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Spark plasma sintering of boron carbide ceramics: Densification mechanisms and thermo-mechanical properties

Guy Antou, N Pradeilles and **A Maitre**
University of Limoges, France

Boron carbide is a promising ceramic in the armor field and in nuclear reactors due to its low weight, its high hardness and its high capacity to absorb neutrons. The poor sinterability inherent to the covalent character of the B-C bonding makes the complete densification of boron carbide powder difficult to obtain by conventional sintering technique (i.e. pressure-less sintering). In this work, fully-dense boron carbide ceramics exhibiting fine microstructure (i.e. sub-micrometric grain size) are elaborated using the spark plasma sintering (SPS) without any sintering additive. The SPS densification mechanisms are investigated through the determination of the associated densification parameters (i.e. stress exponent around 3.6 and apparent activation energy of 101±20 $kJ.mol^{-1}$). These values are correlated with structural observations conducted by transmission electron microcopy. It is shown that the induced deformation mechanism corresponds to a power law creep regime controlled by dislocation motion and potentially associated with a twinning phenomenon at high temperature. In addition, the effect of the impurity content decrease by a suitable heat-treatment of the starting commercial powder is studied on the mechanical properties at room temperature (i.e. Vickers hardness and fracture toughness) and high temperature (up to 1600 °C) by bending tests (i.e. elastic modulus, flexural strength). These properties are correlated with (micro) structural characteristics of both materials. It is shown that heat treatment of the powder decreases the contents of free carbon (exhibiting an onion-like structure) and of secondary oxide phases (silicon and boron-rich) at grain boundaries. It leads to a slight decrease of the hardness, fracture toughness and bending modulus and an increase of the flexural strength. In addition, no brittle-to-plastic transition is noticed up to 1600 °C.

Biography

Guy Antou is the Assistant Professor since 2005 at SPCTS Laboratory, University of Limoges, mainly dealing with the experimental characterization, the modeling and the numerical simulation of the thermo-mechanical behavior (in particular viscoplastic) of ceramic materials during their elaboration by pressure-assisted sintering or in service (creep). His has 29 publications in international journals, 4 invited conferences, 55 oral communications, 3 grants, etc. to his credit.

guy.antou@unilim.fr

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