



The Glenn T. Seaborg Institute at Idaho National Laboratory

May 2024

Changing the World's Energy Future

Rory Kennedy



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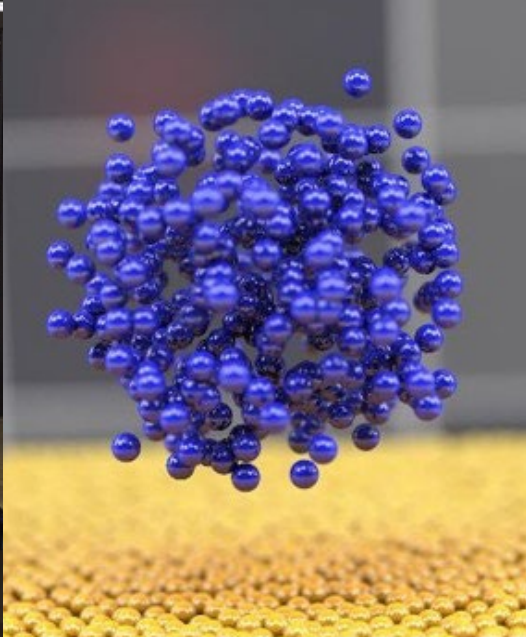
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May 2024

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

<http://www.inl.gov>

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PERIODIC TABLE OF ELEMENTS

GLENN T.
SEABORG
INSTITUTE

Idaho National Laboratory

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
1	<div>1 H Hydrogen 1.008</div>	<div>Atomic # Symbol Name Weight</div> <div><div>C Solid</div><div>Hg Liquid</div><div>H Gas</div><div>Rf Unknown</div></div>																<div>2 He Helium 4.0026</div>	
2	<div>3 Li Lithium 6.94</div>	<div>4 Be Beryllium 9.0122</div>																	<div>10 Ne Neon 20.180</div>
3	<div>11 Na Sodium 22.990</div>	<div>12 Mg Magnesium 24.305</div>																	<div>18 Ar Argon 39.948</div>
4	<div>19 K Potassium 39.098</div>	<div>20 Ca Calcium 40.078</div>	<div>21 Sc Scandium 44.956</div>	<div>22 Ti Titanium 47.867</div>	<div>23 V Vanadium 50.942</div>	<div>24 Cr Chromium 51.996</div>	<div>25 Mn Manganese 54.938</div>	<div>26 Fe Iron 55.845</div>	<div>27 Co Cobalt 58.933</div>	<div>28 Ni Nickel 58.693</div>	<div>29 Cu Copper 63.546</div>	<div>30 Zn Zinc 65.38</div>	<div>31 Ga Gallium 69.723</div>	<div>32 Ge Germanium 72.630</div>	<div>33 As Arsenic 74.922</div>	<div>34 Se Selenium 78.971</div>	<div>35 Br Bromine 79.904</div>	<div>36 Kr Krypton 83.798</div>	
