MATERIALS ENGINEERING

SEMINAR

"Model-Based Image Characterization and Empirical Modeling of High Burnup Monolithic U-Mo Fuel"

By

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ABSTRACT

Monolithic uranium molybdenum alloys (U-Mo) are considered a candidate for converting high-performance research and test reactors from high-enriched uranium to low enrichment alternatives. The metallic fuel is capable of conversion due to the high U loading and favorable radiation performance. During irradiation, the fuel undergoes a three-part swelling behavior, with an initial linear swelling rate followed by an increase in the swelling rate represented by an increase in the nucleation of fission-gas bubbles, and ending with stabilization at the highest fission densities. Understanding the high burnup regime is critical to extending the life of the reactor and creating accurate fuel performance models. To accurately inform swelling models, it is necessary to experimentally characterize the pore evolution as a function of burnup and the influence of diffusion barrier-fuel interaction on the morphology. Therefore, a systematic approach was conducted to experimentally characterize the influence of irradiation and fuel-diffusion barrier interaction on the pore morphology and then empirically model the porosity evolution. Initially, three separate locations in a monolithic U-Mo fuel plate with burnups ranging from $8.9\text{-}9.4\times10^{21}$ fissions/cm^3 were investigated using scanning electron micrography (SEM) to characterize the morphological porosity dependence on fission density. To investigate the impact of the Zr-fuel interface on the pore morphology, two specimens were imaged using synchrotron microcomputed tomography (Sr-µCT) from a U-Mo monolithic miniplate irradiated to 9.8×10^{21} fissions/cm^3, one at the diffusion barrier and one in the bulk fuel. Synchrotron microcomputed tomography allows for the characterization of the influence of fuel-Zr diffusion barrier interaction on the pore morphology in three dimensions; however, due to the novelty of this technique applied to nuclear fuels the results were verified with SEM serial sectioning. The multimodal comparison between the Sr-µCT and SEM serial sectioning allows for a direct assessment of the capabilities of each technique for nuclear fuel applications. Due to the complex microstructure and imaging challenges in analyzing these samples, several model-based image processing and characterization tools were developed to aid in the analysis. An empirical model for porosity evolution in high-burnup U-Mo was developed and accurately modelled the porosity behavior. The experimental results from the current work and the empirical model developed can be used to inform mechanistic modeling efforts in the community.

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