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#5-135 Nondestructive volumetric examination of irradiated tristructural isotropic (TRISO) fuels using X-ray computed tomography

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One promising next-generation fuel form for advanced nuclear reactors is TRISO (tristructural isotropic) fuel, which consists of sub-millimeter-diameter uranium-bearing fuel kernels encapsulated in multiple layers of carbon and ceramic materials. Thousands of these micro-spheres are then dispersed in a carbon or ceramic matrix. The U.S. Department of Energy's (DOE) Advanced Gas Reactor (AGR) program focuses on developing and demonstrating the viability of high-temperature gas-cooled reactors (HTGRs) using TRISO fuel. As part of the assessment of TRISO fuels, post irradiation examination (PIE), is performed to provide information on changes in microstructure, mechanical properties, and potential degradation. X-ray computed tomography is a nondestructive technique that collects a series of two-dimensional radiographs as a function of sample rotation, and mathematically reconstructs them into a three-dimensional dataset that provides volumetric information on the sample's internal features. At Idaho National Laboratory, XCT is performed using a ZEISS Xradia 620 VERSA X-ray Microscope to examine irradiated TRISO particles and AGR compacts with the objective of observing evolution of kernel and layer morphologies, particle sphericity and location in the matrix, and degradation pathways to further inform fuel performance. This 620 VERSA consists of two detection modes, the first employs a solid-state flat panel detector to provide a large field-of-view with relatively coarse spatial resolution (~100 μm/voxel- ~5 μm/voxel), while the second utilizes a series of X-ray scintillators coupled to an optical microscope and a charge-coupled device (CCD) camera to provide a smaller field-of-view but increased spatial resolution (down to ~300 nm/voxel). Quantitative data, including particle layer thicknesses, fission-induced porosity size distribution in the fuel kernels, radiation-induced swelling of the fuel kernels, and kernel sphericity, have all been obtained nondestructively with XCT measurements. Details about custom sample shielding and preparation needed to adequately protect both personnel and electronic laboratory equipment when imaging highly radioactive fuel specimens (the most radioactive to date being 1.2 Sv/hr from ɣ-rays on contact), including radioactive fuels'impact on the imaging detectors, are also featured. Lastly, this discussion concludes with an outlook on future work and how XCT can be used to inform traditional destructive analysis as well as provide inputs and validation for modeling and simulation efforts, ultimately aiding in the reduction of the timeline for commercial implementation of new nuclear concepts.

Primary author: Dr CHUIRAZZI, William (Idaho National Laboratory)

Co-authors: Dr STEMPIEN, John (Idaho National Laboratory); Dr KANE, Joshua (Idaho National Laboratory); Dr KANCHARLA, Rahul Reddy (Idaho National Laboratory); Dr MORANKAR, Swapnil (Idaho National Laboratory)

Presenter: Dr CHUIRAZZI, William (Idaho National Laboratory)

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