Demonstration of a Methodology for Direct Validation of MARMOT Irradiation-Induced Microstructural Evolution and Physical Property Models Using U-10Zr

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ABSTRACT:
The objective of this project is to demonstrate a methodology that enables the direct validation of microstructural evolution models for metallic nuclear fuel in MARMOT. This will include the direct correlation of changes in physical properties due to specific irradiation-induced microstructural features. Once developed, the broad implementation of this methodology will enable the rapid development and validation of MARMOT mesoscale models. The availability of accurate fuel (and material) models on this scale is a key to implementation of predictive models that decrease the timeline required for nuclear fuel and material development and licensing, enabling innovative nuclear technologies to effectively compete in the marketplace with other clean energy technologies.

This approach is made possible by advances in characterization tools available through the Nuclear Science User Facilities (NSUF) that enable direct quantification of the concurrent evolution of microstructure and properties at the same location on the same sample, before and after irradiation. This novel approach provides the closet approximation available to *in situ* observation of the evolution of microstructure and material properties during in-reactor irradiation. Uranium–10 wt% zirconium (U 10Zr) is selected as the base material for this study because it is directly relevant to current NEAMS modeling and simulation efforts and, more broadly, because it is of high interest to current commercial small modular reactor developers and for the potential development of a new U.S. fast test reactor. To this end, the proposed work will seek to accomplish the following objectives:

1. <u>Pre-Irradiation Characterization of U-10Zr Samples</u>: X-ray diffraction computed tomography (XRD-CT) will provide 3D information on the initial state of the microstructure and Thermal Conductivity Microscopy (TCM) will provides high spatial resolution phase and inter-phase thermal property measurements. Standard pre-irradiation characterization (e.g., dimensions, density, x-ray diffraction, and electron microscopy) will also be performed.

2. <u>Irradiation of the U-10Zr Samples in the Advanced Test Reactor (ATR)</u>: Sample irradiations will be performed in a configuration conforming as closely as possible to an existing and well-analyzed ATR experiment capsule design. The intent of this proposal is to insert four identical test capsules containing five types of miniature samples, (with replicates) that have been fully characterized.

3. <u>Post-Irradiation Characterization of U-10Zr Samples</u>: A selected sample set will be characterized using the same methodologies applied prior to irradiation.

4. <u>MARMOT Assessment and Validation for mesoscale models</u>: This project provides critical data needed for understanding the irradiation behavior of U-Zr fuels and for the validation of separate effects models in MARMOT for metal fuels. The data obtained will be used for validation of MARMOT gas bubble swelling and effective thermal conductivity models with respect to the disparate irradiation conditions made available in the samples.

This project provides critical data needed for understanding the irradiation behavior of U-Zr fuels and for the validation of separate effects models in MARMOT on gas bubble swelling and thermal conductivity for metal fuels. Therefore, it is highly relevant for the NEAMS-2 scope. Further, this work will to take advantage of advances in 3D characterization technology to demonstrate this new methodology for directly coupling experiment with modeling and simulation.