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GAIN Innovative Materials Research Workshop Summary Report

July 21, 2022

GAIN Innovative Materials Research Workshop Summary Report

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Prepared for the
U.S. Department of Energy
Office of Nuclear Energy
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GAIN Innovative Materials Research Workshops

INTRODUCTION

The Gateway for Accelerated Innovation in Nuclear (GAIN) initiative organized two Innovative Materials Research Workshops to discuss a potential new Department of Energy Office of Nuclear Energy (DOE-NE) program on advanced and innovative materials research for advanced reactor fuel cladding and structural materials. In addition, nuclear industry participants were asked to identify their needs for research in this area and to input on possible program objectives.

The first workshop was embedded in the American Nuclear Society Annual Meeting on June 15, 2022, with approximately 50 people in attendance. The objectives of the proposed program were provided by Stephen Kung, DOE, and the technical basis was presented by Stuart Maloy, Pacific Northwest National Laboratory (PNNL). The proposed program would cover the following for lower Technology Readiness Level (TRL) research:

- Innovative cladding materials research, including core materials that provide structure (e.g., grid plates, materials that are removed from the core along with refueling activities)
- Innovative characterization and testing methods
- Innovative new methods of qualifying material "quicker"
- Research needs spanning the next 20 years

Three industry representatives discussed gaps and needs based on their technology.

- Ryan Webster, Oklo Inc., Aurora Reactor
- Emre Tatlli, Westinghouse, Lead Fast Reactor (LFR)
- Matt Wargon, TerraPower, Molten Chloride Fast Reactor (MCFR)

National laboratory and university presentations provided technical context.

- Simon Pimblott, Idaho National Laboratory/Nuclear Science User Facility, "Capability Needs for Irradiated and Radioactive Materials Research Study"
- Siddhartha Pathak, Iowa State University, "Probing Nanoscale Damage Gradients in Irradiated Metals"
- TS Byun, Oak Ridge National Laboratory, "Properties of Advanced ODS Alloys and Routes for Application"
- Kevin Field, University of Michigan, "High Dose Ion Irradiate Testing of Materials"

Stuart Maloy summarized the meeting and noted that a second virtual workshop would be held on June 30, to review the outcomes of this workshop and further discuss gaps, needs, and feedback.

The second workshop on June 30, 2022, was virtual. Sue Lesica, DOE, and Stuart Maloy, PNNL, provided the opening presentations. Marc Albert presented the Electric Power Research Institute's (EPRI) "Advanced Reactor Materials Development Roadmap." Farshid Shahrokhi discussed gaps and needs for high temperature reactors.

The final section focused on the following innovative materials research categories for advanced reactor cladding, which were discussed relative to gaps and needs from the attendees.

- Innovative Metal Alloys
- Oxide Dispersion Strengthened Alloys
- Ceramics/Composites
- Innovative Testing and Characterization Methods

The workshop and webinar gave the advanced nuclear industry the opportunity to understand the focus of a potential new program on early TRL materials research, as well as to provide issues, gaps, and needs to inform the program. Stuart Maloy identified the following high-level needs from the workshops:

- An irradiation testing facility is needed in the U.S.
- Qualification of materials/alloys needs to occur in shorter timeframes.
- Prioritization of immediate needs is important to inform the program plan.
- A new materials program would need to address engineering scalability, engineering application, and joining capabilities.

IMARC PROGRAM OVERVIEW

The purpose of the proposed Innovative Materials for Advanced Reactor Cladding (IMARC) Program is to develop and test innovative cladding materials with the potential to revolutionize or transform future nuclear energy applications in the following areas:

- New alloy compositions
- Coatings to eliminate fuel-cladding chemical interaction (FCCI) and improve corrosion resistance
- Innovative microstructures with extreme radiation tolerance
- Innovative manufacturing and joining methods to produce hermetically sealed thin-walled tubing for cladding applications

- Methods to accelerate materials qualification
- Testing methods to investigate high-dose, radiation tolerance
- Mechanical testing over uniformly irradiated materials.

