Ceramics containing graphene type fillers

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Abstract

Over the last few years, there has been a growing interest in developing new ceramics with enhanced mechanical properties together with novel electrical and thermal functionalities. The outstanding electronic and physicochemical properties of graphene sheets make them ideal fillers for the fabrication of conducting and robust ceramic composites.

Silicon nitride (Si_3N_4) based materials are ceramics with a high potential for many applications (bearing and wear parts, gas turbines, machining tools, etc.,) owing to their interesting properties, such as the high hardness, high temperature strength, good behavior under wearing conditions and the extraordinary toughness that can attain if convenient microstructures are developed.

It is valuable to explore how some these properties are altered by the addition of the new graphene nanostructures. In this presentation we show the main steps in the preparation of Si_3N_4– with either exfoliated graphite nanoplatelets or with graphene oxide nano sheets, taken special care in achieving dense materials with homogeneously dispersed nanostructures. These fillers experience some degree of platelets agglomeration, showing actually a range of thicknesses, and also a preferential orientation with the a-b graphene plane perpendicular to the pressing axis, owing to the axial mechanical pressure during consolidation in the spark plasma sintering furnace, state of the art technique for densifying these composites without any damage. Remarkably, the GO reduction takes place in situ along with the composite densification at high temperature in vacuum.

Microstructural features of these composites are very distinctive, showing a significant grain refinement of the ceramic matrix due to the filler location mostly enclosing the Si_3N_4 grains. Conversely to what should be expected for Si_3N_4 ceramics, this microstructure does not convey a toughness reduction in the composite.

Moreover, these composites present extraordinary properties with increases in toughness of 130% attributed to the *crack bridging* effect produced by the fillers. At the same time, an electrically conductive material is achieved for filler contents as low as 4 vol%. The thermal conductivity of the composite is also enhanced by the filler only for the exfoliated pristine graphene nanoplatelets and for the orientations coincident with the graphene plane of the nanostructures. All these properties render real multifunctional composites.