BENDING STRENGTH OF MULTI-LAYERED ALUMINA WITH CONTROLLED RESIDUAL STRESS

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Mechanical properties of ceramics materials can be tailored by controlling their microstructures, such as grain size, second phase, grain boundary and crystallographic orientation, etc. The residual stress is also one of the important factors for improving the mechanical properties, because the residual stress is useful to induce crack arrest and/or deflection. Some researcher reported that the residual stress can be controlled in laminar ceramics composed of different materials with different coefficient of thermal expansion. Even if the laminar structure is composed of the single component, the residual stress can be introduced by the crystalline orientation, because the coefficient of thermal expansion depends on the crystal axes in single crystal with asymmetric unit cells. Alumina has trigonal crystal structure with the anisotropy of the coefficient of thermal expansion along each axis. Consequently, it is expected that expansion and compression residual stress can be introduced in laminar alumina with different crystal orientation alternatively layer by layer. In this report, we try to improve the bending strength of alumina ceramics by introducing the residual stress in laminar structure with different crystalline orientation in each layer.

Control of the layered structure in alumina was used by EPD and Crystallographic orientation in each layer was used by a magnetic field. The starting material was high purity (>99.9%) spherical, single crystalline α-alumina powder with an average diameter of 0.4 μm. Alumina powder was dispersed in ethanol adjusted to pH=6.5 with polyethyleneimine as a dispersant. The slurry with a solid content of 5 vol% was prepared for EPD. The slurry was placed in a superconducting magnet with a room temperature bore of 100mm, and then a strong magnetic field of 12T was applied to the slurry to rotate each particle due to the magnetic torque attribute to the anisotropic magnetic susceptibility. The magnetic field was maintained in the slurry during EPD at a constant current of 1.2mA at room temperature. A pair of palladium electrodes with an area of 25mm x 18mm was put in the slurry. The composites were produced by alternately changing the angle between the vectors E and B, $\varphi_{B\text{-}E}$, layer by layer during EPD. This angle was changed ($\varphi_{B\text{-}E}$=0° and 90°) layer by layer alternatively. After EPD, the green compacts were densified by spark plasma sintering at 1150°C.

Transparent alumina can be prepared after densifying by SPS. Figure 1 shows the photos of specimens with random orientation and laminar structure. The thickness of layered structure was 120 μm approximately. The CTE of the c-axis is larger than that of the a-axis in alumina. Therefore, the tensile residual stress was generated in the layer with $\varphi_{B\text{-}E}$=90°, by contrast, the compression residual stress was generated in the layer with $\varphi_{B\text{-}E}$=0°. The bending strength of the specimen with compression residual stress in bottom layer was higher compared with that of the specimen with tensile residual stress in bottom layer.

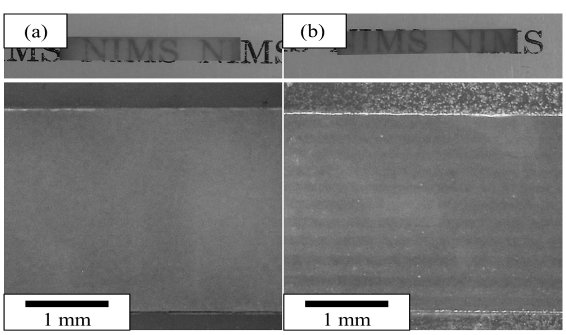

Figure 1 Photos of specimens with (a) random orientation (b) laminar structure.

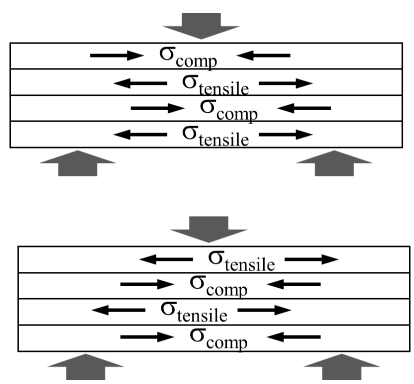

Figure 2 Compressive and tensile residual stress in specimens for 3-point bending test.