**Porosity Control of Thin Film Prepared by Electrophoretic Deposition from Titania Nanoparticle Suspension.**

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**Highlights**

* The titania particle size can be controlled by milling condition.
* The porosity of the particle film prepared by EPD increased with used particle size.
* The film prepared from small-sized particles collapsed easily during drying process.
* The proposed force balance model could explain these conflicting phenomena.

**1. Introduction**

The particle film fabricated by depositing titania nanoparticles (NPs) is widely utilized for novel functional materials, such as the electrode of solar cells and lithium ion batteries, and water purification as photocatalysis. The major processes of making the particle film are the screen printing method, the spin coating method, the dip-coating method, and the electrophoretic deposition method (EPD) [1]. EPD has many superior features compared with other methods where the homogeneous films can be obtained on any forms of substrates, and easy control of the film thickness is achieved by adjusting the applied current and time. When the titania particle films are applied to use for the novel functional materials, the internal structure of the films is one of the key parameters to improve their abilities. However, the experimental conditions of EPD to control the internal structure of the film have not been discussed enough, although several studies have been pointed out to improve the performance of solar cells. In this paper, the effect of the titania particles size used for EPD on the internal structure, especially the porosity, of the film was reported.

**2. Methods**

The commercially available spherical P-25 NPs (Evonik) was used as the titania NPs for EPD. P-25 particle powder was dispersed into dehydrated-ethanol with acetylacetone by using the milling apparatus (HFM02, Ashizawa Finetech) with alumina beads. The particle size in the sample suspension was controlled by milling operation conditions. All the EPD experiments were carried out under DC constant current maintained by a potentiostat (AMEL 7050). The EPD electrodes were staged on a polyvinyl chloride plate with a 10-mm round hole and the distance between electrodes was 15 mm. The film thickness was measured with a surface profile meter (DEKTAK 150, Veeco). The weight of the deposited NPs was determined by the colorimetric method. The porosity of the thin film of particle deposition was calculated from the measured weight and thickness of film with the density of titania.

**3. Results and discussion**

When milling period increased, the particle size decreased, and then the mobility of particles during EPD and the electro conductivity of the suspension increased slightly. We found that the denser packed particle films were obtained by using the suspension with smaller-sized particles, and the local porosity of the film was increased with film thickness, as shown in Figure 1.



**Figure 1.** Effect of particle size on porosity of particle layer deposited by EPD.

Those phenomena could be explained that the new surface of titania particles was created due to break the aggregated particles during milling procedure, and then the surface charge density of titania particles and the counter ions in the medium increased as decreasing particle size. However, the total charge of individual particles increased with particle size, because the particle surface area increased more comparing with decreasing the surface charge density when particle size increased. This could be concluded that larger size particles with high total charge were repulsed strongly each other, and the porosity of the film prepared from those particles increased comparing with the case using small size particles, as a result. Therefore, changing the particle size is one of the effective methods to control the internal structure of the titania particle film fabricated by EPD.

However, the particle film prepared from smaller sized particles collapsed easily during drying process after EPD operation, in spite of the dense packed film. We proposed the force balance model for this phenomenon using van der Waals (*Fv*) and electrostatic (*Fr*) interactions between particles with the Coulomb force (*FE*) from the electric field. The surface distance between particles was calculated, where the attraction forces (*Fv* + *FE*) and the repulsion force (*Fr*) were balanced, and also determined its balanced force strength. In the case of small-sized particles, the surface distance was short, that means particles were packed closely. And the force strength at the force balanced point was weaker comparing with the case of large sized particles, that is particle adhesion force was weak. This calculation could explain the dependencies of the porosity of particle-deposited layer and the collapsed phenomenon at drying process on particle size of suspension.

**4. Conclusions**

In this study, the preparation of thin films of titania NPs by applying EPD from ethanol suspensions of different particle size led to the following findings: the porosity of deposition layer increased with particle size, but the strength of the deposition layer prepared from larger-sized particles was stronger than the case using smaller-sized particles. The proposed force balance model could explain those findings.

**References**

1. Y. Mori, Y. Nobuzane, K. Nishimura, K. Yamada, K. Tsuchiya, Chem. Eng. Trans. 57 (2017) 1507–1512.