PO4058

Dedicated grain-boundary design by glancing angle deposition for fracture toughness enhancement of brittle nanocrystalline films

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Hard and superhard ceramic nanocrystalline thin films are known for extraordinary strength as well as lack of plasticity. The dominant failure mechanism of these materials is intergranular brittle fracture associated with grain boundaries of low cohesive energy. This limits their usage in applications where both strength and toughness are required.
In this contribution, two sets of TiN films with a sculptured chevron like grain morphology differing in density were sputter deposited by glancing angle deposition technique under various conditions. The films were tested by in-situ bending of microcantilever beam specimens in order to evaluate (i) elastic modulus, (ii) fracture stress and (iii) fracture toughness. The repeatedly tilted grain morphology resulted in multiple crack deflections at kink planes of the tilted grains, yielding energy dissipation at the crack tip and an increase of the fracture surface area. Due to the dedicated grain boundary orientation design, the fracture toughness increased up to 150% with respect to the reference TiN film with common columnar microstructure. It is deduced that number of crack deflections as well as density of the deposited film are critical values for the improvement of its fracture toughness. Based on the experimental results, it is expected that by a dedicated design of grain boundary orientation, it is possible to synthesize novel types of materials with enhanced fracture resistance.

Keywords
grain boundary design
micromechanical testing
fracture toughness enhancement