Understand the Fission Products Behavior in UCO Fuel Kernels of Safety Tested Advanced Gas-Cooled Reactor TRISO Fuel Particles by Using Titan Themis 200 with ChemiSTEM Capability

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In support of the Fuel Qualification program, the project aims to acquire knowledge of irradiated microstructure and physical and chemical states of fission products in irradiated TRISO fuel particle kernels.

Experimental or Technical Approach

Microstructure characterizations, elemental analysis, and phase identification were conducted using a Titan Themis 200 scanning transmission electron microscope. Characterizations included STEM, bright-field (BF), high-angle annual dark field imaging, energy-dispersive X-ray spectroscopy (EDS) elemental mapping, and selected-area electron diffraction.

Results

The studies yielded several results shown in Figure 1. The team found that the irradiated-fuel kernel microstructure consists of UO_2 and UC(O) phases. Additionally, fission products of Zr, Ru, and Tc tend to concentrate in the UC(O) phase or precipitate to form $U(Mo)C_2$ or $URuC_2$ phases when the concentrations of Ru and Tc exceed their solubility limits in UC(O) phase. A third observation the team made is that Nb is prone to forming Nb oxides at the peripherals of pores or cracks.

Discussion/Conclusion

The knowledge of chemical states of fission products can help to estimate the oxygen potential more accurately in the irradiated particle fuels. The observation of Pd immobilized in $U_2RU_2C_2$ phase can potentially provide a mechanistic explanation for the superior irradiation performance of UCO TRISO fuel particles compared to UO_2 particle fuel.

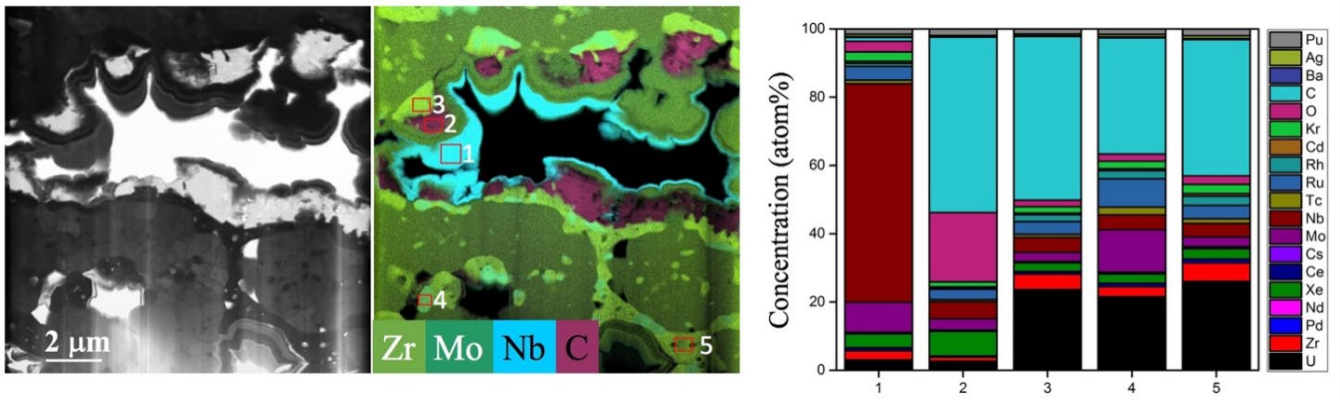

Figure 1. Characterization of irradiated AGR-2 fuel kernel half center: (a) BF TEM image, (b) Zr, Mo, Nb, and C elemental mapping, and (c) compositional analysis from automated optical inspection labeled on (b).

References

[1.] Fu, Zhenyu, et al. 2021. "Microstructural and Micro-Chemical Evolutions in Irradiated UCO Fuel Kernels of AGR-1 and AGR-2 TRISO Fuel Particles." Journal of Physics: Conference Series 2048: 012006. https://doi.org/10.1088/1742-6596/2048/1/012006.

Distributed Partnership at a Glance

NSUF Institution	Facilities and Capabilities
Idaho National Laboratory	Irradiated Materials Characterization Laboratory
Collaborators	
Idaho National Laboratory	Isabella van Rooyen (Co-Principal Investigator), Lingfeng He (Co-Principal Investigator)
University of Florida	Zhenyu Fu (Team Member)
Degrees Granted	
University of Florida	Zhenyu Fu, Ph.D.