

**SECTION A. Coordinated Examination of Microstructure and Thermal Properties of Gamma Uranium-Zirconium Alloy in Volumetric Space**

**SECTION B. Project Description and Purpose:**

**Project description/abstract:**

This project characterizes the gamma phase region of the uranium-zirconium (U-Zr) system to obtain experimental data needed for developing mechanistic understanding of metal fuel performance. Constituent redistribution in U-Zr fuels during irradiation produces radially distributed phase fields, each with different thermal properties and behaviors. The project uses a combination of laser flash analysis (LFA), the thermal conductivity microscope (TCM), and transmission electron microscopy (TEM), all equipped with a furnace or heating stage, to characterize solid volumes at the micrometer ( $\mu\text{m}$ ) level with respect to Zr composition, phases present, crystal orientation, grain sizes, bulk thermal conductivity, local thermal conductivity, and Kapitza resistance across grain boundaries. The project irradiates U-Zr alloy in the Neutron Radiography Reactor (NRAD) and conducts the same examinations. This experimental data is needed to validate the potentials used in molecular dynamics (MD) and phase field simulations focused on modeling the radial thermal conductivity across a fuel segment. These lower length scale models will be used to populate large scale fuel performance models that will support fuel qualification.

**Research Plan:**

The proposed action investigates two gamma phase regions of the U-Zr phase diagram: one between 615-750°C at about 4-40 weight % Zr (9.8-63.5 atomic % Zr), and the other between 615-660°C at about 44-59 weight % Zr (67-79 atomic % Zr). These areas are represented in the red and green boxes in Figure 1. It is important to note that gamma phase is difficult to obtain at room temperature for compositions below 40 weight % Zr (63.5 atomic % Zr) – hence in-situ / heating measurements are necessary. The project will choose several alloy compositions for examination. Only the area in the green box (Fig.1) will be neutron irradiated.

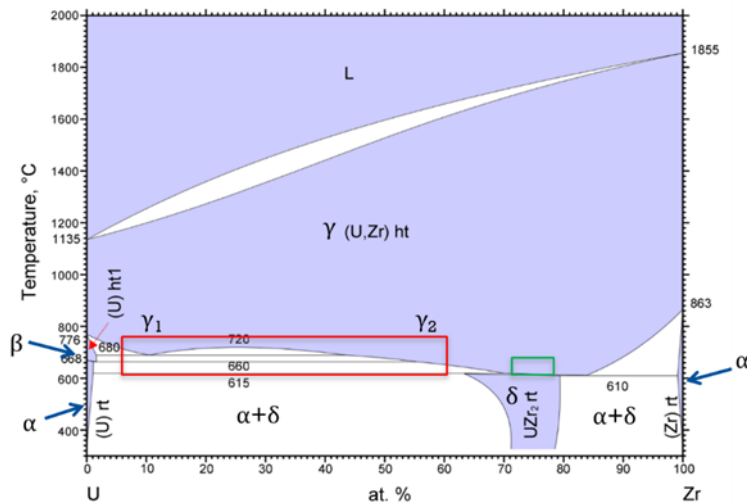
**Task 1: Characterization of Non-Irradiated U-Zr Alloys**

Four alloy compositions (about 4, 12, 25, and 36.5 wt. % Zr, 9.8, 26, 46.5, and 60 atomic % Zr respectively) will be cast, heat-treated, and quenched to increase grain sizes into the 100  $\mu\text{m}$  range. The project will examine each alloy using LFA at equilibrated temperature steps between 615°C and 750°C for bulk thermal conductivity. The project then places the same into a Focused Ion Beam (FIB) instrument to choose locations for TEM analysis. The proposed action cuts numerous lamellae from identified locations to capture relevant microstructural features. The project uses a heating stage on the TEM to identify Zr composition, phases, and crystal orientation, and examines the remaining sample using the heated stage on the TCM.

**Task 2: Characterization of Neutron Irradiated U-Zr Alloys**

The project irradiates two alloy samples of the same Zr composition (about 53 wt. % Zr, (75 at. %Zr)) that are cast, heat-treated, and quenched into stable gamma phase at room temperature. The project sizes these samples to fit the irradiation capsules, and irradiates each capsule to two different burn-ups. The project examines the irradiated specimens at room temperature in the same fashion as described in Task 1.

