# Density Compatibility of Encapsulation of White Inorganic $TiO_2$ Particles Using Dispersion Polymerization Technique for Electrophoretic Display

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## Abstract

*The polymer encapsulation of white inorganic $TiO_2$ pigment particles was prepared by a two stage dispersion polymerization technique for applications in electrophoretic displays (EPDs). In order to give functionality for inorganic pigment particles in the EPD, we have investigated the density of the polymer encapsulated $TiO_2$ particles. The average density of the polymer encapsulated $TiO_2$ particles was 2.2 at 25°C. The average density of the polymer encapsulated $TiO_2$ particles is suitable to 1.7, due to density matching with suspending media. Therefore, we will attempt density compatibility of dispersion polymerization technique for encapsulation of $TiO_2$ particles in suspending media.*

## 1. Introduction

In recent years, reflective paper-like displays have been of great interest for applications in information displays, such as PDAs, electronic newspapers, and e-books as well as out- and in-door advertisement. The paper-like displays involve a microcapsule-type electrophoretic display[1], a twisting ball display[2], an in-plane type electrophoretic display[3], and a cholesetric liquid crystal display[4].

Among them, electrophoretic display (EPD), which showing image and text using moving charged particles by applied voltage, might be one of the most promising candidate because it offer novel advantages such as ink-on-paper appearance, high reflectance, good contrast ratio, wide-viewing angle, image stability in the off state, and extremely low power consumption.

To offer electrophoretic behavior in the EPD, it is required that differently charged pigment particles with different color were dispersed in the suspending medium. $TiO_2$ and carbon black inorganic pigments having opposite charges have been typically used for white and black image, respectively. In order to give functionality for inorganic pigment particles in the EPD, it is highly required to encapsulate the particles with suitable polymer materials for preventing from reaction with the suspending media, density matching with the media to offer image stability in the off state, and attaching charge control agents. Therefore, polymer encapsulation is one of the key processes to fabricate the EPD.

We have investigated encapsulation of white inorganic $TiO_2$ pigment particles with various polymers, especially, poly(styrene-*co*-divinylbenzene) using dispersion polymerization process for applications in EPDs.

## 2. Dispersion Polymerization Technique

The polymer encapsulated $TiO_2$ particles were prepared by a two stage dispersion polymerization technique. $TiO_2$ pigment particles with average particle size of 0.42μm (DuPont, Ti-Pure) were used as white core materials. The two stage dispersion polymerization process is as follows.

First, copolymerization of styrene and divinylbenzene was carried out in methanol containing $TiO_2$ particles at 60°C using 2,2-azobisisobutyronitrile (AIBN) and poly(vinyl pyrrolidone) (PVP), as an initiator and a stabilizer, respectively. After copolymerization, the second stage monomer, either methacrylic acid or acrylamide, is injected into the container which continues to tumble at the same reaction condition for another desired reaction time. The final products made by the two stage dispersion polymerization process is highly crosslinked poly(styrene-*co*-divinylbenzene) encapsulated $TiO_2$ particles with polyacrylamide grafted on the surface in the case of acrylamide as the second stage monomer or, in the case of methacrylic acid, poly(methacrylic acid) is grafted on the surface. Therefore, the surface characteristics of the final particles produced can be selectively altered for particle charging. The surface functionality of the final particles can be varied by introducing different basic or acidic functional monomers, and the like, at the second stage polymerization to produce polymer encapsulated $TiO_2$ particles with basic or acidic surface characteristics which are suitable for positive or negative charging in dielectric media. The polymer encapsulation recipe of white inorganic $TiO_2$ pigment particles is given in Table 1.

**Table 1. The Polymer Encapsulation Recipe of White Inorganic $TiO_2$ Pigment Particles.**

| Materials | Weights (g) |
|---|---|
| Methanol | 100 |
| $TiO_2$ | 2 |
| Divinylbenzene | 5 |
| Styrene | 5 |
| Poly(vinyl pyrrolidone) (PVP) | 2 |
| 2,2'-azobisisobutyronitrile(AIBN) | 0.5 |
| Acrylamide | 0.5 |

