Bending Strength of Textured Alumina Prepared by Slip Casting in a Strong Magnetic Field

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Abstract

The mechanical properties of ceramics materials can be tailored by designing their microstructures. We have reported that development of texture can be controlled by slip casting in a strong magnetic field followed by heating even for diamagnetic ceramics such as alumina. A strong magnetic field of 12T was applied to the suspension indcuding alumina powder to rotate each particle during slip casting. The sintering was conducted at the desired temperature in air without a magnetic field. C-axis of alumina was parallel to the magnetic field. Bending strength of textured alumina depended on the direction of oriented microstructure.

Keywords : texture, fine particle, alumina, strong magnetic field, strength

1. Introduction

Alumina ceramics have been widely used as structural ceramics, because of their excellent properties such as chemical stability, electrical properties and mechanical properties. Many engineering ceramics are now designed and fabricated with microstructures that exhibit a high strength and toughness[1,2)]. Textured structured ceramics have attracted increasing attention, because of their improved mechanical, electrical and other properties. Many trials have resulted in the production of textured ceramics, including templated grain growth and hot forging. We have reported that the development of a textured microstructure in ceramics, such as α-Al_2O_3, TiO_2 and ZnO, could be controlled by slip casting in a high magnetic field followed by heating even for diamagnetic ceramics[3-5)].

A crystal with an anisotropic magnetic susceptibility will rotate to an angle minimizing the system energy when placed in a magnetic field. If the crystal susceptibility parallel to the c axis is $\chi_{//}$, then $\chi_{\perp}$ is perpendicular and the difference is $\Delta\chi$. The magnetic torque, T, attributed to the interaction between the anisotropic susceptibility and magnetic field is estimated from Eq. 1[6)].

$$T = \frac{\Delta\chi V B^2}{2\mu_0}\sin 2\theta \qquad (1)$$

where V is the volume of each particle, μ_0 is the permeability in a vacuum, B is the applied magnetic field and θ is the angle between an easy magnetization axis in a crystal and imposed magnetic field direction. This is the driving force for magnetic alignment.

It is generally difficult to effective apply a magnetic field for rotating diamagnetic fine particles because fine particles spontaneously agglomerate due to strong interaction (van der Waals' forces). The dispersion of particles in a suspension is necessary for the effective utilization of the magnetic field in order to rotate particles. Colloidal processing is powerful technique for controlling the stability of particles in a suspension to avoid agglomeration by using repulsive surface forces.

In this paper, we describe our attempts to control the development of texture in α-Al_2O_3 using a strong magnetic field and colloidal processing, after which the bending strength were investigated.

2. Experimental and Results

A commercially available alumina powder (TM-DAR, Taimai kagaku Co., Ltd., Japan) with average particle size of 0.2 μm was used as the starting material. This alumina powder was dispersed in distilled water with added polyelectrolyte (poly(ammonium)acrylate, Toagohsei Co., Japan) to ensure dispersion by mutual electrosteric rupulsion. Re-dispersion is an indispensable technique for the proper dispersal of fine particles in suspensions that might otherwise undergo spontaneous agglomeration. The suspensions were ultrasonicated for 10 minutes and stirred for more than 8 hours. The suspensions were then consolidated by slip casting in a strong magnetic field of 10 at room temperature. The direction of the magnetic field was parallel to the casting direction. For comparison, other samples were prepared by slip casting without the application of a magnetic field. The green compacts were densified without disturbing the particle orientation by cold isostatic pressing (CIP) at 392 MPa, and were then isothermally sintered at the desired temperatures for 2 h in air, outside of the magnet.

The samples were polished and then thermally etched for the microstructure analysis using a scanning electron microscope (SEM). The bend strength of the samples was determined using the three point bending test.

Fig. 1(a) and (b) show the cross-sectional microstructures of alumina prepared by a slip casting with and without a magnetic field of 12T, respectively. The platelet grains were aligned perpendicular to the applied magnetic field. For comparison, the slightly plate-like grains appear randomly distributed in the untexuture microstructure of a specimen not subjected to a magnetic field.

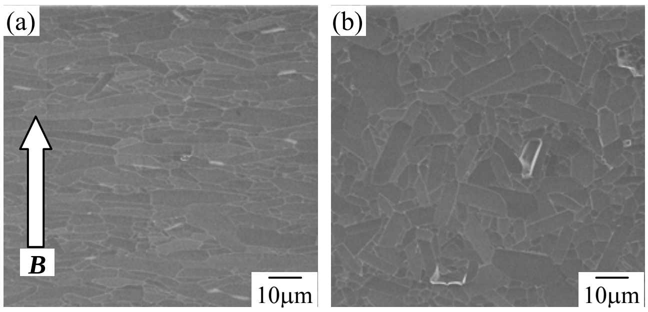

Fig. 1. Microsturcure of the cross-section: (a) alumina prepared by slip casting in a strong magnetic field, (b) alumina prepared without a magnetic field.

The bending strength for the textured specimens prepared using a magnetic field and the untextured specimens without a magnetic field are shown in Fig. 2. The bending strength depends on the crack-growth direction. When the crack-growth direction was parallel to the aligned c-axis, the bending strength was higher than the other test directions even sintering at 1573K or 1873K. The bending strength was the lowest in the case of the fracture surface parallel to the basal plane of alumina.

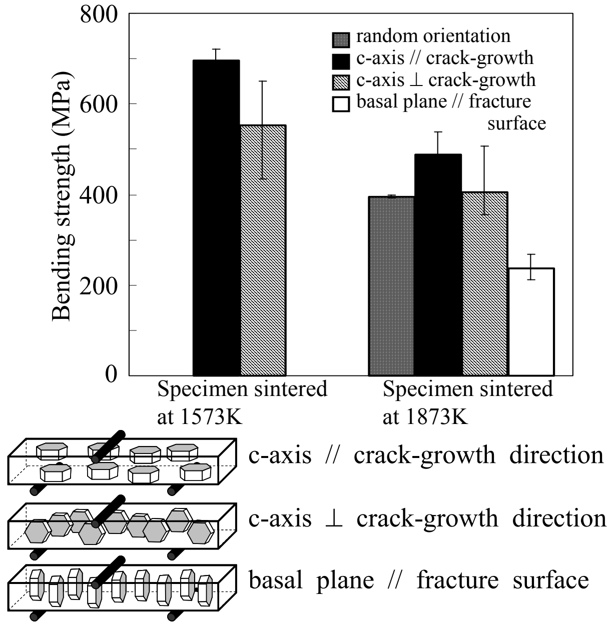

Fig. 2. Bending strength for alumina prepared a slip casting with and wihtout a magnetic field, depending on the crack-growth direction.

3. Summary

Development of texture in alumina can be controlled by a colloidal processing and a strong magnetic field. The bending strength for the crack-growth direction parallel to the aligned c-axis was higher than that for the other testing directions.

4. References

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