Materials innovations required for development of advanced reactor cladding include:

- Advanced alloy development and testing over a wide range of composition space
- Innovative manufacturing technologies for thin-walled tube development and coating techniques over long lengths of tubing (e.g., 9 feet)
- Joining technologies for thin-walled tubes of innovative new alloys
- High-dose irradiation testing techniques and small-scale testing on uniformly irradiated volumes

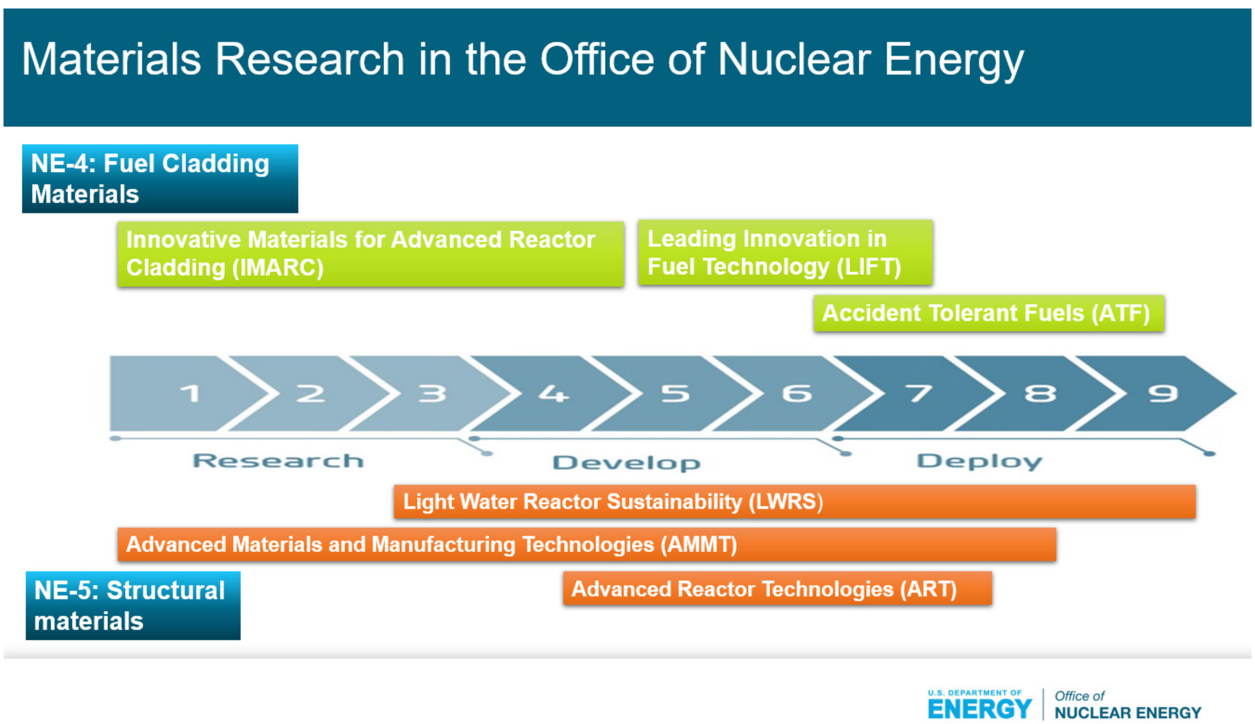


Figure 1: The graphic shows the relationship between the NE-4 and NE-5 materials programs.

Appendix A includes the agenda and attendee list for the June 15, 2022, workshop. Appendix B contains the agenda and attendee list for the June 30, 2022, webinar.

GAPS, NEEDS, AND FEEDBACK

The following information was gathered during the workshop and the webinar. It represents input from presentations, the EPRI Roadmap, and discussion notes. The information, in bullet form, will be used by DOE to determine the need, breadth, and width of the proposed IMARC Program.

General Comments

- Have any of the potential end users for reactors to supply process heat, such as Exxon, shown any interest in having a high temperature reactor at one of their facilities?
  The short answer is "no." As long as natural gas is cheap and available, the process heat users will not buy a reactor. The landscape is changing; industry is still looking for a first adopter.
- What is the effect of the recent Supreme Court ruling that limits the Environmental Protection Agency (EPA) authority to set climate standards for power plants? For nuclear power plants?
- Supply chain is limited. Manufacturers have little interest in manufacturing alloys for nuclear. In the long-term, a commercial source is needed.
  - New manufacturing methods.
  - Fabrication of wire wrap and cladding together.
  - Integration of cladding and fuel fabrication.
- The Nuclear Science User Facilities (NSUF) Library has 6,000 samples for testing. Need to develop a platform for the library to store the data.
  - Include characterization and testing data
  - Physics based, machine learning and digital twins
  - Virtual testing of components database
- Is there a need for development of reactors that use heavy metal coolants?
- It looks like the EPRI Materials Roadmap is based on specific reactor designs, structure, and coolants. Can you group certain materials together, i.e., fluoride salt corrosion on 316 and others?
  - There are issues with broad programs because we need specifics. What tests are most applicable for one material across reactor types? How can we pool resources to do testing that benefits the larger group?

