Control of crystallographic orientation in ceramics by a strong magnetic field

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The physical and mechanical properties of ceramics can be tailored by controlling their microstructure. The controlled development of texture in ceramics is a growing focus of interest in connection with processing because it leads to improved electrical, thermal, mechanical and other properties.

In this decade, we have reported that the successful control of the crystallographic orientation was achieved even in diamagnetic ceramics such as Al_2O_3, TiO_2, α-SiC, ZnO and AlN and so on, by a colloidal processing in a strong magnetic field. When a strong magnetic field is applied to the particles with an anisotropic susceptibility in stable suspensions during colloidal processing, the particles become rotated to an angle that minimizes the system energy by a magnetic torque generated from the interaction between the magnetic anisotropy and the applied magnetic field.

The magnetic torque, T, attributed to the interaction between the anisotropic susceptibility and the applied magnetic field is estimated from Eq. (1).

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

where $\Delta\chi$ is the anisotropy of the susceptibilities, 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 the imposed magnetic field direction. This is the driving force for magnetic alignment, and thus the orientation of the crystal depends on the axes having easy magnetization.

In addition to the magnetic field, other processing can be applied to control an inimitable microstructure. We achieved producing the laminar composites with different crystalline-oriented layers by electrophoretic deposition (EPD) in a strong magnetic field. Figure 1 shows the EBSP map of alumina/alumina laminate composite with different crystalline-oriented layers. This composite was fabricated by alternately changing the angle between the directions of the magnetic and electric fields layer by layer during the EPD in 12T. A tri-axis orientation was achieved by using both anisometric particles and a strong magnetic field.

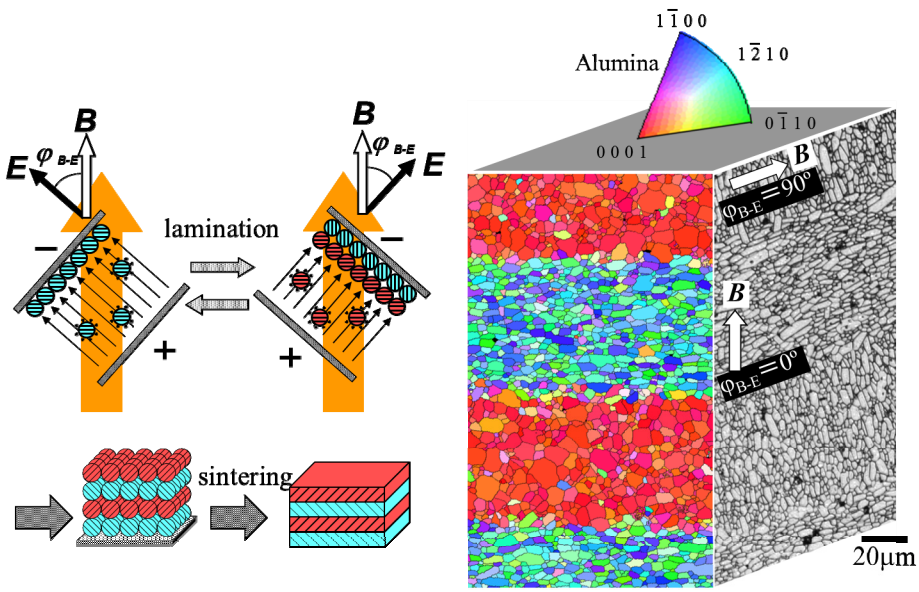

Figure 1 Preparation of laminar structure with alternative orientation by EPD in a magnetic field