INL/CON-24-78164-Revision-0

# The Glenn T. Seaborg Institute at Idaho National Laboratory

May 2024

Changing the World's Energy Future

Rory Kennedy

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**May 2024**

**Idaho National Laboratory**
**Idaho Falls, Idaho 83415**

**http://www.inl.gov**

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GLENN T. SEABORG INSTITUTE
Idaho National Laboratory

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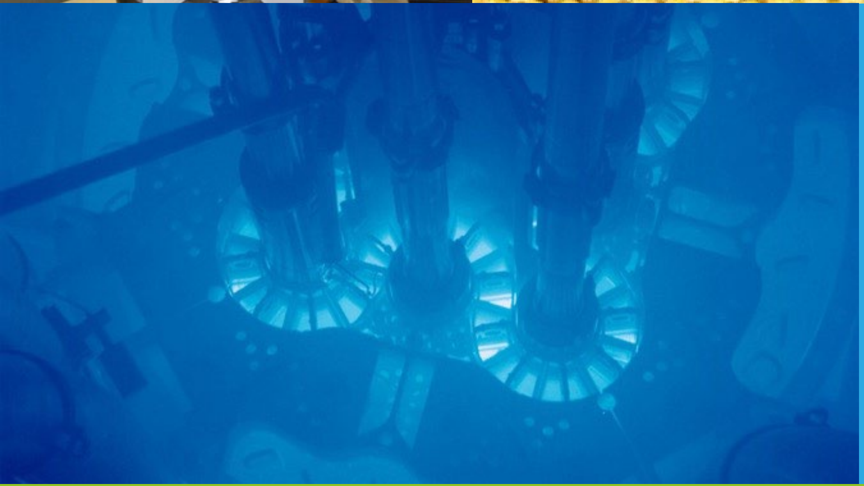
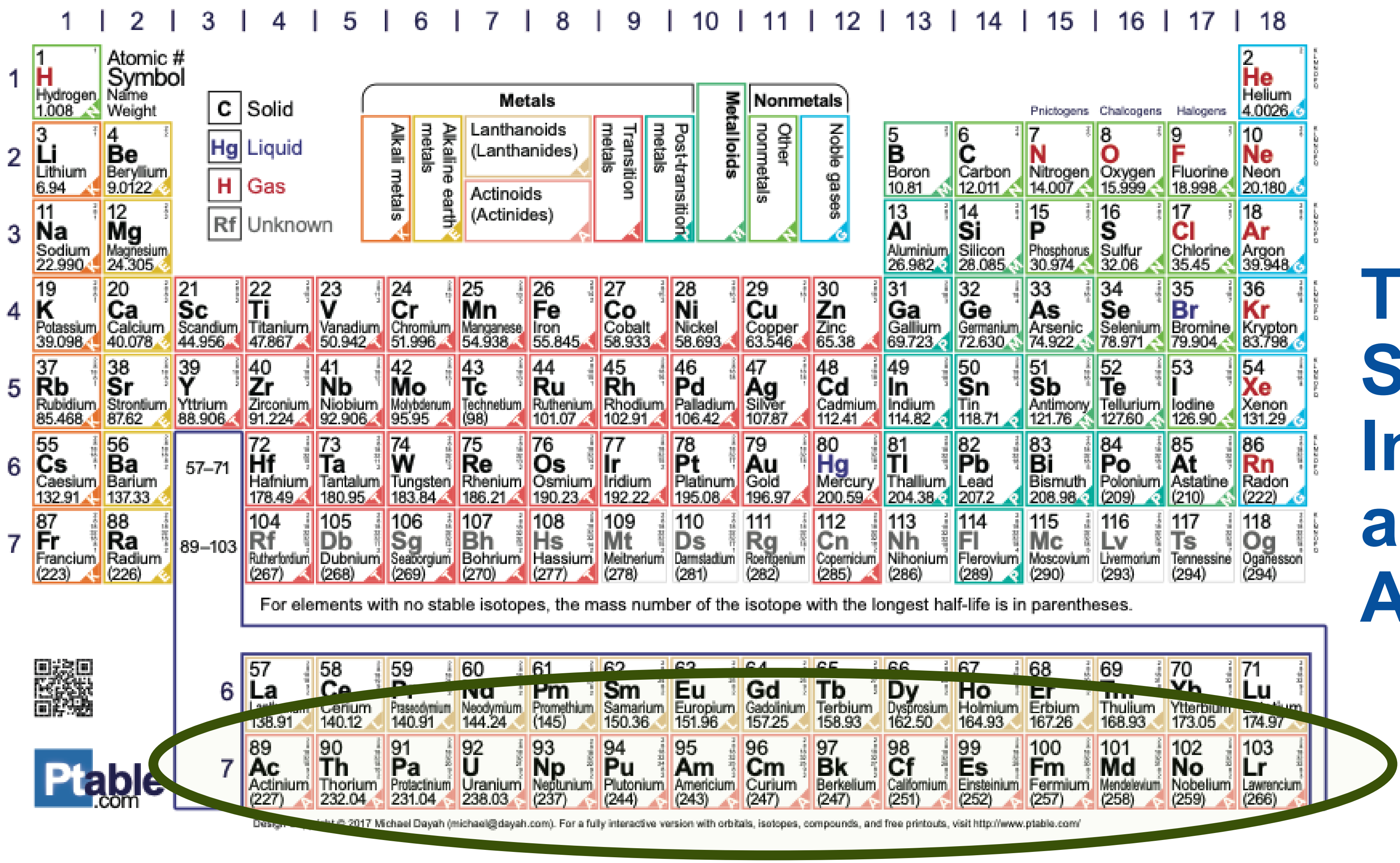


