DE 796/13-1
JA 2482/3-1
UH 77/11-1

Particle-strengthened Compositionally Complex Alloys - interlinking powder synthesis, additive manufacturing, microstructure evolution and deformation mechanisms (PaCCman)

This project will investigate if particle strengthening is a viable mechanism for compositionally complex alloys (CCA) showing exceptional mechanical properties. Even though it is known that many CCA contain nano-scaled particles, their precipitation mechanism, kinetics and influence on plastic deformation mechanisms are not yet understood. It is debated whether stacking fault energy, Peierlsbarrier dominated lattice friction, or precipitates govern the deformation mechanisms in such alloys. Whether precipitates form analogously to conventional alloys, and, if so, with similar precipitation kinetics, still needs to be studied. Extending the concept of CCA to intentionally particle strengthened CCA (p-CCA) in a systematic way requires full microstructure analyses down to the atomic level to separate effects of atomic strain in a random alloy from nano-sized ordered regions impacting dislocation glide. We will tackle these questions by a combination of high-resolution analysis employing transmission electron microscopy and atom probe microscopy, mechanical testing and quantitative in-situ micro-mechanical experiments. We will study two different kinds of p-CCA. First, we will generate alloys strengthened by B2-intermetallic phase particles by adding Al to the A1-matrix alloy CrFeCoNi and by reducing the Mn content of the A2-matrix alloy AlCrMnFeCoNi. Second, we will investigate the same base alloys strengthened by nitride particles generated upon enrichment of the alloy melt with nitrogen. The p-CCA specimens will be fabricated using a flexible powder metallurgical route via alloy melting, gas atomization and Additive Manufacturing by Selective Laser Melting (SLM). This route allows to take advantage of several beneficial features of the SLM process including rapid solidification to avoid microsegregation, access to supersaturated solid solution states as precursor for precipitation, and near-net shape production of specimens in the 10-cm size range. The SLM-process parameters will be tailored to produce fully dense p-CCA specimens. Suitable heat treatments will be developed to accomplish chemical homogeneity of the specimens and to provoke precipitation of intermetallic phases. The powders used for SLM pre-determine the microstructure of the SLM-produced p-CCA: Successful usage in SLM depends on proper powder size, morphology and flowability, while phases in the powder that do not re-dissolve during SLM will leave a fingerprint on the microstructure and mechanical properties of the resulting materials. Thus, the powder technology is a central aspect of the project. We will develop atomization techniques for p-CCA, optimize powder flowability and investigate the usage of flowability enhancing additives. A sound material scientific understanding of p-CCA will be achieved by the combination of alloy selection, powder production, SLM processing, thermal post-processing, mechanical testing and high-resolution analysis as proposed in this project.