FRACTURE PROPERTIES OF CrN HARD COATINGS: INFLUENCE OF THE MICROSTRUCTURE, ALLOYING ELEMENTS, AND COATING ARCHITECTURE

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Transition metal nitrides are well known and applied as protective coating materials based on their unique refractory characteristics, such as high hardness or Young's modulus. However, for long-term applications, the fracture toughness K_{IC} is an essential factor as the integrity of the coating-substrate interface is impaired by cracking and subsequent environmental attacks.

Within this study, we investigated the influence of the microstructure on the fracture properties of cathodic arc evaporated CrN coatings using in-situ micromechanical cantilever bending tests. Our systematic variation in deposition parameters and architectural designs, accompanied by a comprehensive structural and morphological analysis (XRD and HR-TEM), excluded pure size effects prevalent in enhancing fracture toughness. Instead, the column boundary constitution (by implementing stresses or further alloyed elements) dominates the fracture characteristics and needs to be adapted to gain higher K_{IC} (larger than 2.0 $MPa{\cdot}m^{0.5}$). In more detail, we compared the two different strategies of architectural arrangements and alloying to enhance the fracture toughness of hard CrN. Selective alloying by silicon lead to a distinct hardness and fracture toughness increase (up to 27.5 GPa and 2.7 $MPa{\cdot}m^{0.5}$), but on the extent of the young's modulus. Nevertheless, targeted layer architectures achieve the highest fracture toughness values for all CrN coatings investigated. Using a so-called superlattice architecture consisting of alternating CrN and TiN layers with a single-layer thickness of a few nm, a fracture toughness value of 3.7 $MPa{\cdot}m^{0.5}$ was gained. This corresponds to an increase of 85 % compared to monolithic CrN and 28 % compared to the introduced TiN. The enhancement is attributed to introduced coherent stresses between structurally identical (face-centered cubic, SG #225) CrN and TiN unit cells – but with diverging lattice parameters. In contrast, this mechanism is only partly attributed to the observed hardness increase, being more related to a difference in the shear moduli of the individual layers.

This study highlights practical ways to enhance the fracture toughness of hard CrN coatings. Coherent stress fields through superlattice arrangements revealed to be most promising to increase K_{IC} while simultaneously increasing their hardness.