FABRICATION OF HIGHLY STRUCTURE-CONTROLLED CERAMICS BY ADVANCED COLLOIDAL PROCESSING

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The controlled development of texture is one of the ways for effectively improving properties of ceramics. There are two common methods for producing textured ceramics: templated grain growth and hot-working. However, they are difficult to produce textured ones with complex shapes. Recently, high magnetic fields with a field strength up to 14 T is readily available without the use of liquid helium due to the development of superconducting technology. These new magnets have been used in studies of many fields, such as crystal alignment, levitation, separation, etc. We have demonstrated the new processing of textured ceramics with a feeble magnetic susceptibility by colloidal processing in a high magnetic field and subsequent heating [1]. The principle of the process is that a crystal with an anisotropic magnetic susceptibility will rotate to an angle minimizing the system energy when placed in a magnetic field. To obtain the oriented materials with feeble magnetic susceptibilities, the following conditions are necessary: (1) the particle should be single crystal and well dispersed, (2) crystal structure should be non-cubic to yield an anisotropic magnetic susceptibility, (3) magnetic energy should be larger than thermal motion energy, (4) the viscosity of the suspension should be low enough to rotate the particles with a low energy, and (5) grain growth is necessary to obtain a highly oriented structure especially when spherical particles are used.

As colloidal processing, slip casting and electrophoretic deposition (EPD) have been conducted successfully. Slip casting is a powerful method to prepare dense and fine grained ceramics. The EPD is useful for preparing laminated ceramics. Here, the direction of the electric field relative to the magnetic field can be altered to control the dominant crystal faces. Crystalline-textured controlled laminated composites can be fabricated using EPD by varying the angle between the vectors of electric field and magnetic field [2].

The colloidal processing in a strong magnetic field can be applied to fabrication of textured ceramics, such as α-alumina, titania, zinc oxide, tin oxide, hydroxyapatite (HAP), aluminium nitride, silicon carbide, silicon nitride, MAX phase materials, etc. Also textured ceramics with complicated structure can be fabricated by reaction sintering, such as β-alumina, β-Si_3N_4, etc. The *a, b*-axis textured β–Si_3N_4 ceramics has been obtained using the static magnetic field because of the magnetic susceptibility of $\chi_{a,\ b} > \chi_c$ for β-Si_3N_4. However, the *c*-axis textured β-Si_3N_4 has also been successfully obtained using a rotating magnetic field [3].

The degree of orientation depends on the processing factors, such as heating temperature, particle size, applied magnetic field, concentration of the suspension, etc. When using heavily agglomerated particles or agglomerated nanoparticles it was impossible to control the particle orientation by imposing a highly magnetic field. The de-agglomeration treatments were successfully carried out by beads milling equipment using smaller size of beads less than 50 μm in diameter. As an example fabrication of highly textured HAP has been demonstrated for heavily agglomerated or nano-sized HAP particles.

References

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