5	<div>37 Rb Rubidium 85.468</div>	<div>38 Sr Strontium 87.62</div>	<div>39 Y Yttrium 88.906</div>	<div>40 Zr Zirconium 91.224</div>	<div>41 Nb Niobium 92.906</div>	<div>42 Mo Molybdenum 95.95</div>	<div>43 Tc Technetium (98)</div>	<div>44 Ru Ruthenium 101.07</div>	<div>45 Rh Rhodium 102.91</div>	<div>46 Pd Palladium 106.42</div>	<div>47 Ag Silver 107.87</div>	<div>48 Cd Cadmium 112.41</div>	<div>49 In Indium 114.82</div>	<div>50 Sn Tin 118.71</div>	<div>51 Sb Antimony 121.76</div>	<div>52 Te Tellurium 127.60</div>	<div>53 I Iodine 126.90</div>	<div>54 Xe Xenon 131.29</div>	
6	<div>55 Cs Caesium 132.91</div>	<div>56 Ba Barium 137.33</div>	<div>57–71</div>	<div>72 Hf Hafnium 178.49</div>	<div>73 Ta Tantalum 180.95</div>	<div>74 W Tungsten 183.84</div>	<div>75 Re Rhenium 186.21</div>	<div>76 Os Osmium 190.23</div>	<div>77 Ir Iridium 192.22</div>	<div>78 Pt Platinum 195.08</div>	<div>79 Au Gold 196.97</div>	<div>80 Hg Mercury 200.59</div>	<div>81 Tl Thallium 204.38</div>	<div>82 Pb Lead 207.2</div>	<div>83 Bi Bismuth 208.98</div>	<div>84 Po Polonium (209)</div>	<div>85 At Astatine (210)</div>	<div>86 Rn Radon (222)</div>	
7	<div>87 Fr Francium (223)</div>	<div>88 Ra Radium (226)</div>	<div>89–103</div>	<div>104 Rf Rutherfordium (267)</div>	<div>105 Db Dubnium (268)</div>	<div>106 Sg Seaborgium (269)</div>	<div>107 Bh Bohrium (270)</div>	<div>108 Hs Hassium (277)</div>	<div>109 Mt Meitnerium (278)</div>	<div>110 Ds Darmstadtium (281)</div>	<div>111 Rg Roentgenium (282)</div>	<div>112 Cn Copernicium (285)</div>	<div>113 Nh Nihonium (286)</div>	<div>114 Fl Flerovium (289)</div>	<div>115 Mc Moscovium (290)</div>	<div>116 Lv Livermorium (293)</div>	<div>117 Ts Tennessine (294)</div>	<div>118 Og Oganesson (294)</div>	

