Powder Metallurgy of Hybrid Materials for Advanced Applications

The field-assisted sintering technology (FAST) is a versatile powder consolidation method, which uses electrical current for rapid heating of the sintered material. It is routinely used for sintering of various metallic materials, but mostly with prealloyed powders as a feedstock. The aim of the thesis is to explore the capabilities of FAST for sintering of composite materials and for using blended elemental powders as a raw material in following areas:

1. Manufacturing of architectured composites
2. Consolidation and ageing in a single processing run (in-situ ageing)
3. Rapid alloy prototyping using blended elemental powders
4. High-throughput experimental investigations of multicomponent phase diagrams

Al6061 + Ti-6Al-4V architectured composite was produced, but issues with the powder penetration into the lattice have arisen due to the small lattice dimensions. Mechanical properties could have been assessed by a three-point bending only. The composite has shown improved strength over the plain, unannealed Al6061 matrix, but a premature fracture when the Al matrix was aged properly. Using FAST was found to be inconvenient for architectured composite manufacturing.

A long, fully dense rod was manufactured from the Ti-5Al-5V-5Mo-3Cr alloy with blended elemental powders as a starting material. The whole process of consolidation, homogenization and ageing was carried out in a single process run and the tensile properties of the alloy was fully comparable to the commercially available material, reaching 1183 MPa of yield strength and a ductility of 6 %. It was shown that FAST can be used for preparation of alloys with good mechanical properties from blended elemental powders.

The phase stability of the Ti-(20–29)Nb-7Zr-(0.2–0.8)O system was investigated using materials with deliberately produced Nb concentration gradient. The critical concentration of 22 wt% of Nb was measured to suppress the α/α'' precipitation. Homogeneous alloys were prepared from the elemental powder blend as well, the phase composition and elastic modulus were measured by X-ray diffraction and resonant ultrasound spectroscopy in the as-sintered and water quenched conditions. The lowest elastic modulus of 64 GPa was measured in the quenched Ti-29Nb-7Zr-0.7O sample. It was demonstrated that samples with a tunable chemical heterogeneity can be prepared FAST.

Finally, we have designed a method for sintering multiple powder blends in a single specimen, able to produce a heterogeneous sample with a wide range of alloy compositions. This method allowed high-throughput investigations of phase equilibria in an AlTiTaNbZr refractory complex concentrated alloy. Using FAST is considered viable and will be explored further.

Out of the explored areas of FAST applications, manufacturing of architectured composites is not very much viable, while the blended elemental based methods have proven themselves useful in research and should be exploited further.