The Novel Preparation of White and Black Pigments by Functionalized Polymer Coating for Electrophoretic Display

Meyoung Ju Joung, Chul Am Kim, Seong Deok Ahn, Yong Eui Lee, Seung Youl Kang, Kyung Soo Suh and Chul Hwan Kim[*]
Electronics and Telecommunications Research Institute, Daejeon, 305-350 KOREA +82-42-860-5075
joungmj@etri.re.kr, * DPI Solution, Inc. Daejeon, KOREA

Abstract

In this study, we have investigated a process of preparation of white and black pigment particles by physical or chemical coating with functionalized polymers for the flexible low-cost paper-like display. This polymer coating provided <1 μm monodispersed particles changed their dispersion, density, optical and electrical properties.

1. Introduction

Lightweight, flexible reflective paper-like displays are of great interest for applications in portable displays and advertisement. The reflective paper-like displays involve a microcapsule-type electrophoretic display[1-3], a twisting ball display[4], an in-plane type electrophoretic display[5], and a cholesteric liquid crystal display[6]. Among them, microcapsule-type electrophoretic display, which showing image and text using moving charged particles by applied voltage, might be one of the most promising candidate because it offers 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.

The microcapsule-type electrophoretic display consists of millions of tiny microcapsules; each one containing charged particles that react to an external electric field to form an image. These particles are dispersed in a suspending fluid and then would be encapsulated into microcapsules by in-situ polymerization process microcapsules with diameters in a range of 50-200 μm.

The one possible structure of microcapsule-type electrophoretic displays is illustrated in Figure 1. The white/black electrophoretic medium comprises two different types of white and black particles, bearing charges of opposite polarity, in a colorless suspending fluid. Optical contrast is achieved by moving charged particles separately to the opposite electrode. From the front electrode the viewer can observe white or black particles held electrostatically to the front electrode depending on the electric field and the particle charge.

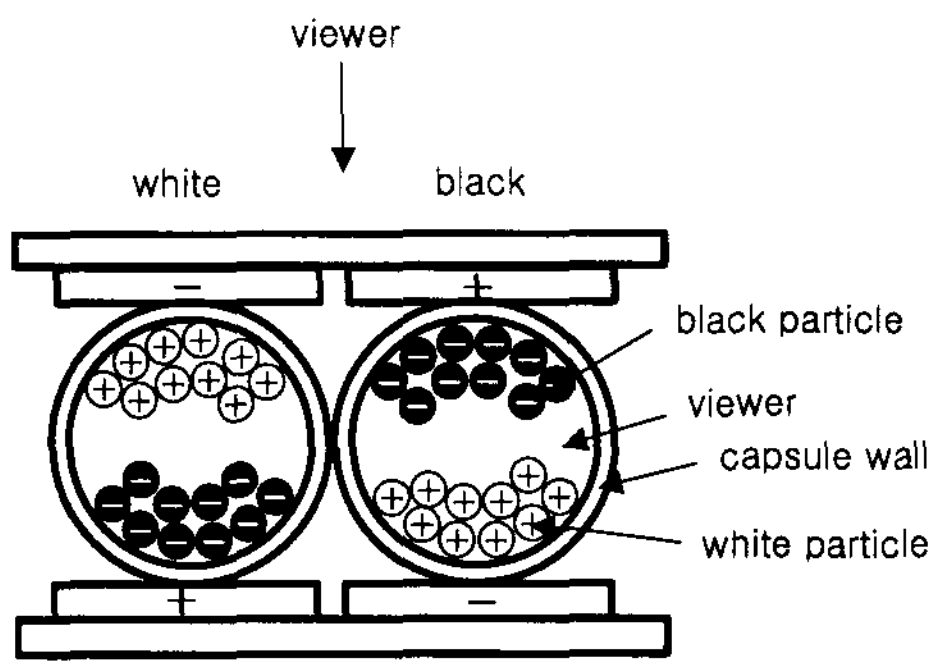

Figure. 1 Schematic illustration of microcapsule-type electrophoretic display.

The degree of bistability can be controlled through appropriate chemical modification of the electrophoretic particle.

Recently we have reported the polymer coating of TiO_2 to give electrophoretic white particles, which was proved to be essential for density matching, improving dispersion of the particles and also controlling surface charge of the pigments[7]. In this investigation we will focus on the preparation of charged black pigment particles by physical or chemical coating with functionalized polymer for the flexible low-cost paper-like display.

2. Results and Discussion

First, black pigment could be simply fabricated by physical coating with functionalized wax or polystyrene polymer as follows. To prepare well-dispersed colloid solution, in an appropriate solvent bare black pigment was sonicated with dispersant. To the colloid solution, functionalized polymer was added with stirring at high temperature around 90 ~130 °C. By allowing the reaction mixture to cool or to be quenched with ice water, the dissolved polymer was absorbed onto the surface of the particle, finally it was precipitated to form spherically like coated particles. After removing the solvent by centrifuging then freeze-drying, the dried powder was obtained. Second, those pigments could be polymer coated by PMMA emulsion or dispersion polymerization also. The solvent used for polymer coating can be aqueous, or organic solvent. The black pigment can be one of the nano to micro-sized organic or inorganic pigments (carbon black, acetylene black, special black, lamp black, black polymer, or Spinels, etc.). The surface charges of the particles could be controlled by coated polymer type and charge control agents. Therefore positively charged and negatively charged black particles could be fabricated by surface treatment of bare black pigments.

