruments *by Wei Liu*
25 (11:15 AM) The Stewardship of the Nigerian Tandem Particle Accelerator: Preparing Ground for Expertise in Minerals Prospecting and Radiation Therapy *by Felix Olise*

AP-IA-04: Advances in Accelerator-Based Sterilization Systems and Blood/Food Irradiators
Chaired by: Leo Fifield
Wednesday at 10:00 AM in West Fork II

89 (10:00 AM) The next evolutionary steps of the Rhodotron, introducing high power solid state amplification technology in the RF chain and digitalization of E-Beam and Xray systems. *by Adam Gabriel*
200 (10:15 AM) Reveam, Inc.'s Groundbreaking Application of Accelerator Systems to Treat Food Using their Patented Electronic Cold Pasteurization (ECP^{TM}) Process *by Michael Paul Christofaro*
215 (10:30 AM) The impact of recent advances in accelerator sterilization and irradiator systems on cost, adoption, and availability. *by Marcos Ruelas*
189 (10:55 AM) Toward Use of Low Energy Electron Beams for Sterilization *by Leonard S Fifield*
173 (11:10 AM) Effects of Radiation-Driven Changes in Physical Properties of Polymers *by Matt Pharr*

AR-NP-11: Nuclear Astrophysics, I
Chaired by: Dan Bardayan
Wednesday at 10:00 AM in West Fork I

18 (10:00 AM) The $^{13}C(\alpha,n)^{16}O$ differential cross section *by James deBoer*
40 (10:20 AM) Measuring the cross section of the $^{15}N(\alpha,\gamma)^{19}F$ reaction using a single-fluid bubble chamber *by David Neto*
115 (10:40 AM) Progress Towards a Single Atom Microscope (SAM) for Nuclear Astrophysics *by Karina Martirosova*

42 (11:00 AM) Measuring the $^{88}Sr(\alpha, n)^{91}Zr$ reaction cross section with Accelerator Mass Spectrometry *by Maria Anastasiou*
49 (11:20 AM) First measurements with the Enge split-pole spectrometer at the Notre Dame Nuclear Science Lab (NSL) *by D.W. Bardayan*

AR-RE-03: Irradiation Effects in Ceramics
Chaired by: MIGUEL L. CRESPILLO
Wednesday at 10:00 AM in Elm Fork I

113 (10:00 AM) Using Cryo-Ionoluminescence to Differentiate the Electronic and Nuclear Origins of Emission Bands in Strontium Titanate *by Joseph Graham*
268 (10:25 AM) He implantation and radiation effects on coatings for fusion applications *by Marta Malo*
136 (10:50 AM) Review on the state of knowledge of neutron and gamma radiation effects on concrete *by Elena Tajuelo Rodriguez*
183 (11:15 AM) Elucidating Radiation-Induced Degradation in Siliceous Minerals in Concrete via Multi-modal Imaging *by Nishant Garg*
303 (Poster session) Carbon Reinforced Boron sub-Oxide Nanocomposite (CaRBON) *by David Wright*

MC-NE-01: Nuclear Energy: Basics and Advances
Chaired by: Yongqiang Wang
Wednesday at 10:00 AM in Post Oak

282 (10:00 AM) Electrical Power from Nuclear Fission: A Tutorial for Conventional and Advanced Reactors *by Peter Hosemann*

SN-OM-06: Facility Updates III
Chaired by: Thomas Tunningley
Wednesday at 10:00 AM in Trinity Central

70 (10:00 AM) CAIS AMS Status Report *by Gurazada Ravi Prasad*
135 (10:20 AM) Control System Upgrade for ANSTO's 2MV STAR Tandetron Accelerator *by JIAN WANG*
206 (10:40 AM) Center for Accelerator Mass Spectrometry Status Report *by John Wilkinson*
228 (11:00 AM) Lab update and future neutron facilities at AWE *by David Wright*

AC-AF-05: Accelerator Facilities II
Chaired by: Fuhao Ji
Wednesday at 1:00 PM in Elm Fork II

180 (1:00 PM) Recent Scientific and R&D Highlights from Brookhaven's Accelerator Test Facility (ATF) *by Mark Palmer*
160 (1:30 PM) The Argonne Wakefield Accelerator (AWA) facility and recent advances in two-beam acceleration *by Xueying Lu*
247 (2:00 PM) Cable installation management for the Advanced Light Source Upgrade (ALS-U) Project *by Adrien Talon*
129 (Poster session) Improving Charge Exchange Performance in a Tandem Accelerator through Simulations *by Mark Harrison*

AP-IA-05: Industrial Neutron and X-Ray Imaging and Radiography Devices and Applications
Chaired by: Jay Theodore Cremer
Wednesday at 1:00 PM in Trinity Central

10 (1:00 PM) High Energy Sources Development and Production at Varex Imaging Corporation *by Andrey V Mishin*
219 (1:30 PM) Fast and Thermal Neutron Imaging for Industrial Radiography with Neutron Generators *by Jay Theodore Cremer*
309 (2:00 PM) High Resolution Lens-coupled MeV X-Radiography of Dense Additively Manufactured Objects *by N. J. Cherepy*
187 (Poster session) MeV Neutron and X-ray Imaging Radiography and Computed Tomography using Advanced Scintillators *by Nerine Cherepy*

AR-NP-12: Nuclear Astrophysics, II
Chaired by: Dan Bardayan
Wednesday at 1:00 PM in West Fork I

96 (1:00 PM) Advances in mass spectrometry towards the r-process path at TITAN-TRIUMF *by Anna Kwiatkowski*
55 (1:20 PM) Precision mass measurements with the Canadian Penning Trap for the astrophysical r-process *by Adrian A Valverde*
124 (1:40 PM) Creating New Isotopes at FRIB for Experiments in Nuclear Astrophysics *by Mallory K. Smith*
126 (2:00 PM) Experimentally Constrained ^{93}Sr(n,γ)^{94}Sr Cross Section via the Surrogate Reaction Method *by Andrea Richard*

AR-NST-06: Focused Ion Beams
Chaired by: Michael Titze, Alex Belianinov
Wednesday at 1:00 PM in West Fork II

190 (1:00 PM) Development of diamond platforms for quantum sensing by ion implantation *by Luca Basso*
279 (1:30 PM) Nanofabrication of Josephson Junctions with Focused Helium Ion Irradiation *by Shane Andrew Cybart*
227 (2:00 PM) Ultra-low energy ion implantation as a powerful tool to create new nanostructures within 2D materials *by Harriet Åhlgren*

AR-RE-04: Combination of Irradiation + Stress + Corrosion, I
Chaired by: Charles Hirst, Franziska Schmidt
Wednesday at 1:00 PM in Elm Fork I

106 (1:00 PM) Synergistic irradiation-thermomechanical loading with integrated strain mapping capability *by Dave Lunt*
134 (1:30 PM) Developing synergistic irradiation-thermomechanical testing capability *by Laurence Skidmore*
150 (1:50 PM) Multimodal characterization of radiation and transmutation extremes in SNS components *by Timothy Gerald Lach*

MC-VAC-02: Vacuum Class II
Chaired by: John M Screech, Yongqiang Wang
Wednesday at 1:00 PM in Post Oak

281 (1:00 PM) Ultra-High Vacuum Seminar: Part 2 of 2 Session Series *by John Screech*

PS-PS-03: Thursday Plenary Session
Chaired by: Arlyn Antolak
Thursday at 9:00 AM in Rio Grande Ballroom

267 (9:00 AM) Accelerator Production of Medical Radionuclides *by Cathy Sue Cutler*

AA-IBTM-02: Light Element Detection Using IBA
Chaired by: Mikko Laitinen
Thursday at 10:00 AM in Post Oak

68 (10:00 AM) Elemental Quantification of Carbon Nanotube (CNT) Pellicles for EUV Lithography Applications *by Masoud Dialameh*
263 (10:25 AM) Investigating hydrogen in nanoscale transition metal hydrides with high-energy ion beams *by Kristina Komander*
142 (10:50 AM) Hydrogen thin film standards for high-resolution hydrogen depth profiling *by Lyudmila V Goncharova*
225 (11:05 AM) Detection of light elements by a ToF-ERD telescope *by Mikko Laitinen*

291 (11:20 AM) Development of a Compact Magnetic Backscattered Ion Beam Deflector System for Light Element Ion Microscopy *by Charles Thomas Bowen*
185 (Poster session) Lithium depth profiling with proton beam NRA *by Patrick Kirscht*
292 (Poster session) Required for novel semiconductor materials: ToF-ERDA spectrometer *by Mikko Laitinen*

AP-MA-01: Developments in Medical Accelerator Technology and Applications
Chaired by: Martin Bues
Thursday at 10:00 AM in Elm Fork II

66 (10:00 AM) FLASH Radiotherapy and Precision X-ray Imaging enabled by Distributed Charge Compact Accelerators *by Christopher PJ Barty*
162 (10:20 AM) Electron beam optimization on a modified Varian clinical linear accelerator for FLASH preclinical studies at RARAF *by Yuewen Tan*
270 (10:40 AM) Dosimetry calibration for low-energy protons (2-4 MeV) using Gafchromic film dosimeters *by Homeira Faridnejad*
35 (11:00 AM) Neutron Beam System for Accelerator-based Boron Neutron Capture Therapy *by Alexander Dunaevsky*

AR-AMP-01: Atomic Collisions: Fundamental Processes & Applications
Chaired by: Sylwia Ptasinska
Thursday at 10:00 AM in Trinity Central

277 (10:00 AM) Development of a velocity map imaging spectrometer and its application in understanding the dynamics of low energy electron-molecule collisions. *by Dipayan Chakraborty*
16 (10:30 AM) L X-ray production cross sections of Ag induced by the impact of $^{12}C^{3+}$ and $^{13}C^{3+}$ ions *by Javier Miranda*
26 (11:00 AM) Calculated He^{+} Induced L X-ray Production Cross Sections for Rare Earth Elements *by Felix S. Olise*

AR-RE-02: Irradiation Effects in Low-Dimensional Materials and Thin Films
Chaired by: Yang Tan, Feng Ren
Thursday at 10:00 AM in Elm Fork I

304 (10:00 AM) Ion Beam Synthesis of Layer-Tunable and Transfer Free Graphene for Device Applications *by Yongqiang Wang*

159 (10:25 AM) Mechanisms of Ion Irradiation Induced Ordering in Amorphous TiO_2 Nanotubes: Effects of Ion Mass and Energy *by Tristan T Olsen*
8 (10:40 AM) Interfaces enhanced plasma irradiation resistance in CrMoTaWV/W multilayer films through blocking He diffusion *by Chenyi Qu*
75 (10:55 AM) Hydrogen Retention in Copper-Tungsten Nanocomposites *by Mina Tavakolzadeh*
17 (11:10 AM) Modification of (Photo)electrocatalytic nanomaterials by ion beam technology *by Feng Ren*

SN-TA-01: Teaching with Accelerators
Chaired by: Andy Roberts, Graham F Peaslee
Thursday at 10:00 AM in West Fork II

174 (10:00 AM) Undergraduate training and research with 400 keV electrons at Minnesota State University *by Andrew Roberts*
110 (10:15 AM) Undergraduate Training and Research Involvement on the St. Andre 9SDH 3-MV Tandem Accelerator at the University of Notre Dame *by Anthony M Miller*
231 (10:35 AM) University of Wisconsin Isotope Production HIPPOCampus Summer School *by Paul A Ellison*
140 (10:55 AM) An Undergraduate Advanced Lab teaching: Measurement and analysis of Ions and Photons *by Rahul Mehta*
262 (11:15 AM) Teaching activities with accelerators at the Universidad Politécnica de Madrid in Undergraduate and Graduate Programs *by Raquel Gonzalez-Arrabal*
238 (Poster session) Compact Ion Beam System for Studying D-D and p-^{11}B Fusion Reactions *by Allan Xi Chen*
295 (Poster session) Educational Activities and Research at Tarleton's Nuclear Laboratory *by Daniel Keith Marble*

AA-NBAT-01: Neutron Production and Detection Methods
Chaired by: Jason Dugger
Thursday at 1:00 PM in Post Oak

165 (1:00 PM) Computational Techniques for Electrostatic Ion Accelerator Component Design and Optimization *by Ryan M. Hedlof*
161 (1:30 PM) Computational study of tungsten and depleted uranium photoneutron targets for a 20 MeV electron linear accelerator *by Kevin Yim*

153 (2:00 PM) Prediction of performance for a short, multi-pulse photoneutron source based on the NNSS Scorpius linear induction accelerator *by Amber Guckes*

AC-AF-04: Neutron generator-based technology for planetary science
Chaired by: Mauricio Ayllon Unzueta
Thursday at 1:00 PM in Trinity Central

131 (1:00 PM) Neutron Generator for Space Applications: From Oil Field to Outer Space *by Jani Reijonen*
112 (1:25 PM) The BECA and DraGNS Instruments for In situ Planetary Geochemistry *by Ann Parsons*
28 (1:50 PM) Exploring the Surface of Mars with Active Neutron Measurements on the Mars Science Laboratory Curiosity Rover *by Craig Hardgrove*
121 (2:15 PM) Non-Destructive Interrogation using Associated Particle Imaging for Planetary Surface Missions *by Emily Surry*

AP-SD-01: Accelerator-Based Security & Defense Systems
Chaired by: Joseph Bendahan, Arlyn Antolak
Thursday at 1:00 PM in West Fork II

253 (1:00 PM) Battery-Operated Linacs for Portable Threat Detection *by Amy Shiroma*
182 (1:20 PM) How a 40 year old machine remains world class, characteristics and use of a Scanditronix M22 Microtron for industrial imaging *by James Hunter*
95 (1:40 PM) Tunable Intense High-Energy Photon Source Development and Testing *by Igor Jovanovic*
168 (2:00 PM) Portable Isotopic Assay via Nuclear Resonance Transmission Analysis Using a Short-Pulse Neutron Source *by Andrea Schmidt*
119 (2:20 PM) Impact of Solid-State Pulsed Power on The Scorpius Multi-Pulsed Radiography Accelerator *by Saeed Assadi*

AR-NP-05: Artificial Intelligence -Machine Learning Advancements and Applications, I
Chaired by: Jakub Kvapil, Xuan Li
Thursday at 1:00 PM in West Fork I

252 (1:00 PM) Report on STREAMLINE collaboration *by Xilin Zhang*
94 (1:25 PM) Towards Realtime Neural Compression for Sparse Time-Projection Chamber Data *by Yihui Ren*
194 (1:50 PM) Graph Learning for Operation of Particle Accelerators *by Chris Tennant*

305 (2:15 PM) Autonomous Detector Control and Fast Data Processing for sPHENIX and future EIC detector *by Jakub Kvapil*

AR-RE-08: Radiation Effects in Nuclear Materials
Chaired by: Andy Smith, David Lunt
Thursday at 1:00 PM in Elm Fork I

196 (1:00 PM) Development of In-situ Ion Irradiation Tools for Nuclear Engineering Applications: Lessons Learned and Future Directions *by Khalid Hattar*
236 (1:30 PM) Microshear deformation for evaluating effects of void swelling on mechanical properties of heavy ion irradiated metals *by Tongjun Niu*
45 (1:50 PM) Effect of surface orientation on blistering of copper under high fluence of keV hydrogen ion irradiation *by Alvaro Lopez-Cazalilla*
209 (2:10 PM) Effect of Mo on oxidation, irradiation and creep properties of FeCrAl alloys *by Pengcheng Zhu*

AA-IBTM-03: Multiple Technique Analyses Including Ion Beams (TOTAL IBA)
Chaired by: Iva Bogdanovic Radovic, Lyudmila Goncharova
Thursday at 3:00 PM in Post Oak

31 (3:00 PM) Bias and synergy in the self-consistent analysis of IBA data *by Tiago Fiorini Silva*
144 (3:30 PM) Fast simulation of ion beam analysis spectra using binary collision approximation *by Felix Junge*
123 (3:50 PM) Progress on Improving SIMS Quantification of Erbium Through the Development of Ion-Implanted Calibration Standards *by Sage D.C. Buchanan*
101 (4:10 PM) The Upgraded Ion Beam Analysis Capability at LANL *by Igor Usov*
264 (4:30 PM) IBIC technique for the in-situ assessment of the ion beam spot size and single-ion counting. *by Greta Andrini*
125 (Poster session) A Multimodal Approach Towards Advancing the Characterization and Analysis of Erbium *by Sage D.C. Buchanan*
296 (Poster session) Investigation of Elemental concentration in Olivine using PIXE, EDAX, and XRF. *by Sailza Sailza*
297 (Poster session) Ion Resonance Energy Coupling using Induction Field *by Devesh S. Bhosale*

AP-MA-04: Radioisotopes in Medicine
Chaired by: Cathy Sue Cutler, Sergey Chemerisov

Thursday at 3:00 PM in Elm Fork II

233 (3:00 PM) Hot Stuff-producing At-211 for novel medical applications *by Lauren McIntosh*
237 (3:20 PM) Accelerator Based Production of Mo-99: Target Design Considerations. *by Sergey Chemerisov*
23 (3:40 PM) Photonuclear cross-section and yields of ^{100}Mo(g,x)^{99}Mo, ^{100}Mo(g,np)^{98m}Nb, and ^{59}Co(g,xn; x=1-4) $^{58-55}$Co reactions with intermediate bremsstrahlung energies *by Md Shakilur Rahman*
272 (4:00 PM) The CERN-MEDICIS facility - An offline mass separation facility for the production of research medical radionuclides *by Laura Lambert*

AR-ISM-01: Special Topics on Ion Enhanced Synthesis and Modification

Chaired by: Anand Prakash Pathak

Thursday at 3:00 PM in West Fork II

61 (3:00 PM) High Energy Wafer Implantation updates at the Tandem User Facility at Brookhaven National Lab *by Tom Kubley*
27 (3:30 PM) Studies on the gamma and swift heavy ion irradiation induced effects on the Resistive Switching Properties of Transition Metal Oxides *by Anand Prakash Pathak*
293 (4:00 PM) The new Pulsed Power Electron Gun (PPEG) at Sandia National Labs *by Barney L Doyle*
20 (Poster session) Effects of Induced Structural Modification on Properties of V^+ Ion implanted RF - Magnetron Sputtering Deposited ZnO Thin Films of thickness 120 nm on borosilicate glass substrates *by Olakunle Oluwaleye*
257 (Poster session) Ongoing research on surface modification by low energy protons *by B. E. Fuentes*

AR-NP-07: Artificial Intelligence -Machine Learning Advancements and Applications, III

Chaired by: Jakub Kvapil, Xuan Li

Thursday at 3:00 PM in West Fork I

260 (3:00 PM) Online Autonomous Tuning of the FRIB Accelerator Using Machine Learning: DOE NP AI Project Status *by Alexander Scheinker*
244 (3:30 PM) Machine Learning Tools for Improved SRF Operations at CEBAF *by Adam Carpenter*
199 (3:55 PM) An Induction type of Septum for the EIC *by Nicholaos Tsoupas*

AR-RE-09: Radiation Effects in Chemical and Biological Systems.

Chaired by: Naresh T. Deoli

Thursday at 3:00 PM in Elm Fork I

217 (3:00 PM) Identification of an Epigenomic Signature of Mixed Field Neutron Exposure at Low Doses: Benefit to Military Operators in a Post-Nuclear Detonation *by Alexandra C Miller, PhD*
186 (3:25 PM) DNA damage as a probe to assess the dose rate and chemistry of low-temperature plasma radiation *by Sylwia Ptasinska*
197 (3:50 PM) Simulation Study of Ionizing Radiation Effects on Biomolecular Structures *by Yujie Chi*
158 (4:15 PM) Differential analysis of Normal Rat Leg Bones subjected to Space Conditions *by Rahul Mehta*
9 (4:30 PM) Measurements of Radiological Health Risks to Students in Abo-Odo Ota, Nigeria *by Maxwell Omeje*

AA-NBAT-03: Neutron detector material development and beamline measurement/characterization facilities
Chaired by: Patrick Feng
Friday at 9:30 AM in Post Oak

141 (9:30 AM) Harnessing Event-Based Neutron Imaging Systems for Fast Neutron Imaging at LANSCE *by Alexander M. Long*
230 (9:55 AM) Neutron production and detection capabilities at Ohio University for basic science and applications *by Cody E. Parker*
239 (10:10 AM) Scalable Manufacturing of Melt-Blended Organic Scintillators for High Efficiency Neutron Detectors *by Gail Frances Hernandez Garcia*
167 (10:25 AM) Net Shape Production of Organic Glass-Based Neutron Detectors *by Patrick Feng*
302 (10:40 AM) New neutron detectors for beta-delayed neutron studies *by Peter Dyszel*

AP-IA-06: Advanced Manufacturing of Industrial Accelerators and Power Supplies
Chaired by: Matthew David Coventry
Friday at 9:30 AM in Trinity Central

102 (9:30 AM) On the Simulations and Control of Cockcroft-Walton Ladders *by Vincent Ernst*
242 (10:00 AM) Managing Electric Fields in Compact Accelerator Environments *by Paul W Groth*
164 (10:20 AM) Split Structure Manufacturing of Compact Accelerators for Industrial Applications *by Amirari Diego*
11 (10:40 AM) Development of 10 MeV electron linear accelerator for space environment simulation *by Yunlong Chi*

AP-MA-03: Medical Imaging and Real Time Adaptive AI in Particle Therapy
Chaired by: You Zhang, Anissa Bey
Friday at 9:30 AM in Elm Fork II

214 (9:30 AM) Prompt gamma imaging for particle therapy: from sparse sampling to AI *by Mingwu Jin*
240 (9:50 AM) AI-enabled Real-time Imaging for Adaptive Particle Radiotherapy *by You Zhang*
266 (10:10 AM) Mid-range probing and range-guided adaptive particle therapy *by Weiguo Lu*
250 (10:30 AM) PET Image-Guidance for Conventional and FLASH Proton Therapy *by John Paul Cesar*
261 (10:50 AM) Advances in In Vivo Imaging for Particle Radiotherapy: A Topical Overview *by Anissa Bey*

AR-NP-06: Artificial Intelligence -Machine Learning Advancements and Applications, II
Chaired by: Jakub Kvapil, Xuan Li
Friday at 9:30 AM in West Fork I

285 (9:30 AM) AI-Assisted Detector Design at EIC *by Cristiano Fanelli*
213 (10:00 AM) Machine Learning Tools to support Accelerator Operations *by Brahim Mustapha*
269 (10:20 AM) Machine learning based control systems for Nuclear Physics Experiments *by Torri Jeske*
271 (10:40 AM) 2D Convolutional Neural Networks with Early Data Fusion for Rare Event Search in GADGET II TPC Data *by Tyler Wheeler*

AR-RE-05: Combination of Irradiation + Stress + Corrosion, II
Chaired by: Franziska Schmidt, Charles Hirst
Friday at 9:30 AM in Elm Fork I

21 (9:30 AM) Exploring Radiation-Corrosion Coupling in High-Temperature Molten Salt and Liquid Metal Environments through Proton Irradiation Studies *by Weiyue Zhou*
246 (10:00 AM) Isolating the effects of beam heating in simultaneous irradiation-corrosion experiments *by Franziska Schmidt*
118 (10:20 AM) Development of microscale in-situ irradiation and corrosion experiment (Micro-ICE) *by Matthew Chancey*
181 (10:40 AM) Exploring 2D graphene as atomic armor to protect uranium from ambient corrosion *by Yongqiang Wang*

Posters
Will be presented on poster boards during the Poster Sessions

AA-IBTM-01 # 108 Homogenous and Robust Gypsum-Based Standard Materials for Trace Element Analysis by PIGE/PIXE *by Anthony M Miller*

AA-IBTM-02 # 185 Lithium depth profiling with proton beam NRA *by Patrick Kirscht*

AA-IBTM-02 # 292 Required for novel semiconductor materials: ToF-ERDA spectrometer *by Mikko Laitinen*

AA-IBTM-03 # 125 A Multimodal Approach Towards Advancing the Characterization and Analysis of Erbium *by Sage D.C. Buchanan*

AA-IBTM-03 # 296 Investigation of Elemental concentration in Olivine using PIXE, EDAX, and XRF. *by Sailza Sailza*

AA-IBTM-03 # 297 Ion Resonance Energy Coupling using Induction Field *by Devesh S. Bhosale*

AA-IBTM-04 # 145 Low energy ion-solid interactions: a quantitative experimental verification of binary collision approximation simulations *by Felix Junge*

AA-NBAT-02 # 169 Advancements in field measurement of soil composition: Introducing the tagged neutron technique mobile system *by Galina Yakubova*

AC-AF-02 # 47 Suppression of X-ray radiation from a 2 MV electrostatic ion accelerator *by Ihor Hennadievich Ihnatiev*

AC-AF-05 # 129 Improving Charge Exchange Performance in a Tandem Accelerator through Simulations *by Mark Harrison*

AP-IA-03 # 301 Compensated Neutron Logging with nGen® D-D Neutron Source *by John E Tolar*

AP-IA-05 # 187 MeV Neutron and X-ray Imaging Radiography and Computed Tomography using Advanced Scintillators *by Nerine Cherepy*

AP-SD-03 # 223 Comparison of Neutron Generator Output Estimate Using a $LaBr_3$ and an Organic Scintillator *by Caryanne R. Wilson*

AR-ISM-01 # 20 Effects of Induced Structural Modification on Properties of V^+ Ion implanted RF - Magnetron Sputtering Deposited ZnO Thin Films of thickness 120 nm on borosilicate glass substrates *by Olakunle Oluwaleye*

AR-ISM-01 # 257 Ongoing research on surface modification by low energy protons *by B. E. Fuentes*

AR-NP-13 # 306 Background Characterization Efforts for Future Neutrino Experiments at H *by D. Martínez-Montiel*

AR-NP-13 # 307 Sensitivity to 144Pr-Antineutrino Production with the PROSPECT Expe *by F. Silva-Garcia*
AR-NST-01 # 82 Real-time In-situ and Post-facto Study of the Mechanisms of Ion Beam Nanopatterning: Angle Dependence and Stress Behavior *by Benli Jiang*
AR-NST-05 # 179 Single Ion Multispecies Positioning at Low Energy for Fabrication of Quantum Technologies *by Ella Schneider*
AR-RE-01 # 103 High energy ion implantation for photoconducting terahertz switches *by Vitalij Kovalevskij*
AR-RE-01 # 283 Synthesis of topological surface and superconductivity via implantation of Sn into InSb crystal *by Soumya Srotaswini Sahoo*
AR-RE-01 # 300 Measurements of radiation tolerance of Superlattice (Al)GaAs by Positron Annihilation Spectroscopy *by Thai hang Chung*
AR-RE-03 # 303 Carbon Reinforced Boron sub-Oxide Nanocomposite (CaRBON) *by David Wright*
AR-RE-06 # 221 Temperature range of deuterium retention from ferritic-martensitic steel implanted deuterium at 100K and 300K *by V. I. Zhurba*
SN-TA-01 # 238 Compact Ion Beam System for Studying D-D and p-^{11}B Fusion Reactions *by Allan Xi Chen*
SN-TA-01 # 295 Educational Activities and Research at Tarleton's Nuclear Laboratory *by Daniel Keith Marble*

CAARI-SNEAP Abstracts

Abstract 92 at 9:00 AM

Session PS-PS-01 Monday 9:00 AM - Rio Grande Ballroom

Novel approaches for in situ interrogation of irradiated materials

Blas Pedro Uberuaga

Materials Science and Technology Division, Los Alamos National Laboratory, Los Alamos New Mexico, United States

Radiation damage is inherently a non-equilibrium phenomena. Energetic particles smash into materials and displace thousands upon thousands of atoms, leading to a damage state that is characterized by a super-saturation of point defects. The kinetic evolution of those defects determines the ultimate fate of the material to the radiation damage spectrum. Thus, the more we know about how those defects are produced and evolve, the greater our ability to describe and ultimately predict how the material will respond to the damage. Critically, we must know about the transient state of these defects, as they are produced under irradiation, as their number and nature drastically changes once the radiation source is removed.

To this end, we have been developing novel in situ approaches for characterizing radiation damage in materials as they are being bombarded by ion beams. First, to understand what types of defects are being produced and how many, we have designed, constructed, and installed a positron beam line that is coincident on a target with our ion beam line. Positrons - the antimatter particle of electrons - are extremely sensitive to vacancies. We will describe how even ex situ studies with positrons can provide novel insight into radiation damage effects in materials. We will then show initial results from our in situ positron beam line, highlighting the unique insights in situ positron studies can provide. Then, to probe the transient kinetics of radiation-induced defects, we have developed an in situ electrochemical impedance spectroscopy (EIS) capability that directly measures the conductivity of a material as it is being irradiated. This affords new opportunities to understand transport mechanisms associated with non-equilibrium defects that would be very challenging to examine any other way.

Together, these new capabilities add to the existing suite of in situ characterization methods for studying radiation damage, providing an overall more comprehensive picture of the non-equilibrium defects that drive this phenomenon.

Abstract 71 at 10:00 AM

Session AA-NBAT-02 Monday 10:00 AM - Post Oak

Time-resolved SANS study of deformation-induced demixing in polymer blends

Yangyang Wang

Center for Nanophase Materials Sciences, Oak Ridge National Laboratory, Oak Ridge Tennessee, United States

While the application of the small-angle neutron scattering (SANS) technique to flowing polymers has a long history, many fundamental issues have not been fully addressed. In this talk, we will describe the development of a rotatable sliding-plate shear cell that allows time-resolved SANS studies of full anisotropic structures of deformed soft materials. The use of the spherical harmonic expansion technique permits the reconstruction of three-dimensional anisotropic structures in both reciprocal and real spaces, from two-dimensional SANS spectra measured on different planes. To demonstrate the power of this approach, we show how the deformation-induced concentration fluctuations in non-equilibrium steady state can be determined for polymer blends undergoing large-amplitude oscillatory shear. Our investigation reveals that the migration of short chains in the direction perpendicular to the shear direction is driven by the elastic stress imbalance between the two components.

Abstract 170 at 10:30 AM

Session AA-NBAT-02 Monday 10:00 AM - Post Oak

Tagged neutron technique for in-situ soil composition determination

Aleksandr Kavetskiy, Galina Yakubova, Sidharth Gautam, Stephen A. Prior, H. Allen Torbert

USDA-ARS, National Soil Dynamics Laboratory, Auburn AL, United States

The tagged neutron technique (TNT) was applied for soil composition determination, utilizing a TNT Mobile system equipped with a portable neutron generator (API-120) with a built-in alpha detector, a 7.62×25.4 cm LaBr(Ce) gamma detector, a 4-channel digital pulse processor with a Linux operating system (Pixie-Net) for data acquisition, radiation shielding, GPS, an

autonomous power system, and an operational laptop. This system was used for field measurements to assess soil composition. During field measurements, results were recorded as binary files (~1-1.5 GB for 20-30 minutes of measurements, depending on soil type). These files contained alpha and gamma pulses detected by respective detectors during soil neutron irradiation. Time-of-flight (TOF) spectra (number of gamma ray pulses registered by the detector versus time after the alpha particle's detection), were generated using IGOR software from these binary files. Alpha particles act as "tags" for neutrons. These alpha particles travel from the neutron generator target to the entrance window of the alpha detector that is positioned above the generator target with the soil or other samples located beneath it. The TOF spectra features a high, narrow peak (~10 ns wide) of gamma ray pulses from the soil, superimposed on a relatively low and wide band (~100 ns) of pulses from the TNT Mobile system equipment. The gamma-ray pulses in the TOF peak are specifically due to inelastic neutron scattering (INS) in the soil. The gamma spectrum, representing the number of gamma ray pulses versus their energy within a 7 ns window around the TOF peak, can be derived from binary files using IGOR software. This spectrum characterizes gamma rays produced by INS in the soil, from which soil composition information can be extracted.

Soil can be approximated as a mixture of oxides of its main components: SiO_2, Al_2O_3, Fe_2O_3, CaO, H_2O, and carbon (C). The INS soil gamma spectrum is thus a sum of the INS gamma spectra of these oxides and C. A deconvolution procedure of the TNT soil gamma spectrum into the TNT gamma spectra of these oxides and C provides the content of each oxide and C in soil. Reference samples of oxides and C were sized (~ diameter 100×50 cm) ensuring that the intensity of the TNT gamma spectra reached a steady state and did not increase with further sample size. Monte Carlo simulations of neutron-stimulated gamma spectra (using MCNP6.2 code) were employed for defining these dimensions. The TNT gamma spectra of reference oxides and C were measured in a box with the aforementioned dimensions using the TNT Mobile system. The distance from the neutron generator target to the sample surface was maintained the same as in soil measurements. The TNT gamma spectra of reference samples within the 7 ns time window were extracted from the saved binary files as previously described. These spectra were then used in the deconvolution procedure, which accounted for neutron and gamma-ray attenuation during their propagation in samples and soil.

The TNT method for soil composition determination and results of field measurements will be discussed in more detail during the presentation. These results showed good agreement with those obtained by other methods, such as chemical analysis, dry combustion method, weight method, moisture determination by time domain reflectometry, and nuclear methods. Consequently, TNT can be recommended as a non-destructive, in-situ, less labor-intensive, and time-efficient method for soil content determination, beneficial for agricultural and soil science purposes.

Abstract 86 at 11:00 Session AA-NBAT-02 Monday

AM 10:00 AM - Post Oak

Unraveling the Molecular Mechanisms of Ion-selective Redox-mediated Electrosorption by In Situ Neutron Reflectometry

Shao Wei Tsai[1], Riccardo Candeago[1], Raylin Chen[1], Anaira Roman Santiago[1], Ching-Yu Chen[1], Becky Welbourn[3], Hanyu Wang[2], Mathieu Doucet[2], Robert Hillman[3], James F. Browning[2], Xiao Su[1]

(1)Department of Chemical and Biomolecular Engineering, University of Illinois at Urbana-Champaign, Urbana Illinois, United States
(2)Neutron Scattering Division and Center for Nanophase Materials Sciences, Oak Ridge National Laboratory, Oak Ridge Tennessee, United States
(3)ISIS Neutron and Muon Source, STFC, Oak Ridge Harwell Oxford, United Kingdom

Redox-active polymers can be a powerful materials platform of providing highly specific ion binding and reversible regeneration, when controlled by electrochemical potential. Solvation, charge-transfer interactions, and electrostatics all play an important role in ion selectivity. Elucidating the molecular mechanisms of solvent penetration and ion binding during electrosorption/desorption can provide critical insights for the rational designs of the ion-selective materials. Here, we describe our investigations using In Situ and Operando Neutron Reflectometry to characterize film swelling, solvent profiles and kinetics of target ions with competing ions in various types of redox-mediated electrosorption systems. To explore the relation between film hydrophobicity and ion selectivity, we adopted thermo-electrochemical responsive copolymer electrodes of **N**-isopropylacrylamide (NIPAM) and ferrocenylpropyl methacrylamide (FPMAm) to modulate different film solvation profiles and tuned the selectivity towards various anions. Moreover, we investigated the film morphological response, solvation and ion valency effects at redox-polymer interfaces by comparing the selectivity of ReO_4^- vs MoO_4^{2-} and solvation profiles of two redox-metallopolymers, poly(vinylferrocene) (PVFc) and poly(3-ferrocenylpropyl methacrylamide) (PFPMAm). Lastly, we studied the mechanism of nitrate selective electrosorption on a conductive polymer, polyaniline (PANI) by monitoring the solvent ingression and morphological changes under various redox states. These findings can pave the way for the new engineering strategies to enhance ion selectivity in redox-mediated separation systems.

Abstract 33 at 10:00 AM — Session AC-AF-02 Monday 10:00 AM - Elm Fork II

Adaptive Physics Constrained ML for Autonomous Particle Accelerators

Alexander Scheinker

Applied Electrodynamics Group, Los Alamos National Laboratory, Los Alamos NM, United States

Machine learning (ML)-based tools are incredibly powerful for generative applications, such as virtual diagnostics, but struggle with time-varying systems, for which they require brute-force re-training. Such re-training is often not possible when requiring detailed beam measurements which interfere with operations or are slow procedures. Another challenge faced by generative ML is the tendency to hallucinate and create non-physical outputs. LANL has been developing adaptive machine learning (ML)-based tools, that utilize adaptive model independent feedback control theory together with hard physics constraints within ML models, to make the tools much more robust to time variation and distribution shift. These adaptive ML tools can extrapolate much further beyond the span of the training data than standard ML approaches and are thus more robust for time-varying systems. This talk will give an overview of adaptive and physics-constrained ML tools which are being developed for autonomous control and optimization of particle accelerators. These methods have been applied at accelerator around the world including FACET, LCLS, EuXFEL, HiRES, LANSCE, and NDCX-II.

Abstract 128 at 10:20 AM

Session AC-AF-02 Monday 10:00 AM - Elm Fork II

Leveraging Distance-Aware Uncertainty Estimation for Machine Learning and Advanced Controls in Particle Accelerators

Malachi Schram

Data Science Department, Thomas Jefferson National Accelerator Facility, Newport News VA, United States

The integration of Artificial Intelligence (AI) and Machine Learning (ML) can significantly enhance the design and operation of particle accelerators by detecting anomalies, creating fast data-driven surrogate models, and advancing control systems. This talk will present our research on distance-aware uncertainty estimation anomaly detection and surrogate modeling. We will present our findings on the application of Deep Gaussian Process Approximation (DGPA) methods in two key areas: 1) anomaly detection at the Spallation Neutron Source (SNS) accelerator, and 2) uncertainty-aware surrogate modeling at the Fermi National Accelerator Lab (FNAL) Booster Accelerator Complex. Additionally, we will discuss our ongoing work on the Scientific Optimization and Control Toolkit (SOCT), a composable toolkit designed for particle physics controls workflows.

Abstract 36 at 10:40 AM

Session AC-AF-02 Monday 10:00 AM - Elm Fork II

Latent autoregressive recurrent approach for generation and forecasting spatiotemporal beam dynamics

Mahindra Rautela

Applied Electrodynamics Group (Accelerator Operations & Technology), Los Alamos National Laboratory, Los Alamos New Mexico, United States

Beam diagnostics in particle accelerators is challenging not only due to the limited non-destructive measurements and computationally demanding simulations but also due to the inherent uncertainties in the system. We introduce a two-step unsupervised deep learning framework to learn the full spatiotemporal dynamical nature of the evolution of a charged particle beam through various sections of a linear accelerator. The approach consists of a Conditional Variational Autoencoder (CVAE), which transforms six-dimensional phase space into a lower-dimensional latent distribution, and a Long Short-Term Memory (LSTM) network, which captures temporal dynamics autoregressively. The proposed model, named as Conditional Latent Autoregressive Recurrent Model (CLARM) can generate projections at various accelerator modules by sampling and decoding the latent space representation. The model also forecasts future states (downstream locations) of charged particles from past states (upstream locations). The results demonstrate that the generative and forecasting ability of the proposed approach is promising when tested against a variety of evaluation metrics.

Abstract 117 at 11:00 AM

Session AC-AF-02 Monday 10:00 AM - Elm Fork II

Errant Beam Prognostics with Machine Leaning at SNS Accelerator

Kishansingh Rajput[1,3], Malachi Schram[1], Willem Blokland[2], Yasir Alanazi[1], Pradeep Ramuhalli[2], Alexander Zhukov[2], Charles Peters[2], Ricardo Vilalta[3]

[(1)]Data Science Department, Jefferson Lab, Newport News VA, United States
[(2)]Oak Ridge National Laboratory, Oak Ridge TN, United States
[(3)]Computer Science Department, University of Houston, Houston TX, United States

Particle Accelerators are complex machine with many pieces of equipment running in synchronization to deliver required beam. However, faults in particle accelerators reduce the availability of the beam for experiments affecting the overall science output. To avoid these faults, we apply anomaly detection techniques to predict any unusual behavior and perform preemptive actions to improve the total availability. Many researchers have adopted semi-supervised Machine Learning (ML) methods such as auto-encoders and variational auto-encoders for such tasks. However, supervised ML techniques designed for similarity learning such as Siamese Neural Network (SNN) can outperform semi-supervised or unsupervised methods for anomaly prediction. One of the challenges associated with application of ML models to particle accelerators is the variability in observed data over time due to system configuration changes. We employ conditional models such as Conditional Siamese Neural Networks (CSNN), and Conditional-VAE (CVAE) to learn the variability in the data by using beam configuration parameters as conditional input. We apply these models for errant beam prediction at Spallation Neutron Source accelerator under different system configurations and compare their performance. We demonstrate that CSNN outperforms CVAE in our application. This talk will present the

data source, collection, analysis, data-preparation, model development, hyper-parameter studies and the results.

Abstract 64 at 11:15 AM

Session AC-AF-02 Monday 10:00 AM - Elm Fork II

Safe Extremum Seeking in Accelerators and Machine Learning

Alan Williams, Alex Scheinker

Accelerator Operations and Technology - Applied Electrodynamics, Los Alamos National Laboratory, Los Alamos New Mexico, United States

We present a form of extremum seeking, traditionally employed for optimizing unknown objective functions, now adapted to accommodate an unknown yet measurable constraint. We consider the constraint to be a safety metric, which is maintained, practically, throughout the optimization process. We demonstrate that our approach can ensure safety violations be made arbitrarily small, parallel to how classical extremum seeking controllers achieve stability near optimal points. The power of this algorithm is particularly underscored in its application to particle accelerator systems, shown in several examples, where safety is critical. This work broadens the scope of extremum seeking methods and establishing an approach for integrating safety considerations into optimization processes, useful in situations where balancing optimal performance with stringent safety requirements is essential. We also use the key ideas from safe extremum seeking in machine learning settings, for modeling, estimation, and control of particle beams.

Abstract 265 at 10:00 AM

Session AR-NST-04 Monday 10:00 AM - West Fork II

Ultra-low kV Ion Implantation Depths Analyzed by Atom Probe Tomography

Joanthan D Poplawsky[1], Michael Titze[2], Alex Belianinov[2]

[(1)]Center for Nanophase Material Sciences, Oak Ridge National Laboratory, Oak Ridge TN, United States
[(2)]Ion Beam Laboratory, Sandia National Laboratories, Albuquerque NM, United States

The Stopping Range of Ions in Matter (SRIM) model for predicting ion implantation in materials becomes inaccurate for ultra-low energy implantations. Better models need to be developed to predict low voltage ion implantation that is key for the shrinking devices in the semiconductor industry. Accurate and precise measurements of low kV ion implantation is important to validate and develop new models. Atom probe tomography (APT) is an ideal technique to measure depth profiles in ion irradiated materials due to its ~10 ppm sensitivity and sub-nm resolution in the Z-dimension; however, there are challenges. Capping materials are typically utilized to act as a fiducial for and preserve

the surface. Unfortunately, capping materials can cause aberrations that can affect the measurement precision, particularly when the top few atomic layers are of interest. Also, deviations from a hemispherical end form of the APT specimen can cause resolution issues. To overcome these problems, a sample preparation method suitable for ion implantation and an ideal APT experiment was developed. A sharp APT specimen prepared by any method (focused ion beam (FIB), electropolishing, etc.) is field evaporated in the atom probe until the extraction voltage reaches 5 kV. This creates an ~100 nm, "perfectly spherical" end form. This specimen is then irradiated with a sub-1 kV ion beam and transferred back to the atom probe for imaging the subsequent depth profile. The APT results reveal sub-2 nm depth profiles for the ion irradiation that are used to validate and develop new models to predict low-kV ion implantation depths. Overall, the talk will be focused on the use of atom probe tomography to measure ultra-low kV ion penetration depth profiles, and how these profiles help develop and verify new ion implantation models. APT research was supported by the Center for Nanophase Materials Sciences (CNMS), which is a US Department of Energy, Office of Science User Facility at Oak Ridge National Laboratory.

Abstract 286 at 10:30 AM

Session AR-NST-04 Monday 10:00 AM - West Fork II

Pseudo-Epitaxial and Aligned Growth of Transition Metal Dichalcogenide Heterostack

Ludwig Bartels

Dept. of Chemistry and Materials Science & Engineering Program, UC Riverside, Riverside CA, United States

The idea of stacking different 2-dimensional (2D) materials on top of each other (like Lego!) has captured the imagination of physicists and electrical engineers alike as it allows the assembly of device structures in an, at least conceptually, very simplistic manner. Pickup and stacking is, however, not a scalable technique. Here we present recent work on growing sharp material interfaces and aligned layers of different transition metal dichalcogenide (TMD) materials on top of each other in high vacuum avoiding challenges of cleanliness, alignment, trapped gas bubbles, etc. associated with the stacking process. The growth process can be monitored in real time using inexpensive colorimetric analysis and offers substrate- (wafer-)scale homogeneity.

Growth starts on a GaN surface, which is closely lattice matched to MoS_2. Once a first pseudo-epitaxial layer of MoS_2 is established, virtually any other TMD material can be deposited. The resultant material will align to the substrate and for closely matched lattice size (e.g., MoS_2, WS_2) adopt that of the substrate resulting in non-standard layer stacking.

Abstract 98 at 11:00 AM

Session AR-NST-04 Monday 10:00 AM - West Fork II

Coincidence Doppler broadening spectroscopy of single layer graphene on copper using a variable energy positron beam

V. A. Chirayath[1], H. Mahdy[1], S. Lotfimarangloo[1], R. W. Gladen[1], J. Driscoll[1], M. Chrysler[1], A. J. Fairchild[1,2], P. A. Sterne[2], A. R. Koymen[1], A. H. Weiss[1]

[(1)]Department of Physics, University of Texas at Arlington, ARLINGTON TX, United States
[(2)]Lawrence Livermore National Laboratory, Livermore CA, United States

Our recent results show that gamma photons, emitted after the annihilation of positrons that are trapped in the image potential induced well, carry chemical information of the topmost atomic layer. We used the ratio curve analysis to reveal that the Doppler broadened line shape, specifically, the high-energy region of the annihilation gamma reflects the elemental composition of the top-most atomic layer. To obtain the ratio curves, we divided the area normalized Doppler spectra from various surfaces with the normalized Doppler spectra from the clean copper surface. In these studies, we showed that, the measured ratio curves could be least squares fit using a linear combination of theoretical ratio curves and thus, obtain the chemical composition of the probed surface. The theoretical ratio curves were obtained by taking the ratio of the calculated Doppler spectra from various elements to a model Doppler spectrum representing clean copper surface.

Here we extend the method to analyze depth-resolved Doppler broadening spectra measured from a single-layer graphene on a copper substrate collected using a variable low-energy positron beam. Ratios of the annihilation gamma spectra collected at various positron energies to the spectrum collected from the clean copper surface shows the evolution of the shape of the annihilation gamma spectra from the surface, i.e., from graphene to the Cu substrate. As the implantation energy of the positrons increases, the probability for the surface trapping of positron and the subsequent annihilation with carbon electrons decreases. On a similar note, the probability to form positronium at the sample surface decreases and the chance for annihilation with the bulk Cu electrons increases. By least squares fitting the depth resolved ratio curves using the theoretical ratio curves, we can derive the variation of the annihilation probability of positrons with carbon electrons, copper electrons or after forming positronium with the positron beam energy. These results provide a tool to derive the positron diffusion length in a system with a single atomic layer of carbon atoms on copper and thus, extract depth-resolved elemental information.

Abstract 58 at 11:15 AM

Session AR-NST-04 Monday 10:00 AM - West Fork II

Measuring the chemical composition of the topmost atomic layer of clean and adsorbate covered metal surfaces using a low energy positron beam

Hany Mahdy[1], S Lotfimarangloo[1], V A Chirayath[1], P A Sterne[2], R W Gladen[1], M Rooks[1], M Chrysler[1], A R Koymen[1], J Asaadi[1]

[(1)]Department of Physics, The University of Texas at Arlington, Arlington Texas, United States
[(2)]Lawrence Livermore National Laboratory, Livmore California, United States

We present measurements and theoretical modeling of the Doppler Broadened annihilation gamma spectra from the clean and adsorbate covered copper (Cu), silver (Ag) and gold (Au) surfaces. By comparing the chemical composition of the probed surfaces obtained using coincidence Doppler broadening spectroscopy (CDBS) to that derived from simultaneously performed positron annihilation induced Auger electron spectroscopy (PAES), we provide evidence that gamma photons, emitted after the annihilation of surface-trapped positrons, offer chemical information from the topmost atomic layer. The shape of the Doppler broadened gamma spectrum analyzed using ratio curves reveal that the Doppler broadened line shape, specifically, the high-energy region of the annihilation gamma reflects the elemental composition. This is observed even with the presence of annihilation gamma from positronium annihilation and the significant reduction in contribution from core electron annihilation. The ratio curves were obtained by dividing the normalized Doppler spectra from various surfaces to the normalized Doppler spectra from the clean Cu surface. The measured ratio curves were least squares fit using a linear combination of theoretical ratio curves to estimate the chemical composition of the probed surface. The theoretical ratio curves were obtained by taking the ratio of the calculated Doppler spectra from various elements to a model Doppler spectra representing clean Cu surface. The modeled gamma spectra from clean Cu surface contained contribution from the calculated Doppler spectra from Cu (88%) and the gamma spectrum from positronium annihilation (12%) consistent with previous results. Using this method we were able to model the ratio curves of multiple surfaces which consisted of Cu with sulfur (S) adsorption, Cu with oxygen adsorption, Cu with a thin film of Selenium, Cu with a single layer of graphene, Ag with S coverage and clean Au. The estimated chemical composition is compared to what was driven from PAES and our results indicate that CDBS can be a highly surface selective tool for chemical characterization. Given that the 511 keV annihilation gamma has the capability to traverse several millimeters of sample or reaction cell wall without the loss of the chemical information, CDBS can become an in-operando characterization tool for probing the hidden, buried or internal surfaces of systems like the nanoporous materials. We will discuss as to how CDBS can be possibly be used to capture variations in the internal surface composition of nanoporous metals resulting from catalytic reactions or surface migration induced by exposure to reactive gases.

Abstract 77 at 10:00 AM

Session AR-RE-07 Monday 10:00 AM - Elm Fork I

Functionally Graded Joints from Tungsten to Ferritic/Martensitic Steels Fabricated using Laser - Directed Energy Deposition as Plasma Facing Components

Ibrahim Karaman[1], Deniz Ebeperi[1], Tim Graening[2], Ying Yang[2], Yutai Kato[2]

[(1)]Department of Materials Science and Engineering, Texas A&M University, College Station Texas, United States
[(2)]Materials Science and Technology Division, Oak Ridge National Laboratory, Oak Ridge TN, United States

Joining dissimilar metals may promote performance and functionality. However, for systems like W to Steel joints, where there is no metallurgical compatibility, the formation of deleterious phases prevents crack-free bonding. The use of filler alloys may lead to microstructure degradation at elevated temperatures, thus, not suitable for extreme environments. The coefficient of thermal expansion (CTE) mismatch between W and steel, gives rise to localized stresses during the thermal cycling associated with processing and operation. Functionally grading along a well-designed compositional pathway, where the composition and CTE of successive layers are deliberately graded, reduction of thermal stresses and elimination of deleterious phase formation will produce more robust and durable joints. Here, we design interlayers between W and martensitic steel and fabricate compositionally graded porosity free joints between them using laser-directed energy deposition and multipowder feeders. The microstructure and mechanical properties of these joints have been characterized. Important findings and remaining challenges will be discussed.

Abstract 139 at 10:30 AM

Session AR-RE-07 Monday 10:00 AM - Elm Fork I

On the application of an engineered ferritic/martensitic alloy for fusion environments

Hyosim Kim[1], Jonathan Gigax[1], Matthew Chancey[1], Jon K.S. Baldwin[1], Yongqiang Wang[1], Stuart Maloy[2], Osman El Atwani[2]

[(1)]Los Alamos National Laboratory, Los Alamos NM, United States
[(2)] Pacific Northwest National Laboratory, Richland WA, United States

The combination of extreme conditions in fusion reactors, such as elevated temperatures with plasma and displacing radiation from 14 MeV neutrons produced by T(D,n)α reaction, induce changes to the microstructure of the material and challenge material performance. Here we introduce efforts towards improving radiation resistance of a blanket material candidate, ferritic-martensitic (F/M) HT-9 steel. A variety of HT-9 heats with varying composition were subject to a range of damage levels via self-ions. Microstructural engineering through large strain extrusion machining (LSEM) was applied in an effort to improve the void swelling resistance and tested for the first time at high dose using a 3.5 MeV Fe ion beam up to 600 peak displacement-per-atom (dpa) at 450 °C. Results were characterized using a

transmission electron microscopy (TEM) and compared against other HT-9 variants irradiated by neutron and ion beams.

Abstract 99 at 11:00 AM

Session AR-RE-07 Monday 10:00 AM - Elm Fork I

Revealing radiation-induced defects and defect-phonon scattering in ThO_2

Mia Jin[1], Beihan Chen[1], Linu Malakkal[2], Kaustubh Bawane[2], Boopathy Kombaiah[2], Yongfeng Zhang[3], Marat Khafizov[4], David Hurley[2]

(1)Penn State University, State College PA, United States
(2)Idaho National Laboratory, Idaho Falls ID, United States
(3)University of Wisconsin, Madison WI, United States
(4)Ohio State University, Columbus OH, United States

Understanding radiation-induced defects and their impact on phonon transport in candidate nuclear fuel ThO2 are of significance for fission reactors. This presentation will delve into the pertinent endeavors concerning ThO2, encompassing both atomistic modeling and experimental characterization of irradiated samples. Topics to be covered include defect formation from primary radiation damage, the characteristics and behavior of dislocation loops, defects-assisted anion transport, and the consequent degradation of thermal conductivity by these various defect types. With a detailed analysis of the defect dynamics, we were able to compare with the experimental characterization of radiation-induced microstructure. Furthermore, insights such as the phonon-defect scattering cross-section were extracted, offering a quantification of defect impact, and serving as foundational data for large-scale computational methodologies.

Abstract 85 at 10:00 AM

Session SN-OM-01 Monday 10:00 AM - Trinity Central

Status report for the Australian National University's Heavy Ion Accelerator Facility (HIAF)

Peter Linardakis

Heavy Ion Accelerator Facility, Australian National University, Canberra ACT, Australia

The Heavy Ion Accelerator Facility (HIAF) at the Australian National University operates a 14UD Pelletron as one of five electrostatic accelerators in the Heavy Ion Accelerators (HIA) national research capability. After celebrating 50 years since the first proton beam in August of 2023, several major upgrades of HIAF are ongoing. An update on the progress of these will be presented with discussion of the required modernisation and/or move to industry standards for networking infrastructure, functional/machine safety development, beamline alignment amongst others and procurement.

Abstract 107 at 10:20 AM

Session SN-OM-01 Monday 10:00 AM - Trinity Central

ANSTO Centre for Accelerator Science Lab Report for 2024

David Button, Michael Chalk, Philip Chatfield, Andrew Downes, John Lawlor, Michael Mann, Matthew Rees, Jake Sheath, Glenn Small, Marjan Veleski, Jian Wang

Centre for Accelerator Science , Australian Nuclear Science and Technology Organisation, Lucas Heights NSW, Australia

The Centre for Accelerator Science (CAS) runs, maintains, and develops its fleet for four tandem accelerators range in terminal voltages of 1MV - 10MV.

The Accelerator Systems Development (ASD) group have been heavily engaged in programs of works to de-risk our aging facilities, ANTARES and STAR. This has involved the replacement of key assets, and the redevelopment of controls and compliance of systems to modern expectations and requirements.

Additionally, CAS has been successful in obtaining uplift funding for additional scopes of works, and preparing for the engagement of more staff, and to undertake additional developments, and capabilities developments.

CAS continue to navigate the evolution of expectations and requirements within the industry and can report from the perspective of a national government facility.

Abstract 149 at 10:40 AM

Session SN-OM-01 Monday 10:00 AM - Trinity Central

Status report for the Columbia Radiological Research Accelerator Facility

Naresh T. Deoli, Andrew D. Harken, Yuewen Tan, Guy Garty, David J. Brenner

RARAF, Center for Radiological Research, Columbia University, Irvington, New York, United States

The Radiological Research Accelerator Facility, the physics arm of the Center for Radiological Research at Columbia University, was originally founded at Brookhaven National Laboratory in 1967 to study the biological effects of monoenergetic neutrons. Since then, it has expanded to offer radiobiologists with a broad palette of radiation types. Using a 5.5 MV High Voltage Engineering Singletron accelerator, micron-diameter and broad beams of proton, deuteron and helium beams are available for irradiation of cells and tissues. An electron beam ion trap ion

source is integrated into Singletron for delivery of heavy ions (i.e., carbon, boron, and oxygen). To increase beam energy and penetration, a radiofrequency linac booster from Ion Linac Systems, Inc is installed in-line with the Singletron. Neutrons are available for irradiation of cell cultures and mice, using monoenergetic beams as well as a broad spectrum mimicking that seen at Hiroshima. Electron beams at 6-15 MeV are provided from a retired medical linac that has been modified by us to allow ultra-high dose rate irradiations for FLASH radiotherapy studies and for modeling A-Bomb exposures. A progress report on these endeavors will be provided, accompanied by a discussion on necessary commissioning steps, among other relevant aspects.

Acknowledgments

National Cancer Institute (S10OD025190 and U01CA236554); National Institute of Biomedical Imaging and Bioengineering (P41EB002033); NYS Empire State Development Capital Project #AC710. National Institute of Allergy and Infectious Diseases (U19AI067773).

Abstract 191 at 11:00 AM

Session SN-OM-01 Monday 10:00 AM - Trinity Central

Facilities at the UK National Ion Beam Centre

Luke Antwis, Ella Schneider, Satheesh Krishnamurthy, Roger Webb

Ion Beam Centre, University of Surrey, Guildford England, United Kingdom

Ion beams are ubiquitous in materials research and development. Whether it's the ion implantation enabled electronics revolution of the last few decades [1], generating radioisotopes for medical diagnosis and treatment, analysis and characterization of exciting new materials and historical artefacts or developing the next generation quantum technologies [3], ion beams are involved.

The UK National Ion Beam Centre is a consortium of three state-of-the-art ion beam facilities across the UK, offering a comprehensive and unparalled range of ion beam techniques and capabilities with a single point of access for UK and international users.

Capabilities include:

Ion implantation

Ion Beam Analysis (MEIS, RBS, PIXE, TOF-ERD…)

Irradiation with in-situ TEM

Nuclear irradiation

Single Ion Deterministic Implantation

Focussed Ion Beams

Details of the capabiltites and applications will be given, along with information about accessing the facility.

Abstract 248 at 1:00 PM

Session AA-IBTM-04 Monday 1:00 PM - Post Oak

Status of the Scanning Light Ion Microprobe at the University of North Texas

Todd A Byers, Mohin Sharma, Charles T Bowen, Darshpreet Kaur Saini, Mritunjaya Parashar, Bibhudutta Rout, Gary A Glass

Department of Physics, University of North Texas, Denton TX, United States

Since its completion in 2014, the scanning light ion microprobe in the Ion Beam Laboratory at the University of North Texas has been one of the lab's most utilized beamlines. As such, it was necessary to upgrade it to increase its capabilities. A high throughput ion beam focusing system utilizing two Louisiana magnetic doublets in a separated quadruplet configuration was installed. With a working distance of 18 cm, it provides an orthomorphic demagnification of ~100x100, and it can be easily reconfigured to run in a doublet or triplet configuration. A data acquisition system from Oxford Microbeams LLC and an array of detectors were installed for performing RBS, PIXE and STIM simultaneously.

We will be presenting theoretical simulations and experimental results demonstrating the high demagnification and high current density of the upgraded microprobe as well as present some of the results of ion microprobe analysis of biomedical, environmental, and photovoltaic samples and devices. We will also discuss more upgrades currently underway, which include the following: installation of a more versatile spherical chamber, a high precision multi-axis piezoelectric stage with goniometer functionality and a compact magnetic deflector for use with light element PIXE.

Abstract 203 at 1:15 PM

Session AA-IBTM-04 Monday 1:00 PM - Post Oak

The fabrication and design of a liquid target holder for Ion Beam Analysis.

Jorden Matty

Physics, University of North Texas, DENTON TX, United States

A liquid target holder is proposed, to provide a liquid target of uniform thickness held under vacuum with the designed purpose for ion beam application. This 'liquid cell' allows for ion beam analysis for targets that could not typically handle vacuum environment, such as liquids with high vapor pressure. The current design utilizes 4 silicon-rich nitride windows to 'sandwich' 3 separate volumes, an entrance volume, an exit volume, and a middle volume of sub-micron thickness that will contain a liquid target. The entrance and exit volumes are filled with helium gas, to provide a uniform pressure along the inner two silicon-rich nitride windows to provide a uniform target thickness. The non-uniformity of the entrance and exit volumes due to the pressure differential is then neglected, due to the low stopping power of the helium relative to the liquid target. Values for energy loss in the silicon-rich nitride windows have been measured and will be used for post analysis to determine true yields for ion beam analysis on these liquid targets. The design can be made in-house using a CNC mill, allowing for fabrication and use in most laboratories where a simple machine shop is present. This allows the user access to more target materials without the utilization of an external beam.

Abstract 249 at 1:30 PM

Session AA-IBTM-04 Monday 1:00 PM - Post Oak

Trace Element Analysis of Air Dust Samples using Particle-Induced X-ray Emission Spectroscopy

Darshpreet Kaur Saini[1], Shivcharan Verma[2], Biraja Mohanty[2], Todd A. Byers[1], Mohin Sharma[1], Mritunjaya Parashar[1], Charles T. Bowen[1], Gary A. Glass[1], Bibhudutta Rout[1]

[(1)]Department of Physics, University of North Texas, Denton Texas, United States
[(2)]Department of Biophysics, Punjab University, Chandigarh, India

Particulate matter (PM) found in air samples is one of the major sources of pollution and air-borne diseases. Therefore, it is important to examine the trace elements composing the PM. Air dust samples collected from the urban areas in north India from outdoor and indoor regions were investigated using Particle-Induced X-ray Emission (PIXE) spectroscopy techniques. A scanning proton beam (micro-PIXE) with an energy of 2 MeV and a spot size of around 1 μm^2 was used to analyze the composition, correlation, and spatial distribution of the trace elements in the air dust. The elemental concentrations were extracted with a minimum detection limit (MDL) of ng/mg from the different regions of interest (ROI). The outdoor air sample showed high concentrations of significant elements such as silicon, potassium, and calcium. In contrast, the indoor air sample had elevated levels of chromium, possibly because of its presence in the room's wall paint. The distribution of particulates was further examined to study the relation between the size and the source of PM using different elemental maps.

Abstract 76 at 1:45 PM

Session AA-IBTM-04 Monday 1:00 PM - Post Oak

Imaging Seeds for Archaeology

Philip Jackle[1], Suzanne Villeneuve[3], Brian Hayden[2], Karen L Kavanagh[1]

[1]Physics , Simon Fraser University, Burnaby BC, Canada
[2]Archaeology, Simon Fraser University, Burnaby BC, Canada
[3]Anthropology, University of Toronto, Toronto ON, Canada

Imaging objects with a large depth of field is well known to be feasible with scanning electron microscopy. However, in many cases the objects to be studied are non-conducting. A thin conducting coating (for example Au or C, 5 nm) is often applied to avoid charging the sample while scanning it with an electron beam. Another option is to use a variable pressure environment within the SEM which also aids in the reduction of surface charging but requires the use of backscattered electron detectors. The focussed He+ ion microscope (HIM) is an instrument that maintains a neutral surface by the application of an electron flood gun while scanning the beam to generate secondary electron images. The technique provides higher depth of field, does not require coating, and has a similar resolution to that of SEMs. This talk will present a comparison of images obtained from optical, SEM, and HIM images of small chenopod seeds (mm) from archaeological excavations near Lillooet, BC (Keatley Creek Site).

