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Microencapsulation and characterization of poly(vinyl alcohol)-coated titanium dioxide particles for electrophoretic display

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ABSTRACT

Titanium dioxide (TiO_2) particles were coated by poly(vinyl alcohol) (PVA) via a simple method of coacervation without a conventionally practiced polymerization step. Transmission electron microscopy (TEM) images clearly showed that the successful coating was achieved on the surface of TiO_2 particles. The average thickness of PVA coating layer was about 1.07 μm and the amount of coated PVA was 1.40 wt.% relative to TiO_2. The existence of PVA layer on TiO_2 was also verified from FT-IR spectra. The PVA-coated TiO_2 particles were further microencapsulated via coacervation of gelatin and gum Arabic. Regarding the performance of the resulting microcapsules, the resulting PVA-coated TiO_2 particles showed both a good electrophoretic movement and a good bistability in the microcapsules. Therefore, these microcapsules embedding PVA-coated TiO_2 particles can be used as a good candidate for the electrophoretic displays.

1. Introduction

Recently, electronic displays have attracted much attention in information displays due to its low cost, lightweight, flexibility, portable characteristic, and low power consumption [1–3]. There are various types of the electronic displays such as a microencapsulated electrophoretic display, a twisting ball display, an electrowetting display, and electrochromic display [4]. Among these, the microencapsulated electrophoretic display is known to be one of the most promising technologies due to its high contrast and wide view angle [5]. The microcapsules consist of electrophoretic particles and dielectric media. The electrophoretic particles are based on electrophoresis, the movement of charged particles dispersed in a fluid, under the influence of an electric field. Such a movement of particles in dielectric media under an applied electric field leads to the optical contrast. Therefore, the electrophoretic particles should maintain a steady dispersion state in dielectric media.

Titanium dioxide (TiO_2) has been extensively used as electrophoretic particles because of its remarkable optical, electrical, and chemical properties. However, it has drawbacks such as sedimentation occurring due to its high density, agglomeration, and a strong interaction with the displays' electrodes [6,7]. To prevent these problems, TiO_2 particles have been coated by polymers via various polymerization methods such as surfactant-free emulsion polymerization [6], precipitation polymerization [7], and dispersion polymerization [4,8]. However, the polymerization step is meticulous and time consuming.

Recently, a simple method, namely coacervation, has been explored to prepare polymer-encapsulated pigment particles without polymerization steps, which utilizes the difference of solubility of polymers in solvents in the presence of pigment particles in solution [9]. Li et al. [10] reported that waterborne poly(vinyl alcohol) (PVA)-coated carbon black pigment nanoparticles could be readily prepared by this coacervation.

A microencapsulation process has been introduced by the same token and shown to conspicuously reduce the agglomeration and lateral migration of the electrophoretic particles [8,11,12]. It is also an effective method to incorporate the liquid and solid materials into a capsule. Therefore, microencapsulation is a useful process to cover very tiny electrophoretic particles with a continuous film of polymeric materials. To dates, two different methods and types of microcapsules have been introduced. One is the *in situ* polymerization of urea, melamine and formaldehyde [13–15], and the other is the coacervation of gelatin and gum Arabic [16,17]. The microcapsules formed by gelatin and gum Arabic are more attractive because of their flexibility compared to the one formed by urea, melamine, and formaldehyde [17].

In our study, TiO_2 particles were coated by PVA via a facile method of coacervation in order to reduce density mismatch between the dispersed TiO_2 particles and the dielectric medium. The PVA-coated TiO_2 particles suspension was further microencapsulated by the coacervation of gelatin and gum Arabic. The resulting PVA-coated TiO_2 particles showed both a good electrophoretic movement and a good bistability in the microcapsules. Therefore,

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these microcapsules embedding PVA-coated TiO_2 particles can be used as a good candidate for the electrophoretic displays.

2. Experimental

All of the materials used in this study were commercially available and were used without further purification. The preparation of microcapsules embedding the PVA-coated TiO_2 particles consisted of two steps. In the first step, pristine TiO_2 particles were coated by PVA via sophisticated coacervation. In the second step, PVA-coated TiO_2 particles were microencapsulated by coacervation of gelatin–gum Arabic.

2.1. Preparation of the PVA-coated TiO_2 via coacervation

1.5 g TiO_2 (R-103, DuPont), 7.5 g poly(ethylene glycol) (PEG, Yakuri Pure Chem. Co., Japan), and 60 mL deionized water were charged into a 250 mL round bottom flask with a mechanical stirrer. The specific gravity of TiO_2 is 4.1 and its particle size is 0.18 μm. PEG was used as a surfactant. The mixture was stirred at 300 rpm for 1 h to a uniform dispersion, and then 15 mL 5 wt.% poly(vinyl alcohol) (PVA, Mw: 89,000–98,000 g/mol, the degree of hydrolysis: 99+%, Aldrich, USA) aqueous solution was added. Methanol (100 mL) as a nonsolvent of PVA was dropped into the above mixture through a syringe pump at the rate of 0.5 mL/min to induce coacervation of PVA onto TiO_2 particles.

