ADVANCED STRUCTURAL AND WEAR RESISTANT CERAMICS

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In the last 20 years increasing importance has been given to ceramics materials for engineering applications, despite their inherent brittleness. Due of their high strength, hardness and thermal stability, silicon nitride and silicon carbide based ceramics are among the most important materials for structural applications. The effect of several oxide additives (SiO2-Al2O3-Y2O3) on the densification of silicon carbide was investigated using experimental design. The (SiO2-RE2O3-Al2O3) additive compositions were chosen with help of centroid simplex mixture design. Several compositions containing 90 vol.% SiC were sintered at 1950ºC/1h. A range of optimal compositions could be estimated considering the response surface of the studied variables, like density, weight loss, hardness and fracture toughness. Dilatometric experiments revealed, basically, the presence of two shrinkage peaks during sintering of silicon carbide. The first is related to a slight particle rearrangement and, at higher temperatures, a second peak indicates the liquid formation and solution re-precipitation process. A series of silicon carbide based ceramics with different sintering additives were liquid-phase sintered (LPS) to high densities. Yb2O3 in combination with AlN was used as the additive, instead of the commonly used Y2O3- AlN, to improve the refractoriness of the secondary phase. Use of the heavier rare-earth element modified the liquid phase formed during sintering and reduced the phase transformation controlled grain growth rate, compared to Y2O3 doped materials. It also permitted microstructure tailoring through post-sintering heat treatments in nitrogen. Materials with self-reinforced microstructures, formed as a result of anisotropic grain growth, were obtained. Improved fracture toughness and good flexural strength retention up to 14000C were also observed. Fully dense SiC ceramics were produced by LPS with 10 vol.% Yb2O3-AlN as sintering additives containing different Yb2O3/AlN molar ratios. Although the beta-SiC → alfa-SiC phase transformation in the materials investigated here was apparently sluggish, especially with increase in Yb2O3 content in the additive, successful tailoring of the microstructure was possible through post-sintering heat treatments. In situ growth of reinforcing alfa-SiC platelet-like grains resulted in higher fracture toughness, of 4.5-5 MPa m-1. Silicon Nitride has been deeply studied due to its excellent combination of thermo-mechanical properties. Second phase as fibers, whiskers, particles or platelets can be used to minimizing the low fracture toughness problem. Sintering behaviour of silicon nitride based composites, with addition of beta-SiC, alfa-SiC, NbC, TiC and TaC, and Al2O3 and Y2O3 as sintering additives, was investigated (FIG.1).

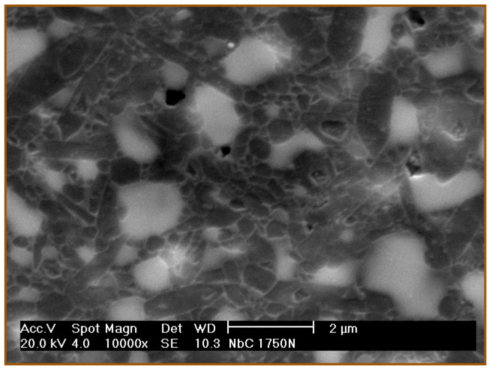

FIGURE 1 - Microstructure of Si3N4:20vol%NbC after plasma etching, sintered at 1750°C/1h.

Ceramic materials obtained from the pyrolysis of a polymer precursor have gained growing interest due to their unique combination of low temperature processing, versatile shaping and the formation of a novel material class like nano structured or molecular composite. During pyrolysis of poly(methylsiloxane)-PMS precursor releases gaseous products and is converted gruadually to a amorphous silicon oxycarbide (SiOC) phase and an excess of free carbon. In presence of active filler, the amorphous phase reacts with the nitrogen gas atmosphere and gases liberated upon pyrolysis in temperatures above 1200ºC to form mainly nano-phases. On pyrolysis reactions between the matrix, filler and N2 take place giving rise to phases in the Si-Al-O-N system. The nanostructure of the pyrolysed composite matrix was observed at HREM. It was observed the formation of anisotropic SiC regions, as well as small cristallites, with an average size of 5-10 nm. Formation of Si2ON2 via vapour phase reaction between SiO and N2 results in structures containing nanocrystalline regions. Neither SiO2 precipitates nor carbon clusters was observed, suggesting low diffusion caused by the amount of carbon and decreasing diffusion during the phase separation process and also owing to the carbothermical reduction.

Zirconia ceramics has been employed as structural materials due to the high values of toughness arising from the transformation toughening phenomena. This remarkable potential is possible by addition of oxides such as yttria that allows the stabilization of the tetragonal phase at room temperature that transforms to monoclinic phase under stress, preventing crack propagation. YTZP ceramics prepared by coprecipitation have Vickers hardness and fracture toughness values as high as 13 GPa and 6 MPa.m$^{1/2}$, respectively. The addition of titania to these ceramics improves fracture toughness (8 MPa. m$^{1/2}$).