Abstract 201 at 1:00 PM

Session AP-SD-03 Monday 1:00 PM - West Fork II

Development towards a field-portable tagged neutron interrogation system for imaging and chemical analysis

Brian Bucher[1], Matthew Heath[2], Paul Hausladen[2], Edward Seabury[1]

[1]Idaho National Laboratory, Idaho Falls Idaho, United States
[2]Oak Ridge National Laboratory, Oak Ridge Tennessee, United States

Prompt Gamma-ray Neutron Activation Analysis (PGNAA) is a powerful tool for non-destructively assaying suspect items for the presence of harmful chemicals or explosives. Field-portable systems, such as the Portable Isotopic Neutron Spectroscopy (PINS) system developed at Idaho National Laboratory, have been in use for this purpose for many years. When it comes to the detection and discrimination of chemicals primarily composed of light elements such as carbon and oxygen, the sensitivity of the conventional PGNAA approach is limited by high background caused by the presence of these same elements in the surrounding field environment, as well as low gamma-ray production and detection efficiencies. In order to boost signal-to-background ratios for these key elements, an Associated Particle Imaging (API) system, developed at Oak Ridge National Laboratory, has been tested with a PINS-like high purity germanium based PGNAA system with various chemical simulants. The results display a substantial improvement in sensitivity and discriminability across a wide range of elements, including

carbon, nitrogen, oxygen, silicon, and chlorine. Moreover precise 2D spatial mapping of the gamma-rays of interest has been achieved using simultaneously recorded neutron transmission radiographic data. Experimental results recorded from simulated explosives and chemical warfare materiel in field-relevant configurations will be presented.

Abstract 275 at 1:30 PM

Session AP-SD-03 Monday 1:00 PM - West Fork II

Associated Particle Imaging for security and defense applications

Mauricio Ayllon Unzueta, Arun Persaud, Thomas Schenkel

Lawrence Berkeley National Laboratory, Berkeley CA, United States

The technique known as Associated Particle Imaging (API) or Associated Particle Method (APM) or Tagged Neutron Method (TGM) has been used or proposed for cargo screening applications, non-destructive interrogation for nonproliferation activities, and in-situ explosives detection among others. In this talk, I'll provide an overview of API technology and its potential applications in the fields of security and defense.

API is based on the coincident detection between a neutron or neutron-induced gamma ray and an alpha particle, which are emitted 180 degrees from each other in a Deuterium-Tritium type neutron generator. The ability to perform these coincident measurements allow for an effective "electronic collimation" of the neutron beam known as the API cone, which in turn allows for the significant suppression of background signals together with the possibility to perform non-destructive full 3D compositional imaging. I'll discuss the possible applications of this technology, the current limitations, and future prospects to further advance this promising technology.

Abstract 241 at 2:00 PM

Session AP-SD-03 Monday 1:00 PM - West Fork II

Uranium Detection using Photon Active Interrogation based on Delayed Neutron Analysis

Mairead E. Montague[1], Abbas J. Jinia[1,2], Shaun D. Clarke[1], Igor Jovanovic[1], Sara A. Pozzi[1]

[(1)]Department of Nuclear Engineering and Radiological Sciences, University of Michigan, Ann Arbor MI, United States
[(2)]Department of Medical Physics, Memorial Sloan Kettering Cancer Center, Manhattan NY, United States

Nuclear security and nonproliferation applications require techniques to detect and identify special nuclear material (SNM) during cargo transit. Active interrogation methods use external radiation sources to search for unique signatures of SNM. Non-

SNM targets, such as Pb or other high-Z materials, produce neutrons through photonuclear reactions (γ, n) when interrogated by radiation sources; however, SNM produces neutrons through both photonuclear (γ, n) and photofission (γ, f) events. Of those, only photofission leads to the creation of delayed neutrons, making delayed neutrons an important signature of SNM.

These neutrons can be detected in-between the pulses of interrogating sources, such as linear accelerators and neutron generators. Previous work has demonstrated this approach using liquid organic scintillators and capture-based detectors such as ^{3}He and ^{6}Li-loaded organics and glass. Systems based on ^{3}He and other capture detectors are the standard for delayed neutron detection in active interrogation applications due to their large detection efficiency and insensitivity to gamma rays. Furthermore, because there is no low-energy threshold for interactions in capture detectors, neutrons from SNM that thermalize in various shielding configurations are still detectable.

Using a recoil detector allows for the performance of neutron spectroscopy to gather additional information during active interrogation. Neutron spectroscopy from recoil-based detectors (e.g., organic scintillators) can be used to isolate neutrons produced during interrogation from neutrons produced in non-SNM. Organic scintillators are sensitive to delayed neutrons from SNM, but are also sensitive to photons that must be filtered using pulse shape discrimination (PSD). Pulse shape discrimination of delayed neutrons is difficult given their low average energy of approximately 0.5 MeV. At these energies, distinguishing neutrons from gamma-ray background is particularly difficult. Analysis is underway to determine whether such low-energy delayed neutrons could be detected directly as nuclear recoils with scintillators that exhibit best-available PSD, such as **trans**-stilbene detectors.

One benefit to using **trans**-stilbene detectors over liquid organic scintillators is the improved PSD capabilities at lower energy thresholds. Previous work at the University of Michigan showed that **trans**-stilbene detectors are 95% accurate at discriminating neutrons with energies at 0.6 MeV or above, compared to the liquid organic scintillator EJ309 which has a minimum energy threshold of ~1 MeV. **Trans**-stilbene detectors also have the additional benefit of eliminating leakage hazards associated with liquid organic scintillators when deployed in an active interrogation system.

At the University of Michigan, we have already developed an active interrogation system, which previously focused on prompt neutrons for SNM detection. At present, work is underway to determine if it is possible to exploit the delayed neutron signatures in our interrogation system by measuring delayed neutrons from ^{238}U photofission between accelerator pulses during active interrogation. We have created an experiment based on a 9-MeV linear electron accelerator that allows us to measure resulting signatures on various targets, including depleted uranium (DU). In this experiment, ^{3}He and **trans**-stilbene detectors were used to measure gamma-rays and neutrons being produced from photonuclear reactions on Pb and DU. The accelerator operates at an average rate of 44 Hz with a 4 μs long pulse. After filtering out counts detected during beam operation, the neutron emissions during the 22.7 milliseconds per pulse where the beam is not operating are being analyzed to determine whether **trans**-stilbene detectors were able to detect delayed neutrons from photofission on ^{238}U.

Strong evidence for verifying that neutrons detected with the **trans**-stilbene detectors are delayed neutron scatters on protons is a light output spectrum consistent with delayed neutrons in the selected neutron fiducial region. By examining the light output spectrum collected after DU interrogation, **trans**-stilbene detectors will be analyzed to determine their potential at detecting delayed neutrons and therefore being used to differentiate SNM from non-SNM cargo.

Abstract 278 at 2:15 PM

Session AP-SD-03 Monday 1:00 PM - West Fork II

Testing and evaluation of an associated particle imaging neutron generator

Matthew D Coventry

Starfire Industries, Champaign IL, United States

Several applications of neutron generators for security and defense applications use the associated particle imaging (API) technique. API neutron generators have special requirements in addition to standard D-T neutron generators and enable special measurement modalities. Under the DOE SBIR program, an API generator, nGen®-400-API, has been developed by Starfire to meet the demand for API neutron generators. A prototype unit is being tested using various detectors and sample materials. This includes using pulse-shaped discriminating liquid scintillators for fast neutron detection and gamma scintillators with various target materials for inelastic scatter gamma ray measurement from select materials including carbon, nitrogen, iron, and copper.

This talk shows the basic design elements of the generator, preliminary measurements with a single-pixel photomultiplier tube on the alpha detector, and measurements that confirm the neutron time of flight and provide material-specific gamma ray responses.

Abstract 51 at 1:00 PM

Session AR-NP-09 Monday 1:00 PM - West Fork I

Measurement of 14 MeV tD neutron production from the reaction-in-flight of dD fusion

Sean W Finch[1], Mark B Chadwick[2], John P Lestone[2], Werner Tornow[1], Jerry B Wilhelmy[2]

[(1)]Triangle Universities Nuclear Laboratory, Duke University, Durham NC, United States
[(2)]Los Alamos National Laboratory, Los Alamos NM, United States

The popular neutron production reaction D(d,n)^{3}He (hereto referred to as dD fusion) is accompanied, with equal probability, by the D(d,t)P reaction channel. In this channel, the triton (t) is produced with sufficient kinetic energy to induce the D(t,n)^{4}He (hereto referred to as tD fusion) reaction in the deuterium target. This tD reaction is referred to as a "reaction-in-flight" (RIF) since it occurs in inverse kinematics from the traditional dT fusion. The tD fusion will preferentially occur at the large t+d cross-section resonance, producing the 14 MeV neutrons characteristic of d+t fusion. Experiments searching for these RIF neutrons were conducted at the Triangle Universities Nuclear Laboratory (TUNL) tandem accelerator laboratory. Deuteron beams were impinged on a deuterium gas target. We use the neutron time-of-flight technique to observe the 14 MeV RIF neutrons and distinguish them from the much larger dD neutron flux. The tD RIF neutrons are found to have a flux five orders of magnitude smaller than the primary flux from dD fusion. According to our knowledge, this is only the second time that RIF tD neutrons have been recorded in an accelerator experiment; the first ever experiment was reported in 1938 by Ruhlig (Phys. Rev. **54**, 308), who discovered by accident the huge cross section of the tD reaction while studying the dD reaction. The effect of adding noble gas impurities to the D_2 target gas was investigated as a means of measuring the stopping power of the triton at low energies, around the large resonance in the tD fusion cross section. This work has applications to inertial confinement Fusion (ICF) facilities, such as NIF, where reaction-in-flight neutrons are routinely produced in high-yield shots.

Abstract 87 at 1:30 PM

Session AR-NP-09 Monday 1:00 PM - West Fork I

Differential neutron scattering measurements on U-238 using monoenergetic beams

Richard Hughes[1], Ching Yen Wu[1], Daniel Rhodes[1], Stanimir Kisyov[3], Werner Tornow[2], Sean Finch[2], Calvin Howell[2], Forrest Friesen[2], Ethan Mancil[2], Kaixin Song[2]

[(1)]Lawrence Livermore National Laboratory, Livermore CA, United States
[(2)]Triangle Universities Nuclear Laboratory, Durham NC, United States
[(3)]Lawrence Berkeley National Laboratory, Berkeley CA, United States

For the major actinides, the inelastic and elastic neutron scattering reaction channels have significant cross sections that compete with the fission channel from 1-6 MeV incident neutron energy. However, the actinide scattering reaction channels are much more poorly constrained than fission in this energy range. Consequently, nuclear data associated with inelastic/elastic neutron scattering often present a major source of uncertainty in models and predictions relevant to applications like nuclear energy and stockpile stewardship. These poor constraints come, in large part, as a result of the significant experimental challenges associated with appropriate measurements - often neutrons are the only reliable experimental probe, while neutron backgrounds from beam as well as target fission are significant. We recently initiated a long-term effort to address key neutron scattering data needs for actinides by performing time of flight neutron scattering measurements at the Triangle Universities Nuclear Laboratories (TUNL) tandem accelerator. The experiments employ pulsed, monoenergetic neutron beams from 2 to 5 MeV produced via 3H(p,n)3He and 2H(d,n)3He reactions. Results from our measurements on U-238, including neutron spectra and differential cross sections will be presented along with an outlook for our future plans for measurements on U-235 and Pu-239. This work was performed under the auspices of the US Department of Energy by Lawrence Livermore National Laboratory under Contract No. DE-AC52-07NA27344. TUNL work performed under DOE/NP Grant No. DE-FG02-97ER41033.

Abstract 46 at 2:00 PM

Session AR-NP-09 Monday 1:00 PM - West Fork I

Neutron reaction experiments in inverse kinematics with the Neutron Target Demonstrator and Low-Energy Heavy Ion Source at LANSCE

Andrew Leland Cooper, Shea Mosby, Rene Reifarth, Aaron Couture, Eames Bennett, Nathan Gibson, Dmitry Gorelov, Corey Keith, Amy Lovell, Gordon Misch, Matthew Mumpower

Los Alamos National Laboratory, Los Alamos NM, United States

The capability to directly measure neutron reactions on unstable isotopes would grant access to
many reactions of interest to the mission science and nuclear astrophysics communities.
However, precision measurements in forward kinematics are currently prohibited because the
radiation fields originating from stationary targets overwhelm the detection system, the target
sample sizes are too small, or the target lifetimes are too short. These experimental challenges
can be overcome by circulating the radioactive sample within an ion beam storage ring and
through a thermal neutron field to induce reactions in inverse kinematics. We are pursuing such
a neutron target facility consisting of a high-intensity, heavily moderated spallation neutron

target coupled with a radioactive ion beam storage ring at the Los Alamos Neutron Science Center (LANSCE). A first experiment with the Neutron Target Demonstrator (NTD) and Low-Energy Heavy Ion Source (LEHIS) at LANSCE is underway to validate this concept. This NTD experiment will use intense heavy ion beams to induce resonant neutron capture reactions within a large-volume moderator and spallation target assembly. Following transmutation, the unstable heavy ions will be implanted into foils downstream for offline decay gamma-ray counting analysis. Results from recent simulations and experimental tests of the NTD subsystems and LEHIS will be presented.

Abstract 290 at 1:00 PM

Session AR-RE-06 Monday 1:00 PM - Elm Fork I

Processing and Characterization of Refractory High Entropy Alloys as Candidates for Fusion Reactor Materials

Emily H. Mang[1], Sebastian Lech[1], Annie Barnett[1], Joshua Hubbard[1], Sicong He[2], Xinran Zhou[2], David Beaudry[1], Michael Falk[1], Jaime Marian[2], Mitra L. Taheri[1]

(1) Johns Hopkins University, Baltimore Maryland, United States
(2) University of California, Los Angeles CA, United States

Refractory high entropy alloys (RHEAs) are considered candidates for plasma facing components in fusion reactors due to their inherent high-temperature strength, electrical and thermal conductivity, and resistance to corrosion. They've been known to be radiation tolerant, possibly due to vacancy migration energy barrier landscapes and a greater volumetric strain in their lattices Tungsten is considered a primary component for plasma facing components, but to date has been fraught with susceptibility to He, experiencing mass loss through surface substructures (known as "fuzz"). This ultimately leads to unpredictability in conductive performance. RHEAs have been proposed as a solution, through their compositional complexity, to limit fuzz growth and blistering in plasma conditions, and have been shown to have a decrease in defect size (increased density) with chemical complexity. Here we present a combination of alloy forecasting and modeling using both thermodynamic predictions as well as physics-based high-fidelity modeling of defect and atomic scale phenomena coupled with in situ and ex situ irradiation. Post-irradiation characterization reveals promising behavior of RHEAs due to their inherent lattice frustration, revealing opportunities for microstructural tunability in relevant irradiation conditions. We discuss paths forward for both alloy design and scale-up based on these findings.

Abstract 218 at 1:30 PM

Session AR-RE-06 Monday 1:00

PM - Elm Fork I

Novel Refractory High Entropy Alloys for Applications in Extreme Environments

Osman El Atwani[1], Enrique Martinez[2], Matheus Tunes[3]

[(1)]Pacific Northwest National Laboratory, Richland WA, United States
[(2)]Clemson University, Clemson NC, United States
[(3)]Montanuniversität Leoben, Leoben, Austria

In the quest of new materials that can withstand severe irradiation and mechanical extremes for advanced applications (eg. fission reactors, fusion devices, space applications, etc.), design, prediction and control of advanced materials beyond current material designs become a paramount goal. W-based refractory high entropy alloys (HEAs) have been recently developed in the context of high temperature applications. Here, we present novel W-based refractory nanocrystalline and coarse grained HEAs and their performance to extreme environments. **In-situ** TEM thermal stability experiments, mechanical properties and irradiation resistance to single and dual beam irradiations are assessed. The results are elucidated based on theoretical modeling combining ab initio and Monte Carlo techniques. The simulation (CALPHAD, DFT and Cluster Expansion) guided HEAs demonstrated outstanding irradiation resistance and high thermal stability and mechanical properties, establishing a breakthrough in the design of new materials for extreme environments. The results are compared to pure materials' forms and other conventional W-based alloys. High throughput downselection characterization techniques, other novel materials for nuclear applications, and outstanding questions in literature are also discussed.

Abstract 105 at 2:00 PM — Session AR-RE-06 Monday 1:00 PM - Elm Fork I

Rapid Selection and Elastic Property Determination of Novel High-Entropy Alloys using Resonant Ultrasound Spectroscopy

Boris Maiorov

National High Magnetic Field Laboratory, Los Alamos National Laboratory, Los Alamos New Mexico, United States

Elastic constants describe the extent to which materials resist elastic deformation, providing important information on mechanical performance. Because they describe changes in free energy with strain, elastic constants also encode microscopic details about the nature of bonding and characteristic energy scales in materials. These features mean elastic constants naturally connect experiment and theory, leading to their adoption as a benchmark for materials design, model development, and model validation. In addition to measuring elastic constants at ambient conditions, it is particularly useful to experimentally determine the temperature-dependence of elastic constants down to cryogenic temperatures to establish phonon energy scales (**e.g.**, Debye

temperature), quantify the amount of anharmonicity, and directly compare with **T** = 0 K first-principles predictions.

In this talk, I will share elastic constant measurements on refractory high-entropy alloys down to 2K to exemplify the bonding and energy scale insights obtainable from elastic constants. The effects of composition on elastic constants and characteristic phonon energy scales (**e.g.**, Debye temperature) are examined and compared with theoretical predictions. Resonant ultrasound spectroscopy (RUS) is used for these experiments because of its ability to non-destructively determine the entire elastic constant tensor from a single measurement with high accuracy and precision. This approach, which entails extracting elastic constants from mechanical resonant frequencies, is amenable to all high-entropy materials, from metals to ceramics, and compatible with any amount of crystalline anisotropy or texture. As such, elastic constant determination with RUS is an enticing platform to examine functional properties in novel classes of high-entropy materials and identify key energy scales to incorporate in predictive models.

Abstract 72 at 1:00 PM

Session SN-OM-02 Monday 1:00 PM - Trinity Central

CASPAR Underground Accelerator Facility Update and Planning

Daniel Robertson

Physics and Astronomy, University of Note Dame, Notre Dame IN, United States

The Compact Accelerator System for Performing Astrophysical Research (CASPAR) is a deep underground accelerator laboratory located at the Sanford Underground Research Facility in Lead, SD. The system is at the 4850 ft level of the old Homestake gold mine and is based on a 1 MV JN model VdG accelerator producing protons and alphas for nuclear astrophysics reactions of interest. This is the 4th "new life" of the JN accelerator which has undergone multiple refits and upgrades over 60 years of operation. The system became operational underground in 2018 and put into hibernation in 2021 for further excavation work in the vicinity, start-up and recommissioning is planned for mid 2024. Presented here will be the current status of the system and challenges in maintaining its necessary performance levels moving forwards.

Abstract 234 at 1:20 PM

Session SN-OM-02 Monday 1:00 PM - Trinity Central

Status Report for Edwards Accelerator Laboratory at Ohio University

Gregory Michael Leblanc

Physics/Astronomy, Ohio University - Edwards Accelerator Lab, Athens Ohio, United States

A status report for the Edwards Accelerator Lab at Ohio University will be presented. Updates on existing facilities improvements and additions will be included. The lab houses an HVEC TN accelerator (one of 2 worldwide). Some discussion on the unique features of this machine will be discussed, along with an overview of significant upgrades/changes over the past 4 years.

Abstract 73 at 1:40 PM

Session SN-OM-02 Monday 1:00 PM - Trinity Central

Lab Status Report for Notre Dame's Nuclear Science Laboratory

Edward Stech

Physics & Astronomy, University of Notre Dame, Notre Dame Indiana, United States

Notre Dame's Institute for Structure and Nuclear Astrophysics (ISNAP) operates three pelletrons. I will summarize the latest developments in the NSL including operational summaries for the FN, 5U and 9S accelerators. I will recap two issues with the charging chains in the FN as well as give an overview of our SF6 gas testing. I will also show the results of an unexplained failure of a turbo pump.

Abstract 80 at 2:00 PM

Session SN-OM-02 Monday 1:00 PM - Trinity Central

Status Report for Michigan Ion Beam Laboratory

Prashanta Niraula, Zhijie Jiao, Fabian Naab, Kai Sun, Alexander Flick, Kevin Field

Nuclear Engineering and Radiological Sciences, University of Michigan, Ann Arbor MI, United States

The Michigan Ion Beam Laboratory (MIBL) at the University of Michigan in Ann Arbor, Michigan, USA, is a charter laboratory of the NSUF (National Scientific User Facility) and plays a significant role in supporting the mission of the U.S. DOE Office of Nuclear Energy. MIBL houses 3 MV and 1.7 MV tandem accelerators and 400 kV single-ended accelerator. MIBL provides single, dual, and triple beam irradiation capabilities and single and dual beam in situ capabilities in a 300 kV transmission electron microscope (TEM). The lab can conduct irradiations with large beam fluences, in ultra-high vacuum chambers, and with full remote control of irradiation conditions. This presentation will cover the current status of the machinery and equipment at MIBL. The most recent opening of the 3.0 MV Pelletron and its operational performance, as well as the upcoming upgrade of the TORVIS ion source for helium beam production will be discussed.

Abstract 284 at 3:00

Session AA-IBTM-01 Monday

Revealing Radiation Response in Atomically-Thin Transition Metal Sulfides (MoS_2, WS_2) through In-Situ Ion Irradiation Experiments

Christopher Smyth[1], Alex Boehm[1], Mark Reymatias[1,2], Kory Burns[3], Catalin Spataru[4], John Cain[1], Tzu-Ming Lu[1,5], Taisuke Ohta[1], Matthew Breeding

(1)Sandia National Laboratories, Albuquerque New Mexico, United States
(2)Nanoscience and Microsystems Engineering, University of New Mexico, Albuquerque New Mexico, United States
(3)Materials Science and Engineering, University of Virginia, Charlottesville Virginia, United States
(4)Sandia National Laboratories, Livermore California, United States
(5)Center for Integrated Nanotechnologies (CINT), Sandia National Laboratories, Albuquerque New Mexico, United States

Novel materials are needed to meet the demand for resilient electronics in extreme environments. Two-dimensional (2D) transition metal dichalcogenides (TMDs) exhibit a unique trifecta of high radiation tolerance, promising computing performance, and atomically thin profile. However, studies of radiation effects in TMDs have employed ex-situ approaches to probe their radiation response, which convolutes radiation effects by spontaneous TMD degradation in air. Because air exposure alone alters the carrier concentration, electronic band structure, and transport behavior in monolayer TMDs, air exposure effects need to be decoupled from radiation-induced degradation through in-situ experimental approaches.

In this presentation, we describe our progress in examining the impact of ion irradiation on monolayer MoS_2 and WS_2 films and transistors, using 5 MeV Fe^{2+} ion beams, and in-situ characterization without air exposure.

The ion irradiation experiment performed on MoS_2 transistors is based on back-gated devices that are wire bonded to enable in-situ transport measurements. We employ an ion beam with an end-of-range that is microns beyond the back gate oxide in the MoS_2 transistors, which highlights the impressive resilience of the MoS_2 channel to heavy ion irradiation based on the constant drain current (I_D), threshold voltage (V_T), and subthreshold swing (SS) up to a moderate ion fluence. A relatively small V_T shift is measured after ion irradiations in our work, but the magnitude of the shift is significantly less than previous reports in which the ion end of range resides within the back gate oxide, which highlights our ability to suppress ion irradiation effects on the back gate oxide that convolute radiation effects in the MoS_2 channel. These results highlight the importance of tuning the ion beam conditions to highlight irradiation effects on critical device nodes is achieved by selecting where ion beam energy is deposited in the device stack.

Radiation effects in TMD transistors are largely dictated by the electronic structure changes in the TMD due to radiation-induced defects. Most reports of radiation-induced defects in TMDs indicate hole doping in transition metal sulfides (MoS_2, WS_2)-

from ion irradiation, in conjunction with ex-situ transfer (i.e., samples are exposed to air) between irradiation and characterization. In an effort to isolate intrinsic radiation effects, we irradiate suspended monolayer WS_2 under 5 MeV Fe^{2+} ion beams and use an ultra-high vacuum (UHV) suitcase to transfer samples without air exposure between the ion accelerator end station to a UHV photoemission electron microscopy (PEEM) system, where the WS_2 electronic structure is mapped as a function of radiation conditions. We found that the elimination of air exposure in our experiment resulted in a reduced work function in ion irradiated WS_2 contrary to reported hole doping. Critically, we found that creating defects in WS_2 on the order of 10^{12} cm^{-2} at a 5×10^{11} cm^{-2} ion fluence resulted in significant change in the photoelectron line shape of the valence band spectra near the Γ-point, the center of the Brillouin zone. Our preliminary analysis based on the Shockley-Read-Hall model suggests the valence-hole lifetime in the suspended WS_2 decreases by 50% and the defect density increases by a factor of 4× after exposure to a 2.5×10^{13} cm^{-2} ion fluence. The sensitivity of the photoelectron spectra to the defect density is remarkably high, and has potential to enable the study of technologically-relevant defect densities on the order of $<10^{12}$ cm^{-2} on the electronic band structure of two-dimensional semiconductors, which has remained inaccessible to date using spectroscopic techniques.

Overall, these results highlight the importance of studying ion irradiation effects in air-sensitive TMDs using in-situ techniques and reveal important effects of ion irradiation in TMDs previously convoluted by air exposure in reported ex-situ experiments.

This work was supported by a Laboratory Directed Research & Development program at Sandia National Laboratories. Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc., for the U.S. DOE's National Nuclear Security Administration under contract DE-NA-0003525. The views expressed in the correspondence do not necessarily represent the views of the U.S. DOE or the United States Government. This work was performed, in part, at the Center for Integrated Nanotechnologies, a User Facility operated for the U.S. DOE Office of Science.

Abstract 143 at 3:30 PM

Session AA-IBTM-01 Monday 3:00 PM - Post Oak

Quantifying radiolysis effects for in-situ RBS and electrochemical impedance spectrometry (EIS)

Hunter Feltham[1], Jamie J Noel[1], Lyudmila V Goncharova[1,2]

[(1)]Chemistry, Western University, London ON, Canada
[(2)]Physics and Astronomy, Western University, London ON, Canada

Titanium is a versatile metal with a wide range of applications. The corrosion resistance of titanium is due to the rapid formation of a thin, protective oxide layer on the surface of the metal. In this study, an in-situ cell was developed and used to study explore the oxidation mechanism of titanium in water solution in the presence of alpha particles in contact with 0.27 M NaCl. The cell allowed in-situ TiO2 anodization while concurrent depth profile studies with Rutherford backscattering spectroscopy (RBS) and electrochemical impedance spectrometry (EIS) were performed. The RBS results showed that the TiO_2 was thicker after in-situ RBS experiments, even without an applied anodization bias. Our results showed that the oxide growth was enhanced several times due to the formation of radiolysis products in the electrolyte solution from interactions of α particles with the liquid water. The radiolysis products in solution acted as oxidizing species that enhanced the growth rate and changed the grain size and morphology of the resulting TiO_2. The electrochemical impedance spectroscopy results showed that the resistance of the oxide film was overall higher after radiation exposure. Several major regions were identified in EIS growth curves. Region 1: initial system stabilization, with Ti achieving stable open circuit potential (OCP). Region 2 (introduction of He+ flux): sharp increase in OCP, indicating the initial interaction of alpha particle flux with Ti and solution. Region 3 (continued exposure to alpha particle flux): OCP plateaus, signifying a steady state of oxide thickness with no significant increase in OCP. Region 4 (alpha particle flux is off): charge dissipation and returning to the system's non-polarized state. Region 5 (post-experimental stabilization): the system returns to an elevated OCP compared to the initial state. The scanning electron microscopy (SEM) results showed that the morphology of the oxide film changed after irradiation, resulting in a more uniform film with a smaller average grain size. This study provides new insights into the oxidation of titanium in the presence of α particles. The results can be used to improve the understanding of the oxidation mechanism of Ti and to develop new methods for controlling the growth of TiO_2.

Abstract 245 at 3:45 PM

Session AA-IBTM-01 Monday 3:00 PM - Post Oak

Ion and neutral time-of-flight spectroscopy as an in-situ diagnostic for probing plasma-exposed surfaces

Robert D Kolasinski, Antonio Cruz

Plasma & Reacting Flow Science, Sandia National Laboratories, Livermore CA, United States

A major obstacle to improving our understanding of plasma-material interactions is the difficulty of surface characterization during plasma exposure. Most surface analysis and microscopy techniques rely on charged particles as a probe or signal, and are designed for well-controlled, ultra-high purity vacuum environments. Consequently, they are incompatible with the high neutral pressures and electromagnetic fields present in a plasma environment. These techniques have generally been applied only for ex-situ analyses, and therefore cannot provide any real-time information on how the surface evolves and are blind to the

behavior of any volatile or mobile surface species (e.g. hydrogen isotopes and/or impurities).

To address these limitations in existing surface diagnostics, our research group has been developing a surface probe based on neutral beam scattering spectroscopy (NBSS). Our approach is analogous to the well-established ion scattering spectroscopy (ISS) surface diagnostic, but uses neutral particles to probe the surface, rather than ions. The surface composition is determined by the energies of detected particles obtained by time-of-flight (TOF) spectroscopy. Crucially, NBSS will be compatible with the plasma environment, as the neutral beam is unaffected by electromagnetic fields and can operate at relevant neutral pressures. Furthermore, NBSS retains ISS's ability to detect hydrogen isotopes, another deficiency of most surface diagnostics. The main measurement goal is to demonstrate three key aspects of plasma-material interactions: (a) evolution in surface composition caused by sputtering, (b) the behavior of hydrogen isotopes at plasma-exposed surfaces, and (c) changes in surface chemistry arising from implantation of impurities.

As a demonstration of this approach, we have constructed a prototype instrument for time-of-flight (TOF) spectroscopy that consists of a differentially-pumped ion source and flight tubes. We relied on a pulsed alkali ion source with customized ion optics to probe a variety of targets. This equipment was attached to an ultra-high vacuum chamber where the scattered and recoiled particles are sampled at angles of 65° and 160° relative to the incident ion beam, enabling detection of both forward and back-scattered particles simultaneously. Initial characterization of 10 keV Li^+ scattered from Au, W, Pd, Ni, and Al surfaces at pressures of 5×10^{-2} Pa and above revealed minimal attenuation of the scattered signal and good mass resolution. A potential advantage of the instrumentation as discussed above is its compact size in comparison with the equipment needed for high energy ion beam analysis (e.g. Rutherford backscattering), making it easier to implement on smaller systems. Preliminary results from these experiments will be presented, including initial studies of chemisorbed hydrogen on different metal surfaces of interest for hydrogen-surface interactions R&D.

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Abstract 256 at 4:00 PM

Session AA-IBTM-01 Monday 3:00 PM - Post Oak

Investigating the in-situ radiation damage in optical sensors using ion beam-induced charge microscopy

Mohin Sharma, Mritunjaya Parashar, Todd A. Byers, Darshpreet Kaur Saini, Charles Bowen, Gary A. Glass, Bibhudutta Rout

Department of Physics, Ion Beam Laboratory, University of North Texas, Denton Texas, United States

Ion Beam Induced Charge (IBIC) microscopy is an effective method for determining the electronic characteristics and defect regions of semiconductor materials and devices. This study shows how IBIC microscopy can be used to analyze optical sensors such as InGaAs and Si-PiN diodes, providing information on their charge collection efficiency (CCE), defect distribution, and minority carrier diffusion lengths. It has the advantage of offering a wide range of damage levels caused by ions of varying masses and energies in different sections of the same sample, as well as the ability to examine CCE deterioration using the same or different ions. Spatial maps of CCE were created, giving important information on material quality and uniformity. The IBIC data showed areas of varied charge collection efficiency, indicating the presence and distribution of defects.

Abstract 184 at 4:15 PM

Session AA-IBTM-01 Monday 3:00 PM - Post Oak

An attempt to predict oligomer sputtering using binary collision approximation simulations

Hans Hofsaess, Patrick Kirscht, Felix Junge

II Institute of Physics, Georg-August-University, Goettingen, Germany

The binary collision approximation (BCA) program IMINTDYN [1] allows a prediction of ion solid interactions. For sputtering of carbon and SiO2 experimental sputter yields are significantly higher than yields from BCA simulations. SDTrimSP simulations [2] reproduce experimental sputter yields by adjusting the surface binding energies. For O atoms 1 eV instead of the elemental sublimation energy of 2.58 eV and for carbon 4.5 eV instead of 7.4 eV is used. For sputtering of carbon it was shown [3] that sputtering of oligomers and clusters is relevant. We introduce a model to simulate oligomer sputtering using the IMINTDYN program based solely on thermodynamic formation enthalpies. In particular sputtering of O2 and SiO dimers and carbon oligomers is energetically favorable. To predict the oligomer sputter fraction, we use Boltzmann factors based on the ratios of oligomer and monomer formation enthalpies. We show that we can quantitatively predict the carbon and SiO2 experimental sputter yields.

[1] H. Hofsäss, A. Stegmaier, Nucl. Instr. Meth B 517 (2022) 49

[2] A. Mutzke, R. Schneider, W. Eckstein, R. Dohmen, K. Schmid,

U. von Toussaint, G. Bandelow, SDTrimSP Version 6.00, MPI Plasma

Physics, report IPP 2019-02 (2019)

[3] E.Oyarzabal, R.P. Doerner, M. Shimada, G.R. Tynan, J. Appl. Phys. 104 (2008) 043304

Abstract 229 at 3:00 PM | Session AP-IA-02 Monday 3:00 PM - West Fork I

Development of Pre-Clinical Electron FLASH LINACS with X-Ray Capability

Marcos Ruelas[1], Sergey Kutsaev[1], Ronald Agustsson[1], Adam Moro[1], Ke Sheng[2], Alexander Smirnov[1], Robert Berry[1], Osvaldo Chimalpopoca[1]

(1)RadiaBeam, Santa Monica California, United States
(2)Department of Radiation Oncology, University of California, San Francisco, San Francisco California, United States

Electron FLASH radiotherapy linacs in the circa 10 MeV range are limited to treating only superficial tumors due to their limited penetration. While VHEE promises to apply direct electrons for deep-seated tumors in clinical settings, there is still value in pre-clinical linac for research with energies below the neutron activation threshold. In this presentation, we describe RadiaBeam's low-cost, pre-clinical FLASH systems with electron doses exceeding 400 Gy/s per pulse at appreciable stand-off distances. We also roadmap using the same linac concept to achieve X-ray FLASH. Finally, the concept for a VMAT-compatible X-ray FLASH linac is described.

Abstract 212 at 3:30 PM | Session AP-IA-02 Monday 3:00 PM - West Fork I

Design efforts to upgrade beam power of a 10 MeV S-band e-beam system from 15 kW to 25 kW

Yoko Kawai Parker, Anthony Tylenda, Fred Gower, Glenn James, Brian Rapp

Fisica, Inc, San Leandro CA, United States

Fisica, Inc has experience in providing turn-key electron beam sterilization solutions world-wide for >30 years. Our first 10 MeV e-beam sterilization system was commissioned in 1993, with involvement in over 70 linac systems since then. The systems have proven to be robust and reliable with many approaching or exceeding 20 years of service. Our primary market is medical device sterilization, but we also offer 5 - 7.5 MeV e-beam/x-ray systems for food irradiation.

Our main product line is a S-band 10 MeV e-beam system with a beam power of 15kW to 18kW. The turn-key solution includes the modulator, controls and safety system, conveyor/material

handling system, radiation shield design, installation, validation and commissioning. Market demands have shifted to higher power, which prompted the development of a 25 kW beam power e-beam system.

The footprint of the new 25kW system remains the same as our current 15/18kW systems; in addition, existing lower power systems can easily be upgraded in the field to 25 kW with a few component upgrades (e.g. Accelerator Waveguide, Klystron, RF circulator and RF window) and minimal downtime. The new 25 kW accelerator waveguide can also operate at lower power to serve as a drop-in replacement for existing 15/18kW systems. This paper reports the summary of the design effort and validation test results.

Abstract 152 at 4:00 PM

Session AP-IA-02 Monday 3:00 PM - West Fork I

Development of deuteron nuclear reaction database and its applications: from compact to large scale neutron sources

Shinsuke Nakayama

Nuclear Data Center, Japan Atomic Energy Agency, Tokai Ibaraki, Japan

Deuteron-induced reactions on light nuclei (Li, Be, C and so on) are being considered for usage in accelerator-based neutron sources ranging from small to large scales. Recently, they have also attracted attention as neutron production reactions in laser-driven neutron sources. Applications of these neutron sources range from nondestructive inspection, material irradiation testing, medical radioisotope production, nuclear waste transmutation, basic nuclear physics experiments, and so forth.

To contribute to the design study of these neutron sources, we developed and released JENDL/DEU-2020 [1], a deuteron nuclear reaction database for Li-6,7, Be-9, and C-12,13 up to 200 MeV. Subsequently, we added data for the major accelerator structural materials Al-27, Cu-63,65, and Nb-93 to JENDL/DEU-2020 and released them as the deuteron sub-library of JENDL-5 [2], the latest version of Japanese general-purpose evaluated nuclear data library. Various studies so far have shown that the deuteron sub-library of JENDL-5 is much more accurate than the competing choice, the deuteron nuclear reaction database of the TENDL series [3], especially for neutron production.

In this talk, the evaluation methodologies for the deuteron sub-library of JENDL-5 are reviewed and the results of the Monte Carlo transport simulations using these data also are presented. Though the comparison with available experimental data, the accuracy of these data is discussed. As one of the application examples, the results of the recent design simulation of small d+Be neutron sources [4] for nondestructive inspection will also be presented.

[1] S. Nakayama et al., J. Nucl. Sci. Technol. 58, 805-821 (2021).

[2] O. Iwamoto et al., J. Nucl. Sci. Technol. 60, 1-60 (2023).

[3] A. Koning et al., Nucl. Data Sheets 155, 1-55 (2019).

[4] S. Nakayama, J. Nucl. Sci. Technol. 60, 1447-1453 (2023).

Abstract 274 at 3:00 PM

Session AR-ISM-02 Monday 3:00 PM - Elm Fork I

Metal Halide Perovskite Solar Cells for Emerging Space Applications

Ian R Sellers

Electrical Engineering, University at Buffalo, Buffalo New York, United States

In this presentation the potential of metal halide perovskite solar cells for space power applications will be presented. This presentation will focus on our recent work on the feasibility of metal halide perovskites for space, which includes the assessment of the systems in low-intensity-low-temperature (LILT) conditions for outer planetary missions, in addition to exposure to high temperatures and variable radiation conditions that directly and independently impact the absorber and transporting layers of the devices. Here, the discussion will include a number of perovskite systems such as solution processed mixed Pb-Sn systems and the FAMACs family of metal halide perovskites, as well as blade-coated architectures. It will be shown that perovskites display remarkable tolerance to high radiation exposure and that while measurements **do** suggest high energy radiation negatively affects the transporting layers and interfaces in the devices: the perovskite absorber **is not affected** in any significant way. Moreover, these systems are observed to self-heal under ambient conditions in the dark demonstrating the unique behavior of perovskite solar cells and their potential for future space applications. This is further substantiated by high temperature measurements that indicate specific triple cation perovskites displays no appreciable or permanent degradation up to 500 K, supporting in particular their potential as candidate systems for future lunar missions.

Abstract 207 at 3:25 PM

Session AR-ISM-02 Monday 3:00 PM - Elm Fork I

Effects of Electronic Energy Loss on Ion-Beam Modification of Oxide Perovskites

William J. Weber[1], Gihan Velisa[2], Eva Zarkadoula[3], Ritesh Sachan[4], Yanwen Zhang[5]

(1)Materials Science & Engineering, University of Tennessee, Knoxville TN, United States
(2)Horia Hulubei National Institute for Physics and Nuclear Engineering, Măgurele, Romania

[3]*Oak Ridge National Laboratory, Oak Ridge TN, United States*
[4]*Mechanical & Aerospace Engineering, Oklahoma State University, Stillwater OK, United States*
[5]*Mechanical & Materials Engineering, Queen's University, Kingston ON, Canada*

Oxide perovskites (ABO_3) exhibit fascinating properties that identify them as key materials for the next generation of multifunctional devices, and ion-beam modification can be used to tune their functionality. Further, their response to ion beam modification can provide guidance to the behavior expected in metal-halide perovskites, which have limited data on response to ion irradiation. It is well-established that atomic-level defects are created by elastic energy transfer (nuclear energy loss), S_n, from charged particles to atomic nuclei; however, the effects of inelastic electronic energy loss, S_e, to target electrons is more complicated. At low to medium energies (10 keV to several MeV), the response of many oxide perovskites to ions is dependent on the ratio of S_e/S_n. When S_e is comparable to S_n, ionization-induced dynamic annealing can occur along the ion trajectory, reducing the rate of damage accumulation. High-energy ions with S_e values above a threshold can form amorphous nanotracks due to melt-quenching along the ion trajectory. In the presence of pre-existing crystalline disorder, amorphous tracks are formed at much lower values of S_e, and the track sizes increases with S_e and the level of pre-existing disorder. Below the S_e thresholds for amorphous track formation, ions with high S_e/S_n values, where electronic energy loss dominates, ionization-induced annealing of defects occurs as the inelastic thermal spike causes sufficient local heating via electron-phonon coupling to induce defect recovery. Experimental data on $SrTiO_3$, $KTaO_3$ and $LiTaO_3$ will be presented to demonstrate these phenomena. Molecular dynamics simulations combined with the inelastic thermal spike model in these materials confirm the formation of the amorphous tracks due to melt-quenching along the ion trajectory at high values of S_e, while at intermediate values of S_e, defect recovery is demonstrated. ions. Two distinct regimes of ionization-induced recovery are observed in $SrTiO_3$, and only a single recovery regime is observed in $KTaO_3$.

Abstract 273 at 3:50 PM

Session AR-ISM-02 Monday 3:00 PM - Elm Fork I

Observation of Superconducting Transition at ~ 25 K in Ag Implanted Au Thin Film

Manas Kumar Dalai[1,2,3], Soumya Srotaswini Sahoo[3], Darshpreet Kaur Saini[3], Mohin Sharma[3], Mritunjaya Parashar[3], Todd A. Byers[3], Soumyakanta Panda[4], Niharika Mohapatra[4], Bibhudutta Rout[3]

[1]*CSIR - Institute of Minerals and Materials Technology, CSIR, Bhubaneswar Odisha, India*
[2]*Academy of Scientific and Innovative Research, AcSIR, Ghaziabad, India*
[3]*Department of Physics, University of North Texas, Denton Texas, United States*
[4]*School of Basic Sciences, Indian Institute of Technology, Bhubaneswar Odisha, India*

Materials development using ion irradiation is one of the well established methods in order to achieve their respective electronic, magnetic and optical properties for potential applications. The ion beam irradiation over the pristine samples modifies their structure and composition as a result of formation of defects, islands, doping, stoichiometric changes etc. These changes modify the electronic, magnetic and crystal structure of the pristine materials. One of the focused electronic properties is Superconductivity and there are various methods to develop such materials, in bulk, thin films etc. However rare superconductors are developed using ion beam irradiation methods. One of the interesting combination, which shows Superconductivity is Ag-Au system. In this talk, we will be discussing about the observation of low temperature Superconductivity at around ~ 25 K in Ag - implanted Au thin film. The structural and compositional analysis by using various characterization techniques such as; RBS, XRD, SEM, EDS, AFM, etc. will be discussed for both the pristine (non superconducting) and implanted (superconducting) samples. The structural modification in Au thin film due to the Ag ion implantation plays a crucial role for transforming the system to Superconductivity.

Acknowledgements

MKD acknowledges CSIR Raman Research Fellowship, India for this work.

References:

1. Wickramaarachchige J. Lakshantha, Mohit Kumar, Tapobrata Som, Floyd D. McDaniel, Bibhudutta Rout, Nucl. Inst. And Meth. B 488, 64 (2021).

2. Satyabrata Singh, Joshua M. Young, Daniel C. Jones, Diana Berman, Bibhudutta Rout, Appl. Phys. A 126, 232 (2020).

3. Manas Kumar Dalai, Braj Bhusan Singh, Salila Kumar Sethy, Satya Prakash Sahoo and Subhankar Bedanta, Physica B, 601, 412607 (2021)

4. Dev Kumar Thapa, Anshu Pandey, 08572 arxiv 1807 (2018)

5. G. Baskaran, International Journal of Modern Physics B, 36, 2250184 (2022)

Abstract 216 at 4:10 PM

Session AR-ISM-02 Monday 3:00 PM - Elm Fork I

Study of the Elemental Diffusion and Radiation Tolerance of Metal Halide Perovskite Solar Cells

Mritunjaya Parashar[1], Mohin Sharma[1], Darshpreet Kaur Saini[1], Todd A. Byers[1], Jospeh M. Luther[2], Ian R. Sellers[3,4], Ahmad R. Kirmani[2,5], Gary A. Glass[1], Bibhudutta Rout[1]

[(1)]Department of Physics, Ion Beam Laboratory, University of North Texas, Denton, Texas 76203, United States
[(2)]National Renewable Energy Laboratory (NREL), Golden, Colorado 80305, United States
[(3)]Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman, Oklahoma 73019, United States
[(4)]Department of Electrical Engineering, University at Buffalo SUNY, Buffalo, New York 14260, United States
[(5)]School of Chemistry and Materials Science, Rochester Institute of Technology, Rochester, New York 14623, United States

Metal halide perovskite solar cells (PSCs) have attracted interest in recent years due to their potential for both terrestrial and space applications. To optimize the PSC structures effectively and predict the device performance, the analysis of various interfaces is crucial. Most advanced characterization techniques to study buried interfaces are destructive in nature and can induce further degradation. Ion beam techniques, such as Rutherford backscattering spectrometry (RBS), offer a useful non-destructive approach for examining the elemental depth profile of multilayered PSCs. It also allows for the study of the inter-diffusion of various elemental species across interfaces, addressing contentious topics in photovoltaics such as hysteresis, defect effects, and elemental. As interest grows in using PSCs for practical space photovoltaic applications, it becomes critical to investigate the impact of radiation-induced degradation in PSCs. RBS can be simultaneously utilized to analyze the radiation effects induced by the He^+ beam on the device, given their presence in space orbits. In the present work, a 2 MeV He^+ beam was used to study elemental diffusion across PSC interfaces with the architecture glass/ITO/SnO_2/$Cs_{0.05}(MA_{0.17}FA_{0.83})_{0.95}Pb(I_{0.83}Br_{0.17})_3$/Spiro-OMeTAD/$MoO_3$/Au [1].

During the analysis, the active area of the device was exposed up to irradiation equivalent to 1.62×10^{15} He^+/cm^2. Despite this exposure, no measurable evidence of beam-induced ion migration from the perovskite layer was detected. This observation indicates that the PSCs with the above device architecture exhibit a high tolerance to radiation. On the other hand, aged PSCs after 5 months duration in an ambient atmosphere exhibited indications of the movement of diverse elemental species such as Au, Pb, In, Sn, Br, and I, in the active area of the device which was quantified with the help of the RBS. In this presentation, we will elucidate the potential of RBS technique in the non-destructive characterization of complex devices such as PSCs.

[1] Mritunjaya Parashar, Mohin Sharma, Darshpreet Kaur Saini, Todd A. Byers, Joseph M. Luther, Ian R. Sellers, Ahmad R. Kirmani, Bibhudutta Rout; Probing elemental diffusion and radiation tolerance of perovskite solar cells via non-destructive Rutherford backscattering spectrometry. APL Energy 1 March 2024; 2 (1): 016109. https://doi.org/10.1063/5.0193601.

Abstract 69 at 3:00 PM

Session AR-NST-01 Monday 3:00 PM - Elm Fork II

Investigation of Ar/Si Ion Beam Nanopatterning Near the Critical Angle

Karl Ludwig[1,2], Benli Jiang[2]

(1)Physics, Boston University, Boston MA, United States
(2)Division of Materials Science & Engineering, Boston University, Boston MA, United States

Self-organized nanopattern formation was investigated near the critical angle during 250 - 2000 eV Ar+ bombardment of Si using both a Kaufmann-type source with a graphite grid and an ion gun. Post-bombardment surfaces were characterized by atomic force microscopy (AFM) and x-ray photoelectron spectroscopy (XPS). With the wide-aperture divergent Kaufmann source beam, a continuous range of average bombardment angles could be investigated simultaneously on a single Si wafer. However, as has been previously reported, use of the Kaufmann-type source resulted in significant surface contamination from Fe and Cr. In this case, an increase in ripple wavelength was observed as a bombardment angle of approximately 45 degrees is approached from above, but the wavelength as function of bombardment angle saturates, with no divergence. When using the ion gun, no transition metal surface contamination was observed, but measurable amounts of Ar were detected. Again, an increase but no divergence of ripple wavelength was observed when approaching a bombardment angle of approximately 45 degrees from above.

Abstract 259 at 3:30 PM

Session AR-NST-01 Monday 3:00 PM - Elm Fork II

Large area periodically modulated plasmonic and 2D Transition Metal Dichalcogenide layers featuring flat-optics light harvesting

Matteo Barelli, Maria Caterina Giordano, Matteo Gardella, Giulio Ferrando, Mukul Bhatnaghar, Debasree Chowdhury, Francesco Buatier de Mongeot

Physics Department, University of Genoa, Genoa, Italy

Transition Metal Dichalcogenides (TMDs) are two-dimensional semiconductors featuring high optical absorption coefficient combined with good transport and mechanical properties. Although mechanically exfoliated TMD flakes ensure the best optoelectronic properties, homogeneous large-area growth techniques are mandatory for real-world applications (1,2)At the same time, in view of light conversion applications in the extreme thickness regime of 2D-TMDs, it is essential to develop effective photon harvesting strategies derived from nanophotonics.

Here we demonstrate that periodic modulation of MoS_2 layers on large area nanostructured samples (either MoS_2 nanostripes arrays or conformal MoS_2 layers grown on top of nanogrooved silica templates) efficiently steers light parallel to the 2D material, exploiting photonic anomalies in the flat-optics regime [3,4].

Large-area nanofabrication of supporting silica templates can proceed both via self-organized ion beam sputtering and/or laser interference lithography. In this way, it is possible to tailor the slope of faceted silica templates which can be employed for confining both TMD nanotripes or plasmonic metal arrays. In one example we demonstrate the possibility of steering and routing light exploiting plasmon resonances of tilted metal nanostripes [5], in another example, we highlight the possibility of exploiting the periodic TMD nanostripes for enhancing light scattering as Fabry-Perot nanoresonators.

As a case study aiming at photoconversion applications, we demonstrate that flat-optics light harvesting in periodically corrugated TMD layers (MoS_2) employed as photocatalysts, can boost photodissociation of Methylene Blue (MB), a polluting dye molecule commonly used in the textile industry. When illumination occurs at the optimized angles which couple light to the photonic anomalies a two-fold faster photodissociation rate is observed with respect to planar MoS_2 films [6].

Our preliminary results also demonstrate the potential of ion beam sputtering for fabricating ultrathin and ultrasmooth Au films in a regime not accessible to conventional thermal deposition. The latter can be employed as transparent conductive electrodes for integration in flexible optoelectronic applications and for integration with TMD materials.

References

[1] MC Giordano,et al Advanced Materials Interfaces 10 (5), 2201408 (2023)

[2] C. Mennucci et al. Advanced Optical Materials 9 (2), 2001408, 2021.

[3] M. Bhatnagar, et al. Nanoscale 12 (48), 24385, 2020.

[4] M. Bhatnagar, et al. ACS Applied Materials & Interfaces 13 (11), 13508, 2021.

[5] M Barelli, et al. Nano Letters 20 (6), 4121-4128 (2020)

[6] G Ferrando, et al.Nanoscale 15 (4), 1953-1961 (2023)

Abstract 132 at 4:00 PM

Session AR-NST-01 Monday 3:00 PM - Elm Fork II

Some Advancements in the Continuum Modeling of Ion-Induced Nanopattern Formation

Scott A Norris[1], Tyler P Evans[2], Jennifer M Swenson[3]

[(1)]Mathematics, Southern Methodist University, Dallas TX, United States
[(2)]Mathematics, University of Utah, Salt Lake City UT, United States
[(3)]Raytheon, Dallas TX, United States

When semiconductor surfaces are irradiated at room temperature with energetic ions at oblique incidence, they can spontaneously develop ripple patterns with characteristic lengthscales in the tens to hundreds of nanometers. The specific characteristics of these patterns depend on the target species, ion species, ion energy, and irradiation angle. Although significant progress has been made toward an understanding of the basic pattern forming mechanism, it has so far remained difficult to correctly predict the significant variations in behavior that can occur across the very large parameter space of target / ion / energy / angle combinations.

In this talk, we share a number of advancements in the continuum modeling of these ion-irradiated surfaces, including

* the precise location of the ion-induced amorphous-crystalline boundary [1]

* the density change at that moving boundary as it advances into the bulk [1]

* continued radiation-induced swelling of the target over subsequent time [2,3]

These additions to past models provide insight into several relevant experimental observations, including that

* Increasing ion energy can cause sudden increases in the critical angles [4,5]

* Germanium exhibits higher critical angles for pattern onset than Silicon [5]

In addition to highlighting the qualitative intuition gained by the modeling of these effects, we present preliminary efforts to compare our model to a compilation of around 20 experimental results on the critical angle of pattern onset for **Ar+**, **Kr+**, **Xe+** ions, irradiating **Si** and **Ge** targets, at energies between **200 eV** and **2000 eV**. This process returns reasonable values of some parameters for which estimates exist, and sheds light on expected values of other, more difficult-to-measure parameters. In so doing, it also emphasizes the critical need for continued experimental measurements across key regions of parameter space.

[1] Evans and Norris. https://doi.org/10.21203/rs.3.rs-3731902/v1

[2] Swenson and Norris. https://doi.org/10.1088/1361-648X/aacb71

[3] Evans and Norris. https://doi.org/10.1088/1361-648X/acd31b

[4] Hofsass et al.. https://doi.org/10.1063/1.4940141

[5] M. Teichmann et al.. https://doi.org/10.1088/1367-2630/15/10/103029

Abstract 198 at 3:00 PM

Session SN-OM-03 Monday 3:00 PM - Trinity Central

Safety Review of the BNL Tandem Facility

Dannie Steski

Brookhaven National Laboratory, Upton NY, United States

The Tandem Van de Graaff Facility at Brookhaven National Laboratory recently underwent a DOE mandated Accelerator Readiness Review. There were many challenges making a 50+ years old facility compliant with modern safety standards. The safety review process will be discussed along with any lessons learned.

Abstract 220 at 3:20 PM

Session SN-OM-03 Monday 3:00 PM - Trinity Central

Update on ANSTO's New BPM Interface and Measurement System

David Button[1], Karina Taylor[2], Jake Sheath[1]

[(1)]Centre for Accelerator Science , ANSTO, Lucas Heights NSW, Australia
[(2)]EnvisEng, EnvisEng Pty Ltd, Wahroonga NSW, Australia

ANSTO like many facilities ubiquitously utilise NEC Beam Profile Monitors (BPM) to provide profile information for ion beams within our electrostatic accelerator facilities. The helix rotating wire systems are still deployed largely in the same manner, utilising a selection station to activate and provide conditioned signals for an oscilloscope to display a sweep through Y and then X which are representative of the secondary electron yield from the wire as it traverses the beam.

ANSTO has been developing an alternative interface to the standard NEC BPM to provide alternative pseudo representation of the beam shape, as well as providing quantitative measurements of the beam properties such as full width half maximum, geometric measurement in mm, and integration of beam with aim to normalise to faraday cup readings as a method to have regular measure of the beam current which may enable alternative methods for dual beam experiments on a single stage.

This talk will look at our current progress in implementing a 4 BPM channel interface as part of the ANTARES and STAR uplift projects.

Abstract 84 at 3:40 PM

Session SN-OM-03 Monday 3:00 PM - Trinity Central

Rejuvenation of the 14UD at ANU

Thomas Tunningley

Nuclear Physics and Accelerator Applications, The Australian National University, Acton ACT, Australia

The 14UD at the Australian National University's Heavy Ion Accelerator Facility (HIAF) operated at a maximum voltage of 15.5 MV after the installation of tubes with a compressed geometry in the 1990s. In recent years, the performance of the accelerator has shown a gradual decline to a maximum operation voltage of ~14 MV. While there are some fundamental factors that limit the high voltage performance the degradation of components, particularly the ceramics, has a significant impact.

In 2019 ANU committed to replace the entire inventory of supporting posts, acceleration tubes and grading resistors in the 14UD. Undertaking a project of this size and scope has presented the opportunity to improve things along the way. Newer tube technology brings magnetic electron suppression, larger sections, and more gaps, which along with reconfiguration of equalising stringers, means less high gradient stress. The extent of work also presents an opportunity to redesign resistor assemblies and explore new resistor technologies.

This presentation will discuss the plan, the progress, and the challenges of this project.

Abstract 226 at 4:00 PM

Session SN-OM-03 Monday 3:00 PM - Trinity Central

Accident in the JYFL Accelerator Laboratory - Lessons Learned

Mikko Laitinen, Timo Sajavaara

Accelerator Laboratory, Department of Physics, University of Jyvaskyla, P.O. Box 35, FI-40014, Jyväskylä, Finland

One cannot out-source safety. Safety is a responsibility of the everyone and at every level. The accident which took place 11.4.2021 in the Accelerator Laboratory of the University of Jyväskylä, Finland, reminded everyone for the collective importance of the safety.

During the Sunday morning, a normal shift change was taking place during the week-long 24/7 nuclear physics experiment. Similar experiments, with similar tools had been taking place for the past 30+ years, yet something still went now wrong in a life-threatening way.

However, the symptoms of the looming problem were already in the air earlier during the on-going experiment, but the things went wrong even after many experienced physicists were discussing the next, normal looking, to-do's during the measurement. The Sunday morning culminated to the "airplane-crash" -type accident where

more than one, two or even three+ failures were needed to cause the actual catastrophe.

Presentation will go through the events which led and caused the accident, leading to a gas explosion, where a researcher got seriously injured. Ultimately, the catastrophic explosion of the over pressurized metal cylinder, injuring seriously a senior researcher, could have been avoided. Today, even more focus to the safety aspects of the laboratory have been went through and the processes are still to be scrutinized further, for example with the peer reviews - safety walks - by other research groups within the laboratory. What was fortunate in this chain leading to the accident, is that no lives were lost and the researcher recovered well from the physical injuries.

Abstract 299 at 4:20 PM

Session SN-OM-03 Monday 3:00 PM - Trinity Central

The 2 low energy Van de Graaf Accelerators AN2000 and CN maintenances and operation of Legnaro National Laboratories (Italy)

Luca Maran

Dipartimento di Fisica e Astronomia, Univerity of Padua, Padua Padova, Italy

In this contribution we'll present the 2 low energy Accelerators AN2000 and CN and their facilities. Now they are both in regular operation, measuring shifts and development projects are proceeding simultaneously, in particular the new CN Accelerator Danfysik magnet power supply control software, the project of CN accelerating tube substitution and the AN2000 new OM Magnet scanning system for MicroBeam facility. We will also talk about our experience on developments related to new IoT technologies applied to supervision and data logging: we believe that a correct reading of logging data is an important information to better understand the behavior of machines and equipment.

Abstract 308 at 9:00 AM

Session PS-VR-01 Tuesday 9:00 AM - Rio Grande Ballroom

Tuesday Vendor Roadshow

Gary Glass

University of North Texas, Denton TX, United States

The 2024 CAARI-SNEAP International Conference will be hosting a Vendor Roadshow in the Rio Grande Ballroom on Tuesday, July 23, 2024. The vendors can take this opportunity to introduce themselves and their companies, what products they offer, and where their booth location is in the exhibit hall. To participate, the vendors will need to load their presentations on a memory stick so that it can be put on the speaker podium's computer. Due to the short-allotted time, there will be little to no

time for questions and answers, but folks can talk to the vendors offline at their booths.

Abstract 111 at 10:00 AM

Session AP-SD-05 Tuesday 10:00 AM - Post Oak

Applications of laser-produced plasmas in the fields of space security and nuclear non-proliferation

Sivanandan S. Harilal[1], Mathew P Polek[1,2], Youssef Abouhussien[3], Elizabeth J Kautz[1], Gennady Miloshevsky[3], Farhat N Beg[2]

[(1)]National Security Directorate, Pacific Northwest National Laboratory, Richland WA, United States
[(2)]Center for Energy Research, University of California San Diego, La Jolla CA, United States
[(3)]Department of Mechanical and Nuclear Engineering, Virginia Commonwealth University, Richmond VA, United States

Laser-produced plasmas (LPP) generated in laboratory conditions can be exploited to simulate physical conditions in astrophysical objects, X-ray blow-off, and thermo-mechanical shock. LPPs are also helpful in examining plume chemistry in a nuclear or high explosion. In this presentation, the applications of nanosecond duration laser ablation generated with low-intensity lasers ($\leq$ 1J) will be discussed in the context of space security and nuclear non-proliferation. To understand laser-target coupling, we use various diagnostic tools (shadowgraphy, interferometry, Faraday cup, and fast-gated imaging). Optical spectroscopic tools such as emission, absorption, and laser-induced fluorescence techniques are used to explore plume chemistry, particularly in U and Pu plasmas.

Abstract 127 at 10:35 AM

Session AP-SD-05 Tuesday 10:00 AM - Post Oak

Plasma ablation and shock generation to study the effect of laser impulse

Farhat Beg

Mechanical and Aerospace Engineering, University of California San Diego, LA Jolla CA, United States

X-ray driven thermo-mechanical shock (TMS) is a major risk for electronics operating outside the Earth's atmosphere. Direct measurements using X-rays to drive TMS are of significant interest as experimental platforms with high X-ray flux are limited. However, high power lasers can be used to mimic intense X-ray pulses to drive target ablation and the production of TMS at the relevant multi-Mbar levels. One important question that needs to be addressed is: how does the target ablation and subsequently TMS properties change with the laser pulse length. Experiments were performed at the Omega laser facility at a constant laser intensity of 6×10^{14} W/cm^2 with a varying laser pulse length (100 ps, 500 ps, 1 ns, 10 ns). The targets consisted of three layers of single crystalline nominally undoped silicon, polycrystalline

Copper, and crystalline SiO_2 quartz (Si/Cu/Qz). The ablation front temperature was found to be independent of pulse duration, measuring ~500 eV across all cases. Ablation density was indirectly inferred from the **A**ngular **F**ilter **R**efractometer (AFR) diagnostic through a comparison with synthetic AFR images post-processed from the rad-hydro simulations. The resulting TMS propagation into the dense target was measured in the quartz witness layer using ASBO (shock velocity) and SOP (shock temperature) diagnostics. For the longest pulse length (10 ns), the measured shock velocity was ~35 km/s (~22 Mbar), in agreement with the analytical scaling laws after considering the shock impedance matching of the Si/Cu/Qz layers. Interestingly, the measured shock velocity for the shortest pulse (0.1 ns) is <5 km/s (<1 Mbar), marking a significant decrease in the shock pressure for sub-ns pulses. This trend is also observed to a lesser extent in the 0.5 ns and 1 ns pulse lengths, signaling that the supported shock pressure is proportional to the pulse duration and that shock decay effects (rarefaction, dispersion, reflection/transmission) are not insignificant.