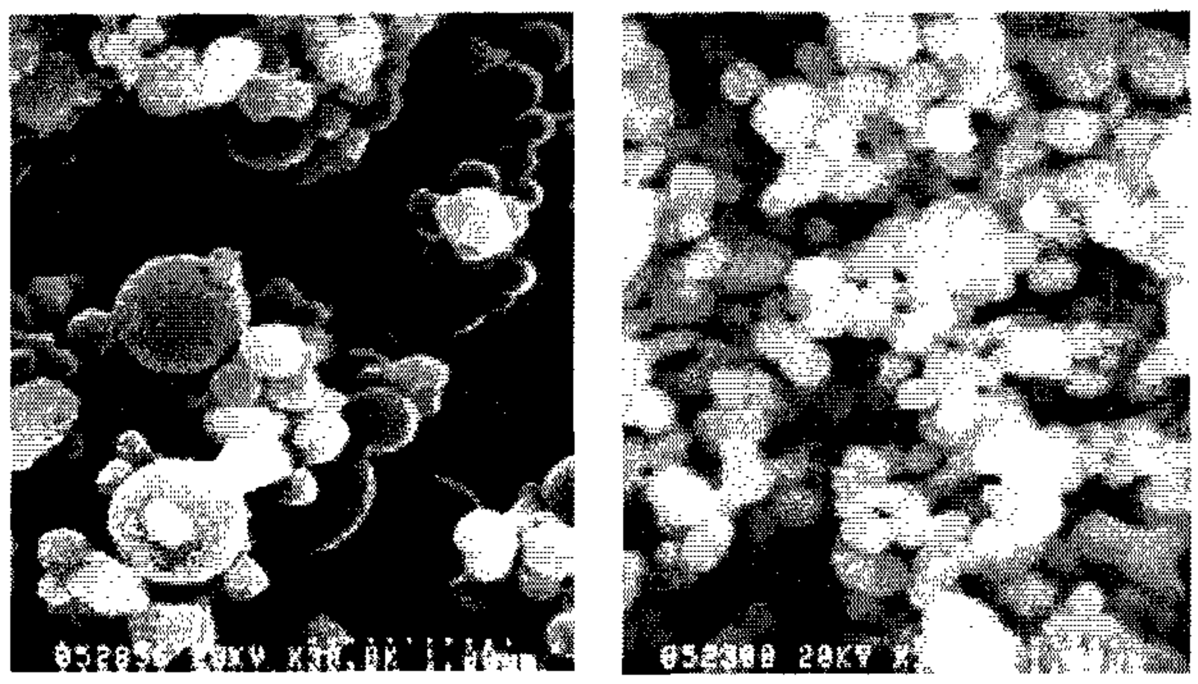
## 3. Results and Discussion

We obtained the polymer encapsulated $TiO_2$ particles via two stage dispersion polymerization technique. The polymer encapsulation of $TiO_2$ particles was confirmed with scanning electron microscopy (SEM), thermal analysis, and Fourier Transform Infrared Spectroscopy (FTIR) spectroscopic analysis.

In Figure 1, a SEM photograph of the encapsulated particles shows the surface microstructure of polymer encapsulated and bare $TiO_2$ particles, respectively. It shows somewhat size distribution for the encapsulated pigment particles. The size distribution of the polymer encapsulated $TiO_2$ particles was due to bare $TiO_2$ particles size distribution and monomer concentration.

Thermal analysis of the encapsulated particles was followed by thermogravimetric analysis (TGA) as shown in Figure 2 The TGA results show that 20% wt loss occurred at 400°C in nitrogen, due to the degradation of the encapsulating polymer of $TiO_2$ particles. Therefore, it is thought that the mean weight percent of encapsulating polymer could be calculated to 20% and 80% for remaining $TiO_2$ among the encapsulating polymer $TiO_2$ particles.

In order to give functionality for inorganic pigment particles in the EPD, it is highly required to encapsulate the particles with suitable polymer materials for preventing from reaction with the suspending media, density matching with the media to offer image stability in the off state.