# The Glenn T. Seaborg Institute at Idaho National Laboratory

# PERIODIC TABLE OF ELEMENTS

GLENN T. SEABORG INSTITUTE
Idaho National Laboratory




**The Glenn T. Seaborg Institutes/Center are all about the Actinides!**

# The Glenn T. Seaborg Institutes/Center

**The original and ongoing purpose of the institutes is two-fold:**

1) **Education and training to meet the projected needs of the diverse and multidisciplinary field of actinide science**
2) **Performing actinide research to maintain US knowledge and expertise in the production, processing, purification, characterization, analysis, applications, and disposal of actinides.**

**Both applied and fundamental research are essential components of the institutes in relation to both defense and energy.**

Lawrence Livermore National Laboratory Glenn T. Seaborg Institute (1991)

Los Alamos National Laboratory Glenn T. Seaborg Institute (1997)

Lawrence Berkeley National Laboratory Glenn T. Seaborg Center (1999)

Idaho National Laboratory Glenn T. Seaborg Institute (2017)

Oak Ridge National Laboratory Glenn T. Seaborg Institute (2023)

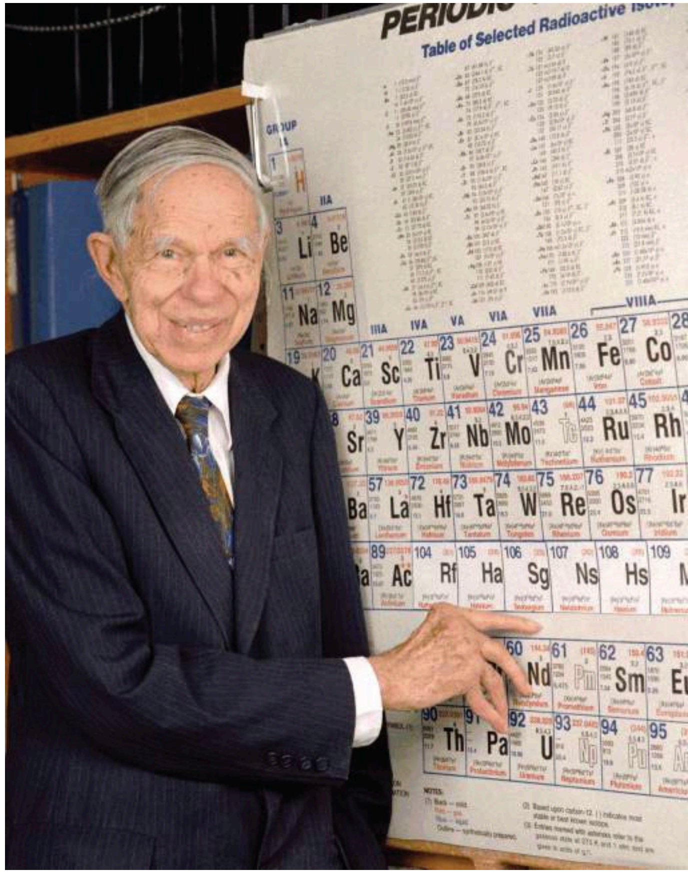


Photo provided by Ernest Orlando Lawrence Berkeley National Laboratory

# The INL Glenn T. Seaborg Institute

## *Vision*

- Enhance U.S. pre-eminence in the science of the chemical, physical, nuclear, and metallurgical properties of the transactinium elements.