IMARC Program Feedback

Feedback from the workshop and the webinar relative to the program is included below.

- A program is needed to build core competencies to support industry.

- Outside of candidate materials that will be used in the next two years, new materials would be needed in the next 5-10 years.
- This program, the Advanced Materials and Manufacturing Technologies (AMMT) program, and some of the others need to discuss possible overlaps in research and scope.
- Is there overlap with radiation damaged materials?
- There must be a material that can be developed and used in engineering applications.
- Excited to see this topic is gaining interest. For seven years I have been submitting proposals that could solve these problems and yet politics/preferences get in the way. Small Business Innovation Research (SBIR) is not a viable option. We need to minimize roadblocks that are not technical.
- IMARC should:
  - Also focus on materials that do not yet have data
  - Help on non-traditional claddings
  - Have engineering scalability, application, and joining
  - Integrate with other DOE programs
  - Support modeling and/or use Nuclear Energy Advanced Modeling and Simulation (NEAMS)

Cladding Materials

- Molten salt reactors (MSR) need cladding materials C-276, high nickel alloy. "Tack-on" cladding options, such as cold spray.
- Will IMARC cover functionally graded material systems? ODS Nickel based alloys?
- Molten chloride salt fast reactors (MCFR) will be curious whether ODS can mitigate He embrittlement at high temperatures in Ni alloys. There is not a lot of irradiation data for Ni alloys at >600C.
- How is cladding material qualified? Code is needed for structural materials. Code is not required to qualify cladding for fuel.
- Thickness of cladding is an issue. What about ceramics? Matrix composites?
- What materials need to be joined in the reactor core? Is it functional or structural joining or both?
- Cladding is needed for "heat pipe" type microreactors. Non-traditional metallic cladding.

Qualification

- We don't have a materials selection problem; we have a material qualification problem.
- GAIN needs to investigate NQA-1 data. Data is not covered under NQA-1.
- Any rapid qualification plan for pressure retaining applications should go through ASME Code, which also has Nuclear Regulatory Commission (NRC) participation.

- Need to shorten the time it takes for material qualification.

Characterization

- It may be categorized under novel characterizations, but "non-destructive" characterization techniques are also valuable.
- Irradiation creep experiments using pressurized tube geometries have been done at Oak Ridge National Laboratory's (ORNL) High Flux Isotope Reactor (HFIR) and are planned in the future on 8-9% Cr Ferritic/Martensitic (FM) steels.
- There is a need for performing round robin-studies for novel technique developments to define uncertainties and verification of data.
- Is there any plan to coordinate small scale testing of irradiated materials with somewhat similar ongoing international efforts on SSTTs led by the International Atomic Energy Agency (IAEA)?
- There have been some round-robin tests done previously using in-situ mechanical testing on ion-irradiated materials to establish a standard for mechanical testing. This can be done on neutron-irradiated materials.
- Our designers need to have better confidence that the data from these novel techniques can be qualified for use as design input for safety class components with some documented blessing from an independent oversight agency.
- Technical basis and justification for correlations of novel testing techniques is critical. This is an area where EPRI could encourage DOE' support. EPRI is working on specific tests that need technical basis. This coordinated effort should lead to a topical report or other mechanism that could then be submitted to regulators.

Materials Irradiation

- Testing facilities are needed in the United States.
- We have some good candidate material selections, and we are developing capabilities to test those. The big gap is access to fast neutron sources.
- What is the viability of ion-beam radiation to get insights on neutron radiation? Even though one-to-one mapping may not be possible, can ion-beam data provide more insights on effectiveness of advanced manufacturing vs. traditional irradiation?
- What about dose mapping of candidate materials using both neutrons and ions? While ultra-high doses are an ambition in reactor concepts, many key phenomena are already saturated by mid-dose levels, such as hardening in FM steels saturates by ~15-20 dpa. Thus, all doses will be needed, and certainly medium to relatively high-dose neutron irradiation testing is important to understand materials, in addition to fundamental studies with ions.

