Performance of SiC-SiC Cladding and Endplug Joints Under Neutron Irradiation with a Thermal Gradient

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Program: Nuclear Science User Facilities (NSUF) Work Scope 1.2C

ABSTRACT:

Silicon carbide (SiC) composites (SiC-SiC) that offer high-temperature strength, low gas permeability, and stable behavior under neutron irradiation are being developed for accident tolerant fuel (ATF) cladding applications. Techniques to produce high-performance, irradiation-stable joints between SiC components are a critical enabling technology for SiC-based materials. However, a SiC joint material property database must be established to enable more accurate simulation and design of SiC joints. Under the project contemplated in US Department of Energy Funding Opportunity Announcement No. DE-FOA 0001515, GA and ORNL will measure key thermal and mechanical properties, and joint performance will be assessed in novel experiments under realistic conditions and in representative geometries.

Project Description: SiC joint specimens will be fabricated and characterized using out-of-pile testing to investigate properties as a function of temperature and post-irradiation examination (PIE). The project will leverage access to the NSUF High Flux Isotope Reactor and associated facilities for the irradiation and PIE. Thermal properties of SiC joints not previously reported will be measured, and irradiation performance of SiC joints under realistic thermal gradient conditions will be characterized. The work will provide a better understanding of the performance of realistic tube-endplug geometries, where thermal gradients and stress concentrations can occur. Mechanical and thermal joint properties will be incorporated into a material property database to enable more accurate SiC joint performance modeling using fuel thermo-mechanical stress analysis codes, such as BISON.

Scope and Objective: The objective is to obtain critical performance data for three promising SiC joint formulations in representative joint geometries as a function of temperature and irradiation, and to use these results to generate a material properties database to enable more accurate modeling of SiC joints. The scope of the work is comprised of three main tasks:

- Out-of-pile testing to characterize SiC joint strength, permeability, and thermal properties as a function of temperature (fills critical gaps in the knowledge base).
- Irradiation of SiC joint specimens under realistic temperature and thermal gradient conditions. Two irradiation temperatures will be used. PIE will assess mechanical and thermal properties of irradiated SiC joints, and changes in hermeticity, swelling, and microstructure.
- Development of a SiC joint material property database incorporating temperature and irradiation effects to enable more accurate modeling of SiC joints. The BISON fuel code will be used to simulate stresses in realistic cladding geometries, with comparison to out-of-pile and PIE results.

Impact of Project: The work will fill a critical gap in the understanding of the performance of SiC joints and will advance the development of ATFs: a high priority area for nuclear energy development. The demonstration of SiC joint performance is a key milestone in the implementation of SiC materials in cladding applications. The investigation of SiC joints in a representative tube-endplug configuration will support performance improvements for these innovative joint manufacturing techniques. SiC and associated joining technologies are applicable to a wide variety of advanced reactors beyond ATF cladding applications, most notably where materials with high corrosion resistance and high-temperature capability are required (e.g., molten salt and gas-cooled reactors). The GA and ORNL team brings extensive experience and SiC joint fabrication and characterization capability to successfully meet project objectives.