## *Mission*

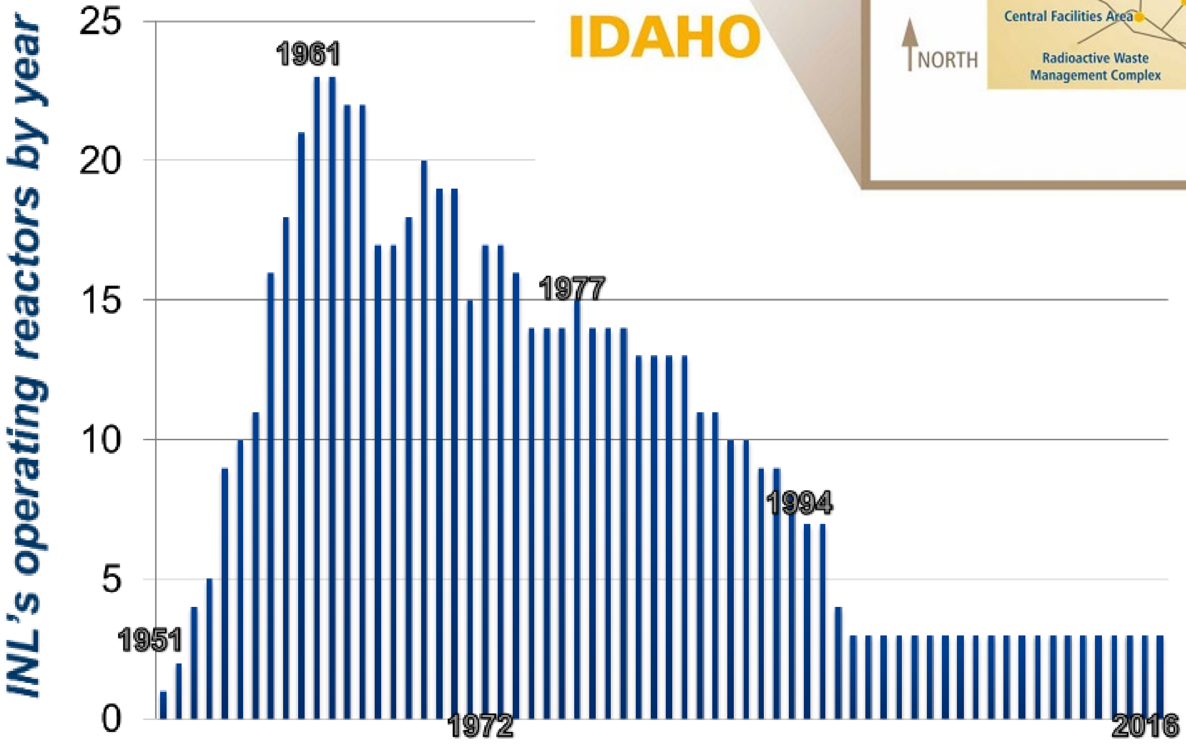
- Provide scientists and engineers with the opportunities and tools to develop their knowledge and expertise in support of the mission of the US Department of Energy and Idaho National Laboratory.