- An IAEA international round robin study (ASTM E691) on Ion irradiation of T91 involving 12 ion beam laboratories is underway to assess the agreement in irradiated microstructure.
- Ion irradiation can emulate void swelling in the reactor based on an article by S. Taller in Sci. Rep. 2021.
- BOR-60 testing. There are many materials available for testing. Neutron testing is a good idea.
- Use previous irradiated materials as a benchmark.
- Collaborate with testing facilities.
- Neutron irradiation is needed to prove materials.

Mechanical Testing

- Any thoughts about "meso-scale" mechanical testing compared to "micro-scale?"

Chemistry / Corrosion

- MSRs need corrosion solutions.
- Chemistry problems, coupled with modeling and simulation, should be considered.
- Helium embrittlement studies are needed.
- Plate-out of metals is important for research.
- Redox control of salt is important.

Material Development Outside of the Program

- Intermediate heat exchanger – Ceramic
- Vessel systems with 9Cr-1Mo
- Helium to molten salt

Industry, National Labs, EPRI, and Universities - Specific Needs

- Near term (1-5 years)
    - Core materials from existing alloys (e.g., F/M and Austenitic SS)
    - Challenged by limited supply chain capacity, capability, and interest

- Intermediate term (5-10 years)
    - Existing alloys with FCCI barriers
    - Incremental improvement in existing alloys
    - Commercial availability of new alloys (e.g., refractory-based metal alloys)
    - Challenged by lack of performance data and supply chain development

- Long term (10 + years)
    - ODS alloys
    - New manufacturing methods
    - Advanced fuel forms
    - Challenged by lack of performance data and limited to no existing supply chain

- Qualify new material(s) to allow for greater reliability at high temperatures
    - Alumina-forming austenitic (AFA)
    - FeCrAl ODS, SiC/SiC, tantalum

- MCFR program focused on materials test for design analysis and also leveraged for NRC licensing and qualification
    - Materials of Interest
        - Alloy 625 grade 2
        - Alloy 617
        - 316H
        - Refractory alloys
        - Ceramics (SiC, etc)
    - Engineering properties of interest
        - Creep, Fatigue, creep-fatigue, corrosion, and erosion -(550-800C)
        - Irradiation effects on mechanical properties and corrosion – (550-800C, 0-100 dpa fast spectrum)

- University and National Lab Capabilities and Testing
    - Capability for irradiated and radioactive material
    - Advanced ODS alloys and routes for application
    - Nanoscale mechanical testing
    - High dose ion irradiation

EPRI Advanced Reactor Materials Development Roadmap

The Advanced Reactor Materials Development Roadmap provides for a planned coordination of materials development and validation programs to directly address gaps to support the near-term deployment and progress on advanced non-light water reactor designs. The following information from the 2021 EPRI Materials Roadmap, presented by Marc Albert, Sr Technical Leader, Advanced Nuclear Technology, is specific to cladding and core materials.

Molten Salt Reactors

Core Support / Structural Materials	316 and Austenitic Alloys	• Proof of resistance to long-term corrosion in properly controlled salt environment • Time dependent properties for ASME code Sec III Div 5 qualification • Demonstration of performance – resistance to EAC (Environmentally Assisted Cracking) – in salt under loading • Development and demonstration of cladding (Mo rich) for protection
	Hastelloy N and variants	• Demonstration of radiation tolerance of Hast N variants (Proper understanding of chemistry -> microstructure -> properties • Development of properties for ASME code Sec III Div 5 qualification

High Temperature Gas and Gas Fast Reactors

HIGH TEMP GAS REACTOR Core Support/ Structural Materials	316 and Austenitic Alloys	• Code approval of time dependent properties – creep, creep-fatigue
	316FR	• Code qualification properties for ASME code Sec III Div 5 for 316FR including time dependent properties
	800H	• Summary Document of Properties • Support ASME code extension of properties • Develop and qualify improved weld filler metal(s)

GAS FAST REACTOR Core support	Ferritic-Martensitics	• Demonstration of adequate resistance to swelling at high dpa. • Time dependent properties for ASME code Sec III Div 5. (including development of fabrication technologies – and demonstrate properties of joints
GAS FAST REACTOR Cladding and reflector	Ceramics	• For advanced GFR – SiC-SiC, Zr_3Si need materials endurance data for these materials

