Chapter 5
Effect of Transition Metal Silicides on Microstructure and Mechanical Properties of Ultra-High Temperature Ceramics

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ABSTRACT

The IV and V group transition metals borides, carbides, and nitrides are widely known as ultra-high temperature ceramics (UHTCs), owing to their high melting point above 2500°C. These ceramics possess outstanding physical and engineering properties, such as high hardness and strength, low electrical resistivity and good chemical inertness which make them suitable structural materials for applications under high heat fluxes. Potential applications include aerospace manufacturing; for example sharp leading edge parts on hypersonic atmospheric re-entry vehicles, rocket nozzles, and scramjet components, where operating temperatures can exceed 3000°C.

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The extremely high melting point and the low self-diffusion coefficient make these ceramics very difficult to sinter to full density: temperatures above 2000°C and the application of pressure are necessary conditions. However these processing parameters lead to coarse microstructures, with mean grain size of the order of 20 μm and trapped porosity, all features which prevent the achievement of the full potential of the thermo-mechanical properties of UHTCs.

Several activities have been performed in order to decrease the severity of the processing conditions of UHTCs introducing sintering additives, such as metals, nitrides, carbides or silicides. In general the addition of such secondary phases does decrease the sintering temperature, but some additives have some drawbacks, especially during use at high temperature, owing to their softening and the following loss of integrity of the material.

In this chapter, composites based on borides and carbides of Zr, Hf and Ta were produced with addition of MoSi$_2$ or TaSi$_2$. These silicides were selected as sintering aids owing to their high melting point (>2100°C), their ductility above 1000°C and their capability to increase the oxidation resistance.

The microstructure of fully dense hot pressed UHTCs containing 15 vol% of MoSi$_2$ or TaSi$_2$, was characterized by x-ray diffraction, scanning, and transmission electron microscopy.

Based on microstructural features detected by TEM, thermodynamical calculations, and the available phase diagrams, a densification mechanism for these composites is proposed.

The mechanical properties, namely hardness, fracture toughness, Young’s modulus and flexural strength at room and high temperature, were measured and compared to the properties of other ultra-high temperature ceramics produced with other sintering additives. Further, the microstructural findings were used to furnish possible explanations for the excellent high temperature performances of these composites.

1. STATE OF THE ART

1.1 UHTCs’ Background

In the last 10 years, the attention towards ultra-refractory compounds, also known as Ultra-high Temperature Ceramics (UHTCs), has been raised again after some forty years of apparent inactivity (Kaufman, 1966; Fahrenholtz, 2007; Guo, 2009). This class of materials, constituted by borides and carbides of group IV-VI tran-
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