## *Goals*

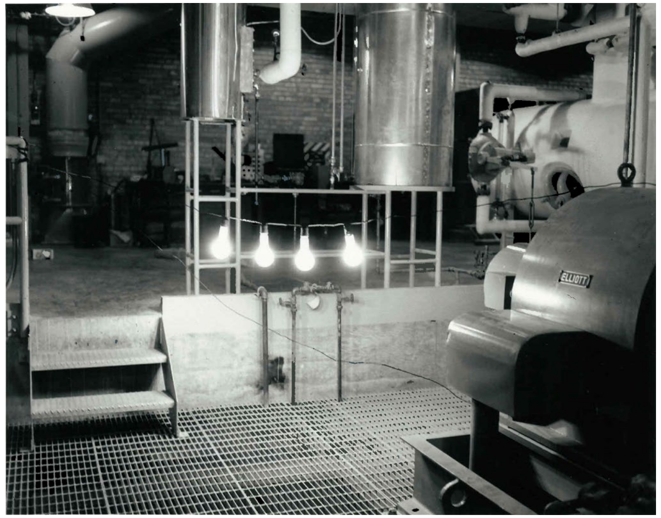
- Produce the highest quality research results that will impact and increase understanding of actinide bearing systems important to DOE and other national priorities.
- Produce the highest quality scientists and engineers that will fill the national needs in national security, energy and environmental policy, and cutting edge science.
- Bring INL to primacy in cutting edge actinide science.

# INL History

- **The INL began in 1949 as the National Reactor Testing Station**
  - ~900 square miles of available federal land, far removed from any city
  - 52 reactors have been built and operated at the INL
  - Aggressive experiments could be conducted in which the outcome was not all that predictable

# INL History



LOFT

S5G

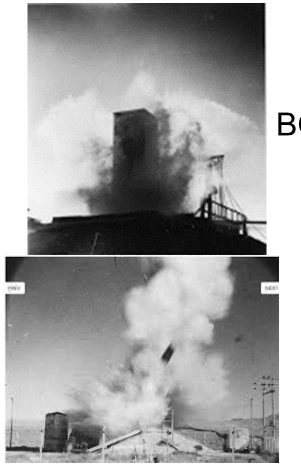
EBR-I

MTR

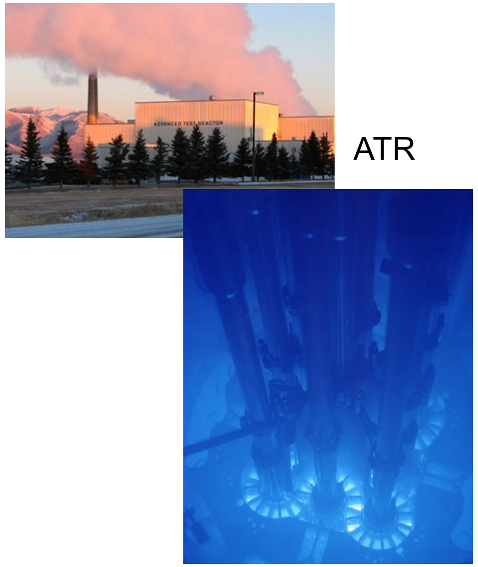
TREAT

Aircraft Nuclear Propulsion

BORAX



EBR-II

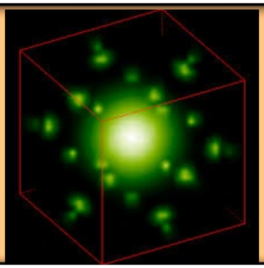


ATR

# INL Glenn T. Seaborg Institute Focus Areas

## Topical areas of interest

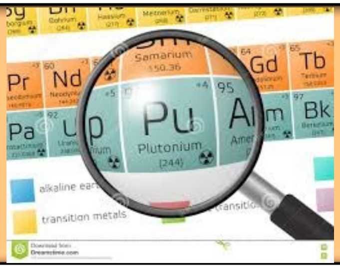
**Solid-State Actinide Chemistry and Physics**



Lead: Krzysztof Gofryk

- Fundamental actinide properties
- Structure/property (electronic, magnetic, thermal) relations
- Nuclear fuels
- Actinide quantum criticality
- f-electron interactions, electron correlations, computational studies
- New phases
- Defect effects

**Actinide Forensics and Standards**




Lead: Matt Watrous

- Isotope Separation
- Isotope Production
- Forensic Analytical Chemistry/Separations
- Gamma Spectroscopy
- Monitoring and Analyzing Multi Modal Signal Streams
- Surrogate Nuclear Debris

