

Alloy design for Mo-based silicide materials to tailor the mechanical and oxidation response

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Refractory metal-based alloys are attractive candidates for high temperature structural applications, especially when combining a ductile and tough solid solution phase with creep and oxidation resistant silicide phases. The properties of this type of multi-phase materials is significantly affected by the microstructural design, i.e. the chemical composition of the solid solution phase using various alloy additions, the volume fraction and homogeneous distribution of the solid solution phase and the silicide phases, the grain size and orientation as well as the concentration of dissolved detrimental impurities and impurity phases. Balancing the ambient and high temperature properties of such alloys requires to tailor their microstructures. This needs an optimization of the chemical composition using additional alloying elements and the modification of alloying concepts with respect to the manufacturing methods. Analysing the solidification path to understand microstructural evolution or – in other cases- the diffusion mechanisms during sintering is essential. However, processing of refractory metals and alloys is quite challenging due to the ultra-high melting point above 2000°C and their strong tendency to oxidize at intermediate temperatures. Different processing routes of multi-phase Mo-Si-B alloys by powder metallurgical (PM) routes, directional solidification (DS) processes and laser-based additive manufacturing (AM) techniques will be presented. It will be shown that the AM materials are crack-free and the constituents are homogeneously distributed. The microstructure is very fine as can be compared to powder metallurgically processed Mo-Si-B. Interestingly, the brittle ductile-transition temperature of AM Mo-Si-B materials is lower as compared to similar alloy compositions produced by other processing methods. Creep response is investigated by stress controlled creep tests at temperatures > 1000°C. In general, the creep resistance of Mo-Si-B alloys depends not only on the microstructure size scale but also on the morphology and volume fraction of the weak Mo solid solution phase and the creep resistant silicide phases. Furthermore, the experimental data were used as a basis for thermal and mechanical analyses by the finite element method using a simple turbine blade geometry.