DEPARTMENT OF ENERGY
UNITED STATES OF AMERICA

X-ray diffraction tomography analysis of SiC composite tubes neutron-irradiated with a radial high

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STRUCTURAL MATERIALS

ABSTRACT:

Silicon carbide (SiC) fiber–reinforced SiC matrix (SiC/SiC) composites are of interest for accident-tolerant fuel cladding in light water reactors (LWRs) because of their high strength at elevated temperatures, relatively low neutron absorption, and steam oxidation resistance. However, modeling has predicted that thermal gradients can have a significant effect on the stress states of SiC components during irradiation because of inversely temperature-dependent, irradiation-induced swelling. The temperature gradient is a result of the temperature difference between the fuel and water coolant. This temperature-dependent swelling is known to play a major role in the stress state of the irradiated cladding in normal operating environments. The current knowledge gap is experimental quantification of the irradiation-induced stress under a temperature gradient within the SiC cladding. To experimentally evaluate such stress, a prototypic SiC/SiC cladding has been neutron-irradiated at LWR-relevant temperatures and dose conditions with a radial high heat flux in the High Flux Isotope Reactor at ORNL.

The overarching goal of the proposed project is to experimentally verify the modeling results of a prototypical SiC-based fuel clad subject to neutron irradiation under high radial heat flux, which is relevant to practical LWR fuel operation. Specifically, this project is intended to obtain critical experimental data that can be directly overlaid and compared with the modeling results. The proposed work will conduct x-ray diffraction computed tomography (XRD-CT) analysis of neutron-irradiated SiC tubes in the NSLS-II XPD Beamline at Brookhaven National Laboratory.

This project will provide experimental data on lattice strain for the response of SiC tubes to neutron irradiation under a temperature gradient, which will be used to validate or provide an opportunity to improve the thermomechanical modeling of SiC/SiC tubes. More specifically, the 2D and/or 3D distribution of lattice strain within the neutron-irradiated SiC/SiC composite tubes will be obtained. This experimental result will be compared with simulated lattice strains conducted in our previous work. In addition, the lattice strain distribution and conventional x-ray computed tomography microstructure will be overlaid so that the effects of local microstructure on lattice stress will be understood. This information is necessary to improve a finite element model with a key microstructural feature. Finally, the material data will be registered to the NSUF fuel and material library.