ICSMA19 Metz, France, June 26 - July 1, 2022
International Conference on Strength of Materials

Microscale fracture toughness of (Hf-Nb-Ta-Zr)C multi-element carbide coatings

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Super hard materials with good toughness find several applications, prominently in the tool industry. We show that multi-element carbides are promising candidates to achieve high hardness, fracture strength and modest fracture toughness. DC-magnetron sputtering was utilized for depositing (Hf-NbTaZr)C coatings on Si (SiNx) substrate at different temperatures (573,723,873 and 1023 K). X-ray diffraction was used to finger-print crystal structure, determine residual stresses and the thermal expansion coefficient. Extensive microstructural characterization of deposited films were carried out through scanning electron microscopy, transmission electron microscopy and atom probe tomography. Modest variation in microstructure (grain widths 10-25 nm) with columnar grain boundaries enriched in carbon was observed with increasing deposition temperature. Nanoindentation with a Berkovich tip revealed nearly super hard coatings were obtained for low deposition temperatures (~39 GPa). Microcantilevers with a starter notch were fabricated through focused ion beam (FIB) milling. An Asmec in situ nanoindenter inside the SEM was used to determine fracture toughness of coatings. Cube corner indentation and FIB serial sectioning was also employed to determine the true toughness of the coatings by deconvoluting the effect of residual stresses. Fracture in these coatings were controlled predominantly at the carbon enriched grain boundaries.

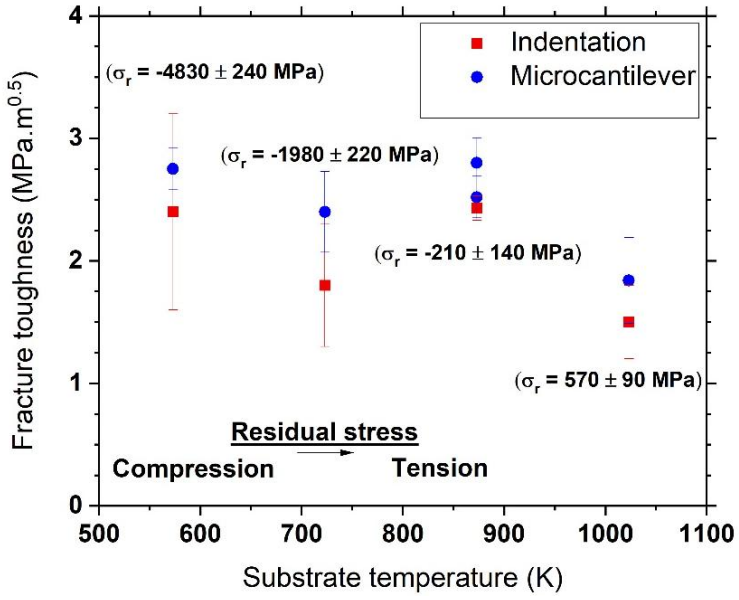

Figure 1. A comparison of true toughness of coatings deposited at different temperatures through cube corner indentation and notched microcantilever tests.