Purdue Materials Engineering

"Advanced Microstructural Characterization of Thoria and Uranium-Zirconium Nuclear Fuels by Correlative Atom Probe Tomography and Transmission Electron Microscopy"

By

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Purdue MSE PhD Dissertation

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ABSTRACT

The next generation of nuclear reactor designs promise to provide clean, safe, and efficient energy to address our current climate crisis. But with these new technologies, nuclear fuel materials must be carefully designed and understood to meet these demands. Candidate oxide and metallic nuclear fuel materials being considered for use in these new reactor technologies, despite their potential, still have significant remaining materials challenges in understanding their long-term performance and integrity under extreme reactor conditions. As such these candidate fuels require extensive materials characterization to understand their long-term performance under reactor conditions. The objective of this study is to evaluate the microstructural evolution of candidate fuels U-50wt%Zr and ThO_2 in the following contexts: 1) Investigation of phase stability in metallic fuel U-50wt%Zr under thermal and irradiation treatment; 2) Investigation of the influence of irradiation effects on localized thermal properties in oxide fuel ThO_2 under proton irradiation through a novel correlative microscopy approach.

The influence of thermal and irradiation treatment on phase stability in δ-U50wt%Zr was investigated through conventional APT-TEM methodology. U-Zr is a candidate metallic fuel for advanced fast reactor applications. However, there is still work remaining to better understand how these materials evolve under extreme reactor conditions, especially for the δU-50wt%Zr composition. Metallic fuels are susceptible to significant chemical redistribution under extreme conditions resulting in potential degradation of fuel properties and performance. In these experiments, U-50wt%Zr was subjected to thermal annealing and proton irradiation respectively. These treatments produced very different modulated structures in U-50wt%Zr, and the implications of such on phase stability in U-50wt%Zr will be discussed.

Additionally, long-term nuclear reactor operation hinges upon efficient thermal transport in nuclear fuels. There is a critical need to understand localized thermal transport in these materials to enable intelligent design of high-performance fuels. A novel correlative atom probe tomography (APT)-transmission electron microscopy (TEM) approach was developed to investigate the influence of irradiation defects on localized thermal diffusivity in ThO_2 upon proton irradiation, and implications of such results will be discussed.

Date: Thursday, November 17, 2022
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Place: via WebEx http://purdue.webex.com/meet/jwharry

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