Study of long-length scintillating fiber bundles is part of a larger effort to explore innovative methods for radiation detection. Laboratory Directed Research and Development projects such as this support INL's core mission as well as DOE and national needs.

Successes from cutting-edge research program

By Sarah Robertson, *INL Communications & Governmental Affairs*

Each year, some of Idaho National Laboratory's best and brightest researchers submit proposals to explore state-of-the-art concepts and proof of principle ideas as part of the Laboratory Directed Research and Development (LDRD) program.

The LDRD program supports research in INL's core mission areas that is aligned with the needs of the laboratory, the Department of Energy and the nation. Researchers submit proposals that explore creative solutions and nurture partnerships with top universities and industries. Projects that are deemed technically sound and strategically aligned are awarded funding based upon the fiscal year's allocation. Then it's up to the researchers to plan and execute the project and to report their research results in many different forums.

Read highlights from INL's LDRD program below and learn more about the program's cutting edge research in the LDRD Snapshot annual report summary.

Melissa Teague: Characterization and Modeling of High Burn-up Mixed Oxide Fuel

Goals: Melissa Teague set four goals for her LDRD project. First, she planned to develop and apply new techniques for studying irradiated oxide fuels. This would include developing and demonstrating modeling framework for incorporating experimental results into fuel performance models. She also would study the effect of burn-up on thermal conductivity of oxide fuel. Finally, she aimed to complete her Ph.D. in materials science from Colorado School of Mines.

Melissa Teague studies irradiated oxide fuels.

Relevance to INL/DOE missions: Atom Probe Tomography (APT) provides chemical information on an atomic scale, which allows researchers to reconstruct a sample atom by atom. During this project, the first sample with simulated fission products was created as was the first-ever APT of plutonium-bearing material. An APT of irradiated oxide fuel is planned next. This program used LDRD-developed MOOSE and BISON modeling software to perform virtual measurement of effective thermal conductivity.

Innovative aspects: INL's unique hot focused ion beam (FIB) made it possible to prepare samples for APT. Because the size of the samples is so small, it allows for collaboration with universities and other laboratories for follow-on characterization. Researchers used INL-developed MOOSE and BISON modeling programs for coupling experimental data.

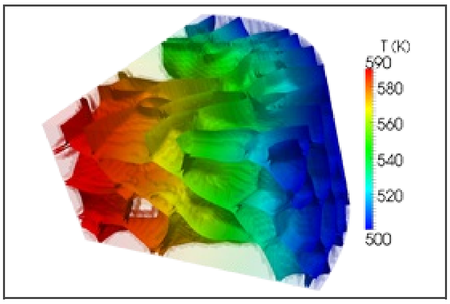
Why INL? INL's one-of-a-kind irradiated fuel characterization facilities and unique hot cell facilities were able to handle high-radioactive samples. INL is the only facility in the DOE complex capable of performing FIB and APT work on irradiated fuel. The large number of historic samples at the lab provided an opportunity to gain new insights into irradiation performance while realizing a significant cost savings.

Melissa Teague and Michael Tonks: 2-D and 3-D EBSD Technique Development and Microstructure Reconstruction for Phase Field Microstructure Evolution Models

Goals: The project aimed to advance our understanding of reactor material behavior using a unique combination of experiments and modeling. This improved understanding will promote accident-tolerant reactor design and support light water reactor life extension.

Relevance to INL/DOE missions: This project fulfills INL and DOE core objectives by helping to resolve materials issues in the current reactor fleet as well as in new reactor design.

Innovative aspects: In this project, the researchers developed techniques to analyze irradiated materials with 3-D electron backscatter diffraction (EBSD) and energy dispersive spectroscopy



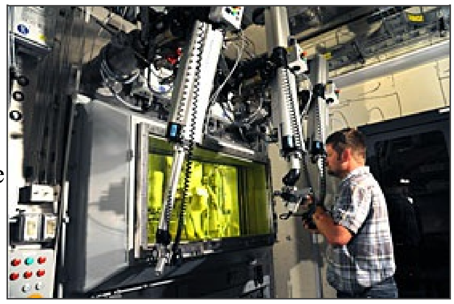
Together, Teague and Tonks are using microstructual data to improve nuclear fuel modeling.

(EDS). They collected the first-ever EBSD and EDS scans of irradiated fuel, providing critical insight into radiation damage. In order to take advantage of this advanced data to improve INL's modeling and simulation capability, the researchers developed the capability to reconstruct experimental microstructure in the MARMOT code from the 3-D EBSD and EDS data. This capability improves mesoscale modeling capability by providing realistic initial microstructures, data for model validation and the capability to virtually characterize material properties.

Why INL? This research could be accomplished only at INL because of the lab's advanced post-irradiation examination capabilities and its advanced modeling and simulation capabilities.

John Jackson (INL) and William Gerberich (University of Minnesota): Characterization of the Nanomechanical Response of Material to Determine Key Variables in Stress Corrosion Cracking

Goals: The goal of this research was to determine relevant variables and their effect on crack initiation in structural materials in nuclear reactors.



The irradiation assisted stress corrosion cracking (IASCC) test rig at INL's Materials & Fuels Complex.

