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Fabrication of Crystalline-Oriented Titania by Electrophoretic Deposition under a High Magnetic Field

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Titania (anatase) has a tetragonal crystalline structure and anisotropic magnetic susceptibility. This anisotropy is quite small but the energy of anisotropy $\Delta E=\Delta\chi VB^2/2\mu_0$, in a strong magnetic field (~Tesla) can be higher than the energy of thermal motion at room temperature (~kT). Therefore, when titania particles are placed in a strong magnetic field, they rotate to an angle minimizing the system energy. We demonstrate in this paper that a crystalline-oriented titania ceramics are fabricated using the property of magnetic alignment.

Spherical, single crystalline titania particles (average particle size of 30 nm, anatase 80%) was dispersed with polyethylenimine in distilled water by ultrasound, and aqueous suspension was prepared. The suspension was placed in a superconducting magnet and a strong magnetic field of 10 T was applied to the suspension to rotate each particles. Consolidation of the particles was carried out by electrophoretic deposition (EPD). The magnetic field was kept on applying to the suspension during EPD at room temperature. The angle of the electric field relative to the magnetic field was altered to control the crystal faces of the particles. Schematic illustrations of the experimental concept and actual apparatus are shown in Fig. 1 and Fig. 2, respectively. The titania particles in the deflocculated suspension were aligned due to their anisotropic magnetic susceptibility and then deposited on a cathodic substrate. The green compacts were dried at room temperature and then sintered at 923 K for 2 h. The sintering was conducted in air out of the magnetic field.

X-ray diffraction (XRD) patterns of the sintered compacts are shown in Fig. 3. The orientation of the crystallites was dependent on the angle between the directions of a magnetic field and an electrophoresis of the particles. This result is explained as follows. The magnetic field fixes the orientation of each particle; the c-axis of titania is aligned parallel to ***B*** in the suspension. When an electrical field is then applied to the oriented particles, they move along with the electric field lines while retaining their orientation against the magnetic field lines, and then deposit on the substrate. By varying the angle between the vectors ***E*** and ***B***, the crystalline orientation in the bulk and dominant crystal faces at the surface can be controlled. Higher photocatalytic property was confirmed for the (001) oriented anatase film.

Electrophoretic deposition in a strong magnetic field is a promising method to fabricate crystalline oriented titania. This method can be applied for other ceramic materials to fabricate crystalline oriented, or specific crystal face appeared, thin films for functional applications.

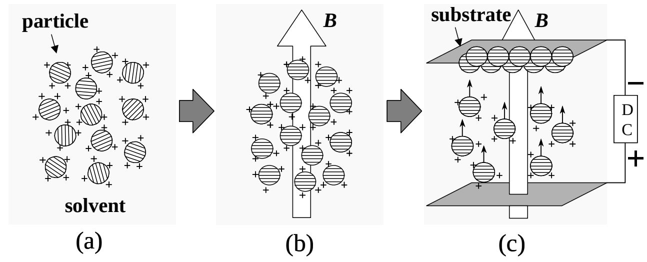

Fig.1 Schematic illustration of the concept of the electrophoretic deposition in a high magnetic field; (a) deflocculated suspension, (b) orientation in a high magnetic field, (c) EPD

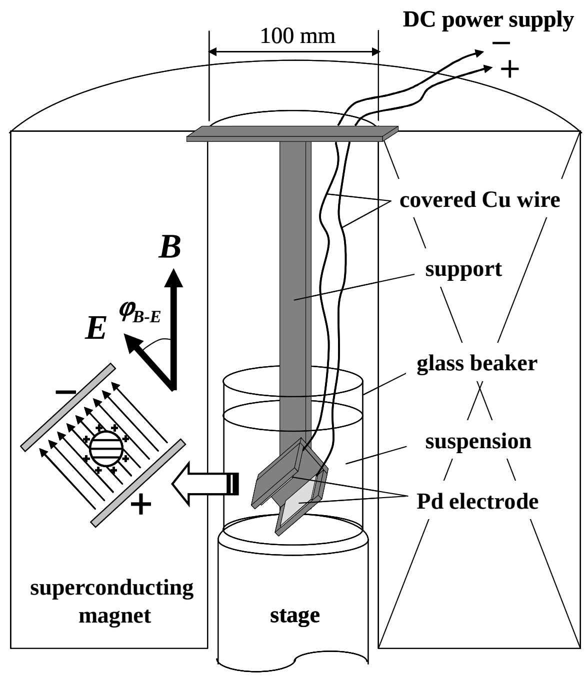

Figure 2. Schematic illustration of the apparatus for EPD in a superconducting magnet.

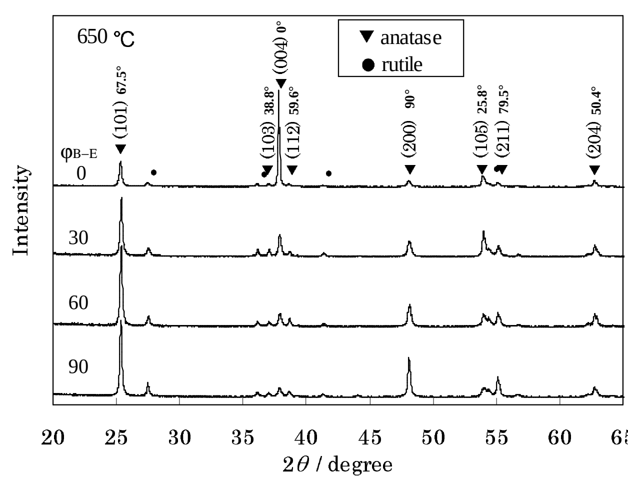

Figure 3. XRD patterns of the surfaces of titania films and their ***B-E*** angle ($\varphi_{B\text{-}E}$) dependence. The interplanar angles ϕ_{hkl} between the planes (*hkl*) and the basal plane (*00l*) of a tetragonal unit cell of titania are also shown in this figure.