For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.



Ptable.com

Design © 2017 Michael Dayah (michael@dayah.com). For a fully interactive version with orbitals, isotopes, compounds, and free printouts, visit <http://www.ptable.com/>

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)

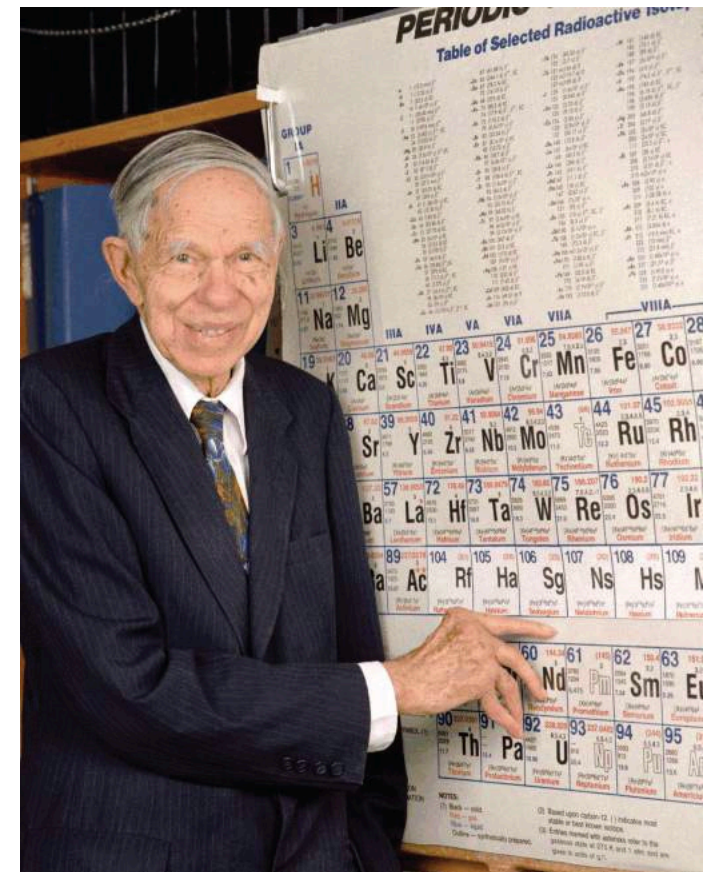


Photo provided by Ernest Orlando Lawrence
Berkeley National Laboratory

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

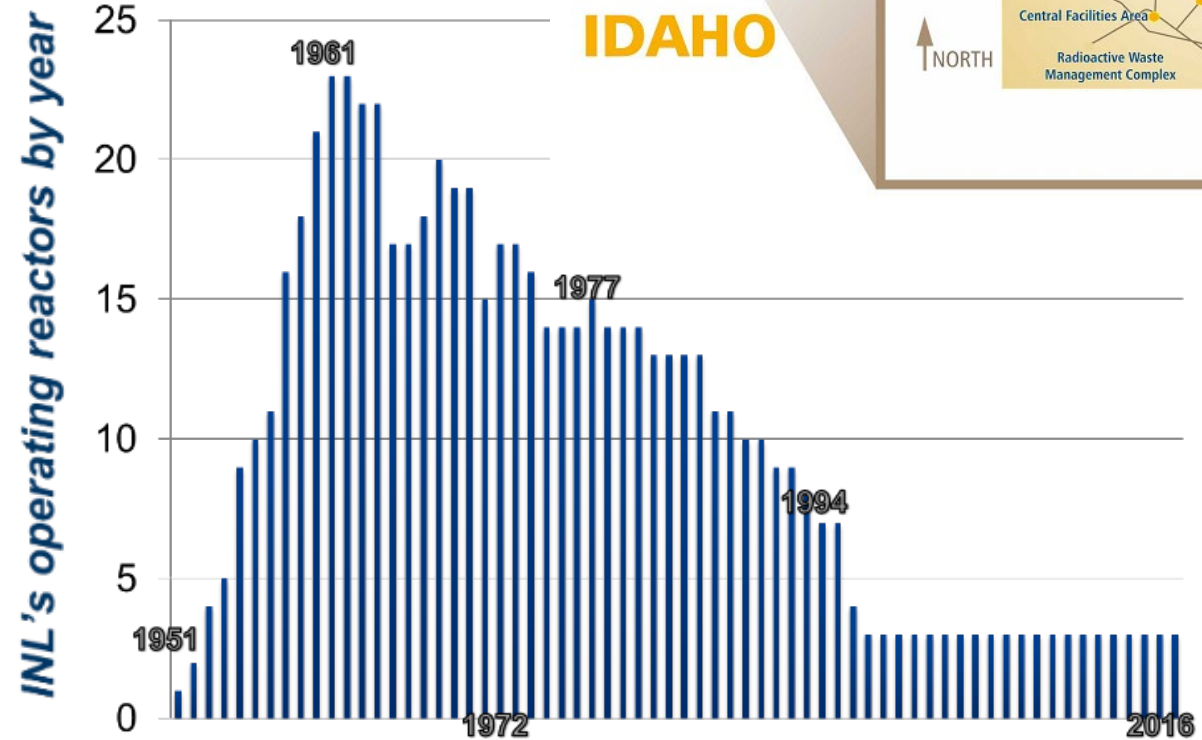
- Provide scientists and engineers with the opportunities and tools to develop their knowledge and expertise in support of the mission of the US Department of Energy and Idaho National Laboratory.