Abstract 120 at 11:10 AM

Session AP-SD-05 Tuesday 10:00 AM - Post Oak

MIRDIC computer code for predictive modeling of electrostatic discharge induced by space radiation in dielectric and insulating materials of spacecrafts

Gennady Miloshevsky

Department of Mechanical and Nuclear Engineering, Virginia Commonwealth University, Richmond VA, United States

Up to 80 percent of energy is released as high intensity X-ray flux in an exo-atmospheric nuclear blast (1)The surface and near-surface layers of exposed solar arrays, optics, and sensors in DoD strategic space systems could be vulnerable to a high intensity X-ray pulse caused by a high-altitude nuclear detonation. Predictive modeling and improved understanding of X-ray power deposition, charge production and accumulation in dielectric and insulating materials, material electrostatic breakdown or blow-off, warm dense plasma generation and evolution in extreme X-ray environments is required for ensuring the survivability of DoD space systems in the absence of nuclear weapons testing. The evaluation of charging and electrostatic breakdown requires solving both (1) X-ray transport problem to compute the charge deposition and radiation dose rates within the material; and (2) electrostatic problem to obtain the electrostatic fields and potentials due to the charge density accumulating with time.

The Modeling Ionizing Radiation Deep Insulator Charging (MIRDIC) code is developed in collaboration with the NASA's Marshal Space Flight Center to model the charge production by blackbody X-rays in dielectrics and insulators and predict the electrostatic material breakdown (2)Open source GEANT4 and OpenFOAM software toolkits were used in development of the MIRDIC code. The transport of cold X-rays (1.0 keV-1.5 keV) in multi-layer materials, energy deposition and redistribution by secondary photon and electron radiations (dose rate (DR)), charge production and accumulation (charge density rate (CDR)) in dielectric and insulating layers of materials by high-intensity X-rays with blackbody spectra are calculated using developed MIRDIC-GEANT4 computer code. The MIRDIC code based on GEANT4 libraries was written in C++ and validated against the available computational and experimental data on the energy (dose) and charge deposition in materials.

The deposited charge in insulating or dielectric layers creates a large electric field, which may exceed the strength of the material resulting in an electrostatic discharge. The calculated DR and CDR distributions in slab materials are used then as input in the MIRDIC-OpenFOAM code that solves the electrostatic problem and predicts the strength of the radiation-induced electric field. The internal electric fields in insulators and dielectrics are calculated by numerically solving the system of 3D differential equations comprised of the Poisson equation for electric potential, equation relating potential and electric field, charge continuity equation, and Ohm's law for electric current density (2)The CDR of charge generation by the radiation is used as a source term in the charge continuity equation. The electrical conductivity used in the Ohm's law is comprised of the dark conductivity of insulating materials in the absence of exposure to radiation and the radiation induced conductivity. The profiles of electric potential and charge density along the depth of a slab calculated from the MIRDIC-OpenFOAM code are validated against the 1D analytical solution of the electrostatic problem for the case when CDR and electrical conductivity are both independent of position and time (constant values).

Studies are performed using MIRDIC code to investigate the charging, electrostatic discharge, and breakdown of single-layer and multi-layer insulating materials by the electrons, X-rays, and γ-rays. Charge production, electrostatic discharge, and breakdown of a kapton film by X-rays with blackbody 1-keV spectrum originated from an exo-atmospheric nuclear detonation is predicted to take place during 2 μs because the strength of generated electric field has exceeded the breakdown strength of kapton material. The strength of electric field induced by monoenergetic electrons, gammas, and X-rays with spectral energy distribution in three-layer slab configuration composed of an EPDM-based insulator, HTPB-based liner, and HTPB-based propellant is predicted and analyzed.

Acknowledgments: This work was supported by the U.S. Defense Threat Reduction Agency under Grants No. DTRA1-19-1-0019 and HDTRA1-20-2-0001.

[1] Conrad, E.E., Gurtman, G.A., Kweder, G., Mandell, M.J. and White, W.W. (2010). **Collateral damage to satellites from an EMP attack**. Fort Belvoir.
https://apps.dtic.mil/sti/citations/ADA531197

[2] Miloshevsky, G. and Caffrey, J.A. (2019). **Electron deposition and charging analysis for the Europa Lander Deorbit Stage**. Marshall Space Flight Center Faculty Fellowship Program, 57.

https://ntrs.nasa.gov/api/citations/20200000048/downloads/20200000048.pdf#page=65

Abstract 195 at 10:00 AM

Session AR-ISM-04 Tuesday 10:00 AM - Elm Fork I

Coupling Ion Accelerators to Small-scale Mechanical Testing and Analytical Tools for Rapid Screening of Complex Material Systems

Khalid Hattar

Department of Nuclear Engineering, University of Tennessee, Knoxville TN, United States

A myriad of new and complex material systems are being considered for both structural and functional material applications. These materials are also being recommended for increasing complex environments. These two factors coupled create a bottleneck of promising but untested and thus untrusted materials for a range of energy, cyber, and defense applications in desperate need of new material to advance systems development.

The often limited amount of the new material made and the complexity of the environments of interest regularly make most classical testing standards difficult, if not impossible, to follow. As a result, small scale testing under very controlled environments and highly characterized regions of the sample is sometimes the only resort to analyzing such samples. The benefits of such an approach is that only small regions of the sample are altered per test, the samples are not activated, and most importantly scores if not hundreds of data points can be obtained per test sample.

This presentation will first review nearly 20 years of development of tool to explore the thermal, mechanical, and radiation stability of new and complex material systems. This will start with the exploration of nanolayered metallic systems, both model and application focused, utilizing nanoindentation and post implantation examination (1)The presentation will then focus on advancements in both electron microscopy and small-scale nanomechanical testing to permit detailed understanding of materials both during and after exposure to coupled extreme environments. This presentation will briefly highlight the In-situ Ion Irradiation Transmission Electron Microscope (I3TEM) and Scanning Electron Microscope (I3SEM) developed for these tasks (2,3)These advancements have greatly increased our ability to screen new alloys, such as high entropy alloys and refractory heavy alloys, while gaining fundamental understanding of the microstructural evolution, even during ion bombardment. However, these approaches are limited in the regions that can be evaluated, the feasibility to be performed during irradiation, and the property data that can be collected.

To overcome this limit, a parallel effort utilizing a range of pump-probe laser-based techniques including, but not limited to, Time Domain ThermalReflectance (TDTR) and Transient Grating

Spectroscopy (TGS) were incorporated to investigate the thermal conductivity, thermal boundary conductance, and elastic constants of materials exposed to combinations of heating and ion irradiation (4,5)This approach provides a wealth of data tailored to the material system, local crystal orientation, boundary character, and irradiation environments. Coupled together these techniques provide a rapid method for initial material system screening in controlled and complex environments, while also advancing our understanding of materials degradation. Both of which are essential for the development of new materials essential for many future energy and related applications.

[1] Höchbauer, T., et al. "Influence of interfaces on the storage of ion-implanted He in multilayered metallic composites." Journal of applied physics 98.12 (2005).

[2] Parrish, Riley J., et al. "Exploring coupled extreme environments via in-situ transmission electron microscopy." Microscopy Today 29.1 (2021): 28-34.

[3] Lang, Eric Joseph, et al. "Development of an in situ ion irradiation scanning electron microscope." Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms 537 (2023): 29-37.

[4] Cheaito, Ramez, et al. "Thermal conductivity measurements via time-domain thermoreflectance for the characterization of radiation induced damage." Journal of Materials Research 30.9 (2015): 1403-1412.

[5] Dennett, Cody A., et al. "Real-time thermomechanical property monitoring during ion beam irradiation using in situ transient grating spectroscopy." Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms 440 (2019): 126-138.

This work was performed, in part, at the Center for Integrated Nanotechnologies, an Office of Science User Facility operated for the U.S. Department of Energy (DOE) Office of Science by Los Alamos National Laboratory (Contract 89233218CNA000001) and Sandia National Laboratories (Contract DE-NA-0003525).

Abstract 166 at 10:30 AM

Session AR-ISM-04 Tuesday 10:00 AM - Elm Fork I

Development of ODS steels for fusion and other harsh environments

Malgorzata Lewandowska

Faculty of Materials Science and Engineering, Warsaw University of Technology, Warsaw, Poland

Low activation steels are candidate materials for structural parts of fusion reactors. Such parts are expected to operate at the temperatures reaching 750^{o}C under considerable neutron irradiation. At the same time, the material used for their fabrication should have a high toughness at room temperature. In order to assure such challenging properties, oxide dispersion strengthened (ODS) steels are currently being developing. Their fabrication routes are based on powder metallurgy (PM), however, one of the challenges in fabrication via PM route is relatively high porosity and insufficient impact properties.

Various attempts to enhance the properties of ODS steels such as post-processing using hydrostatic extrusion (HE) and or heat treatment, alloying (with vanadium) will be reported. The emphasis will be on microstructural features which affect the mechanical properties. Hardness, tensile strength, ductility and fracture toughness will be of interest. The effect of Ar-ion irradiation on the microstructure and mechanical properties will also be discussed.

ODS steels exhibit a complex structure consisting of ultrafine grained matrix and nanoscale precipitates, which requires multiple techniques to be used to fully characterize the microstructure and understand its properties. While electron microscopy allows to easily determine matrix grain size, the information on size and spatial distribution of nanoparticles comes from a very small volume giving rather poor statistics. Therefore, the complementary techniques based on X-ray or neutron scattering, where the information comes from a relatively large volume, were employed guiding the determination of the chemical composition, size and number density of the nanoparticles over a wide size range, while probing a large sample volume.

Abstract 172 at 11:00 AM

Session AR-ISM-04 Tuesday 10:00 AM - Elm Fork I

Irradiation-Induced Defect Characteristics and Hardening Behaviour of Oxide-dispersion Strengthened Concentrated Solid Solution Alloys

Sri Tapaswi Nori[1], Pedro Ferreiros[2], Damian Kalita[1], Katarzyna Mulewska[1], Witold Chrominski[1,3], Yanwen Zhang[4,5], Karlsen Wade[2], Lukasz Kurpaska[1]

(1)NOMATEN Centre of Excellence, National Centre for Nuclear Research, Otwock Mazowieckie, Poland
(2)Centre for Nuclear Safety, VTT Technical Research Centre of Finland, Espoo Uusimaa, Finland
(3)Faculty of Materials Science and Engineering, Warsaw of University of Technology, Warsaw Mazowieckie, Poland
(4)Department of Materials Science and Engineering , University of Tennessee, Knoxville Tennessee, United States
(5)Energy and Environment Science & Technology, Idaho National Laboratory, Idaho Falls Idaho, United States

Due to the extreme service conditions, the structural material discovery for high-temperature irradiation applications is challenging. The current work explored an innovative approach involving nano oxide dispersion strengthened-concentrated solid solution alloys (ODS-CSAs) with nanosized grains to address the challenge. We demonstrate the efficacy of this approach in ODS-NiCoFe and ODS-NiCoFeCr alloys as model materials, which were irradiated with Ni^{2+} ions at 580°C. We studied the characteristics of irradiation-induced defects such as voids and dislocations via transmission electron microscopy (TEM) and scanning TEM. In addition, we calculated nano-hardness values from the pristine and irradiation regions of the materials via the nanoindentation technique. Our study correlated the defect characteristics with the irradiation-hardening behavior of the alloys. Our analysis also reveals the changes in the defect and hardening behavior with compositional changes in the alloys. We will present all such findings, which divulge the high-temperature radiation resistance of the novel ODS-CSAs, and present a state-of-the-art strategy for designing structural materials.

Abstract 251 at 11:15 AM

Session AR-ISM-04 Tuesday 10:00 AM - Elm Fork I

In-situ Transmission Electron Microscopy study of irradiation-induced crystallization in advanced amorphous ceramic coatings

Andrea Stinchelli[1,2,3], Davide Loiacono[1,2,3], Matteo Vanazzi[1], Mattia Cabrioli[1,2], Giulio Fierli[2,3], Giacomo Leonardis[2,3], Marco Beghi[2], Fabio Di Fonzo[1,3]

(1)Center for Nano Science and Technology @PoliMi, Istituto Italiano di Tecnologia, Milano Milano, Italy
(2)Energy Department, Politecnico di Milano, Milano Milano, Italy
(3)X-nano s.r.l., Milano Milano, Italy

The concepts of Generation IV fast fission reactors and fusion reactors currently under development often incorporate working fluids based on heavy liquid metals (HLMs, particularly Pb for fission and Pb16Li for fusion) or molten salts. Despite their favorable thermophysical properties, these fluids exhibit significant aggressiveness towards structural steels, resulting in severe corrosion and embrittlement. The application of ceramic coatings has been identified as a promising mitigation strategy. Among these, amorphous Al2O3 coatings fabricated via Pulsed Laser Deposition (PLD) have shown a unique combination of mechanical and chemical properties, making them ideal candidates as multifunctional barriers against corrosion and tritium permeation.

However, the behavior of this material under the combined effects of temperature and irradiation had not been thoroughly studied until recently. In-situ Transmission Electron Microscopy (TEM) was utilized to investigate the kinetics of irradiation-induced crystallization effects in PLD amorphous Al2O3 coatings, identifying growth regimes and activation energies associated with the grain growth process. In light of these findings, the addition of doping elements was explored as a strategy to control the amorphous-to-crystalline phase transition.

A preliminary irradiation campaign on Y2O3-doped Al2O3 films demonstrated that doping effectively shifts the crystallization onset towards higher radiation damage doses. Subsequent analysis of the Y2O3-doping effect identified an optimal range of dopant concentrations, where the ceramic coatings can maintain an amorphous microstructure up to 950°C under pure thermal conditions.

The present work aims to expand the understanding of the irradiation-induced crystallization behavior of Y2O3-doped optimized PLD Al2O3 coatings. Three different Y2O3-doped Al2O3 coating formulation were irradiated with 700 keV Kr ions at a dose rate of 10^12 ions/cm^2/sec, with a background temperature ranging from 600°C to 900°C. Real-time recording of defect nucleation and evolution was captured using a high-speed CCD camera. Crystallization kinetics were studied by incrementally increasing the radiation dose to capture comprehensive image sets for each displacement per atom (dpa) value. TEM analysis included both bright and dark field imaging for crystal nucleation and growth analysis, and selected area electron diffraction patterns to identify different crystalline phases.

The radiation-induced crystallization kinetic was elucidated by measuring the evolution of grain dimension using TEM dark field images. For each composition were obtained the amorphous fraction evolution, the minimum radiation damage needed for the crystallization to start and the K value of Arrhenius plots at different temperatures.

This study provides insights into the mechanisms underlying the impact of dopant concentration, facilitating the development of new materials with improved properties. The results offer a framework to describe the complex processes involved in the structural evolution of amorphous ceramic thin films, providing key information for the application of protective coatings in high-temperature, radiation-rich environments.

Abstract 19 at 10:00 AM

Session AR-NP-10 Tuesday 10:00 AM - West Fork I

Neutron capture cross sections measured with DANCE

Ingrid Knapova

Los Alamos National Laboratory, Los Alamos NM, United States

Neutrons have been used as one of the probes to study nuclear interactions. Radiative neutron capture is a type of nuclear reaction where a neutron is captured in a nucleus, forming an excited state, which then decays via emission of gamma rays. Understanding neutron capture reactions is crucial for nuclear astrophysics to describe processes occurring in stars, responsible for nucleosynthesis of heavy elements we observe in our universe. Furthermore, knowledge of neutron capture cross sections is important for other applications such as nuclear reactors or stockpile stewardship.

Los Alamos Neutron Science Center (LANSCE) located at Los Alamos National Laboratory employs one of the most powerful neutron sources in the world. Detector for Advanced Neutron Capture Experiments (DANCE) utilizes neutrons with energies ranging from thermal up to hundreds of keV to measure neutron capture cross sections on small samples. This scintillator array consists of 160 BaF_2 crystals forming an almost 4π ball around the sample of interest. Its high granularity and high efficiency makes DANCE an ideal instrument to detect complete gamma decay following the neutron capture. Its unique capabilities have been used to measure neutron capture cross sections for a broad range of medium-heavy and heavy nuclei, reaching from nickel to actinides.

One of the recent analyses is focused on the neutron capture cross section of ^{169}Tm, the only stable isotope of thulium. This nucleus presents an ideal activation monitor for neutron density diagnosis, where its precise neutron capture cross section is of critical importance. In this talk, we will show results on ^{169}Tm neutron capture cross section measured with DANCE over the resolved-resonance region, as well as the region of overlapping resonances that is relevant for nuclear astrophysics.

Abstract 83 at 10:25 AM

Session AR-NP-10 Tuesday 10:00 AM - West Fork I

Fundamental Physics using Pulsed Neutron Sources: Using Compound Nuclear (Resonance) States to Search for Exotic Beyond the Standard Model Physics

Danielle Schaper

Physics Division (P-1), Los Alamos National Laboratory, Los Alamos NM, United States

The Standard Model of Physics is the most complete, robust, and well-tested theory in perhaps all of human history. It is our current 'rulebook,' containing all of the known particles, their allowed interactions, and is the best description of the laws of physics to date. However, there are many open questions in physics which cannot be explained by the Standard Model in its present state, leading physicists to look for signatures of new, 'Beyond the Standard Model' physics.

One telling signature for new physics is the breaking (or 'violation') of intrinsic symmetries which underpin the Standard Model. Because of their willingness to interact via all of the (known) physical forces, neutrons provide an excellent environment in which to test these underlying fundamental symmetries and, if properly exploited, can allow one to access a broad range of tests of Beyond the Standard Model physics.

Of particular interest in recent years are tests of fundamental symmetries in compound nuclei. A compound nucleus occurs when a neutron is briefly bound to a nucleus (of nuclear mass **A**), forming an excited, metastable, resonant nuclear state (**A** + 1)*. Previous theoretical work has shown that certain symmetries (such as parity (P) symmetry) can be tested with particularly high sensitivity in the domain of isolated compound-nucleus resonances [1], and experimental campaigns (such as the TRIPLE Collaboration [2]) have observed P-violation in these compound nuclear systems in various nuclear species. In addition, heavy nuclei which exhibit a high density of these resonance states have also been experimentally shown to exhibit large amplifications (on the order of 10^7 times larger than otherwise predicted for weak-mediated interactions in these systems) of these parity-violating effects due to the complex, many-body nature of these nuclei, making them an exceptionally attractive system to study.

The present theories which account for the enhancement of these parity-violating effects in compound nuclear resonances also predict similar enhancements in tests of time-reversal (T) symmetry violation in the region of these compound resonant states. Such additional sources of time-reversal-violation are not presently accounted for in the Standard Model and are needed to explain the striking matter-antimatter asymmetry observed in the Universe; however, it has not been until recent decades that accelerator technology has advanced enough to make such tests experimentally feasible, leading to renewed interest in the subject.

This talk will first present a broad overview of the various fundamental physics campaigns taking place at neutron facilities around the globe before highlighting a few searches for exotic physics in the compound nuclear resonance system.

[1] V. E. Bunakov et al., "**Tests of fundamental symmetries on isolated compound-nucleus resonances"**, Phys. Rev. C **42** (1990).

[2] N. R. Roberson et al., "**An apparatus and techniques of tests for fundamental symmetries in compound-nucleus scattering with epithermal polarized neutron beams**", Nucl. Instrum. Meth B **326** (1993)

[3] G. E. Mitchell et al., "**Parity violation in compound nuclei: experimental methods and recent results**", Phys. Rept. **354** (2001)

[4] J. D. Bowman and V. Gudkov, "**Search for time reversal invariance violation in neutron transmission**", Phys. Rev. C **90** (2014)

Abstract 13 at 10:50 AM | Session AR-NP-10 Tuesday 10:00 AM - West Fork I

Development of a high-resolution fast-neutron detector

Thomas Baumann[1], Adriana Banu[2], James A. Brown[3], Paul DeYoung[4], Nathan Frank[5], Paul Guèye[1,6], Anthony Kuchera[7], Belen Monteagudo Godoy[4], Thomas Redpath[8], Warren F. Rogers[9]

(1)Facility for Rare Isotope Beams, Michigan State University, East Lansing MI, United States
(2)Dept. of Physics & Astronomy, James Madison University, Harrisonburg VA, United States
(3)Dept. of Physics, Wabash College, Crawfordsville IN, United States
(4)Dept. of Physics, Hope College, Holland MI, United States
(5)Dept. of Physics, Augustana College, Rock Island IL, United States
(6)Dept. of Physics & Astronomy, Michigan State University, East Lansing MI, United States
(7)Dept. of Physics, Davidson College, Davidson NC, United States
(8)Dept. of Chemistry, Virginia State University, Petersburg VA, United States
(9)Dept. of Physics, Indiana Wesleyan University, Marion IN, United States

The MoNA Collaboration is developing a fast-neutron detector based on plastic scintillator with a SiPM light readout. A tiled design with light-sensor arrays will be able to achieve an improved position resolution compared to current neutron detectors that are based on long plastic scintillator bars and use the time difference of the signals from each end to determine the neutron interaction point.

At this stage of the project, analysis of data collected with scintillator test kits consisting of a plastic scintillator, a small SiPM array, and a desktop digitizer is ongoing. The test kits were distributed to collaborators and assembled by undergraduate students from eight different institutions. After assembly, the students performed tests using LED light sources, radioactive sources, and cosmic rays. An experiment using the Triangle Universities Nuclear Laboratory's 11 MeV neutron beam and different configurations of test detectors, varying optical coupling, reflective wrapping, sensor placement, and SiPM types has also been performed. Data from these tests are being analyzed and used to benchmark detector simulations.

The next phase of the project involves the construction of a prototype detector that will be used for further tests and optimizations. Finally, the completed detector will consist of many detector tiles to form a large-area detector array that will be used in the investigation of neutron-unbound states using rare isotope beams in the energy range of 100 to 200 MeV/u at the Facility for Rare Isotopes Beams (FRIB). The unbound states of neutron-rich nuclei will be reconstructed by means of invariant mass analysis of the decay products, which requires the accurate flight-time and position measurement of the emitted fast neutrons.

Abstract 202 at 11:15 AM

Session AR-NP-10 Tuesday 10:00 AM - West Fork I

Recent High-precision Prompt Fission Neutron Spectra Measurements for Fast Neutron-induced Fission at LANSCE

Matthew Devlin[1], Keegan Kelly[1], John O'Donnell[1], Ching-Yen Wu[2]

(1)P Division, Los Alamos National Laboratory, Los Alamos NM, United States
(2)Nuclear and Chemical Sciences Division, Lawrence Livermore National Laboratory, Livermore CA, United States

Over the last decade, the Chi-Nu project has measured the Prompt Fission Neutron Spectra (PFNS) emitted following neutron-induced fission of the major actinides, $^{235,238}U$ and ^{239}Pu, to high precision and with extensively characterized uncertainties with full covariance information. These measurements have been carried out at the Los Alamos Neutron Science CEnter (LANSCE), over incident neutron energies from below 1 MeV up to 20 MeV. The target foils and fission detectors were provided by LLNL, and two LANL neutron detector arrays were used to cover outgoing neutron energies from 10 keV to 20 MeV. The measurements will be described, and the resulting PFNS data will be presented and discussed. In addition, PFNS measurements have now been extended to 240Pu(n,f) and 240,242Pu(sf), and these data will also be presented. Comparisons among the PFNS of these isotopes will also be discussed.

Abstract 176 at 10:00 AM

Session AR-NST-05 Tuesday 10:00 AM - West Fork II

The tin-vacancy qubit in diamond: an emerging platform for quantum technologies

Eric Irving Rosenthal

E. L. Ginzton Laboratory, Stanford University, Stanford CA, United States

The negatively charged tin-vacancy (SnV) center in diamond is an emerging qubit in diamond. In particular, it is a desirable spin/photon interface for use in quantum networking due to its high quantum efficiency, strong zero phonon emission, and reduced sensitivity to electrical noise. The SnV has a large spin-orbit coupling, which allows for long spin lifetimes at elevated temperatures, but also suppresses the magnetic dipole transitions desired for quantum control. We develop understanding of this relationship including as a function of magnetic field orientation, and strain of the diamond lattice. Doing so, we find a regime where these limitations can be overcome to achieve high fidelity microwave spin control [1], and single-shot spin readout (2)These results pave the way for SnV spins to be used as a building block for future quantum technologies including quantum networking, sensing, and information processing.

[1] Rosenthal **et al.,** Phys. Rev. X **13**, 031022 (2023)

[2] Rosenthal **et al.,** arXiv:2403.13110 (2024)

Abstract 193 at 10:30 AM

Session AR-NST-05 Tuesday 10:00 AM - West Fork II

Synthesis of optically active solid-state spin qubits via ion implantation and irradiation

Yeghishe Tsaturyan[1], Nazar Delegan[1,2], Michael Titze[3], Edward Bielejec[3], Martin V. Holt[2], F. Joseph Heremans[1,2], David D. Awschalom[1,2]

(1)Pritzker School of Molecular Engineering, The University of Chicago, Chicago Illinois, United States
(2)Center for Molecular Engineering, Materials Science Division, Argonne National Laboratory, Lemont Illinois, United States
(3)Sandia National Laboratories, Albuquerque New Mexico, United States

Optically addressable point defects in wide band-gap semiconductor materials possessing an electronic spin are viewed as promising candidates for future quantum technologies. Materials such as silicon carbide and silicon have received a great deal of attention in this pursuit, not the least due to their technological maturity and the availability of high-quality, wafer-scale material. However, deterministic synthesis of relevant spin defects and surrounding crystal environments remains a challenge across material platforms and identifying pathways towards deterministic defect creation is critical in advancing these systems to scalable technologies.

In this talk, we will outline our research efforts in creating optically active point defects using ion implantation and electron irradiation, such as the divacancy (VV^0) and vanadium (V^{4+}) defects in silicon carbide, and the use of advanced x-ray, optical and electron microscopy techniques in characterizing these systems. We will show how nanoimplantation techniques can be employed in deterministic creation of color centers and the use of nano-diffraction in studying the local crystal environment. Lastly, we will present on our ongoing efforts in incorporating relevant optically active spin qubits in heterostructured materials, as we explore pathways to alleviate challenges involved in device integration of optically active spin qubits.

Abstract 254 at 11:00 AM

Session AR-NST-05 Tuesday 10:00 AM - West Fork II

Quantum business opportunities

Vignesh Chandrasekaran

Los Alamos National Laboratory, Los Alamos NM, United States

The current electronics and laser industries have largely benefited from the fundamentals of quantum physics. The next stage where quantum states could be individually controlled making full use of quantum physics has generated interest among private entities in

addition to researchers and governments. In this talk, I will share an overview of quantum business ecosystem and particularly, I will touch upon a use case where nanotechnology, quantum, and focused ion beam meet together.

Abstract 288 at 10:00 AM

Session AR-RE-10 Tuesday 10:00 AM - Elm Fork II

Beam-On Irradiation Effects for Faster Down-Selection of Fusion Reactor Material Candidates

Elena Botica-Artalejo[2], Zoe L Fisher[1], Ben Dacus[1], Angus Wylie[1], Kevin B Woller[3], Takafumi Kamei[4], Hisaki Fujita[4], Greg Wallace[3], Michael P Short[1]

(1)Nuclear Science and Engineering, Massachusetts Institute of Technology, Cambridge MA, United States
(2)Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge MA, United States
(3)Plasma Science and Fusion Center, Massachusetts Institute of Technology, Cambridge MA, United States
(4)Kirishima R&D Center, Kyocera Corporation, Kagoshima, Japan

Near-term commercial fusion power concepts require materials design decisions to be made within the next decade, if not sooner. The current state of the art for materials evaluation and down-selection, even utilizing higher dose rate ion irradiation, takes years to decades. Far faster iteration over potential material candidates for key applications such as plasma facing materials, vacuum vessels, RF antennas, ceramic components, and anti-corrosion coatings must be achieved at the speed of semiconductor innovation to reach the ambitious goal of commercial-scale fusion power in the next decade.

We demonstrate how developing inference models for near-instantaneous beam-on effects correlates strongly to material property changes of ultimate interest in multiple such fusion material systems. We focus specifically on high entropy alloys as structural and plasma-facing materials, Cu-based alloys for radiation-robust RF antennas, and various grades of ceramics for insulating components. Here, we show that instantaneous changes in easy to obtain, ultrasonically measurable material properties correlate well with changes in microstructure, and therefore material properties of ultimate interest. This research is admittedly in its infancy, so our proposed path to further develop ways for **in situ** non-destructive evaluation of radiation-induced microstructural change to be utilized for semiconductor-speed down-selection of potential candidates for final, more realistic testing of fusion components with neutrons.

Abstract 222 at 10:30 AM

Session AR-RE-10 Tuesday 10:00 AM - Elm Fork II

Surface near Helium damage in materials studied with a high throughput implantation method

Peter Hosemann, Mehdi Balooch

Nuclear Engineering, UC Berkeley, Berkeley CA, United States

Helium damage in materials is a significant concern for the nuclear fusion, fission, and spallation communities. Helium generation in bulk materials can cause embrittlement and swelling, while helium implantation near surfaces can lead to blistering, fuzz formation, and spalling. These phenomena result from the accumulation of helium into nanosized bubbles, influenced by temperature and external stress states. Traditionally, studying these effects requires ion beam accelerators and large samples.

In this work, we introduced nanobeam ion implantation methods that enable rapid multi-dose ion beam implantation in surface-near regions, facilitating basic scientific studies in single-crystal and polycrystal materials such as Cu, Si, and W. The integration of helium ion beam implantation using the Helium Ion Beam Microscope, Atomic Force Microscopy, Nanoindentation, and Transmission Electron Microscopy provides new insights into the formation of blisters, the coalescence of helium bubbles, and the associated deformation and cracking mechanisms. We confirmed previously posed hypotheses in tungsten blistering and identified the dose threshold for silicon amorphization.

Abstract 60 at 11:00 AM

Session AR-RE-10 Tuesday 10:00 AM - Elm Fork II

Avalanche Energy: The development of the Orbitron, a micro-fusion reactor for clean, mobile and distributed energy applications

Daniel Velazquez, Sergey Tsurkan, Brian Riordan, Robin Langtry

Avalanche Energy, Seattle WA, United States

Avalanche Energy Designs Inc. is a venture capital funded startup based in Seattle which has developed and patented a novel concept for a plasma confinement device called the Orbitron. This device has the potential for scientific applications as a small micro-fusion reactor capable of several kW of thermal power as well as a high-flux neutron generator for research applications. The Orbitron is a "crossed-field" device that achieves a useful fusion plasma triple product (time, density, energy) by confining high-energy ions electrostatically for long durations (as in an orbitrap), while confining electrons in an ExB weak magnetic field (as in a magnetron). The confined electrons mitigate ion space-charge density constraints, enabling a high density of ions orbiting around a cathode with energies sufficient for ion-ion fusion. This talk is an overview of the working principles of the Orbitron as a stand-alone device, as well as the various R&D branches Avalanche Energy is undertaking in the process of developing this reactor. In particular, we will introduce our ongoing collaborations with PNNL to advance the structural materials and plasma facing components (PFCs) capabilities to enable the long lifetime operation of the Orbitron.

Abstract 156 at 10:00 AM

Session SN-OM-04 Tuesday 10:00 AM - Trinity Central

Heavy ions for radiobiological work at the Columbia Radiological Research Accelerator Facility

Naresh T. Deoli, Andrew D. Harken, Yuewen Tan, Guy Garty, David J. Brenner

RARAF, Center for Radiological Research, Columbia Univeristy, Irvington, New York, United States

Recent trends in cancer radiotherapy pre-clinical research have shifted focus from carbon to other ions (i.e., helium, boron, etc.) due to their intermediate physical and radiobiological properties and lesser economic burden. To conduct radiobiological research in heavy-ion cancer radiotherapy, the Radiological Research Accelerator Facility (RARAF) has integrated an electron beam ion trap (EBIT) source into its 5.0 MV Singletron accelerator (High Voltage Engineering Europa (HVE), Netherlands). The EBIT source generates highly charged ions (B^{5+}, C^{6+}, etc.) which are otherwise not possible using the original configuration of the RARAF accelerator, i.e., HVE Singletron with a radiofrequency ion source. Select heavy ions (Li^{3+}, B^{5+}, C^{6+}) have a mass-to-charge ratio of 2:1, giving ion energies of 2.5 MeV/nucleon from the RARAF Singletron. This system delivers a series of mono-LET beams (protons to carbon ions) that provide 2-D exposures for preclinical cell monolayer investigations. We discuss the methodology for integrating the EBIT source from DREEBIT GmBH into an HVE Singletron and optimizing the range of heavy ions of particular interest in heavy-ion radiotherapy.

Acknowledgments

National Cancer Institute (U01CA236554) and National Institute of Biomedical Imaging and Bioengineering (P41EB002033).

Abstract 211 at 10:20 AM

Session SN-OM-04 Tuesday 10:00 AM - Trinity Central

Current status of the Triton source at Florida State University

Ashton B. Morelock[1], Miguel Madurga[1], Alfredo Galindo-Uribarri[2], Augusto O Macchiavelli[2], Ingo Wiedenhoever[3]

(1)Department of Physics and Astronomy, University of Tennessee Knoxville, Knoxville Tennessee, United States
(2)Oakridge National Laboratory , Oak Ridge Tennessee, United States
(3)Department of Physics, Florida State University, Tallahassee Florida, United States

Florida State University, in collaboration with the University of Tennessee Knoxville and Oakridge National Laboratory, have

developed a Multi-Cathode Source of Negative Ions by Cesium Sputtering (MC-SNICS) at the John D. Fox Laboratory. This MC-SNICS is dedicated to the production of triton beams for use with unique nuclear physics experiments. Deuterated titanium cathodes were successively produced and used for nuclear experiments, and preliminary tritium testing was conducted prior to the commissioning of triton beams. A discussion of safety precautions, cathode production techniques, deuteron beam testing, and future plans will be presented.

Abstract 287 at 10:40 AM

Session SN-OM-04 Tuesday 10:00 AM - Trinity Central

Development and performance of sub-nanoamp beam diagnostics at National Electrostatics Corp.

Eric Alderson, Andrew Gajeski, Mark Stodola, Andrew Soderholm, Allan O'Connor, Thilo Hauser, Mark Sundquist

National Electrostatics Corp., Middleton WI, United States

Typical diagnostics for electrostatic particle accelerators measure beam currents in the range of 1 nA to 1 mA, which covers the functional range of interest for much of the community. However, researchers are continually pushing the boundaries of research, motivating development of components and diagnostics that extend the low and high frontiers of beam current magnitude. This presentation describes a series of beamline components that serve the sub-nanoamp regime of ion beam operation. To produce a controlled sub-nanoamp current NEC has developed a pulsed beam attenuator. After discussing how we control the current amount, we will discuss the a Dynode detector implemented by NEC to measure sub-nanoamp current magnitudes. We will then describe the BPM90-LC, the Low Current Beam Profile Monitor, which has demonstrated a measurement of beam location and profile of ion beams with a current as high as 12 uA and less than 1 pA, an eight decade range.

Abstract 130 at 11:00 AM

Session SN-OM-04 Tuesday 10:00 AM - Trinity Central

Analytic Model for Filament Degradation in Filament-Driven DC Ion Sources

Mark Harrison, Vlad Vekselman, Alex Dunaevsky

TAE Life Sciences, 35 Parker, Irvine CA 92618, United States

In filament-powered, high-current ion sources, the filament is heated with large electrical currents to high temperatures--sometimes approaching the melting point of the filament material--in order to emit enough thermionic electrons to sustain a plasma from which the ion beam is extracted. The filament is gradually

worn away and gets thinner due to material evaporation until it eventually breaks. A filament breaking during operation leads to unplanned and expensive downtime while the filament is replaced and the ion source cleaned of debris. Before breaking, the changing geometry of the filament also changes the amount of current necessary to keep the filament at the correct temperature. In this work, we present an analytic model of filament that tracks and predicts the current required to correctly heat the filament. As the filament is used-usage is parameterized by total integrated incident power-it gets thinner, increasing its electrical resistance and decreasing its mass. These effects lower the electrical current in the filament necessary to sustain the plasma in a predictable way. The model presented here fits a curve to a given filament that tracks the decrease in current as a proxy for filament wear in order to predict when it should be replaced prior to failure. The model is tested using measurement data from the negative ion source in the medical accelerator of the TAE-built BNCT facility in Xiamen, China.

Abstract 34 at 1:00 PM

Session AC-AF-03 Tuesday 1:00 PM - Elm Fork II

Multi-Objective Bayesian Active Learning for MeV-ultrafast electron diffraction

Fuhao Ji

Accelerator Directorate, SLAC National Laboratory, Menlo Park California, United States

Ultrafast electron diffraction using MeV energy beams(MeV-UED) has enabled unprecedented scientific opportunities in the study of ultrafast structural dynamics in a variety of gas, liquid and solid state systems. Broad scientific applications usually pose different requirements for electron probe properties. Due to the complex, nonlinear and correlated nature of accelerator systems, electron beam property optimization is a time-taking process and often relies on extensive hand-tuning by experienced human operators. Algorithm based efficient online tuning strategies are highly desired. Here, we demonstrate multi-objective Bayesian active learning for speeding up online beam tuning at the SLAC MeV-UED facility. The multi-objective Bayesian optimization algorithm was used for efficiently searching the parameter space and mapping out the Pareto Fronts which give the trade-offs between key beam properties. Such scheme enables an unprecedented overview of the global behavior of the experimental system and takes a significantly smaller number of measurements compared with traditional methods such as a grid scan. This methodology can be applied in other experimental scenarios that require simultaneously optimizing multiple objectives by explorations in high dimensional, nonlinear and correlated systems.

Abstract 38 at 1:30 PM

Session AC-AF-03 Tuesday 1:00 PM - Elm Fork II

Machine Learning to improve the Spallation Neutrons Source Accelerator and Target performance

Willem Blokland

SNS/RAD, ORNL, Oak Ridge Tennessee, United States

The Spallation Neutron Source (SNS) facility directs protons accelerated to over 1 GeV to a stainless-steel mercury filled target to produce neutrons in order to explore the nature of materials and energy. The high power facility runs at the cutting edge of technology and while regular maintenance is performed, occasional interruptions in operations still occur.

This talk presents results from an ongoing Machine Learning project at SNS to improve accelerator and target reliability. Various application areas ranging from reducing beam trips, improving target systems reliability, reducing beam losses, to improving on cryogenic system behavior will be discussed as well as lessons learned. Finally, we present our work in integrating the Machine Learning techniques with Operations.

Abstract 39 at 1:50 PM

Session AC-AF-03 Tuesday 1:00 PM - Elm Fork II

Report on accelerator-physics-related machine learning studies from FRIB theory group

Xilin Zhang

Theory, Facility for Rare Isotope Beams, East Lansing MI, United States

In this talk, I will discuss recent machine learning studies in the nuclear theory group at the Facility for Rare Isotope Beams. In particular, I will focus on the studies related to accelerator physics, such as beam tuning and control.

Abstract 65 at 2:05 PM

Session AC-AF-03 Tuesday 1:00 PM - Elm Fork II

Particle Beam Focus Optimization using Stochastic Swarm Technique

Peter Norgard

University of Missouri Research Reactor, Columbia MO, United States

The development of particle beam focusing optics most often boils down to optimizing the strength of focusing components to achieve a desired goal, once the optical elements have been selected. The positions of the constituent lenses are usually fixed and then some form of parametric optimization is employed to find a set of lens strengths that work, or at least work well enough. At present, a non-deterministic strategy for finding parametric solutions involving both lens strength and lens separation is to be discussed. One of the major benefits of the approach described is

that the entire solution space can be assessed in a single simulation. Sequential simulations involving over-parameterized problem spaces quickly reveal the vast array of plausible solutions for any given set of requirements, although as more constraints are enforced the solution set becomes more restricted.

Parametric optimization can work with both trajectory-based or phase-space-based expression sets, although it is less common to work in trajectory-space because a secondary particle simulation is required to evaluate the effectiveness of the parametric selections on the spatial characteristics of the particle beam. By contrast, the phase-space solutions may be directly converted to beam envelope dimensions, if that is desired, so long as the initial beam emissivity is known. Since no particle trajectory simulation is required to validate the phase-space model, the initial computational effort is more efficiently employed. In this work the phase-space simulation is evaluated.

The technique popularized by Kennedy and Eberhard known as "particle swarm optimization" was adapted to the problem of finding optimized Twiss-parameters to achieve specific focusing goals. The particle swarm algorithm as implemented for this problem uses lens strength and lens separation distance as the parameterized inputs, and then uses those inputs to drive the particle beam envelope through the resulting transmission matrices transformed into phase-space. The resulting particle beam envelope characteristics at points within the phase-space are then sampled and compared to target values. When a set of parameters, known in the vernacular as a particle, exhibits low error relative to the other particles in its class of particles, that particle becomes the leader of the pack, and other particles are made to follow it towards a local solution. The leader of the pack is also compared to the lowest overall error observed, and if lower, it also becomes a global leader of the pack. Other particles will attempt to drive towards an apparent global solution as well. In this manner the particle swarm algorithm can optimize a field of local solutions down to a global optimum. This may not always be the case with linearized techniques, or those that rely on root finding or minimum-descent techniques.

Evaluation of the particle swarm optimization technique to find candidate parameters for a four-lens quadrupole configuration was undertaken to demonstrate the properties of the method. This method of solution requires considerable time to arrive at an optimized solution, and in many cases the optimum solution represents an approximation to the desired performance characteristics, although not always. An apparent lack of convergence appears whenever the number of test points where specific performance traits are desired is on par with the number of degrees of freedom the problem has. Nevertheless, the resulting performance match between goal and response appears to be very good provided many particles are modeled, or if the number of test points where performance goals are required can be limited well below the number of degrees of freedom.

Physics-constrained machine learning for electrodynamics based on Fourier transformed Maxwell's equations

Christopher Anders Leon, Alexander Scheinker

Accelerator Operations and Technology - Applied Electrodynamics, Los Alamos National Laboratory, Los Alamos New Mexico, United States

Calculating the electromagnetic fields generated from intense, relativistic particle beams can require extensive computational resources. Recent progress in machine learning (ML) offers the ability to create surrogate models that are faster and more flexible than traditional numerical methods. The incorporation of physics constraints into an ML model can ensure its predictions are consistent with the known physics, while it has also been shown to improve the model's generalization ability. We developed a novel approach based on a Fourier transformation-based representation of Maxwell's equations to create physics-constrained convolutional neural networks for electrodynamics without gauge ambiguity. We label this the Fourier-Helmholtz-Maxwell Neural Operator (FoHM-NO) method. In this approach, both of Gauss's laws and Faraday's law are built in as hard constraints, as well as the longitudinal component of Ampère-Maxwell's law in Fourier space (assuming the continuity equation). A neural network acts as a solution operator for the transverse components of the Fourier transformed vector potential, which is then used for the prediction of the electromagnetic field. This methodology was tested by training the network on data from a conventional simulator of an electron bunch entering a solenoid field. Our findings were that a U-Net architecture performed best across all datasets - training, validation, and test. Not only were the U-Net's predictions accurate, but it also ran many orders of magnitude faster than the conventional simulation. This demonstrates the potential of FoHM-NO in cases where computational speed is paramount.

Abstract 155 at 1:00 PM

Session AP-SD-04 Tuesday 1:00 PM - West Fork II

Scintillation response of gallium oxide to charged particle and gamma radiation produced by radioisotope and accelerator sources

John Derek Demaree[1], Noel A Guardala[2]

[(1)]DEVCOM Army Research Laboratory, Aberdeen Proving Ground Maryland, United States
[(2)]George Washington University, Washington DC, United States

We have measured the response of the wide band gap scintillator Ga_2O_3 (Sn-doped) to a variety of radiation sources, including energetic ion beams, alpha- and beta-emitting radionuclides, and gamma sources to assess its scintillation behavior and possible use as a radiation spectrometer. Using an National Electrostatics 5SDH-2 ion accelerator at the Army Research Laboratory, energetic ion beams of hydrogen, helium and nitrogen were directed onto Ga_2O_3 to assess the relative scintillation efficiency as a function of ion mass, and the limits of the ion energy which

could reasonably be measured using this material coupled to a photomultiplier tube.

The material was also exposed to beta-emitting sources including ^{14}C, ^{99}Tc, ^{36}Cl and ^{90}Sr for energy calibration and to assess its use as a beta spectrometer, reproducing energy spectra in general agreement with spectra calculated using the Betashape model (accessed through IAEA LiveChart of Nuclides). The response to combined beta- and gamma-emitting sources ^{137}Cs and depleted uranium (^{238}U) was also measured, and the scintillation response characterized separately to obtain pure beta spectra for each source. Although the scintillation response of Ga_2O_3 to gamma radiation is relatively low, we were able to measure Compton electron distributions using both gamma emitting radioisotopes and accelerator-generated gamma rays.

Finally, various filters, both inorganic and organic, were placed between beta-emitting sources and the scintillator/PMT system in order to obtain information regarding the absorption of betas in thin filter materials. More detailed data regarding beta energy absorption as a function of energy and depth in organic materials could be valuable in the area of beta-source radiation therapy using beta sources. Additionally, such data could advance our interpretation of spectra obtained in environmental contamination situations where sources may be located beneath an absorbing material, distorting the spectroscopic results.

Abstract 67 at 1:20 PM

Session AP-SD-04 Tuesday 1:00 PM - West Fork II

Detectors for MeV X-ray and Neutron Imaging

Nerine Cherepy

Lawrence Livermore National Laboratory, Livermore CA, United States

High energy X-rays and neutrons can provide 3-D volumetric views of large objects made of multiple materials. Lens-coupled computed tomography using a scintillator imaged on a CCD camera obtains high spatial resolution, while a surface-mounted segmented scintillator on an amorphous silicon (A-Si) array can provide high throughput. For MeV X-ray CT, a new polycrystalline transparent ceramic (Gd,Lu,Eu)2O3 scintillator referred to as "GLO" offers excellent stopping power and light yield for improved contrast in sizes up to a 14" field-of-view. The GLO scintillator can also be formed into pixelated arrays. For MeV neutron CT, we have fabricated both contiguous and segmented plates of "Hi-LY" plastic scintillator, offering light yields 3x higher than standard plastic.

Abstract 43 at 1:40 PM

Session AP-SD-04 Tuesday 1:00 PM - West Fork II

Investigating Ce and Tb Concentrations in Translucent Rare-Earth Aluminum Garnet Ceramic Scintillators

Nathan Gillespie[1,2], Kaden Anderson[1,2], Meredith Harpel[1,2], Sean Drewry[2], Jarek Glodo[3], Yimin Wang[3], Matthias Mueller[3], Charles Melcher[1,2,4], Luis Stand Stracuzzi[1,4], Mariya Zhuravleva[1,2]

[(1)]Scintillation Materials Research Center, University of Tennessee, Knoxville Tennessee, United States
[(2)]Materials Science and Engineering, University of Tennessee, Knoxville Tennessee, United States
[(3)]Radiation Monitoring Devices, Watertown Massachusetts, United States
[(4)]Nuclear Engineering, University of Tennessee, Knoxville Tennessee, United States

The field of high-energy radiography requires improved detectors specialized in the 6-9 MeV range to better detect special nuclear material. New detectors must exhibit improved capabilities without becoming prohibitively expensive or tedious to produce. Rare-earth aluminum garnet ceramic scintillators such as $Gd_3Ga_3Al_2O_{12}$:Ce are being developed to address these needs: they have low afterglow, high light yields, and can be synthesized in cost-effective and scalable manners. However, more chemically complex garnet compositions can uniquely utilize processes such as energy transfer that result in novel scintillators. This work focuses on $(Y,Gd,Tb,Lu)_3Al_5O_{12}$:Ce with the goal of using the ability of Tb to transfer energy to Ce and improve the light yield of the scintillator. Tb concentrations of 25, 50, and 75 mol% were investigated, each with Ce concentrations of 0.5, 1, and 2 mol%. Samples were synthesized as powders with a wet chemistry technique then densified into translucent ceramics using uniaxial hot pressing. Radioluminescence spectra and light yield were measured as the primary indicators of response to ionizing radiation. Additionally, afterglow, scintillation decay, absorbance, and transmittance were measured. The radiation hardness of the samples was investigated by exposing them to gamma radiation with a Co-60 source. Results indicate increasing Tb concentration above equimolar generally improved scintillation properties, In particular, the composition with 75% Tb and 1% Ce exhibits light yield up to 40,000 ph/MeV without visible Tb^{3+} emission. The afterglow of this composition is comparable to $CdWO_4$ under the same testing setup and conditions after about 60 ms.

This material is based upon work supported by the U.S. Department of Homeland Security under Grant Award Number 20CWDARI00037-01-00. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Department of Homeland Security.

Abstract 57 at 2:00 PM

Session AP-SD-04 Tuesday 1:00 PM - West Fork II

Radiation Hardness of New Inorganic Halide Single Crystal Scintillators

Kimberly Pestovich[1,3], Luis Stand[1,2,3], Lakshmi Soundara Pandian[4], Edgar Van Loef[4], Charles L. Melcher[1,2,3], Mariya Zhuravleva[1,3]

(1)Department of Materials Science and Engineering, University of Tennessee, Knoxville TN, United States
(2)Department of Nuclear Engineering, University of Tennessee, Knoxville TN, United States
(3)Scintillation Materials Research Center, University of Tennessee, Knoxville TN, United States
(4)Radiation Monitoring Devices, Inc., Watertown MA, United States

Many national security technologies use scintillator crystals to detect ionizing radiation, and there is a growing need for scintillator materials with improved performance. For high energy X-ray radiography (0.5-9 MeV) of cargo, scintillators must have high light yield, low afterglow, and radiation hardness, among other properties. Several inorganic halide perovskite single crystal scintillators with promising properties were discovered. Namely, these crystals have very high light yield (>70,000 ph/MeV), and promising X-ray afterglow (~1.5% at 2 ms after 100 ms irradiation). However, their sensitivity to radiation damage was unknown. In this work, several newly discovered single crystal scintillators ($RbBX_3$, RbB_2X_5, Rb_4BX_6, B^{2+} = Ca, Sr, Eu, Yb; X^- = Br, I) were grown from the melt, and their light yield, X-ray afterglow, and optical transmittance properties were tested before and after irradiation. Samples were irradiated at the University of Massachusetts, Lowell Gamma Cave Facility with a Co-60 source, investigating dose points of 100 krad up to 10 Mrad, for select compositions. Little to no change in performance was observed for several compositions, including $RbSrI_3$:Eu and Rb_4CaI_6:Eu. Future investigations include scaling up the synthesis of the most promising of these crystals and compositional engineering to further improve radiation hardness.

This material is based upon work supported by the U.S. Department of Homeland Security under Grant Award Number 20CWDARI00036-01-00. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Department of Homeland Security.

Abstract 151 at 1:00 PM

Session AR-RE-01 Tuesday 1:00 PM - Elm Fork I

Displacement Damage and Total Ionizing Dose Response of Ga_2O_3 MOSFETs

Michael Titze

Sandia National Laboratories, Albuquerque NM, United States

Gallium Oxide (here β-Ga_2O_3) is a promising material for compact high-voltage electronics due to its high breakdown voltage compared to Si. Prior to deploying Ga_2O_3-based devices in radiation environments, knowledge of their response to various types of radiation, most notably displacement damage (DD) from neutrons in reactor environments, and total ionizing dose (TID) as

experienced in x-ray / gamma environments. Device testing in appropriate environments is typically expensive and requires very long exposures due to the small interaction cross section of neutrons / gammas. Instead, we demonstrate the use of a dual-beam focused ion beam and scanning electron microscope system (FIB-SEM) to probe radiation effects through surrogate environments. The FIB is used to generate predominantly DD with a small amount of TID while the SEM generates exclusively TID, allowing unraveling the contributions of TID and DD.

We use SRIM and PENELOPE simulations to determine the amount of DD and TID for each beam and observe the drive current and threshold voltage shift in DD and TID environments. We find that DD degrades the drive current but does not alter the threshold voltage. TID does not alter the drive current but changes the device threshold voltage.

Acknowledgement: SNL is managed and operated by NTESS under DOE NNSA contract DE-NA-0003525.

Abstract 88 at 1:25 PM

Session AR-RE-01 Tuesday 1:00 PM - Elm Fork I

Radiation Testing for Electronic Devices in Space at the ANU Heavy Ion Accelerator Facility

Peter Linardakis, Thomas Tunningley, Daniel Tempra, Stephen Battisson, Christian Notthoff, Lauren T Bezzina, Ian P Carter, David J Hinde

Department of Nuclear Physics and Accelerator Applications, ANU Heavy Ion Accelerator Facility, Acton ACT, Australia

The space environment is harsh - with extremes of temperature, high vacuum, and the stresses of launch all posing challenges to the survival and reliability of any device designed to operate in space. An often-overlooked challenge, however, is the radiation environment of space, particularly for smaller payloads. In low earth orbits, the trapped protons and electrons of the Van Allen belts pose a particular challenge, while those orbits intercepting the polar regions are exposed to greater numbers of higher-energy galactic cosmic rays. Once the relative safety of the Earth's magnetic field is left behind, there is an even greater risk of exposure to these high-energy heavy ions.

While radiation testing for the space environment is possible at a number of facilities in the USA and Europe, the cost of access and wait times to these facilities can render them inaccessible to small companies and research institutions with limited budgets, particularly those in Australia and the rest of the southern hemisphere. To address this gap, a new beamline was built at The Australian National University's Heavy Ion Accelerator Facility (HIAF) with funding from the Australian Space Agency.

This new capability takes advantage of the 14UD SSNICS ion source, which can produce ions of any species except noble gases, to emulate parts of the space radiation environment across a wide range of potential mission profiles. Commonly requested species include protons for testing of cumulative damage, along with a range of heavy ion species to test for the vulnerability to single-event effects.

The beamline itself has three main features: a 100Hz rastering magnet which enables the delivery of uniform beam distribution over a large area, a set of four tantalum slits with the option of four scintillators and SiPMs for low-flux dosimetry and a large-volume irradiation chamber with 3-stage goniometer, which can accommodate devices up to 250 x 200 mm^2.

These features combine to form a system which has the capacity to deliver fluxes between 10^3 to 10^12 ions/cm^2/sec, over an area of 40 x 40 mm^2 per irradiation. These fluxes can be delivered to anywhere within a 200 x 200 mm^2 area of a device under test. In-situ communications and power delivery to the user's device is facilitated via standard feedthroughs, including 6 x 25-pin DSUB connectors, 2 x RJ45, 2 x USB-A.

Moreover, this system is not limited to irradiation of devices for use in space - the large volume of the irradiation chamber allows for alternate mounting systems to be hosted, including custom mountings for biological materials such as seeds and cell culture plates. Work is also currently underway to provide additional features for the irradiation chamber, including the addition of temperature control on the sample stage, and a reentrant window, enabling the irradiation chamber to be held at atmospheric pressure.

Abstract 100 at 1:40 PM

Session AR-RE-01 Tuesday 1:00 PM - Elm Fork I

Radiation-induced crystalline defects in $Al_xGa_{1-x}N$

Mia Jin[1], Mahjabin Mahfuz[1], Alexander Hauck[1], Farshid Reza[1], Maik Lang[2], Blair Tuttle[1], Xing Wang[1], Rongming Chu[1]

[(1)]Penn State University, State College PA, United States
[(2)]University of Tennessee, Knoxville, Knoxville TN, United States

GaN, AlN, and their ternary alloys form an important class of wide-bandgap semiconductors employed in a variety of applications, including radiation-hard electronics. To better understand the effects of irradiation in these materials, atomistic modeling and experimental methods were employed to understand radiation-induced crystalline defects. In this presentation, pertinent efforts on defect formation from low-energy recoil events (<tens of keV) and high-energy swift ion impact will be discussed. For the low energy recoils near the threshold displacement energies, point defects are produced. The electronic structure and dynamics of Frenkel pair defects are analyzed and the consequences for

device operation are discussed. For keV-level recoils, a systematic evaluation of defect formation under the compositional variation is performed. Furthermore, the structural alterations in GaN and AlN induced by swift heavy ion irradiation, characteristic of space radiation environments, are unveiled. These findings contribute to a mechanistic understanding of the contrast in ion-matter interactions and induced microstructures in AlxGa1-xN.

Abstract 235 at 2:05 PM

Session AR-RE-01 Tuesday 1:00 PM - Elm Fork I

Radiation defect engineering in hexagonal boron nitride

S. O. Kucheyev

Lawrence Livermore National Laboratory, Livermore CA, United States

Hexagonal boron nitride (h-BN) is a wide-band-gap semiconductor. Ion irradiation can be used to modify h-BN properties geared for specific applications. Here, we study damage buildup in bulk h-BN ceramics and films with thicknesses in the range of ~30-500 nm irradiated with kiloelectronvolt energy ions with different masses (He, N, Ne, Ar, and Xe) and different dose rates. Experiments are complemented by molecular dynamics simulations of the formation and evolution of point defects. Emphasis is on the role of BN polymorphism and transitions between cubic and hexagonal BN phases under ion bombardment. Our results reveal a critical role of intra-cascade defect processes in damage buildup.

This work was performed under the auspices of the U.S. DOE by LLNL under Contract DE-AC52-07NA27344.

Abstract 148 at 2:20 PM

Session AR-RE-01 Tuesday 1:00 PM - Elm Fork I

Defect generation mechanisms in silica under intense electronic excitation by ion beams below 100 K: Interplay between radiative emissions

MIGUEL L. CRESPILLO[1], JOSEPH T. GRAHAM[2], WILLIAM J. WEBER[1], FERNANDO AGULLO-LOPEZ[3]

[(1)]Department of Materials Science and Engineering, University of Tennessee, Knoxville Tennessee, United States
[(2)]Department of Nuclear Engineering and Radiation Science, Missouri University of Science and Technology, Rolla Missouri, United States
[(3)]Centro de Microanálisis de Materiales (CMAM-UAM), University Autonomous of Madrid (UAM), Cantoblanco Madrid, Spain

Ion-beam effects on bulk silica at low temperature have been studied with the aim of understanding the routes and mechanisms leading from the initial generation of free carriers and self-trapped excitons (STEs) to the production of two stable defect structures in irradiated silica, non-bridging oxygen hole centers (NBOHCs) and

oxygen deficient centers (ODCs). Ion beam induced luminescence (ionoluminescence, IL) spectra were obtained using 3 MeV H, 3.5 MeV He, 19 MeV Si, and 19 MeV Cl ions and a range of cryogenic irradiation temperatures from 30 to 100 K. The kinetic behavior of three emission bands centered at 1.9 eV (assigned to NBOHCs), 2.1 eV (assigned to the intrinsic decay of STEs), and 2.7 eV (assigned to ODCs) reveal the physical origin of these emissions under intense electronic excitation. The creation of NBOHCs is governed by a purely electronic mechanism. The kinetics curve of the NBOHC band shows two main contributions: an instantaneous (beam-on) contribution, followed by a slower fluence- and temperature-dependent process correlated with the concentration of STEs. The beam-on contribution is proportional to deposited ionization energy. The growth of the ODC band is linear in fluence up to around 2 × 1012 cm^{-2}. The growth rate is independent of temperature but proportional to the number of radiation-induced oxygen vacancies per ion, showing, unambiguously, that the 2.7 eV emission can be associated with ODCs created in an excited state.

Abstract 280 at 1:00 PM — Session MC-VAC-01 Tuesday 1:00 PM - Post Oak

Ultra-High Vacuum Seminar: Part 1 of 2 Session Series

John Screech

Vacuum Products Division, Agilent Technologies, Santa Clara CA, United States

This class provides the basics for understanding the nature and of ultra-high vacuum (UHV) which is a key enabling condition for many types of scientific inquiry and experimentation. Topics in session one will include an introduction to high vacuum and ultra-high vacuum, including the relationship between Pumping Speed, Throughput, Gas Load and Conductance. A description of the working principles of vacuum pumps and gauges used in rough, high and ultra-high vacuum will also be discussed. The curriculum for this 90 minute class is excerpted from Agilent's one-day UHV Seminar and is intended to provide an introduction to ultra-high vacuum systems and practice for scientists, engineers and technicians. Attendees will receive a printed copy of the slide deck and are encouraged to add notes to this useful resource.

Abstract 74 at 1:00 PM — Session SN-OM-05 Tuesday 1:00 PM - Trinity Central

SNEAP Communications and Web Based Presence

Daniel Robertson

Physics and Astronomy, University of Note Dame, Notre Dame IN, United States

In an attempt to grow and enrich the SNEAP community, which for decades has been an essential resource for accelerator-based facilities, a new website presence has been developed at the

University of Notre Dame. The goal of the website is to provide a resource for all SNEAP members, bringing together expertise and experiences of multiple facilities. The newly proposed SNEAP website will be presented to the community for general input and feedback.

Abstract 255 at 3:00 PM

Session AP-IA-03 Tuesday 3:00 PM - West Fork II

geochemistry and Saturation Applications Utilizing A New Slim Pulsed Neutron Technology

Weijun Guo

Halliburton, Houston TX, United States

As the oil and gas industry continues to mature, wells are drilled in increasingly challenging environments, often putting at risk the formation evaluation program in an open hole environment. Even if the well is accessible, cost and risk of a complete multi-run OH formation evaluation program can be prohibitive, however still required to identify hydrocarbons in complex reservoirs. These and other considerations push operators more than ever to find accurate and complete formation evaluation in a rigless environment, after the completion has been run. Logging runs through the completion reduce both cost and risk, where downhole tools are better protected and efficient conveyance options such as slickline is feasible with memory-capable tools. Cased hole logging data have historically been limited as compared to the vast data that can be acquired in an open hole environment. Additionally, the range of conditions encountered in cased hole environment, and the complexity of the completions will challenge even robust environmental corrections models, putting accuracy at risk. Completions with smaller tubing force the evaluation tools further away from the formation being evaluated and limit the OD of the tools being conveyed through the completion. The statistical nature of spectral nuclear technologies are particularly heavily affected by these constraints.