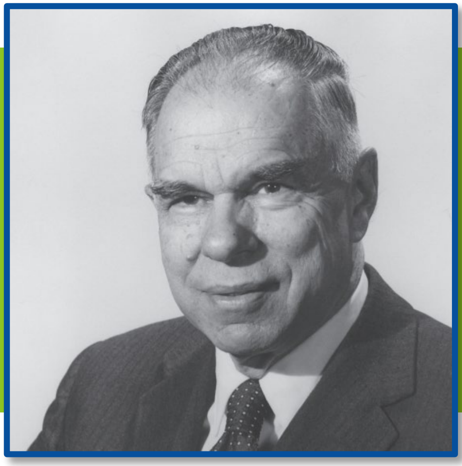
**Actinide Solution Chemistry and Separations**

Lead: Don Wood

- Structure and dynamic properties of actinides in non-aqueous solvents
- Separations chemistry and kinetics for advanced nuclear fuel cycles
- Radiation effects on the chemical behavior of actinides in solution.
- Innovative industrial and medical applications of actinides.
- Innovative and advanced ligand design for complexation of the actinides.

Annual Call

# INL Distinguished Postdoctoral Associate Programs



***Glenn T. Seaborg***
Actinide Science

***Russell L. Heath***
Nuclear energy, critical infrastructure protection, and clean energy deployment

***Deslonde de Boisblanc***
Reactor design, physics, operations, modeling, and safety

Active mentoring | Access to facilities | Discretionary research funds

Competitive salary and benefits | Programmatic research related funds

High expectations | Two-year-plus assignment term

# Distinguished postdoc application process

- **Submit application package (open from 9/1 - 12/31)**
  - Letter of Interest
  - Curriculum Vitae
  - Original Research Proposal
  - Letters of Reference/Recommendation
  - Graduate Work Abstract
  - Transcripts
- **Application package reviewed by Selection Committee**
  - If acceptable, invited for phone (Teams) interview
  - If phone/Teams interview acceptable, invited for on-site interview
    - Graduate work presentation
    - Research proposal presentation
    - Meet with technical leads and INL management
    - Tour INL facilities
- **Decision is made and applicant notified**

# *Role of Uranium Carbide Impurities in the Self Organization of Fission Gas Bubble Superlattice in Uranium-Molybdenum Nuclear Fuel*

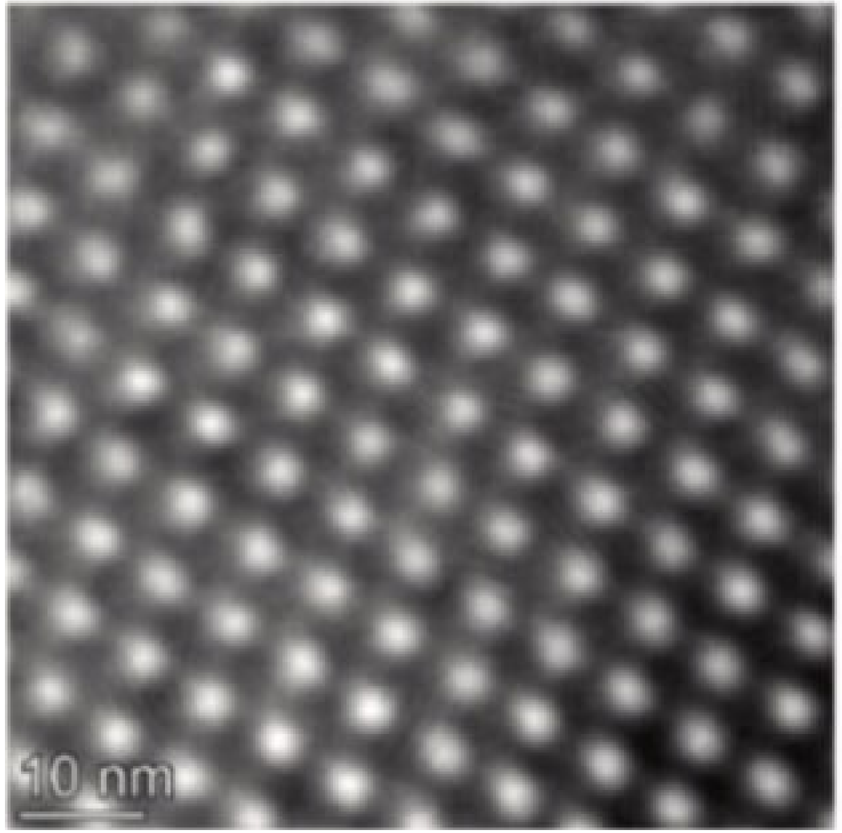

Charlyne Smith

- **Uranium-Molybdenum (U-Mo) alloys are prime candidate nuclear fuels for the conversion of high performance research and test reactors from high enriched uranium (HEU) to low enriched uranium (LEU).**