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



IDAHO



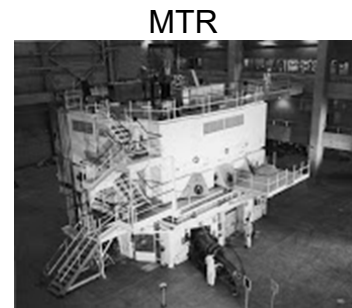
INL History



LOFT



S5G



MTR



BORAX



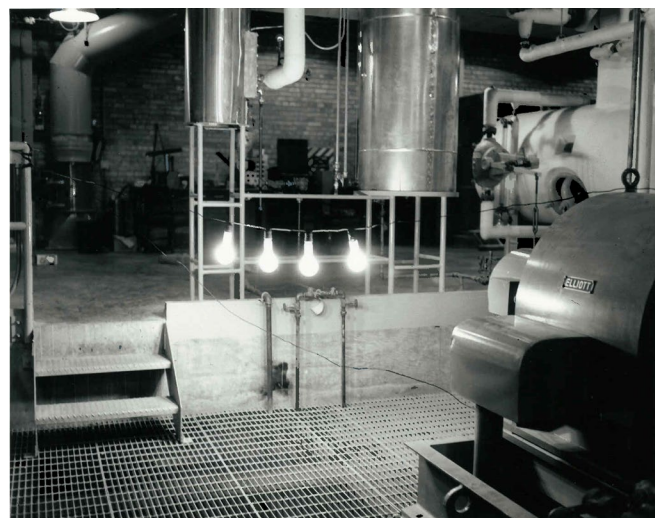
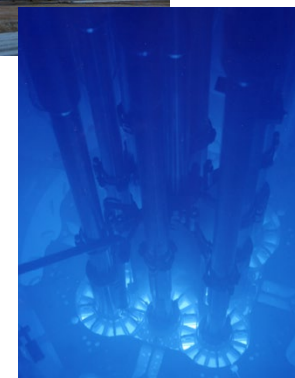
EBR-II



TREAT



ATR



EBR-I



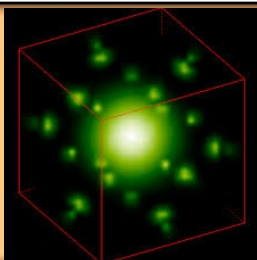
Aircraft Nuclear Propulsion

INL Glenn T. Seaborg Institute

Focus Areas

Topical areas of interest

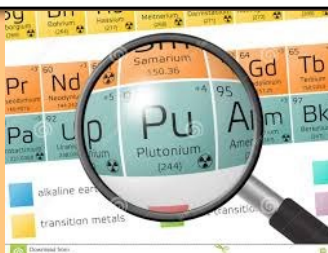
**Solid-State
Actinide
Chemistry
and Physics**



**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

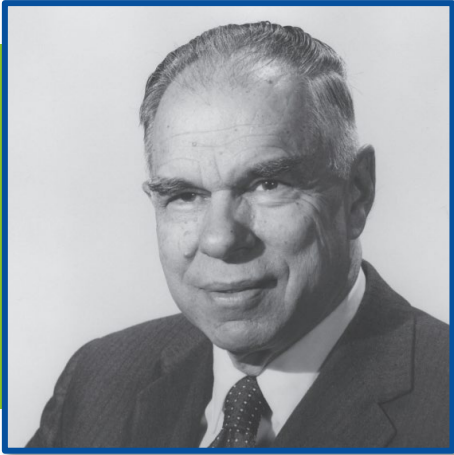
**Actinide
Solution
Chemistry
and
Separations**



**Lead:
Don
Wood**

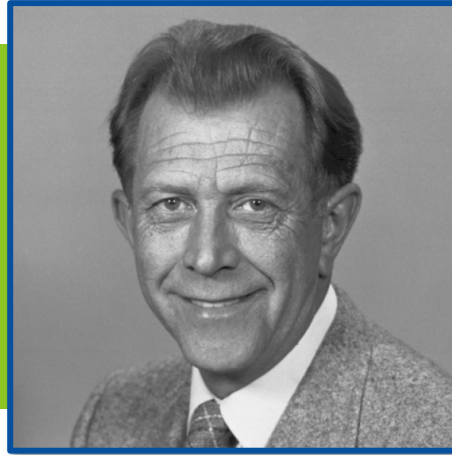
Structure and dynamic properties of actinides in non-aqueous solvents
Separations chemistry and kinetics for advanced nuclear fuel cycles
Radiation effects on the chemical behavior of actinides in solution.
Innovative industrial and medical applications of actinides.
Innovative and advanced ligand design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