Pulsed neutron formation evaluation has historically successfully been employed for water, oil, and gas saturations, whether for initial input into a petrophysical model or as part of a time-lapse well monitoring program. Advancements in electronics and scintillator materials that take advantage of high-yield neutron generators work together to improve the accuracy of the raw output. Continued improvements in MCNP nuclear modeling software coupled with a large variety of characterization lab conditions have improved validation, stretching the limits for the specified operating environment. Individual elemental yields have been fully characterized, both with the neutron generator active and from passive mode with the generator off. Processing software has been developed concurrently that incorporates the traditional parameters with several additional parameters such as cement density.

The new multi-detector pulsed neutron tool can be conveyed in a wide range of borehole sizes, completion configurations, and

borehole fluid types with a more accurate response across this array of challenging conditions. A comprehensive range of characterized elemental yields combined with spectral natural gamma measurements from the same tool enable valuable minerology data to be acquired thru-tubing. It is fully memory capable, where the full data including all energy spectra can be acquired via slickline conveyance. The inclusion of a direct measurement of total carbon yield from the inelastic spectrum lend to accurate physics-based TOC output that can aid in evaluating unconventional reservoir.

Abstract 15 at 3:30 PM

Session AP-IA-03 Tuesday 3:00 PM - West Fork II

"Compact" Accelerators in Geological Probing, Petroleum to Climate Mitigation-State of Technology

Ahmed Badruzzaman

Pacific Consultants & Engineers, Hayward CA, United States

Over the past five decades, use of ionizing radiation in subsurface probing evolved on two tracks in the petroleum industry, (i) formation characterization with radioactive sources and (ii) formation /borehole monitoring with slim accelerator-based devices. Radioactive sources pose safety and security risks and thus accelerator-based devices have also been tested for formation characterization with some success. However, devices designed to date are larger than those used in the monitoring phase. A recent US DOE workshop explored the feasibility of compact accelerator-based tools to enhance the security profile of ionizing radiation tools used in the formation characterization phase and recommended a number of hardware/software features. In conjunction with these developments, recent papers have explored the potential use of ionizing radiation in geological probing that would be necessary in the low-carbon energy future envisioned.

In this paper we briefly review the role of ionizing radiation in geological probing, in general, along with their security profile, and explore the state of slim accelerator-based tools in particular. We then assess its postulated role to achieve a decarbonized energy landscape and assess the advantages accelerator-based tools can offer. While the primary discussion would comprise of compact neutron and photon generators, the paper would also explore the role a ‘compact' muon generator can play in "deep" probing of the geology that could be a game-changer in this endeavor.

Abstract 90 at 4:00 PM

Session AP-IA-03 Tuesday 3:00 PM - West Fork II

Quantification of Mercury Contamination using a Compact Cadmium Zinc Telluride Imaging Spectrometer and Neutron Generator.

Christopher Meert[1], Steven Brown[1], Junwoo Bae[2], Reid Sobota[1], Matthew Petryk[1], Michael Streicher[1], Feng Zhang[1], James Mason[1], Igor Jovanovic[2], William Kaye[1]

(1)H3D, Inc., Ann Arbor MI, United States
(2)University of Michigan, Ann Arbor MI, United States

Mercury contamination at legacy Y-12 facilities is a risk to both workers performing clean-up and the environment and wild-life surrounding the site. Destructive assay techniques can provide accurate quantification but may disturb mercury deposits, increasing the exposure probability for workers, and analysis time may be prohibitively long. Non-intrusive inspection methods, such as in-situ prompt gamma-ray neutron activation analysis (PGAA) can enable workers to find mercury concealed in walls or pipes after a relatively short irradiation time or be incorporated into automated systems to conduct mercury surveys. Commercially available neutron generators can be compact (< 15 lbs) and can produce strong neutron fields with less radiological concern than isotopic neutron sources. Cadmium Zinc Telluride (CdZnTe, or CZT) semiconductor detectors can be made in compact, tile-able systems (< 12 lbs) that provide good energy resolution without cumbersome cooling systems.

In previous work, we used a moderated DD neutron generator, a CZT-based imaging spectrometer, and PGAA to detect mercury in the lab and estimated the minimum detectable amount (MDA) for that single mercury geometry. In this work, we explore quantification of mercury in steel pipes, which is challenging due to photon attenuation by the pipe and the potential interference of the ^{56}Fe(n,γ) 352-keV gamma ray with the ^{199}Hg(n,γ) 368-keV gamma ray. The mercury can be in a pooled, liquid form or oxide scale along the inside surface of the pipe existing at various densities, which may be unknown to the user at the time of an in-field measurement, further complicating the quantification. The work uses a combination of data from PGAA measurements and Monte Carlo N Particle (MCNP) simulations to develop the quantification algorithm, focusing on deposits < 500 g.

This material is based upon work supported by the U.S. Department of Energy, Office of Science, SBIR/STTR Programs Office under Award Number DE-SC0021768.

Abstract 29 at 3:00 PM — Session AR-ISM-05 Tuesday 3:00 PM - Elm Fork I

Nanoscale hydrogen detection using time-of-flight secondary ion mass spectrometry

Zihua Zhu, Yinnge Du, Binod Paudel, Jeffrey Dhas, Min-Ju Choi

Pacific Northwest National Laboratory, Richland WA, United States

Hydrogen in materials attracts tremendous interest as its incorporation leads to significant alterations in structure, composition, and chemistry, which in turn impacts functional properties. Additionally, it has been integral to nuclear fusion

reactors and is regarded as the major source of clean energy. However, nanoscale manipulation and characterization of hydrogen in materials are challenging as only a selected few analytical technique can readily detect hydrogen, among which time-of-flight secondary ion mass spectrometry (ToF-SIMS) is a unique and powerful technique due to its excellent detection limit along with decent lateral and depth resolutions. In our lab, ToF-SIMS has been used for hydrogen detection for more than 16 years, and it became more and more important in the last several years.[1] In this presentation, we will discuss, using selected examples, how the detection and quantification of hydrogen in materials by ToF-SIMS has been utilized to reveal the hydrogenation/protonation-induced novel functional states in different classes of materials along with some tricks on sample preparation, optimized experimental conditions to achieve reasonable detection limits of hydrogen, and future prospects. We emphasize the unique capabilities of ToF-SIMS which can potentially unlock new functional states and answer some outstanding scientific questions in materials science.

References:

[1] B. Paudel, J. A. Dhas, Y. Zhou, M.-J. Choi, D. J. Senor, C.-H. Chang, Y. Du, Z. Zhu, "ToF-SIMS in material research: A view from nanoscale hydrogen detection," Mater. Today, in press.

Abstract 79 at 3:20 PM

Session AR-ISM-05 Tuesday 3:00 PM - Elm Fork I

Radiant Precision: Exploring Material Radiation with the Helium Ion Microscope

Vaithiyalingam Shutthanandan, Sten Lambeets, Libor Kovarik, Mark Engelhard, Arun Devaraj

Pacific Northwest National Lab, RICHLAND WA, United States

Helium ion microscopy (HIM) not only enables material imaging using Helium ions but also permits targeted irradiation with a focused Helium beam (0.25 nm diameter) to achieve controlled displacement damage and Helium dosing. Previous research has explored various materials like ODS steels, nanostructured ceramics, and nanolayered thin films to understand radiation damage mechanisms. Many investigations involved high-energy He ion irradiations covering a large specimen area, followed by radiation damage assessment. However, conventional ion irradiation beams typically had spot sizes in the range of hundreds of microns or larger, hindering site-specific investigation of irradiation damage on individual microstructural features. In such cases, the overall evolution of irradiation damage often reflected a cumulative response from the entire material microstructure, including grain boundaries, interphase interfaces, second phase precipitates, nano-crystalline regions, and other preexisting defects, to the ion beam irradiation. A nanoscale site-specific He ion irradiation approach can isolate and separately analyze the He ion irradiation response of different microstructural features in a mutually exclusive manner. Methodologies have been devised to

utilize the helium ion microscope (HIM) for irradiating specific sites, such as near grain interiors versus grain boundaries or near and on precipitates, of metallic materials using helium ions in a controlled manner. Subsequently, these materials undergo characterization using focused ion beam scanning electron microscopy (FIB/SEM), transmission electron microscopy (TEM), X-ray photoelectron spectroscopy (XPS), and atom probe tomography (APT). Recent studies employing HIM as a radiation tool will be discussed, offering comprehensive insights into material behavior under irradiation.

Abstract 157 at 3:40 PM

Session AR-ISM-05 Tuesday 3:00 PM - Elm Fork I

Effects of Electronic Energy Loss on Amorphization Behavior in Pyrochlore Oxides

William J. Weber[1], A. H. Mir[2], Ritesh Sachan[3], Yanwen Zhang[4]

[(1)]Materials Science & Engineering, University of Tennessee, Knoxville TN, United States
[(2)]School of Computing & Engineering, University of Huddersfield, Huddersfield West Yorkshire, United Kingdom
[(3)]Mechanical & Aerospace Engineering, Oklahoma State University, Stillwater OK, United States
[(4)]Mechanical & Materials Engineering, Queen's University, Kingston ON, Canada

The interaction of energetic ions with solids is well known to result in inelastic energy loss to electrons and elastic energy loss to atomic nuclei in the solid. The coupled effects of these energy loss pathways on defect production, nanostructure evolution and phase transformations in ionic and covalently bonded materials are complex and not well understood. Using experimental and computational approaches, we have investigated the separate and combined effects induced by electronic and nuclear energy loss on the response of simple and high-entropy pyrochlore oxides ($A_2B_2O_7$) to ion irradiation over a range of ions, energies, and temperatures. Experimentally, ion mass and energy are used to control the amount of energy deposition and the ratio of electronic to nuclear energy loss. Large scale molecular dynamics simulations are used to model these effects. In this work, the ion irradiation response of simple and high-entropy titanate pyrochlores ($A_2Ti_2O_7$) structures has been investigated, where the high-entropy pyrochlores have 5 equal-molar elements on the A site. The damage accumulation behavior of single-crystal titanate pyrochlores has been investigated by Rutherford backscattering spectrometry in channeling geometry and transmission electron microscopy. In addition, in situ ion irradiation of titanate pyrochlores in transmission electron microscopy facilities has been employed to reveal the dose and temperature dependence of amorphization over a range of ions. In these pyrochlores, the spatial coupling of electronic and nuclear energy loss often leads to reduced damage production along the ion trajectory, and the athermal annealing induced by the electronic energy loss can significantly impact the evolution kinetics of radiation damage, leading to decreases in the critical temperatures for amorphization. This research has advanced understanding on the role of electronic energy dissipation on amorphization processes, and the results

have significant implications for the response of materials to extreme radiation environments, the dynamics of ion-irradiation effects, and modification of materials using ion beams.

Abstract 53 at 4:00 PM

Session AR-ISM-05 Tuesday 3:00 PM - Elm Fork I

Ionization Effects on Nanostructured Materials Subjected to Ion Irradiation

Yanwen Zhang

Department of Mechanical and Materials Engineering, Queen's University, Kingston Ontario, Canada

Searching for better radiation-resistant materials has been a persistent yet scientifically exciting challenge for nuclear applications. Ion irradiation is the most amenable method to reach high doses in a reasonable time and thus often used as a surrogate for neutron irradiation; however, the impact of electronic energy deposition and dissipation by ions is often neglected. Microstructural response of nanostructured materials, including model oxides and nitrides for nuclear fuels and concentrated solid solution alloys, under ion beam irradiation is reviewed. The role of electronic energy loss on defect production and interface stability is discussed. Understanding ionization effects and the coupling of electronic and atomic processes in the intermediate MeV energy regime, where the energies to displace atoms and induce ionization are both large and comparable, is critically important. Quantified fundamental understanding of radiation damage processes beyond that of simplified displacement events is highly desirable.

Abstract 59 at 3:00 PM

Session AR-NP-13 Tuesday 3:00 PM - West Fork I

Precision spectroscopy of heavy molecular ions using quantum logic scheme

Yan Zhou[1], Jose Mosquera Ojeda[1], Jiaqi Li[2], Stephanie Letourneau[1], Rodrigo Fernandez[1], Govinda Bhandari[1]

[(1)]Physics and Astronomy, University of Nevada, Las Vegas, LAS VEGAS NV, United States
[(2)]Computer Science, University of Nevada, Las Vegas, LAS VEGAS NV, United States

In this presentation, I will discuss a new experimental platform designed to facilitate quantum logic control of polar molecular ions in a segmented ring ion trap, paving the way for precision spectroscopy and precision measurements. This approach focuses on achieving near-unity state preparation and detection, as well as long spin-precession coherence. A distinctive aspect lies in

separating state preparation and detection conducted in a static frame, from parity-selective spin-precession in a rotating frame. Moreover, this method is designed to support both temporally and spatially localized multiplexing measurements, enhancing the ability to probe and minimize potential systematic errors. While the primary focus of this talk is on detecting the electron's Electric Dipole Moment (eEDM) using 232ThF+ ions, the proposed methodology holds promise for broader applications, particularly with ion species like 232ThF+ and 181TaO+ that exhibit enhanced sensitivity to the nuclear Magnetic Quadruple Moment (nMQM).

Abstract 177 at 3:20 PM

Session AR-NP-13 Tuesday 3:00 PM - West Fork I

Probing physics beyond the Standard Model with molecular ion $^{227}ThF^{+}$

Kia Boon Ng[1], Rane Simpson[1,6], Carla Babcock[2], Valery Radchenko[3,9], Andrea Teigelhoefer[1], Ruohong Li[2,4,5], Jens Lassen[2,7,8], Ania Kwiatkowski[1,10], Amar Vutha[1,12], Xing Fan[11], Stephan Malbrunot-Ettenauer[1,12]

(1)Physical Sciences Division, TRIUMF, Vancouver British Columbia, Canada
(2)Accelerator Division, TRIUMF, Vancouver British Columbia, Canada
(3)Life Sciences Division, TRIUMF, Vancouver British Columbia, Canada
(4)Department of Astronomy and Physics, Saint Mary's University, Halifax Nova Scotia, Canada
(5)Department of Physics, University of Windsor, Windsor Ontario, Canada
(6)Department of Physics and Astronomy, University of British Columbia, Vancouver British Columbia, Canada
(7)Department of Physics and Astronomy, University of Manitoba, Winnipeg Manitoba, Canada
(8)Department of Physics, Simon Fraser University, Burnaby British Columbia, Canada
(9)Department of Chemistry, University of British Columbia, Vancouver British Columbia, Canada
(10)Department of Physics and Astronomy, University of Victoria, Victoria British Columbia, Canada
(11)Department of Physics and Astronomy, Northwestern University, Evanston Illinois, United States
(12)Department of Physics, University of Toronto, Toronto Ontario, Canada

The Standard Model of particle physics is one of the most successful models in explaining how the world works at a microscopic level, but it is considered to be incomplete. Efforts on the theoretical front have sought to extend the Standard Model with new physics to explain open questions such as the matter-antimatter asymmetry in the universe. New physics can, for example, manifest as electric dipole moments (EDMs) in atomic/molecular or subatomic systems. Measurements of EDMs in these systems can shed light on the nature of new physics. Following a brief overview of general scientific ambitions at RadMol, I will be explaining how we intend to perform quantum control of monocationic thorium-227 monofluoride ($^{227}ThF^{+}$) to probe for physics beyond the Standard Model.

Abstract 188 at 3:40 PM

Session AR-NP-13 Tuesday 3:00 PM - West Fork I

Precision Measurement Techniques for Isotope Shifts of Unstable Atoms

Alex Brinson

Laboratory for Nuclear Science, MIT, Cambridge MA, United States

Anticipating the unprecedented radioactive isotope production capabilities promised by the Facility for Rare Isotope Beams (FRIB), a number of laser spectroscopy techniques are being developed for the purposes of improving the precision and reach of isotope shift measurements across the nuclear chart. These measurements, typically obtained with a precision on the order of MHz, provide critical data to study the evolution of nuclear charge radii away from stability.

The Resonant Ionization Spectroscopy Experiment (RISE) is an extension to the BECOLA beamline at FRIB, which will enhance the sensitivity of the experiment by introducing laser ionization and direct ion counting as a new detection mechanism for the collinear laser spectroscopy beamline (1)In this talk, I will present the commissioning and first experiments performed with RISE.

Additionally, sub-kHz level isotope shift measurements can provide sensitivity to Beyond Standard Model (BSM) physics. In particular, a thorough analysis of King Plot nonlinearities in stable Yb isotopes has already improved our bounds on allowed "5th force" electron-nucleon couplings (2)To this end, the ability to disentangle a BSM signal from higher-order nuclear effects could be improved by extending the King plot analysis to radioactive isotopes. SCARIEST SCORPIONS (Sideband Cooling, Applied to Radioactive Isotopes in an Entangled State Trap, for Spectroscopy - Consisting Of Ramsey Phase Interferometry - On Nuclear Shifts) aims to accomplish this by loading unstable Yb^+ ions into a linear Paul trap, and directly measuring isotope shifts between pairs of co-trapped ions.

The perspective of the RISE experiment, as well as the ongoing development of SCARIEST SCORPIONS, will be presented.

[1] Flanagan, K. (2013). CRIS: A New Sensitive Device for Laser Spectroscopy of Exotic Nuclei. **Nuclear Physics News**, **23**(2), 24-26. https://doi.org/10.1080/10619127.2013.793094

[2] Door, M., Yeh, C.-H., Heinz, M., Kirk, F., Lyu, C., Miyagi, T., Berengut, J. C., Biero´nbiero´n, J., Blaum, K., Dreissen, L. S., Eliseev, S., Filianin, P., Filzinger, M., Fuchs, E., Fürst, H. A., Gaigalas, G., Harman, Z., Herkenhoff, J., Huntemann, N., …

Mehlstäubler, T. E. (2024). **Search for new bosons with ytterbium isotope shifts.** https://arxiv.org/abs/2403.07792v1

Abstract 138 at 4:00 PM

Session AR-NP-13 Tuesday 3:00 PM - West Fork I

Expanding Experimental Opportunities at TRIUMF with TITAN EBIT

Jaime Damiany Cardona[1,2], Fernando Maldonado[1], John Ash[1], Stefan Paul[1], Rane Simpson[1], Zachary Hockenbery[1,3], Gerald Gwinner[2], Ania Kwiatkowski[1,4]

(1)TRIUMF, Vancouver British Columbia, Canada
(2)University of Manitoba , Winnipeg Manitoba, Canada
(3)McGill University , Montreal Quebec, Canada
(4)University of Victoria, Victoria British Columbia, Canada

The Electron Beam Ion Trap (EBIT) at TRIUMF's Ion Trap for Atomic and Nuclear science (TITAN) is used to further the study of nuclear and atomic physics, from increasing the precision of atomic mass measurements to searching for possible nuclear batteries. Situated at ISAC-TRIUMF, the EBIT has access to radioactive ion beams which can be charge bred to produce highly charged ions (HCI) of nuclides far from stability. The EBIT is designed to produce a 66 kV, 5 A electron beam, enabling the production of HCI up to bare holmium. HCI of exotic nuclei are key to the experimental goals of TITAN. In this work the status, forthcoming upgrades to the system, and experimental goals/results of the TITAN EBIT will be discussed

Abstract 294 at 4:15 PM

Session AR-NP-13 Tuesday 3:00 PM - West Fork I

Advancing EDM searches with ultracold radioactive molecules at FRIB

Xing Wu

Facility for Rare Isotope Beams, Michigan State University, East Lansing MI, United States

Searches for non-zero electric dipole moment (EDM) in fundamental particles shed light on discrete symmetries of nature and constrain new physics beyond the Standard Model. The most sensitive electron EDM and many ongoing nuclear EDM searches are performed with molecules, benefiting from the substantial intra-molecular electric field. At the Facility for Rare Isotope Beams (FRIB), we are building a new generation of EDM searches using ultracold molecules. This project will leverage the unique opportunity to access pear-shaped nuclei (e.g. ^{225}Ra) at FRIB, and the state-of-the-art technology in precision measurement and quantum control of polar molecules. The former further amplifies the Nuclear Schiff Moment thanks to the nuclear octupole deformation, and hence the sensitivity to hadronic **CP**-violation. The latter, built upon recent advances in atomic and optical physics, aims to bring the ^{225}Ra-containing molecules into

the ultracold regime, where both high phase-space density and seconds-long spin precession time have been demonstrated. With the nuclear enhancement and the quantum upgrades combined, this new project envisions to enhance the EDM sensitivity by orders of magnitude from the current best effort.

Abstract 298 at 4:30 PM

Session AR-NP-13 Tuesday 3:00 PM - West Fork I

Precision Measurements with Cavity QED and Molecules for Fundamental Physics

Edwin Pedrozo-Penafiel

Physics, University of Florida, Gainesville Florida, United States

The combination of cold ensembles of atoms and molecules with cavity QED can enable precision measurements that surpass the standard quantum limit. By generating exotic quantum states of molecules, we aim to explore quantum-enhanced measurements approaching the Heisenberg limit. This approach enables quantum-enhanced sensing in cold molecular systems to search for physics beyond the standard model. In this talk, I will present the advances in quantum-enhanced sensing techniques using cavity QED for enhanced metrology in atomic and molecular systems.

Abstract 50 at 3:00 PM

Session AR-NST-02 Tuesday 3:00 PM - Elm Fork II

Ion Bombardment of Carbon Targets and Beyond: Bridging Molecular Dynamics Simulations and Reduced-order Models

Huck Beng Chew, Huy Tran

Department of Aerospace Engineering, University of Illinois at Urbana-Champaign, Urbana IL, United States

Experiments report large scatter in the sputtering yield of carbon materials under the bombardment of low-energy noble gas ions, which has profound implications in estimating the lifetime of electric space propulsion systems. In this presentation, I will report recent results utilizing scale-bridging molecular dynamics (MD) simulations coupled with Monte Carlo (MC) approaches, to quantify the sputtering yield of carbon targets as a function of incident ion energy (75-2000 eV), angle (0-75 deg), and surface morphology, and to resolve uncertainties in the sputtering data.

Our MD simulations show rapid amorphization of the carbon subsurface with ion bombardment, but the structural characteristics (sp/sp2/sp3 bond proportion, atomic density) eventually plateau once steady-state sputtering is achieved. In addition, we obtain virtually indistinguishable "steady-state" amorphous structures across the range of ion energies and ion incidence angles, as well as for several different carbon structures, which suggests that the steady-state sputtering yield data from MD

simulations is independent of the initial carbon structure and prior sputtering history. We upscale our MD simulation results to a MC model to account for the evolving surface morphology and sputtering yield with ion fluence, by considering the shadowing of the incident ion flux, redeposition of sputtered carbon material, and secondary sputtering induced by the surface impact of carbon sputterants. Our MC results show that initially rough surface morphologies are consistently smoothened and flattened by a normal ion flux, resulting in sputtering yields that approach MD predictions. Under a highly oblique ion flux, however, the activation of multiple cooperative roughening and smoothening mechanisms at different scales lead to the formation of characteristic surface steps at the microscale, with steady-state sputtering yields that are up to an order-of-magnitude lower than MD predictions. While the observed surface features and the ensuing sputtering yield at steady-state are generally not sensitive to the initial surface morphology, the initial morphology controls the ion fluence to attain steady-state. The simulation results provide rich insights into surface design strategies to delay and abate sputtering.

Reduced-order analytical model have been proposed by Yamamura, Eckstein, and others, to quantify the sputtering yield for various ion-elemental target materials. Often, the parameters of these analytical formulas are phenomenologically calibrated to fit experimental or computational sputtering data. In concluding this presentation, I will highlight some of our group's efforts to achieve a data-driven, physics-informed reduced order model capable of predicting the sputtering yield of monoatomic solids induced by noble gas bombardment, directly from the physical and material properties of the ion/target system.

Abstract 30 at 3:30 PM

Session AR-NST-02 Tuesday 3:00 PM - Elm Fork II

Insights on silicon nanopatterning induced by low-energy surface bombardment

Alvaro Lopez-Cazalilla, Kai Nordlund, Flyura Djurabekova

Department of Physics, University of Helsinki, Helsinki Finland, Finland

Ion beams are commonly used in industry for composition control of semiconductors as well as for surface processing and thin film deposition. Under certain conditions, they induce from quantum dots to nanoripples. Different theories are proposed to explain the mechanisms that drive the self-reorganization of amorphizable surfaces. One of the prominent hypotheses associates the formation of nanopatterning with the changes in sputtering characteristics caused by changes in surface morphology. At ultralow energy, when sputtering is negligible, the Si surface has still been seen to reorganize forming surface ripples with the wave vector either aligned with the ion beam direction or perpendicular to it.

We investigate the insights of nanopatterning at low energy by means of computational methods in general, and more specifically using molecular dynamics (MD). These MD simulations were used as input for mathematical models with successful results [1,2], but also for direct observation of surface evolution under low energy ion impacts, allowing the visualization of nanopatterning computationally for the first time (3,4)In this work, we explore the formation of ripples in all three regimes of ripple formation: low angles where no ripples form, intermediate regime where the ripple wave vectors are parallel to the beam, and high angles where they are perpendicular to it. We obtain atom-level insight into how the ion-beam driven atomic dynamics at the surface contribute to the organization, or lack of it, in all the different regimes.

[1] A. Lopez-Cazalilla, D. Chowdhury, A. Ilinov, S. Mondal, P. Barman, S. R. Bhattacharyya, D. Ghose, F. Djurabekova, K. Nordlund, S. Norris, Pattern formation on ion-irradiated Si surface at energies where sputtering is negligible. J. Appl. Phys. 21, 123(23), 2018

[2] A. Lopez-Cazalilla A. Ilinov, K. Nordlund, F. Djurabekova, Modeling of high-fluence irradiation of amorphous Si and crystalline Al by linearly focused Ar ions, J. Phys.: Condens. Matter, 31, 075302, 2019

[3] A. Lopez-Cazalilla, F. Djurabekova, A. Ilinov, C. Fridlund, K. Nordlund, Direct observation of ion-induced self-organization and ripple propagation processes in atomistic simulations, Materials Research Letters, 8(3), 110-116, 2020

[4] A. Lopez-Cazalilla, K. Nordlund, F. Djurabekova, Formation of parallel and perpendicular ripples on solid amorphous surfaces by ion beam-driven atomic flow on and under the surface, Phys. Rev. Mater., 7(3), 036002, 2023

Abstract 48 at 4:00 PM

Session AR-NST-02 Tuesday 3:00 PM - Elm Fork II

A Simple Dynamical Model that Leads to Sputter Cone Formation

R. Mark Bradley[1], Nicholas L. Lehnerz[2]

[(1)]Departments of Physics and Mathematics, Colorado State University, Fort Collins CO, United States
[(2)]Department of Physics, Colorado State University, Fort Collins CO, United States

When a solid is bombarded with a broad ion beam and impurity atoms are deposited concurrently, a forest of identical nanoscale cones can emerge on its surface. We introduce a model for the formation of these so-called sputter cones that includes only the angular dependence of the sputter yield and a fourth-order smoothing effect like surface diffusion. In one dimension, a sputter cone is a particular kind of shock wave that is known as an undercompressive shock; there is a nearly discontinuous change in the surface slope at the center of the shock. Simulations of our model show that a wide variety of initial conditions lead to the

formation of sputter cones, and that the opening angle of the cones does not depend on the detailed form of the initial condition. In two dimensions, a sputter cone is a higher dimensional analog of an undercompressive shock. For two particularly simple choices of parameters, a sputter cone is a four-sided pyramid with rounded edges that is produced by the superposition of two orthogonal, one-dimensional undercompressive shocks.

Abstract 276 at 3:00 PM

Session MC-RD-01 Tuesday 3:00 PM - Post Oak

Accelerator-based radiation materials science for nuclear engineering

Lin Shao

Department of Nuclear Engineering, Texas A&M University, College Station Texas, United States

Upon neutron and particle irradiation, the created supersaturated point defects lead to extended defect formation and microstructural changes, eventually causing various material degradations that limit reactor performance. Irradiation responses of great concern for fission reactors include void swelling, irradiation hardening, corrosion, and creep. The past few decades have witnessed success in alloy development, enabling safe reactor operation and additional service time extension. On the other hand, material development for advanced reactors remains a technological bottleneck. Challenges arise from the extreme irradiation conditions and the synergistic effects of various phenomena. Accelerator ion irradiation serves as a surrogate for reactor neutron irradiation, introducing damage at a rate several orders of magnitude higher than a testing reactor. This talk will review the fundamentals of radiation materials science, with a particular focus on methodologies to reduce or avoid material failures. Topics include compositional engineering, grain engineering, and heterogeneous structure engineering. In the second half of the talk, the application of accelerators in radiation materials science is reviewed. Topics include the reliability and challenges of accelerator irradiation, and methods to close the gap between accelerator and reactor irradiation.

Bio

Lin Shao is Robert Cochran University Professor at Texas A&M University. He is also the director of the Accelerator Laboratory in the Department of Nuclear Engineering. He obtained his BS degree in Nuclear Physics from Peking University and his PhD in Physics from the University of Houston. Prior to joining Texas A&M University, he was a postdoctoral fellow at Los Alamos National Laboratory. His research interests are radiation materials science and accelerator-based ion beam processing. He is a fellow of the American Nuclear Society.

Abstract 208 at 3:45 PM

Session MC-RD-01 Tuesday 3:00 PM - Post Oak

Using ion beam irradiation as a surrogate for neutron displacement damage in microelectronics: Simple theory and equivalency considerations

Joshua Michael Young, Gyorgy Vizkelethy, Nick A. Asper, William R. Wampler, Barney L. Doyle, Edward S. Bielejec

Radiation-Solid Interactions, Sandia National Laboratories, Albuquerque New Mexico, United States

Understanding how electronics perform in extreme radiation environments is important for reliable and safe operations in commercial aviation, space exploration vehicles, satellites, and nuclear reactor or accelerator facilities. To understand the degradation in performance of these electronics and the fundamental physics mechanisms, neutron or ion irradiation must be performed as well as computational modeling coupled with device characterization. In this talk we discuss the use of ion irradiation to emulate neutron displacement damage in microelectronics. We begin with a brief facility overview of Sandia's Ion Beam Laboratory and highlight how we explore electronic degradation of transistors due to displacement damage. A theoretical background for displacement damage will be presented followed by practical considerations for converting between ion fluence to equivalent neutron fluence. We will analyze Si and wide bandgap device degradation due to ion irradiation, comparison to neutron irradiation, and correlation of damage metrics and equivalency. Finally, we show how simple models can be used to extract underlying physical processes for electronic device performance.

Bio

Josh Young is a Senior Member of the Technical Staff at Sandia National Laboratories. Josh received his B.S. in physics from Tarleton State University in 2015. He then continued to the University of North Texas where he received his M.S. (2017) and Ph.D. (2020), both in physics. In 2020, he took a post-doctoral appointment at Sandia's Ion Beam Laboratory where he continued on as a staff member. Currently, Josh is leading a wide variety of research tasks including efforts to understand the performance of commercial and custom electronics to various radiation environments. He is also involved in fundamental materials research to understand the role ionizing radiation plays in polymer degradation. When he's not at work, Josh enjoys time with his family, playing music at his local church, or enjoying a good history book.

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc., for the U.S. DOE's National Nuclear Security Administration under contract DE-NA-0003525. The views expressed in the article do not necessarily

represent the views of the U.S. DOE or the United States Government.

Abstract 91 at 9:00 AM

Session PS-PS-02 Wednesday 9:00 AM - Rio Grande Ballroom

Diagnostic development in MIT accelerator lab in support of advances in Inertial Confinement Fusion, including Ignition

Maria Gatu Johnson, Brandon Buschmann, Matt Cufari, Skylar Dannhoff, Audrey DeVault, Tucker Evans, Bryan Foo, Timothy Johnson, Justin Kunimune, Yousef Lawrence, Jacob Pearcy, Ben Reichelt, Lulu Russell, Niels Vanderloo, Joe Varchas, Chris Wink, Chikang Li, Richard Petrasso, Johan Frenje

Plasma Science and Fusion Center, Massachusetts Institute of Technology, Cambridge MA, United States

The student-run MIT High Energy Density Physics (HEDP) Accelerator Facility [1] is used to develop diagnostics in support of HEDP and Inertial Confinement Fusion (ICF) experiments at the OMEGA laser facility [2] in Rochester, NY, the Z machine [3] in Albuquerque, NM, and the National Ignition Facility (NIF) [4] in Livermore, CA, as well as for the Magnetic Confinement Fusion (MCF) SPARC facility [5] currently under construction in Devens, MA. Resources in the lab include a 125-keV ion accelerator, DT and DD neutron sources, and two x-ray sources for development and characterization of diagnostics. The accelerator generates DD and D^3He fusion products through the acceleration of D^+ ions onto a ^3He-doped Erbium-Deuteride target, with fusion product rates up to 10^6 s^{-1}. The DT and DD neutron sources generate up to $6{\times}10^8$ and $1{\times}10^7$ neutrons/s, respectively. One x-ray generator is a thick-target W source with a peak energy of 225 keV; the other uses Cu, Mo, or Ti anode tubes to generate peaked x-ray spectra with a maximum continuum energy of 40 keV.

Diagnostics developed and calibrated at this facility include CR-39-based mono-energetic particle radiography, charged-particle spectrometers, neutron detectors, and the particle Time-Of-Flight (pTOF) CVD-diamond-based bang time detector (see, e.g., [6,7]). As a particular example, the Magnetic Recoil neutron Spectrometers (MRS) [8], developed by MIT and installed at OMEGA since 2007 the NIF since 2010, have been providing yield, ion temperature, areal density and directional flow measurements helping guide the primary cryogenically layered DT campaigns at each facility to recent record performance [9,10], including the first-ever laboratory demonstration of fusion ignition in December 2022 [10].

This talk will include an account of the recent record-breaking ICF experiments at both the NIF and OMEGA. Next steps in ICF and MCF in the era of burning and igniting plasmas and a strong national push to realize the long-standing dream of fusion as an energy source will be discussed. These ground-breaking efforts will be viewed through the lens of student involvement through diagnostic development and data analysis, enabled by the MIT HEDP Accelerator Facility as an invaluable tool.

This work was supported in part by the U.S. Department of Energy NNSA MIT Center-of-Excellence under Contract DE-NA0003868, by LLNL under Contract B656484 and by LLE under Contract 417532G/UR FAO GR510907.
[1] N. Sinenian et al., Rev. Sci. Instrum. 83, 043502 (2012).

[2] B. M. Van Wonterghem et al., Fusion Sci. Technol. 69, 452-469 (2016).

[3] M.E. Cuneo et al., IEEETrans. Plasma Sci. 40, 3222 (2012).

[4] T. R. Boehly et al., Opt. Commun. 133, 495 (1997).

[5] P. Rodriguez-Fernandez et al., Nucl. Fusion 62, 042003 (2022).

[6] J.A. Frenje, Plasma Phys. Control. Fusion 62, 023001 (2020).

[7] M. Gatu Johnson, Rec. Sci. Instrum. 94, 021104 (2023).

[8] D.T. Casey et al., Rev. Sci. Instrum. 84, 043506 (2013).

[9] V. Gopalaswamy et al., Nature Physics (2024); https://doi.org/10.1038/s41567-023-02361-4

[10] H. Abu-Shawareb et al., Phys. Rev. Lett. 132, 065102 (2024).

Abstract 81 at 10:00 AM

Session AC-AF-01 Wednesday 10:00 AM - Elm Fork II

Recent Developments and Scientific Highlights at the FRIB Facility

Mauricio Portillo, Kei Fukushima, Marc Hausmann, Daid Kahl, Elaine Kwan, Peter Ostroumov, Brad M. Sherrill, Mallory K. Smith, Mathias Steiner, Oleg B. Tarasov, Tong Zhang

Facility for Rare Isotope Beams, Michigan State University, East Lansing MI, United States

The Facility for Rare Isotope Beams (FRIB) at Michigan State University is a Department of Energy Office of Science user facility that provides intense beams of rare isotopes for research in basic nuclear science and other societal applications. The current facility consists of a new superconducting linear accelerator and separator system to provide in-flight nuclear reaction products

from fragmentation and fission of primary beams. FRIB runs experiments with up to 10 kW primary beams and is progressing through a ramp-up process with the goal of providing about 400 kW before a high power target. Beam energies are about 200 MeV/u for uranium and higher for for lighter species. Central to the operation of FRIB is the Advanced Rare Isotope Separator (ARIS) which separates fast beams of rare isotopes and transports them to experiments. The target, beam dump and other components are designed with high radiation tolerance and remote capabilities. We will describe recent developments and scientific highlights with emphasis on rare isotope beam production using ARIS.

Acknowledgments:

This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics and used resources of the Facility for Rare Isotope Beams (FRIB) Operations, which is a DOE Office of Science User Facility under Award Number DE-SC0023633 and DE-SC0000661.

Abstract 192 at 10:25 AM

Session AC-AF-01 Wednesday 10:00 AM - Elm Fork II

Pioneering research in accelerator and beam physics: recent highlights and initiatives at Jefferson Lab's CASA

Amy Sy

Jefferson Lab, Newport News Virginia, United States

The Center for Advanced Studies of Accelerators (CASA) at Thomas Jefferson National Accelerator Facility (Jefferson Lab/JLab) is a diverse group of scientists and engineers dedicated to leading-edge research in accelerator and beam physics, with core expertise in recirculating linac and energy-recovery linac (ERL) design, operations, and upgrades; computational accelerator physics, including AI and machine learning; and advanced diagnostics R&D. This talk will highlight recent initiatives, including the two upgrades under study for JLab's Continuous Electron Beam Accelerator Facility (CEBAF).

Abstract 122 at 10:50 AM

Session AC-AF-01 Wednesday 10:00 AM - Elm Fork II

An overview of ongoing and prospective R&D activities at HiRES to advance MeV-UED instruments

Wei Liu, Dan Wang, Tianhuan Luo, Qing Ji, Gang Huang, Arun Persaud, Alexander Scheinker

Accelerator Technology and Applied Physics Division, Lawrence Berkeley national lab, Berkeley CA, United States

HiRES, the High Repetition-rate Electron Scattering apparatus, was designed for ultrafast electron diffraction. The HiRES beamline features a normal conducting VHF electron gun operating at 750 keV, with a frequency of 186 MHz and maximum RF power of 120 kW, capable of achieving RF field gradient ≥ 20 MV m^{-1}. HiRES serves as an ideal platform for advancing high-brightness electron beams technology and physics, but also a powerful tool for characterizing ultrafast structure dynamics in materials. In this meeting, we present our recent R&D activities conducted at HiRES. One notable advancement includes the design of a new cathode plug, which extends the capability of HiRES RF Gun by enabling a higher cathode electric field (> 25MV/m). This enhancement replicates the operational environment of the present LCLS-II injector and provides a testing platform for the development of ultra-low emittance cathode. Additionally, to enhance the MeV UED capability in condensed matter physics and material science, several approaches have been developed to improve temporal, spatial and reciprocal-space resolutions, which includes correction of temporal jitters and drifts, the implementation of nanoscale photoemission sources and collimation technique, as well as the incorporation of strong final focusing units for MeV electrons. To further enhance the beam stability for electron-based applied science and technologies, a global optimal control system has been developed. This system is based on RF-based timing tools and utilizes ML-based adaptive control.

Abstract 25 at 11:15 AM

Session AC-AF-01 Wednesday 10:00 AM - Elm Fork II

The Stewardship of the Nigerian Tandem Particle Accelerator: Preparing Ground for Expertise in Minerals Prospecting and Radiation Therapy

Felix Olise

Department of Physics and Engineering Physics, Obafemi Awolowo University, Ile-Ife Osun, Nigeria

The only Nigerian accelerator is a NEC 1.7 MV Pelletron type acquired in 2008 but upgraded to accommodate the second beam line equipped with NEC RC 43 end station in 2014. The end-station was designed and built at iThemba Labs, South Africa. The facility is located at the Centre for Energy Research and Development (CERD), Obafemi Awolowo University, Ile-Ife. This paper will briefly present the ion beam experiments-centred accelerator structure and its tested capabilities in terms of its applications in diverse research areas using the Particle Induced X-ray Emission (PIXE) spectrometry and Rutherford Backscattering Spectrometry (RBS) experiments. This paper discusses the need to explore heavy-ion PIXE experiments with a view to obtaining adequate cross-sections required for accurate quantitative analysis of PIXE spectra for applications in mineral prospecting and environmental pollution studies. Also, the possibility of the facility being used for neutron-yielding nuclear reaction experiments for the purpose of radiation therapy applications is discussed.

Abstract 89 at 10:00 AM

Session AP-IA-04 Wednesday 10:00 AM - West Fork II

The next evolutionary steps of the Rhodotron, introducing high power solid state amplification technology in the RF chain and digitalization of E-Beam and Xray systems.

Adam Gabriel

IBA industrial, Louvain-la-Neuve Wallonia , Belgium

Today large parts of the existing electron accelerator fleet battle two problems: The reliance on Tetrodes, Pentodes and Klystrons, a proven but dated technology to amplify RF power and a lack of proper data feedback and processing from its array of sensors. Mayor disadvantages of classical tube style amplifiers are the large expenditure in the manufacturing and maintenance of these systems during procurement and periodic replacement of tubes. An elegant solution enabled by the advances in solid state technology is the use of Solid State amplifiers which can replace old conventional tube type amplifiers. The second major problem of the current E-beam install base is that despite a large array of sensors and storage of collected data it is difficult to harvest and processed it to be used for monitoring, predicting maintenance as well as research and development. This presentation will introduce the IBA solid state driver amplifier used on its newest generation Rhodotrons and showcase its innovative design and many advantages as well as IBAs new digitalization of the Rhodotron that allows for the harvesting and processing of all data collected via the Rhodotron's ample sensory and logging devices.

Abstract 200 at 10:15 AM

Session AP-IA-04 Wednesday 10:00 AM - West Fork II

Reveam, Inc.'s Groundbreaking Application of Accelerator Systems to Treat Food Using their Patented Electronic Cold Pasteurization (ECP^{TM}) Process

Michael Paul Christofaro

Nuclear Engineering, Reveam, Inc., Norcross Georgia, United States

Reveam Inc. is a leader in the use of linear accelerators to enhance the safety and quality of fresh produce and other adjacent commodities. Using an electron beam treatment termed "Electronic Cold Pasteurization" (ECP™), Reveam has introduced the innovative use of this accelerator technology within the food processing sector. Reveam's first state-of-the-art facility, The Rio Grande Valley ECP™ Center in McAllen, TX, has been operational and providing commercial treatments for over 2 years. New in-house and collaborative studies are constantly revealing additional benefits to food irradiation, all while phasing out harmful chemical treatments such as methyl bromide.

Some of these results include:

Phytosanitary Control - Ensures the protection of produce and other items by preventing the introduction or proliferation of pests, through neutralizing or eliminating pest activity.

Pathogen Reduction - Effectively neutralizes and diminishes the presence of a broad spectrum of pathogens, including bacteria, fungi, viruses, and parasites.

Shelf-Life Extension - Extends the shelf life of various food products by inactivating spoilage organisms. Fresh produce, meats, and seafood benefit from increased longevity, reducing food waste and enhancing food security.

This presentation will provide an overview of the linear accelerator technology used during the food treatment process, highlighting the added benefits discovered along the way. It will address a spectrum of related topics pertinent to the accelerator community including dosimetry, regulatory compliance concerning both radiation and food safety, material handling, and the broader utilization of accelerator systems in industry. The goal is to impart knowledge about Reveam's contributions to the attendees, fostering further progress in accelerator technology and its myriad applications. This endeavor aims to showcase the tangible outcomes of research and industry collaboration, thereby stimulating ongoing dialogue and innovation within the field.

Abstract 215 at 10:30 AM

Session AP-IA-04 Wednesday 10:00 AM - West Fork II

The impact of recent advances in accelerator sterilization and irradiator systems on cost, adoption, and availability.

Marcos Ruelas, Sergey Kutsaev, Amirari Diego Lopez, Robert Berry

RadiaBeam, Santa Monica CA, United States

Recent political, environmental, and market forces have prompted advances in accelerator-based sterilization and irradiator systems. Several institutions are pursuing miniaturization to allow for cabinet or in-line irradiation, bridging the gap between small-scale keV lab irradiation and high-power contract sterilization. Meanwhile, cost-streamlining efforts aim to increase the adoption of accelerator-based irradiation. On the other hand, National Laboratory-led efforts in industrializing superconducting linacs promise beam powers that rival the highest-power commercial sources in a smaller footprint. Finally, re-thinking of beam

delivery systems can offer similar dose distributions in a smaller, more cost-effective footprint. In this presentation, we survey several of these advances and their impact on the future of sterilization, food irradiation, and disinfestation.

Abstract 189 at 10:55 AM

Session AP-IA-04 Wednesday 10:00 AM - West Fork II

Toward Use of Low Energy Electron Beams for Sterilization

Leonard S Fifield, Mark K Murphy

Pacific Northwest National Laboratory, Richland WA, United States

Most single use medical devices today are sterilized using ethylene oxide gas. Of devices sterilized using ionizing radiation, nearly 90% are processed using Cobalt-60 gamma radiation. As the need for sterilization capacity increases, attention has been growing on use of machine-based alternative radiation technologies including electron beam and X-ray. Low energy electron beam could even be an alternative to ethylene oxide such as for use in-line or end-of-line during product assembly prior to multi-unit packaging. Such an approach to irradiation using low energy electron beam is attractive because it could enable high throughput, reduce transportation costs, and require significantly less power and shielding footprint than necessary for higher energy radiation infrastructure.

Team Nablo, funded by the National Nuclear Safety Administration Office of Radiological Safety and led by the Pacific Northwest National Laboratory, is lowering barriers to use of machine-based radiation for sterilization of medical and biopharmaceutical products by filling knowledge gaps in the relative material effects of alternative technologies. In recent work, Team Nablo directly investigated the relative effects of electron beam energy on the material properties of a series of medical device polymers. Effects at the standard 10 MeV of high energy electron beam processing were compared to those of 4 different electron beam energies below 5 MeV. Data from this effort and other Team Nablo research into the effects of dose rate, temperature, and oxygen atmosphere is being made freely available to the medical device industry to support increased use of accelerators for sterilization.

Abstract 173 at 11:10 AM

Session AP-IA-04 Wednesday 10:00 AM - West Fork II

Effects of Radiation-Driven Changes in Physical Properties of Polymers

Matt Pharr

Mechanical Engineering, Texas A&M University, College Station TX, United States

Stemming from security threats and shortages in supply, a recent push has emerged to transition from radioisotope Cobalt-60 gamma treatment (e.g., for sterilization) of polymers towards machine-based sources, such as electron beam (e-beam) and X-ray. However, before large-scale implementation, the effects of these non-isotope-based methods must be thoroughly investigated from several perspectives, including their potential effects on the structural, thermal, and mechanical properties of the polymers. This talk will discuss our recent experimental studies in this regard in several polymers used in the medical device industry. This talk will also cover recent efforts in using e-beam technologies for the remediation of polymer waste, e.g., for steps in the recycling and upcycling process of polymers. For instance, e-beams can deposit electrons, which can be used in polymer "sorting"; can be used to functionalize surfaces of materials (e.g., by altering bond makeup), which can be used for valorization and compatibilization into composites; and can even provide additional utility in the recycling/remediation process itself (e.g., sterilization, cross-linking, strengthening). e-beam technologies are thus ripe for widespread application in "sorting" for polymer recycling as well as in upcycling processes, e.g., "compatibilization" for integration into infrastructure applications, which will be overviewed in this talk. Overall, this talk will provide valuable insight into radiation-driven chemical and structural changes in polymers that produce changes in physical and functional properties.

Abstract 18 at 10:00 AM

Session AR-NP-11 Wednesday 10:00 AM - West Fork I

The $^{13}C(\alpha,n)^{16}O$ differential cross section

James deBoer

Physics and Astronomy, University of Notre Dame, Notre Dame IN, United States

During helium burning during the asymptotic giant branch phase, the slow neutron capture is fueled by (α,n) reactions mainly on ^{13}C, but reactions on $^{17,18}O$ and $^{25,26}Mg$ may also contribute. Here on earth, radioactive decays from long-lived actinides produce a constant source of α-particles, which then capture on ^{13}C and $^{17,18}O$ producing a constant source of neutrons. The flux is low, but can create a significant background for ton scale neutrino, dark matter, and double beta-decay experiments. In this talk I will focus on a study of the $^{13}C(\alpha,n)^{16}O$ differential cross section that we performed at the University of Notre Dame Nuclear Science Laboratory (NSL). The measurements map out the cross section in approximately 10 keV energy steps at 18 angles between 0 and 160 degrees, resulting in over 700 distinct energy data points. I'll discuss the unique capabilities of the NSL's 5U accelerator setup that allowed for such a measurement in a relatively short amount of beam time of just two weeks.

Abstract 40 at 10:20 AM

Session AR-NP-11 Wednesday 10:00 AM - West Fork I

Measuring the cross section of the $^{15}N(\alpha,\gamma)^{19}F$ reaction using a single-fluid bubble chamber

David Neto[1,2]

[(1)]Physics, University of Illinois Chicago, Chicago IL, United States
[(2)]Physics Division, Argonne National Laboratory, Lemont IL, United States

$^{15}N(\alpha,\gamma)^{19}F$ is believed to be the primary means of stellar nucleosynthesis of fluorine. In this talk, I will present the results of a novel experiment using a single-fluid bubble chamber to measure the cross section of the time-inverse photo-dissociation reaction. This method benefits from a luminosity increase of several orders of magnitude due to the use of a liquid target and from the reciprocity theorem. In a joint experiment between Argonne National Lab and Thomas Jefferson National Accelerator Facility, a superheated fluid of C3F8 was exposed to bremsstrahlung γ-rays produced by impinging a 4 - 5.5 MeV electron beam on a Cu radiator. The cross section for the inverse reaction $^{19}F(\gamma,\alpha)^{15}N$ was extracted from the photodissociation yield by convolution with a Monte Carlo-generated γ-ray beam spectrum. After applying the reciprocity theorem, a cross section for the 15N(α,γ)19F reaction was determined down to hundreds of picobarns. This method is general enough to be applied to measurements of other radiative capture reactions. I will briefly summarize potential future experiments with the Argonne bubble chamber.

Funding Acknowledgment: This work was supported by the US Department of Energy, Office of Nuclear

Physics, under Contracts No. DE-AC02-06CH11357 (ANL) and No. DE-AC05-06OR23177 (JLAB).

Abstract 115 at 10:40 AM

Session AR-NP-11 Wednesday 10:00 AM - West Fork I

Progress Towards a Single Atom Microscope (SAM) for Nuclear Astrophysics

Karina Martirosova[1], Erin White[1], Nicholas Koester[1], Benjamin Mellon[1], Roberto Hernandez[2], Jaideep Taggert Singh[1]

[(1)]Department of Physics, Michigan State University, East Lansing MI, United States
[(2)]Department of Physics, University of Southern Florida, Tampa FL, United States

Development of a detector that is efficient, selective and sensitive at the single atom level is necessary for the measurement of low yield nuclear reactions that are relevant for nuclear astrophysics. These low yield reactions may be due to either very low cross-sections or low beam intensity. We are developing the single atom microscope (SAM) technique to study the 22Ne(α, n)25Mg reaction, which is an important source of neutrons for the s-process. The s-process in stars forms approximately half the

atomic nuclei heavier than iron through neutron capture. This particular reaction is challenging to measure as it requires low background and high selectivity to distinguish the products from the intense unreacted beam. Therefore, as a proof-of-principle measurement, we are aiming to study the 84Kr(p, γ)85Rb reaction first, which plays a role in the p-process in stars. The SAM technique works by first capturing reaction products in a cryogenically frozen noble gas film and then detecting product atoms by laser induced fluorescence via a CCD camera. We will report on our progress towards demonstrating single atom sensitivity, which is feasible due to the large shift between the excitation and emission wavelengths. This work is supported by U.S. National Science Foundation under grant number #1654610 and is based upon wok supported by the Department of Energy National Nuclear Security Administration through the Nuclear Science and Security Consortium under Award Number DE-NA0003996.

Abstract 42 at 11:00 AM

Session AR-NP-11 Wednesday 10:00 AM - West Fork I

Measuring the ^{88}Sr(α, n)^{91}Zr reaction cross section with Accelerator Mass Spectrometry

Maria Anastasiou, Wei Jia Ong, John Wilkinson, Scott Tumey, Shree Neupane, Kay Kolos

Lawrence Livermore National Laboratory, Livermore CA, United States

Supernovae, the explosive conclusion to nuclear burning in massive stars, dominate contributions to the early galactic abundance of the elements. Different astrophysical scenarios, under which supernovae seed the early galaxy with elements heavier than iron, are still being investigated. Of particular interest are the lighter heavy elements from Sr to Ag with their origin being placed in the neutrino-driven ejecta in core-collapse supernovae. While the **s**- and **r**- process have been perceived for years as the dominant mechanisms for the formation of heavier elements, more recent studies support that in particular the elements from Sr to Ag are synthesized via (α, n)-reactions or the so-called "**weak**" **r**-process. Sensitivity studies have shown that (α, n) reaction rates of these lighter heavy nuclei indeed play a crucial role in predicting their abundances, suggesting the need of experimental data to constrain the uncertainties on those rates and thus the abundance predictions. The ^{88}Sr(α, n)^{91}Zr reaction has been identified among the key processes that impact these abundances with no experimental data currently available. At the Center for Accelerator Mass Spectrometry of Lawrence Livermore National Laboratory, we measure this reaction using a combination of target irradiation and Accelerator Mass Spectrometry (AMS). This talk focuses on the development of the experimental methods and the preliminary data obtained.

LLNL-ABS- 850354: This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Abstract 49 at 11:20 AM

Session AR-NP-11 Wednesday 10:00 AM - West Fork I

First measurements with the Enge split-pole spectrometer at the Notre Dame Nuclear Science Lab (NSL)

D.W. Bardayan[1], S. Carmichael[1], P.D. O'Malley[1], T. Bailey[1], C. Boomershine[1], M. Brodeur[1], S. Coil[1], C. Dembski[1], T. Gore[1], C.R. Jones[1], J. Koros[1], K. Lee[1], J. McDonaugh[1], G. Mulcahy[1], S. Porter[1], F. Rivero[1], D. Robertson[1], J. Rufino[1], A. Sanchez[1], E. Stech[1], W.W. von Seeger[1], R. Zite[1], P. Magro[2]

(1)University of Notre Dame, Notre Dame IN, United States
(2)University of Sao Paulo, Sao Paulo Sao Paulo, Brazil

Explosive nucleosynthesis occurs in a number of astrophysical environments including novae, supernovae, and X-ray bursts. Reactions on unstable nuclei critically determine the properties of these astrophysical explosions but are difficult to measure directly owing to the relatively low intensities of these at current-generation radioactive beam facilities. An alternative approach is to gain sufficient knowledge of the relevant nuclear structure so that the astrophysical reactions rates can be estimated using indirect techniques. A Enge split-pole spectrometer has recently been commissioned at the NSL to perform such nuclear structure studies. The first measurements focused on a study of ^{58}Cu of importance to the ^{57}Ni(**p**,γ)^{58}Cu reaction and production of ^{44}Ti in supernovae. The device capabilities, commissioning studies, and first results will be presented.

Research sponsored by the National Science Foundation and the University of Notre Dame.

Abstract 113 at 10:00 AM

Session AR-RE-03 Wednesday 10:00 AM - Elm Fork I

Using Cryo-Ionoluminescence to Differentiate the Electronic and Nuclear Origins of Emission Bands in Strontium Titanate

Joseph Graham[1], Miguel Crespillo[3], William Weber[2], Fernando Agullo-Lopez[4]

(1)Department of Nuclear Engineering and Radiation Science, Missouri University of Science and Technology, Rolla Missouri, United States
(2)Department of Materials Science and Engineering, University of Tennessee, Knoxville, Knoxville Tennessee, United States
(3)Department of Nuclear Engineering, University of Tennessee, Knoxville, Knoxville Tennessee, United States
(4)Centro de Microanálisis de Materiales, Universidad Autonoma de Madrid, Madrid Madrid, Spain

Strontium titanate (STO) is an oxide with remarkable electrical and optical properties, especially at cryogenic temperatures. A 3.15 eV emission band has been observed in low energy ion irradiated STO, electron-doped STO, reduced STO, and stoichiometric STO irradiated under high power continuous laser irradiation. Several authors have suggested a defect-related origin to the emission band but have also commented on the possible importance of electronic excitation. Recently, cryo-ionoluminescence studies were performed with 3 MeV H, 19 MeV Si, and 19 MeV Cl ion beams below 100 K. Emission kinetics have ruled out a defect-related origin of the 3.15 eV band but confirm the correlation with high electronic excitation density. A model is proposed where the emission is connected to the formation of large electron-polarons.

Abstract 268 at 10:25 AM

Session AR-RE-03 Wednesday 10:00 AM - Elm Fork I

He implantation and radiation effects on coatings for fusion applications

Marta Malo[1], Alejandro Moroño[1], Elisabetta Carella[1], Marcelo Roldán[1], Guillermo de la Cuerda[1,2,3], Iole Palermo[1], Fernando Sánchez[1], Raquel Gonzalez-Arrabal[3], Sebastiano Cataldo[4], Andrea Stinchelli[5], Fabio Di Fonzo[5]

(1)National Fusion Laboratory- Fusion Technology Division, CIEMAT, Madrid Madrid, Spain
(2)Instituto de Fusión Nuclear Guillermo Velarde, ETSI Industriales , Universidad Politécnica de Madrid, Madrid Madrid, Spain
(3)Dpto. Ingeniería Energética, ETSI Industriales , Universidad Politécnica de Madrid, Madrid Madrid, Spain
(4)ENEA, Brasimone Bologna, Italy
(5)Italian Institute of Technology and X-nano, Milan Milan, Italy

The development of multi-functional coatings to mitigate tritium permeation and corrosive effects in fusion reactor structural materials is crucial, especially for reactor designs using liquid PbLi as tritium breeding material. Within the Eurofusion program, efforts are underway to develop mainly alumina and silicon carbide based coatings. Evaluating the stability of these coatings under extreme fusion conditions, particularly radiation effects, is essential. One of the main concerns is the He accumulation and bubble formation, which not only might alter the tritium transport properties but also might induce microstructural modification, swelling and general degradation of the coating. Alpha particles are produced in the fusion materials by inelastic (n, α) interactions at a concentration depending on the neutron spectrum. In alumina, Li diffusion into the coatings after exposure to PbLi has been observed [1], potentially leading to enhanced He production upon nuclear transmutation. He bubble formation in certain types of alumina and silicon carbide due to the limited He diffusion and low desorption rate even at high temperatures has been predicted or experimentally observed (2-4)The validation of the coatings for fusion applications thus requires the evaluation of the impact of He generation inside the coatings, taking into account interaction with tritium and general coating performance. For this, He implantations at fusion relevant conditions of temperature and dose will be carried out for two different proposed alumina and silicon carbide based coating compositions at the Ciemat 60 kV Danfysik ion implanter and the 5 MV Tandem Ion accelerator at the Centre for Micro Analysis of Materials (CMAM) in Madrid. He bubble formation in these coatings will be verified by TEM and/or SEM. The interaction of He with H isotopes will be also evaluated at available permeation and desorption facilities at CIEMAT including RIPER (permeation facility attached to a 2 MV Van de Graaff electron accelerator [5]). The He/H accumulation effects will be correlated with macroscopic properties such as resistance to thermal cycles or adherence.

[1] R. GonzÁlez-Arrabal et al., Characterization of the lithium concentration and distribution as a function of depth for alumina coatings after exposure to PbLi, J. Nucl. Mater. 586 (2023) 154688

[2] Nuclear Instruments and Methods in Physics Research B 216 (2004) 149-155

[3] R. Harrison et al., Damage microstructure evolution of helium ion irradiated SiC under fusion relevant temperatures, J. Eur. Ceram. Soc. 38 (2018) 11

[4] L. Pizzagallia, M. L. David, Atomistic simulations of a helium bubble in silicon carbide, J. Nucl. Mater. 531(3) (2020) 151990

[5] P. Muñoz et al., RIPER: An irradiation facility to test Radiation Induced Permeation and release of deuterium for fusion blanket materials Fus. Eng. Des. 145 (2019) 66-71

Abstract 136 at 10:50 AM

Session AR-RE-03 Wednesday 10:00 AM - Elm Fork I

Review on the state of knowledge of neutron and gamma radiation effects on concrete

Elena Tajuelo Rodriguez[1], Yann Le Pape[1], Nishant Garg[2], William Hunnicutt[5], Lawrence Anovitz[1], Aniruddha Baral[4], Jan Ilavsky[3], Ercan Cakmak[1], Hongbin Sun[1], Paula Bran[1], Adam Brooks[1], David Arregui[1]

(1)ORNL, Oak Ridge TN, United States
(2)University of Illinois at Urbana Champaign, Urbana IL, United States
(3)Advance Photon Source, ANL, Lemont IL, United States
(4)Sheffield University, Sheffield, United Kingdom
(5)Columbia University, New York NY, United States

The energy demand in the US and antropogenic climate change make nuclear energy a key player in the near future. The life prolongation of light water reactors by the approval of second licence renewals has opened several questions regarding the effects of radiation at extended operation in all plant components such as metals, cables and concrete. Concrete, composed by cement paste and aggregates (rocks sourced from local quarries to construction sites) constitutes the biological shield surrounding reactor pressure vessels. Aggregates are mainly affected by neutron radiation that causes amorphization of minerals, while cement paste is more affected by gamma rays which cause radyolisis of water in cement hydrates. Both types of radiation have effects in the structure, mechanical and physical properties of both cement paste an aggregates. A review on the state of knowledge on neutron effects on aggregates and gamma rays on cement paste will be discussed. Links between doses, mineralogical composition of aggregates, and changes in properties will be made.

Abstract 183 at 11:15 AM

Session AR-RE-03 Wednesday 10:00 AM - Elm Fork I

Elucidating Radiation-Induced Degradation in Siliceous Minerals in Concrete via Multi-modal Imaging

Nishant Garg

Civil and Environmental Engineering, University of Illinois Urbana-Champaign, Urbana IL, United States

Deteriorating nuclear infrastructure escalates the need for accurate characterization of radiation damage in various structural components of a nuclear power plant, including the concrete biological shield (CBS). Exposure of concrete in CBS to neutron radiation induces damage from cracking and residual stresses caused by radiation-induced volumetric expansion (RIVE). In the literature, most studies have investigated irradiation damage in pure and single-phase minerals, however, the RIVE behavior of multi-phase polycrystalline materials such as granite (present in concrete aggregates) is not entirely understood. Here, we investigate granite samples with Si^{2+} ions to mimic neutron radiation and deploy a detailed multi-modal imaging approach to understand RIVE. Specifically, we use chemical (Raman imaging, laser spectroscopy, scanning electron microscopy) and mechanical (nano-indentation) techniques to create information-rich hypermaps of the pristine and irradiated surfaces of mineral phases. Using this multi-imaging dataset, we elucidate that the RIVE and associated mechanical properties of the siliceous minerals gradually deteriorate with increasing radiation exposure. These experimental results, in combination with simulations of RIVE, enhance our understanding of mineral-specific responses to nuclear radiation.