- **Unique characteristic of neutron irradiated U-Mo fuel is the formation of a highly ordered complex defect structure known as the fission gas bubble superlattice (GBS).**

- **Uranium Carbide (UC) inclusions are most common impurity found from fabrication of U-Mo fuels arising from feedstock and/or casting.**

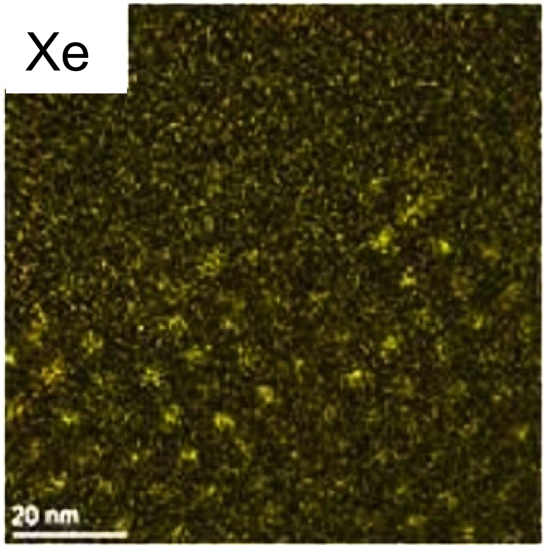
- **UC inclusions can affect the microstructural evolution and irradiation performance U-Mo fuels.**

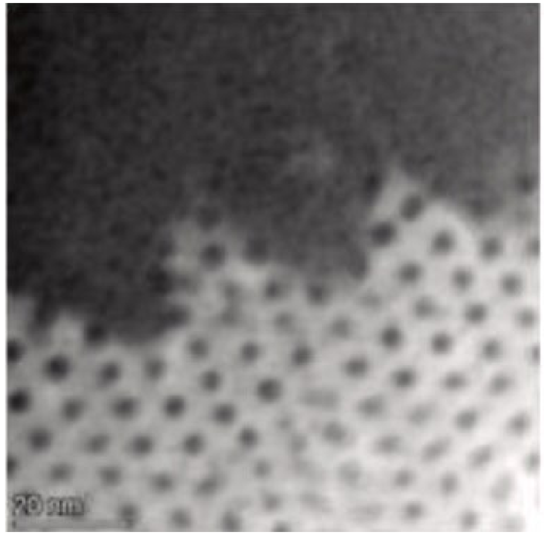



C. Smith, K. Bawane, J. Gan, D. Keiser, D. Salvato, M. Bachhav, J.-F Jue,
*J. Nucl. Mater.* 575, 154474 (2023)

# Fission Gas Bubble Superlattice (GBS) in U-Mo Fuel

- **Stores high energy fission gasses (Xe and Kr) thus delaying the release of these fission gasses that could lead to fuel swelling and degrade thermal conductivity and the neutron economy.**
- **Typically, superlattices of this type that form in metals are isomorphic with their host material. Not so in U-Mo alloy where the alloy host matrix is bcc and the GBS is fcc.**
- **The organized fission gas bubbles are 3-4 nm in diameter.**
- **At high fission densities, the increased fission gas production causes the GBS to become supersaturated leading to its collapse and release of the stored fission gasses that later agglomerate into micron sized pores.**
- **The formation and collapse mechanisms of the GBSs are not well understood.**

