Precursor-Derived Nanostructured Si-C-X Materials for Nuclear Applications

PI: Rajendra Bordia – University of Washington

Collaborators: Chuck Henager – Pacific Northwest National Laboratory; Vikas Tomar – Purdue University

Program: GEN IV

ABSTRACT

Silicon carbide (SiC) is an attractive material for several nuclear applications (e.g., high-temperature structural material, fuel cladding, and waste form for storage of inert gas fission products). Recent results indicate that preparing materials in nanostructured forms may revolutionize the development of radiation damage resistant materials. Thus in order to fully realize the potential of SiC, there is a need to develop a processing approach that can make dimensionally stable nanostructured SiC based materials in a variety of forms (e.g., composites, monoliths, porous, coatings, tubes). The proposed research is an investigator-initiated research (IIR) activity to develop a novel class of SiC-based ceramic materials (referred to as Si-C-X materials with X standing for minor amounts of O or N) with tailored compositions based on nanostructured SiC and to demonstrate their potential in targeted nuclear applications.

The proposed materials possess a unique nanostructure. They have dispersions of graphene separating nanostructured crystalline SiC nanodomains. The comprehensive research will focus on investigating the effect of precursor and processing conditions on the resultant nanostructure and on understanding the effect of the nanostructure on important properties of interest to nuclear energy applications. The goal is to develop a fundamental understanding and a predictive relationship among precursor chemistry/processing/nanostructure/properties that will produce highly crystalline nanostructures that are known to have intrinsic radiation damage tolerance. The research is based on the postulate that nanostructured SiC domains in the new materials will have higher irradiation damage resistance when compared to the SiC produced using well-established procedures such as chemical vapor deposition. The presence of carbon-based internal interfaces will act as point defect recombination centers leading to a reduction in defect densities and radiation damage. It has already been shown that SiC is an ideal candidate for storage and retention of radioactive C, Xe, and Kr. This research program has the following objectives:

- To understand the effect of precursor chemistry and processing conditions on the resulting Si-C nanostructure including the state of carbon (graphene/turbostatic/carbon nanotubes)
- To investigate the effect of the nanostructure on the resulting mechanical (such as fracture toughness and creep resistance) and thermal (such as thermal conduction) properties of the material (including thermal stability of the nanostructure as a function of temperature)
- To investigate the effect of irradiation (both experimentally and computationally) on the changes in nanostructure and material thermal and mechanical properties
- To understand the storage and retention of inert-gas fission products, such as Kr85, in such nanostructures and how this might be optimized.

Overall, in the three years of the integrated collaborative research, our team with complementary expertise will evaluate the potential of the proposed new class of materials for radiation stability and long-term inert-gas, fission-product storage. The deliverables will consist of polymer precursor compositions, appropriate processing conditions, and process steps involved in optimizing the nanostructure of this family of materials along with nanostructure-material property correlation database. The results will be presented in reports and published in peer-reviewed journals and conference proceedings.