Fabrication of Textured Al_2O_3-Mullite-SiC Nano-composite by Slip Casting in a High Magnetic Field and Reaction Sintering

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Abstract

We have demonstrated that textured Al_2O_3-mullite-SiC nanocomposites can be fabricated by slip casting followed by partial oxidation – reaction sintering of mixed suspensions of Al_2O_3 and SiC powders in a high magnetic field. The sintered density was changed by the degree of oxidation at 1200Cand 1300C. The degree of orientation of alumina in the nanocomposite was examined on the basis of the X-ray diffraction patterns and scanning electron micrographs. It is confirmed that alumina-oriented nanocomposites were fabricated. The three-point bending strength at room temperature was observed for the nanocomposites.

Keywords : Al_2O_3-mullite-SiC, nanocomposites, high magnetic field, slip casting

1. Introduction

Alumina-based ceramics are known to show good mechanical properties, corrosion resistance, frictional resistance, etc., and mullite is considered to be a candidate ceramic for high temperature structural applications. Nanocomposites, in which nanometer-sized second-phase particles are dispersed in a micron or sub-micron sized ceramic matrix, are known to show enhanced mechanical properties [1].

The controlled development of a textured microstructure is also known to be one way to improve the mechanical properties. Recently, we reported that the crystal orientation of alumina can be controlled in a high magnetic field due to its crystal magnetic anisotropy [2,3]. To align each particle it is necessary to disperse the powder in the suspension, since feeble magnetic materials in an applied high magnetic field have a low magnetic torque. Therefore, preparing a well-dispersed suspension is very important from the standpoint of a low viscosity and non-agglomerated particles for rotation. It is also very important to obtain excellent mechanical properties by decreasing the large pores due to agglomeration.

We have reported that Al_2O_3-mullite-SiC nanocomposites can be prepared by partial oxidation–reaction sintering of the Al_2O_3-SiC green body [4]. In this study, a suspension with a controlled dispersion and viscosity was prepared, and the creation of textured Al_2O_3-mullite-SiC nanocomposites was fabricated by slip casting in a high magnetic field.

2. Experimental

High purity α-Al_2O_3 powder (Taimei Chemical: TM-DAR) with a mean particle diameter of 0.15μm and β-SiC powder (Ibiden Co., Ltd.) with a mean particle diameter of 0.27μm were used as the starting powders. Colloidal aqueous suspensions with a solid content of 30vol% were prepared. The SiC powder content of each colloidal suspension was fixed at 5, 10 and 15vol%, and each one after consolidation was labeled T-5SiC, T-10SiC and T-15SiC, respectively. The powder mixtures were dispersed with an appropriate amount of polyelectrolyte. After ultrasonic vibration was applied to facilitate dispersion of the powder agglomerates, slip casting was done with and without a high magnetic field (12 T). The partial oxidation treatment was conducted in an alumina crucible in a stream of O_2 at 1200C and 1300 C for 1h. Reaction sintering was then carried out in a stream of Ar at 1600 C for 2h. The partial oxidation treatment and reaction sintering were continuously conducted. The phases and texture analyses were done by XRD. The resulting microstructures were observed by SEM and TEM. The mechanical properties of the samples were evaluated by the three-point bending.

3. Results and discussion

Fig. 1 shows the relative densities of the green bodies after CIP treatment for the sintered bodies with and without oxidation treatment, followed by sintering in an Ar atmosphere at 1600C for 2h. It was confirmed that the relative density of the sintered bodies significantly increased by the oxidation treatment. The sintered density increased with a high oxidation temperature and with a small SiC content. When a large quantity of SiO_2 was generated at a high oxidation temperature, densification was enhanced by the viscous sintering of the surface SiO_2 of SiC and Al_2O_3. Fig.2 shows XRD for T-15SiC after reaction sintering. It is confirmed that the mullite phase is formed by reaction sintering and remains SiC without SiO_2. By TEM observation, the existence of dispersed nano-sized SiC particles was confirmed in the matrix. These results indicate that a dense Al_2O_3-mllite-SiC nanocomposite without SiO_2 was fabricated by this method.

