DFG Schwerpunktprogramm / Priority Programme Compositionally Complex Alloys – High Entropy Alloys (CCA-HEA)

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Solid solution strengthening in TiZrNbHfTa BCC high entropy alloys

The proposed research program aims at contributing to a better understanding of solid solution strengthening in body centered cubic (BCC) TiZrNbHfTa high-entropy alloys (HEAs) and shed light on elementary deformation mechanisms responsible for their mechanical properties. HEAs contain five or more elements and are defined in the frame of this priority program as single solid solution phases. Only few alloys were reported in the literature which comply with this definition. Recent studies provided relevant data for a better understanding of solid solution strengthening and a theory was recently developed for FCC HEAs. While this constitutes an important breakthrough in our understanding, such a theory is still lacking for BCC HEAs. BCC HEAs have so far received less attention from metallurgists due to their extreme brittleness at 293 K. However single phase BCC alloys belonging to the TiZrNbHfTa system have been recently reported to have an excellent combination of strength and ductility. Refractory metals such as those present in TiZrNbHfTa HEAs are difficult to melt by casting due to their high melting points. In this context, additive laser manufacturing appears as a promising alternative processing route to produce HEAs by in situ alloying of refractory elemental powders. Indeed, this technique involves a highly focused laser beam which allows to rapidly melt particles of refractory metals. More importantly, HEAs with a gradient of chemical composition can be produced using different powder blends. This possibility makes additive laser manufacturing particularly attractive to study the effect of chemical composition on mechanical properties. In the present research project, pseudo-binary composition libraries of TiZrNbHfTa HEAs will be produced and phase analyses will be performed to identify in which composition range a single BCC phase is present. After having characterized their mechanical properties (strength), the composition dependencies of the elastic and lattice parameters, which constitute the basis of most of existing solid solution strengthening theories, will be determined. These experimental data will serve as benchmark data that will help to establish a theory for solid solution strengthening in BCC HEAs. Finally, Bulk TiZrNbHfTa HEAs with promising compositions will be produced. An effort will be made to process these alloys in order to obtain a homogeneous microstructure in terms of grain size distribution and composition. For the first time, tensile tests of TiZrNbHfTa HEAs will be performed in the temperature range [77-293 K] to determine whether these alloys exhibit a brittle-to-ductile transition. Moreover, the microstructural evolution during straining will be characterized by transmission electron microscopy. These experiments will shed light on the deformation mechanisms responsible for the mechanical properties of BCC HEAs.