Abstract 282 at 10:00 AM

Session MC-NE-01 Wednesday 10:00 AM - Post Oak

Electrical Power from Nuclear Fission: A Tutorial for Conventional and Advanced Reactors

Peter Hosemann

Departments of Nuclear Engineering and Mechanical Engineering, University of California at Berkeley, Berkeley CA 94720, United States

Currently, nuclear power contributes approximately 18% of the United States' electricity production, with 94 operational power reactors. For the past 60 years, nuclear fission has provided substantial benefits, and today, more advanced nuclear reactor concepts are being developed for the future. But how is electricity generated from fission, and why is there a push to develop new reactor concepts? What differentiates thermal and fast reactors, and how is the heat produced that eventually transforms into electricity?

This lecture will cover the fundamental concepts of nuclear fission as it stands today and explore the various types of reactors that have operated in the past and are operational now. Additionally, we will discuss historical issues that have occurred in nuclear power plants and the lessons learned to improve the design and safety of future plants. Furthermore, we will discuss how accelerators can play a vital role to help address the issues associated with nuclear power generation.

About Speaker:

Peter Hosemann is Professor in the Department for Nuclear Engineering and Mechanical Engineering at the University of California Berkeley and director of Manufacturing 360 research center and the associated shared user facility. Professor Hosemann received his PhD in Material Science from the Montanuniversität Leoben, Austria in 2008 while he conducted the research on lead bismuth eutectic corrosion, ion beam irradiations and microscale mechanical testing was carried out at Los Alamos National Laboratory. He continued his research at Los Alamos National Laboratory and joined the UC Berkeley faculty in 2010. Professor Hosemann has authored more than 300 per reviewed publications since 2008. In 2014 he won the best reviewer of the journal of nuclear materials award, the ANS literature award and in 2015 he won the TMS early career faculty fellow award and the AIME Robert Lansing Hardy award, was awarded the E. S. Kuh Chair of the college of Engineering at UCB and won the TMS-Brimacombe medal 2022.

Abstract 70 at 10:00 AM

Session SN-OM-06 Wednesday 10:00 AM - Trinity Central

CAIS AMS Status Report

Gurazada Ravi Prasad

Center for Applied Isotope Studies, University of Georgia, Athens GA, United States

The CAIS AMS facility has two particle accelerators for Accelerator Mass Spectrometry(AMS) of radiocarbon: a 500 kV

NEC CAMS and a 250 kV NEC SSAMS. AMS measurements are offered as a service to academic researchers in the fields of geology, archaeology etc. and also to the industry dealing with natural and bio-based products. While the SSAMS unit has been operating last couple of years without major issues, we had faced some issues with the CAMS unit which caused longer than the usual down time. There were issues with the sample indexer, a failed turbopump inside the accelerator tank and a leak in the injection magnet chamber. These issues and the fixes will be presented during the status report presentation.

Abstract 135 at 10:20 AM

Session SN-OM-06 Wednesday 10:00 AM - Trinity Central

Control System Upgrade for ANSTO's 2MV STAR Tandetron Accelerator

JIAN WANG, David Button, Andrew Dones, Matthew Rees, Michael Mann

Center for Accelerator Science, Australia Nuclear Science and Technology Organisation (ANSTO), Lucas Heights NSW, Australia

ANSTO's STAR Accelerator is a 2MV Tandetron facility which primarily preforms IBA techniques, and was commissioned in 2004.

STAR consists two duoplasmatron sources, one for hydrogen, and other for helium, and has solid target Cs sputter 846B source formally used for AMS carbon 14 measurements.

The Original Control System C14OS was supplied by the manufacturer, and deployed on a Windows NT platform, interfacing to the accelerator via a PLC digital I/O and PC based analogue I/O with field telemetry units interconnected with Plastic Optic Fiber (POF). The operating system has previously been upgraded to "New C14OS" deployed on a Windows XP platform, with the original control system code redeveloped on Visual Studio 2008 from Visual Studio 6 in 2010. The original control system hardware has been experiencing failures, and become difficult to support, which has made it necessary to replace both the computer control system and the field telemetry units with a modern solution.

The new STAR Control System uses EPICS with control interfaces built in Control System Studio, with field hardware based on Beckhoff PLC platform, with machine controls implemented in TwinCAT interconnecting nodes with terminals connected to devices via EtherCAT.

This presentation will provide an overview and current status of the replacement control system development and installation.

Abstract 206 at 10:40 AM

Session SN-OM-06 Wednesday 10:00 AM - Trinity Central

Center for Accelerator Mass Spectrometry Status Report

John Wilkinson

Center for Accelerator Mass Spectrometry, Lawrence Livermore National Laboratory, Livermore California, United States

The Center for Accelerator Mass Spectrometry (CAMS) houses three accelerators, a 1 MV compact AMS system, a 1.7 MV 5SDH microprobe, and a 10 MV FN tandem. A report on recent activities within CAMS labs will be presented.

Abstract 228 at 11:00 AM

Session SN-OM-06 Wednesday 10:00 AM - Trinity Central

Lab update and future neutron facilities at AWE

David Wright, Bill Tominey

AWE Aldermaston, Reading Berkshire, United Kingdom

We present a brief overview of facility upgrades and recent work at AWE's fast neutron capability, ASP, in addition to perspectives on the successor facility VENOM (Variable Energy Neutron Output Machine).

ASP is an electrostatic accelerator producing deuterium ion beams since commissioning in 1964. ASP is an aging facility that has undergone a modernisation programme in the past decade. We give updates on recent activities at the facility.

We discuss the multi-disciplinary challenges facing the VENOM project, which is underway to enable AWE to deliver a fast neutron capability in the years to come. The concept's neutron field will have a variable peak energy, utilising multiple neutron generating reactions, high brightness of up to 10^{13}n/cm^2/s, will consist of two irradiation cells, in addition to an accelerator mass spectrometer (AMS).

Abstract 180 at 1:00 PM

Session AC-AF-05 Wednesday 1:00 PM - Elm Fork II

Recent Scientific and R&D Highlights from Brookhaven's Accelerator Test Facility (ATF)

Mark Palmer[1], Navid Vafaei-Najafabadi[1,2], Igor Pogorelsky[1], Mikhail Fedurin[1], Mikhail Polyanskiy[1], William Li[1], Dismas Choge[1], Marcus Babzien[1], Karl

Kusche[1], Andrew Simmonds[1], Kelly Roy[1], Thomas Ilardi[1], Mark Peniera[1]

(1)Accelerator Science and Technology Department, Brookhaven National Laboratory, Upton NY, United States
(2)Department of Physics and Astronomy, Stony Brook University, Upton NY, United States

The Accelerator Test Facility (ATF) at Brookhaven National Laboratory is a DOE Office of Science User Facility supported by the DOE Office of Accelerator R&D and Production. It provides its users with 3 major beam capabilities: 75 MeV high brightness electron beams, multi-terawatt long-wave infrared (LWIR) laser beams, and near infrared (NIR) laser beams. These capabilities can be used individually or in any combination by users. Over 20 active experimental efforts in advanced accelerator and laser research are presently underway. Recent research highlights and plans for further R&D at the facility are described.

Abstract 160 at 1:30 PM

Session AC-AF-05 Wednesday 1:00 PM - Elm Fork II

The Argonne Wakefield Accelerator (AWA) facility and recent advances in two-beam acceleration

Xueying Lu[1,2], Chunguang Jing[1], Philippe Piot[1], John Power[1]

(1)Argonne National Laboratory, Lemont IL, United States
(2)Northern Illinois University, DeKalb IL, United States

The Argonne Wakefield Accelerator (AWA) at Argonne National Laboratory is an accelerator test facility dedicated to fundamental research on advanced accelerators, with a focus on wakefield acceleration and its applications in compact accelerators for future colliders and light sources. The AWA's 65 MeV electron beamline is equipped with an L-band photocathode capable of generating the world's highest bunch charge for research and development on advanced accelerator concepts, beam physics and diagnostics, and beam production. In this presentation, I will provide an overview of the AWA facility and highlight some of our research and development achievements. As an example, I will discuss one area of research with major recent advancements on the concept of short-pulse two-beam acceleration.

Abstract 247 at 2:00 PM

Session AC-AF-05 Wednesday 1:00 PM - Elm Fork II

Cable installation management for the Advanced Light Source Upgrade (ALS-U) Project

Adrien Talon, Daniela Leitner, Elliot Newman, Christopher Bullock, Andrew Lodge, Priyanka Gupta

Advanced Light Source Upgrade, Lawrence Berkeley National Laboratory, Berkeley California, United States

Since the ALS was commissioned in 1993 it has developed into a premier user facility for soft X-rays. The 43 existing beamlines service more than 2,100 annual users with light capabilities extending from infrared to hard X-rays. The ALS-U project will provide a soft X-ray source that is up to 1,000 times brighter than today's capabilities, while generating a significantly higher fraction of coherent light in the soft X-ray region than is currently available at the ALS.

The project has two primary objectives: to replace the existing Storage Ring (SR) with a new high performance multi-achromat ring, and to add a new Accumulator Ring (AR) which is necessary to precondition the beam from the injector complex prior to injection into the storage ring. For the majority of the circumference, the AR and SR are independent machines that occupy separate areas within the tunnel. Therefore, the AR can be installed prior to the extended 12 months facility shutdown when the SR and all of its associated electronics will be replaced.

This contribution is focused on the first phase of the installation, the AR, which is currently in progress at LBNL. Both the AR and SR consist of 12 sectors each with a sector consisting out of a straight section and a curved section that makes up the ring. While the curved sections of the AR sectors are functionally identical, the equipment in the straights changes based on accelerator need. In the planned upcoming summer maintenance shutdown of the ALS, a first article installation of the cable support structures, cable trays and cables will occur in sector 8. For the first time for ALS-U, enabling complete electrical integration of an AR sector, from electrical racks to tunnel equipment. The tools used to understand and manage the cable plant are described in this work. The sector-based layout is the main structure of the cable management tools which will be described in more detail below. Since the two accelerators are installed during different installation phases, the cable plants are designed to be as independent from each other to the greatest extent. The AR equipment database consists of approximately 4,000 cables, the SR database consists of 11,000 cables. The current cable database management system consists of collecting design documents, cable input sheets, termination information and specifications from technical subsystems and stakeholders. These input sheets are then submitted to a single cable management group that collects these input sheets and designs the overall routing from the racks to the individual devices. This group is also responsible for routing the cables, ensuring code compliance and gaining approvals from the electrical safety group at the laboratory.

Excel spreadsheets, google sheets, AutoCAD files and many other document formats are currently used to track the cable details. The dispersed documentation requires extensive manual checking by the installation team preparing installation kits and documentation for the cable pulls and terminations to ensure accuracy of the data.

Therefore, the cable installation team has started to implement a solution to collect and present that data in a systematic way. This contribution is describing the pilot program for the installation of a small portion of the cable plant in sector 8. It consists of approximately 50 cables which is a small enough scope to manually verify and develop workflows that will eventually be scaled up to the fully automated cable plant. A commercially available routing tool is being trialed that is connected to our central PLM system. Between the adjusted workflow and automated routing method, a standardized set of cable definitions, installation work instructions, test reports and commissioning reports will be developed. The ultimate goal for the database is to be a web-based tool that allows an installation, operation or maintenance user to call up cable information through QR code based tagging.

Following the initial first article effort, lessons learned will be reviewed and will feed into the final cable management system for the remaining AR sectors and full SR installation.

Abstract 10 at 1:00 PM

Session AP-IA-05 Wednesday 1:00 PM - Trinity Central

High Energy Sources Development and Production at Varex Imaging Corporation

Andrey V Mishin

High Energy Sources (LINAC) R&D and ABC Production, Varex Imaging Corpopation, SALT LAKE CITY UT, United States

Varex Imaging Corporation has become an independent public company in January 2017 (NASDAQ: VREX), with its Headquarters located in Salt Lake, after its separation from Varian Medical. Eight months earlier, Varian Medical honored me by acquiring my two LLCs and hiring me in a role of a Senior Director; the primary objective for me was set to establish the linac beam centerline production at future Varex, eventually replacing Varian as a supplier of their Beam Centerlines (BCL). We now use abbreviation "ABC" for Accelerator Beam Centerlines as our new products. We have reported our progress on ABC and linac systems earlier, and it is our pleasure to update all of you and the charged particle accelerator community on our further progress in our linac design work and production, thanks to the Session Chair Dr. Ted Cremer for the invitation. Over past 7 years, we were able to build an A+ team of nearly 30 superb Varex professionals, who are responsible for many advances and our overall success - we completed design of many various ABC prototypes, in process of moving them to production, and our production rate reached a mix of 16 ABC per month for security, NDT and medical applications, so we can claim substantial completion the original objective. Among our recent advances, I would list some improvements in our ABC performance, which, from time to time, exceed some features of the predecessor products. We modified our Solid-State Modulator (SSM) system to include our own produced Triode Electron Gun Driver (TEGD) and the ABC with a Triode Electron Gun (TEG), hence expanding the performance range and adding some features combining "High" and "Low" output linacs, for example. The system is being moved to production, currently. The record small beam spot we obtained in our TEG-based 6 MeV ABC is 0.8 mm (compared to the common 1.5 mm), which might substantially improve image quality. We will continue to work on the spot reduction. Now we are working on finalizing the 3 MeV and 9 MeV production

prototypes, while redesigning our K-15 system from operating frequency of 2856 MHz, used by the predecessor, to a common 2998 MHz used for all our other ABCs. This linac will have a higher average electron beam power (hence, higher dose rate) capability for high power target testing and operation and it may become our High-Power Platform (HPP) for other systems and applications. As usual, I would like to honor memory of my late mentors, colleagues, and friends Dr. Igor Shchedrin, Russell Schonberg, Hank Deruyter, Dr. Ted Roumbanis, others. I will always treasure their invaluable contributions and mentorship, and I devote any and all my achievements to them.

Abstract 219 at 1:30 PM

Session AP-IA-05 Wednesday 1:00 PM - Trinity Central

Fast and Thermal Neutron Imaging for Industrial Radiography with Neutron Generators

David Williams, Jay Theodore Cremer, Charles K Gary, Eugene Guan, Randall Urdahl, Craig Brown, Melvin Piestrup

Adelphi Technology, Inc., Redwood City California, United States

Adelphi Technology manufactures neutron sources and has performed experimental imaging measurements using scintillation-based detectors (digital cameras that image large area scintillators) to demonstrate the suitability of these neutron generators to imaging. For imaging, a high yield (neutrons per second) and small neutron emission spot size (a few millimeters), are key parameters that influence the achievable resolution. Coupling Adelphi's neutron generators with varied neutron detectors, images have been produced that demonstrate the capabilities of these systems. Measurements of the resolution, using USAF 1951 resolution standards have been compared with modulation transfer function (MTF) analysis to illustrate the performance of these systems.

The advantage of the neutron-based technique over X-rays is the ability to image "low-Z" (such as hydrogenous) materials, resolution can be determined by using a plastic resolution phantom object, examples being the USAF 1951 standard and also the Siemens star/spoke target.

Adelphi Technology, Inc. manufactures high yield neutron generators which can be used for neutron imaging applications. Neutron energy choices include: 14.1 MeV fast neutrons arising from the Deuterium-Tritium (D-T) reaction, 2.45 MeV fast neutrons arising from the Deuterium-Deuterium (D-D) reaction and Thermal (0.025eV) neutrons which are typically generated by moderating 2.45 MeV neutrons. Adelphi's products range from 10^8 n/s to $2x10^{10}$ n/s for D-T, D-D and Thermal neutron generators.

The radiographic contrasts obtained by 14.1 MeV Fast Neutron Radiograph (FNR) are similar to those obtained with high-energy X-ray and gamma-ray radiography and in general are smaller than

those achieved with thermal neutron radiography. However, unlike with X-ray and gamma-ray radiography, the broader contrast latitude allows low-atomic-number materials to simultaneously be observed with heavier metals.

Adelphi Technology has been developing miniature, portable D-T neutron generators, which could have applications in neutron radiography and also Associated Particle Imaging. A small neutron source enables the possibility that the neutron imaging system can be taken to an object rather than the object being brought to the imaging system. This allows for the possibility of imaging structures allowing the technique to be used for non-destructive testing.

Abstract 309 at 2:00 PM

Session AP-IA-05 Wednesday 1:00 PM - Trinity Central

High Resolution Lens-coupled MeV X-Radiography of Dense Additively Manufactured Objects

N. J. Cherepy[1], D. Schneberk[1], Z. M. Seeley[1], S. A. Payne[1], C. McNamee[1], Paul Carriere[2], Robert Berry[2], Jarvis Caffrey[3]

[(1)]Lawrence Livermore National Laboratory, Livermore CA, United States
[(2)]Radiabeam, Santa Monica CA, United States
[(3)]NASA, Huntsville CA, United States

Additive manufacturing techniques are being extended to refractory metals and other metals capable of operating in high-temperature environments. Many of these metals are higher-Z and high density necessitating higher X-ray inspection energies. 3D volumetric lens-coupled X-ray computed tomography (X-ray CT) has emerged as a strategic inspection choice for these parts. The internal channels and features are often complicated and can articulate in spiral configurations for longer chord lengths that are difficult to inspect in a single or ensemble of radiographs. In particular, it is the entire 3D structure of the part that is of interest not just one or two locations in the volume. At the same time, 3D printing is extending the spatial resolution limits for small, manufactured details as well as defects, such as porosity. CT inspection requirements for these parts include resolution down to 0.1 mm at MeV energies. In this context, properties of the GLO transparent ceramic scintillator (Gd0.3Lu1.6Eu0.1O3): high-stopping power, high-brightness, high transparency in large area plates combined to produce high intrinsic spatial resolution, which could be pivotal for delivering 3D inspections of these parts. Radiabeam has configured an area-detector CT camera-scintillator system employing GLO (other scintillators have been used in this system) in combination with the Radiabeam ARCIS LINAC (adjustable from 2-9 MeV). A variety of AM-fabricated refractory metal components have been scanned at 7.8 MeV, providing robust transmitted signal for high density parts with 2-3" chord lengths, in parts that are up to 6 inches in diameter. Lens-coupled X-ray CT using a transparent scintillator imaged on a sCMOS camera obtains higher spatial resolution than the more commonly employed phosphor-enhanced amorphous silicon (A-Si) panels. The result is higher contrast imaging due to increased stopping

power. Interior features of the additively manufactured components have been resolved down to a voxel size of 80 microns. Inspection data from this system with representative AM parts will be reviewed and evaluated.

This work was supported by the US DOE, Office of NNSA and was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Abstract 96 at 1:00 PM

Session AR-NP-12 Wednesday 1:00 PM - West Fork I

Advances in mass spectrometry towards the r-process path at TITAN-TRIUMF

Anna Kwiatkowski[1,2]

[1] TRIUMF, Vancouver BC, Canada
[2] University of Victoria, Victoria BC, Canada

As production of the most neutron-rich nuclides, including those involved in the rapid-neutron-capture or r-process, has advanced, the challenges have increased: decreasing half-life, dwindling production cross-sections, and increasing contamination. Meeting this increasingly difficult challenges had been at the forefront of the technical upgrades at TITAN-TRIUMF, which is best known for ion-trap-based mass spectrometry. In this talk, I will describe how the Multi-Reflection Time-Of-Flight mass separator (MR-TOF) surmounts these obstacles and has, as such, become the tool of choice for such measurements. These r-process mass surveys from Ga (Z=31) to Tm (Z=69), including many first-time determinations. I will present a selection of recent results.

Abstract 55 at 1:20 PM

Session AR-NP-12 Wednesday 1:00 PM - West Fork I

Precision mass measurements with the Canadian Penning Trap for the astrophysical r-process

Adrian A Valverde[1], Maxime Brodeur[2], Jason A Clark[1], Biying Liu[1,2], W Samuel Porter[2], Dwaipayan Ray[1,3,4], Guy Savard[1,6], Kumar S Sharma[3], Nicole Vassh[4], Daniel P Burdette[1], Aaron T Gallant[5], Daniel E.M. Hoff[5], Alicen M Houff[2], Kay Kolos[5], Filip G Kondev[1], Gail C McLaughlin[7], Graeme E Morgan[8,9], Matthew R Mumpower[11], Rodney Orford[10], Fabio Rivero[2], Daniel Santiago-Gonzalez[1], Nicolas D Scielzo[5], Rebecca Surman[2], Louis Varriano[1,6]

[1] Physics Division, Argonne National Laboratory, Lemont IL, United States
[2] Department of Physics & Astronomy, University of Notre Dame, Notre Dame IN, United States

[3]*Department of Physics & Astronomy, University of Manitoba, Winnipeg MB, Canada*
[4]*TRIUMF, Vancouver BC, Canada*
[5]*Nuclear and Chemical Sciences Division, Lawrence Livermore National Laboratory, Livermore CA, United States*
[6]*Department of Physics, University of Chicago, Chicago IL, United States*
[7]*Department of Physics, North Carolina State University, Raleigh NC, United States*
[8]*Department of Physics & Astronomy, Louisiana State University, Baton Rouge LA, United States*
[9]*Physics Division, Argonne National Laboratory, Lemont IL, United States*
[10]*Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley CA, United States*
[11]*Theoretical Division, Los Alamos National Laboratory, Los Alamos NM, United States*

Understanding the astrophysical **r**-process requires nuclear data about neutron-rich nuclei far from the valley of stability; key among these are nuclear masses. The Canadian Penning Trap (CPT) has recently finished a decade-long campaign at the CARIBU facility, measuring over 200 nuclei produced through the spontaneous fission of ^{252}Cf. This has focused on masses that are of interest to the formation of the rare-earth peak, exhausting those that are available from CARIBU (1,2,3)The next step for the CPT's studies is to continue this experimental program after reassembly at the N=126 Factory, where multi-nucleon transfer reactions will produce nuclei further from stability at rates that make Penning trap mass measurements possible. Measurements at the N=126 Factory will begin with masses of interest for the formation of the heaviest **A~195 r**-process abundance peak, but will also extend the CPT's rare earth peak campaign farther from stability.

This work is supported in part by the U.S. Department of Energy, Office of Nuclear Physics, under Contract No. DE-AC02-06CH11357; by NSERC (Canada), Application No. SAPPJ-2018-00028; by the National Science Foundation under Grant No. PHY-2310059; by the University of Notre Dame; and with resources of ANL's ATLAS facility, an Office of Science User Facility.

[1] R. Orford, N. Vaash **et al.**, PRL 120 262702 (2018)

[2] R. Orford, N. Vaash **et al.**, PRC 105 L052802 (2022)

[3] D. Ray, PhD thesis, University of Manitoba (2022)

Abstract 124 at 1:40 PM

Session AR-NP-12 Wednesday 1:00 PM - West Fork I

Creating New Isotopes at FRIB for Experiments in Nuclear Astrophysics

Mallory K. Smith, Marco Cortesi, Salvatore Di Carlo, Kei Fukushima, Marc Hausmann, Daid Kahl, Elaine Kwan, Brad M. Sherrill, Mathias Steiner, Oleg B. Tarasov

Facility for Rare Isotope Beams, Michigan State University, East Lansing MI, United States

"Creating New Isotopes at FRIB for Experiments in Nuclear Astrophysics"

M. K Smith, M. Cortesi, S. DiCarlo, K. Fukushima, M. Hausmann, D. Kahl, E. Kwan, B. M. Sherrill, M. Steiner, O. B. Tarasov

The Facility for Rare Isotope Beams (FRIB) is a DOE scientific user facility supporting research in broad areas of science, including nuclear astrophysics. FRIB began operation in 2022 following the commissioning of the FRIB linear accelerator and Advanced Rare Isotope Fragment Separator (ARIS). Currently, FRIB is using primary beams of up to 10 kW to produce rare isotope beams and is steadily advancing toward the design goal of 400 kW. Thousands of new, highly rare, isotopes will become accessible as FRIB upgrades its power. Studies of previously unobtainable neutron-rich nuclei will enable a new era for nuclear astrophysics, with structure, reaction and decay measurements for nucleosynthesis pathways. Recent experiments have already pushed the envelope of discovery, with five new isotopes confirmed in an experiment last year (Tar24)These results indicate the potential of FRIB to allow future experiments around N=126 and with lighter r- and i-process nuclides. Creating and characterizing these new isotopes depends on ARIS's ability to deliver well-separated isotope beams with the required energy, rate, purity and momentum for each particular experiment. ARIS comprises a two-part separator with a system of magnets, slits, wedges and degraders. Secondary beams are produced from fragmentation of a chosen primary beam, from oxygen up to uranium, and soon, from in-flight fission of uranium. ARIS then relies on a system of detectors for optics validation and fragmentation identification. This talk will provide an overview of ARIS and its use, focusing on the recently observed new isotopes and an outlook on future nuclear astrophysics research capabilities.

[Tar24] O.B. Tarasov et al., Phys. Rev. Lett. 132 (2024) 072501

Abstract 126 at 2:00 PM

Session AR-NP-12 Wednesday 1:00 PM - West Fork I

Experimentally Constrained ^{93}Sr(n,γ)^{94}Sr Cross Section via the Surrogate Reaction Method

Andrea Richard[1,2], Richard O. Hughes[2], Daniel Yates[3], Gregory Hackman[3], Reiner Kruecken[3,4], Jutta Escher[2], Gregory Potel[2]

(1)*Department of Physics and Astronomy, Ohio, Athens OH, United States*
(2)*Nuclear and Chemical Sciences Division, Lawrence Livermore National Laboratory, Livermore CA, United States*
(3)*TRIUMF, Vancouver BC, Canada*
(4)*Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley CA, United States*

Neutron-capture cross sections play a vital role in our understanding of heavy element nucleosynthesis. In astrophysical processes such as the intermediate neutron-capture process, or **i**-process, element formation occurs in neutron-rich environments and involves short-lived isotopes for which capture cross sections cannot be measured via direct techniques. Instead reaction rates in these regions rely on calculations that have uncertainties up to a few orders of magnitude. Recent measurements of the β-decay of ^{94}Rb, which compared the neutron-to gamma-ray-branching ratio of state decays above the neutron separation energy in ^{94}Sr, suggest an enhanced γ-ray branch which would in turn lead to an unexpectedly large ^{93}Sr(n,γ)^{94}Sr cross section. If confirmed, such an enhancement could have a strong impact on our understanding of **i**-process nucleosynthesis involving nuclei in this region. In order to investigate this potential enhancement of the ^{93}Sr(n,γ)^{94}Sr cross section and its impact on the **i**-process, an experiment was performed at TRIUMF using an 8 MeV/u ^{93}Sr beam impinging on a CD_2 target. ^{93}Sr(d,pγ)^{94}Sr coincidence data was measured using the SHARC and TIGRESS arrays. Experimental details from the measurement of ^{93}Sr(d,pγ)^{94}Sr will be presented along with preliminary ^{93}Sr(n,γ)^{94}Sr analysis using the Surrogate Reaction Method. Implications for **i**-process nucleosynthesis will also be discussed.

Abstract 190 at 1:00 PM

Session AR-NST-06 Wednesday 1:00 PM - West Fork II

Development of diamond platforms for quantum sensing by ion implantation

Luca Basso[1], Pauli Kehayias[2], Jacob Henshaw[1], Jasmine J. Mah[1], Gajadhar Joshi[1], Khalifa M. Azizur-Rahman[1], Michael Titze[3], Ed Bielejec[3], Tzu-Ming Lu[1], Michael P. Lilly[1], Andrew M. Mounce[1]

(1)*Center for Integrated Nanotechnologies, Sandia National Laboratories, Albuquerque NM, United States*
(2)*MIT Lincoln Laboratory, Lexington MA, United States*
(3)*Sandia National Laboratories, Albuquerque NM, United States*

Magnetic microscopy with high spatial resolution is crucial for a wide range of diverse applications, such as failure analysis of integrated circuit, characterization of microwave devices, and biomagnetism. Magnetometry based on Nitrogen-Vacancy (NV) centers in diamond represents a powerful tool, as it provides micron-scale resolution, millimeter-scale field of view, high sensitivity, and non-invasive magnetic field imaging compatible with a large variety of samples. However, integrating diamond-based platforms with other devices consistently and efficiently remains challenging. Single-crystal, color-center-enriched, nanoscale-thick diamond membranes could serve as crucial layers in heterostructure devices, with applications ranging from

nanophotonics to quantum sensing. Traditional methods for membrane production involve "smart-cut," where a diamond is implanted with He^+ ions to form a graphitized layer beneath the surface, which is then etched to lift off the resulting thin membrane. However, this process is time-consuming due to the high ion flux fluence required.

In this talk, I will show our results in the production of diamond membranes through Ne^+ implantation of a diamond substrate, resulting in membranes approximately 300 nm thick. Various Ne^+ flux fluences are tested to determine the graphitization threshold and the implanted diamonds as well as the resulting membranes are fully characterized. Compared to He^+ smart-cut, we demonstrate that utilizing a heavier ion like Ne^+ reduces fabrication time tenfold without compromising membrane quality.

Finally, I will give an overview on our recent advances in using NV centers for wide-field imaging of magnetic fields, in particular on the different quantum sensing experiments we have developed for imaging both DC and AC magnetic fields up to GHz frequencies.

SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525

Abstract 279 at 1:30 PM

Session AR-NST-06 Wednesday 1:00 PM - West Fork II

Nanofabrication of Josephson Junctions with Focused Helium Ion Irradiation

Shane Andrew Cybart

Electrical and Computer Engineering, UC Riverside, Riverside California, United States

Our group at UC Riverside has been utilizing the gas field ion source (GFIS) for direct patterning of ceramic high-temperature superconductors (HTS) and conventional metal low temperature superconductors (LTS) for quantum electronics. The helium ion beam induces nanoscale disorder from irradiation into the material which disrupts superconductivity and converts the electrical properties of the material from superconductor to normal metal and insulators (in the case of HTS). Josephson junctions with critical dimension sizes of less than 2nm have been successfully demonstrated and many unique novel devices have been realized, such as magnetic field sensors and digital logic. In this talk I will compare and contrast the irradiation properties of HTS and LTS and highlight some of the digital circuits, magnetic field sensors and high frequency devices demonstrated by our group.

Abstract 227 at 2:00 PM

Session AR-NST-06 Wednesday 1:00 PM - West Fork II

Ultra-low energy ion implantation as a powerful tool to create new nanostructures within 2D materials

Kenizhiro Mizohata[1], Wael Joudi[2], Alberto Trentino[2], Georg Zagler[2], Manuel Längle[2], Rabia Nawaz[1], Patrick James[1], Clemens Mangler[2], Kimmo Mustonen[2], Toma Susi[2], Jani Kotakoski[2], Harriet Åhlgren[1,2]

(1)Department of Physics, University of Helsinki, Helsinki, Finland
(2)Department of Physics, University of Vienna, Vienna, Austria

Ions with ultra-low energies in the range of few hundred eV's all the way down to thermal energies, offer a versatile method to modify the atomic structure of low dimensional materials. In this work, we show how the atomic structure of 2D material is functionaliszed using ion implantation directly into the 2D framework employing a deceleration setup in a conventional 500 kV ion implanter. The created nanostructures can be selectively designed by controlling the implantation energy, element, dose and sample configuration showcasing atomic scale control in the in-plane and out-of-plane directions. Implantation at ultra-low energies offers a powerful tool to create functional nanostructures for applications in single atom catalysis, optoelectronics and quantum photonics.

The ions can be embedded within a monolayer of graphene, creating covalently bound individual dopants as well as size controlled dispersed nanoparticles anchored in graphene vacancies (1,2)We demonstrate the approach across the periodic table [3], extending it to heavier atomic species that otherwise would not stop in the thin target due to inefficient momentum transfer that stems from the large mass difference between the projectile and the target atoms.

Moreover, we can achieve implantation directly into the van der Waals gap between two monolayers of graphene [4] indicating implantation accuracy in the range of few nm in the depth direction. By trapping the ion in the van der Waals gap, we create crystalline noble gas clusters with atomically flat 2D structures that are supported by the strong graphene network. The unique 2D frame that encapsulates the clusters allows direct imaging with a scanning transmission electron microscope offering an atomic scale view into the material.

[1] E. H. Åhlgren et al., Phys. Rev. B **83**, pp. 115424 (2011)

[2] Trentino et al., 2D Materials **9**, pp. 025011 (2022)

[3] Trentino et al. accepted, Micron (2024)

[4] Längle et al. Nature Materials (2024), https://doi.org/10.1038/s41563-023-01780-1

Abstract 106 at 1:00 PM

Session AR-RE-04 Wednesday 1:00 PM - Elm Fork I

Synergistic irradiation-thermomechanical loading with integrated strain mapping capability

Dave Lunt[1,2], Thomas Hughes[2], Laurence Skidmore[2], Samir de Moraes Shubeita[3], Ben Poole[1], Chris Hardie[1], Philipp Frankel[2], Ed Pickering[2], Cory Hamelin[1], Allan Harte[1]

[(1)]UK Atomic Energy Authority, Culham Campus Abingdon, United Kingdom
[(2)]Department of Materials, University of Manchester, Manchester Greater Manchester, United Kingdom
[(3)]Dalton Cumbrian Facility, University of Manchester, Whitehaven Cumbria, United Kingdom

Nuclear materials performance under synergistic irradiation-temperature-stress environments is the primary component life-limiting factor to account for in materials qualification; this environment is known to have a significant impact on materials, leading to changes in microstructure, composition and mechanical performance. However, there is a lack of understanding on the impact that this harsh environment will have on the structural integrity of candidate materials for nuclear fusion devices. Testing in a synergistic environment provides a realistic assessment of the expected in-service performance, reducing over-conservatism in component design. Here, we highlight the recent commissioning of an in-situ ion irradiation-thermal-mechanical materials testing capability at the UK's Dalton Cumbrian Facility and the novel methods we have developed to quantify the resulting deformation and damage at multiple length scales. The main goal of these experiments is to understand the difference between the synergistic response and more traditional sequential testing campaigns, with a focus on irradiation-enhanced creep as a critical failure mode to capture for timely qualification of high temperature structural materials for nuclear fusion power plant build. Here, we present a summary of the overall capability and preliminary commissioning experiments along with set ups and patterning methodologies for multi-scale digital image correlation to facilitate high fidelity model validation at multiple length scales and under representative loading conditions. Additionally, there will be an introduction to potential round-robin testing campaigns with other facilities with similar and complimentary capabilities to validate different experimental methodologies.

Abstract 134 at 1:30 PM

Session AR-RE-04 Wednesday 1:00 PM - Elm Fork I

Developing synergistic irradiation-thermomechanical testing capability

Laurence Skidmore[1], Dave Lunt[2], Thomas Hughes[1], Adeel Shaikh[3], Aidan Cole-Baker[3], Edd Pickering[1], Philipp Frankel[1]

[(1)]Department of Materials, University of Manchester, Manchester Greater manchester, United Kingdom
[(2)]UK Atomic Energy Association, Manchester Greater Manchester, United Kingdom
[(3)]Jacobs, Warrington Cheshire, United Kingdom

An in-situ ion irradiation and tensile mechanical loading frame has been developed in collaboration with The University of Manchester, the UK Atomic Energy Authority and rig developers at NewTec. This enables through-thickness in-situ proton mechanical tests on samples up to 150 μm in thickness.

In situ irradiation mechanical testing aims to better replicate the conditions that will likely be experienced by structural materials within nuclear reactors. This may lead to an improved mechanistic understanding of material deformation under irradiation for reactor core and near core structural components. After the irradiation tests, Digital Image Correlation (DIC) will be used as an approach to assess strain localisations at the micro and macro scales.

Abstract 150 at 1:50 PM

Session AR-RE-04 Wednesday 1:00 PM - Elm Fork I

Multimodal characterization of radiation and transmutation extremes in SNS components

Timothy Gerald Lach, Maxim Gussev, Kinga Unocic, David McClintock

Oak Ridge National Laboratory, Oak Ridge TN, United States

Simultaneous high-energy proton and spallation-neutron irradiation induce microstructural and mechanical responses in structural materials that are unique from fission/fusion neutrons or accelerator-based ion beams. The target module and proton beam window (PBW) at the Spallation Neutron Source (SNS) at Oak Ridge National Laboratory (ORNL) are irradiated in these unique environments during operation. In addition to recoil damage up to about 10-15 displacements per atom (dpa) at moderately low component temperatures (100-120°C), transmutation reactions produce large levels of helium (up to ~190 appm/dpa) and hydrogen (up to ~740 appm/dpa). To maintain proper spallation neutron production and potentially extend component lifetime, accurate understanding of the radiation-induced changes to the microstructure and mechanical properties is essential, with particular focus here on the transmutation gas interactions. Mechanical tensile testing with digital image correlation has shown that the materials in these components have interesting and potentially unique behaviors not found in other radiation environments. The 316L stainless steel target module material deforms via deformation waves with little martensite transformation, and the solution-annealed alloy 718 PBW materials experience recovery of ductility with increasing radiation dose. To investigate these interesting phenomena further, specimens from these materials were characterized using a multitude of microstructural and microanalytical characterization techniques including scanning transmission electron microscopy (STEM) with energy dispersive x-ray spectroscopy (EDS) and electron energy loss spectroscopy (EELS), thermal desorption

mass spectrometry (TDS), differential scanning calorimetry (DSC), and in-situ scanning electron microscopy (SEM) heating and tensile testing.

In the as-irradiated condition, both the 316L and 718 materials exhibit a high density of nanometer-size cavities. These cavities were assumed to contain both He and H, similar to the cavities found in metals and alloys that have a high He/H concentration after triple-beam ion irradiation or neutron irradiation and transmutation, with H appearing on the periphery of He-filled bubbles. However, the results show that the cavities did not necessarily contain both gasses after the low temperature irradiation, as only H was observed by STEM-EELS. To understand why this is the case and to examine the stability of the transmutation gas/defect complexes and their effect on mechanical properties, the materials were characterized using multiple different methods before and after post-irradiation annealing. TDS and DSC experiments were used to gain insights into the types of defects that are present and how the gasses are stored in the materials. DSC experiments have previously shown that a large amount of stored energy from irradiation is present in defects that are too small to be seen by TEM. Here, the radiation-induced stored energy - difference between energy released during first scan and subsequent annealed scans - are strongly correlated with the radiation damage and H and He levels and recrystallization of amorphized phases. This correlation may help explain why there is an increase in radiation ductility with increasing dose in the PBW 718 material. With the DSC results in mind, post-irradiation annealing microstructural characterization and mechanical testing revealed that the nanocavities retain relatively stability to high temperatures and are highly pressurized - enhancing dislocation emission during straining and thus work hardening. It is only after high temperature annealing above 500 °C that the cavities grow large enough to see the core-shell structure of hydrogen around helium. These results show that there could be a critical size and a critical concentration at which the core-shell gas-filled cavities form, as the number density of cavities dropped but the size increased.

Abstract 281 at 1:00 PM

Session MC-VAC-02 Wednesday 1:00 PM - Post Oak

Ultra-High Vacuum Seminar: Part 2 of 2 Session Series

John Screech

Vacuum Products Division, Agilent Technologies, Santa Clara CA, United States

This class provides further details into the challenges in achieving ultra-high vacuum (UHV) pressure. Session two will delve into the inter-relationship of pumping technologies used from primary vacuum to UHV, system troubleshooting techniques, and material selection. The curriculum for session two of this 90 minute class is excerpted from Agilent's one-day UHV Seminar and is intended to provide an introduction to ultra-high vacuum systems and practice for scientists, engineers and technicians. Attendees will receive a printed copy of the slide deck and are encouraged to add notes to this useful resource.

Abstract 267 at 9:00 AM

Session PS-PS-03 Thursday 9:00 AM - Rio Grande Ballroom

Accelerator Production of Medical Radionuclides

Cathy Sue Cutler, DMITRI Medvedev, VANESSA Sanders, JASMINE Hatcher Lamarre, DOHYUN Kim

Isotope Research and Production Department, Brookhaven National Laboratory, Upton NY, United States

In 1931 Ernest Lawrence invented the cyclotron and with it the ability to produce radioactive isotopes of interest for biological applications. Since that time major advances have enabled the production of small compact cyclotrons to be installed at hospitals and pharmacies enabling the supply of short-lived radionuclides around the world. This and the development of the generator allowed for remote access to radionuclides and the expansion of nuclear medicine. In the 1970's and 80's major accelerator facilities operating at 100 MeV and higher were installed in many of the national labs and used for production of radionuclides at energies and currents not available on the small compact machines. These high energy accelerators have played an important role in supplying Radionuclides such as Sr-82 used in Sr/Rb generators for cardiac imaging and Ac-225 for cancer therapy. They continue to be advanced to further production yields by installing beam rastering systems that have allowed higher intensities and thus higher production yields. As well as adding mass separation techniques that enable novel radionuclides to be produced in quality suitable for use. Recently electron accelerators have become available and new means for harvesting isotopes produced from large accelerators. These enhanced accelerator capabilities and the production of these novel radionuclides will be presented.

Abstract 68 at 10:00 AM

Session AA-IBTM-02 Thursday 10:00 AM - Post Oak

Elemental Quantification of Carbon Nanotube (CNT) Pellicles for EUV Lithography Applications

Masoud Dialameh[1], Quan Bai[1,2], Niels Claessens[1,2], Yide Zhang[1], Marina Y.Timmermans[1], Fabian Holzmeier[1], Johan Meersschaut[1,2]

[(1)]imec, Leuven, Belgium
[(2)]Quantum Solid State Physics, KU Leuven, Leuven, Belgium

High-volume chip manufacturing utilizing extreme ultraviolet (EUV) lithography necessitates protecting the photolithography mask from fall-on particles (1)An effective solution has been demonstrated by positioning a protective free-standing carbon nanotube (CNT) pellicle a few millimeters in front of the reflective photomask. It significantly mitigates the defect formation on the reticle while keeping the retained stray particles

out of focus and preserving the EUV transmission above 90% (2)The composition, density, and bundle size of CNTs are being tuned to optimally withstand the harsh operating environment within the EUV scanner (3)However, achieving the suitable CNT pellicle requires accurate characterization, presenting a significant metrology challenge due to the nanometric thinness of these membranes.

In this work, we focus on the application of Rutherford backscattering spectrometry (RBS) for the analysis of CNT pellicles. We demonstrate that RBS enables to accurately quantify the elements in the CNT pellicles, including light elements such as C and N, and even B for the case of coated pellicles. Furthermore, we illustrate that the RBS-derived quantification can be employed to estimate the EUV transmission of CNT pellicles.

The quantification of light elements in nanometer-thin self-supporting foils using RBS is associated with multiple challenges. The first challenge relates to the low backscattering cross-section for light elements. This, combined with the nanometric thickness of CNT pellicle, results in an extremely low count rate. The second challenge pertains to the presence of the low-energy background signal which we have identified as originating from multiple scattering. As a third challenge, we identify the unwanted C growth on the sample surface when it is exposed to an ionizing beam. The C growth interferes with the initial C areal density of the CNT pellicles. Finally, we discuss the difficulty to accurately measure the beam fluence and the concern of inducing ion-beam damage to the CNT pellicles.

To address the challenges, we developed an experimental setup for the RBS analysis of the CNT pellicles. The sample is mounted on a manipulator which does not block the transmitted beam, and the beam-stop is geometrically hidden to the detectors; the set-up incorporates a multidetector system to increase the detector solid angle [4]; the scattering chamber is engineered to reach high vacuum conditions of better than 3 E-8 mbar; and extra measures are implemented to suppress the low energy background. The reported advancements enable elemental quantification in the CNT pellicles with an improved sensitivity, e.g. 3.4×10^{12} atoms/cm^2 for Fe, and a high repeatability, < 0.8% for Fe at $\sim4\times10^{15}$ atoms/cm^2. Besides the experimental advancements, we also developed a procedure to accurately quantify the initial areal density of C and its associated uncertainty.

The results obtained with the new RBS setup on CNT pellicles will be contrasted to that obtained using a standard RBS setup and a ToF-E elastic recoil detection. We will also compare the RBS approach with X-ray photoelectron spectroscopy (XPS).

Finally, we demonstrate that the areal densities determined with RBS can be used to estimate the EUV transmission at λ = 13.5 nm. We found a good agreement between calculated EUV transmission based on the RBS and that directly obtained from an EUV transmission measurement. The RBS analysis provides distinct information about the elemental-specific absorption of EUV light. For this, RBS has become a valuable tool to support the development of CNT pellicles to be used in the EUV lithography technology.

References

[1] P.J. Van Zwol, **et al.** "Pellicle films supporting the ramp to HVM with EUV." **Photomask Technology 2017**, SPIE 10451 (2017).

[2] M.Y. Timmermans, **et al.** "Free-standing carbon nanotube films for extreme ultraviolet pellicle application." **Journal of Micro/Nanolithography, MEMS, and MOEMS** 17.4 (2018).

[3] M.Y. Timmermans, **et al.** "Carbon nanotube EUV pellicle tunability and performance in a scanner-like environment." **Journal of Micro/Nanopatterning, Materials, and Metrology** 20.3 (2021).

[4] G. Laricchiuta, **et al.** "High sensitivity Rutherford backscattering spectrometry using multidetector digital pulse processing." **Journal of Vacuum Science & Technology A** 36, 2 (2018).

Abstract 263 at 10:25 AM

Session AA-IBTM-02 Thursday 10:00 AM - Post Oak

Investigating hydrogen in nanoscale transition metal hydrides with high-energy ion beams

Kristina Komander, Gunnar K. Pálsson, Max Wolff, Daniel Primetzhofer

Physics and Astronomy, Uppsala University, Uppsala, Sweden

Hydrogen, a renewable and eco-friendly energy carrier, holds significant promise for various energy applications.The formation of transition metal hydrides provides versatile hydrogen storage solutions, supporting fuel cell technologies as well as superconducting materials (1)In the crystalline phase, hydrogen occupies specific interstitial sites. Nanostructuring can enhance reaction kinetics and reduce the enthalpy of formation, making these materials suitable for practical applications (2)Also, fully amorphous transition metal alloys recently gained attention as potential storage materials.

For both material systems, ion beams offer distinctive real-space detection to assess concentration and spatial distribution through elastic and inelastic interactions. In particular, highly energetic ^{15}N-ion beams, selectively sensitive to hydrogen in materials, allow direct concentration measurements and depth profiling via nuclear reaction analysis (NRA) and due to the loss of kinetic energy (3)We investigated the effect of hydrogen absorbed in amorphous V_xZr_{1-x} thin films on the electronic energy deposition of ^{15}N-ions, addressing the lack of experimental reference data hindering the accuracy of the analytical technique. The energy loss increases linearly with hydrogen content, validating the use of Bragg's additivity rule for a wide range of materials with large storage capacity up to ~2 H/M. This finding paves the way for novel methods to gauge hydrogen concentration with an estimated sensitivity to >10^{22} H-atoms/cm^3 indirectly via Rutherford backscattering spectrometry (RBS) employing various ion species across a broader range of facilities [4].

Furthermore, we explored the influence of finite size, interfaces, and strain on hydrogen absorption in two-dimensional single-crystalline nanostructures using Fe(Cr)/V-superlattices as model systems. Ion channelling experiments with ^{15}N-NRA combined with Monte-Carlo simulations reveal hydrogen site occupations and thermal vibrational motion [5], while calibrated optical transmission measures pressure-concentration isotherms and simultaneous resistivity measurements detect changes in the order of hydrogen indicative of phase transformations. We find strong evidence that the proximity to Fe introduces a more extensive non-absorbing layer at the vanadium interface relative to Cr, which affects the magnitude of hydrogen uptake at similar thermodynamic conditions and lowers the critical temperature due to finite size effects.

[1] M.S. Salman, et al., J. Alloys Compd. 920 (2022) 165936

[2] V. Bérubé, et al., Int. J. Energy Res. 31 (2007) 637

[3] M. Wilde, K. Fukutani, Surf. Sci. Rep. 69 (2014) 196-295

[4] K. Komander, et al, Int. J. Hydrog. Energy 57 (2024) 583-588

[5] K. Komander, et al., Phys. Rev. Lett. 127 (2021) 136102

Abstract 142 at 10:50 AM

Session AA-IBTM-02 Thursday 10:00 AM - Post Oak

Hydrogen thin film standards for high-resolution hydrogen depth profiling

Casee Griffith[1], Jamie J Noel[1], Lyudmila V Goncharova[1,2]

(1)Chemistry, Western University, London ON, Canada
(2)Physics and Astronomy, Western University, London ON, Canada

Understanding surface and interface processes such as hydrogen adsorption, absorption, and interdiffusion is critical to improving the performance of many technologically advanced materials necessary for electronic devices, fuel cells, and medical implants. These processes also have a significant role in predicting and preventing the effects of hydrogen embrittlement (HE) within metals. To elucidate hydrogen diffusion processes on the molecular level, sensitive analytical techniques are vital to characterizing hydrogen interactions on surfaces, within thin

layers, and at interfaces. Most current hydrogen analysis techniques are primarily designed for bulk analysis and lack sensitivity to surface hydrogen. Thus, a new technique sensitive to surface hydrogen or an existing technique with improved resolution is necessary to better understand surface processes. Additionally, to analyze hydrogen it is essential to have calibration standards with a known quantity of hydrogen. Hydrogen depth profiling was achieved using two surface sensitive techniques, elastic recoil detection analysis (ERDA, Western Tandetron Accelerator Lab) and secondary ion mass spectrometry (SIMS, Surface Science Western). Titanium hydride (TiH_x) thin films served as the calibration standards, since metal hydrides are effective at storing large amounts of hydrogen. Ti metal films with 20, 50, and 100 nm thicknesses were deposited on Si (001) using magnetron sputter deposition (conducted at Western Nanofab). Subsequently, TiHx/Si(001) samples was formed by (1) annealing in a N2/H2 tube frunace and (2) through electrochemical polarization. A comparative analysis of ERDA and SIMS was performed to gain insight into hydrogen sensitivity and depth resolution of these techniques. The stability of TiH_x /Si (001) was tested to make comparisons with the stability of other known hydrogen standards. The improvement of surface-sensitive techniques and the establishment of hydrogen standards hold significant importance for future engineering applications requiring hydrogen depth profiling, as well as for advancing our fundamental understanding of hydrogen related processes.

Abstract 225 at 11:05 AM

Session AA-IBTM-02 Thursday 10:00 AM - Post Oak

Detection of light elements by a ToF-ERD telescope

Olga Beliuskina[1], Petter Ström[2], Mauricio A. Sortica[3], Mikko Kivekäs[1], Daniel Primetzhofer[2], Mikko Laitinen[1]

(1)Accelerator Laboratory, Department of Physics, University of Jyvaskyla, P.O. Box 35, FI-40014, Jyväskylä, Finland
(2)Department of Physics and Astronomy, Uppsala University, Box 516, 751 20, Uppsala, Sweden
(3)Tandem Laboratory, Uppsala University, Box 529, 751 20, Uppsala, Sweden

Time-of-Flight Elastic Recoil Detection Analysis (ToF-ERDA) provides quantitative depth profiles of all elements present in thin film samples, simultaneously and with data acquisition time of minutes. However, the lightest elements, especially the hydrogen, typically has significantly less than 100% detection efficiency in the carbon foil time pick-up detectors (1)The detection efficiency is known to be reduced by the limited electron emission from the carbon foils and due to the small signal amplification in the MCPs - where single electrons need to be detected, in particular for light recoils.

The traditional ToF vs E -efficiency is commonly used to account for the foil efficiency in the analysis results, but also other factors affect the overall efficiency in recoil detection. The total detection efficiency does also depend on the ToF-telescope design. Parameters such as voltages in the mirror and in the foil, and the thickness of the carbon foils play more important role than previously thought. The voltage design of the carbon foil time pick-up detectors may cause that some of the hydrogen ions never reach the energy detector [2] and thus remain unconsidered in the analysis. The same applies for the carbon foil thickness, which has an even more prominent role due to the scattering of light ions, but having a particularly huge impact also for heavy recoils.

In this presentation we will show from recent test measurements on one of the ToF-ERDA systems at Uppsala University [3], how critical the single electron detection efficiency, at the MCP-level is, for light ion analysis. Additionally, we will demonstrate the difference between the traditional carbon foils and ALD coated carbon foils - which clearly enhance the electron emissivity. We will also show the magnitude of the trajectory bending for the hydrogen and how to compensate it but also show the importance of choosing the thinnest possible carbon foils for the first timing detector, to reduce scattering effects. Thus, all these effects are important to consider to increase the accuracy and overall efficiency of the ToF-ERD method for light, but also for the heaviest recoiling elements.

[1] Secondary electron flight times and tracks in the carbon foil time pick-up detector, M. Laitinen, M. Rossi, J. Julin, Timo Sajavaara, Nucl. Instr. Meth. Phys. Res. B, 336 (2014), p. 55.

[2] Trajectory bending and energy spreading of charged ions in time-of-flight telescopes used for ion beam analysis, M. Laitinen, T. Sajavaara, , Nucl. Instr. Meth., B325 (2014), p. 101.

[3] A Combined Segmented Anode Gas Ionization Chamber and Time-of-Flight Detector for Heavy Ion Elastic Recoil Detection Analysis. Ström, P.; Petersson, P.; Rubel, M.; Possnert, G., Rev. Sci. Instrum. 2016, 87 (10), 103303.

Abstract 291 at 11:20 AM

Session AA-IBTM-02 Thursday 10:00 AM - Post Oak

Development of a Compact Magnetic Backscattered Ion Beam Deflector System for Light Element Ion Microscopy

Charles Thomas Bowen, Todd A Byers, Darshpreet Kaur Saini, Mohin Sharma, Mritunjaya Parashar, Bhibudutta Rout, Gary A Glass

physics, University of North Texas, Denton TEXAS, United States

Recent advances in ultra-thin windows for Silicon drift detectors (SDD) have allowed for the high efficiency transmission of low energy X-rays. Due to the damage caused by high energy backscattered particles to the active area of the detector, most Particle Induced X-ray Emission (PIXE) setups utilizing thin

window SDD detectors use filters to block high energy particles from damaging the detector. These filters also prevent low energy x-rays from (≤1 keV) from reaching the detector. Previous work at the UNT Ion Beam Laboratory (IBL) has shown that a compact magnetic deflection system can prevent backscattered protons from reaching X-ray detectors for broad beam applications, eliminating the need for detector absorbers. An improved design has been installed in the microprobe vacuum chamber at IBL. With an average field strength of 0.7615T, the magnetic deflector is capable of preventing 1.3 MeV backscattered protons from reaching an Amtek 25 mm2 Fast silicon drift detector with a C1 entry window. Micro-PIXE maps with spot sizes of ≤10μm have been obtained with a 1 MeV proton beam on salt, rat brain tissue, Hibiscus rosa-sinenesis leaf, vitreous carbon, and Vanadium Oxide (VOx) samples: measuring X-ray signals from elements as light as Carbon. We will present ion beam microscopy analysis of light elements present in organic and inorganic samples.

Abstract 66 at 10:00 AM

Session AP-MA-01 Thursday 10:00 AM - Elm Fork II

FLASH Radiotherapy and Precision X-ray Imaging enabled by Distributed Charge Compact Accelerators

Christopher PJ Barty[1,2]

(1)Physics and Astronomy, University of California, Irvine, Irvine California, United States
(2)Lumitron Technologies, Inc., Irvine California, United States

Laser-Compton sources are capable of producing ultra-bright beams of tunable, mono-energetic x-rays and gamma-rays via the collision of short duration, energetic laser pulses with beams of relativistic electrons. In the MeV spectral range, the peak brightness of optimized laser-Compton sources can exceed that of the world's largest synchrotrons by more than 15 orders of magnitude. In the 30 keV to 3 MeV range, such systems are enabling to a wide range of clinical, industrial and basic science applications. This presentation will review the fundamentals of laser-Compton sources, describe how such sources are optimized both with respect to size, flux and bandwidth via a distributed charge Compton architecture, and then introduce the unique hardware that has been developed and fabricated to enable this architecture. Recent demonstrations from an operational, compact, x-band (11.424 GHz) distributed charge Compton system at Lumitron Technologies, Inc. in Irvine, California will be presented. These demonstrations include precision x-ray tuning, production of narrow bandwidth beams of x-rays, 100-keV-class x-ray imaging with micron-scale resolution, elemental analysis and imaging based on k-edge subtraction and scanning k-edge subtraction, and production of very high energy electron (VHEE) beams suitable for image-guided, FLASH radiotherapy.

Abstract 162 at 10:20 AM

Session AP-MA-01 Thursday 10:00 AM - Elm Fork II

Electron beam optimization on a modified Varian clinical linear accelerator for FLASH preclinical studies at RARAF

Yuewen Tan, Naresh T. Deoli, Andrew D. Harken, Guy Garty, David J. Brenner

Radiological Research Accelerator Facility, Center for Radiological Research, Columbia University, New York New York, United States

FLASH effect and its potential clinical applications have attracted considerable interest recently. Extensive research has been conducted to understand its unknown mechanisms and explore its optimal clinical uses. A decommissioned Varian clinical linear accelerator (Clinac) at the Radiological Research Facility (RARAF) was modified to perform electron FLASH irradiation for preclinical studies. To optimize the performance of the ultrahigh dose-rate electron beam which was monitored in real-time by a coil pickup detector installed at the beam exit in the gantry head, we regulated various beam parameters, including the electron gun current, pulse-forming network voltage, and RF auto frequency control. This beam-tuning technique helps to provide much higher beam intensity and better reproducibility than we previously reported. The optimized beams used for FLASH studies were precisely characterized in the 15 MeV electron beam mode, modified from a clinical 15 MV photon mode. We measured the maximized dose rate and dose per pulse vs source-to-surface distance (SSD), the field size profile vs SSD, and the percentage depth dose at various SSDs. At SSD = 100 cm, the maximum iso-dose rate is roughly 350 Gy/sec with a field size of 90% and 80% isodose over 2 and 3 cm, correspondingly. This increase in field size allows the mouse's ultrahigh dose-rate total-body irradiation with a dose rate over 90 Gy/sec at SSD = 150 cm. We also demonstrated a short-term and long-term reduction in uncertainty of beam intensity and dosimetry to within 2%.

This work was supported by grant number U19-AI067773 from the National Institute of Allergy and Infectious Diseases (NIAID), and National Institutes of Health (NIH). The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIAID or NIH.

Abstract 270 at 10:40 AM

Session AP-MA-01 Thursday 10:00 AM - Elm Fork II

Dosimetry calibration for low-energy protons (2-4 MeV) using Gafchromic film dosimeters

Homeira Faridnejad, Regina DeWitt, Jefferson Shinpaugh, Chris Bonnerup

Department of Physics, East Carolina University, Greenville NC 27858, United States

Proton beams are one of the most significant beams in radiation therapy since the Bragg peak in their energy-deposition profile enables more localized irradiation than is possible with photons. In the accelerator laboratory at East Carolina University low-

energy proton beams, with energies 2-4 MeV, are used for various investigations of proton beam interactions with cells. To evaluate the results correctly, it is crucial to know the exact radiation dose that was delivered to the cells. Calculations of the dose are generally based on beam energy and current. At ECU, beams pass through a Havar exit window and 10-20 mm of air before reaching the cells, resulting in a change in the energy and shape of the beam. Calculations of the dose are therefore no better than estimates. This research aims to test and develop methods to accurately measure the radiation dose delivered during cell experiments in the ECU accelerator lab. Our approach is focused on the use of various types of Gafchromic films.

Gafchromic films are largely used for quality assurance in radiotherapy treatments. These types of films are made of polyester outer layers, sandwiching a radiation-sensitive layer of microcrystalline diacetylene suspended in gelatine. When exposed to ionizing radiation, they suffer polymerization via a free-radical mechanism, resulting in a color change that is correlated with dose. Films of different layers, thicknesses, and densities are commercially available, and we tested the films EBT-3, EBT-4, EBT-XD, MDV-3, and HDV-2. HDV-2 is different from the other films, since it has only one inactive layer and the active layer is on the surface and directly exposed to the radiation. Simulations with the SRIM code indicated that 4 MeV beams would reach the active layers in all of the films, but protons of lower energy would be absorbed in the first inactive polyester layer, making HDV-2 the obvious film of choice. Calibration of the films, i.e. gray value versus dose, was obtained in two different ways. In a first attempt, all films were irradiated with a well calibrated 350 kV X-ray source (Model XRAD-350) with doses from cGy to kGy. 24 hours after irradiation the samples were scanned with a high-resolution scanner, and the resulting images were analyzed with ImageJ to obtain the gray values in the red, green and blue channels. The red channel had the largest dynamic range and Mathematica was used to create a fit of the resulting calibration curve. In a second step, the films were irradiated in the ECU accelerator lab in a vacuum chamber. This ensured that beam energy, current and shape were known, and that the dose to the films could be calculated. The range of dose was 0.2 to 420 Gray, energies used ranged from 2-4 MeV. While all 5 types of film were irradiated with 4 MeV, only HDV-2 was used for the lower energies. From the 4 MeV data we concluded that HDV-2 had the best resolution and accuracy of all 5 films. When using HDV-2, one single calibration curve could be created for the entire energy range from 2-4 MeV. Films irradiated with 2 MeV agreed well with the calibration curves from other energies and vice versa. However, films irradiated with protons did not agree with X-ray irradiated films. We conclude that X-ray calibration is not suitable for establishing a calibration curve for low-energy protons, likely because of their very different nature of dose deposition. While X-rays pass through the films and deposit only part of their energy, protons deliver all their energy to the films.

After obtaining the proton-dose calibration curve, HDV-2 films were irradiated with the cell beamline at different energies, currents, and distances from the exit window. The dose rates and their uncertainties were evaluated. In our presentation, we will present the results and discuss implications for the cell-irradiation experiments.

Abstract 35 at 11:00 AM

Session AP-MA-01 Thursday 10:00 AM - Elm Fork II

Neutron Beam System for Accelerator-based Boron Neutron Capture Therapy

Alexander Dunaevsky

TAE Life Sciences, Irvine California, United States

Neutron Beam System (NBS) is a compact accelerator-based neutron source designed for Accelerator-based Boron Neutron Capture Therapy (AB-BNCT). NBS is a basis of the Alphabeam System, a complete AB-BNCT clinical solution offered by TAE Life Sciences. NBS is also the key part of the NeuPex™ AB-BNCT system offered by Neuboron MedTech. NeuPex system was recently installed in Xiamen Humanity Hospital in Xiamen, China.

The NBS is based on an electrostatic tandem accelerator, a mature technology with proven reliability, record high energy efficiency, and low cost. The NBS generates a proton beam with currents up to 10mA and adjustable proton energies in the range of 1.8 - 2.35 MeV. Stability of the proton energy and the beam current do not exceed 2%. The proton beam generates neutrons by the $^{7}Li(p,n)^{7}Be$ nuclear reaction with a solid lithium target. The neutron beam for clinical use is shaped by a NeuPex beam shaping assembly. Replacement lithium target assemblies are supplied by TAE Life Sciences. Life expectancy of the lithium targets exceeds 200 mAh with depreciation of the neutron flux of less than 10%. Overall energy efficiency of the NBS is above 40%, with the tandem accelerator efficiency of 73%.

The NBS can deliver the proton beam into up to three treatment rooms. At present, only one treatment room has been fully commissioned in the Xiamen Humanity Hospital. In this single-room configuration, the NBS supports treatment of up to 6 patients per day, up to 1,400 per year. The throughput is expected to increase proportionally after second and third treatment rooms are commissioned.

