U.S. Department of Energy

Developing a macro-scale SiC-cladding behavior model based on localized mechanical and thermal property evaluation on pre- and post-irradiation SiC-SiC composites

PI: Peter Hosemann- University of California Berkeley

Collaborators: J. Tucker, B. Bay Oregon State Univ.; D. Cahill, Univ. of Illinois Urbana Champaign; C. Deck, General Atomics; S.G. Roberts and D. Armstrong Univ. of Oxford, UK

Program: FC 2.2.

ABSTRACT:

Silicon carbide is being investigated for accident tolerant fuel cladding applications due to its good neutronic performance, high temperature strength, exceptional stability under irradiation, and reduced oxidation compared to Zircaloy under accident conditions. The development and investigation of these materials is particularly important in the light of the Fukushima event and subsequent emphasis in DOE on accident tolerant fuel (ATF) concepts. In this work, we propose to develop and improve upon existing small-scale mechanical and thermal characterization methods, including micro-cantilever bend tests and fiber push-out tests, and time-domain thermoreflectance measurements. These techniques will be applied to evaluate micro-scale properties of SiC-SiC composite constituents (matrix, fibers, interphase). The results will be coupled with meso-scale fiber and void structural information and be used as input to develop a comprehensive, finite element-based model based on constituent properties. This multi-scale model will be used to predict anisotropic mechanical and thermal cladding behaviors.

The model will be benchmarked against measurements of bulk properties and validated for radiation-damaged materials by utilizing irradiated SiC-SiC composites available from General Atomics. The characterization approach developed under this program will have particular application in the property prediction of reactor irradiated materials, as only small volumes need to be tested, minimizing associated hazards and costs. The micro-scale test methods developed here will be used along with meso-scale structural data to inform a finite element model of the full SiC-based cladding system. This model will capture fabrication and irradiation effects and importantly include for the first time separate material data for each system component. The incorporation of these micro-scale effects will lead to a more accurate model of SiC-SiC composite behavior, enabling further advancements in the development and design of SiC-based materials for improved fuel cladding performance.

In summary: ***The aim of this work is to develop advanced localized material characterization techniques to directly measure mechanical and thermal properties of the individual constituents of SiC-based claddings at the relevant micro-scale. SiC-SiC composites will be evaluated before and after irradiation and these results will be coupled with macro-scale properties and microstructural information in order to provide the input parameters for a comprehensive finite element model, which will be developed in this program.***