Role of grain boundaries and temperature on the fracture toughness of CrN and AlN hard coatings

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Abstract

The application of hard coatings, such as carbides and nitrides, has become essential in industries like aerospace, automotive engineering, and cutting tools, primarily due to their high hardness and ability to withstand harsh environments. However, fracture toughness is equally crucial, as coatings with insufficient toughness are prone to cracking and failure under cyclic thermal or sudden impact stress (e.g. in interrupted cutting processes). Grain boundaries (GBs) play a significant role in influencing both hardness and fracture toughness, yet the mechanisms governing fracture toughness, particularly at elevated temperatures, remain unclear. At room temperature, we conducted in situ scanning electron microscope microcantilever bending tests to examine the effects of GB orientation and density on the fracture toughness of CrN, AlN, and CrN/AlN multilayered structures. Specifically, we varied the loading direction relative to the columnar grain structure, observing a 10% increase in fracture toughness when the loading direction was perpendicular to the growth direction. Additionally, we compared submicron-sized columnar microstructures with epitaxial structures, noting a 30% higher fracture toughness in the epitaxial coating, which was free of GBs. Furthermore, at elevated temperatures, fracture toughness significantly decreased due to void formation and oxidation, particularly at the deposition temperature.

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