Sodium Fast Reactors

Core Support Structure and Cladding	Ferritic-Martensitics	• Prove adequacy of swelling resistance at high fluence • Development of fabrication technology and proof of performance of welds

Lead-Cooled Reactors

LEAD FAST REACTOR Near core structures and cladding	Ferritic-Martensitics	• Demonstration of adequate resistance to swelling at high dpa. • Time dependent properties for ASME code Sec III Div 5. (including demonstrating properties of joints) • Demonstration of resistance to lead corrosion/development of corrosion data • Development of fabrication and effective joining methods

HIGH TEMP LEAD REACTOR Cladding	SiC-SiC	• Development of SiC-SiC structures • Demonstration of resistance to lead corrosion • Development of properties and support to code qualification

WEBINAR DISCUSSION CATEGORIES

Innovative Metal Alloys

Examples:

- Advanced F/M alloys
- Advanced austenitic alloys (e.g., alumina forming austenitics)
- Refractory metal alloys
- High entropy alloys
- Metallic glasses
- Novel microstructures (e.g., nanostructured grain size, fine precipitate distribution)
- Novel manufacturing techniques to produce thin-walled tubes
- Joining methods for thin-walled tubing
- Coatings to prevent FCCI (if needed)

Discussion:

- What is the effect of the recent SC ruling that limits EPA authority to set climate standards for power plants? For nuclear plants?
- Look at the environmental side of these materials. Also added thin-walled tube characteristics
- Will you cover functionally graded material systems?

Oxide Dispersion Strengthened Alloys

Examples:

- ODS ferritic steels (e.g., 14YWT, 12YWT)
- ODS FeCrAl (e.g., MA956, PM2000)
- ODS austenitic alloys
- Processing methods for producing thin-walled tubes
- Processing methods to form a uniform, fine and stable oxide dispersion
- Joining methods for thin-walled tubing that maintain microstructure
- Coating methods to prevent FCCI (if needed)

Discussion:

- ODS nickel-based alloys?
- ODS, with the inclusion of advanced manufacturing techniques, will make it more feasible
- Advanced manufacturing techniques allow for the change in the microstructure to leverage things that were not available in the past.

- MCFR will be curious whether ODS can mitigate the embrittlement issue at high temps in Ni alloys. There is not a lot of irradiation data for Ni alloys at >600 C.
- We need some revolutionary thinking in this area.

Ceramics/Composites

Examples:

- SiC/SiC composites
- Other ceramic/ceramic composites
- Metal matrix composites
- Processing methods to produce thin-walled tubing
- Methods to assure tubing his hermetically sealed (e.g., coating methods)
- Joining methods

No Discussion:

Innovative Testing and Characterization

Examples:

- High dose irradiation testing (e.g., ion irradiation)
- Microscale mechanical testing
- In-situ mechanical testing under irradiation
- Novel characterization techniques (e.g., X-ray measurements in situ)

Discussion:

- There is no standardized way of doing this. How can we get novel testing methods approved by NRC for use?
- It may be categorized under novel characterizations, but "non-destructive" characterization techniques are also valuable.
- Irradiation creep experiments using pressurized tube geometries have been done at the HFIR at ORNL and are planned in the future on 8-9% Cr FM sheets.
- Is there any plan to coordinate small scale testing of irradiated materials to establish a standard for mechanical testing? This can be done on neutron-irradiated materials.
- Establish an ASTM standard for these small-scale tests.
- Involve NRC early.
- Helpful coordinated push is needed from industry or DOE on this topic.
- Solid plan is needed for rapid qualification that NRC can comment on.

- NRC is looking for a concerted effort on the rapid qualification. Cladding materials would be the first step.
- Remember that nuclear fuels testing is completely different than cladding testing.
- Any rapid qualification planned for pressure retaining applications should go through American Society of Mechanical Engineers (ASME) Code, which NRC participates in.
- Any thoughts about meso-scale mechanical testing compared to micro-scale?
- Any structural items should start with the ASME code before it goes to NRC.

