The Research Reports of the Faculty of Engineering, Kagoshima University, No.48 (2006)

Doctoral Dissertation, Graduate School of Science and Engineering, Kagoshima University, Doctorate No.227

Control of Microstructures and Mechanical Properties of SiC Using Liquid Phase Sintering

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1. Introduction

Silicon carbide with high covalent bond shows the excellent properties such as high elastic modulus, high hardness, high strength, high creep resistance, low thermal expansion coefficient, high thermal conductivity and high oxidation resistance. These properties allow silicon carbide to use as high temperature structural materials. The purpose of present work is to apply colloidal processing to the forming of sinterable SiC compact with oxide additives. As sintering additives, Al_2O_3 and Y^{3+} ion were studied to accelerate the uniform addition of a small amount of the oxide liquid.

2. Results and Discussion

An SiC powder of median size 0.8 μm was mixed with an Al_2O_3 powder of median size 0.2 μm in a 0.3 M-$Y(NO_3)_3$ solution at pH 5 to distribute homogeneously the sintering additives (Al_2O_3+Y^{3+} ion) around the SiC particles. Electrostatic repulsion between the positively charged Al_2O_3 surface with isoelectric point pH 7.7 and Y^{3+} ion, suppressed the adsorption of Y^{3+} ion. The network structure of SiC particles was formed by the heterocoagulation through the adsorbed Al_2O_3 and Y^{3+} ion. The aqueous suspension of the SiC-Al_2O_3 (1.17–3.87 vol%)-Y^{3+} ion (0.94 vol% Y_2O_3) system was consolidated to form green compacts of 52-55 % of theoretical density. These compacts were hot–pressed at 1850° -1950°C to relative density of 95 – 99 %. The SiC densified with Al_2O_3 plus Y_2O_3 showed 565-666 MPa of average strength and 5.0-6.5 MPa·m$^{1/2}$ of fracture toughness.

Only the addition of Y_2O_3 (as Y^{3+} ions) needed a higher hot-pressing temperature (1950°C) for the densification. Addition of a small amount of Y_2O_3 was more effective than the addition of Al_2O_3 or Al_2O_3-Y_2O_3 additive to increase the strength of dense SiC (average strength 719 MPa).

The influence of polytitanocarbosilane (PTC) addition on the densification, microstructures and mechanical properties of the SiC with Al_2O_3 and Y_2O_3 was studied at 1950°C in an Ar atmosphere. PTC decomposes to nanometer-sized SiC and C at a high temperature. Infiltration of PTC of 0.04-5.3 vol% into green SiC compacts with the oxide additives increased the sinterability of SiC. PTC addition suppressed the grain growth of SiC during the hot-pressing and increased the mechanical strength and fracture toughness.

The influence of addition of 30 nm-SiC particles (SiC B) on the properties of aqueous suspensions of 800 nm-SiC particles (SiC A), the densification of the consolidated SiC compacts and the mechanical properties of hot-pressed SiC was studied. Addition of SiC B to SiC A increased the density, and decreased the grain size and flaw size of hot-pressed SiC. The addition of SiC B was effective in increasing the flexural strength. The Weibull moduli of the present SiC compacts were in the range from 5.9 to 12.1 and little increase of Weibull modulus was measured by the addition of SiC B. The Weibull modulus was closely related to the magnitude of flaw size distribution in the SiC compacts.

3. Conclusions

The microstructures and mechanical properties of highly dense of SiC can be controlled by the interaction between SiC and oxide additives in an aqueous suspension. The addition PTC or 30 nm SiC to 800 nm SiC improved the strength, but gave no significant influence on the fracture toughness.

Date of Conferment of the Degree: March 24, 2006
Sumitomo Osaka Cement Corporation