U.S. DEPARTMENT OF ENERGY
NUCLEAR ENERGY RESEARCH INITIATIVE
ABSTRACT

PI: **Russell Jones** **Proposal No.: 99-0281**

Institution: **Pacific Northwest National Laboratory**

Collaborators: **None**

Title: **Advanced Ceramic Composites for High-Temperature Fission Reactors**

Advanced ceramic composites, such as radiation-resistant SiC/SiC, offer the potential for creating fission reactors featuring high-temperature (>1000°C) and, therefore, high-efficiency reactor operation. Silicon carbide is also a very low activation material so these materials, if used to make reactor components, help reduce the quantity of high-level radioactive waste. Composites made with SiC fibers in a beta-SiC matrix have been engineered to exhibit moderate fracture toughnesses (25 MPa $m^{1/2}$) and fracture strengths (500 MPa) at temperatures greater than 1000°C in the unirradiated condition. These properties have been achieved by taking advantage of high-strength SiC fibers for fracture strength and engineered fiber/matrix interphases to achieve the necessary crack deflection and fiber pullout for fracture toughness. Under irradiation, the beta-SiC crystal structure is known to exhibit exceptional dimensional stability at temperatures of 800-1000°C, but the design and development of a radiation-resistant SiC/SiC composite will require a fundamental understanding of the effects of radiation on the fibers and the fiber/matrix interfaces, as well as the matrix.

Ceramic matrix composites are currently being developed for high-temperature applications such as combustors and combustor liners for land-based gas turbines and jet engines, heat exchangers, diesel engine valve guides, and many more. Many advances made for these applications are directly benefiting the development of radiation-resistant SiC/SiC composites. These advances include better high-temperature fibers, more oxidation-resistant interphases, and improved matrix materials. Many of these improvements aimed at increased high-temperature performance are also expected to provide improved radiation resistance.

The radiation resistance of SiC/SiC is currently being investigated by DOE's Office of Fusion Energy Sciences and The Office of Nuclear Energy. An important finding of these investigations is the susceptibility of non-stoichiometric SiC-fibers to radiation damage processes. While these programs have demonstrated the inadequacy of off-the-shelf materials and have identified many of the problem areas for these materials, they have also demonstrated the exciting potential of SiC/SiC composites as high-temperature reactor materials. However, funding limitations have restricted them from taking advantage of the potential for enhancing the material performance with a modeling-based approach. And, there are several issues associated with the use of SiC/SiC in a fusion reactor, such as high rates of transmutation and displacement damage, that will not be faced by an advanced fission reactor.

The proposed research will focus on modeling a radiation-resistant ceramic matrix composite by utilizing existing fundamental knowledge about radiation effects in structural ceramics, and extending that fundamental knowledge as needed to explore the unique aspects of ceramic matrix composites under

fission reactor conditions.