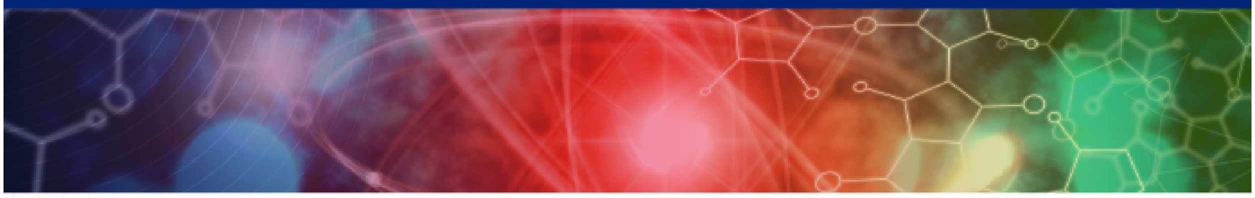
ACRONYMS

AFA	Alumina-forming austenitic
AMMT	Advanced Materials and Manufacturing Technologies
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BOR-60	Fast 60MW sodium-cooled reactor commissioned in 1969
DOE-NE	Department of Energy – Office of Nuclear Energy
DPA	Displacements Per Atom
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
FCCI	Fuel-Cladding Chemical Interaction
FeCrAl	Iron-chromium-aluminum alloy
FM	Ferritic/Martensitic steels
GAIN	Gateway for Accelerated Innovation in Nuclear
HFIR	High Flux Isotope Reactor
IAEA	International Atomic Energy Agency
IMARC	Innovative Materials for Advanced Reactor Cladding
INL	Idaho National Laboratory
LANL	Los Alamos National Laboratory
LFR	Lead Fast Reactor
MCFR	Molten Chloride Fast Reactor
MSR	Molten Salt Reactor
NEAMS	Nuclear Energy Advanced Modeling and Simulation
Ni	Nickel
NQA	Nuclear Quality Assurance
NRC	Nuclear Regulatory Commission
NSUF	Nuclear Science User Facilities
ODS	Oxide Dispersion-Strengthened Alloy
ORNL	Oak Ridge National Laboratory
PNNL	Pacific Northwest National Laboratory
SBIR	Small Business Innovation Research
SiC	Silicon Carbide
SRNL	Savannah River National Laboratory
TRL	Technology Readiness Level

REFERENCES

EPRI, "Advanced Reactor Materials Development Roadmap," M. Albert, Rev. 0, 2021

APPENDIX A: GAIN Innovative Materials Research Workshop Agenda



GAIN Innovative Materials Research Workshop

Wednesday, June 15, 2022, 1:00 p.m.-5:30 p.m.
ANS Annual Meeting, Hilton Anaheim, Anaheim, CA, Avila A Room

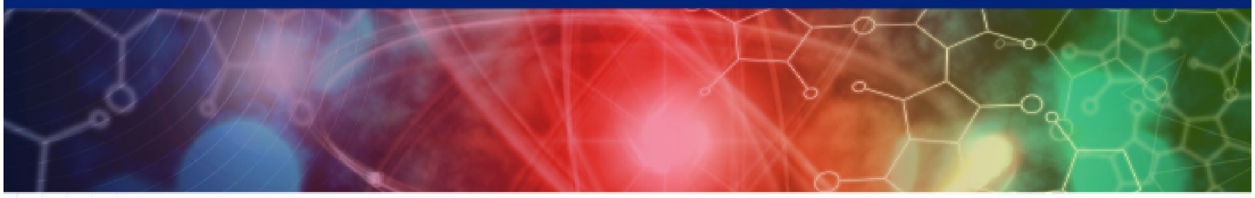
Discuss a potential new DOE program on advanced and innovative materials research for advanced reactor fuel cladding. Identify possible program objectives and gather industry input to determine priority research directions for Fiscal Year 2023.

