Nanostructured materials | Jožef Stefan Institute Ljubljana, Slovenia

Masters - SEMINAR II

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Rapid Radiation Sintering of Additively Manufactured Alumina Tetrahedron Frameworks

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Additive manufacturing (AM), particularly fused filament fabrication (FFF), enables cost-effective manufacturing of larger-sized, complex-shaped ceramic components that are otherwise difficult to form using traditional shaping methods. However, achieving complete densification through a sintering process while retaining submicron-sized microstructure remains challenging. Spark plasma sintering (SPS) is the most straightforward advanced sintering concept to rapidly sinter nanoceramics through the application of electric current and uniaxial pressure, but the applied pressure prevents sintering of ceramics produced via AM. In the present seminar FFF technique is employed for the fabrication of complex alumina shapes, sintered using a modified SPS set-up, called pressure-less spark plasma sintering (pSPS). The goal was to obtain dense, fine-grained microstructures by exploiting intense thermal radiation during high heating rates (33, 100 and 300 K/min) and short dwell times. Here, the effect of increased heating rates on the sintering outcome (homogeneity), densification, microstructural evolution and mechanical properties of larger-sized complex tetrahedra geometries with strut thickness of 5 mm, whereas the edge lengths varied from 15 mm to 40 mm, was studied in detail.

The three heating rates yielded completely dense (~96%), fine, micron-sized alumina microstructures with comparable grain sizes. The increased heating rates limited grain growth, which was in the range of the particle size of the commercial filament feedstock. A distinct core-shell microstructure formed due to non-uniform heating, with the shell exhibiting coarser grains and higher hardness, due non-uniform heating. The Hall-Petch effect was evident in the increased hardness of finer-grained base edges compared to lateral edges. Variations in shrinkage and crack types are explained by anisotropic nature of the FFF method and the differences in heating rate and sample size. Cracks were observed only in large tetrahedra, resulting from thermal gradients and shrinkage mismatches during sintering. Additionally, the grey discoloration of sintered samples is attributed to oxygen vacancy formation under vacuum conditions. These findings demonstrate the potential of PSPS for pressure-less, radiation-assisted rapid densification of complex shaped ceramics, enabling energy-efficient, rapid fabrication of advanced fine-grained ceramic (micro)structures.

Kindly invited.