2.2. Microencapsulation of the PVA-coated TiO_2 particles

Internal phase was prepared by mixing 0.46 g PVA-coated TiO_2 with 0.023 g DISPERBYK174 (BYK-Chemie, Germany), 4.2 mL tetrachloroethylene (99%, OCI Co., Ltd., Korea), and 5.8 mL cyclohexane (99%, Duksan Pure Chemicals Co., Korea). This suspension was mixed by ultrasonication for 1 h at room temperature. Tetrachloroethylene and cyclohexane were used as the suspension medium for the internal particles. DISPERBYK 174 is a solution of a high molecular weight block copolymer with pigment affinic groups and hence was selected as a dispersing agent.

Li et al. have prepared the microcapsules via sophisticated coacervation achieved by the mutual neutralization of two oppositely charged polymers, gelatin and gum Arabic [18]. Herein, we used the same method. 1 g gum Arabic (OCI Co., Ltd.) was dissolved in

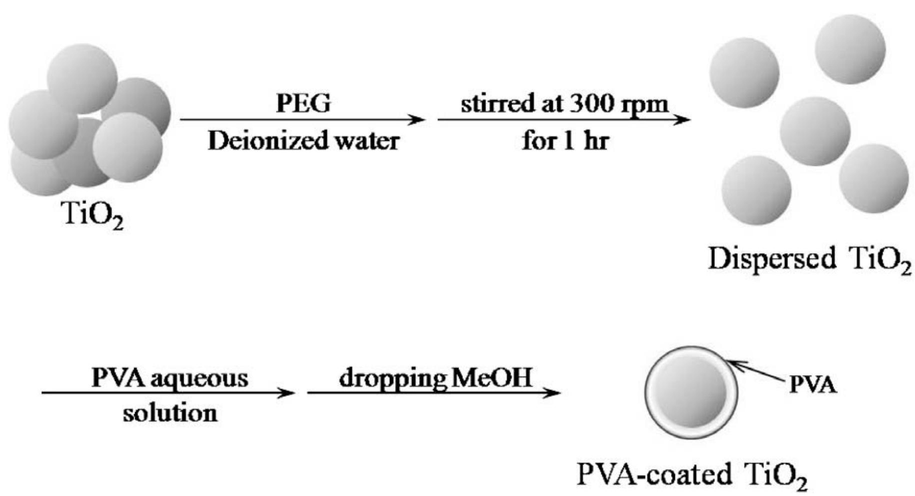

Fig. 1. Procedure for the preparation of PVA-coated TiO_2 particles via a simple coacervation process.

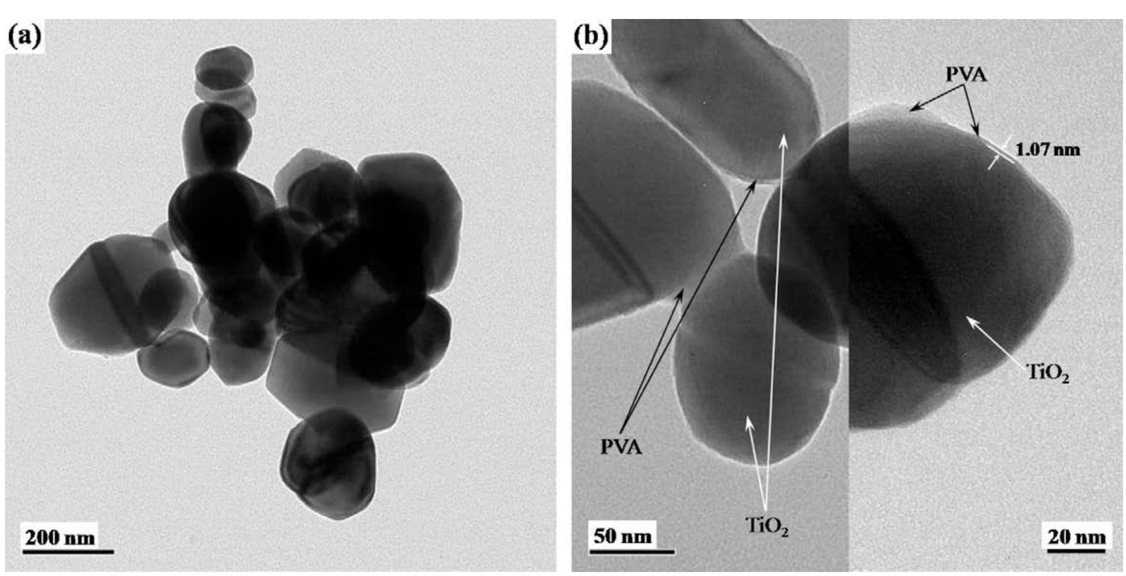

Fig. 2. TEM micrographs of (a) pristine TiO_2 and (b) PVA-coated TiO_2 particles.