PT	Topic	Presenter
1:00 p.m.	Welcome, Introductions, Purpose, Agenda	Lori Braase, GAIN
1:15 p.m.	DOE *Tentative New* Program Objectives	Stephen Kung, DOE
1:30 p.m.	Innovative Cladding Materials for Advanced Reactors / Q&A	Stuart Maloy, PNNL
Advanced Nuclear Industry Gaps and Needs (10 Minute Presentations)		Lori Braase, GAIN
2:00 p.m.	Aurora Reactor	Ryan Webster, Oklo
2:15 p.m.	Westinghouse Lead Fast Reactor	Emre Tatli, Westinghouse
2:30 p.m.	Molten Chloride Fast Reactor (MCFR)	Matt Wargon, TerraPower
2:45 p.m.	*Discussion*	Stuart Maloy, PNNL
National Laboratory Capability and Methods (15 Minute Presentations)		
3:00 p.m.	Summary of the "Capability Needs for Irradiated and Radioactive Materials Research Study"	Simon Pimblott, INL/NSUF
3:20 p.m.	Probing Nanoscale Damage Gradients in Irradiated Metals	Siddhartha Pathak, Iowa State
3:40 p.m.	Properties of Advanced ODS Alloys and Routes for Application	TS Byun, ORNL
4:00 p.m.	High Dose Ion Irradiation Testing of Materials	Kevin Field, U of Michigan
4:20 p.m.	Gaps and Needs Discussion	
5:00 p.m.	Identify Path Forward and Actions	Stuart Maloy, PNNL
5:30 p.m.	Adjourn	

Registration List: June 15, 2022

First Name	Last Name	Organization
Arunodaya	Bhattacharya	Oak Ridge National Laboratory
Lori	Braase	Idaho National Laboratory
Shirmir	Branch	Pacific Northwest Laboratory
Thak Sang	Byun	Oak Ridge National Laboratory
Hangbok	Choi	General Atomics Electromagnetic Systems
Ian	Clark	Missouri University of Science & Technology
Adam	Deatherage	AMS Corporation
Juliana	Duarte	Virginia Tech
Ben	Eftink	Los Alamos National Laboratory
Jess	Gehin	Idaho National Laboratory
Hash	Hashemian	AMS Corporation
Tony	Hill	Natura Resources
John	Jackson	Idaho National Laboratory
Ericmoore	Jossou	Brookhaven National Laboratory
Veda	Joynt	University of Michigan
Hongdeok	Kim	Korea Hydro & Nuclear Power Co. Central Research Institute
Stephen	Kung	DOE-NE
Stephen	Lam	University of Mass Lowell
Jung-Kun	Lee	University of Pittsburgh
Christina	Leggett	Booz Allen Hamilton/ARPA-E
Susan	Lesica	DOE-NE
MEIMEI	LI	Argonne National Laboratory
Stuart	Maloy	Pacific Northwest National Laboratory
Corey	McDaniel	Idaho National Laboratory
Yinbin	Miao	Argonne National Laboratory
Terrance	Nolan	NNL
William	Nutt	Pacific Northwest National Laboratory
Sid	Pathak	Iowa State University
Mark	Patterson	Kratos SRE
Allyson	Pearce	Analysis and Measurement Services, Corporation
Simon	Pimblott	Idaho National Laboratory
Holly	Powell	Idaho National Laboratory (GAIN)
Steve	Rhyne	NuGen
Desire	Rivera	University of Puerto Rico
Tarik	Saleh	Los Alamos National Laboratory
Jenifer	Shafer	ARPA-E
Farshid	Shahrokhi	Framatome Inc.
Guinevere	Shaw	DOE Office of Science
Joshua	Silverstein	Pacific Northwest National Laboratory
John	Strumpell	Framatome Inc.
Breanna	Vestal	University of Tennessee
Yong	Wang	Los Alamos National Laboratory
Matt	Wargon	TerraPower
Ryan	Webster	Oklo
Sam	Wurzel	ARPA-E

APPENDIX B: GAIN Innovative Materials Research Webinar Agenda



GAIN Innovative Materials Research Webinar

Thursday, June 30, 2022, 10:00 a.m. - 1:00 p.m. (*Mountain Daylight Time*)

Purpose:

- Discuss a potential new DOE Program on innovative materials research for fuel cladding for advanced reactors.
- Review the results of the GAIN Innovative Materials Research Workshop help on June 15, 2022.
- Inform program objectives and gather supplier, developer, university researcher, and national laboratory input to determine priority research directions.