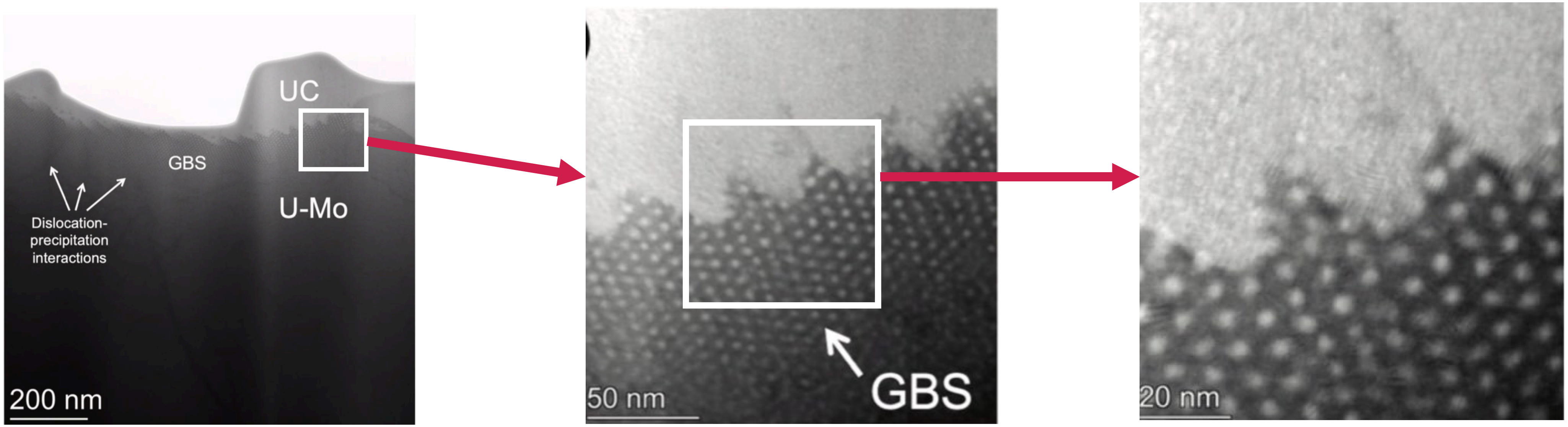



C. Smith, K. Bawane, J. Gan, D. Keiser, D. Salvato, M. Bachhav, J.-F Jue,
*J. Nucl. Mater.* 575, 154474 (2023)

# Fission Gas Bubble Superlattice (GBS) in U-Mo Fuel

- **U-10Mo is bcc (a=0.3412 nm)**
- **UC is fcc (a=0.4960 nm)**
- **GBS formation appears as directional from interface to U-Mo grain interior.**
- **Wavy periodicity at interface suggestive of concentration wave mechanism**
- **Both phases oriented near the ⟨110⟩ symmetry equivalent lattice directions (zone axes).**




C. Smith, K. Bawane, J. Gan, D. Keiser, D. Salvato, M. Bachhav, J.-F Jue,
*J. Nucl. Mater.* 575, 154474 (2023)

# Understanding the role of Americium (Am) in Used Nuclear Fuel (UNF) extraction flowsheets

Amy Kynman

- Although +3 is the dominant oxidation state for americium, resolving the radiation-induced redox chemistry of americium complexes is important for the long-term management of used nuclear fuel (UNF), particularly under the process conditions of high nitric acid concentrations and elevated temperatures.

- For example, what function does the elusive Am(IV) play in the reduction and disproportionation of Am(V)?
  - $2AmO_2^+ + 4H_{aq}^+ \rightarrow AmO_2^{2+} + Am^{4+} + 2H_2O$
  - $AmO_2^+ + Am^{4+} \rightarrow AmO_2^{2+} + Am^{3+}$
  - $2Am^{4+} + 2H_2O \rightarrow Am^{3+} + AmO_2^+ + 4H_{aq}^+$

- Studies to uncover of the formation and stabilization of Am(IV) is of interest both for practical reasons and to increase our knowledge of f-element properties.

A. E. Kynman, T. S. Grimes, S. P. Mezyk, B. Layne, A. R. Cook, B. M. Rotermund and G. P. Horne, **2024,** Manuscript under review.

# Generation and Study of Am(IV) by Temperature-Controlled Electron Pulse Radiolysis

- In collaboration with *Brookhaven National Laboratory,* electron pulse radiolysis and transient absorption spectroscopy techniques were employed to generate $NO_3^{\bullet}$ radical, observe the growth and decay of tetravalent Am(IV) in nitric acid for the first time (Fig. 1A), conduct the first ever temperature dependent study of an actinide in solution (Fig. 1B), and from that determine the associated reaction kinetics for the reaction:

$$Am^{3+} + NO_3^{\bullet} \rightarrow Am^{4+} + NO_3^{-}$$

- The transient Am(IV) species was found to have a lifetime of ~16 microseconds, sufficiently long-lived to play a critical mechanistic role in UNF reprocessing systems.

