Microstructural and nanomechanical studies of PVD Cr coatings on SiC for LWR fuel cladding applications

The microstructure and nanomechanical properties of pure Cr coatings deposited on SiC with various physical vapor deposition (PVD) methods have been investigated for the mitigation of hydrothermal corrosion of SiC-SiCf (SiC fiber-reinforced SiC matrix) composite fuel cladding in light water reactors (LWR). Cr coatings (4–7 μm thick) were deposited on unbiased SiC substrates using six variants of magnetron sputtering processes: (i) standard (S-DCMS), (ii) pulsed (P-DCMS), (iii) ion-assisted (I-DCMS), and (iv) pulsed ion-assisted direct current magnetron sputtering (PI-DCMS), (v) high-power impulse magnetron sputtering (HiPIMS), and (vi) bipolar HiPIMS (B-HiPIMS). Microstructural characterization and nanoindentation testing were used to evaluate effects of deposition technique on coating microstructure and nanomechanical properties. The application of positive reverse pulses to the sputter target induced coarsening of the columnar grain structure, while ion bombardment of substrates during deposition promoted densification of the coating microstructure. Both effects are exemplified in B-HiPIMS deposition, resulting in a high-density microstructure with compressive residual stress. Material pile-up around nano-indents and plastic work during nanoindentation were analyzed to understand deformation behavior of the coatings. The results suggest the B-HiPIMS process to be among the promising methods for the deposition of Cr coatings on SiC-SiCf for LWR cladding application.