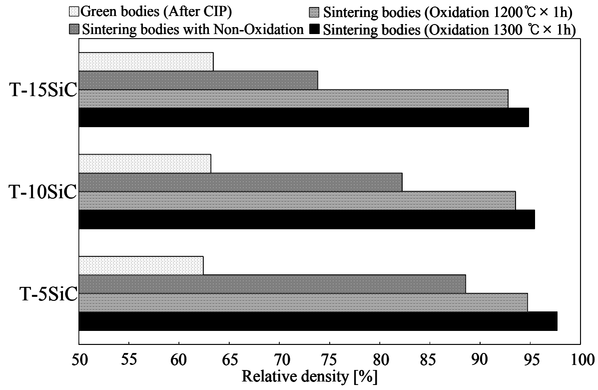

Fig. 1. Relative densities of green bodies after CIP treatment and sintered bodies with oxidation treatment and without oxidation treatment.

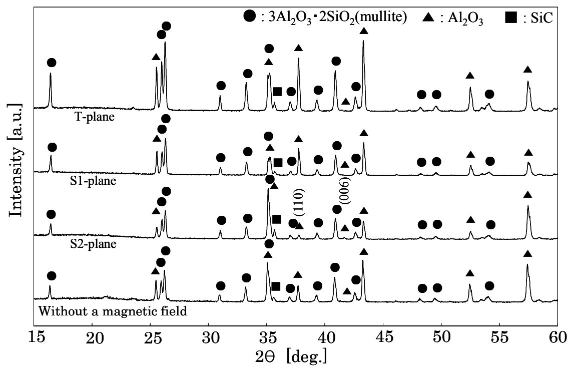

Fig. 2. X-ray diffraction patterns forT-15SiC sintered at 1600C for 2h in an Ar atmosphere after oxidation treatment at 1300C for 1h in an O_2 atmosphere.

Fig. 2 also shows the diffraction patterns of the (006) and (110) of alumina. In the T plane perpendicular to the casting direction and in the S1 plane parallel to the high magnetic field direction, the intensities of (110) were high while the intensities of (006) were very low. In contrast, in the S2 plane perpendicular to the high magnetic field direction, the intensity of (110) was low and the intensity of (006) was higher than that of T and S1. These results indicate that the c-axis of the alumina crystal was aligned in the high magnetic field direction. The degree of crystalline texture was determined from intensity ratio of (006) and (110) as follws: $P=I_{006} / (I_{006}+I_{110})$. Here, the degree of crystalline texture increased as the value of P approached unity. Fig.3 illustrates the degree of crystalline texture for the specimens prepared by slip casting at 12T after reaction sintering under different oxidation conditions. The degree of crystalline texture significantly increased when the SiC content was low and the oxidation treatment temperature was 1200C. It is seen that the degree of crystalline texture depended on the Al_2O_3 content but not as high in comparison with the single phase of Al_2O_3.

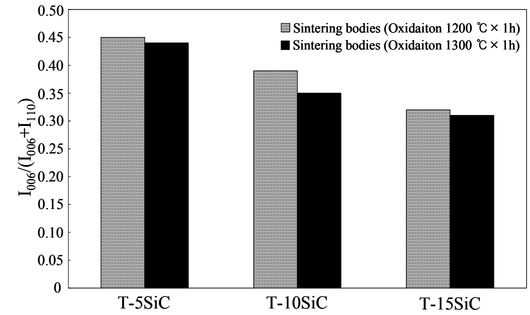

Fig. 3. The degree of crystalline orientation for the specimens prepared by slip casting at 12T followed by reaction sintering.

Fig. 4 shows the bend strength for the textured nano-composite with different directions. The fracture strengths decreased with increased SiC (i.e., mullite) contents due to the content of mullite in sintered bodies because the fracture strength of mullite is not very high at room temperature (300-400MPa). Further detailed experiments will be undertaken to show the superiority of the present processing.

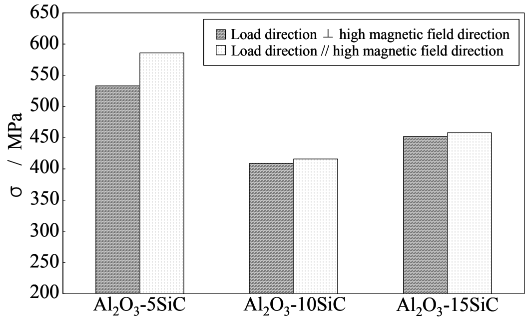

Fig. 4. Three point bend strength for bodies partially oxidized at 1200C for 1h and sintered at 1600C for 2h.

4. References

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