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Improving phase stability, hardness and oxidation resistance of reactive magnetron sputtered (Al,Cr,Nb,Ta,Ti)N thin films by Si-alloying

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High-entropy alloyed nitrides are promising materials for hard coatings. One major drawback is a lack of oxidation resistance in most coatings, which limits high-temperature applications in ambient conditions. In this work we report a method to increase the oxidation resistance while also improving thermal and mechanical stability of the alloy.

(Al_wCr_wNb_xTa_yTi_z)N coatings were formed in a cubic solid solution in thin film form by reactive magnetron sputtering in N₂-atmosphere using a powder metallurgically prepared metal target (Plansee) with nominal composition of 20 at% of each element. Si was alloyed by placing different numbers of pieces (about 2x2x0.4 mm³ each) of Si on the cathode racetrack during deposition. The hardness and indentation modulus of the as-deposited samples were ~32.6 GPa and ~462 GPa without Si, and ~35.4 GPa and ~328 GPa with Si, respectively. X-Ray Diffraction (XRD) measurements of the samples after vacuum annealing to temperatures up to 1200 °C revealed that Si delays the decomposition from 1000 °C to 1200 °C. After vacuum annealing to 1100 °C we measured a hardness of ~30.3 GPa and ~38.1 GPa as well as an indentation modulus of ~445 GPa and ~430 GPa for the samples without and with Si, respectively.

We gauged the oxidation resistance of the coatings by placing the samples in a furnace in ambient air at 850 °C for 0.5, 1, 5, 10, 30, and 100 h. After these durations we extracted the samples from the hot zone and analysed them with XRD, and Energy-Dispersive-X-Ray-Analysis (EDX). Without Si, the oxide scale was 2800 nm thick after 100 h, with Si-alloying the oxide was only 300 nm thick. Thus the oxidation resistance was improved significantly.

Based on our results we can conclude that this type of high entropy nitride coatings, especially when alloyed with Si, provides excellent thermomechanical properties as well as oxidation resistance.

Keywords

High Entropy Ceramic
Hard Coating
Oxidation