Effect of Composition on Microstructure and Mechanical Properties of Pressureless Sintered Boron Carbide

Francisco Cristovão Lourenço de Melo,[1] Cosme Roberto Moreira da Silva,[1] Jose Carlos Bressiani,[2] and Ana Helena de Almeida Bressiani[2]

[1]Centro Técnico Aeroespacial-IAE-AMR, São José Cos Campos, S.P., Brasil

[2]Instituto de Pesquisa Energéticas e Nucleares IPEN-CNEN/SP-Caixa Postal-11049, São Paulo, S.P., Brasil

INTRODUCTION

Boron carbide is a remarkable material among those with high hardness. This work presents the results of the pressureless sintering studies of a commercial B_4C powder with $C+B_2O_3+Al_2O_3$ and Ni, Ti, Ni + Ti used as sintering aids. The effect of aids on several parameters as sintering temperature, phase formation, microstructure, fracture toughness (K_{IC}) and microhardness (HV) are also studied.

Six kinds of raw materials were used for the studied compositions, as follows:

- Boron carbide powder F-1200, from HCST (Hermann C. Starck)
- Phenolic resin as carbon source
- Alumina BACO (G450), from Union Carbide Company
- Nickel powder P.A., from Fisher Scientific Company
- Titanium powder obtained from $TiCl_4$ through the "Kroll process" at the Materials Division of IAE/CTA (Brasil)

RESULTS

The influence of Al_2O_3, B_2O_3 and carbon addition as sintering aids of B_4C was evaluated. Alumina reacts with B_2O_3 at low temperature forming a liquid phase.

A densification occurs at 1973 K followed by a rapid densification between 2223 and 2273 K. The relative density varies from 75.6% up to 90.4%, reaching 96% of theoretical density at 2373 K. Fusion occurs at 2473 K.

High hardness (21.0 GPa) was exhibited by the material at 2373K. The K_{IC} values show the low fracture toughness of these materials.

X-ray diffraction studies showed the phases B_4C, graphite, Al_2O_3 and $Al_{18}B_4O_{33}$; at the material was sintering (2273 K) revealed only B_4C, graphite and Al_2O_3. One can believe that a liquid phase was formed without recrystallization during the cooling step. In fact it may explain the high density rate when the temperature was increased. Another hypothesis supposes that a small quantity of the phase $Al_{18}B_4O_{33}$ is not detected by X-ray diffraction technique.

Nickel is more effective as a sintering aid than titanium.

A proportionality was observed between both microhardness and relative density values. When high nickel content is present, higher values for both properties mentioned above were observed.

A spread dispersion was observed amon K_{IC} values. Nickel rich materials showed coherent K_{IC} values with this type of materials.

CONCLUSIONS

The use of $C+B_2O_3+Al_2O_3$ as sintering aids is effective for pressureless sintering of BCAl composition. The mechanism may be understood as the "in-situ" reaction between Al_2O_3, B_2O_3 and C, with the formation of B_4C and $Al_{18}B_4O_{33}$.

No good densification was observed when Ti was used for sintering temperatures up to 2373 K.

Nickel is an effective sintering aid for B_4C. It is possible for BNi composition to reach value of 95% of the theoretical density and a microhardness value of 23.7 GPa, when the material is sintered at 2373 K.