Coating development for SiC/SiC fuel cladding to prevent fission gas release

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The evolution of SiC ceramic matrix composites has provided an interesting nuclear fuel cladding alternative. SiC provides high-temperature oxidation resistance, radiation resistance, and maintains high-temperature mechanical properties. However, its brittle nature necessitates a composite structure, which has the potential to compromise its ability to hold fission gas during normal operation; the thermal and radiation induced swelling as well as pellet/clad interaction can induce micro-cracking in and around the fibers. To combat this, seal coatings are being investigated to provide a hermetic layer on the outer surface of the cladding. These coatings need to withstand hydrothermal corrosion, property changes due to neutron irradiation, thermal cycling, and SiC irradiation induced swelling. Existing coating work on zirconium-based fuel cladding material has provided foundational work for potential corrosion resistance coatings. However, the large swelling induced interfacial stresses anticipated in SiC cladding requires more mechanically tough coating than for Zr-based fuel . The first generation of Cr, CrN, and TiN coatings produced at ORNL experienced cracking post neutron irradiation . To understand the mechanical properties of the coating, x-ray residual stress analysis, scratch tests, and nano-indentation results of the as-fabricated first generation of cathodic arc coatings will be related to the irradiation induced cracking phenomena. Subsequently, characterization of the second generation of high-power impulse magnetron sputtering (HiPIMS) and b-field assisted cathodic arc deposited coatings will be presented. The mechanical properties of the first and second generation coatings are compared to determine the efficacy of HiPIMS and multilayer coatings.

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