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

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Tailored precipitation (B2, L21) strengthened, compositionally complex FeAlCr (Mn, Co, Ni, Ti) alloys for high temperature applications

High entropy alloys (HEAs) or compositionally complex alloys (CCAs) are multicomponent systems with typically more than five alloying elements. The large compositional space offers attractive alloy design strategies and initially it was assumed that by maximizing the entropy of mixing, true single phase solid solutions can be established. However, only very few successful single phase alloys could be obtained in the past 10 years of HEA development and in the majority of cases multi-phase microstructures, including intermetallic phases, form. However, such multi-phase alloy systems could yield alloys bridging the enormous gap between Titanium and Nickel-based alloys in terms of alloy density and application temperature, but this application field is rarely explored. The aim of the present work is to develop body-centered cubic (BCC) CCAs with tailored precipitates based on B2- and/or L21-phases with densities of < 7 g/cm3 for high temperature applications up to 900ºC. In a first step, the phase formation in the rather unexplored composition space of FeAlCr (Mn, Co, Ni, Ti) is explored by high throughput screening and characterization based on thin film deposition techniques. Promising alloy candidates are identified fulfilling the conditions to have a BCC crystal structure and showing either B2, L21 or both types of precipitate phases. In further steps, these alloy candidates are then obtained by conventional casting techniques to investigate the microstructure and precipitate structure in as-cast alloys and to evaluate their high temperature stability after thermal exposure of up to 900ºC. The alloy design approach is based on a microstructural optimization in terms of precipitate morphology, coherency with the supersaturated BCC matrix and their volume fraction. Tailored microstructures are then mechanically tested from room up to temperatures of 900ºC to establish the microstructure-property relationship for further optimization steps. In addition, first high temperature creep experiments give insights into the microstructural stability at elevated temperatures under load and the operating deformation mechanisms. The microstructural characterization and mechanical property evaluation throughout the alloy design process are cornerstones of the presented research. The combination of mechanical testing with advanced characterization techniques such as X-ray diffraction, transmission electron microscopy and atom probe tomography is guiding the development of these novel alloy systems from a mesoscopic length scale down to the atomic scale.