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

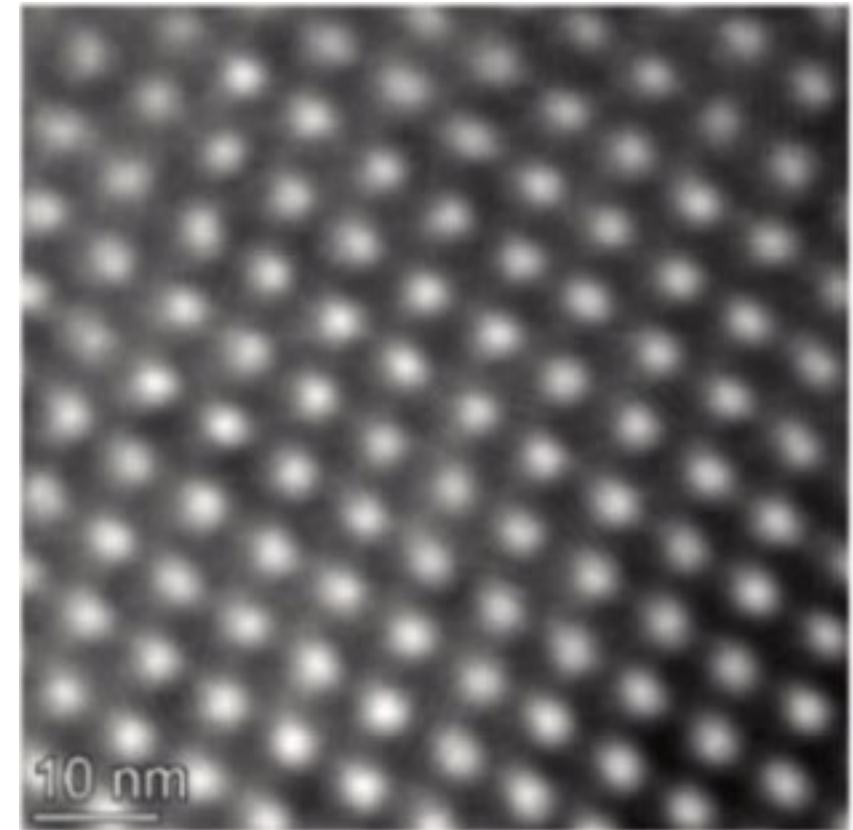
- **Submit application package (open from 9/1 - 12/31)**
 - Letter of Interest
 - Curriculum Vitae
 - Original Research Proposal
 - Letters of Reference/Recommendation
 - Graduate Work Abstract
 - Transcripts
- **Application package reviewed by Selection Committee**
 - If acceptable, invited for phone (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

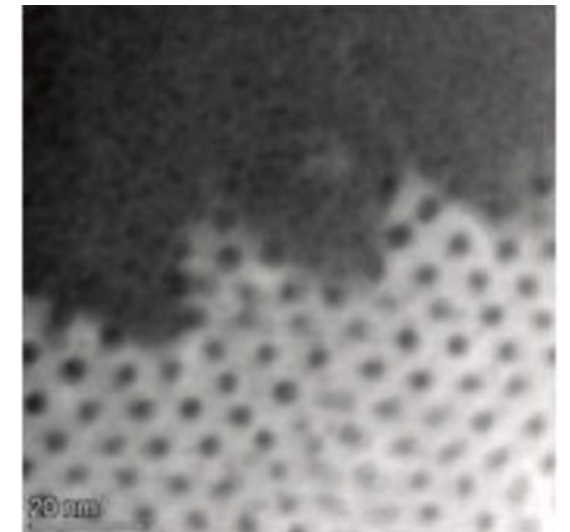
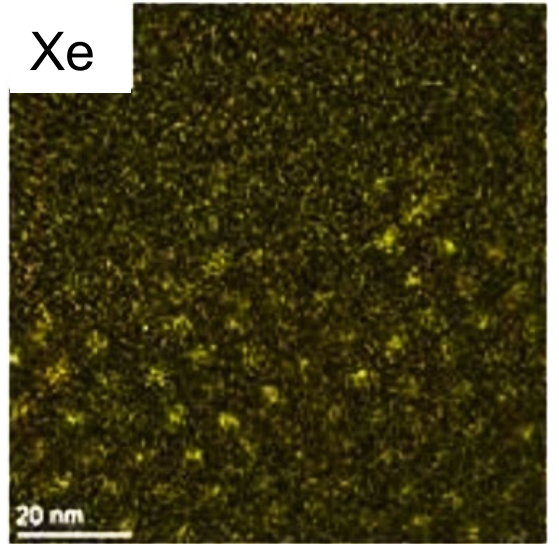
- Uranium-Molybdenum (U-Mo) alloys are prime candidate nuclear fuels for the conversion of high performance research and test reactors from high enriched uranium (HEU) to low enriched uranium (LEU).
- Unique characteristic of neutron irradiated U-Mo fuel is the formation of a highly ordered complex defect 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

