Advanced Coating and Surface Modification Technologies for SiC-SiC Composite for Hydrothermal Corrosion Protection in LWR

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Program: FC- 2.3: Damage and Failure Mechanisms for SiC/SiC Composite Fuel Cladding and Mitigation Technologies

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ABSTRACT:
The proposed research will focus on the development of coatings and surface modification approaches for hydrothermal corrosion protection of SiC-SiC composite in normal LWR operation environments. SiC-SiC composite is emerging as a lead candidate for the replacement of Zr-alloy in LWR as an accident tolerant fuel (ATF) cladding material. This composite is expected to extend coping time under a loss-of-coolant accident (LOCA) and other possible accident scenario by virtue of its excellent high temperature oxidation resistance and strength, and good radiation stability. However, aqueous hydrothermal corrosion of SiC in water coolant is an important concern in normal LWR operating conditions. A loss in weight of SiC is attributed to the dissolution of silica phase formed due to oxidation of SiC in reactor coolants.

A variety of innovative concepts ranging from overlay coatings with compositionally-tailored interfaces and multilayers to intrinsic modification of the near-surface chemistry of the composite will be developed and investigated. Several commercial surface treatment processes have been selected for this study, including the cold spray process, thermal spray process, electroplating, physical vapor deposition process (PVD), and pack cementation. We will investigate both metallic (FeCrAl alloy and Cr) and ceramic coatings (Cr-oxide, Cr-nitrides, Cr-carbides, and Zr- and Y-silicates). Innovative surface treatment recipes will be investigated using these materials and processes, including interfacial stitching to improve adhesion, multi-layered structures to improve ductility, and compositions and structures resulting from thermal treatments. The processes used are commercial and amenable to industrial scalability for the cladding application.

To facilitate the timely accomplishment of tasks, the research will proceed with an emphasis on prioritization and down-selection. Initial testing of the optimized surface treatments will be performed by water autoclave testing under prototypic conditions of temperature and pressure followed by corrosion testing of ion-irradiated surfaces. Down-selected surface treatments from this study will be tested in a water flow-loop with prototypical LWR water chemistry. The effect of water radiolysis on hydrothermal corrosion of SiC-SiC composite and engineered surfaces will be evaluated using γ- and β- rays in a Van de Graff generator. Finally, the most promising surface treatments will be tested in prototypical LWR water flow under neutron irradiation in a test reactor.

Materials characterization using SEM-EDS, EBSD, XRD, XPS, HRTEM, and STEM-EDS to elucidate the mechanisms and magnitude of corrosion and mechanical tests of the surface treatments such as scratch test, 4-point bending test, expanding plug test, and hermeticity test for coating-substrate adhesion strength and ductility of coatings will be a cross-cutting theme throughout the research program, and vitally important for the down-selection process.