By April 2024, 26 patients have been treated by the Xiamen Humanity Hospital as a part of the Investigator Initiated Trials. The total operating time of the NBS, mostly dedicated to regulatory and technical tests, exceeded 4000 mAh. The NBS successfully completed acceptance tests and regulatory registration inspection. At present, Neuboron MedTech is moving forward with clinical trials.

Abstract 277 at 10:00 AM

Session AR-AMP-01 Thursday 10:00 AM - Trinity Central

Development of a velocity map imaging spectrometer and its application in understanding the dynamics of low energy electron-molecule collisions.

Dipayan Chakraborty[1], Sylwia Ptasinska[1,2]

(1)Radiation Laboratory, University of Notre Dame, Notre Dame IN - Indiana, United States
(2)Department of Physics & Astronomy, University of Notre Dame, Notre Dame IN - Indiana, United States

We investigate the effect of secondary low-energy electrons formed due to ionizing radiation. In this context, dissociative electron attachment (DEA) becomes particularly relevant. DEA is a two-step resonant electron-molecule interaction process. Typical DEA studies focus on the detection and yield measurements of negative ions produced as a function of the incident electron energy using mass spectroscopic techniques. Such studies are useful in determining the resonant energy and the corresponding dissociation channels. To advance in this field, we deployed the well-known Velocity Map Imaging (VMI) technique [1] in DEA studies to understand the underlying dynamics of the process. Using this technique, one can simultaneously measure the kinetic energy and the complete 360° angular distribution of the fragment negative ions. The kinetic energy dictates the threshold of the dissociation process, whereas the angular distribution dictates the symmetry of the resonant states.

Using this technique, we experimentally investigated the DEA dynamics of ethanol at the 9.5 eV resonance (2)The kinetic energy distribution of the OH^- ions indicates that the C-O dissociation process is either a three-body dissociation or a two-body dissociation with significantly rovibrationally excited fragments. The small but significant anisotropy in the OH^- angular distribution provides signatures of the molecular symmetry of the associated resonant state under the axial recoil approximation, which assumes the dissociation is much faster than any rotation of the dissociation axis. Under this assumption, the angular distribution of the OH^- ions indicates that it is a p^2-Feshbach resonance with an electronic transition from the 10a' orbital to the 4a" orbital. At the conference, I will discuss the complete dissociation dynamics in detail. [1] A. T. J. B Eppink and D. H. Parker **Rev. Sci. Instrum., 68**, 3477 (1997) [2] D. Chakraborty, D. S. Slaughter, S. Ptasinska **Phys. Rev. A 108**, 052806 (2023).

This work is supported by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences under Award No. DE-FC02-04ER15533.

Abstract 16 at 10:30 AM

Session AR-AMP-01 Thursday 10:00 AM - Trinity Central

L X-ray production cross sections of Ag induced by the impact of $^{12}C^{3+}$ and $^{13}C^{3+}$ ions

Derian Leonel Serrano-Juárez, Javier Miranda, Juan Carlos Pineda, Salvador Reynoso-Cruces, Arturo Rodríguez-Gómez

Instituto de Fisica, Universidad Nacional Autonoma de Mexico, Coyoacan Cd Mx, Mexico

The L X-ray production cross sections of Ag induced by the impact of 2.62 MeV to 3.98 MeV $^{12}C^{3+}$ and $^{13}C^{3+}$ ions were determined. Thin Ag films were deposited on metallic substrates and irradiated with ion beams produced by the Tandetron® accelerator at the Accelerator Mass Spectrometry Laboratory, Instituto de FÍsica. The influence of different projectile masses could be observed. The $^{13}C^{3+}$ ions penetrate the target atom's inner shells less when they have the same energies as $^{12}C^{3+}$ ions, decreasing ionization probability. However, when the data are plotted as a function of the reduced velocity variable $\mathbf{v}_1/\mathbf{v}_{2L}$, all the cross sections seem to follow a single curve, together with previously published experimental results (1)The ECPSSR theory [2], with corrections due to electron capture [3], multiple ionization [4], and united atom effect [5], was used to make comparisons. It was found that there is a better agreement when the multiple ionization and united atom corrections are considered. Moreover, different databases of atomic parameters (fluorescence yields and Coster-Kronig transition probabilities) are contrasted with no significant differences.

References

[1] J. Braziewicz, et al., J. Phys. B 27 (1994) 1535-1547.

[2] W. Brandt, G. Lapicki, Phys. Rev. A 23 (1981) 1717-1729.

[3] G. Lapicki, F. D. McDaniel, Phys. Rev. A 22 (1980) 1896-1905.

[4] G. Lapicki et al., Phys. Rev. A 34 (1986) 3813-3821.

[5] G. Lapicki, Nucl. Instrum. Meth. B 189 (2002) 8 20.

The authors acknowledge A. Huerta's technical assistance with accelerator operation. D.L. Serrano JuÁrez and S. Reynoso-Cruces thank CONAHCyT for the scholarship support.

Abstract 26 at 11:00 AM

Session AR-AMP-01 Thursday 10:00 AM - Trinity Central

Calculated He+ Induced L X-ray Production Cross Sections for Rare Earth Elements

Felix S. Olise[1], Adedamola D. Aladese[1,2]

[(1)]Department of Physics and Engineering Physics, Obafemi Awolowo University, Ile-Ife Osun, Nigeria
[(2)]Department of Physics and Material Science , University of Memphis, Memphis Tennessee 38152, United States

For some relevant applications, inner-shell process involving interactions between ions and atoms have been widely investigated. In this study, L-shell X-ray production cross sections of industrially important Rare Earth Elements (REEs), induced by helium particles of energies 0.20 MeV-3.00 MeV, have been calculated. The cross sections for the targets were obtained using the ISICSoo and ERCS08 computer codes based on ECPSSR-UA and PWBA+OBKN theories, respectively. Also, the role of multi-ionisation from the outer shells was considered in addition to using an accurate analysis of the uncertainty arising from the atomic parameters. The calculated cross sections were compared with existing experimental data and validated at the same helium ions probing energy range. We have also compared the predicted cross sections from both theories.

Abstract 304 at 10:00 AM

Session AR-RE-02 Thursday 10:00 AM - Elm Fork I

Ion Beam Synthesis of Layer-Tunable and Transfer Free Graphene for Device Applications

Yongqiang Wang[1], Gang Wang[2], Caichao Ye[3]

[(1)]Los Alamos National Laboratory, Los Alamos NM, United States
[(2)]Ningbo University, Ningbo Zhejiang, China
[(3)]Southern University of Science and Technology, Shenzhen Guangdong, China

Direct synthesis of layer-tunable and transfer-free graphene on technologically important substrates is highly valued for various electronics and device applications. State of the art in the field is currently a two-step process: a high-quality graphene layer synthesis on metal substrate through chemical vapor deposition (CVD) followed by delicate layer-transfer onto device-relevant substrates. Here, we report a novel synthesis approach combining ion implantation for a precise graphene layer control and dual-metal smart Janus substrate for a diffusion-limiting graphene formation, to directly synthesize large area, high quality, and layer-tunable graphene films on arbitrary substrates without the post-synthesis layer transfer process.

Carbon (C) ion implantation was performed on Cu-Ni film deposited on a variety of device-relevant substrates. A well-controlled number of layers of graphene, primarily monolayer and bilayer, is precisely controlled by the equivalent fluence of the implanted C-atoms (1 monolayer ~ 4E15 C-atoms/cm2). Upon thermal annealing to promote Cu-Ni alloying, the pre-implanted C-atoms in the Ni layer are pushed towards the Ni/substrate interface by the top Cu layer due to the poor C-solubility in Cu. As a result, the expelled C-atoms precipitate into graphene structure at the interface facilitated by the Cu-like alloy catalysis. After removing the alloyed Cu-like surface layer, the layer-tunable graphene on the desired substrate is directly realized.

This presentation will focus on graphene layer formation mechanism, detailed characterizations, and performance characteristics of select devices fabricated through this ion beam approach.

Abstract 159 at 10:25 AM

Session AR-RE-02 Thursday 10:00 AM - Elm Fork I

Mechanisms of Ion Irradiation Induced Ordering in Amorphous TiO_2 Nanotubes: Effects of Ion Mass and Energy

Tristan T Olsen[1], Wei-Ying Chen[2], Miu Lun Lau[3], Cyrus Koroni[1], Chao Yang[4], Md Ali Muntaha[4], Sarah Pooley[1], Zhongxia Shang[4], Dewen Hou[1], Ling Wang[5], Min Long[2], Janelle P Wharry[4], Hui Xiong[1]

(1)Micron School of Materials Science & Engineering, Boise State University, Boise ID, United States
(2)Argonne National Laboratory, Lemont IL, United States
(3)Department of Computer Science, Boise State University, Boise ID, United States
(4)School of Materials Engineering, Perdue University, West Lafayette IN, United States
(5)SLAC National Accelerator Laboratory, Menlo Park CA, United States

Amorphous TiO_2 nanotubes were irradiated **in-situ** in a transmission electron microscope (TEM) with Kr^+ ions at energies of 46 keV, 150 keV, and 1 MeV and with 46 keV Xe^+ ions, to investigate the structural and morphological evolution of the nanotubes under irradiation. At all irradiation conditions, amorphous TiO_2 nanotubes exhibited significant morphological instability, and tended to undergo volumetric swelling with increasing ion counts, often until collapse of the original nanotube structure. Molecular dynamics (MD) simulations confirmed that irradiation-induced defects can explain the observed swelling. Structurally, nanotubes remain amorphous following all Kr^+ irradiation conditions, but irradiation with 46 keV Xe^+ leads to the formation of anatase nanocrystallites. Importantly, through systematically varying ion energy and ion species, we try to elucidate the influence of nuclear and electronic stopping power on ion irradiation induced changes. By contextualizing these results within the existing literature, we propose that the observed changes in TiO_2 nanotube morphology and structure could be due to a competition between two mechanisms: (1) disorder-induced swelling and, (2) irradiation-induced amorphous-to-crystalline transformation.

Abstract 8 at 10:40 AM

Session AR-RE-02 Thursday 10:00 AM - Elm Fork I

Interfaces enhanced plasma irradiation resistance in CrMoTaWV/W multilayer films through blocking He diffusion

Chenyi Qu

Condensed matter physics, wuhan unversity, wuhan Hubei, China

The performance of Plasma-facing materials (PFMs) is one of the key factors that significantly impact the stability of operation in fusion reactors. Herein, a new CrMoTaWV/W (HEA/W) multilayer structure is designed as PFM to investigate its resistance to He plasma irradiation. It was observed that the introduction of the interfaces effectively absorbed plenty of He atoms, preventing them from diffusing into the material and delaying the formation of fuzz incubation zone, therefore, enhancing the resistance to plasma irradiation. The thickness transfer to fuzz in the HEA/W multilayer films was observed to be about two-thirds of those in the CrMoTaWV (HEA) film. Additionally, the fuzz growth rates in HEA/W multilayer films are lower than the average growth rate of bulk W and HEA films. These findings highlight a promising new avenue for the exploration of high-performance PFMs.

Abstract 75 at 10:55 AM

Session AR-RE-02 Thursday 10:00 AM - Elm Fork I

Hydrogen Retention in Copper-Tungsten Nanocomposites

Mina Tavakolzadeh[1], Emmeline Sheu[1], Yongqiang Wang[2], Kelvin Y. Xie[1], Michael J. Demkowicz[1]

(1)Material Science and Engineering, Texas A&M university, College Station Texas, United States
(2)Material Science and Technology Division, Los Alamos National Laboratories, Los Alamos New Mexico, United States

Copper-tungsten (Cu-W) nanocomposites are explored as a potential plasma facing material for future fusion reactors. As-prepared and radiation-damaged Cu-W nanocomposites made up of alternating layers of copper and tungsten were implanted with 20 kV protium at different temperatures. The retention of hydrogen in these layers was analyzed via Elastic Recoil Detection (ERD) using a He ion beam. ERD results revealed no measurable amount of hydrogen in the as-prepared composites. Microscopy results revealed delamination of multilayers implanted at room temperature implying outgassing occurred through top and bottom of the film. Blisters were found on the surfaces of the samples implanted at 300 °C and 600 °C. The implications of out work for development of plasma-facing materials will be discussed.

Abstract 17 at 11:10 AM

Session AR-RE-02 Thursday 10:00 AM - Elm Fork I

Modification of (Photo)electrocatalytic nanomaterials by ion beam technology

Feng Ren, Liqiu Huang, Shixin Wu, Derun Li, Tao Jiang

School of Physics and Technology, Wuhan University, Wuhan Hubei, China

Modification of (Photo)electrocatalytic nanomaterials by ion beam technology

(Photo)electrochemical energy storage and conversion technology is an important part in the development of environmentally friendly, efficient and universal access renewable energy technology. Ion beam technology is a powerful and versatile physical method in modification of various catalytic materials from the surface to interface and thin film can be realized by controlling the species, energy, fluence of implanted ions. Ion beam technology has its unique advantages, including its compulsivity of element doping and its high controllability, accuracy and repeatability. This makes it possible for the ion beam technology to adapt to the modification requirements of catalytic materials to tailor the electronic structure, interface structure and morphology of the materials more finely. In this work, we simultaneously realize the several kinds of regulation in a catalyst by using unique ion irradiation technology. (1) A nanosheet structured $NiO/NiFe_2O_4$ heterostructure with rich oxygen vacancies converted from $NiFe(OH)_2$ nanosheets by Ar^+ ions irradiation shows significant enhancement in both OER and HER performance. (2) A general and novel method of low-energy-recoil ion implantation and subsequent annealing is successfully developed to synthesize high-entropy oxide nanoparticles catalysts. By controlling the fluence of irradiation Ar^+ ions, the size and the load of HEO nanoparticles can be accurately controlled. The obtained (FeCoNiCrX)O HEO nanoparticles exhibit good OER performance and good stability. (3) The catalytic activity of $MoSe_2$ nanosheet arrays is activated by a novel and controllable method of He^+ ion irradiation to introduce multiple vacancies simultaneously into their inert basal planes. The vacancies activated $MoSe_2$ have improved electrocatalytic performance and stability.

References:

Shixin Wu[#], Huizhou Zhong[#], Shuangfeng Jia, Derun Li, Tao Jiang, Yichao Liu, Hengyi Wu, Guangxu Cai, **Feng Ren***, A general method to synthesize high-entropy oxide nanoparticles by low-energy-recoil ion implantation for efficient oxygen evolution reaction, Applied Physics Reviews, 10 (2023) 031420.

Liqiu Huang, Hengyi Wu, Guangxu Cai, Shixin Wu, Derun Li, Tao Jiang, Biyan Qiao, Changzhong Jiang, **Feng Ren***, Recent Progress in the Application of Ion Beam Technology in Modification and Fabrication of Nanostructured Energy Materials, ACS Nano 18 (2024) 2578−2610.

Huizhou Zhong#, Guoping Gao#, Xuening Wang, Hengyi Wu, Shaohua Shen, Wenbin Zuo, Guangxu Cai, Guo Wei, Ying Shi, Dejun Fu, Changzhong Jiang, Lin-Wang Wang, **Feng Ren***, Ion Irradiation Inducing Oxygen Vacancy-rich $NiO/NiFe_2O_4$

Heterostructure for Enhanced Electrocatalytic Water Splitting, Small 17 (2021) 2103501.

Abstract 174 at 10:00 AM

Session SN-TA-01 Thursday 10:00 AM - West Fork II

Undergraduate training and research with 400 keV electrons at Minnesota State University

Andrew Roberts

Physics and Astronomy, Minnesota State University, Mankato MN, United States

Minnesota State University Mankato has a long history of undergraduate student involvement in our Applied Nuclear Science Lab. While most work initially used 400keV protons or deuterons from our AN400 accelerator, the more recent switch to electron acceleration has opened numerous avenues for creative studies of beam interactions with external targets. The teaching of fundamental physics and applied nuclear techniques using the extracted beams will be discussed, and results from cross disciplinary biological radiation dose experiments will be presented.

Abstract 110 at 10:15 AM

Session SN-TA-01 Thursday 10:00 AM - West Fork II

Undergraduate Training and Research Involvement on the St. Andre 9SDH 3-MV Tandem Accelerator at the University of Notre Dame

Anthony M Miller[1], Yukun Jin[1], Graham F Peaslee[2]

(1)Chemistry and Biochemistry, University of Notre Dame, Notre Dame Indiana, United States
(2)Physics and Astronomy, University of Notre Dame, Notre Dame Indiana, United States

The 9SDH accelerator is capable of providing up to 6 MeV protons and 9 MeV alpha particles. The 90-degree beamline is equipped with a 20" diameter scattering chamber. This apparatus allows for IBA techniques such as RBS and ERD. The beamline terminates with an 8-micron thick 1-cm diameter kapton window for beam extraction. By extracting proton beams into air, **ex vacuo** PIGE/PIXE measurements can be performed on hundreds of samples per week. During the academic year, undergraduate students are trained to perform tasks such as ion source and accelerator start-up, data collection, sample preparation, and analysis of spectra. While the majority of samples are environmental or commercial products under screening for contaminants of concern by PIGE/PIXE, students are encouraged to design their own trace-element concentration measurements. We present a review of the material students are expected to understand, exams administered, and topics that often require further review. These include a basic understanding of electronics, accelerator function, ion-beam interactions with matter, and

radiation detection. We also summarize projects that students have contributed to or designed themselves over the past four years.

Abstract 231 at 10:35 AM

Session SN-TA-01 Thursday 10:00 AM - West Fork II

University of Wisconsin Isotope Production HIPPOCampus Summer School

Paul A Ellison[1], Jonathan W Engle[1,2], Reinier Hernandez[1,2], Lauren McIntosch[3], Sherry Yennello[3,4]

[(1)]Department of Medical Physics, University of Wisconsin, Madison WI, United States
[(2)]Department of Radiology, University of Wisconsin, Madison WI, United States
[(3)]Texas A&M Cyclotron Institute, College Station TX, United States
[(4)]Department of Chemistry, Texas A&M University, College Station TX, United States

The Horizon-broadening Isotope Production Pipeline Opportunities (HIPPO) program is a Department of Energy Office of Isotope R&D and Production funded, multi-institutional collaboration created to give undergraduate and graduate students research experience in the production of radionuclides used in medical, industrial, and research applications. As part of this program, the University of Wisconsin hosts a week-long summer school that combines laboratory-based instruction and didactic lectures on the cyclotron production and radiochemical isolation of radionuclides, as well as the synthesis, purification, and nuclear medicine imaging applications of radiopharmaceuticals. This instruction is further augmented with opportunities for community and network development and social activities. Each day shares a common format: Mornings begin with a lecture building the foundation for the day's laboratory exercises and are followed by hands-on experiments. The students then have a 'working-lunch' with catered food and a research presentation from a local graduate student or postdoc discussing their radionuclide production/application-related research project. In the afternoon, the students will complete the laboratory work, followed by a 1 hour debrief and invited guest lecture.

Day 1: The first day's laboratory exercises focus on the GE PETtrace 16 MeV proton, 8 MeV deuteron cyclotron. Students will participate in the irradiation and radiometric characterization of these materials (typically foil targets), making measurements of beam profile and (indirectly) quantifying beam fluence and energy. These measurements will be compared with accelerator reported irradiation parameters and related explicitly to cross section measurement, a fundamental technique essential in radionuclide production.

Day 2: The focus will be on the techniques of radionuclide isolation from irradiated target materials. Didactic lectures cover the fundamentals of elemental separations used in nuclear chemistry including liquid-liquid extractions, ion and extraction chromatography, and dry distillation. Laboratory exercises put these principles into practice through the chemical dissolution of a

proton-irradiated ^{nat}Y foil, and isolation of ^{89}Zr radionuclide product via extraction chromatography. Additionally, the students perform radionuclide product quality control analyses, including gamma ray spectroscopy, a half-life measurement, and apparent molar activity measurements of their purified radionuclide solution to determine both radioactive and non-radioactive contaminants.

Day 3: The focus is on radiochemical labeling of molecules of medical, industrial, or scientific interest. Didactic lectures present the basics of coordination chemistry, bioconjugation chemistry, and methods of radiopharmaceutical quality control analysis. The laboratory exercises perform a ^{89}Zr radiolabeling reaction, followed by purification via high performance liquid chromatography or size exclusion chromatography.

Day 4: The focus will be on radionuclide imaging modalities, including positron emission tomography and single photon emission tomography. The laboratory exercises in this final day are performed in the University of Wisconsin Small Animal Imaging and Radiotherapy Facility where the students image a ^{99m}Tc-filled, Derenzo-type line phantom using a MILabs SPECT/CT small animal scanner. Multiple scans of the phantom with different collimators and counting statistics are acquired and, during an afternoon computer laboratory, analyzed with an emphasis on a key image quality performance characteristic: spatial resolution.

This work is supported by the U.S. Department of Energy Isotope Program, managed by the Office of Science for Isotope R&D and Production, Grant Number DE-SC0022550 (Yennello).

Abstract 140 at 10:55 AM

Session SN-TA-01 Thursday 10:00 AM - West Fork II

An Undergraduate Advanced Lab teaching: Measurement and analysis of Ions and Photons

Rahul Mehta

Physics & Astronomy, University of Central Arkansas, Conway AR, United States

Experiments are discussed that involve using ion beams and radioisotopes. Measurements of incident ions interacting with solid multilayer samples allowed analysis of Rutherford and non-Rutherford nature of scattering as a function of atomic numbers, ion-beam energy and the scattering angles. Undergraduate students could apply conservation principles to understand the nature of the scattering - elastic or inelastic. This lead to using kinematical scattering factor in identifying elemental compositions of samples. Measurement of photons using x-ray and/or gamma ray detectors together with scattering properties provided a techniques of measuring thickness of atomic and molecular layers. Some other photon measurement techniques involved using X-ray Fluorescence (XRF) experiments more advanced particle induced X-ray emission (PIXE) measurements and x-ray production and

ionization cross sections to ascertain trace elements presence and determination of elemental layer thicknesses. Radioisotope usage allowed to learn calibration techniques of different type of detectors (Sodium Iodide (NaI) and Lithium drifted Silicon (Si(li) detectors). Also α-, β-, and γ spectroscopy were used in learning atomic and nuclear physics.

Abstract 262 at 11:15 AM

Session SN-TA-01 Thursday 10:00 AM - West Fork II

Teaching activities with accelerators at the Universidad Politécnica de Madrid in Undergraduate and Graduate Programs

Raquel Gonzalez-Arrabal[1,2], David Garoz[1,2], Jorge Kohanoff[1,2], Ovidio Peña-Rodriguez[1,2], Gastón Garcia[3]

[(1)]Instituto de Fusión Nuclear Guillermo-Velarde, Universidad Politécnica de Madrid, Madrid, Spain
[(2)]Departamento de Ingeniería Energética, ETSI de Industriales, Universidad Politécnica de Madrid, Madrid, Spain
[(3)]Centro de Micro-Análisis de Materiales (CMAM), Universidad Autónoma Madrid, Madrid, Spain

Particles accelerators are essential tools for industry, medical and biological applications as well as, for fundamental research. However, the number of academic programs fully focussed on educating accelerator physics and engineers is scarce.

Founded in 1971 la Universidad Politécnica de Madrid offers courses that cover all areas of architecture and engineering necessary for today's society, in which more and more scientific and engineering responsibility is acquired. It has among its objectives the creation, development, transmission and criticism of science, technology, and cultures, assimilating the changes taking place in our society and maintaining its vocation for excellence, which is why it has both national and international recognition.

Nowadays la Universidad Politécnica de Madrid consists on: 18 Schools and Faculties and 17 research and development canters holding 41 degrees, 78 Master, 41 Phd programs, 75 permanent master´s training qualification, 333 permanent postgraduate training qualifications and 91 double degree agreements and has international agreements with 1617 universities all around the world. The total number of students is around 50.000.

In some of its Degrees, Master and PhD programs the use of accelerators in teaching activities is focussed on the following topics:

Basis knowledge on accelerators´ physics and engineering..

Understand radiation-matter interaction

Mimic radiation-induced damage in nuclear materials to be used both in fission and fusion reactors

Use the Ion Beam Analysis Techniques (IBA) to characterize elemental composition and microstructural properties of the materials. Understand their role in the development of new materials.

Use of ions to modify materials properties and to create new spintronic and plasmonic devices

To carry out these activities master classes are complemented with computer simulations lessons and visits to the Centro de MicroanÁlisis de Materiales (CMAM/UAM). The latter is oriented to promote learning by seeing. For that we signed an agreement with the CMAM which allows to interchange students, of all levels and to carry out common research projects.

In this contribution we will briefly be summarized some of these activities showing examples of our fruitful and successful collaboration and present our experience on how the curricula of the subjects is adapted to fulfil students and teachers' expectations.

Abstract 165 at 1:00 PM

Session AA-NBAT-01 Thursday 1:00 PM - Post Oak

Computational Techniques for Electrostatic Ion Accelerator Component Design and Optimization

Ryan M. Hedlof

Sandia National Laboratories, Albuquerque NM, United States

The optimization of the design of components in electrostatic ion accelerators is challenging at best, and full-system design optimization often proves to be impossible for many reasons (e.g., curse of dimensionality, computational cost, etc.). One path toward an optimized design is via the Edisonian approach in which many designs are conceived, built, and tested. As computational techniques such as particle-in-cell (PIC) were developed, computers have been used to enhance the design process and shorten the design cycle. However, simulations with codes utilizing the standard momentum-conserving explicit-PIC algorithms are extremely computationally expensive, prompting large-scale efforts to refactor existing, or develop completely new, codes that make use of GPUs and/or other advanced computer architectures to reduce run times. Here, a complementary approach is presented in which a relatively simple-to-implement energy-conserving semi-implicit particle-in-cell (SIPIC) algorithm is combined with the use of reduced-mass ions yielding, conservatively, an order of magnitude decrease in the computational cost. Computational tools and techniques for building a robust workflow for accelerator component design optimization are discussed (e.g., automated geometry modification, meshing, code execution, post-processing, etc.), and

remaining challenges in the automation of the design cycle are presented.

Abstract 161 at 1:30 PM

Session AA-NBAT-01 Thursday 1:00 PM - Post Oak

Computational study of tungsten and depleted uranium photoneutron targets for a 20 MeV electron linear accelerator

Kevin Yim[1], Alexander Barzilov[1], Amber Guckes[2], Jesse Andrew Green[2]

[(1)]Mechanical Engineering, University of Nevada Las Vegas, Las Vegas NV, United States
[(2)]Nevada National Security Sites, Las Vegas NV, United States

Neutron production can be realized with a high energy electron linear accelerator by using
Bremsstrahlung and photoneutron converters. In this study, Monte Carlo N-Particle Code
(MCNP) was used to evaluate potential photonuclear target designs for a high energy electron
linear accelerator for applications such as neutron radiography and neutron resonance
spectroscopy. A computational model was developed to inform a target design that would yield a
high number of neutrons. It consists of a 20 MeV electron beam incident on a Bremsstrahlung
target and a photonuclear target to generate neutrons. This computational model showed a
thickness of 0.75 inches for both tungsten and depleted uranium yields the most neutrons from
photoneutron reactions. Saturation in the total number of generated neutrons was observed at
over 0.75-inch thickness for both evaluated materials. Depleted uranium yielded approximately
twice the number of neutrons overall compared to tungsten. The highest neutron surface flux for
Depleted Uranium was 1.06 x 10^{-4} neutrons/cm^2/source electron, and for Tungsten it was 5.12 x
10^{-5} neutrons/cm^2/source electron. The optimal target design for this study's application would
consist of a 0.75-inch-thick block of depleted uranium with the length, width, and/or diameter
varying dependent on application.

Abstract 153 at 2:00 PM

Session AA-NBAT-01 Thursday 1:00 PM - Post Oak

Prediction of performance for a short, multi-pulse photoneutron source based on the NNSS Scorpius linear induction accelerator

Amber Guckes[1], Jesse Andrew Green[1], Kaleab Ayalew[1], James Mellott[1], Allan Ortiz[2], Elizabeth Bell[1], Kevin Yim[3], Alexander Barzilov[3]

[(1)]Nevada National Security Sites, North Las Vegas NV, United States
[(2)]Nevada National Security Sites, Los Alamos NM, United States
[(3)]Department of Mechanical Engineering, University of Nevada, Las Vegas, Las Vegas NV, United States

The highly anticipated Scorpius linear induction accelerator (LIA) is expected to be commissioned and operating at the Nevada National Security Sites (NNSS) in the next 5 to 10 years. Its primary mission will be X-ray radiography of subcritical experiments. However, neutron production can be realized with Scorpius by fielding an appropriately selected photodisintegration target with it. This would make Scorpius a multi-probe diagnostic capability that would enable neutron-based measurements such as neutron radiography and neutron resonance spectroscopy in that testbed.

Monte Carlo N-Particle Code (MCNP) simulations, together with surrogate experimental measurements at the Idaho State University (ISU) Idaho Accelerator Center (IAC), were performed to inform the photoneutron target design and predict its performance ahead of Scorpius becoming operable.

A 20 MeV electron beam into a known Bremsstrahlung X-ray converter was simulated in MCNP. The response of different photoneutron target material and thicknesses to this source were studied. The results indicated that a ¾ inch-thick target made from depleted uranium would maximize the total photoneutron flux at an estimated 1.06×10^{-4} neutrons/cm^2/source electron. A ¾ inch-thick tungsten target was the next best configuration with a total estimated photoneutron flux of 5.12×10^{-5} neutrons/cm^2/source electron.

The ¾ inch-thick tungsten photoneutron target configuration was selected for use in the experimental measurements at the ISU IAC due to tungsten material being readily available in the correct thickness. The purpose of these measurements was to validate the simulations and provide an experiment-based prediction of the total photoneutron yield and the photoneutron energy spectrum. The IAC's L-band linear accelerator (linac), operated at 20 MeV electron endpoint energy with a pulse width of 100 ps, was used to generate Bremsstrahlung X-rays in a thin tungsten converter. The photoneutron target was centered on the thin target converter. Four NNSS PMD-362 neutron time-of-flight (nToF) detectors were fielded with the L-band linac measurements to infer the neutron energy spectrum. The IAC's S-band multiport linac operated at 20 MeV and a pulse width of 4 μs, maximizing charge on target, was used in a similar way with the thin tungsten converter and photoneutron target. Neutron activation foils were fielded with the S-band linac for total and thermal neutron yield measurements. The activated foils were then analyzed using a High Purity Germanium (HPGe) detector.

The total neutron yield and neutron energy spectrum measured during the experimental campaign at the ISU IAC were compared to the results of the MCNP simulations. Furthermore, both the computational and experimental results were extrapolated to account for the much larger beam current (2 kA versus tens of μA) that is expected from the Scorpius LIA. That extrapolation formed the prediction of total neutron yield and neutron energy spectrum from the Scorpius LIA with either a ¾ inch-thick tungsten or depleted uranium photoneutron target.

This work was done by Mission Support and Test Services, LLC, under Contract No. DE-NA0003624 with the U.S. Department of Energy, the National Nuclear Security Administration's Office of Defense Programs, and supported by the Site-Directed Research and Development Program. DOE/NV/03624--1964.

Abstract 131 at 1:00 PM

Session AC-AF-04 Thursday 1:00 PM - Trinity Central

Neutron Generator for Space Applications: From Oil Field to Outer Space

Jani Reijonen, Frederic Gicquel

Houston Formation Evaluation - Nuclear, SLB, Sugar Land Texas, United States

SLB has been involved in development of space instrumentation since the 1960s. The highly ruggedized instrumentation used in oilfield applications downhole are well suited for the rigors of space exploration. Throughout the 65-year history of the SLB nuclear teams, there have been multiple instruments developed for various NASA missions, such as the Cassini-Huygens probe, the NEAR spacecraft, and the Hubble Space Telescope. While the instruments in those missions, namely the fine guidance system for Hubble and the X-ray/gamma ray spectrometer and ultraviolet imaging spectrograph for Cassini, are based on optical instruments, the latest project is to provide a neutron generator (NG) for the Dragonfly mission as part of the Dragonfly gamma neutron spectrometer instrument. This active neutron spectrometer is developed to study the subsurface elemental composition on Titan and to provide a first-step analysis and a gate for sample taking and further analysis with the other instruments on-board the Dragonfly lander. This paper will discuss the design, application, and progress of the NG development for Dragonfly and other space applications.

Abstract 112 at 1:25 PM

Session AC-AF-04 Thursday 1:00 PM - Trinity Central

The BECA and DraGNS Instruments for In situ Planetary Geochemistry

Ann Parsons[1], Mauricio Ayllon Unzueta[2], David Lawrence[3], Patrick Peplowski[3], Jack Wilson[3], Zachary Yokley[3], Frederic Gicquel[4], Jani Reijonen[4]

[(1)]NASA Goddard Space Flight Center, Greenbelt Maryland, United States
[(2)]E. O. Lawrence Berkeley National Laboratory, Berkeley California, United States
[(3)]Johns Hopkins University Applied Physics Laboratory, Laurel Maryland, United States
[(4)]SLB, Sugar Land Texas, United States

The Bulk Elemental Composition Analyzer (BECA) and the Dragonfly Gamma-Ray and Neutron Spectrometer (DraGNS) on the Dragonfly mission are both nuclear spectrometry space flight instruments designed to measure the bulk elemental composition of surface materials of other planets in the solar system. The Dragonfly mission will explore the prebiotic chemistry on Saturn's moon, Titan. DraGNS measurements will provide geochemical context to other Dragonfly measurements at multiple landing sites. BECA is a similar instrument designed to measure the near surface composition of Earth's Moon. BECA will provide data relevant to understanding the evolution of the Moon and the solar system and to scout prospective locations for retrieving lunar samples for both science and lunar resource utilization.

BECA and DraGNS contain the identical deuterium-tritium neutron generator, each supplied by SLB in Sugar Land, Texas. BECA consists of a pulsed neutron generator (PNG) combined with He-3 neutron sensors and a $CeBr_3$ gamma ray spectrometer (GRS) that is read out using silicon photomultipliers (SiPMs). The DraGNS' neutron spectrometer also uses He-3 neutron sensors, and its GRS is a High Purity Germanium (HPGe) detector that is passively cooled by Titan's surface environment, which has a temperature of 94 K. With HPGe's excellent energy resolution but slower response time, it is optimal for DraGNS to run the SLB neutron generator in a steady state with no pulsing. Because of the difference in GRS spectral resolution, BECA's spectral data will be analyzed using full spectrum fitting techniques, while DraGNS' data will be analyzed using peak identification and fitting methods.

While both instruments measure the planetary surface bulk elemental composition down to cm-scale depths, the interpretation of the data from the two will be very different. Since Titan's thick water-ice crust is covered with only a thin layer of organic material, its response to the neutron generator's 14 MeV neutrons will be different from the rocky lunar regolith. Titan's water-ice crust will moderate the neutrons quickly so that the primary gamma ray contribution to the spectra should be thermal-neutron capture gamma rays from the near surface. BECA's PNG neutrons will not be moderated so quickly and will penetrate much farther into the rocky lunar regolith. We thus expect the BECA gamma ray spectra to have an increased contribution from the prompt inelastic neutron scattering gamma rays than seen for DraGNS on Titan. The response of the neutron spectrometers to the Titan water-world and the rocky Moon will also be different. Since neither of these instruments have been launched yet, these spectral differences are being explored using experiments on Earth and both MCNP and Geant Monte Carlo computer simulations. We will thus present a comparison between the BECA and DraGNS planetary elemental composition instruments and their expected spectral response to lunar and Titan materials.

Abstract 28 at 1:50 PM

Session AC-AF-04 Thursday 1:00 PM - Trinity Central

Exploring the Surface of Mars with Active Neutron Measurements on the Mars Science Laboratory Curiosity Rover

Craig Hardgrove

School of Earth and Space Exploration, Arizona State University, Tempe AZ, United States

Since the mission began in 2012, the Dynamic Albedo of Neutrons (DAN) instrument on the Mars Science Laboratory Curiosity rover has acquired thousands of measurements within Gale Crater on the surface of Mars. DAN measures thermal and epithermal neutron counts between pulses of a 14.1 MeV D-T pulsed neutron generator. The resulting neutron die-away curves can be used to interpret the bulk hydration, subsurface geology, and layering structure of the shallow subsurface of Curiosity's landing site in Gale Crater. Analyses of DAN data have characterized the hydration and extent of high-silica materials at several locations along the rover's traverse. DAN data have also been used to study an active dune field, which was determined to be some of the least hydrated material investigated by the rover. The hydration state of the dunes can then be used to constrain the abundance of amorphous phases within the dune sand, which is an important indicator of environmental conditions during sediment transport. Neutron measurements have also revealed hydrogen-rich clay deposits and unique properties of other geologic layers measured at the base of Mount Sharp. These neutron measurements are the first to be made on the surface of another planet. Interpretations of these highly localized neutron data require a careful approach to simulations, geochemical modeling, and geologic settings to test hypotheses at the site. Active neutron observations provide planetary scientists with a rich nuclear dataset that will help unravel the geologic history of Gale Crater and should be a valuable tool for future missions to understand the origins of polar ice deposits on the Moon and Mars.

Abstract 121 at 2:15 PM

Session AC-AF-04 Thursday 1:00 PM - Trinity Central

Non-Destructive Interrogation using Associated Particle Imaging for Planetary Surface Missions

Emily Surry[1], Arun Persaud[1], Mauricio Ayllon Unzueta[1], Patrick N Peplowski[3], Jack T Wilson[3], Ann Parsons[2]

(1)ATAP/IBT, Lawrence Berkeley National Laboratory, Berkeley CA, United States
(2)NASA Goddard Space Flight Center, Greenbelt MD, United States
(3)Applied Physics Laboratory, Johns Hopkins University, Laurel MD, United States

In-situ 3D compositional imaging of planetary surfaces has the potential to revolutionize our understanding of the origin and evolution of our solar system. We are developing an Associated Particle Imaging instrument capable of non-destructive 3D imaging of the elemental composition of near-surface regions below a planetary rover or lander. Our instrument, the In-situ Nuclear Spectrometer with 3D Resolution (INSPECT3R) will allow for unprecedented spatial resolution and sensitivity by enabling 3D compositional imaging and background suppression during measurement. The goal of the project is for INSPECT3R to measure the surface bulk elemental composition with centimeter spatial resolution and perform depth-dependent elemental analysis to allow for layering determination and the localization of distinct compositional irregularities beneath the planetary surface. To work towards this goal, multiple experiments are planned over the course of the next two years. The first experiment consists of irradiating a matrix of different samples of elements relevant to planetary science to quantify cross-talk within voxels, the 3D spatial resolution, and the projected measurement times and sensitivities for each element. The experiment uses an Associated Particle Imaging (API) system to detect a neutron-induced gamma ray and alpha particle in coincidence and determine the location of the particle interaction in the element sample. The API system consists of a Deuterium-Tritium (DT) neutron generator, a position-sensitive alpha particle detector, and a gamma ray detector (LaBr3) located close to the inspection volume. To support the experimental data, simulations are being conducted using MCNP, a Monte Carlo particle transport code. These MCNP simulations allow for result comparison and evaluation of experimental data since variables such as the exact position of inelastic scattering, are known in the simulation. These simulations are used to characterize key features of the experiment such as detector response and elemental crosstalk. The proposed first experiment and accompanying simulations will reveal more information about INSPECT3R's capabilities, paving the road for future experiments to increase the space flight Technical Readiness Level (TRL) from 3 to 4. We will present the current state of our system design, simulation results, and first experiment results as well as INSPECT3R's potential applications for planetary science missions.

This work was supported by the PICASSO program from NASA.

Abstract 253 at 1:00 PM

Session AP-SD-01 Thursday 1:00 PM - West Fork II

Battery-Operated Linacs for Portable Threat Detection

Amy Shiroma, Jefferson Amacker

TibaRay, Inc., Fremont California, United States

Compact and light-weight x-ray sources that are man-portable and easily deployed in the field are very desirable for security and inspection as well as non-destructive testing purposes. In principle, a high-energy x-ray imaging source could be easily built using existing linac technology. However, size, weight, cost, and power consumption are significant limitations of these systems.

Recent breakthroughs in particle accelerator design have enabled compact accelerators to generate large gradients and high output energies. Their efficient use of RF power allows for lower demand on RF power requirements. Pairing these components with a novel battery-powered modulator will allow for a very efficient and, most importantly, compact portable x-ray imaging system.

In this talk, we will review compact, portable, variable-energy linear accelerator systems based on TibaRay technology. The talk will look at the novel enabling technology of accelerators, compact isolators, battery-operated modulators, and the system designs for both 2.5 MeV and 7 MeV peak-energy accelerators.

The linacs are designed based on the concept of distributed coupling source developed at the SLAC National Accelerator Laboratory. This approach led to highly efficient resonant cavities and simplified approaches to manufacture them. They operate at X-band frequencies that are standard for medical and industrial applications as well as for large research accelerators. The efficiency of the accelerator design allows it to run at much lower power, decreasing the size, cost, and weight of the power-generation system.

These accelerators are both designed to be powered by a compact commercial 400kW RF source. This RF source is powered by a 30kV modulator designed and built by TibaRay. This modulator uses the concept of distributed Marx capacitor bank where lower voltage modular units are stacked up as per requirement to generate the high voltage. A removable battery pack powers the modulator for up to15 minutes of imaging time.

Another successful size and weight reduction was TibaRay's invention of a compact isolator based upon a novel circular polarizer design. The isolator is broad band and less than half the size of comparable isolators.

Our accelerator and RF component technology offer cost and size reductions for accelerator-based x-ray sources that are used for imaging, medical, security and industrial applications. Because of their efficiency and compactness, they can offer an attractive alternative for betatron-based mobile imaging systems. The system efficiency can also be used to greatly increase the output for Radiation Therapy, one day enabling FLASH therapy.

Abstract 182 at 1:20 PM

Session AP-SD-01 Thursday 1:00 PM - West Fork II

How a 40 year old machine remains world class, characteristics and use of a Scanditronix M22 Microtron for industrial imaging

James Hunter

E-6 Non-destructive Testing Group, Los Alamos National Lab, Los Alamos New Mexico, United States

Los Alamos National Lab (LANL) has maintained and used a Scanditronix M22 Microtron since the early 1990s for industrial x-ray imaging. This system was originally built for cancer therapy in the early 1980s and has been refurbished multiple times while at LANL. A common question about this machine is "why not replace or upgrade it with an industrial Linear accelerator source that is easier to maintain"? This talk covers the basic characteristics of what the M22 Microtron is and then reviews the imaging chain for different modes of high energy x-ray imaging from film radiography through high resolution computed tomography. The key Microtron characteristics of flexibility in end point energy and source spot size are then discussed in the context of different imaging modalities and impacts these characteristics have on data quality and facility size. Finally, areas that could be improved on the Microtron or on a comparable future system are also discussed.

Abstract 95 at 1:40 PM

Session AP-SD-01 Thursday 1:00 PM - West Fork II

Tunable Intense High-Energy Photon Source Development and Testing

Igor Jovanovic[1], Robert Berry[2], Ronald Agustsson[2], James Rosenzweig[2,3], Alex Murokh[2]

(1)University of Michigan, Ann Arbor MI, United States
(2)RadiaBeam Technologies, Santa Monica CA, United States
(3)University of California, Los Angeles CA, United States

There is a growing demand in multiple communities for laboratory-scale high-brightness, energetic photon sources at a wide range of average power. High average power sources are needed for industrial processing; moderate power sources could be applied in industrial metrology, and lower power sources could be used for qualification, inspection, and testing. In medical applications, such sources may enable significant advances in the imaging of biological tissue and skeleton, thereby improving clinical treatments. In global security, high-energy photon sources could be used to address long-standing problems in nuclear security, arms control, and forensics. Finally, high-brightness photon sources may enable fundamental advances across many scientific disciplines by imaging that exhibits exceptional spatial, energy, and time resolution. Inverse Compton Scattering (ICS) is a promising technology on the lower end of the power spectrum, with the promise of a compact and energy-tunable hard X-ray light source of a near synchrotron beam quality, and with excellent potential scalability into gamma-ray spectral range. We will discuss a considerable volume of the experimental work performed to date on the ICS sources and discuss the recent and ongoing accelerator industry efforts to develop and commercialize the technology. In addition, an overview of the RadiaBeam internal ICS demonstrator program will be presented, including its status and outlook.

Abstract 168 at 2:00 PM

Session AP-SD-01 Thursday 1:00 PM - West Fork II

Portable Isotopic Assay via Nuclear Resonance Transmission Analysis Using a Short-Pulse Neutron Source

Andrea Schmidt[1], Enrique Anaya[1], Michael Anderson[1], Steve Francis Chapman[1], Chris Cooper[1], Areg Danagoulian[2], Owen Drury[1], Luis Frausto[1], Clement Goyon[1], Ethan Klein[2], Anthony Link[1], Don Max[3], Jaebum Park[1], Sophia Rocco[1], James Kurt Walters[1], Amanda Youmans[1]

[(1)]Lawrence Livermore National Laboratory, Livermore CA, United States
[(2)]Massachusetts Institute of Technology, Cambridge MA, United States
[(3)]Nevada National Security Site, North Las Vegas NV, United States

Nuclear Resonance Transmission Analysis (NRTA) is a technique used to identify and measure the concentrations of specific isotopes in a test object. By irradiating the test object with broadband neutrons, and measuring which energies of neutrons are not transmitted, the observer can determine the presence and quantity of various isotopes. Most metals and actinides have resonances in the 1-100 eV range, allowing them to be identified with this technique. NRTA measurements have primarily been performed at large, stationary, accelerator facilities, limiting their utility in the field. Our group recently performed proof-of-principle NRTA experiments using the MJOLNIR dense plasma focus (DPF) as the neutron source. Because the neutron energy is determined by time-of-flight, the DPF's short (~50 ns) pulse presents an advantage over more traditional accelerator neutron sources by allowing a 2-3 meter distance between source and detector while still providing sufficient energy resolution for the measurement. While MJOLNIR itself is not portable, an analogous DPF whose driver produces the same plasma current could be designed to fit on a semi-truck. Such a system could be used for nuclear waste clean-up and/or safeguards, and would be capable of making an isotopic measurement with a single neutron pulse. Smaller pallet-portable or backpack portable systems could be designed to be rapidly pulsed so that a similar NRTA measurement could be made through the addition of many pulses over the course of several minutes. Initial NRTA measurements will be presented, as well as the development of the MJOLNIR DPF, and concepts for deployable systems of different scales.
Prepared by LLNL under Contract DE-AC52-07NA27344.

Abstract 119 at 2:20 PM

Session AP-SD-01 Thursday 1:00 PM - West Fork II

Impact of Solid-State Pulsed Power on The Scorpius Multi-Pulsed Radiography Accelerator

Saeed Assadi

National Security Engineering Division, Lawrence Livermore National Lab, Livermore CA, United States

Scorpius is a multi-pulse, single-axis radiographic system that will be installed in the underground U1a facility at the Nevada National Security Site (NNSS). This capability is being developed by the Department of Energy's National Nuclear Security Administration (NNSA) under the Advanced Source and Detectors (ASD) Project as a joint effort between Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL), Sandia National Laboratories (Sandia), and the NNSS. This project was initially described at the 2017 Pulsed Power Conference in Brighton, England. Since then, significant changes to the overall design have taken place. While the primary architecture of a multi-pulse linear induction accelerator remains intact, the pulsed power driver design has been completely updated. Scorpius will be powered in entirety by a **solid-state pulsed power architecture**. This architecture provides significant operational advantages, including the ability to generate a nearly arbitrary electron beam (and therefore radiographic) pulse structure and an impressive modulation capability that enables correction of reflected voltages that can perturb the electron beam transport and degrade the radiographic spot-size due to chromatic aberration. In addition to the major design updates that enable both the injector and accelerator cells to be coupled to the relatively low voltage solid-state pulsed power (SSPP) systems overcame a significant design challenge the system stays compatible with the restrictive space and environment in the underground U1a complex. This presentation describes our progress, overall design of the Scorpius system, the major design and implementation challenges, and an evaluation of system performance.

Abstract 252 at 1:00 PM

Session AR-NP-05 Thursday 1:00 PM - West Fork I

Report on STREAMLINE collaboration

Xilin Zhang

Theory, Facility for Rare Isotope Beams, East Lansing MI, United States

The US Department of Energy recently funded our STREAMLINE (**S**mar**T** **R**eduction and **E**mulation **A**pplying **M**achine **L**earning **I**n **N**uclear **E**nvironments) collaboration. In this multi-institution project, we aim to advance the frontiers of theoretical and computational research on the nuclear many-body problem using machine learning. In this talk, I will report on some of our scientific achievements.

Abstract 94 at 1:25 PM

Session AR-NP-05 Thursday 1:00 PM - West Fork I

Towards Realtime Neural Compression for Sparse Time-Projection Chamber Data

Yi Huang[1], Yihui Ren[1], Shinjae Yoo[1], Jin Huang[2]

[(1)]Computational Science Initiative, Brookhaven National Laboratory, Upton NY, United States

(2)Physics, Brookhaven National Laboratory, Upton NY, United States

High-energy, large-scale particle colliders generate data rapidly, amounting to about 1 terabyte per second in nuclear physics and even reaching petabytes per second in high-energy physics. The development and co-designing of real-time, high-throughput artificial intelligence algorithms, particularly for cutting-edge AI hardware, are gaining more attention. At the sPHENIX experiment located at the Relativistic Heavy Ion Collider (RHIC), Brookhaven Lab, a time projection chamber serves as the primary tracking detector, capturing particle paths within a cylindrical 3D space. The data collected are typically sparse, posing difficulties for traditional learning-free lossy compression algorithms like SZ, ZFP, and MGARD. However, the 3D convolutional neural network-based Bicephalous Convolutional Autoencoder (BCAE) and its derivatives surpass these traditional methods in terms of compression efficiency and accuracy of reconstruction. BCAE also benefits from the computational abilities of graphics processing units and novel non-von Neumann AI hardware, making it suitable for use in a diverse high-performance computing setup. This presentation will cover the challenges of TPC data compression, the BCAE algorithms, their optimization, and preliminary performance results on other advanced AI platforms like Groq and GraphCore's IPU.

Abstract 194 at 1:50 PM

Session AR-NP-05 Thursday 1:00 PM - West Fork I

Graph Learning for Operation of Particle Accelerators

Chris Tennant[1], Theo Larrieu[1], Daniel Moser[1], Song Wang[2], Jundong Li[2]

(1)Jefferson Laboratory, Newport News Virginia, United States
(2)Department of Electrical and Computer Engineering, University of Virginia, Charlottesville Virginia, United States

We describe research in deep learning on graph representations of the injector beamline at the Continuous Electron Beam Accelerator Facility (CEBAF) to develop a tool for operations. We leverage operational archived data - both unlabeled and labeled configurations - to train a graph neural network (GNN) via our methods of self-supervised training and supervised fine tuning. We demonstrate the ability of the GNN to distill high-dimensional beamline configurations into low-dimensional embeddings and use them to create an intuitive visualization for operators. By mapping out regions of latent space characterized by good and bad setups, we describe how this could provide operators with more informative, real-time feedback during beam tuning compared to the standard practice of interpreting a set of sparse, distributed diagnostic readings. We further describe the results of a framework that provide users with explanations for why a configuration changes location in the latent space.

Abstract 305 at 2:15 PM

Session AR-NP-05 Thursday 1:00

Autonomous Detector Control and Fast Data Processing for sPHENIX and future EIC detector

Jakub Kvapil

Los Alamos National Laboratory, Los Alamos NM 87545 , United States

The push for increasing data-rates at high-energy nuclear facilities such as the Large Hadron Collider (LHC), the Relativistic Heavy Ion Collider (RHIC), and the future Electron-Ion Collider (EIC) pose challenges for data-processing. This talk will focus on an R&D project, initiated by the DOE Nuclear Physics AI-Machine Learning initiative in 2022 that leverages AI to address these challenges. Our focus is on developing a demonstrator for real-time processing of high-rate data streams from the tracking detectors of the sPHENIX experiment. This demonstrator will use algorithms implemented on the FPGAs that when integrated with streaming readout will efficiently identify rare heavy-flavor events in high-rate pp collisions (3MHz) using GNN and hls4ml. Therefore, this demonstrator serves a dual purpose that also benefits the scientific mission of sPHENIX. This approach is transferable and will be used in the EIC for DIS-electron tagging.

In this talk these projects will be discussed that showcase the transformative potential of AI and FPGA technologies in high-energy nuclear and particle experiments real-time data processing pipelines.

Abstract 196 at 1:00 PM

Session AR-RE-08 Thursday 1:00 PM - Elm Fork I

Development of In-situ Ion Irradiation Tools for Nuclear Engineering Applications: Lessons Learned and Future Directions

Khalid Hattar[1], Eric J. Lang[2]

(1)Department of Nuclear Engineering, University of Tennessee, Knoxville TN, United States
(2)Department of Nuclear Engineering, University of New Mexico, Albuquerque NM, United States

The need for clean reliable energy to meet the global demand without contributing significantly to carbon dioxide emissions has resulted in rapid growth in a range of advanced fission and fusion reactor concepts gaining traction over the last decade. Whether it be small modular reactors for next step fission or stellarator for a promising leap in fusion, all of these concepts will agree to different degrees that a major hurdle is the proper selection of nuclear and structural materials that can survive the lifetime of the component in the reactor with the reliability that has come to be expected from the nuclear industry. To develop such knowledge base without decades of testing, the field has relied on the development of predictive models to understand potential material degradation pathways and thus predict lifetime. These models

need refining and validating data but cannot wait decades giving the global demand. As such, ion accelerator coupled with advanced analytical tools can provide insight into materials response to tailed environments that can be directly compared to various length scale models.

This presentation will start with a review of past work that has been done to couple ion accelerators to analytical tools. Starting with the coupling between three ion accelerators and a JEOL 2100 TEM in the creation of the In-situ Ion Irradiation Transmission Electron Microscope (I3TEM) [1] and the associated coupling to a field emissions Scanning Electron Microscope (I3SEM) (2)The first part of this section will focus on results related to extremely small, but insightful, nuclear materials. This includes the analysis of nuclear fuel post high burn-up [3] and tritium containing materials. It will then follow with a detailed discussion of leason learned from such couplings and the resulted suggestions for the development of future such facilities.

The presentation will then highlight the efforts currently underway at the Tennessee Ion Beam Materials Laboratory (TIBML) to develope new class of tools for evaluating materials degradation when exposed to coupled extreme environments. TIBML is the next evolution of the world-class Ion Beam Analysis (IBA) facility based on a 3 MV Tandem accelerator [4] to explore more Radiation Effects Microscopy (REM), Ion Beam Modification (IBM), and in-situ characterization. This is added by the addition to new ion sources (20 kV and 5 kV), a 300 kV implanter, and a highly modified JEOL 2100+ Scanning Transmission Electron Microscope (STEM). In addition to these four new particle generating devices, the facility is developing a range of custom end stations and testing apparatus to better understand materials important to nuclear applications. These include the development of in-situ TEM ion and laser irradiation capabilities, the incorporation of in-situ nanoscale mechanical testing, in-situ acoustic emissions spectroscopy, a range of optical spectroscopy techniques, and pump-probe laser-based techniques. In addition to controlling the thermal (30 K to 1473+ K) and irradiation species, energy, flux and fluence, TIBML hopes in the near future to control the mechancial load, gas or liquid environment, and magnetic field the sample is experiencing during ion bombardment. The use of one or multiple of these tool sets to control the radiation environment should provide a path for greater understanding of nuclear related materials response to coupled extreme environments. This insight can help to advance predictive models and expedite the introduction of new materials into future reactor designs.

[1] Parrish, Riley J., et al. "Exploring coupled extreme environments via in-situ transmission electron microscopy." Microscopy Today 29.1 (2021): 28-34.

[2] Lang, Eric Joseph, et al. "Development of an in situ ion irradiation scanning electron microscope." Nuclear Instruments and Methods in Physics Research Section B 537 (2023): 29-37.

[3] Barr, C. M., et al. "The complex structural and chemical nature of monolithic U-10Mo fuel and Zr barrier layer." Journal of Nuclear Materials 573 (2023): 154083.

[4] Zhang, Yanwen, et al. "New ion beam materials laboratory for materials modification and irradiation effects research." Nuclear Instruments and Methods in Physics Research Section B 338 (2014): 19-30.

This work was performed, in part, at the Center for Integrated Nanotechnologies, an Office of Science User Facility operated for the U.S. Department of Energy (DOE) Office of Science by Los Alamos National Laboratory (Contract 89233218CNA000001) and Sandia National Laboratories (Contract DE-NA-0003525).

Abstract 236 at 1:30 PM

Session AR-RE-08 Thursday 1:00 PM - Elm Fork I

Microshear deformation for evaluating effects of void swelling on mechanical properties of heavy ion irradiated metals

Tongjun Niu[1], Hyosim Kim[2], Matthew Chancey[2], Yongqiang Wang[2], Jonathan Gigax[1], Nan Li[1]

(1)Center for Integrated Nanotechnologies, Los Alamos National Laboratory, Los Alamos New Mexico, United States
(2)Materials Science and Technology Division, Los Alamos National Laboratory, Los Alamos New Mexico, United States

Understanding the mechanical properties of irradiated materials has been an emerging research area for the design of radiation-tolerant materials. In this study, a novel microshear testing geometry was developed to investigate the mechanical property changes of heavy ion irradiated single crystal Cu (110). High-density voids were introduced into the Cu specimens after 10 MeV Cu^{4+} ion irradiation to peak damage levels of 11 dpa and 110 dpa. Microshear testing revealed irradiation hardening in Cu irradiated to 11 dpa, followed by softening by 110 dpa. The interactions between dislocations and voids were examined by post-mortem TEM analysis. Micropillar compression and nanoindentation were implemented to validate and compare with the results from microshear testing, where a good agreement was found between micropillar compression and microshear responses. The discrepancy with nanoindentation results was likely to arise from several factors, including residual stress and dislocation content. Additionally, the influence of size and aspect ratio of microshear specimens on shear deformation response was investigated to provide guidelines for the shear specimen geometry design.

Abstract 45 at 1:50 PM

Session AR-RE-08 Thursday 1:00 PM - Elm Fork I

Effect of surface orientation on blistering of copper under high fluence of keV hydrogen ion irradiation

Alvaro Lopez-Cazalilla[1], Catarina Serafim[1,2], Sergio Calatroni[2], Flyura Djurabekova[1]

[(1)]Helsinki Institute of Physics, University of Helsinki, Helsinki Uusima, Finland
[(2)]CERN (European Organization for Nuclear Research), Geneva, Switzerland

Increasing demands for energy, along with the yet increasing concern for the development of environmentally friendly technologies, call for exploring new ways of cost-efficient energy production. Hydrogen is one of the primary candidates for this purpose, due to its abundance and diverse ways of how it can be used. Moreover, hydrogen-based technologies are carbon-neutral, and hence their use could have a major effect on slowing down climate change. Hence, the insights into the interaction of H with metals are crucial to reach that ambitious goal.

Blistering is a process that usually takes place close to the surface of metals when they are irradiated, as can be seen in radio-frequency quadrupoles accelerating structures. This pronounced change of the surface morphology has been measured when extended irradiation is done with energetic light ions.

We use computational methods to address the fast bubble growth in Cu, associated with blistering, when exposed to H^- irradiation (1)We analyze the interaction of the formed dislocation loops with the different surface orientations of copper. Furthermore, we focus on the H depth profile and vacancy distributions along low-indice crystallographic directions [2].

We find a strong correlation between the blistering and crystallographic orientations. The distance between the mean penetration depth of H and the vacancies (recoils) creation is considerably different along the considered directions, and provides an explanation of the resistance to blistering of some grain orientations. Furthermore, we introduce some successful initial tests performed with the newly developed machine-learned interatomic potential.

Abstract 209 at 2:10 PM

Session AR-RE-08 Thursday 1:00 PM - Elm Fork I

Effect of Mo on oxidation, irradiation and creep properties of FeCrAl alloys

Pengcheng Zhu, Hyosim Kim, Yongqiang Wang

Los Alamos National Laboratory, Los Alamos NM, United States

The FeCrAl alloys are promising substitute materials of zriconum-based alloys for fuel cladding to increase the accident tolerance of

light water reactors. The adding of Mo has been considered to enhance the oxidation resistance of FeCrAl alloys. In this study, the Fe-12Cr-6Al alloys with 0 and 2 wt. % Mo are prepared at pristine and oxidized (1200 °C for 2 hours in the air) status. The specimens subjected to 8 MeV Fe^{3+} irradiation at 300 °C with a fluence of $5.26 \times 10^{16}/cm^2$ are investigated to provide improved understanding of Mo effect on FeCrAl oxidation, irradiation and creep properties. TEM characterizations will elucidate the influence of Mo on the formation of oxide layer and the subsequent effect on irradiation damage. High temperature micropillar compression for creep tests on the pristine and irradiated FeCrAl samples will be performed to reveal the mechanical response and failure mechanism. This study will provide more insight into the development of accident fuel tolerant (ATF) core materials.

Abstract 31 at 3:00 PM

Session AA-IBTM-03 Thursday 3:00 PM - Post Oak

Bias and synergy in the self-consistent analysis of IBA data

Tiago Fiorini Silva[1], Cleber Lima Rodrigues[2], Manfredo Harri Tabacniks[2], Matej Mayer[3], Udo von Toussaint[3]

[(1)]Nuclear Physics Department, Universidade de São Paulo, São Paulo São Paulo, Brazil
[(2)]Applied Physics Department, Universidade de São Paulo, São Paulo São Paulo, Brazil
[(3)]E2M, Max-Planck-Institut für Plasmaphysik, Garching Bayern, Germany

Using multiple Ion Beam Analysis (IBA) measurements or techniques combined with self-consistent data processing allows extracting more (or more accurate) information from the measurements than processing data from single measurements (1)The approach has gained many adepts thanks to the exploitation of the synergy by combining multiple measurements. Solving ambiguities, increasing depth resolution, defining constraints and extending applicability are the main strengths of the approach.

The self-consistent data processing consists in formulating a multi-objective minimization problem that can be tackled by the adoption of the weighted-sum method (2)This is a convenient way to incorporate constraints and limits.

However, questions that may rise with such a procedure are: Which weights to choose and how biased are the final results by the use of weights? When such synergy does really occurs and what is the gain of combining different measurements? Which additional measurements provide more information?

We study possible answers to these questions using information theory. A case study where the synergy in the combination of techniques is the key to solve the inverse problem will be presented (3)As consequence, we demonstrate that measurements can be ranked by its information content, and certain combinations of measurements may result in better accuracy than others. The tests were performed using the MultiSIMNRA software [4], with SIMNRA 7 [5] as calculation engine.

[1] C. Jeynes, M. J. Bailey, et al., Nucl. Instrum. Meth. B, 271, 107-118, 2012.

[2] T. F. Silva et al., Nucl. Instrum Meth B., 506, 32-40, 2021.

[3] T. F. Silva, et al., Nucl. Instrum. Meth. B, 533, 9-16, 2022.

[4] T. F. Silva, C. L. Rodrigues, et al., Nucl. Instrum. Meth. B, 371, 86-89, 2016.

