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Optimization of boride containing boron suboxide (B6O) materials

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2012-01-31
http://hdl.handle.net/10539/11212

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ABSTRACT

The search for suitable sintering additives for boron suboxide (B_6O) materials which could improve densification, reduce sintering temperature and tailor the microstructure has been of great importance. In an earlier study it was shown that transition metal borides qualify as sintering aids for B_6O, but partial segregations of the boride secondary phases were found. In this work, efforts have been made to investigate in detail, factors which influence the mechanical properties of boride containing B_6O materials and to understand the processing-to-microstructure-to-properties (hardness & fracture toughness) relationships for this class of materials. Based on this knowledge, the fabrication of B_6O-based materials with tailored properties could be possible for industrial applications such as cutting tool, drill bits, grinding wheels, abrasives and ballistic armour.

A reaction couple of sintered B_6O, cobalt or nickel and green compact B_6O were assembled and heat treated at 1850^oC for 20 mins. XRD and SEM examinations of the reaction zone showed the formation of cobalt boride and nickel boride respectively, at the interface, which diffuses into the B_6O compacts. This is an evidence of good wetting between the boride and the B_6O phase.

The relationships between densification and microstructure and mechanical properties (hardness and fracture toughness) of boron suboxide (B_6O) materials have been studied in detail using hot pressing technique. B_6O powders were initially milled using steel balls in an attrition mill to drive the particle sizes down to sub-micron range. Contaminations from steel balls were acid washed in HCl. The amounts of impurities remaining in the powders were characterized using Inductively Couple Plasma (ICP) technique. Sub-micron B_6O powders were then coated separately with different volume content of cobalt and nickel

using precipitation method. Additionally, admixing of B_6O powder with different TiB_2 powder, and boron with TiO_2 powder was done in an attrition mill.

Hot pressing experiments were conducted in a temperature range of 1750^oC–1900^oC under pressures of 50-80MPa for 5-40mins in an argon atmosphere. The microstructure and phase composition of the hot pressed materials were characterized using scanning electron microscopy (SEM), transmission electron microscopy (TEM) and X-ray diffractometry (XRD). Densities of the samples were measured to determine the extent of densification. Vickers hardness and fracture toughness measurements were used to characterize the mechanical properties of the hot pressed materials.

The B_6O materials with boride sintering additives showed higher density in comparison with the pure B_6O material despite the fact that the sintering temperature of these materials was 50^oC lower. Although the hardness of pure B_6O was 30.2 GPa (1kg load), it was found to be brittle. Materials with increased fracture toughness [from 1 for pure B_6O to 3-6 MPa.m$^{0.5}$ for B_6O *with boride additives (Indentation-Method)] with only slightly reduced hardness were prepared. It was found that the composition of the grain boundary phase in B_6O materials is very important for the tailoring of the mechanical properties.*