NANOMECHANICAL CHARACTERIZATION OF HIGH PRESSURE TORSION PROCESSED HfNbTaTiZr HIGH ENTROPY ALLOY

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High entropy alloys (HEAs) are a new material class in which the configurational entropy of a multicomponent solid solution phase is maximized so that the entropy of mixing stabilizes disordered solid solution phases against the possible intermetallic phases development. Generally, to achieve high entropy of mixing, the alloys contain typically five or more major elements in equimolar concentrations. The composition of HEAs is generally based on 3d transition metals, refractory metals, light metals, lanthanide transition metals, precious metals, brasses and bronzes. The HEAs exhibit promising structural and mechanical properties in wide range of applications.

Mechanical properties of such alloys can further be improved by grain refinement especially by severe plastic deformation. However, studies of ultrafine grained HEAs are rather scarce in the literature. An increase of strength with decreasing grain size was achieved in the probably most investigated HEA i.e. Cantor alloy (equiatomic CoCrFeMnNi with fcc structure) processed by high pressure torsion (HPT) [1]. Much less attempts were made to process in such a way HEAs with bcc structure. Recently HfNbTaTiZr bcc HEA was successfully nanostructured by HPT straining [2]. It was reported that grain refinement by HPT resulted in a significant enhancement of the strength of this bcc HEA, keeping excellent ductility during room temperature straining. Nevertheless, there is still a lack of information about the development of microstructure and physical properties of this refractory metal HEA subjected to severe plastic deformation processing.

Recent investigations [3] revealed that thermodynamically stable system of HfNbTaTiZr alloy at room temperature is a mechanical mixture of Zr, Hf rich hcp phase and Ta, Nb rich bcc phase. The decomposition of the solid solution after long-term annealing obviously leads to the deterioration of mechanical properties (loss of ductility and decrease of strength). The difference in hardness of both phases is relatively small and both are softer than the random solid solution. On the other hand, considerable contribution to the solid solution strengthening can arise from atomic size misfit (phase separation on the nano-meter scale) which is provoked by the high density of vacancies introduced by HPT.

This work thus aims on the relationship between phase (de)composition, microstructure, lattice defects, and length-scale-dependent material response of HfNbTaTiZr HEA after different thermal treatment and HPT straining. The microstructure and phase composition evolution were characterized by the electron microscopy and X-ray diffraction. The length-scale-dependent material response was characterized by indentation at various indentation depths. The contributions of different hardening mechanisms were separated and attributed to distance between dislocation pinning defects so that the differences between thermal treatment (diffusion) and HPT (straining) -induced hardening could be explained.

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