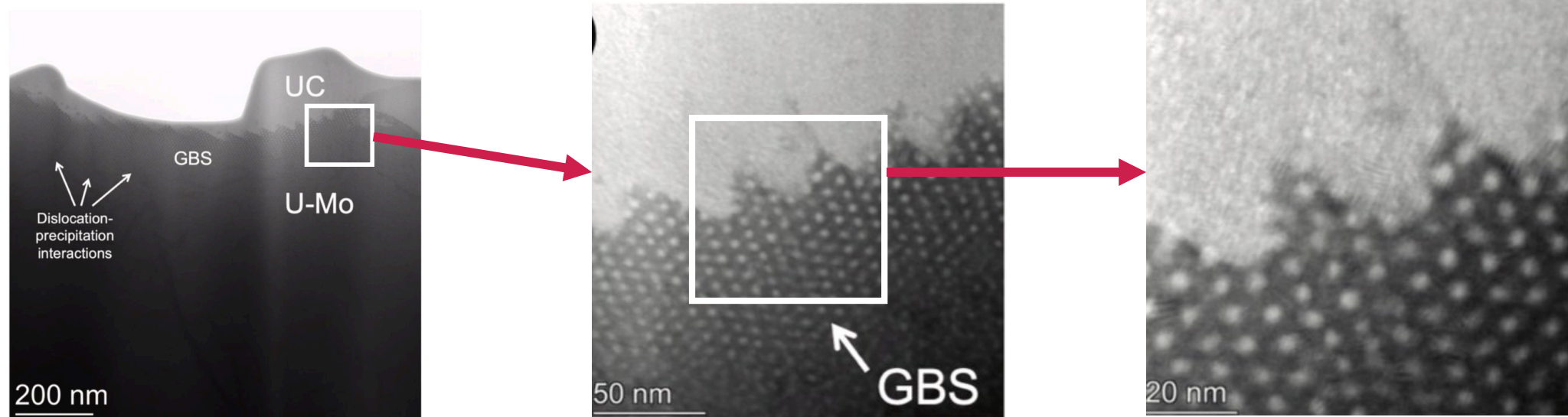
- Stores high energy fission gasses (Xe and Kr) thus delaying the release of these fission gasses that could lead to fuel swelling and degrade thermal conductivity and the neutron economy.
- Typically, superlattices of this type that form in metals are isomorphic with their host material. Not so in U-Mo 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 $\langle 110 \rangle$ 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

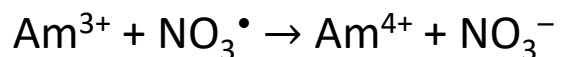


Amy Kynman

- 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)?
 - $2\text{AmO}_2^+ + 4\text{H}_{\text{aq}}^+ \rightarrow \text{AmO}_2^{2+} + \text{Am}^{4+} + 2\text{H}_2\text{O}$
 - $\text{AmO}_2^+ + \text{Am}^{4+} \rightarrow \text{AmO}_2^{2+} + \text{Am}^{3+}$
 - $2\text{Am}^{4+} + 2\text{H}_2\text{O} \rightarrow \text{Am}^{3+} + \text{AmO}_2^+ + 4\text{H}_{\text{aq}}^+$
- Studies to uncover the formation and stabilization of Am(IV) is of interest both for practical reasons and to increase our knowledge of f-element properties.

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:



- 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.