**Figure 1.** Uranium-Zirconium phase diagram. The blue areas represent single phase regions and the white areas represent two-phase regions. The red and green boxes indicate the regions of interest for this study



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**SECTION C. Environmental Aspects or Potential Sources of Impact:**

**Air Emissions**

The laser flash analysis, thermal conductivity microscope, and/or transmission electron microscope are equipped with a furnace or heating stage that may result in changes to air emissions. Operation of this equipment will release small quantities of radioactivity into ventilation systems. These emissions are not expected to increase above historical levels released by the facility and therefore would not constitute a new source or modification.

**Discharging to Surface-, Storm-, or Ground Water**

N/A

**Disturbing Cultural or Biological Resources**

The proposed activity will be conducted at HFEF which is eligible to be a National Historic Landmark.

**Generating and Managing Waste**

Both radioactive and non-radioactive waste will be generated. Project personnel will work with Waste Generator Services to properly manage and dispose of all solid waste using approved laboratory procedures. No TRU waste will be generated.

**Releasing Contaminants**

All chemicals typically used will be managed in accordance with laboratory procedures. All chemicals and associated Safety Data Sheets (SDS's) must be submitted in the vendor data system for approval. The Chemical Coordinator would track these chemicals in the INL Comply Plus Chemical Management System. Chemical use has a potential for small air emissions and spills. Although not anticipated, there is a potential for spills when using chemicals. In the event of a spill, notify facility environmental staff. If environmental staff cannot be contacted, report the release to the Spill Notification Team (208-241-6400). Clean up the spill and turn over spill cleanup materials to Waste Generator Services.

**Using, Reusing, and Conserving Natural Resources**

The project will practice sustainable acquisition, as appropriate and practicable, by procuring construction materials that are energy efficient, water efficient, are bio-based in content, environmentally preferable, nonozone depleting, have recycle content or are non-toxic or less toxic alternatives. New equipment will meet either the Energy Star or SNAP requirements as appropriate (see <https://sftool.gov/GreenProcurement>).

**SECTION D. Determine Recommended Level of Environmental Review, Identify Reference(s), and State Justification:** Identify the applicable categorical exclusion from 10 Code of Federal Regulation (CFR) 1021, Appendix B, give the appropriate justification, and the approval date.

For Categorical Exclusions (CXs), the proposed action must not: (1) threaten a violation of applicable statutory, regulatory, or permit requirements for environmental, safety, and health, or similar requirements of Department of Energy (DOE) or Executive Orders; (2) require siting and construction or major expansion of waste storage, disposal, recovery, or treatment or facilities; (3) disturb hazardous substances, pollutants, contaminants, or Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)-excluded petroleum and natural gas products that pre-exist in the environment such that there would be uncontrolled or unpermitted releases; (4) have the potential to cause significant impacts on environmentally sensitive resources (see 10 CFR 1021). In addition, no extraordinary circumstances related to the proposal exist that would affect the significance of the action. In addition, the action is not "connected" to other action actions (40 CFR 1508.25(a)(1) and is not related to other actions with individually insignificant but cumulatively significant impacts (40 CFR 1608.27(b)(7)).

**References:**

10 CFR 1021, Appendix B, B3.6, "Small-scale research and development, laboratory operations, and pilot projects"

**Justification:**

The proposed R&D activities are consistent with CX B3.6 "Siting, construction, modification, operation, and decommissioning of facilities for small-scale research and development projects; conventional laboratory operations (such as preparation of chemical standards and sample analysis); small-scale pilot projects (generally less than 2 years) frequently conducted to verify a concept before demonstration actions, provided that construction or modification would be within or contiguous to a previously disturbed area (where active utilities and currently used roads are readily accessible). Not included in this category are demonstration actions, meaning

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actions that are undertaken at a scale to show whether a technology would be viable on a larger scale and suitable for commercial deployment;"

Is the project funded by the American Recovery and Reinvestment Act of 2009 (Recovery Act)     Yes     No

Approved by Jason Anderson, DOE-ID NEPA Compliance Officer on: 04/08/2021