Nanostructured materials | Jožef Stefan Institute Ljubljana, Slovenia

SEMINAR II

Wednesday, 25.9.2024, 10:00, Kolar's Lecture Hall

In situ graphitisation of cellulose nanofibers in 3Y-TZP during the rapid radiation sintering

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Ceramic matrix composites (CMC) comprise of matrices of ceramic grains "reinforced" by the grain boundary (GB) phase, which alter their intrinsic properties or embed new ones (electrical conductivity). Processing of CMCs, where sintering is a crucial step of consolidation, is gaining a lot of momentum. Usually, CMCs are obtained by the incorporation of carbon nanofillers, such as carbon nanotubes or graphene, sintered in a conventional Spark Plasma Sintering (SPS) apparatus. However, especially in the case of graphene flakes, the uniaxial pressure during SPS results in the anisotropic alignment of the flakes perpendicular to the application of pressure giving rise to anisotropy of properties (electrical versus mechanical). To mitigate this, it was recently shown that it is possible to employ a more sustainable approach, where cellulose nanofibres (CNF) in an aqueous gel form can be homogeneously incorporated into alumina and zirconia powders. After sintering using SPS process, the incorporated CNF in the ceramic matrices were in situ graphitised into few-layered graphene (FLG) GB phase homogeneously throughout the matrix providing electrical percolation. The electrical conductivity was 400 S/m for the alumina CMC and 250 S/m for the zirconia CMC. Nevertheless, such approach is limited to simple geometries not suitable for additively manufactured complex shaped ceramic components.

However, the so-called pressureless (PSPS), a modification of SPS technique, has already proved to be successful for sintering of additively manufactured, complex-shaped ceramics through its radiation-assisted heat transfer without the application of mechanical pressure nor electrical current. The goal of the PhD project presented in Seminar II was to exploit the intense thermal radiation that evolves in PSPS apparatus and investigate the effect of different heating rates (5 °C/min to 500 °C/min) on the potential in situ graphitisation of CNF into FLG when using 3 mol.% yttria-stabilised ZrO_2 ceramic matrix. High heating rates up to 500 °C/min inducing grain sliding and rearrangement similar to that of conventional SPS is hypothesised to graphitise the CNF into FLG as in the case of conventional pressure-assisted SPS. Raman spectroscopy was used to detect characteristic graphitic bands (D, G, 2D) and their ratios were used to quantify the extent of graphitisation. In addition, the effect of heating rate and the presence of CNF on the densification, microstructure evolution, and fracture modes of zirconia ceramic with or without added CNF was studied. Preliminary TEM imaging indicated on the presence of FLG layers along the GBs, acting as a diffusion barrier that limited densification and grain growth.

Kindly invited.