(a) (b)

**Figure 1. A SEM Photograph of (a) Polymer Encapsulated $TiO_2$ Particles and (b) Bare $TiO_2$ Particles.**

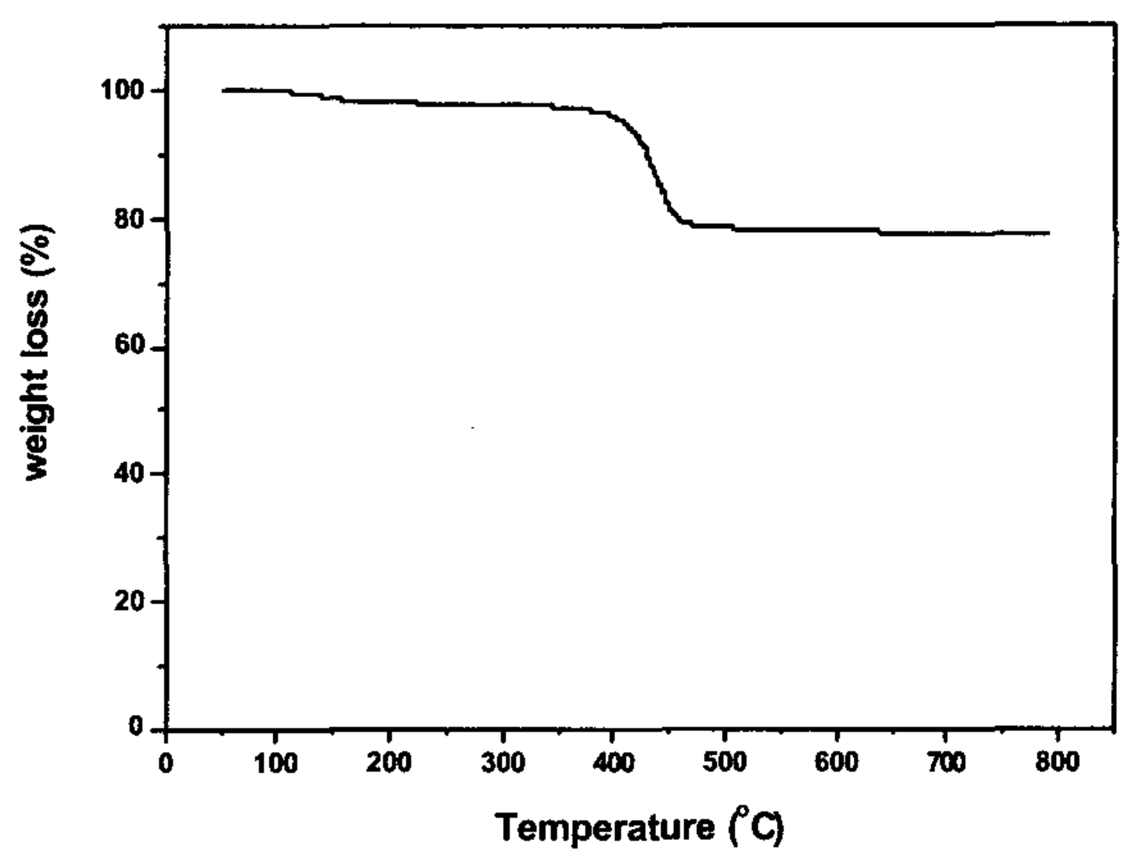



**Figure 2. TGA Curve of the Polymer Encapsulated $TiO_2$ Particles.**

We have investigated the density of the polymer encapsulated $TiO_2$ particles. The average density of the polymer encapsulated $TiO_2$ particles was 2.2 at 25°C. The average density of the polymer encapsulated $TiO_2$ particles is suitable to 1.7, due to density matching with suspending media. Based on this result of the polymer encapsulated $TiO_2$ particles, we will attempt to density compatibility of dispersion polymerization technique for encapsulation of $TiO_2$ particles in suspending media. The optical properties of the polymer encapsulated $TiO_2$ particles will be also investigated

## 4. Summary

The polymer encapsulated $TiO_2$ white particles were prepared by a two stage dispersion polymerization technique. The polymer encapsulation of $TiO_2$ particles was confirmed with SEM, thermal analysis, and FTIR spectroscopic analysis. In order to give functionality for inorganic pigment particles in the EPD, we have investigated the density of the polymer encapsulated $TiO_2$ particles. The average density of the polymer encapsulated $TiO_2$ particles was 2.2 at 25°C. The average density of the polymer encapsulated $TiO_2$ particles is suitable to 1.7, due to density matching with suspending media. Therefore, we will attempt to density compatibility of dispersion polymerization technique for encapsulation of $TiO_2$ particles in suspending media. Also, the optical properties of the polymer encapsulated $TiO_2$ particles will be investigated.

## 5. Acknowledgements

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## 6. References

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