[5] M. Mayer, Nucl. Instrum. Meth. B., 332, 176-180, 2014.

Abstract 144 at 3:30 PM

Session AA-IBTM-03 Thursday 3:00 PM - Post Oak

Fast simulation of ion beam analysis spectra using binary collision approximation

Hans Hofsäss, Felix Junge, Patrick Kirscht

II. Institue of Physics, Georg-August-University Goettingen, Goettingen, Germany

The dynamic binary collision approximation program IMINTDYN [1,2] allows a reliable prediction of ion solid interaction. We have extended the IMINTDYN program to efficiently simulate high energy ion scattering as well as ion induced nuclear reaction spectra. This includes RBS, LEIS, ERDA, coincidence ERDA, ERCS, NRA and SIMS. The optimization includes (i) adjustable mean free path of high energetic ions (ii) enforced large angle scattering with scattering cross sections stored in weight factors, and (iii) enhanced data handling to identify coincident scattering events. The program runs on a AMD Ryzen Threadripper PRO 5965WX workstation. Typical simulations with millions of projectiles are finished within 2-20 minutes, faster than the duration of the experiment. The simulations provide details of the spectra, like single, dual and multiple scattering events, energy versus depth information, isotope information etc. We present selected examples for He ion RBS [1], Low energy He ion scattering (LEIS) as well as non-Rutherford backscattering of MeV H ions.

[1] H. Hofsäss, F. Junge, P. Kirscht and K. van Stiphout, Material Research Express (2023) DOI 10.1088/2053-1591/ace41c

[2] H. Hofsäss, A. Stegmaier, Nucl. Instr. Meth B 517 (2022) 49

Abstract 123 at

Session AA-IBTM-03 Thursday

3:50 PM 3:00 PM - Post Oak

Progress on Improving SIMS Quantification of Erbium Through the Development of Ion-Implanted Calibration Standards

Sage D.C. Buchanan[1,2], Lyudmila V. Goncharova[1,3], Mark C. Biesinger[2,3]

[(1)]Physics and Astronomy, Western University, London Ontario, Canada
[(2)]Surface Science Western, Western University, London Ontario, Canada
[(3)]Chemistry, Western University, London Ontario, Canada

Erbium is an essential component in various clean energy and modern technology applications from nuclear control rods to infrared optics. As demand grows for these high-tech applications alongside geopolitical supply chain risks, the need to advance resource development through all available means is apparent, including both mining and recycling. In order to develop and maintain responsible resource management strategies, it is crucial to be able to reliably identify and quantify rare-earth-containing materials and to have a comprehensive understanding of their properties.

This talk will discuss our efforts in advancing current methodologies surrounding the analysis and characterization of erbium through the development of ion-implanted standards. In this work we utilize a Tandem accelerator and an Er_2O_3 sputter source to implant 2.5 x 10^{15} atoms/cm^2 of Er^+ into Si and SiO_2 substrates at 800 keV. Implantation parameters are optimized using Monte Carlo simulations within the Stopping Range of Ions in Matter (SRIM) software to achieve the desired concentrations and depth distributions of implanted ions. Subsequent Rutherford Backscattering Spectrometry (RBS) measurements are carried out on the respective Tandetron beamline using He^+ ions at 1 MeV, up to a dosage of 1.0 μC. These analyses coupled with the information of implantation dosage can be compared to the depth distributions obtained through Secondary Ion Mass Spectrometry (SIMS) analyses to calibrate and improve the quantification of erbium and other rare-earths within materials. To achieve the desired near-surface implantation profile, Au/Ti masking layers are used to slow the Er^+ ions. The masking layers are deposited onto the wafer surfaces before implantation and etched off afterwards. RBS and X-ray Photoelectron Spectroscopy (XPS) analyses reveal that some of these making layers knock into the underlying substrate and cannot be fully removed with additional etching. As expected, these masking layers do effectively slow down the Er^+ ions to achieve a relatively uniform near-surface concentration profile, and significantly reduced implantation damage to the surface layer of the Si / SiO_2 substrates, evident through RBS channeling measurements. We are also developing XPS curve-fitting procedures and will present results that allow the reliable chemical state identification of erbium compounds. However, these Er atomic percentages prove to be insufficient within Si-rich substrate matrices to allow chemical state identification via XPS due to the strong overlap of Si plasmon loss structures with low intensity Er 4d signals.

Abstract 101 at 4:10 PM

Session AA-IBTM-03 Thursday 3:00 PM - Post Oak

The Upgraded Ion Beam Analysis Capability at LANL

Igor Usov, Matthew Chancey, Arthur DuBay, Yongqiang Wang

Los Alamos National Laboratory, Los Alamos New Mexico, United States

In this presentation we describe the Ion Beam Analysis (IBA) capability upgrades recently installed at the Ion Beam Materials Laboratory (IBML) at LANL. The NEC RC61 Analysis Endstation replaced the obsolete instrumentation on the R15° beamline of the 3MV NEC Pelletron tandem ion accelerator. The new characterization facility includes all major IBA methods: RBS, PIXE, ERDA, NRA, PIGE, Channeling and Ion Beam Induced Luminescence (IBIL). It will better support material science programs at LANL, as well as university and industry collaborators. A few selected examples focused on the measurement's accuracy will be presented and discussed.

Abstract 264 at 4:30 PM

Session AA-IBTM-03 Thursday 3:00 PM - Post Oak

IBIC technique for the in-situ assessment of the ion beam spot size and single-ion counting.

Greta Andrini[1], Alberto Bortone[1], Marko Brajković[3], Matteo Campostrini[4], Emilio Corte[1,2], Andreo Crnjac[3], Sviatoslav Ditalia Tchernij[1,2], Jacopo Forneris[1,2], Milko Jakšić[3], Elena Nieto Hernández[1,2], Georgios Provatas[3], Valentino Rigato[4], Zdravko Siketić[3], Ettore Vittone[2]

(1)INFN - TO, Istituto Nazionale di Fisica Nucleare, Turin, Italy
(2)Physics Department, University of Turin, Turin, Italy
(3)Laboratory for Ion Beam Interactions, Ruđer Bosǩović Institute, Zagreb, Croatia
(4)Laboratori Nazionali di Legnaro, Istituto Nazionale di Fisica Nucleare, Legnaro PD, Italy

MeV ion beams represent a powerful resource for characterizing and functionalizing solid-state materials. For instance, ion beam nanoscale lithography and deterministic implantation technologies have strongly benefitted from steady improvements in the focusing and collimation of ion beams over the last decade, thus offering new opportunities for the functionalization of materials at the nanoscale. While the scientific community has recently started to employ ion implantation target samples themselves as resources for single ion detection with position sensitivity [1], their exploitation as diagnostic tools for the assessment of ion beam parameters is still under investigation. So far, STIM (Scanning Transmission Ion Microscopy) and PIXE (Particle-Induced X-ray Emission) are the main techniques commonly implemented for beam size assessment in ion microbeam technology. However, they rely on the imaging of patterned standards [2], e.g., TEM grids, different from the sample to be processed, and a separate measurement system is typically required.

Here, we report on the recent experimental activities performed at the University of Torino and the Italian National Institute of Nuclear Physics on the exploitation of rarefied ion beams to achieve position-sensitive single-ion counting by means of the Ion Beam-Induced Charge technique.

Activities are based on two primary directives. The first one regards the assessment of the ion beam spot size impinging a given target. This was performed by exploiting IBIC as an alternative technique with respect to conventional STIM. In particular, we performed an IBIC experiment using a custom Si photodiode micromachined via FIB milling, which is exploited as an integrated beam diagnostic tool for the real-time assessment of the beam spot size of the probe beam. In particular, taking advantage of the spatial correlation between the induced charge pulse amplitude and the micro-structures through Charge Collection Efficiency (CCE) measurements, we were able to extract the spatial information on the size of a 2 MeV Li^+ ion micro-beam. The proposed approach [3], validated with the support of numerical simulations based on the Shockley-Ramo-Gunn model, allowed the qualification of the ion beam by the CCE mapping of the very same target of the ion beam analysis and to compare the results with conventional STIM method.

The second experimental approach aims at the direct position sensitivity to the impact location of the single ion strike. For this reason, the use of the target itself as a solid-state particle detector is also discussed to remark on the potentiality of the Ion Beam Induced Charge technique in the implementation of a deterministic approach to implant single impurities in silicon. In fact, the recent isolation of radiation-induced optically active defects in silicon at the single-emitter level [4], [5] unlocked a promising perspective for the development of integrated silicon photonics based on native defects. However, among the main fabrication challenges in the realization of large-scale single-photon devices by means of ion implantation is undoubtedly the delivery of individual impurities at each implantation site. In this regard, the same photodiode was initially used to test the IBIC charge-sensitive electronic chain for single-ion detection using MeV protons at the AN2000 accelerator of the National Laboratories of Legnaro (LNL-INFN) in Padova. Subsequently, a dedicated IBIC experiment was carried out at the Ion Implantation Laboratory of the Physics Department of the University of Torino, using a 100 keV proton collimated beam down to a 10-um spot as probing ions. Therefore, a brief overview will be provided on the current activities exploiting the Ion Beam Induced Charge technique as a post-detection technique for the fabrication of solid-state quantum emitters.

References

[1] J. L. Pacheco et al., Rev. Sci. Instrum. 88, doi: 10.1063/1.5001520, (2017)

[2] J. E. Manuel et al., Rev. Sci. Instrum. 89, 1, doi: 10.1063/1.5017824, (2018)

[3] G. Andrini et al, Vacuum 203, (2022).

[4] W. Radjem et al., Nature Electronics volume 3, pages738-743 (2020)

[5] G. Andrini et al., communication materials 5.47, (2024)

Abstract 233 at 3:00 PM

Session AP-MA-04 Thursday 3:00 PM - Elm Fork II

Hot Stuff-producing At-211 for novel medical applications

Lauren McIntosh[3], Jonathan Burns[2], Brooklyn Green[1,3], Lauren Hoekstra[1,3], Christine Lawrence[3], Laura Bills[1,3], Gabriel C Tabacaru[3], Evgeny E Tereshatov[3], Justin Tobar[1,3], Sherry J. Yennello[1,3]

(1)Chemistry Department, Texas A&M University, College Station TX, United States
(2)Chemistry Department, University of Alabama at Birmingham, Birmingham AL, United States
(3)Cyclotron Institute, Texas A&M University, College Station TX, United States

Targeted alpha therapy (TAT) is an area of discovery for cutting-edge cancer treatments. Astatine-211 (At-211) has a 7.2 hour half-life, and desirable properties for TAT. Due to the production mechanism of At-211, very few facilities have the capability to produce it. It has no stable isotopes, and shipping quickly is important to have it in a usable form upon arrival. This talk will discuss recent TAMU efforts in production, separation, and fundamental chemistry.

Abstract 237 at 3:20 PM

Session AP-MA-04 Thursday 3:00 PM - Elm Fork II

Accelerator Based Production of Mo-99: Target Design Considerations.

Sergey Chemerisov

Argonne National Laboratory, Lemont IL, United States

The National Nuclear Security Administration's (NNSA), in partnership with commercial entities and the US national laboratories, is working to accelerate the establishment of a reliable domestic supply of Mo-99 for nuclear medicine while also minimizing the civilian use of HEU. Several target configurations

and cooling approaches were used for neutron generation and production of Mo-99 either through fission on LEU or photonuclear reaction of the enriched Mo-100.

In both approaches a high-power electron accelerator was used to produce the required flux of high energy photons/neutrons through the bremsstrahlung process.

The ability to remove heat from the target is a limiting factor in the production of Mo-99. To test a photonuclear approach a pressurized gaseous helium cooling system was installed and tested at Argonne to allow study of the thermal performance of the target and production of Mo-99. Multiple irradiations of the natural and enriched Mo-100 targets were conducted at different beam energies to study the thermal performance of the target. In the latest experiments production scale target performance was investigated by varying beam size and helium cooling flow to benchmark the CFD simulations. A comparison of the computer simulations and experimentally measured target system parameters will be presented.

For fission-based production of Mo-99 DU x-ray/neutron converter was used. The thermal hydraulic performance and limitations of water-cooled targets will be also discussed.

Work supported by the U.S. Department of Energy, National Nuclear Security Administration's (NNSA's) Office of Defense Nuclear Nonproliferation, under Contract DE-AC02-06CH11357.Argonne National Laboratory is operated for the U.S. Department of Energy by UChicago Argonne, LLC.

Abstract 23 at 3:40 PM

Session AP-MA-04 Thursday 3:00 PM - Elm Fork II

Photonuclear cross-section and yields of $^{100}Mo(g,x)^{99}Mo$, $^{100}Mo(g,np)^{98m}Nb$, and $^{59}Co(g,xn; x=1\text{-}4)\ ^{58\text{-}55}Co$ reactions with intermediate bremsstrahlung energies

Md Shakilur Rahman[1], Guinyun Kim[2]

[(1)]Institute of Nuclear Science and Technology, Bangladesh Atomic Energy Commission, Dhaka Dhaka, Bangladesh
[(2)]Department of Physics, Kyungpook National University, Kyungpook National University, Daegu Daegu, Korea

Nuclear reaction data with photon beam is important in a variety of existing and emerging applications in practical aspect of science and technology. When photon interacts with the nucleus above the separation energy, the collective oscillations of nucleons is vigorously excited by absorbing the incoming photon. The intense photon source with 50-70 MeV energy is suitable for separating reaction channel that makes it possible to study multi-particle photonuclear reaction by residual activation analysis (1)On the other hand, photonuclear data has significant values for the management of long-lived radioactive nuclei generated from nuclear facilities. The transmutation and incineration of nuclear reactor wastes by Accelerator Driven Sub-Critical System (ADSS), is of great importance that have received interest in the past fifty years. Basically, any theoretical model for photonuclear reaction must include the different reaction mechanism with possible photo-excitation processes. This requires the experimental data for complex mechanism of photonuclear cross-section at intermediate bremsstrahlung energy. In the present study, the average cross-sections of $^{100}Mo(g,\mathbf{x})^{99}Mo$, $^{100}Mo(g,pn)^{98m}Nb$, and $^{59}Co(g,\mathbf{x}n; \mathbf{x}=1\text{-}4)\ ^{58\text{-}55}Co$ reactions was measured with bremsstrahlung end-point energies of 55-, 60- and 65-MeV via photo-activation technique at Pohang Accelerator Laboratory (PAL), Korea. Bremsstrahlung beam is generated from 100 MeV electron accelerator by hitting electron in a thin tungsten target. High-purity metallic foils of ^{nat}Mo and ^{59}Co with monitor foil Au were irradiated with bremsstrahlung beam and the activation product was then measured by off-line g-spectrometric system. Flux correction factors from monitor foil reaction to observed reaction were calculated from bremsstrahlung spectrum via GEANT4 simulation code. The measured experimental values together with other literature data are compared with theoretical nuclear reaction code Talys 1.6 and Empire 3.2.2 Malta that shows in general agreement with theoretical prediction. The possibility of photo production of medically important isotopes ^{99}Mo, $^{58\text{-}55}Co$ via thin target irradiation using electron accelerator was investigated. The specific activity of measured ^{99}Mo shows an agreement which lies within the reported values by different authors with photon beam. On the other hand, the specific activities ^{58}Co and ^{57}Co isotopes are the first-time measurement with photon beam. The measured activities of ^{58}Co and ^{57}Co show the possibilities of a new production route via electron accelerator. The specific activities of medically important isotopes ^{99}Mo, ^{58}Co and ^{57}Co were found (1.114±0.082), (9.337±0.554), and (1.718±0.108) MBq/mA.h.gm at bremsstrahlung end point energy 65 MeV which shows an excellent possible production route via electron accelerator. From the experimental cross-section data, it is observed that the average cross-sections increase with bremsstrahlung energy up to Gaint Dipole Resonance (GDR) and thereafter shows a small change at higher energies. The decrease of the average cross-sections at intermediate bremsstrahlung energy indicates the effect of QD (Quasi Deuteron) beside GDR.

Abstract 272 at 4:00 PM

Session AP-MA-04 Thursday 3:00 PM - Elm Fork II

The CERN-MEDICIS facility - An offline mass separation facility for the production of research medical radionuclides

Laura Lambert[1], Elodie Aubert[1], Cyril Bernerd[1], Philippe Bertreix[1], Antoine Boucherie[1], Nadine Conan[1], Bernard Crepieux[1], Matthieu Deschamps[2], Alexandre Dorsival[1], Charlotte Duchemin[1], Simone Gilardoni[1], Muhammed Inzamam[4], Jake Johnson[3], Edgars Mamis[1,5], Ralitsa Mancheva[3], Bruce Marsh[1], Stefano Marzari[1], Nabil Menaa[1], Ricardo Muniz[1], Maxime Munos[1], Fabio Pozzi[1], Jean-Yves Rinchet[1], Ralf Rossel[1], Thierry Stora[1], Julien Thiboud[1], Carlos Veiga[1], Joachim Vollaire[1]

(1)CERN, Meyrin Geneva, Switzerland
(2)CERAP, Geneva Geneva, Switzerland
(3)KU Leuven, Leuven Flemich Brabant, Belgium
(4)Pakistan Atomic Energy Commission, Islamabad the Islamic Republic of Pakistan, Pakistan
(5)Institute of Chemical Physics of the University of Latvia, Riga Riga, Latvia

CERN-MEDICIS is a facility dedicated to the production of radionuclides in the field of nuclear medicine research. Its primary focus is on isotope mass separation with developed methods resulting in the production of high purity non-conventional radionuclides to be used for cancer diagnostics, imaging, and therapeutic applications.

Radionuclide production at CERN-MEDICIS is initiated by either thick target irradiation using the 1.4 GeV proton beam from the PS Booster accelerator or receiving radioactive sources from one of the collaborator institutes, produced by neutron activation or by irradiation at cyclotrons. These irradiated materials are then placed on the CERN-MEDICIS target station (so called Frontend) and radionuclides are ionized and extracted in the form of a radioactive ion beam passing through a mass separator resulting in high specific activity samples collected into different solid materials. Since the laboratory hosting the CERN-MEDICIS facility is designed for the safe handling of unsealed radioactive sources, one strength of MEDICIS is that it remains one of the few facilities at CERN adapted to run during CERN's long shutdown (LS3), as it does not solely rely on CERN proton beam. In addition, operation with external sources provides flexibility and access to a wider range of radionuclides.

Profiting from several years of experience the facility has gained since commissioning in 2017, CERN-MEDICIS has advanced significantly along the Technical Readiness Level (TRL) scale to reach mature processes for some of the radionuclides; with 50% separation efficiencies and production of several clinically

relevant activities in a single batch. In line with this, recent updates to the CERN-MEDICIS infrastructure, have further improved on the facilities capabilities allowing for finer purities due to enhanced diagnostic tools as well as increased capacity on radioactive material handling.

In the last year of operating the facility, CERN-MEDICIS has reached several milestones achieving record efficiencies as well as record collected activities. A few notable experiments include the separation and double collection of both Ra-224 and Ra-225 with high purity results, as well as High Specific Activity Sm-153 from a nuclear reactor source, which has received impressive pre-clinical results leading to the demand for clinical tests as their next step in the process.

Abstract 61 at 3:00 PM

Session AR-ISM-01 Thursday 3:00 PM - West Fork II

High Energy Wafer Implantation updates at the Tandem User Facility at Brookhaven National Lab

Tom Kubley, Dannie Steski, Chuck Carlson

Colider-Accelerator, Brookhaven National Lab, Upton New York, United States

The implantation depths required for the development and fabrication of future generations of silicon carbide (SiC) semiconductor devices require ion energies that are well above the capabilities of most conventional ion implanters. To generate implantation profiles that extend from more than 10 μm to the surface of the wafer, a wide range of energy ions (kV to 10 s of MeV) is required. The Tandem facility runs a novel multi-energy implantation system that satisfies these requirements using heavy ion beam. This talk will describe that system as well as the addition of in-situ heating of the wafers. It will also discuss the test results from mi-2 factory's Energy-Filtered Ion implantation (EFII).

The Tandem User Facility at Brookhaven National lab operates two 15 MeV MP Tandem Accelerators. Both accelerators (MP-6 and MP-7) have been upgraded to run at a maximum terminal voltage of 15 MV and are also capable of high-intensity, pulsed-beam operation. Both accelerators are currently in service providing beam for Single Event Upset (SEU) users. The Tandem can support Brookhaven's accelerator complex - which includes the Alternating Gradient synchrotron (AGS) Booster, the AGS, the Relativistic Heavy Ion Collider (RHIC) and the NASA Space Radiation Laboratory (NSRL) - and the outside user program simultaneously. The Tandem runs SEU, ion implantation, radiobiology research, submicron filter material production, and other applied programs year round.

Abstract 27 at 3:30 PM

Session AR-ISM-01 Thursday 3:00 PM - West Fork II

Studies on the gamma and swift heavy ion irradiation induced effects on the Resistive Switching Properties of Transition Metal Oxides

R Sai Prasad Goud[1,2,3], S V S Nageswara Rao[1,2,3], Anand Prakash Pathak[1,2,3]

(1)School of Physics, University of Hyderabad, Hyderabad Telangana, India
(2)School of Physics, University of Hyderabad, Hyderabad Telangana, India
(3)School of Physics, University of Hyderabad, Hyderabad Telangana, India

A detailed study on the influence of ion and gamma irradiation on the resistive switching phenomenon observed in various transition metal oxides will be presented. The resistive switching devices i.e., Resistive Random Access Memory (RRAM) devices have been fabricated by employing e-beam deposition and photolithography techniques. Non-stoichiometric Hafnium oxide (HfO_x) and Tantalum oxide (TaO_x) films have been evaluated for their suitability as switching layers in these devices. Swift heavy ion and gamma irradiation experiments have been performed to study the effects on the switching properties of HfO_x and TaO_x-based RRAM devices. The radiation response of these devices has been studied by critically examining the photoluminescence and current-voltage (I-V) characteristics of pristine and irradiated devices. The study indicates that low-dose irradiation (below a critical dose) can improve the device's performance. Further, this study yields the necessary information to tune the switching properties of RRAMs and to analyze their reliability in radiation-harsh environments. A detailed discussion on the role of defect dynamics in the resistive switching phenomenon will be presented. Consequent effects on the tunability, radiation response, and reliability of corresponding devices will also be discussed.

Abstract 293 at 4:00 PM

Session AR-ISM-01 Thursday 3:00 PM - West Fork II

The new Pulsed Power Electron Gun (PPEG) at Sandia National Labs

Barney L Doyle[1], George Vizkelethy[1], Alex A Belianinov[1], Joshua M Young[1], Michael Titze[1], Shea S Su[1], Edward M Bielejec[1], George H Gillespie[2]

(1)Sandia National Labs, Albuquerque NM, United States
(2)AccelSoft Inc., Del Mar CA, United States

Sandia has a 75-year history of developing and testing most of the non-nuclear components of nuclear weapon systems. An important part of this testing involves the exposure of materials and electronics in the weapon to the radiation of nuclear countermeasures, i.e. high energy neutrons, gamma rays and x-rays. Since the conclusion and opening for signatures of the Comprehensive Test Ban Treaty (CTBT) in 1996, these tests could no longer be performed with underground nuclear detonations. Even before this, to more easily facilitate hostile radiation testing,

Sandia developed a rich assortment of nuclear reactor facilities bremsstrahlung accelerators and intense x-ray sources. The Ion Beam Lab at Sandia has also been involved with this type of testing, but not at the entire system level, but rather of individual electronic components such as transistors, diodes, etc. We also use surrogates for the radiation: MeV ions instead of neutrons for simulating atomic displacement effects, and keV electrons instead of gammas to simulate total dose and dose rate induced photocurrents. But even with these easily accelerated particles, relevant equivalent neutron fluences and gamma dose rates can only be reached with mm size beams. Ontheotherhand, there has recently been interest in increasing the size and range of the electron beams while maintaining their high dose rate. To accomplish this a Pulsed Power Electron Gun (PPEG) has been developed based around a pulsed (30ns) 300 kV Marx Generator (Applied Physical Electronics L.C.). The MARK1 system involves an Al cold cathode electron emitter with variable AK gap, a magnetic solenoid lens midway to a targeting stage ~1m from the emitter. SIMION (Scientific Instrument Services) and PBO-Lab (AccelSoft Inc.) electron optics calculations indicate that space charge broadening will saturate the dose rate at ~1e12 rads/s(Si) for a 2A beam on target. For higher currents, the area of the beam increases holding the dose rate at this value. This is a good result because it enables much larger exposure areas in the IBL at dose rates comparable to the large bremsstrahlung accelerators. The range of these electrons also increases from 50µm in Si for our existing Kimball e-gun (100 keV) to 300µm for the PPEG.

[*]Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Abstract 260 at 3:00 PM

Session AR-NP-07 Thursday 3:00 PM - West Fork I

Online Autonomous Tuning of the FRIB Accelerator Using Machine Learning: DOE NP AI Project Status

Alexander Scheinker[1], Kyung Hwang[2], Dean Lee[2], Peter Ostroumov[2]

[(1)]Applied Electrodynamics, Los Alamos National Laboratory, Los Alamos NM, United States
[(2)]Facility for Rare Isotope Beams, Michigan State University, East Lansing MI, United States

Generative Machine learning (ML)-based tools provide an incredibly powerful approach to virtual 6D phase space diagnostics and fast autonomous accelerator tuning and optimization, especially when utilized together with physics constraints and robust model-independent adaptive feedback techniques from control theory. In this talk we report on the status of our ongoing project "Online Autonomous Tuning of the FRIB Accelerator Using Machine Learning" which is part of the DOE Office of Science Nuclear Physics (NP) program and is funded by the call: Data, Artificial Intelligence, and Machine Learning at DOE Scientific User Facilities Projects. We report on various adaptive and generative ML-based tools being developed for autonomous tuning of the complex charged particle beams in the facility for rare isotope beams (FRIB). Our efforts include the development of machine learning tools such as neural networks (NN), Gaussian processes, and reinforcement learning, in which NNs are incorporated to represent system models and optimal feedback, using powerful open-source software packages. These include the use of neural network-based prior-mean assisted Bayesian Optimization (pmBO) for setting up the Front End (FE) for selected ion species and the development of virtual 6D phase space diagnostics via generative variational autoencoders whose low-dimensional latent space embeddings are adaptively tuned based on limited beam measurements.

Abstract 244 at 3:30 PM

Session AR-NP-07 Thursday 3:00 PM - West Fork I

Machine Learning Tools for Improved SRF Operations at CEBAF

Adam Carpenter[1], Kawser Ahammed[2], Hal Ferguson[2], Steven Goldenberg[1], Khan Iftekharuddin[2], Jiang Li[2], Md. Monibor Rahman[2], Riad Suleiman[1], Christopher Tennant[1], Dillion Thomas[1], Dennison Turner[1]

(1)Jefferson Laborartory , Newport News Virginia, United States
(2)Old Dominion University, Norfolk Virginia, United States

Jefferson Lab's primary accelerator facility, the Continuous Electron Beam Accelerator Facility (CEBAF), uses hundreds of superconducting radio-frequency (SRF) cavities in its two main linacs. These accelerating cavities are installed in several styles of cryomodules that were designed, built, and deployed over the span of decades. A variety of operational challenges arise from this disparate mix, including unnoticed cavity instabilities, frequent trips, and field emission that produces radiation. In this talk we describe new diagnostic hardware and machine learning methods that are being developed to help operations staff address these problems through post-mortem analysis of suspicious beam loss faults using fast-sampled RF data, pseudo-real-time RF fault prediction, and RF gradient redistribution powered by a surrogate model of radiation detectors.

This work is supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics under Contract No. DE-AC05-06OR23177.

Abstract 199 at 3:55 PM

Session AR-NP-07 Thursday 3:00 PM - West Fork I

An Induction type of Septum for the EIC

Nicholaos Tsoupas, Bijan Bhandari, Chuyu Liu, Ioannis Marneris, Christoph Montag, Vadim Ptitsyn, Sankar Poopalasingam

Brookhaven National Laboratory, Upton NY, United States

The Electron Ion Collider (EIC) complex [1] is under design and will be built at the Brookhaven National laboratory (BNL). Induction type of septum will be used to inject the Hadron beam. In this technical note we will describe the EM design of the induction septum which includes laminations to build the iron of the magnet. The results from the calculations, of the 3D transient-module of the OPERA code [2], will be presented.

[1] https://wiki.bnl.gov/eic/index.php [2] https://www.3ds.com/

Abstract 217 at 3:00 PM

Session AR-RE-09 Thursday 3:00 PM - Elm Fork I

Identification of an Epigenomic Signature of Mixed Field Neutron Exposure at Low Doses: Benefit to Military Operators in a Post-Nuclear Detonation

Alexandra C Miller, PhD[1,2,4], Velkjo Grilj, PhD[3], Rafael Rivas, MS[1], Andrew Harken, PhD[3], Vyktoria Riley, PhD[4], Naresh Deoli, PhD[3], Guy Garty, PhD[3], David Brenner, PhD[2,3]

(1)Science Research Department, Uniformed Services University of Health Sciences/AFRRI, Bethesda MD, United States
(2)Center Radiological Research, Columbia University Medical Center, New York NY, United States
(3)Center Radiological Research, RARAF - Columbia University , Irvington NY, United States
(4)Department of Environmental Medicine, New York University, New York NY, United States

The recent news of the potential use of weapons of mass destruction (WMDs) and in particular, nuclear weapons, has significantly highlighted the danger and effects of radiation exposure. Diminishing the threat posed by use of WMDs, i.e. nuclear weapons, and improving diagnostics for troops who may have been exposed to threat agents is critical. Our laboratory has been developing a methodology that could enable the use of an individual's epigenome to reveal their history of exposure to WMD and WMD precursors. This is a technology that could benefit both exposure detection and adverse health prognosis. The epigenome is the set of chemical modifications to the DNA, i.e., DNA methylation, and DNA-associated proteins, i.e. histones, in the cell. These modifications, which alter gene expression are heritable (via meiosis and mitosis) and can be altered in response to environmental exposures like radiation or to disease development. Epigenetic changes like DNA methylation, histone modification, miRNAs, and RNA associated gene silencing have been linked to development of radiation damage in both directly irradiated cells and nearby cells. Our laboratory has been evaluating the effect of radiation quality, radiation dose rate, and radiation dose on epigenetic mechanisms in vitro and in vivo.

For this study human neural stem cells, astrocytes, brain microvascular endothelial and immortalized human osteoblast cells were used. Cells were irradiated with either accelerator-generated mixed field neutrons (2.5 cGy/min) or reactor-generated mixed field neutrons (60 cGy/min). ELISA methods were used to assess DNA methylation and histone modifications.

Investigations with different mixed field neutron dose rates and neutron energies have revealed specific histone modifications, i.e., methylation and acetylation, following mixed field neutron exposure, are both dose rate- and neutron energy- dependent. A comparison to gamma or x-ray exposure revealed different patterns for low LET radiations.

Based on these comparative results further studies on identification of an epigenomic signature of low level or trace radiation exposure is warranted. This mechanistic information has assisted with testing specific countermeasures that affect histone acetylation to combat neutron radiation injury. These types of mechanistic insights will assist operational planners and clinicians with assessing radiation risk and radiation injury development.

Acknowledgements: NIH P41-20100079; AFRRI RAB42436218/19, NIH R01-72736210

Disclaimer: The opinions expressed are those of the authors and are not the opinions of the Armed Forces Radiobiology Research Institute, the Uniformed Services University, or the U.S. Government.

Abstract 186 at 3:25 PM

Session AR-RE-09 Thursday 3:00 PM - Elm Fork I

DNA damage as a probe to assess the dose rate and chemistry of low-temperature plasma radiation

Sylwia Ptasinska

Radiation Laboratory & Department of Physics and Astronomy, University of Notre Dame, Notre Dame IN, United States

A low-temperature plasma (LTP) is being advanced as an alternative radiation source that offers unique chemical properties owned by a variety of reactive plasma species (RPS), such as radicals, electrons, and excited species, delivered and formed in targets upon exposure. Our recent research explored the possibility of implementing DNA and its damage as a probe for specific plasma diagnostics such as RPS formation and transient local heating (1)Both LTP characteristics have been analysed based on the detection of two types of DNA damage: strand breaks and DNA denaturation. We implemented a physics-guided neural network model to predict the formation of both types of damage and their yields for a given combination of LTP parameters. Based on our findings we suggested that denaturation of DNA can be attributed to transient local heating of the aqueous DNA. Moreover, our results showed that DNA can be utilized as a probe for RPS, particularly for reactive oxygen and nitrogen species that cause strand breaks in aqueous DNA. A similar approach which explores the experimental data-driven predictive modelling of DNA damage, was utilized by us to determine a dose rate of LTP radiation [2].

In addition to the fundamental aspect of our work, the outcomes of these studies have potential for further breakthroughs in plasma applications ranging from industrial to medical areas. Since many chemical processes are involved during plasma interaction with the target that can be varied by process parameters, choosing the ideal parameter combinations for obtaining the desired chemical effects is often challenging. The knowledge of RPS dynamics for specific plasma conditions is an invaluable key to overcoming this challenge.

[1] A. Sebastian, D. Lipa, S. Ptasinska, DNA Strand Breaks and Denaturation as Probes of Chemical Reactivity versus Thermal Effects of Atmospheric Pressure Plasma Jets. ACS Omega 8 (2023) 1663-1670

[2] A. Sebastian, D. Spulber, A. Lisouskaya, S. Ptasinska, Revealing low-temperature plasma efficacy through a dose-rate assessment by DNA damage detection combined with machine learning models. Scientific Reports 12 (2022) 18353

Abstract 197 at 3:50 PM

Session AR-RE-09 Thursday 3:00 PM - Elm Fork I

Simulation Study of Ionizing Radiation Effects on Biomolecular Structures

Yujie Chi

Physics, The University of Texas at Arlington, Arlington Texas, United States

Ionizing radiation (IR) deposits energies in objects it traverses through ionization and excitation. Within organisms, it can

directly liberate electrons from macromolecules and elevate oxidative stresses both intracellularly and extracellularly. This process leads to complex chemical bound breakages and reformations in cellular matrices, eventually triggering complex biological responses at tissue and organ levels.

Different IR types and delivery formats have been observed to induce varying biological effects. For example, FLASH radiotherapy, delivering ionizing radiation at an ultra-high dose rate (> 40 Gy/s), can enlarge response differences between normal tissue and tumor cells compared to conventional radiotherapy. However, the mechanisms behind these differential responses remain unclear.

To understand the biological effects induced by IR, microscopic Monte Carlo (MMC) simulation emerges as a critical tool. It enables the examination of fundamental physical and chemical processes triggered by IR and their damaging effects on critical subcellular matrices such as water and DNA. In this talk, I will discuss our continuous efforts in developing and applying an open-source, high-performance microscopic Monte Carlo simulation tool - gMicroMC-- for the quantification of radiation physics and chemistry processes under various radiation scenarios. gMicroMC utilizes cutting-edge algorithms such as dynamic time steps, cost-effective GPU parallel computing technique to support transport simulation, geometry modeling and particle tracking, resulting in simulations that run over 500 times faster than those on CPU. It has the capability to simulate the irradiation processes under different radiation types (electron, proton, heavy ions), doses, dose rates, oxygen concentrations and cellular stages. Additionally, gMicroMC was released as an open-source tool on GitHub (https://github.com/utaresearch/gMicroMC), supporting user groups worldwide.

The simulation framework developed in gMicroMC has enabled novel applications. With the support of physical transport of different IR types over a broad energy spectrum and the subsequent DNA damage quantification, the study of relative biological effectiveness (RBE) over different linear energy transfers (LETs) using DNA damages as surrogate was enabled. With the step-by-step simulation of chemical reactions among radicals and environmental molecules, such as dissolved oxygen molecules at different concentrations, oxygen enhancement ratio (OER) effect in radiotherapy can be derived from microscopic simulations. Further, by introducing the temporal structure of IR beam delivery, we successfully quantified oxygen depletion effects in FLASH RT. Except for physical and chemical reactions, it is known that radiation response heterogeneity can arise from the heterogeneous biomolecular structures. By developing the DNA models of the entire human lymphocyte nucleus in different cellular phases like G0/G1 and metaphase, we successfully explained the varying radiosensitivity among cell phases measured by experiments. Overall, our current development and application of gMicroMC shows that it is a powerful simulation platform, which can be used to study the underlying mechanisms behind observable radiobiological effects.

To further enhance the simulation capabilities of gMicroMC, we have also conducted molecular dynamics simulations to explore reaction details at the atomic and electron orbital levels. This effort aims to better understand the appropriateness of various parameters and assumptions used in gMicroMC.

Abstract 158 at 4:15 PM

Session AR-RE-09 Thursday 3:00 PM - Elm Fork I

Differential analysis of Normal Rat Leg Bones subjected to Space Conditions

Rahul Mehta[1], Brent J.F. Hill[2]

[(1)] *Physics & Astronomy, University of Central Arkansas, Conway Arkansas 72035, United States*
[(2)] *Biology, University of Central Arkansas, Conway Arkansas 72035, United States*

This study uses a weightlessness animal model and examines the effects of 0.3 Gy radiation dose given every other day for a 10-day periods, on skeletal biomarkers. The variables in this research are the control group and irradiated (IR) group. The bones were subjected to bending techniques to measure the stress, strain, and elastic modulus. The bending method fixes the bones at both ends (3-point bending) while a known force is applied perpendicular to the bone. Each leg bone (tibia and femur) is bent with a force prod acting on posterior or medial or lateral or anterior points of the bone center. After the four-point bending experiments, the bones were cut in a thin cross-section with a diamond tip saw. Next bone samples were sputter coated with gold for analysis using SEM (Scanning Electron Microscope). The bone cross sections were differentially analyzed using 15-20 kev electron beam in a SEM (Scanning Electron Microscope). An energy dispersive analysis (EDX) quantifies the relative percentages of carbon, oxygen, phosphorus, and calcium present. The bone cross-sections were also imaged using a Leica MZ6 microscope equipped with an OptixCam digital camera. The image analysis program, ImageJ is used to measure the cortical and cavity areas. The pixel area was converted to mm square for each respective area.

The stiffness and flexure force showed no change between irradiated and control at all four points (posterior or medial or lateral or anterior points of the center of the bone). The elemental compositional ratios of calcium (Ca) to phosphorus (P) revealed no difference between control versus irradiated rats on the tibia at all sides. A statistically significant decrease in elastic Young's modulus (Y) was found for irradiated rats compared to control on the tibia. The decrease in Y on tibia was much less on the lateral side then on the posterior side. The anterior side of tibia showed a much greater decrease in Y for irradiated rats over the control rats.

Acknowledgment: Arkansas Space Grant Consortium (ASGC), INBRE manuscript grant and the assistance of Hypatia Mereviglia, and Manling Cheng.

Abstract 9 at 4:30

Session AR-RE-09 Thursday 3:00

Measurements of Radiological Health Risks to Students in Abo-Odo Ota, Nigeria

Maxwell Omeje[1], Umanah Idaraobong Felix[3], Adewoyin Olusegun[4], Joel Sunday Emmanuel[2]

(1)Physics, Covenant University, Ota Ogun, Nigeria
(2)Earth Sciences, Anchor University, Lagos Lagos, Nigeria
(3)Physics, Covenant University, Ota Ogun, Nigeria
(4)Physics, Covenant University, Ota Ogun, Nigeria

Underage students in Ado-Odo Ota are exposed to activity concentrations of naturally occurring radionuclides and terrestrial background gamma dose rate from geological features (Soils from their playing ground) without their knowledge. There is an urgent need to ascertain the exposure level recommended by International Commission on Radiological Protection. This study assessed the exposure level and other radiological risks associated with the terrestrial gamma dose rate emanating from the naturally occurring radionuclide in the study area. In-situ measurements were carried out using calibrated Super spec RS-125 gamma detector. The activity concentrations of ^{238}U, ^{232}Th and ^{40}K range from 11.73 Bq/kg to 36.43 Bq/kg for Uranium (^{238}U), 23.35 Bq/kg to 98.35 Bq/kg for Thorium(^{232}Th), and 31.30 Bq/kg to 446.03 Bq/kg for Potassium (^{40}K). For all the radionuclides at the zones where the gravels were packed, the highest values were above the International Reference Standard which could pose health risks to the students. The highest value of the gamma dose rate with a value of 3.481 mSv/y was found on the same spot which is more than three higher when compared with the world average value according to the International Commission on Radiological Protection. The results from this study identified the potential risk zones that could pose health risks to students. As such, the study calls the attention of the school management to immediately evacuate the packed gravel within the school premise which serves as the source. This study will be used as a guide to monitor other radiological exposure to students within Ado-Odo Ota primary and secondary schools and forward to the policy makers for urgent implementation.

Abstract 141 at 9:30 AM

Session AA-NBAT-03 Friday 9:30 AM - Post Oak

Harnessing Event-Based Neutron Imaging Systems for Fast Neutron Imaging at LANSCE

Alexander M. Long[1], Tsviki Hirsh[2], Adrian S. Losko[3], Alexander Wolfertz[3], Aaron Craft[4], Tim Jaeger[5], Anton Khaplanov[6], Sven C. Vogel[1]

(1)Material Science and Technology, Los Alamos National Laboratory, Los Alamos NM, United States
(2)Soreq Nuclear Research Center, Yavne, Israel

[3]Forschungs-Neutronenquelle Heinz Maier-Leibnitz, Garching, Germany
[4]Idaho National Laboratory, Idaho Falls ID, United States
[5]Technische Universität Darmstadt, Darmstadt ID, Germany
[6]Oak Ridge National Laboratory, Oak Ridge TN, United States

Photon-counting sensors have the potential to significantly enhance both in-field and large facility fast neutron radiography capabilities by enabling event-mode neutron imaging setups. When paired with fast plastic scintillators, these sensors can record light emission from proton recoil paths with high spatial and temporal resolution. We have recently initiated the development of advanced photon-counting sensors coupled with neutron-sensitive plastic scintillators at the Weapons Neutron Research (WNR) Facility at the Los Alamos Neutron Science Center (LANSCE). Utilizing this innovative approach, we have performed several fast neutron imaging measurements, ranging from large field of view (10 cm^2) fast neutron resonance radiography (FNRR) to smaller field of view neutron imaging via proton recoil tracking. These measurements showcase the versatility and robustness of our optical-based photon-counting system in capturing a wide array of fast neutron interactions, providing essential imaging capabilities for safeguards and security applications. In this presentation, I will discuss several of these initial measurements in detail, highlighting the unique insights they offer, from elemental identification to neutron spectrometry measurements. Special focus will be placed on how different setups and configurations of the optical components, material choice of scintillators, and neutron-event reconstruction algorithms influence the quality and applicability of the neutron images obtained. Through this work, we hope to demonstrate the potential applications of this emerging sensor technology and its impact on various safeguards and security systems.

Abstract 230 at 9:55 AM

Session AA-NBAT-03 Friday 9:30 AM - Post Oak

Neutron production and detection capabilities at Ohio University for basic science and applications

Cody E. Parker, Carl R. Brune, Joseph A. Derkin, David C. Ingram, Thomas N. Massey

Physics & Astronomy, Edwards Accelerator Laboratory, Ohio University, Athens Ohio, United States

Ohio University's Edwards Accelerator Laboratory (EAL) houses a 4.5-MV tandem Pelletron accelerator with multiple beamlines dedicated to low-energy nuclear science. The laboratory has decades of experience in the production and detection of quasi-monoenergetic and broad-spectrum neutrons up to about 24 MeV. Currently, two beamlines are available for neutron production operations via various proton- or deuteron-induced reactions on gas cells or solid targets. The beam swinger magnet coupled with the 30-meter-long neutron time-of-flight tunnel provides unique capabilities, such as collimating the neutron beam (significantly reducing background from scattered neutrons) and measuring multiple reaction angles without the need to relocate detectors. This beamline has been the primary configuration for delivering pulsed and continuous neutrons for reaction measurements,

detector calibrations, and irradiations for 40 years. The recently commissioned Fixed-Angle Short Trajectory (FAST) neutron source provides much shorter neutron flight paths. This is of interest for reaction measurements with small cross sections or shortening the time in which a sample must be irradiated for damage studies. In addition to neutron production, characterization of the neutron beams and measurements of neutrons from reactions of interest can be done using various scintillators, cross-calibrated silicon detector monitors, and a polyethylene moderated detector array. This talk will give an overview of the EAL, detailed descriptions of the neutron production capabilities and characterization methods, and touch on specific reaction measurements and applications.

Abstract 239 at 10:10 AM

Session AA-NBAT-03 Friday 9:30 AM - Post Oak

Scalable Manufacturing of Melt-Blended Organic Scintillators for High Efficiency Neutron Detectors

Gail Frances Hernandez Garcia, Nicholas Myllenbeck, Annabelle Benin, Ryan Witzke, Tyler Eckles, Patrick Feng

Materials Chemistry, Sandia National Labs, Livermore California, United States

Plastic scintillators (PSs) are widely used as radiation detection media in homeland security, medical imaging and nuclear physics applications. Their advantages include low cost, scalability, facile compositional tuning and mechanical durability. Chemical curing (CC) is the typical method for producing PSs, and involves exposure to chemical hazards, long reaction times, and specialized equipment to achieve high levels of monomer conversion. Thus, our group explored melt blending (MB) as a new production method, where a powdered, pre-cured polymer is mixed in the solid state with high efficiency fluorophores (specifically, organic glass scintillator, or OGS) and co-melted in flexible or rigid mold material. With optimized conditions, we have achieved reproducible casting results, and scintillation performance that exceeds benchmark commercial scintillators, using a fraction of the curing time and energy input compared to CC. Similar to CC, MBS can be formulated successfully across a wide range of scintillator compositions, but can incorporate additives such as phenolic antioxidants that are not tolerated by CC.

Additional applications of MBS as the subject of ongoing collaborations include high aspect ratio monoliths molded to near-net shape, segmented detectors, and scintillating waveguides for high resolution radiographic imaging. Additionally, we will detail our efforts to produce 100 x 8 x 6 mm rectangular specimens at near-net shape for fracture toughness characterization of these materials. Finally, we will show that MBSs are readily compatible with existing thermoplastic processing methods, including hot-melt extrusion, injection molding and three-dimensional printing, as the next implementation of scalable manufacturing.

Abstract 167 at 10:25 AM

Session AA-NBAT-03 Friday 9:30 AM - Post Oak

Net Shape Production of Organic Glass-Based Neutron Detectors

Patrick Feng[1], Nick Myllenbeck[1], Annabelle Benin[1], Ryan Witzke[1], Neil McIntyre[2], David Welker[2], Alex Long[3], Sven Vogel[3], Danny Eigelbach[3]

(1)Sandia National Labs, Livermore California, United States
(2)Incom, Inc., Vancouver Washington, United States
(3)Los Alamos National Labs, Los Alamos New Mexico, United States

Organic-based scintillators are used for large-scale radiation detection applications such as radiation portal monitors, owing to their potential for low cost and large scale. However, limitations in their scintillation and optical properties preclude their wider use for neutron detection applications. In this presentation, I will describe the first-principles design of Organic Glass Scintillators (OGS) as a means to address these limitations. OGS possess scintillation properties that rival single crystals but can be readily scaled to large sizes via melt-casting or other themoplastic processing methods. The blending of OGS with polymer constituents will also be described, providing the ability to modify the thermomechanical properties. These characteristics will be reduced to practice in the configuration of these materials into various net-shape detector geometries, including bulk monoliths, optically segmented arrays, exotic shapes, and optical waveguide configurations.

Abstract 302 at 10:40 AM

Session AA-NBAT-03 Friday 9:30 AM - Post Oak

New neutron detectors for beta-delayed neutron studies

Peter Dyszel, Robert Grzywacz

Department of Physics and Astronomy, University of Tennessee, Knoxville, Knoxville TN, United States

Beta-delayed neutron emission is a prevalent decay mode for most neutron-rich nuclei. The neutron energy measurements are essential to understand the microscopic foundations of this process. University of Tennessee group led the development of several neutron detector arrays used in beta-delayed neutron emission studies on exotic neutron-rich nuclei. The neutron time-of-flight arrays VANDLE and INDIE were implemented in experiments at ORNL, ANL, CERN, and RIKEN to study fission fragment nuclei. This array relies on an EJ200 plastic scintillator, and the creative use of a digital data acquisition system achieved its excellent performance. VANDLE array has been recently expanded and implemented at the FRIB Decay Station Initiator in several successful light and medium mass nuclei experiments. Recently, we commissioned two new detector systems. The NEXT array is a digital TOF array, which employs pulse shape discrimination and neutron interaction tracking to improve energy resolution. We recently developed a low-energy companion array

that uses the new material Organic Glass Scintillators, enabling measurements of neutrons down to a few tens of keV energy.

This research was sponsored by the National Nuclear Security Administration under the Stewardship Science Academic Alliances program through DOE Cooperative Agreements Nos. DE-NA0003899 and DE-NA0004068.

It is also supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics under Contract No. DE-FG02-96ER40983 and by the National Science Foundation under the contract NSF-MRI-1919735.

Abstract 102 at 9:30 AM

Session AP-IA-06 Friday 9:30 AM - Trinity Central

On the Simulations and Control of Cockcroft-Walton Ladders

Vincent Ernst

Houston Formation Evaluation Center, SLB, Sugar land TX, United States

SLB is a global technology company that has provided high-performance tools for the oil and gas industry has a strong 100+ year history of developing the instrumentation needed for its advanced formation evaluation tools in-house. One key component for the modern nuclear instrument is a high-voltage generator, whether used in detector photomultiplier tubes or in extreme high-voltage systems within a pulsed neutron generator (PNG). Although the widely used Cockcroft-Walton (C-W) ladder is a critical component in a modern PNG system, the virtualization of the ladder has proved challenging. Attempts to simulate the behavior of a ladder is a challenge in both time and frequency domains, complicating the design of a controller for C-W ladders. Although PID control is widely used in the industry, this type of controller falls short when dealing with the varying system dynamics of the PNG as well as modeling errors and component tolerances. This presentation describes some of the difficulties encountered in simulating the ladder behavior in both time and frequency domains and explains the need for robust control design to better control the C-W ladder.

Abstract 242 at 10:00 AM

Session AP-IA-06 Friday 9:30 AM - Trinity Central

Managing Electric Fields in Compact Accelerator Environments

Paul W Groth

Oak Ridge National Laboratory, Oak Ridge Tennessee, United States

As the demand for compact radiation generating devices with increasingly high output energies has surged over recent years, the management of high electric potentials within confined spaces has become an important area of research and engineering. This talk explores the key challenges associated with managing these high electric fields and discusses potential strategies to address them.

Firstly, this talk will outline the fundamental principles governing electric field behavior in confined spaces, highlighting the enhancements of electric field effects due to proximity and geometries of the electrodes. It then identifies the critical issues arising from these enhanced fields, including field-induced electron emission which can lead to undesired breakdowns and system failures.

Next, the talk will review some existing approaches and techniques employed to mitigate the adverse effects of high electric fields in compact geometries. These include the use of both liquid and gaseous dielectrics while highlighting the differences between fields induced by direct current (DC) supplies and pulsed power supplies as well as the challenges in containing the liquid or gas used as an insulator. Furthermore, the use of solid dielectrics will be discussed including the inverse relationship between sample thickness and dielectric strength found in most materials.

Finally, the talk emphasizes the interdisciplinary nature of managing high electric fields in compact geometries, requiring collaboration between electrical engineers, mechanical engineers, materials scientists, physicists, and computational experts. It underscores the need for continued research and development efforts to overcome existing limitations.

Abstract 164 at 10:20 AM

Session AP-IA-06 Friday 9:30 AM - Trinity Central

Split Structure Manufacturing of Compact Accelerators for Industrial Applications

Amirari Diego, Ronald Agustsson, Robert Berry, Salvador Uvalle, Osvaldo Chimalpopoca, Marcos Ruelas, Alexander Smirnov, Sergey Kutsaev

RadiaBeam, SANTA MONICA CA, United States

Split structure manufacturing is on the front line of cost reduction of compact accelerator when compared to conventional stacked cell accelerator manufacturing. This split structure approach has proven its application at the national lab and university levels as demonstrated by ASU's x-FEL facility. To bridge into the industry sector, we present split structures approach at the S-, C-, X-, Ku-, and W- band widths and will discuss the advantages and challenges with this split structure approach. Advantages in cost reduction in manufacturing are evident, however with the appropriate design cost can also be reduced by eliminating the need for RF tuning and can be applied up to W-band frequency range. We will also discuss the challenge for lower frequencies such as the inheritably increased size and weight of the structure, and the limitations of this fabrication method.

Abstract 11 at 10:40 AM — Session AP-IA-06 Friday 9:30 AM - Trinity Central

Development of 10 MeV electron linear accelerator for space environment simulation

Yunlong Chi

Accelerator Division, Institute of High Energy Physics, Chinese Academy of Sciences, Beijing Beijing, China

A compact 10 MeV S-band irradiation electron linear accelerator has been developed to simulate electronic radiation in outer space and carry out electron irradiation effect tests on spacecraft materials and devices. According to the requirements of space environment simulation, the electron beam energy is adjustable in the range of 3.5 MeV to 10 MeV, and the average current is adjustable in the range of 0.1 mA to 1 mA. The Linac should be capable of providing beam irradiation over a large area of 1 m^2 with a uniformity of larger than 90% and a scanning rate of 100 Hz. A novel method has been applied to achieve such a high beam scanning rate, utilizing a combination of a kicker and a scanning magnet.

Abstract 214 at 9:30 AM — Session AP-MA-03 Friday 9:30 AM - Elm Fork II

Prompt gamma imaging for particle therapy: from sparse sampling to AI

Mingwu Jin[1], Hao Peng[2]

[(1)]Physics, University of Texas at Arlington, Arlington TX, United States
[(2)]Radiation Oncology, University of Texas Southwestern Medical Center, Dallas TX, United States

Dose distributions of particle therapy (PT) are far more sensitive to the treatment uncertainties than X-ray beams due to the high ballistic precision and biologic effectiveness of particle beams. Thus, a real-time range/dose monitoring is critical to minimize treatment uncertainties and significantly improve the efficacy and safety of PT. Prompt gamma imaging (PGI) is a promising dose monitoring technique because of correlation between the PG and beam ranges, instantaneous gamma emission without biological

washout concern, and additional gamma spectra for the tissue composition information. In this work, we propose novel sparse sampling strategies for 1D and 3D PGI. The mapping from PG distribution to PT dose distribution will be established through deep-learning based translation algorithms. Our simulation results show that a cost-effective and compact PGI system is feasible for real-time dose monitoring of PT.

Abstract 240 at 9:50 AM

Session AP-MA-03 Friday 9:30 AM - Elm Fork II

AI-enabled Real-time Imaging for Adaptive Particle Radiotherapy

You Zhang, Hua-Chieh Shao, Yunxiang Li, Jing Wang, Steve Jiang, Weiguo Lu

Radiation Oncology, UT Southwestern Medical Center, Southlake TX, United States

Real-time imaging is key to the success of adaptive particle therapy, by capturing the real-time deformable motion of the treatment targets and surrounding anatomy to optimize the treatment delivery in real-time. We have recently developed AI-enabled techniques to generate high temporal resolution volumetric images and achieve deformable anatomy tracking from minimal signals (one x-ray projection), to guide real-time dose assessment, accumulation, and adaptive treatment delivery optimization. The presentation will focus on an AI-enabled dual-task learning technique for dynamic and real-time lung imaging; and a real-time liver imaging technique using a registration-driven approach that combines the inputs from optical surface imaging, x-ray imaging, and biomechanical modeling.

Abstract 266 at 10:10 AM

Session AP-MA-03 Friday 9:30 AM - Elm Fork II

Mid-range probing and range-guided adaptive particle therapy

Weiguo Lu[1], Mingli Chen[1], Dongxu Yang[1], Qingying Wang[1], Lin Ma[1], Xiaorong R Zhu[2], Yiping Shao[1]

[(1)]Radiation Oncology, University of Texas Southwestern Medical Center, Dallas Texas, United States
[(2)]Radiation Physics, University of Texas MD Anderson Cancer Center, Houston Texas, United States

Particle beams offer dosimetric advantages with a low entrance dose, peak dose before the end of range, and a sharp distal fall-off, allowing for the same target dose while lowering the integral dose compared to photon beams. However, particle beams are susceptible to range uncertainty. To address this, we proposed therapeutic mid-range probing and range-guided adaptive particle therapy (RGAPT). We developed a prototype PET system to measure the probing beam range and conducted experimental verification. The PET system can measure proton-induced

positron emitters with an accuracy of 0.6±0.3 mm with 60 seconds of acquisition and a probing beam (~5 MU) delivered to a head phantom. The measured PET activity ranges (AR) were converted to proton beam range (BR) via AR-BR calibration calculated by the Monte Carlo method and provided range shift measurements. The adaptive plans, accounting for range shift and the probing beam dose, achieved an average gamma passing rate of 95% using the 2%/2 mm criteria. We demonstrated the feasibility of mid-range probing and RGAPT planning and delivery. Mid-range beams have versatile applications. When used as probing beams, they ensure safe probing to mitigate range uncertainty. Additionally, they can address challenging scenarios in proton arc planning and delivery. The advantages of mid-range proton arc therapy will be demonstrated.

Abstract 250 at 10:30 AM

Session AP-MA-03 Friday 9:30 AM - Elm Fork II

PET Image-Guidance for Conventional and FLASH Proton Therapy

John Paul Cesar[1], Firas Abouzahr[1], Paulo Crespo[2,3], Michael Gajda[1], Alex Kuo[1], Osama Mawlawi[4], Andrey Morozov[2], Aryan Ojha[1], Falk Poenisch[4], Marek Proga[1], Narayan Sahoo[4], Joao Seco[5,6], Takeshi Takaoka[4], Stefaan Tavernier[7], Uwe Titt[4], Xiaochun Wang[4], Xiaorong Zhu[4], Karol Lang[1]

(1)The University of Texas at Austin, Austin Texas, United States
(2)Laboratório de Instrumentaçao e Fisica Experimental de Particulas, Coimbra, Portugal
(3)Universidade de Coimbra, Coimbra, Portugal
(4)MD Anderson Cancer Center, Houston Texas, United States
(5)German Cancer Research Center (DKFZ), Heidelberg, Germany
(6)University of Heidelberg, Heidelberg, Germany
(7)PETsys Electronics, SA, Porto Salvo, Portugal

Proton therapy has long been valued as a highly effective and promising technique in radiation oncology, particularly because of its ability to limit radiation dose to healthy tissue surrounding tumors. Over time, this form of therapy has seen numerous advancements in medical accelerators, beam delivery technology, modeling of beam energy, and the overall treatment planning process. However, a lacking and highly desired feature is the ability to monitor and assess, in-vivo, the dose and end-point location of each irradiation. Known as proton range verification, this capability can be employed by incorporating a positron emission tomography (PET) system in both conventional and emerging proton therapy treatment modalities, such as FLASH proton therapy, to greatly improve patient outcomes.

Furthermore, FLASH proton therapy, with its ultra-high dose and dose rates, has the potential to revolutionize radiation oncology with its purported ability to better spare healthy tissue while still eradicating cancerous tumor cells. One of the chief reasons that this modality hasn't been fully exploited in clinical treatment up to this point is that the underlying mechanisms for the so-called "FLASH effect" have not yet been understood. In this endeavor, an in-beam PET (and possibly a hybrid PET/PGI/SPECT) system would be an invaluable tool to compare conventional and FLASH proton beam irradiations to understand the mystery of the FLASH effect.

We summarize here our work in developing PET scanner technology focused on establishing in-beam PET modalities and elucidating the mystery of the FLASH effect. We discuss the Time-of-Flight PET for Proton Therapy (TPPT) project as well as early results from experiments producing quantitative PET imaging data from FLASH beam irradiations.

Abstract 261 at 10:50 AM

Session AP-MA-03 Friday 9:30 AM - Elm Fork II

Advances in In Vivo Imaging for Particle Radiotherapy: A Topical Overview

Anissa Bey

Department of Radiation Oncology, School of Medicine, Washington University in St. Louis, St. Louis, MO, United States

The Bragg peak characteristic of ion beams energy deposition in matter makes particle radiotherapy (PRT) a distinctly advantageous treatment modality to deliver highly conformal dose distributions to target tumors, compared to conventional x-rays, while sparing surrounding healthy tissues and organs. On this account, the past years witnessed a heightened public health interest in PRT and widespread development of external beam - mainly proton and carbon ions - treatment facilities worldwide. According to the Particle Therapy Co-Operative Group (PTCOG) [1], there were 137 operational PRT (proton 89%, carbon 11%) centers in the world as of May 2024.

Precise tumor localization is an essential consideration in PRT, and uncertainties stemming from the ion range in the patient's tissue, intra-fraction motion, and anatomical changes pose challenges to accurate dose delivery, as well as to dose escalation options that may improve therapeutic outcome. Institution- and disease site-based strategies are adopted clinically to mitigate for these uncertainties by generally adapting treatment planning or delivery, and reducing anatomical motion [2].

A paradigm shift has also operated in the field towards obtaining real-time, **in-vivo** information about the particle beam profile (range, dose distribution, spot position) to verify PRT treatment during delivery and for plan adaptation. **In vivo** imaging for PRT exploits signature radiation emissions that accompany treatment delivery, whether the transmitted ion beam itself, such as proton and carbon CT, or byproducts of nuclear interactions of the beam with tissues, e.g., positron emitters, prompt gamma-rays, and charged light fragments. Quality **in vivo** imaging necessitates innovative technology developments, from dedicated detection systems and techniques to adequate signal processing electronics and data acquisition capabilities.

This contribution aims to provide an overview of recent research developments in **in vivo** imaging for PRT, with quality assurance impetus, that show potential for clinical application.

References

[1] Particle Therapy Co-Operative Group (PTCOG) website, https://www.ptcog.site/index.php/facilities-in-operation-public

[2] J. Pakela et al., Frontiers in Oncology, 12, 806153 (2022).

Abstract 285 at 9:30 AM

Session AR-NP-06 Friday 9:30 AM - West Fork I

AI-Assisted Detector Design at EIC

Cristiano Fanelli

William & Mary, Williamsburg VA, United States

Artificial Intelligence is set to revolutionize the design of large-scale detectors like ePIC and a potential second detector at the future Electron Ion Collider. These experiments, with their complex design parameters and objectives, can leverage innovative approaches to design. Our project, AID(2)E, develops a scalable, distributed AI-assisted detector design using state-of-the-art multiobjective optimization. Supported by Geant4 simulations and the ePIC software stack, our method leverages PanDA and iDDS systems to handle compute-intensive demands. Enhancements to PanDA focus on usability, scalability, and automation. This project aims to create a robust design capability, apply it to the EIC detectors, and extend it to other experimental designs and tasks such as calibration and alignment. Advanced data science tools are also being developed to manage the complex trade-offs in this optimization process.