Relevance to INL/DOE missions: This research helped provide higher clarity in predicting the lifetime of nuclear power plant components. Mitigating irradiation assisted stress corrosion cracking (IASCC) is a top concern for industry, DOE and regulatory agencies. This work also supported the research objective of improving designs so reactor systems are more affordable, safe, effective and efficient.

Innovative aspects: Recent advances in equipment and capability have allowed material examination at unprecedented levels. This research uses focused ion beam milling combined with electron backscatter diffraction to isolate grain boundaries. Nano- or pico-indenters were used to measure material response at sub-micrometer scales.

Why INL? INL is the nation's nuclear laboratory and has significantly advanced its suite of capabilities that support fundamental nuclear materials research. Some examples of capabilities that supported this research are the Center for Advanced Energy Studies Microscopy and Characterization Suite and the Advanced Test Reactor National Scientific User Facility network and capability.

Marat Khafizov (INL), Kenan Gundogdu (North Carolina State University), Izabela Szlufarska (University of Wisconsin-Madison): Observation of Zirconium Oxidation at Atomic Level Using Nonlinear Optical Spectroscopy

Goals: Develop a science-based understanding of initial oxidation in nuclear fuel cladding material.

Relevance to INL/DOE missions: Science-based understanding of initial oxidation in zirconium supports the development of accident-tolerant nuclear fuel and aligns with the mission of INL, DOE and industry needs. This LDRD addresses the INL R&D objectives of developing technologies that extend the life, improve performance and sustain the safety of the current fleet of nuclear power plants, as well as improving reactor designs so reactor systems are more affordable, safe, effective and efficient.

Innovative aspects: To validate atomic-level models, laser-based nonlinear optical spectroscopy is used to study the arrangements of atoms on the surface of zirconium during the initial stages of oxidation.

Why INL? As the nation's nuclear energy research lab, INL has experience identifying and addressing the key technological hurdles in safer and more efficient utilization of nuclear energy.

Leigh Martin's work supports development of a sustainable closed nuclear fuel cycle.

Leigh Martin: Development of Simplified Soft Donor Technique for Trivalent Lanthanide Actinide Separations

Goals: This project aimed to develop a significantly improved process, which works in conditions suitable for industrial deployment, for separating the trivalent actinides (americium, Am^{3+} and curium, Cm^{3+}) from the fission product lanthanides.

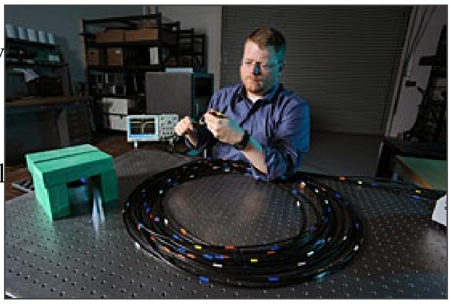
Relevance to INL/DOE missions: In order to develop a sustainable closed nuclear fuel cycle, there must be greater fuel utilization with minimal long-term heat loading and radiotoxicity in the final waste forms sent for disposal. We can help achieve these goals by removing americium and curium to destroy them in a reactor. This will reduce both the heat loading and radiotoxicity of wastes entering a repository.

Innovative aspects: Amino acids — cheap, natural products — were used to develop a separation process for the trivalent actinides and lanthanides that could be deployed at industrially relevant conditions. The radiation chemistry of this system was studied and found to be more resistant to radiation than the current processes considered for this application. In addition, the separation behavior was successfully modeled over a wide range of conditions — unlike some existing techniques.

Why INL? The laboratory has a dedicated research facility for actinide solution chemistry, the Radiochemistry Lab at the Materials and Fuels Complex. This lab has state-of-the-art radiochemistry instruments to interrogate "real" actinide solutions. INL has nationally and internationally recognized facilities for radiation chemistry research and an established mentoring program for young researchers.

David Chichester: Unconventional Radiation Detection Methods for Nuclear Nonproliferation, Safeguards and Treaty Verification

Goals: Evaluation of different methods for detecting and characterizing special nuclear material (SNM) in support of nonproliferation applications, including development and demonstration of new concepts and approaches for nuclear safeguards and treaty verification.



David Chichester is studying unconventional radiation detection methods.

Relevance to INL/DOE missions: INL is a steward of DOE nuclear material assets and facility resources. Developing new methods for detecting shielded nuclear materials is important for national security and nuclear nonproliferation.

Innovative aspects: Evaluated more than 10 methods for detecting and characterizing SNM, including methods not reliant on the measurement of ionizing radiation, approaches using low-cost sensors suitable for large-scale deployment in low-technology field systems, and sensors capable of generating radiation-field maps over large areas. This project also helped expand INL's ability to support experimental research using SNM at the Materials and Fuels Complex.

Why INL? Nuclear security and nuclear nonproliferation are important for ongoing and future nuclear energy use in the United States and throughout the world; research activities in these areas directly support INL's primary mission related to the advancement of nuclear energy science and technology. With unique experimental capabilities related to the use of SNM, INL plays an important role supporting technology development in the United States for nonproliferation, safeguards and treaty verification.

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Feature Archive