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Role of Defects in Swilling and Creep of Irradiated SiC

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ABSTRACT

Silicon carbide is a promising cladding material because of its high strength and relatively good corrosion resistance. However, SiC is brittle and therefore SiC-based components need to be carefully designed to avoid cracking and failure by fracture. In design of SiC-based composites for nuclear reactor applications it is essential to take into account how mechanical properties are affected by radiation and temperature, or in other words, what strains and stresses develop in this material due to environmental conditions. While thermal strains in SiC can be predicted using classical theories, radiation-induced strains are much less understood. In particular, it is critical to correctly account for radiation swelling and radiation creep, which contribute significantly to dimensional instability of SiC under radiation. Radiation-induced volume swelling in SiC can be as high as 2%, which is significantly higher than the cracking strain of 0.1% in SiC. Swelling-induced strains will lead to enormous stresses and fracture, unless these stresses can be relaxed via some other mechanism. An effective way to achieve stress relaxation is via radiation creep.

Although it has been hypothesized that both radiation swelling and radiation creep are driven by formation of defect clusters, existing models for swelling and creep in SiC are limited by the lack of understanding of specific defects that form due to radiation in the range of temperatures relevant to fuel cladding in light water reactors. For example, defects that can be detected with traditional transmission electron microscopy techniques account only for 10-45% of the swelling measured in irradiated SiC.

In this project we will undertake an integrated experimental and modeling research effort to discover the previously invisible defects in irradiated SiC and to determine the contributions of these defects to radiation swelling and radiation creep. Knowledge of the most stable defect structures and the rate controlling processes during defect evolution is essential for development of predictive models for swelling and creep as a function of temperature and radiation dose. The proposed research will be enabled by state-of-the-art imaging techniques, such as the aberration corrected scanning transmission electron microscopy (FEI TITAN) and atom probe tomography (APT), closely coupled with *ab initio* based models of stable defect clusters and their evolution. The proposed research will lay the essential groundwork for adoption of SiC in light-water reactors, including rigorous design of SiC-based composites for fuel cladding.