Abstract 213 at 10:00 AM

Session AR-NP-06 Friday 9:30 AM - West Fork I

Machine Learning Tools to support Accelerator Operations

Brahim Mustapha, Jose Martinez

Physics Division, Argonne National Laboratory, Lemont Illinois, United States

At a heavy ion linac facility, such as ATLAS at Argonne National Laboratory, a new ion beam is tuned once or twice a week. The use of machine learning can be leveraged to streamline the tuning process, reducing the time needed to tune a given beam and allowing more beam time for the experimental program. After establishing automatic data collection and two-way communication with the control system, we have developed and deployed machine learning models to tune and control the machine. We have successfully trained online different Bayesian Optimization (BO)-based models for different sections of the linac, including the commissioning of a new beamline. We have demonstrated transfer learning from one ion beam to another allowing fast switching between different ion beams. We have also demonstrated transfer learning from a simulation-based model to an online machine model and used Neural Networks as prior-mean for BO optimization. More recently, we have succeeded in training a Reinforcement Learning (RL) model online for one beam and deployed it for the tuning of another beam. These models are being generalized to other sections of the ATLAS linac and can, in principle, be adapted to control other ion linacs and accelerators with modern control systems.

Abstract 269 at 10:20 AM

Session AR-NP-06 Friday 9:30 AM - West Fork I

Machine learning based control systems for Nuclear Physics Experiments

Torri Jeske

Thomas Jefferson National Accelerator Facility, Newport News VA, United States

The Experimental Physics Software and Computing Infrastructure (EPSCI) group at Jefferson Lab is leading the use of machine learning (ML) to enhance control systems in nuclear physics experiments. Collaborating closely with domain experts and data scientists, we have developed an ML-based control system that uses a Gaussian process to dynamically adjust the high voltage of the GlueX Central Drift Chamber. This results in stable detector performance by adapting to environmental changes, thereby reducing the offline calibration effort. Furthermore, we are developing ML-driven systems for optimizing the polarization of photon beams and polarized cryotargets. These systems will maintain the optimal microwave frequency in cryogenic targets and make real-time adjustments to diamond radiators for polarized photon sources, tasks traditionally handled by human operators. By automating these functions, we aim to optimize the polarization, reduce downtime, and minimize human error. This talk will highlight the development of reliable ML-based control systems and the policies to ensure they are both effective and trustworthy.

Abstract 271 at 10:40 AM

Session AR-NP-06 Friday 9:30

AM - West Fork I

2D Convolutional Neural Networks with Early Data Fusion for Rare Event Search in GADGET II TPC Data

Tyler Wheeler[1,2,3], Ruchi Mahajan[2], Sai Ravishankar[3], Chris Wrede[1,2], Arian Andalib[1,2], Adam Anthony[1,2], Yassid Ayyad[2], Bahavya Jain[1,2], Logan Schaedig[1,2]

(1)Physics and Astronomy , Michigan State University, Lansing MI, United States
(2)Facility for Rare Isotope Beams, Michigan State University, Lansing MI, United States
(3)Computational Math, Science, and Engineering, Michigan State University, Lansing MI, United States

Sensitivity studies have shown that $^{15}O(\alpha, \gamma)^{19}Ne$ carries one of the most important reaction rate uncertainties affecting the modeling of Type I X-ray burst light curves. This reaction is expected to be dominated by a narrow resonance corresponding to the 4.03 MeV excited state in ^{19}Ne. This state has a well-known lifetime, so only a finite value for the small alpha-particle branching ratio is needed to determine the reaction rate. This state is populated in the decay sequence of ^{20}Mg, with $^{20}Mg(\beta p\alpha)^{15}O$ events yielding a characteristic signature: the near simultaneous emission of a proton and alpha particle. To capture these events of interest the GADGET II TPC was used at the Facility for Rare Isotope Beams during Experiment 21072. To find the rare two-particle events in the data we present a comprehensive approach for leveraging Convolutional Neural Networks (CNNs) and various data processing methods. To address the inherent challenges of working with 3D TPC track reconstructions, we employ early data fusion techniques to transform the data into 2D representations, capitalizing on the diverse data modalities of the TPC. This not only allows us to utilize the computational efficiency of 2D CNNs but also benefits from the vast array of pre-trained models available. Given the scarcity of real training data for the rare events of interest and the potential for distribution shifts when predominantly depending on simulations, our strategy is multifaceted. We embed significant perturbations within our simulations to account for potential physics parameter and detector response uncertainties, bolstering the model's resilience to variations between simulated and actual data. In parallel, we refine our training process to ensure our CNNs function as ultra-sensitive filters. By incorporating events that display features hinting at our target events, we ensure that any potential event of interest, no matter how subtle its indications, is flagged. Our data augmentation strategies further amplify the value of each authentic two-particle event, enriching the training pool. Together, these techniques produce models adept at finding rare events in the data, achieving an optimal balance between detection sensitivity and accuracy. We present the methods and outcomes of our investigation and discuss the potential future applications of these techniques.

Abstract 21 at 9:30 AM

Session AR-RE-05 Friday 9:30 AM - Elm Fork I

Exploring Radiation-Corrosion Coupling in High-Temperature Molten Salt and Liquid Metal Environments through Proton Irradiation Studies

Weiyue Zhou[1], Wande Cairang[2], Adria Peterkin[2], Riley Moeykens[2], Kevin B. Woller[1], Michael P. Short[1,2], Ertugrul Demir[3], Saikumaran Ayyapan[3], Djamel Kaoumi[3], Guiqiu Zheng[4], Nouf AlMousa[5], Yang Yang[6]

(1)Plasma Science and Fusion Center, Massachusetts Institute of Technology, Cambridge Massachusetts, United States
(2)Department of Nuclear Science and Engineering, Massachusetts Institute of Technology, Cambridge Massachusetts, United States
(3)Department of Nuclear Engineering, North Carolina State University, Raleigh North Carolina, United States
(4)Commonwealth Fusion Systems, Devens Massachusetts, United States
(5)Department of Physics, Princess Nourah Bint Abdul Rahman University, Riyadh, Saudi Arabia
(6)Department of Engineering Science and Mechanics, The Pennsylvania State University, University Park Pennsylvania, United States

Advanced nuclear systems demand a thorough comprehension of the interplay between radiation and corrosion in structural materials, especially before deployment. This understanding is critical for informed material selection and the safe deployment of such systems. However, neutron irradiation presents prohibitive costs, limited availability, and challenges in examination due to activation. As a result, conducting experiments that examine coupled neutron radiation effects is exceedingly difficult. Ion beams offer a promising avenue to bridge this research gap, enabling the exploration of coupled phenomena to inform material development or complement neutron irradiation tests. To this end, we have developed a facility enabling simultaneous irradiation and corrosion experiments utilizing a 3 MeV proton beam from a Tandem accelerator, coupled to a vial of high-temperature molten salt or liquid metal.

In our setup, sample foils are subjected to corrosion by a liquid medium on one side while being irradiated by the proton beam on the opposite side. This allows for direct observation of the effects induced by proton irradiation on the same sample foil, particularly at the metal-liquid interface. In this presentation, we outline the experimental setup, report on the performance of model and commercial alloys under molten fluoride corrosion with proton irradiation, and discuss our characterization and image processing methodologies to illustrate observed effects. Additionally, we present new findings on the coupled effects of commercial alloys in liquid lead and lead-bismuth corrosion, along with similar phenomena in ceramic (SiC) samples.

While proton irradiation serves as the primary point of differentiation between irradiated and non-irradiated regions, the interaction between protons and the solid-liquid system has yet to be fully understood. Proton-solid interactions can introduce point defects and increase diffusivity within solids, while interactions with liquids and the solid-liquid interface further complicate the picture. Radiation-enhanced wettability in particular appears to enhance initiation of corrosion, particularly in liquid metal systems, by passive oxide film breakdown and/or by surface defect-induced contact angle reduction. Disentangling the contributions of these various factors necessitates cleverly designed comparative experiments and simulation tools. We will discuss considerations for uncovering interaction modes and outline our vision for advancing coupled irradiation and corrosion experiments using ion beams.

Abstract 246 at 10:00 AM

Session AR-RE-05 Friday 9:30 AM - Elm Fork I

Isolating the effects of beam heating in simultaneous irradiation-corrosion experiments

Franziska Schmidt[1,2], Matthew Chancey[1], Hyosim Kim[1], Peter Hosemann[2], Yongqiang Wang[1]

(1)Los Alamos National Laboratory, Los Alamos New Mexico, United States
(2)University of California Berkeley, Berkeley California, United States

Irradiation-corrosion experiments allow the study of the simultaneous effects of both extremes on materials, with results that are often different from those of sequential experiments. One popular version of these experiments involves ion beams as the source of radiation damage because they are more easily accessible than more directly reactor-relevant neutron sources. Since the goal is to gain an understanding of a material's long-term performance in a combined radiation-corrosion environment, high absolute dpa values and high dpa rates are desirable. However, increased radiation exposure requires intense beams that will induce localized beam heating in the sample, which likely influences the corrosion process. In this talk, we will discuss the potential effects of beam heating on the results of irradiation-corrosion experiments, based on experimental results obtained in pure Fe corrosion studies in lead-bismuth eutectic under simultaneous proton irradiation. We will present our attempts at mitigating beam heating effects and explore their implications with regards to determining a lower boundary for radiation dose rates below which radiation may no longer have a measurable impact on the corrosion process.

Abstract 118 at 10:20 AM

Session AR-RE-05 Friday 9:30 AM - Elm Fork I

Development of microscale in-situ irradiation and corrosion experiment (Micro-ICE)

Hyosim Kim, Franziska Schmidt, Matthew Chancey, Yongqiang Wang, Blas Uberuaga

MST-8, Los Alamos National Laboratory, Los Alamos NM, United States

Structural materials in advanced reactors are expected to withstand extreme environments including high temperature, corrosive media, high-dose radiation, and stress. It is challenging to test and screen candidate materials under reactor-like conditions where these extreme conditions concurrently degrade the materials. In

this study, an in-situ corrosion and irradiation experiment was conducted on the microscale for the first time using focused ion beam (FIB) preparation and ion irradiation. A small volume of molten salt was loaded in the small chamber fabricated by FIB on Ni or NiCr alloys and irradiated using 5-9 MeV Ni ions at 500-800 °C to 20-50 dpa through the thin film (1-2 um thick) from the same material. The ion beam had a full penetration through the thin film and the interface of the film and the salt was examined using SEM and TEM to observe the effect of concurrent corrosion and irradiation.

Abstract 181 at 10:40 AM

Session AR-RE-05 Friday 9:30 AM - Elm Fork I

Exploring 2D graphene as atomic armor to protect uranium from ambient corrosion

Yongqiang Wang, Nolan Regis, Matt Chancey, Michael Pettes, Hisato Yamaguchi

Associate Laboratory Directorate for Physical Sciences, Los Alamos National Laboratory, Los Alamos, New Mexico, United States

Uranium (U) is a nuclear material with tremendous technological importance. One outstanding

challenge in preserving its intrinsic nuclear properties is its high susceptibility to ambient corrosion.

The corrosion, initiates at surfaces and interfaces, can form different phases, alter the dimensions of components, and even cause surface spalling, thus degrade the nuclear performance. Protective coatings are effective means to prevent metals from corrosive environments. However,anticorrosion coatings, when applied to actinides including U, faces a unique challenge from self-irradiation, which can degrade coatings' integrity by radiation damage and thus compromise the long-term efficacy of the applied coatings for corrosion protection.

This research aims to explore the feasibility of 2D graphene coating as atomic armor to protect U from ambient corrosion. Compared with traditional vapor-deposited film coatings, the defect formation in 2D material coatings is randomly distributed across layers, thus drastically reducing gas permeation paths. This unique 2D characteristics enables us to use significantly thinner coatings to achieve required anticorrosion efficacy; thus, can better preserve nuclear properties of the U material by minimizing unwanted "impurities" from the anticorrosion coatings itself.

Ion beams are used to mimic U self-irradiation environments including high energy alpha particle ionizations and heavy daughter product recoil cascades; thus, the accelerated irradiation doses of years and decades equivalent U-shelf lifetime can be effectively evaluated at the aboratory scale. Raman spectroscopy is used to evaluate irradiation stability of our 2D graphene coatings. Sieverts corrosion techniques are used to evaluate anticorrosion efficacy of the 2D graphene coatings when uncoated and coated U surfaces are exposed to hydrogen gas environments.

Abstract 169 Poster Poster Sessions

Advancements in field measurement of soil composition: Introducing the tagged neutron technique mobile system

Galina Yakubova, Aleksandr Kavetskiy, Sidharth Gautam, Stephen A. Prior, H. Allen Torbert

USDA-ARS, National Soil Dynamics Laboratory, Auburn AL, United States

We present the development and implementation of a mobile system designed for in-situ field measurement of soil composition utilizing the tagged neutron technique (TNT). The system is comprised of a portable neutron generator API-120 equipped with a built-in alpha detector, a diameter 7.62×25.4 cm LaBr(Ce) gamma detector with a thermostabilizing module, a 4-channel digital pulse processor running on a Linux operating system (Pixie-Net) for data acquisition, radiation shielding, GPS, autonomous power system, and an operational laptop. This equipment, particularly the Pixie-Net pulse processor, enables the measurement of gamma rays' spectra using the tagged neutron technique. These gamma spectra are generated solely by inelastic neutron scattering in soil or other samples, excluding contributions from external sources or other processes. Deconvolution of these spectra into their component parts facilitates the determination of the content of the studied object. The TNT gamma spectra of reference components (SiO_2, $Al2O_3$, Fe_2O_3, CaO, H_2O, and carbon, C) are essential for the deconvolution procedure. Reference samples of oxides and C were sized (approximate diameter 100×50 cm) to ensure that the intensity of the tagged neutron technique (TNT) gamma spectra reached a steady state and did not increase with further sample size. To define this, Monte Carlo simulations of neutron-stimulated gamma spectra (using the MCNP6.2 code) were employed. Experimental TNT gamma spectra of reference oxides and C were measured in a box with the aforementioned dimensions using the TNT Mobile system and utilized in the deconvolution procedure. This procedure accounts for neutron and gamma-ray attenuation during their propagation in samples or soil. The deconvolution algorithm was rigorously tested against both Monte-Carlo simulations and experimental gamma spectra, demonstrating good agreement between defined and actual sample component content.

In this poster presentation, we will delve into the detailed design of the TNT Mobile system, present results of samples measurements (including time-of-flight and energy spectra), discuss the deconvolution procedure using both Monte-Carlo simulated and experimental spectra, and compare field results of soil composition measurements with those obtained by various other methods including chemical analysis, dry combustion method, weight method, moisture determination by time domain reflectometry, and nuclear methods.

Suppression of X-ray radiation from a 2 MV electrostatic ion accelerator

Ihor Hennadievich Ihnatiev

National Academy of Sciences of Ukraine, Institute of Applied Physics, Sumy, Ukraine

The problem of radiation safety is one of the most important issues suppressing the application of low and medium energy ion accelerators.

It is well known that direct action low and medium energy ion accelerators are sources of strong X-ray radiation generated by electron avalanches in accelerator tubes (AT).

Electron avalanches occur as a result of ion-electron interaction of an ion and electron beam with elements of the high-voltage structure of the AT (electrodes, insulators) and with particles of the AT residual gas. X-rays are basically generated when their hard part (corresponding to electron energy over 100 keV) passes through metal walls of an accelerator tank.

If special protective measures are not taken, the radiation dose rate in the working area of an accelerator will exceed tens of μR/sec, which hinders the work of personnel and leads to the failure of equipment and units of a facility. The problem is particularly urgent for the construction of compact ion microprobes of MeV energy.

In the present work we present the results of experimental research of a system of suppression of X-ray radiation emission for a compact accelerating facility (AF) "Sokol" of the Institute of Applied Physics, National Academy of Sciences of Ukraine (Sumy).

Measurements of radiation dose rate were carried out on the surface of a tank (high-voltage tank). The beam current was 20 μA in the range of H^+ ion energy from 600 - 1400 keV, the pressure of residual gas in the AT was at most 10^{-4} Pa.

Characteristic maxima depend on the energy range at the beginning of a conductor, where the density of electrons, their energy and gas pressure are maximum.

In the zone of maxima, the dose rate exceeds the natural background radiation by more than 3 orders of magnitude.

The dose rate of AF "Sokol" was suppressed by a magnetic system consisting of 20 pairs of constant Nd-Fe-B magnets. This system allowed to suppress the dose rate by 2 orders of magnitude.

The dose rate of AF "Sokol" was suppressed by a magnetic system consisting of 20 pairs of constant Nd-Fe-B magnets. This system allowed to suppress the dose rate by 2 orders of magnitude.

As for numerical calculations, the proton deflection from the AT axis at the tube outlet does not exceed fractions of mm at energies of 0.6 - 2 MeV, which is within the normal operating regime of the facility. However, the electron travel time does not exceed the AT aperture radius (15 mm) at energies in the range of 10 eV, then the electrons are deposited on the electrodes and do not participate in the avalanche.

In the energy range up to 1500 keV peak, shifts of the beam profile around the geometric axis of the accelerating tube do not exceed 0,5 mm and can be eliminated by the electromagnet correctors.

Abstract 145 Poster Poster Sessions

Low energy ion-solid interactions: a quantitative experimental verification of binary collision approximation simulations

Hans Hofsäss, Felix Junge, Patrick Kirscht, Koen van Stiphout

II. Institue of Physics, Georg-August-University Goettingen, Goettingen, Germany

Ultra-low energy ion implantation has become an attractive method for doping of 2D materials. The dynamic binary collision approximation Monte Carlo program IMINTDYN [1,2] allows a reliable prediction of low energy implantation profiles and target compositional changes, as well as efficient simulation of high energy light ion scattering. To demonstrate the quality of these simulations, we present implantation of W ions into tetrahedral amorphous carbon with low (10 keV) and ultra-low (20 eV) energies and high resolution Rutherford backscattering spectrometry (HR-RBS) to analyze the W implantation profiles with (1)The experiment is compared with a complete simulation of all aspects of ion-solid-interactions of the experiment using the IMINTDYN. A unique novel simulation option is the inclusion of the vacancy as target species with dynamic vacancy generation and annihilation. We find excellent agreement between simulated and measured HR-RBS spectra if vacancy formation is included.

[1] H. Hofsäss, F. Junge, P. Kirscht and K. van Stiphout, Material Research Express (2023) DOI 10.1088/2053-1591/ace41c

[2] H. Hofsäss and A. Stegmaier, Nucl. Instr. Meth B 517 (2022) 49-62

Abstract 223 Poster Poster Sessions

Comparison of Neutron Generator Output Estimate Using a $LaBr_3$ and an Organic Scintillator

Caryanne R. Wilson[1], Oskar Searfus[2], Colton Graham[1], Valentin Fondement[1], Shaun D. Clarke[1], Sara A. Pozzi[1], Igor Jovanovic[1]

(1)Nuclear Engineering and Radiological Sciences, University of Michigan, Ann Arbor MI, United States
(2)Sandia National Laboratories, Livermore CA, United States

Active interrogation uses a neutron source, such as a D-T neutron generator, to induce radiation signatures in cargo that can be indicative of narcotics, explosives, and special nuclear material. Precise knowledge of the neutron output of a D-T neutron generator is crucial to estimate the required interrogation time to detect a minimum quantity of material. The objective of this work is to measure the neutron output of a Thermo Fisher P211 generator using two different approaches. The first approach uses activation analysis of a 3.8 cm x 3.8 cm $LaBr_3$ detector. ^{78}Br is only produced through the ^{79}Br(n,2n) reaction, which has a high energy threshold. Using the activity of ^{78}Br to determine the output of the neutron generator eliminates the interference of neutrons thermalized in the environment. A sum of exponentials is fit to the first 1800 s of the total decay time profile measured by the detector. The fit incorporates terms for ^{78}Br and ^{80}Br produced by neutron activation of the crystal and ^{28}Al produced by neutron activation of the environment. The data is under analysis and will be compared with a previous measurement that employed a liquid scintillator. The second experiment will employ a stilbene organic scintillator. Similar to this earlier measurement with a liquid scintillator, the neutron spectrum will be isolated using pulse shape discrimination, and the flux will be determined by matching the measured neutron spectrum to Monte Carlo simulations.

Abstract 221 Poster Poster Sessions

Temperature range of deuterium retention from ferritic-martensitic steel implanted deuterium at 100K and 300K

V. I. Zhurba, O. Morozov, V. O. Progolaeva

NSC-Kharkiv Institute of Physics and Technology, NAS of Ukraine, Kharkiv-61108, Ukraine

Deuterium thermal desorption spectra were investigated on the samples of ferritic-martensitic steel (16Cr12W2VTiAB) implanted deuterium at temperatures 100 K, 300 K with deuterium ions in the dose range from 5×10^{16} to 4×10^{18} D/cm^2. It has been determined that for low implantation doses, the thermal desorption spectrum of ion-implanted deuterium is a wide temperature range of deuterium desorption in the temperature range of 400-1000 K. As the dose increases, this temperature range of deuterium desorption expands in the direction of decreasing temperature and at a dose of 1.6×10^{17} D/cm^2, a wide peak with a maximum temperature of 400 K appears. A further increase in the implantation dose of deuterium is accompanied by the appearance of a lower temperature region of deuterium desorption with a maximum temperature in the temperature range of 200-250 K. At

doses above 8×10^{17} D/cm^2, a qualitative change in the deuterium thermal desorption spectrum occurs, which manifests itself in the appearance of a lower temperature region of deuterium desorption in the form of a clearly pronounced peak with a maximum temperature of ~180 K.

A further increase in the dose of implanted deuterium leads to an increase in the intensity of the lowest temperature peak of the deuterium thermal desorption spectrum, and it becomes dominant. The formation of a low-temperature intense peak in the deuterium thermal desorption spectrum may indicate the appearance of a new phase state, which can be considered as the formation of a hydride. The conclusion about the formation of a hydride was made on the basis of the data obtained by us in the study of the thermal desorption spectra of deuterium from Pd, Ti and ASS steel. These works show that the formation of hydrides is reflected in the deuterium thermal desorption spectrum by the appearance of lower temperature peaks. It is important that the formation of low-temperature deuterium desorption regions is accompanied by the appearance of a deuterium desorption region extended along the temperature scale in the temperature range of 200-1000 K.

Deuterium implantation at temperatures of 300 K and 600 K leads to a significant decrease in both the temperature range of deuterium desorption and the amount of retained deuterium.

E-mail: zhurba@kipt.kharkov.u; morozov@kipt.kharkov.ua

Abstract 108 Poster Poster Sessions

Homogenous and Robust Gypsum-Based Standard Materials for Trace Element Analysis by PIGE/PIXE

Anthony M Miller[1], Gunnar M Brown[2], Graham F Peaslee[2]

[(1)]*Chemistry and Biochemistry, University of Notre Dame, Notre Dame Indiana, United States*
[(2)]*Physics and Astronomy, University of Notre Dame, Notre Dame Indiana, United States*

Trace element surface analysis with Particle Induced Gamma Emission (PIGE) and Particle Induced X-ray Emission (PIXE) spectrosopy relies on the use of standard materials for detector calibration and data normalization. An inexpensive and rapid technique for producing gypsum-based target materials with homogeneously-dispersed trace elements is presented. These gypsum-based targets, spiked with fluorine and several first-row transition elements, are shown to be robust and reproducible standard materials for ex-vacuo surface analysis. Background trace elements present in bulk material along with limits of detection for various elements are provided. X-ray and gamma yields were estimated using a combination of measured and calculated cross sections, radiative yields, stopping powers, and attenuation coefficients available in literature. Comparisons between predicted yields and experimental results are provided

using an 50-100 nA, 3.5 MeV proton beam--which stopped within an ex vacuo target.

Abstract 82 Poster [Poster Sessions]

Real-time In-situ and Post-facto Study of the Mechanisms of Ion Beam Nanopatterning: Angle Dependence and Stress Behavior

Benli Jiang[1], Wei-Jing Chen[1], Jiaqi Tang[1], Anubhav Wadehra[1], Karl Ludwig[1,2]

[(1)]Division of Materials Science and Engineering, Boston University, Boston MA, United States
[(2)]Department of Physics, Boston University, Boston MA, United States

Ion bombardment can lead to a spontaneous formation of a range of nanopatterns on surfaces, including nanodots, nanoscale ripples, and nanoscale pits or holes under different ion irradiation conditions. Here, we are utilizing both real-time **in-situ** (x-ray and laser) and **post-facto** (atomic force microscope (AFM)) techniques to study the kinetics of the patterning process.

Motivated by a recent theory predicting the development of well-ordered ripples when the ion incidence angle is close to the critical angle [1], a series of experiments of low-energy ion beam patterning of Si were carried out around the critical angle, which were monitored by real-time **in-situ** grazing incidence small angle x-ray scattering (GISAXS) and were studied by **post-facto** AFM. Better-ordered ripples with long wavelength were observed when the ion incidence angle approaches about 45° from above. However, a divergence of ripple wavelength was not found.

Stress accumulation during the low energy normal incidence ion bombardment of Si was studied **in-situ** by using a multi laser beam optical stress sensor (MOSS) in a custom vacuum chamber. Our current results indicate that the typical stress response at the initial bombardment, a compressive stress peak [2], could be related to a removal of the native oxide layer of the sample.

[1] Bradley, R.M., 2020. Theory of nanoscale ripple topographies produced by ion bombardment near the threshold for pattern formation. **Physical Review E**, 102(1), p.012807.

[2] Perkinson, J.C., 2017. Nanoscale pattern self-organization under ion bombardment (Doctoral dissertation, Harvard university).

Abstract 179 Poster [Poster Sessions]

Single Ion Multispecies Positioning at Low Energy for Fabrication of Quantum Technologies

Ella Schneider[1], Kristian Stockbridge[2], Nathan Cassidy[2], Paul Blenkinsopp[2], Ian Brown[2], Tony Adams[2], Ben Murdin[1], Mateus Gallucci Masteghin[1], David Cox[1], Roger Webb[1]

(1)Ion Beam Centre, University of Surrey , Guildford Surrey, United Kingdom
(2)Ionoptika, Eastleigh Hampshire, United Kingdom

Donor spin qubits hosted in silicon are attractive quantum computing architectures due to their extremely long coherence times, scalability and compatibility with CMOS industrial manufacturing. Construction of a million or billion qubit Si-based quantum computer requires new fabrication technology to achieve precise placement of single qubit atoms in enriched defect-free ^{28}Si. Ion beams will play an important role in this new technology.

SIMPLE- Single Ion Multispecies Positioning at Low Energy, is an ion beam system with the capability to deterministically place ions into a substrate with sub-20nm precision (1)The tool is being developed at Surrey with Ionoptika and uses current state of the art focused ion beam technology to act as an implantation tool, along with ultrahigh vacuum systems to create a clean environment for the construction of qubit systems. In the regime of controlled single ion implantation, the process is essentially statistical in nature and the key to deterministic implantation is a high (>95%) detection capability for each ion as it arrives at the surface. A series of liquid-metal ion sources capable of delivering a range of ions including Au, Si, Ge, Sn, Bi and Er will be available along with a separate instrument fitted with a gas source for N, C and O ions. The current system will be described, and its operational parameters explored.

[1] N. Cassidy, **et al.** Phys. Status Solidi A, **2020**, 218, 2000237

Abstract 103 Poster Poster Sessions

High energy ion implantation for photoconducting terahertz switches

Vitalij Kovalevskij, Ignas Nevinskas, Mindaugas Gaspariūnas, Ričardas Norkus, Mindaugas Kamarauskas, Vaidas Pačebutas, Andžej Urbanovič, Andrejus Geižutis, Arturas Plukis

State research institute Center for Physical Sciences and Technology, Vilnius, Lithuania

Photoconductive switches that are gated by femtosecond laser pulses are the most common devices for the terahertz (THz) radiation generation and detection [1], which is starting to expand from lab doorsteps to the real world applications in spectroscopy, microscopy, medical sensing, security imaging, detection of substances and ultrafast data transfer. To ensure efficient

operation of these devices, the semiconductor must be characterized by free carrier lifetimes comparable to the gating laser pulse duration, as well as high carriers mobility and high dark resistivity. Introduction of carrier-trapping defects via implantation is a well known technique for reducing the carrier lifetime in a controlled manner (2)InP, GaAs, GaAsBi, and Ge semiconductors were implanted at a few different doses. Three tendencies were observed. First, the compounds require an order of magnitude lower implantation dose than Ge to achieve the same free carrier lifetime. Second, the mobility of implanted semiconductors is far better preserved as compared to molecular-beam-epitaxy introduced defects. Third, the implanted Ga-based materials are characterized by a higher dark resistivity due to the Fermi level pinning in the middle of the band gap [3]. Taking these observations into consideration the implantation conditions were optimized for the photoconductive terahertz switches, which allowed to achieve microwatt power of THz radiation and a 7 THz spectrum bandwith in GaAs.

[1] Auston, D. H. "Picosecond Optoelectronic Switching and Gating in Silicon." Applied Physics Letters 26(3), 1975, p.101-3. https://doi.org/10.1063/1.88079.

[2] Tan, Hark Hoe, C. Jagadish, K.P.Korona, J. Jasinski, M. Kaminska, R. Viselga, S. Marcinkevicius, and A.Krotkus. "Ion-Implanted GaAs for Subpicosecond Optoelectronic Applications." IEEE Journal of Selected Topics in Quantum Electronics 2(3), 1996, p. 636-42. https://doi.org/10.1109/2944.571762.

[3] Pearton, S. J. "Ion Implantation Doping and Isolation of III-V Semiconductors." Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms 59-60, 1991, p. 970-77. https://doi.org/10.1016/0168-583X(91)95744-X.

Abstract 283 Poster Poster Sessions

Synthesis of topological surface and superconductivity via implantation of Sn into InSb crystal

Soumya Srotaswini Sahoo

Department of Physics, University of North Texas, Denton Texas, United States

Soumya Srotaswini Sahoo[1], Darshpreet Kaur Saini[1], Sailza Sailza[1], Mohin Sharma[1], Mritunjaya Parashar[1], V. Nirmal Kumar[2,3], Manas Kumar Dalai[2,3], and Bibhudutta Rout[1]

1. Department of Physics, University of North Texas, Denton, TX 76201, USA

2. CSIR - Institute of Minerals and Materials Technology, Bhubaneswar - 751013, India

3. Academy of Scientific and Innovative Research (AcSIR), Ghaziabad - 201002, India

Recently Sb based III-V elements compound semiconductors have been used for high-speed and low-power applications such as telecommunications for aircraft, satellites, wireless communication, and global positioning systems, as well as thermophotovoltaic cells, THz medical imaging, and remote sensing, IR sensors for space exploration, high-resolution biomedical spectroscopy, and military systems, including security scanner. In this presentation, we will discuss about the study involving the implantation of Sn into InSb crystals. The choice of InSb crystals are due to their matching lattice parameters with α-Sn. The bandgap of InSb is 0.17 eV (narrow bandgap semiconductor) whereas Sn is a zero-bandgap semiconductor (almost metallic). Some researchers have observed the topological surface states, superconductivity, etc. on the Molecular Beam Epitaxy (MBE) grown α-phase of Sn deposited InSb substrates. Our work focuses on forming the α-phase of Sn using low-energy ion implantation of Sn into the InSb substrate and subsequent thermal annealing. The implantation range of Sn varies in the 80 - 700 nm range from the surface of the substrate by varying the fluence and energy of the beam respectively. The electronic and magnetic properties at different phases of Sn will be discussed from their respective electrical measurements and an overall comparison with that of MBE grown α-Sn over InSb substrate.

References:

1. V. Nirmal Kumar, M. Arivanandan, T. Koyoma, H. Udono, Y. Inatomi & Y. Hayakawa, **Applied Physic A**, **122**, 885 (1-9) (2016).

2. M. Haris, P. Veeramani, P. Jayavel, Y. Hayakawa, D. Kanjilal, S. Moorthy Babu, **Nucl. Instr. Meth. B,** 244, 179 (2006).

3. Wickramaarachchige J. Lakshantha, Mangal S. Dhoubhadel, Tilo Reinert, Floyd D. McDaniel, Bibhudutta Rout, **Nucl. Instr. Meth. B**, 365, 114 (2015).

4. Cai-Zhi Xu, Yang-Hao Chan, Yige Chen, Peng Chen, Xiaoxiong Wang, Catherine Dejoie, Man-Hong Wong et al., **Phys. Rev. Lett.,** 118, 146402 (2017).

5. A. Barfuss, L. Dudy, M. R. Scholz, H. Roth, P. Höpfner, C. Blumenstein, G. Landolt, J. H. Dil, N. C. Plumb et al., **Phys. Rev. Lett.**, **111**, 15 (2013).

6. I. Didschuns, K. Fleischer, P. Schilbe, N. Esser, W. Richter, K. Lüders, **Phy. C: Superconductivity,** 377, 89 (2002).

7. E Magnano, C Cepek, S Gardonio, B Allieri, I Baek, E Vescovo, L Roca, J Avila, Maria Grazia Betti, C Mariani, M Sancrotti, **Journal of electron spectroscopy and related phenomena** 127, 29 (2002).

8. Huanhuan Song, Jinshan Yao, Yuanfeng Ding, Yu Gu, Yu Deng, Ming-Hui Lu, Hong Lu, Yan-Feng Chen, **Adv. Eng. Mater.** 21, 1900410 (2019).

Abstract 300 Poster Poster Sessions

Measurements of radiation tolerance of Superlattice (Al)GaAs by Positron Annihilation Spectroscopy

Thai hang Chung[1,4], Ella K. Pek[3], Adric C. L. Jones[1], Maciej O. Liedke[2], Andreas Wagner[2], Kevin D. Vallejo[3], Kaustubh Bawane[3], David H. Hurley[3], Yongqiang Wang[4], Farida A Selim[1]

(1)School for Engineering of Matter, Transport and Energy, Arizona State University, Tempe AZ, United States
(2)Institute of Radiation Physics, Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany
(3)Condensed Matter and Materials Physics Department, Idaho National Laboratory, Idaho Falls ID, United States
(4)Materials Science and Technology, Los Alamos National Laboratory, Los Alamos NM, United States

We present positron annihilation spectroscopy measurements on superlattice (Al)GaAs samples
of 10 nm and 20 nm thickness to study point defects in pristine and irradiated samples. 1.5
MeV protons were used to damage the samples uniformly over 5um and less than 2x10 -5 dpa is
accumulated within the sample. No amorphization or defects were detected by TEM, however
PAS has remarkable sensitivity of 0.01 ppm and unique capability to measure atomic scale
vacancies. Using both Doppler broadening spectroscopy and (DBS) and positron annihilation
lifetime spectroscopy (PALS), we observe that superlattice samples both 10 nm and 20 nm
spacings show significantly lower defect content after irradiation compared to bulk AlGaAs film.
Additionally, the measurements reveled remarkable radiation tolerance in the 20 nm superlattice
sample, which was interpreted due to high quality of the interfaces revealed by TEM. These
interfaces impact the migration of defects in AlGaAs superlattice and facilitate their annihilation.
Our PAS measurements are consistent with the annealing of radiation induced defects
mechanism observed in the 20 nm superlattice samples in thermo-reflectance measurements.

Abstract 301 Poster [Poster Sessions]

Compensated Neutron Logging with nGen® D-D Neutron Source

John E Tolar, Daniel R Braun, Robert A Stubbers, Brian E Jurczyk

Starfire Industries LLC, Champaign IL, United States

In traditional compensated neutron logging (CNL), a 241Am-Be radionuclide neutron source is spaced some distance from a pair of neutron detectors - one near the source and one farther away. The porosity of the formation is determined in part from the ratio of the count rates from neutrons scattering from the formation back to the near and far detectors.

Although a good measurement to estimate porosity, regulations, risk, cost constraints, and operational limitations of radionuclide sources often limit the use of traditional CNL logging at many well sites. Starfire Industries has developed a promising alternative utilizing its "end-target" nGen®- 100 D-D neutron generator. When coupled with two neutron detectors (near and far), the neutron generator + detector assembly becomes a suitable replacement for traditional 241Am-Be CNL probes.

At the 2022 CAARI conference, Starfire presented sandbox data showing excellent near/far ratio response for 2.5 MeV neutrons to changes in porosity. This sandbox data was recorded using the nGen®- 100 D-D neutron generator + detector assembly. Subsequent design iterations have led to full tool integration into a QL40-style probe housing (provided by Mount Sopris Instruments) and operation over a 1000' wireline compatible with ALT's industry standard LoggerSuite package.

In this poster, we present actual geophysical data logged in the Ralston Creek well outside Denver, CO. The near/far detector ratio from the D-D neutron generator CNL probe exhibits good agreement with other previously recorded logs, notably neutron porosity data from a 241Am-Be single detector probe. Additional sandbox data verifying consistent porosity response of D-D neutrons and future D-D neutron applications in the geophysical logging space are also discussed.

Abstract 306 Poster [Poster Sessions]

Background Characterization Efforts for Future Neutrino Experiments at H

A. Galindo-Uribarri, D. Martínez-Montiel, G. Rodríguez-Guijarro

ORNL, Oak Ridge TN 37830, United States

The High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory is a versatile research facility utilizing a highly-enriched U-235 core. HFIR provides a robust and well-documented source of MeV-scale electron antineutrinos, making it an excellent choice for short-baseline neutrino experiments. The PROSPECT experiment, recently conducted at HFIR, not only pursued its primary research objectives but also assessed HFIR's background conditions, showcased technology for surface-based rare event detection, and validated HFIR's suitability for fundamental neutrino studies. With future experiments on the horizon at this exceptional facility, further efforts are necessary to quantify both intrinsic building and cosmic backgrounds. This poster presents two local initiatives at ORNL focused on accurately characterizing these background sources.

Abstract 307 Poster Poster Sessions

Sensitivity to 144Pr-Antineutrino Production with the PROSPECT Expe

A. Galindo-Uribarri, F. Silva-Garcia, D. Venegas-Vargas

on behalf of the PROSPECT collaboration, ORNL, Oak Ridge TN 37830, United States

PROSPECT is a reactor antineutrino experiment utilizing a 4-ton liquid scintillator detector segmented into an 11x14 array of optically isolated cells. This detector is designed to investigate sterile neutrino oscillations and precisely measure the antineutrino spectrum arising from the betadecay of neutron-rich byproducts produced during the nuclear fission of U-235. Data was collected in 2018 and 2019 with the first-generation detector, PROSPECT-I, situated approximately 7 meters from the 85 MW High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory. HFIR's 24-day operational cycle offers unique opportunities to gather and analyze data during fuel disassembly phases when the reactor is shut down. As the fuel cools, most beta-decaying isotopes contributing to the U-235 antineutrino spectrum decay, leaving predominantly longer-lived isotopes such as Pr-144. This poster presents the first exploration of PROSPECT-I data, focusing on isotope-specific neutrino production from residual antineutrino emissions during reactor-off periods.

This work is supported by the US DOE Office of High Energy Physics, the Heising-Simons Foundation, CFREF and NSERC of Canada, and internal investments at all institutions.

Abstract 303 Poster Poster Sessions

Carbon Reinforced Boron sub-Oxide Nanocomposite (CaRBON)

Jonathan Kenny, David Wright

AWE Nuclear Security Technologies, Aldermaston, Reading, Berkshire RG7 4PR, United Kingdom

The aim of the following project was to demonstrate that it is possible to produce a nanocomposite consisting of the novel, ultrahard experimental ceramic material, Boron Suboxide (B_6O), intimately blended with an ultrafine microstructure of Boron Carbide (B_4C) formed via the reaction of the B_6O with carbon (C) deriving from reduced Graphene Oxide (rGO) precursor nanomaterial. The range of uses of this material could vary from neutron moderation and absorption applications to ballistic armour applications, as well as possibly supercapacitance and hydrogen storage technology owing to the complex structure and behaviours of boron-based compounds.

This nanocomposite was formed by blending the B_6O with rGO in aqueous suspension with deionised water before filtering and de-agglomerating it, and then consolidating it via Spark Plasma Sintering (SPS). A full suite of materials characterisations was then performed, both before and after sintering. This included Laser Scattering Particle Size Analysis (LSPSA), X-Ray Diffraction (XRD), Thermogravimetric Analysis/Differential Scanning Calorimetry (TGA/DSC), Optical Spectroscopy methods such as Fourier Transform Infrared (FTIR) and Raman Spectroscopy, Scanning Electron Microscopy/Electron Dispersive X-ray (SEM/EDX) Spectroscopy and Vickers Hardness Testing. To assess the materials behaviours against high energy neutron bombardment, the Accelerator Source Pulsed (ASP) facility was used in conjunction with the Diamond Detectors experimental setup.

It was shown that the pure B_6O sintered at 1850 °C, densified to ~95% of the samples theoretical density (TD), was able to exhibit a comparable hardness to near-fully dense B_4C made through similar processing methods (~35 GPa at ~95% of TD for B_6O, compared to ~32.5 GPa at >98.5% TD). Due to the exponential effect that densification has on material hardness, if all the CaRBON samples were made to near-full density via synthesis optimisation, they would likely exhibit comparatively superior mechanical properties.

Additionally, the B_6O + 1 wt.% GO samples, sintered at 1570 °C for 15 and 30 mins respectively, achieved a greater degree of densification and average hardness compared to the pure B_6O sintered at the same temperature for 30 mins. Unlike the brittle pure B_6O, it was only the CaRBON composite samples that were able to be retrieved in a geometrically intact form after sintering, indicating that the addition and subsequent reaction of GO could have a cementing effect on the B_6O.

XRD data proved that the addition of GO to B_6O caused it to react with the matrix in-situ to form B_4C. In 1 wt.% GO additions, the sample was able to display characteristic patterns indicating a mixture of both B_6O and B_4C when sintered at 1570 °C for 15 mins. When the same sample was left to sinter for a total of 30 mins, the pattern indicates an almost total transformation of the sample to B_4C, thereby proving the hypothesis of the study.

Furthermore, it was possible to prove that the material's chemical properties under local deformation were different to pure B_4C, which undergoes a phenomenon called 'shock amorphisation' (whereby it's crystal structure, under critical shock stresses, collapses into a more dense, amorphous form, thereby deteriorating B_4C's mechanical properties).

By contrast, none of the significant indicators of sample amorphisation were present in any of the B_6O samples. This gives backing to the idea that a B_4C additive phase, which undergoes this failure mechanism more readily, could potentially be used with a B_6O matrix to dissipate crack energy by being deflected along a more torturous path through the material. This would make the composite more mechanically resistant to the effects of catastrophic failure via transgranular cleavage.

The Accelerator Source Pulsed (ASP) facility was used to expose 2 of the CaRBON samples (containing 1 wt.% GO, sintered for 15 and 30 mins respectively) and 2 B4C analogues (made with commercial grade and lab synthesised material) for 2 x 4 consecutive day periods over 2 weeks. During testing, the samples were exposed to a neutron fluence of 39.6 ± 3.41 n/cm^2 with energies of 13.7 ±~1.5 MeV. By the end of the test, all samples had a radioactivity of 0.2 mSv (equivalent to 2 bananas). Post irradiation optical and SEM analysis revealed no signs of radiation-induced damage taking place across any of the tested samples. This suggests that CaRBON could potentially stand as an effective refractory material in neutron scattering and deflection applications.

Abstract 129 Poster Poster Sessions

Improving Charge Exchange Performance in a Tandem Accelerator through Simulations

Mark Harrison, Vlad Vekselman, Alex Dunaevsky, Kirill Martianov, Alex Makarov

TAE Life Sciences, 35 Parker, Irvine CA 92618, United States

Tandem-type accelerators have an advantage over other static-field accelerators because the entire outside of the accelerator is at ground voltage--including the beam entrance and exit. However, these require an ion beam that can change ionization midway through so that the beam is accelerated on the way in and out. The efficiency of this charge exchange (CEX) is critical to maximizing the amount of accelerated current. In this study, we examine the charge exchange target (CXT) at the center of the tandem accelerator in TAE's BNCT (boron-neutron capture therapy) accelerator in Xiamen, China. The target is a narrow tube into which argon flows. The H^- beam that enters the tube interacts with the argon gas to strip two electrons, creating a proton beam that accelerates out of the tandem. Varying geometries and modifications of the CXT are simulated to increase CEX efficiency and reduce the required argon flow rate. Furthermore, modifications to the tandem accelerator itself that reduce the

amount of argon gas that leaks into the upstream beamline are simulated. Such argon leakage causes premature charge exchange outside the tandem that results in the loss of useful beam since positive ions are accelerated in the wrong direction and neutral ions fail to be accelerated in the first half of the tandem. Molflow+ is used for vacuum simulations to predict the distribution of argon gas throughout the beam line. A linear, iterative simulation of the charge exchange process is used to predict the resulting amount of proton beam current that exits the tandem accelerator. Much faster analytic solutions to the charge exchange process are derived for constant-energy sections of the beam line--such as inside the CXT. The simulations are benchmarked against measurements from the Xiamen accelerator.

Abstract 187 Poster Poster Sessions

MeV Neutron and X-ray Imaging Radiography and Computed Tomography using Advanced Scintillators

Nerine Cherepy

LLNL, Lawrence Livermore National Laboratory, Livermore CA, United States

MeV X-rays and neutrons can provide 3-D volumetric views of complex additively manufactured components made of multiple materials. While considerable effort has been focused on engineering high flux sources, we report here on recent advances in detector materials to enhance throughput and resolution. Lens-coupled computed tomography using a transparent scintillator imaged on a CCD camera obtains higher spatial resolution than the standard phosphor-enhanced amorphous silicon (A-Si) panels. For MeV X-ray CT, we developed a new polycrystalline transparent ceramic scintillator referred to as "GLO" with excellent stopping power and light yield for improved contrast in sizes up to 14" field-of-view. Pixelated arrays of GLO are being fabricated into imaging screens via direct-ink-write additive manufacturing to increase efficiency. For MeV neutron CT, we have fabricated large plates of "Hi-LY" plastic scintillator employing Iridium complex fluors with light yields 3-4x higher than standard plastic. For high throughput but moderate resolution neutron imaging, a "Hi-LY" voxelated plastic scintillator screen may be mounted on an A-Si array. We will present the materials properties, optical design and imaging performance of these imaging systems.

Abstract 185 Poster Poster Sessions

Lithium depth profiling with proton beam NRA

Patrick Kirscht, Felix Junge, Hans Hofsaess

II Institute of Physics, Georg-August-University, Goettingen, Germany

Lithium is one of the most important elements for energy storage. There are several methods available for detection - one of which is nuclear reaction analysis (NRA). The nuclear reaction 7-

Li(p,alpha) 4-He with a Q value of 17 MeV is suitable for lithium detection (1)Two alpha particles with 7.5 MeV each are generated, which are detected using PIN diodes. We use our Pelletron accelerator to generate a proton beam with an energy of 2.5 MeV. The aim of the investigations is to make a statement about the depth profile of the lithium which is not dominated by the statistical energy distribution of the alpha particles. For this purpose, ta-C coated silicon wafers are implanted with 30 keV lithium, measured, covered with an additional carbon layer using sputter deposition and measured again. This leads to a shift in the alpha spectrum to lower energies due to the additional energy loss in the deposited carbon. Furthermore, the experiments are simulated using the binary collision approximation (BCA) Monte Carlo program IMINTDYN (2,3)Additionally to the aspects of ion-solid interactions, IMINTDYN offers the option of generating the NRA for a specific isotope and projectile after simulating an implantation, taking into account energy loss and deflection of the projectiles and the generated alpha particles.

[1] F. Junge, P. Kirscht, H. Hofsäss, Quantitative light element analysis: Complementary IBA methods for H to O detection using an external proton beam, Nuclear Instruments and Methods in Physics Research Section B (517) (2022), 16-23

[2] H. Hofsäss, A. Stegmaier, Binary collision approximation simulations of ion solid interaction without the concept of surface binding energies, Nuclear Instruments and Methods in Physics Research Section B (517) (2022), 49-62

[3] H. Hofsäss, F. Junge, P. Kirscht, K. Van Stiphout, Low energy ion-solid interactions: a quantitative experimental verification of binary collision approximation simulations, Materials Research Express (2023), DOI 10.1088/2053- 1591/ace41c

Abstract 292 Poster Poster Sessions

Required for novel semiconductor materials: ToF-ERDA spectrometer

Mikko Laitinen

Accelerator Laboratory, Department of Physics, University of Jyvaskyla, P.O. Box 35, FI-40014, Jyväskylä, Finland

The need for the ToF-ERDA in IBA: Time-of-Flight Elastic Recoil Detection Analysis (ToF-ERDA) is a powerful method for elemental characterization and depth profiling of thin films (1-5)ToF-ERDA can easily quantify elements lighter than substrate (the main difference to RBS) but at the same time, also the heavier than substrate materials are measured. This requires proper detectors, software and ion beam for the analysis process. One specialty of the technique is the quantitative depth profiling possibility of hydrogen, along with all other elements. This is something that cannot be achieved by other methods like XPS or SIMS, which often are used to provide similar data.

In the Silicon IC-era, with thin films being heavier than the Si, the RBS method was sufficient for the most IBA analysis tasks. This, however, is now changing rapidly. The modern green materials utilize both heavy and light element-compounds, and at the same time the light impurities withing the films are crucial to be analyzed. Even more importantly, as the novel semiconductor substrates have become much heavier than the Silicon, being GaAs, InSb, or CdTe for example, the need for the ToF-ERDA method has increased dramatically.

However, only handful of laboratories have had access to this method in the past. One reason for the "unpopularity" of the method has been the complex data-analysis and the lack of ready, even commercially available, spectrometers, or individual detector components. These obstacles have been now cleared by the persistent work done in Jyväskylä and both the ToF-ERD analysis tools and software are readily available for the IBA community.

Jyväskylä ToF-ERDA spectrometer: The key design goal in the ToF-ERDA is to avoid sample damage. If one destroys the sample during the measurement, then one doesn't measure anything. The quantification of the as-is sample composition is done by minimizing the required beam fluence and maximizing the efficiency and solid angle. Additionally, to improve the efficiency of the labour, automation is also important.

During the past years, ToF-ERDA components from timing detectors up to full ToF-ERD spectrometers (Figure 1) have been delivered to several laboratories by the JYFL ACCLAB. The performance of the latest setup achieves the key design goals by maximizing the gas detector entrance window ~360 mm^2, maximizing the hydrogen detection efficiency >50 %, allowing shorter time-of-flight by concentrating low energy heavy ions and thus receive the advantage of the increased scattering cross sections and lower beam induced damage to the sample.

Additionally, new version of the Analysis software Potku [5] has been recently released. By the Potku analysis software one can obtain the quantitative thin film depth profiles, or energy spectra, and can also take account the potential elemental losses. The Monte-Carlo calculation, required for the lowest energies and heaviest films, is also fully working and the speed and the stability of the software has been significantly increased.

In this presentation the requirements for the complete ToF-ERDA spectrometer, the design parameters and how to achieve those targets will be gone through and the latest performance related figures will be presented.

References

[1] M. Laitinen, M. Rossi, J. Julin, T. Sajavaara Nucl. Inst. Methods Phys. Res. B, 337 (2014), pp. 55-61.

[2] M. Laitinen, T. Sajavaara, M. Rossi, J. Julin, R.L. Puurunen, T. Suni, T. Ishida, H. Fujita, K. Arstila, B. Brijs, H.J. Whitlow, Nucl. Inst. Methods Phys. Res. B, 269 (2011), pp. 3021-3024.

[3] K. Arstila, T. Sajavaara and J. Kejonen, Nucl. Instr. Meth. B 174 (2001) 163-172.

[4] J. Julin, M. Laitinen, T. Sajavaara, Nucl. Instr. and Meth. B 332 (2014) 271-274.

[5] K. Arstila, J. Julin, M.I. Laitinen, J. Aalto, T. Konu, S. Kärkkäinen, S. Rahkonen, M. Raunio, J. Itkonen, J.P. Santanen, T. Tuovinen, T. Sajavaara, Nucl. Instr. and Meth. B 33 (2014) 34-41.

Abstract 238 Poster

Poster Sessions

Compact Ion Beam System for Studying D-D and p-^{11}B Fusion Reactions

Allan Xi Chen, Nai-Wei Liu, Alexander Gunn, Zhe Su

Alpha Ring International Ltd., Gardena California, United States

Alpha Ring International (ARI) presents a compact ion beam system capable of accelerating H^+/D^+ ions up to tens of keV energies with sufficient beam current for studying fusion reactions involving light nuclei. The ion beam system comprises a high-density microwave driven plasma to produce the ions which are then accelerated to high energy via a single gap acceleration structure. Plasma operation is sustained by coupling of microwave power from a solid-state RF amplifier impedance matched to the ISM (2.4-2.5GHz) band frequency. A dielectric gap is utilized to isolate the high potential plasma chamber from the microwave tuning structure at ground potential. To facilitate the use of various detectors around the target, the plasma chamber is biased to a high positive voltage while the target remains grounded. For studying D-reactions (e.g. D-D fusion), a pre-loaded target is used to maximize the yield while minimizing unwanted radiation. For p-reactions (e.g. p-^{11}B), we use either B_4C or LaB_6 as a stable solid boron-containing target. The primary detectors are a solid-state charged particle detector and a scintillation fast neutron detector. Alternatively, a cloud chamber or CR-39 coupon could be used as a non-electronic method to observe the fusion charged particles. The complete ion beam system can fit on a typical laboratory table and is a useful tool for teaching undergraduate and graduate students on various fusion concepts.

Abstract 295 Poster

Poster Sessions

Educational Activities and Research at Tarleton's Nuclear Laboratory

Daniel Keith Marble[1], Christopher Brian Marble[1],
Kassie Scott Marble[2]

(1)Chemistry, Geoscience, and Physics, Tarleton State University, Stephenville Texas, United States
(2)Physics, Texas A&M University, College Station Texas, United States

Tarleton State University's nuclear laboratory provides educational activities for K-12 students and teachers as well as for undergraduates at Tarleton and other institutions in the Texas Physics Consortium (TPC). Over the past 20 years over 1500 K-12 students have done educational activities at the facility as part of summer camps, boy scout nuclear badge, and other visitation groups while undergraduate students in engineering and physics have performed labs for physics courses including elastic collisions, measuring Q-values of nuclear reactions, calibrating an accelerator magnet, etc. The facility also supports the required year-long senior research requirement of all physics majors as well as collaborative faculty/student research with other institutions. This presentation will discuss the capabilities of the Tarleton facility, workshops on low cost nuclear labs developed by Tarleton faculty, and give examples of some of the research and educational activities that have been performed over the years at the facility.

Abstract 125 Poster Poster Sessions

A Multimodal Approach Towards Advancing the Characterization and Analysis of Erbium

Sage D.C. Buchanan[1,2], Lyudmila V. Goncharova[1,3],
Mark C. Biesinger[2,3]

(1)Physics and Astronomy, Western University, London Ontario, Canada
(2)Surface Science Western, Western University, London Ontario, Canada
(3)Chemistry, Western University, London Ontario, Canada

Erbium is one element in the globally-recognized class of critical minerals, the rare earth elements (REE's). It is an essential component in various clean energy and modern technology applications from nuclear control rods to infrared optics. Growing demand for these high-tech applications alongside geopolitical supply chain risks underscore the critical status of REE's. To address this, it is of interest to advance resource development through all available means, including both mining and recycling. In order to develop and maintain responsible resource management strategies, it is crucial to be able to reliably identify and quantify rare-earth-containing materials and to have a comprehensive understanding of their properties.

This work presents an effort to advance current methodologies surrounding the analysis and characterization of rare-earth-containing materials, with a focus on erbium. Using several analytical techniques such as Secondary Ion Mass Spectrometry (SIMS), Rutherford Backscattering Spectroscopy (RBS), and X-ray Photoelectron Spectroscopy (XPS) we are developing robust characterization procedures for various erbium-containing materials. By identifying subtle binding energy shifts and structural variances in the complex XPS signals of erbium

compounds, we are developing novel and practical standard curve-fitting procedures. These fitting procedures will serve as reference data to allow for the future identification and Er content quantification of these compounds in unknown erbium-bearing materials. We are also exploring the fabrication of element-specific SIMS standards through ion implantation of Er^+ ions into different substrates such as Si and SiO_2 / Si. Erbium concentration profiles aided by subsequent RBS analyses will be compared to quantified depth profiles from SIMS analyses. This will allow for precise calibration of the sensitivity of Er detection in SIMS, allowing for more accurate quantification of Er content in materials through more representative standards. Using both Al-Kα and high-energy Ag-Lα XPS sources in conjunction with elemental mapping via Energy Dispersive X-ray spectroscopy, we have also identified several light REE's residing in interstitial grain boundaries between the associated barite ($BaSO_4$) and calcite ($CaCO_3$) mineral grains within bastnaesite ore.

Improvements on methods of detecting, identifying, and quantifying REE's such as SIMS and XPS can inform and enhance recovery procedures to strengthen REE supply chains from both mining and recycling. Ion implantation with RBS verification has proven as a promising method to develop custom calibration standards for SIMS analyses in an efficient fashion, however more testing is needed. Collectively, XPS, RBS and SIMS provide a strong foundation for our understanding of the composition, electronic structure, and surface chemistry of erbium-containing materials. These advancements are critical for optimizing the extraction and recycling processes by increasing the processing yield, efficiency, and by reducing waste.

Abstract 296 Poster Poster Sessions

Investigation of Elemental concentration in Olivine using PIXE, EDAX, and XRF.

Sailza Sailza, Soumya Srotaswini Sahoo, Darshpreet Kaur Saini, Mritunjaya Parashar, Mohin Sharma, Dr. Bibhudutta Rout, Dr. Garry Glass

Department of Physics, University of North Texas, Denton Texas, United States

Olivines are the members of the group of common magnesium, iron silicates (Mg-Fe-Si-O based alloy). They are important rock-forming mineral groups. They are mainly found in high-temperature metamorphic rocks, lunar basalts, cosmic dust grains, interstellar medium, and some meteorites. The composition of most of the olivine can be represented in the system Ca_2SiO_4-Mg_2SiO_4-Fe_2SiO_4. The most abundant olivine occurs in the system from forsterite (Mg_2SiO_4), and fayalite (Fe_2SiO_4). The general formula for most naturally occurring olivine is $(Mg, Fe)_2SiO_4$. Minor elements such as aluminium, nickel, chromium, and boron can be substituted in olivine. Olivine's study is important because they are found in the inner Earth, Moon, and stony Meteorites etc., it's study will help in understanding the interior of the earth, the origin of meteorites, cosmic dust grains, history, and process in the solar system. In this study, we have investigated the elemental

concentration of commercially available olivine using several complementary nuclear techniques. We will present the experimental data using PIXE, EDAX, and XRF.

Abstract 297 Poster Poster Sessions

Ion Resonance Energy Coupling using Induction Field

Devesh S. Bhosale

Department of Physics, Stevens Institute of Technology, Jersey City New Jersey, United States

Starting from First Principles, the space charge manipulation of charged particles in an induction field in free space based on an unique Magnetic field strength and its oscillation Frequency relationship is demonstrated numerically and theoretically.

The Larmor precession frequency for a time varying magnetic field, instead of conventionally followed static magnetic field is derived for the first time. With the dispersion relation in Ion Resonance depending on its frequency of gyration, an AC driven electromagnet based particle resonance has been proposed circumventing the use of Superconducting Permanent Magnets. Complete resonance achieved under the proposed conditions results in a sustained, fixed-frequency particle trajectory that is independent of its speed or drift. Such oscillation is visualized in a D-Shaped Resonant assembly.

The amplitude and the wavelength calculations for the trajectory are demonstrated analytically.

Principally noting the objectives of Synchrotron in varying the magnetic field and its frequency to generate high energy particles, the present theory addresses the same. Its applications can be explored in Space Propulsion Systems, Magnetic Confinement Fusion, Magnetic Resonance Imaging (MRI) and sub-harmonic heating and cooling. Using this theory one can aptly generate RF Power using device specific designed resonant antennas coupling it with with Plasma.

Abstract 20 Poster Poster Sessions

Effects of Induced Structural Modification on Properties of V^+ Ion implanted RF - Magnetron Sputtering Deposited ZnO Thin Films of thickness 120 nm on borosilicate glass substrates

Olakunle Oluwaleye[1], Morgan Madhuku[3], Bonex Mwakikungaa[4], Joseph Kwaku Ofori Asante[2]

[(1)]Physics, Tshwane University of Technology, Pretoria Gauteng, South Africa
[(2)]Physics, Tshwane University of Technology, Pretoria Gauteng, South Africa
[(3)]Physics, NRF-iThemba LABS, Johannesburg Gauteng, South Africa
[(4)]Material Science and Manufacturing, CSiR, Pretoria Gauteng, South Africa

The effects of induced structural modification on the thermal stabilities, chemical bond and optical properties of zinc oxide (ZnO) thin films of thickness 120 nm, used in optoelectronic (solar cells, LED) and energy nanodevices were studied. These films were synthesized using rf - magnetron sputtering deposition method. Thereafter, the films were implanted with V^+ ions at 170 keV and different ion fluences to investigate the effect of induced structural changes on optical properties, such as optical band gap, transmittance, and absorbance. The V^+ ion implanted films have been characterized by different material characterization techniques such as Ultraviolet-Visible Spectroscopy (UV-Vis), X-ray diffraction (XRD), Atomic Force Microscopy (AFM), and Fourier-transform Infrared Spectroscopy (FTIR).

Changes in structural parameters such as surface roughness and crystallite size due to ion implantation have significant effects on the optical bandgap, transmittance and absorbance of V^+ ion implanted ZnO thin films. It can be observed that as the surface roughness increases, it results in increased optical bandgap and transmittance to 4.10 eV and 82.34 %, respectively, together with decreased absorbance to 0.12 nm. However, the effects of induced crystallite size on the optical band gap and transmittance show a contrasting behavior. It can be observed that optical band-gap and transmittance gradually increase up to a fluence of 1 x 10^{16} ions/cm^2 as the crystallite size decreases together with a slight decrease in absorbance. In addition, the results of estimated thermal stability and chemical bond analysis revealed interesting information.

Therefore, the tailored modification of ZnO thin films by V^+ ions lead to enhanced properties with potential applications in optoelectronics (solar cells, LED) and energy nanodevices.

Abstract 257 Poster Poster Sessions

Ongoing research on surface modification by low energy protons

B. E. Fuentes[1], J. López-Patiño[1], E. Álvarez-Zauco[1], A. López-Suárez[2]

[(1)]Departamento de Física. Facultad de Ciencias, Universidad Nacional Autónoma de México, CDMX Ciudad de México, Mexico
[(2)]Instituto de Física, Universidad Nacional Autónoma de México, CDMX Ciudad de México, Mexico

Protons generated in the low energy accelerator of the Faculty of Sciences in U.N.A.M. were used to study conductivity, optical properties, and surface modifications in C60, C60-H2TPP and ZnO thin films.

Absorption UV-vis spectra and I-V curves were taken before and after irradiation of C60 and C60-H2TPP. Preliminary results show that at 7 keV the C60 thin films present polymerization. At 3 keV, the degradation of the H2TPP molecule can be observed.

ZnO thin films were irradiated at 8 keV. A gradual reduction on the transmittance is observed as the fluence increases. This reduction could be related to the formation of defects and tension in the crystalline structure of ZnO due to the proton irradiation.

Index of CAARI-SNEAP Authors and Co-Authors