ON THE EFFECTS OF MICROSTRUCTURAL ORIENTATION ON FRACTURE TOUGHNESS IN (V,Al)-NITRIDE AND -OXYNITRIDE THIN FILMS

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Keywords: beam bending, fracture toughness, thin films, vanadium aluminium nitride, vanadium aluminium oxynitride

Transition metal nitrides and oxynitrides produced via plasma deposition are widely used as hard, protective coatings in the manufacturing industries. Understanding the mechanisms linking microstructure to their fracture behaviour is required to optimise wear resistance while maintaining fracture toughness.
Two sets of (V,Al)ON samples, one fine-grained, produced by high-power pulsed magnetron sputtering (HPPMS) and one columnar, produced by direct current magnetron sputtering (DCMS) and two sets of columnar (V,Al)N samples, one manufactured by each process route, were investigated. To assess how the microstructure affects fracture, beam bending was performed using microcantilevers oriented parallel and perpendicular to the growth direction. Furthermore, the tests were applied to favour mode I and shear (mode II) fracture.

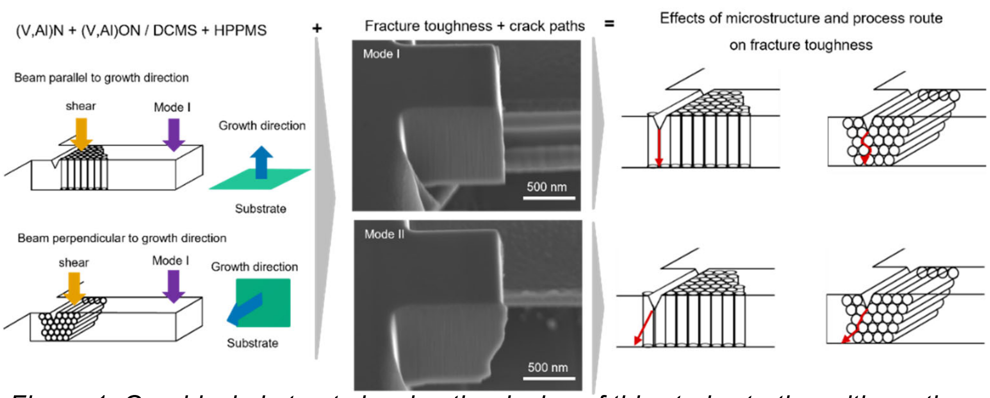

Figure 1: Graphical abstract showing the design of this study starting with coatings exhibiting various microstructures and studying the effects of those on fracture toughness by beam bending.

In the course of this work by comparing mode I and mode II beam bending, we show that HPPMS coatings exhibit denser and stronger interfaces which leads to a higher fracture toughness. Nevertheless, DCMS showed higher fracture toughness values due to the observations that the crack stopped at underdense regions in the microstructure and needed to be newly initiated.
Furthermore, the nitride and oxynitride coatings from the same process routes were compared and it was found that the oxynitrides exhibit a higher fracture toughness caused by oxygen induced stabilisation of the interfaces. However, they showed lower Young's moduli due to the weaker M-O bonds.
In addition, the effects from microstructure could be studied regarding the differences between the typically columnar structures in DCMS coatings and HPPMS nitride compared to the HPPMS oxynitride with its fine-grained structure. Thus, a fracture toughness superior by around 300% could be observed for fine-grained structures, which enhances the toughness more than a chevron-shaped structure would. This effect could also be achieved in a less pronounced way in the columnar structures by changing the orientation of the column growth direction in relation to the loading direction by 90°.
To summarise, we show here that the fracture toughness depends on the alignment of the grain and loading directions as well as on the process route during deposition. Furthermore, an improved fracture toughness was found due to effects coming from microstructure such as crack deflection in the fine-grained microstructure or an interruption of the crack propagation by underdense structure in DCMS coatings. Out of the specimens investigated in this study, the HPPMS deposited oxynitride showed the best combination of elastic properties and fracture toughness. However, all other specimens showed the potential to improve their fracture behaviour by engineering the microstructure and elastic properties.