Nanostructured materials | Jožef Stefan Institute Ljubljana, Slovenia

SEMINAR

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Towards the electrodeposition of high-entropy alloys: Electroplating of homogeneous and graded composition Co–Fe–Ni–Zn films

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One of the most dynamically developing fields of materials science focuses on studying near-equiatomic alloys with three or more elements. In these materials, neither of the components can be classified as either solvent or solute. This material family is frequently called as multi-principal element alloys (MPEAs), compositionally complex alloys (CCAs), or, if the number of the components is at least five, high-entropy alloys (HEAs).

MPEAs can be manufactured with a wide range of traditional metallurgical techniques, but the number of electrochemical processing attempts is very limited. MPEA electrodeposition works apply various approaches: (i) dilute solution of the precursor materials in a non-aqueous solvent; (ii) classical electrodeposition from aqueous baths; and (iii) electroreduction of metal oxide pellets. Due to the small number of paper published so far, only a few selected compositions were studied. The presentation will account in details for the classification of the works published so far.

In our experiments, Co–Fe–Ni–Zn MPEA layers were processed by pulse electroplating for the first time. The reason of choosing pulsed electrodeposition as preparation techniques was multifold, such as to achieve an even in-depth composition, to obtain nanocrystalline layers and to curtail the surface roughening commonly observed in electroplating. The bath used was based on metal chloride precursor compounds and traditional additives. The substrate was a tantalum foil.

In a custom-made symmetrical electrochemical cell, a compositionally very homogeneous deposit could be obtained. The optimization of the bath composition was a time-consuming procedure due to the large variation in the relative deposition preference of the alloy components. The film had a main fcc phase and the average grain size was as small as ~12 nm. The size distribution was wide spanning from 5 to 27 nm. The microstructure also contains a bcc minority phase and ~2 nm thick amorphous boundaries separating polycrystalline columns. The average hardness and elastic modulus determined by nanoindentation were 9.2 and 197 GPa, respectively. This hardness is much higher than the values reported formerly on fcc MPEAs processed by other methods (3.6–6.9 GPa) which can be explained by the very small grain size and the existence of the bcc and amorphous minority phases.

An asymmetric electrodeposition cell configuration was developed for preparing alloys of gradient composition (sample library approach). It was found that the element with the smallest precursor compound concentration, Zn, was gradually replaced with the next element in the preference row, Co. Therefore, the Zn concentration range of 14–44 at.% could be scanned. The lattice constant scaled with the Zn concentration of the deposit, and the hardness changed only little with the composition. The latter aspect is considered as an advantage in practical applications.

Kindly invited.