CHARACTERIZATION OF THE DAMAGE TOLERANCE OF NANODESIGNED COATINGS BASED ON HIGH ENTROPY ALLOYS

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Abstract
Coatings are primarily designed to offer excellent wear and corrosion resistance. However, these properties are adjusted at the expense of the damage tolerance of the materials applied. By introducing the concept of high entropy alloys new property combinations are expected. In this contribution coatings composed of purely refractory HEA nitride as well as coatings containing non-refractory elements such as Al or Si will be presented. The focus is on a comparison of different experimental strategies to evaluate the damage tolerance of these coatings.

1. Introduction
Although there is a great industrial demand for super-hard thin-film systems (hardness > 40 GPa), extremely high temperature resistance (T > 1000 °C) and high damage tolerance for wear protection of tools and components, layers with such a property profile have not yet been synthesized. On the one hand, this is due to the fact that with the existing material and design concepts only a part of the desired property profile can be realized. On the other hand, the mechanical properties determining deformation and damage behavior for thin hard material layer systems are still not sufficiently understood. By linking the material concept of high entropy alloy (HEA) with the design concept of nanostructured thin-film systems offers a potential to reach new levels of the above-mentioned property combinations. By using the characteristics typical of HEA (pronounced solid solution hardening and sluggish diffusion), new and previously unattained macroscopic property combinations are to be expected. The basis will be a nanomultilayer design of the type HEA-N/HEA realizing particular high damage tolerance, since the transition from nitride to metal significantly reduces modulus of elasticity (300 GPa to 130GPa) as well as strength (hardness: 30GPa to 10GPa). The coatings were deposited via DC vacuum arc deposition from compound targets. In the more ductile metallic interlayers, additional stresses can be plastically degraded at the crack tip. However, the determination of the process-microsructure-property corrlations on the nano- and microscale requires the application and further development of established test methods for thin-film characterization and the use of high-resolution in situ and post-mortem structural analysis investigations. Results from in situ bending, nano-indentation and scratch tests are compared and the potential of the nanodesigned HEA-nitride coatings is discussed.

2. Results
Six different HEA nitrides have been deposited by cathodic vacuum arc deposition: AlCrTaTiZr, AlCrMoTaTiZr, AlCrNbSiTiV, HfNbTiVZr, CrHfTiVZr and HfNbTaTiVZr. All coatings display single phase fcc microstructure and their hardness varies between 25 and 37 GPa, see Fig. 1, with the H^3/E^2 ratio serving as toughness indicator. The highest hardness could be achieved for (AlCrTaTiZr)N, (AlCrMoTaTiZr)N and (AlCrNbSiTIV)N and is most likely correlated to pronounced grain refinement. The application of multilayer design further improved hardness from around 33 GPa towards 40 GPa. While the scratch tests revealed a high resistance at R = 100 µm (Fig. 2) the results also indicated a dependence of the wear resistance on the compressive residual stresses of the coating system. In situ bending was applied to correlate the formation of crack lines on the surface with the bending angle. While this approach allows a qualitative comparison of the damage tolerance of the coatings one of the major drawbacks was the associated need for large samples and resulting fluctuations in the coating quality. As a consequence in situ observation of the damage evolution during mechanical loading was transferred from bending to tensile loading by applying a Kammrath&Weiss testing device. The evaluation of the results as well as the

quantitative determination of toughness values on the basis an analytical approach are the focus of ongoing work.

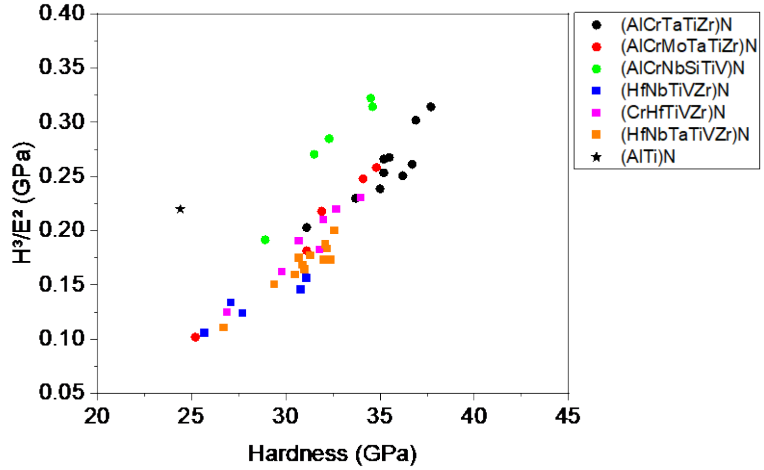

Fig.1 – H^3/E^2 ratio in dependence of the hardness H for different HEA coatings.

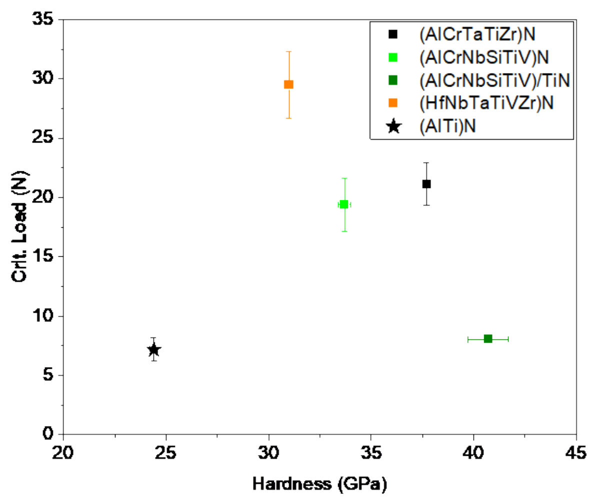

Fig. 2 – Critical load during scratch test inn dependence of the hardness H for different HEA coatings.

3. Conclusions

It could be shown that the concept of HEA nitride coatings have the potential of increasing hardness. Depending on the measuring strategy promising results for the toughness could also be detected. However, further experimental work is needed to clearly separate influence factors coming from the measuring concept from the true coating material design.

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