11th International Conference
on Advanced Materials

Rio de Janeiro Brazil
September 20 - 25

ICAM2009

Hafnium Carbide-based ceramics: processing and properties

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Abstract – Hafnium carbide-cased ceramics, candidate materials as a high temperature solar selective absorbers and conductors, have been produced with the addition of $MoSi_2$ and $TaSi_2$ as sintering aid and as secondary reinforcing phase. Several densification techniques, to obtain near fully dense materials, have been compared and their effects on microstructure and properties have been studied. Porous ceramics have been produced as well.

Hafnium carbide is an excellent candidate material as a high temperature solar absorber and conductors because of its high melting point temperature of 3316°C, and because it is one of the few bulk materials that possess an intrinsic spectral selectivity [1, 2]. At 100°C the absorbance of HfC is about 0.65 and the emittance at about 0.1, thus providing behaviour typical of good selective absorber [3].
Since HfC is useful without coating at temperatures up to about 2700°C, in oxygen free environment, it can be considered also for solar thermal propulsion systems. Moreover, HfC is finding increasing attention as a component in high-temperature absorber multilayers and composite coatings [1].
Hf-carbides can be considered also for thermionic/thermoelectric converters at high temperatures, exploiting proper tuning of grain boundary or secondary phases or modifying carrier concentration and mobility. It is well known that vacancies in the carbon sublattice of transition metals carbides lead to changes in all its physical properties [4].
HfC-based ceramics and composites can exhibit a high degree of flexibility of the optical properties, as well as a combination of mechanical properties (hardness, strength, toughness, wear) and physical properties like oxidation and corrosion resistance, depending on the compositions and processing conditions [5].
The present work is concentrated on the manufacturing processes to produce HfC-based ceramics. Due to their strong covalent bonding, one of the major problems encountered with the fabrication of bulk materials and devices concerns their densification. The results focus the use of sintering aid to facilitate pressureless sintering of near-net-shapes and the role of additives to increase mechanical and oxidation properties [5].
Sinterability is investigated through different techniques like pressureless sintering, spark plasma sintering and hot pressing. Microstructure (Fig. 1, 2) and mechanical properties at room and high temperature of sintered HfC-based ceramics are presented.

The efficient heating of the spark plasma sintering technique allowed the densification with no sintering aid or with very low amount (1vol%). On the other hand, the addition of $MoSi_2$ allowed a considerable decrease of the sintering temperature (300-400°C) compared to the monolithic materials with consequent refinement of the microstructure. The mechanical properties of the composites containing 1-9 vol% $MoSi_2$ were generally higher than those of monolithic materials.
Moreover, preliminary results are shown on the production of porous structures (Fig. 3), considering that, for application in radiation absorbers, properly textured surfaces can produce high solar absorbance by multiple reflections in porous microstructure, on the same scale as the wavelength of the incident radiation.

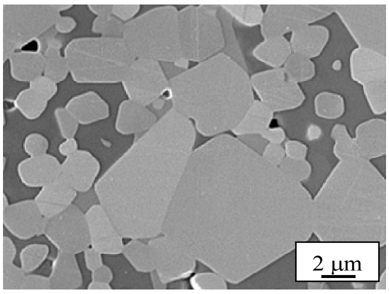

Fig. 1. Microstructure of HfC+20 $MoSi_2$ Pressureless sintered at 1900°C.

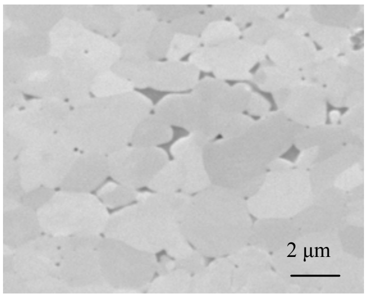

Fig. 2. Microstructure of HfC+3 $MoSi_2$ Spark Plasma Sintered at 1800°C

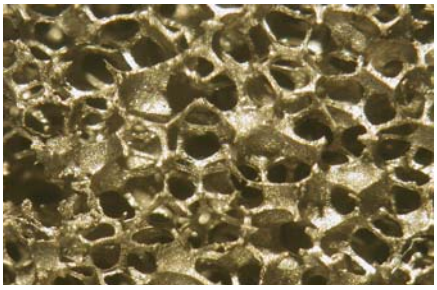

Fig. 3. Porous structure of HfC by foams and pressureless sintering

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