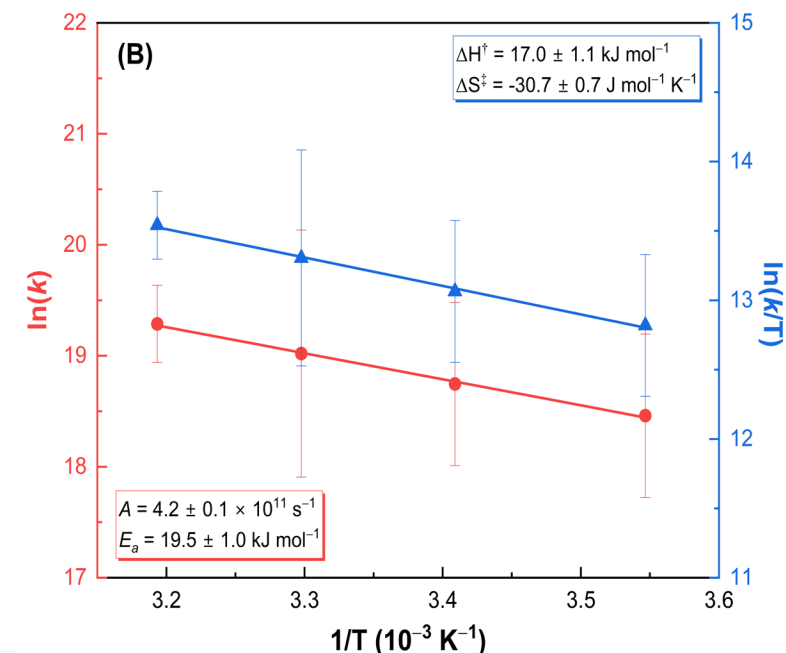
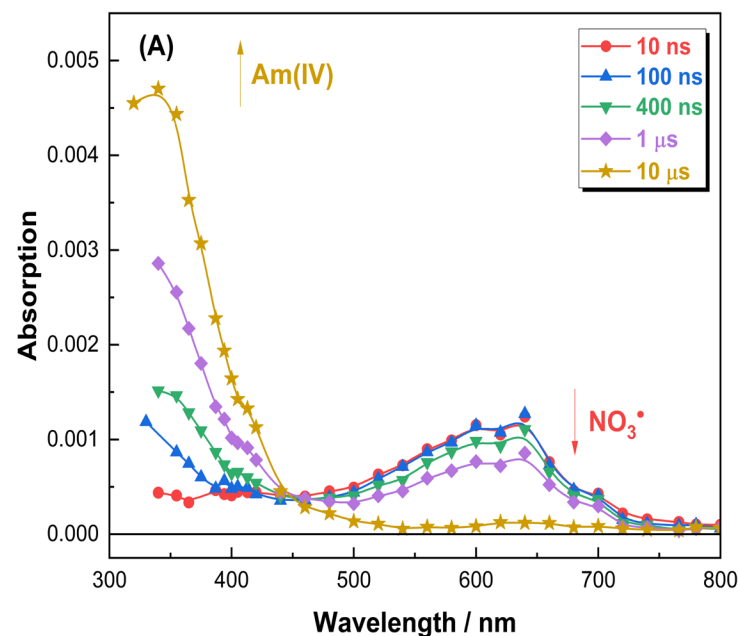


Fig. 1. (A) Dose normalized transient absorption spectra from the electron pulse irradiation of 2.08 mM Am(III) in aerated 6 M nitric acid at $21 \pm 1^\circ \text{C}$ for several time slices after the electron pulse. **(B)** Combined Arrhenius and Eyring plots utilizing second-order rate coefficient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



Idaho National Laboratory

G L E N N T.
S E A B O R G
INSTITUTE

Idaho National Laboratory

*Battelle Energy Alliance manages INL for the U.S. Department of Energy's Office of Nuclear Energy.
INL is the nation's center for nuclear energy research and development, and also performs research
in each of DOE's strategic goal areas: energy, national security, science and the environment.*

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