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Evolution of structure, stresses and mechanical properties of a fcc/hex-AlCrN multilayer system upon thermal loading revealed by cross-sectional X-ray nanodiffraction and micromechanical testing

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The development of hard protective coatings for machining applications relies mainly on the stabilisation of the metastable cubic structure of transition metal nitrides such as AlTiN and AlCrN by alloying to preserve their exceptional mechanical properties also at high temperatures. The suppression of thermal decomposition of the metastable cubic phase (accompanied by loss of strength) thus allows for a better performance of coated tools at high loads and speeds. The cubic structure can also be stabilized by sophisticated stress design and architecture of the coatings. However, although these materials are very strong, they suffer from low fracture toughness. This can be effectively enhanced if phases with different structure and properties are combined in a layered architecture and propagating cracks subsequently arrested or deflected at interfaces. In this work, hard fcc-CrAlN was combined with soft hex-AlCrN in amulti-layered architecture and the effect of microstructure on the development of the stresses and mechanical properties studied. The depth-evolution of the structure and stress state across the coating thickness was revealed by position-resolved cross-sectional X-ray nanodiffraction. The dependence of the mechanical properties of the coatings, such as stiffness and fracture toughness, on their microstructure was studied by micromechanical testing of cantilever beams. Besides the study of as-deposited coatings, the specimens were also annealed above the decomposition temperature to investigate the subsequent development of the microstructure and stresses across the coating thickness and its effect on the mechanical properties. The experiments revealed development of pronounced microstructure-related stress depth gradients dependent on the coating architecture and the stage of decomposition, which significantly affected the mechanical properties.

Keywords
structure-stress relations