MDT	Topic	Presenter
10:00 a.m.	Welcome, Purpose, Agenda	Holly Powell, GAIN
10:10 a.m.	DOE *Tentative New* Program Objectives / Q&A	Sue Lesica, DOE
10:30 a.m.	Innovative Cladding Materials for Advanced Reactors / Q&A	Stuart Maloy, PNNL
Advanced Nuclear Industry Gaps and Needs		
11:00 a.m.	Advanced Reactor Materials Development Roadmap	Marc Albert, EPRI
11:15 a.m.	High Temperature Reactors	Farshid Shahrokhi, Framatome
11:30 a.m.	*Review Feedback from GAIN Innovative Materials Workshop at ANS on June 15, 2022*	Stuart Maloy, PNNL
Innovative Materials Research Categories for Advanced Reactor Cladding Focused Discussion on Gaps and Needs		Stuart Maloy, PNNL
11:45 a.m.	Innovative Metal Alloys	
12:00 p.m.	Oxide Dispersion Strengthened Alloys	
12:15 p.m.	Ceramics/Composites	
12:30 p.m.	Innovative Testing and Characterization Methods	
12:45 p.m.	Identify Path Forward and Actions	
1:00 p.m.	Adjourn	

Registration List – June 30, 2022

Name	Organization
Alex Cozzi	SRNL
Aashish Rohatgi	PNNL
Alex Hashemian	AMS Corp
Ali Zbib	PNNL
Andrew Nelson	ORNL
Andy Casella	PNNL
Antonio Rigato	PNNL
Arthur Motta	Portland State University
Austin Young	NRC
Ayoub Soulami	PNNL
Brendan Dsouza	Terrestrial Energy
Brent Heuser	Illinois State University
Brian Jaques	Boise State University
Bruce Pint	ORNL
Caleb Massey	ORNL
Carl Perez	Elysium
Charles Boohaker	Southern Co
Cheng Sun	INL
Cheng Xu	TerraPower
Colby Jensen	INL
Dalong Zhang	PNNL
Daniel Clark	DOE, Office of Science
Daniel LaBrier	Idaho State University
DannyEdwards	PNNL
David Andersson	LANL
David Hoelzer	ORNL
Dean Finlayson	Terrestrial Energy
Edgar Buck	PNNL
Elizabeth Sooby	University of Texas, San Antonio
Farshid Shahrokhi	Framatome
Francis Tsang	NuScale Power
Gary Was	University of Michigan
Grace Burke	ORNL
Hash Hashemian	AMS Corp
Holly Powell	INL
Ingrid Burgeson	PNNL
Isabella McDonald	Terrestrial Energy
Isabella Van rooyen	PNNL
Iver Anderson	Ames Lab
James Stouch	PCC-York
James Stubbins	University of Illinois
Jason Clobes	Naval Nuclear Laboratory
Jason Schulthess	INL
Javier Romero	TerraPower
Jeff Halfinger	CTP-USA
Jeff Poehler	NRC
Jens Darsell	PNNL
Jesse Carlson	NRC

John Jackson	INL
Jorge F. dos Santos	PNNL
Joshua Silverstein	PNNL
Ken Kimball	Naval Nuclear Laboratory
Ken Ross	PNNL
Kevin Field	University of Michigan
Khadija Mahbuba	North Carolina State University
Kurt Harris	Flibe
Lei Li	PNNL
Lori Braase	INL
Mahmoud Hawary	North Carolina State University
Marc Albert	EPRI
Margaret Audrain	NRC
Mark Patterson	Kratos SRE
Matthew Hiser	NRC
Meimie Li	ANL
Michael Ickes	Westinghouse
Nachiketh Chandran	NRC
Nicolas Woolstenhulme	INL
Osman Anderoglu	University of New Mexico
Raj Iyengar	NRC
Ramprashad Prabhakaran	PNNL
Rob Tregoning	NRC
Robert Alicandri	Terrestrial Energy
Robert Armstrong	INL
Robert Armstrong	Terrestrial Energy
Robert Davis	NRC
Robert Hayes	North Carolina State University
Seann Bishop	Naval Nuclear Laboratory
SeungMin Lee	PNNL
Sheyene Gerardi	
Sid Pathak	IA State University
Simon Pimblott	INL
Sophie Hitson	NRC
Stephen Kung	DOE-Office of Nuclear Energy
Stephen Rhyne	
Stuart Maloy	PNNL
Susan Lesica	DOE- Office of Nuclear Energy
Tanvi Ajantiwalay	PNNL
Teresa Krynicki	INL
Thak Sang Byun	ORNL
Thomas Hartmann	PNNL
Ting-Leung Sham	INL
Tom Angeliu	
Tuhin Muhkerjee	Portland State University
Weiju Ren	ORNL
Wendy Reed	NRC
Xiao-YingYu	ORNL
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