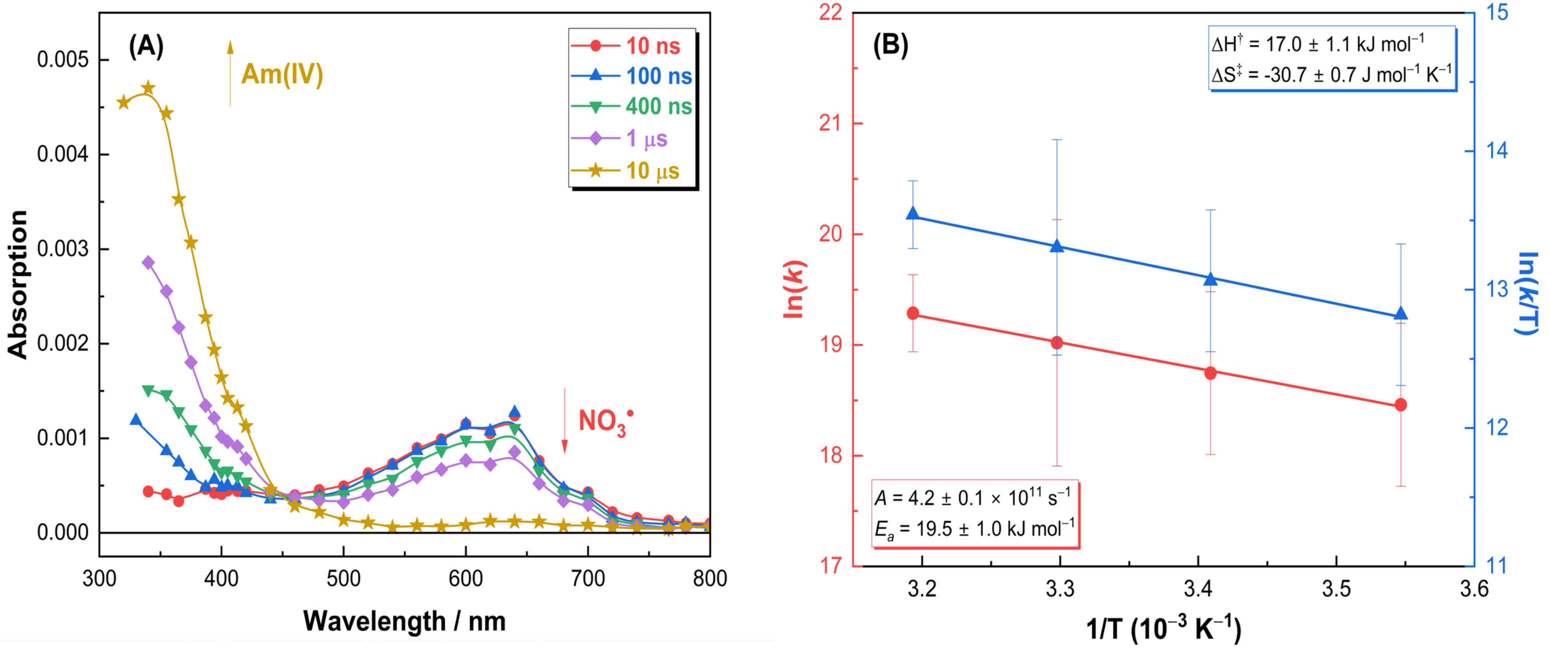



**Fig. 1. (A)** Dose normalized transient absorption spectra from the electron pulse irradiation of 2.08 mM Am(III) in aerated 6 M nitric acid at 21 ± 1 °C for several time slices after the electron pulse. **(B)** Combined Arrhenius and Eyring plots utilizing second-order rate coefficient ($k$) data from the reaction of Am(III) with $NO_3^{\bullet}$ at 8, 22, 30, and 40 ± 1 °C, where T is absolute temperature, $E_a$ is activation energy, $A$ is a pre-exponential factor, and ΔH† and ΔS‡ are the enthalpy and entropy of activation, respectively.

A. E. Kynman, T. S. Grimes, S. P. Mezyk, B. Layne, A. R. Cook, B. M. Rotermund and G. P. Horne, **2024,** Manuscript under review.

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