Physical Polymer Coating in Hydrophilic Solvent	Solvent: water, alcohol, ethylene glycol, DMF, etc. Dispersant: SMA, byk-190, 183
Hydrophobic Solvent	Solvent: Halocarbon, Isopar Dispersant: Span, Tween, byk-161, 110

Table 1. Reaction conditions of physical coating of black pigments with functionalized wax or polystyrene polymer.

Two types of physical polymer coating are possible depending on the polarity of solvent media, used solvent and dispersant in each case were summarized in Table 1. One of the PMMA dispersion polymerization recipes of black pigment was shown in Table 2. The surface morphology of black particles could be changed by modification of the materials relative ratios.

Figure 2 shows SEM micrograph of the functionalized polystyrene coated special black, monodispersed 100 nm sized particles, however the polymer was very slightly coated, the thickness was thin and not enough for density matching as shown in Figure 3 TGA graph.

Materials	Weight (g)
Methanol	300
Di(ethylene glycol) dimethacrylate	1
Methyl methacrylate	12
Methacrylic acid	1.4
Poly(vinyl pyrrolidone)	2
2,2'-azobisisobutyronitrile	0.8

Table 2. PMMA dispersion polymerization recipe of black pigment.

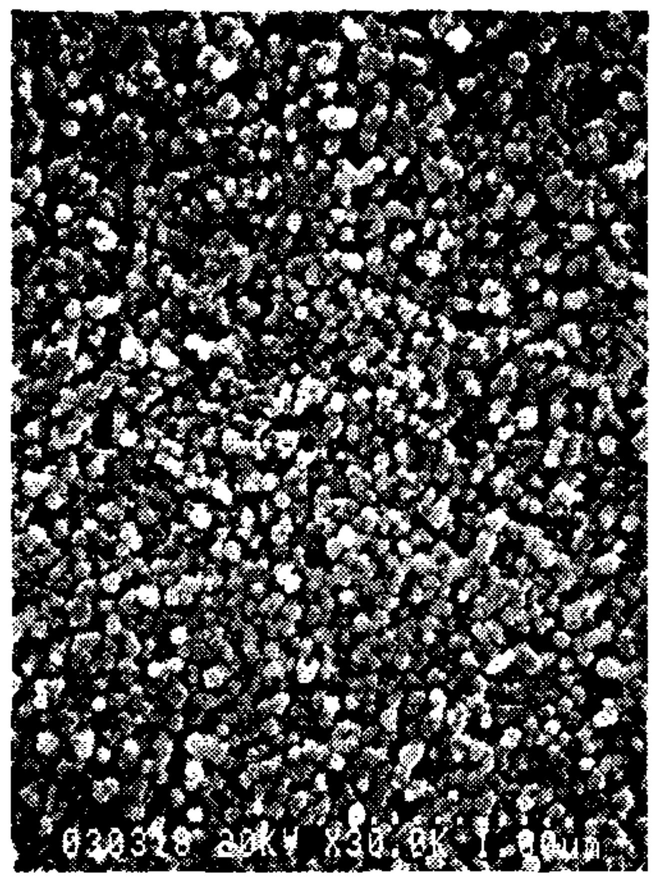

Figure 2. Scanning electron microscopy photograph of polymer coated Special Black.

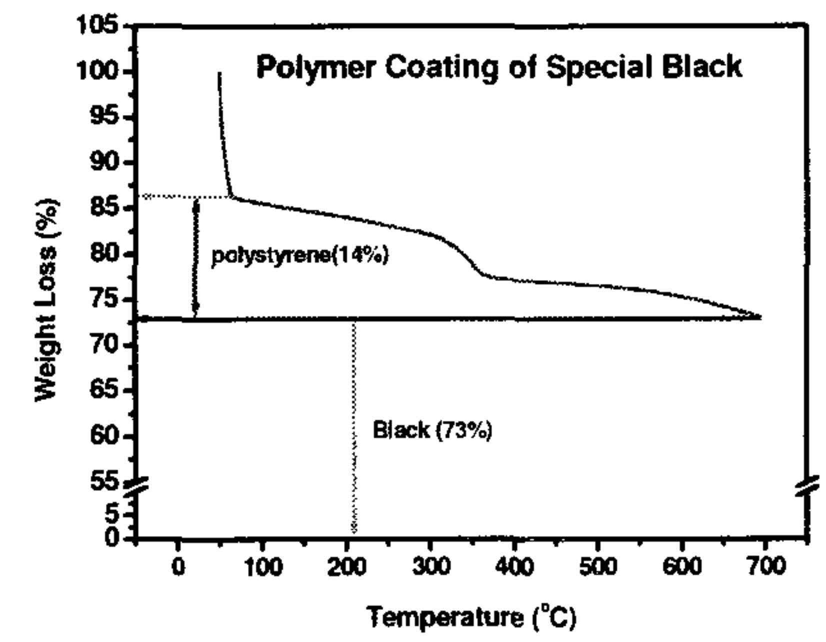

Figure 3. Thermogravimetric analysis of polymer coated Special Black.

Figure 4 and 5 indicate SEM micrograph and TGA graph of wax coated Spinel type black pigment, 100 ~300 nm sized. Similarly to special black, the physical polymer coating has some restriction of thickness control for density matching.

Figure 4. Scanning electron microscopy photograph of wax coated black pigment.

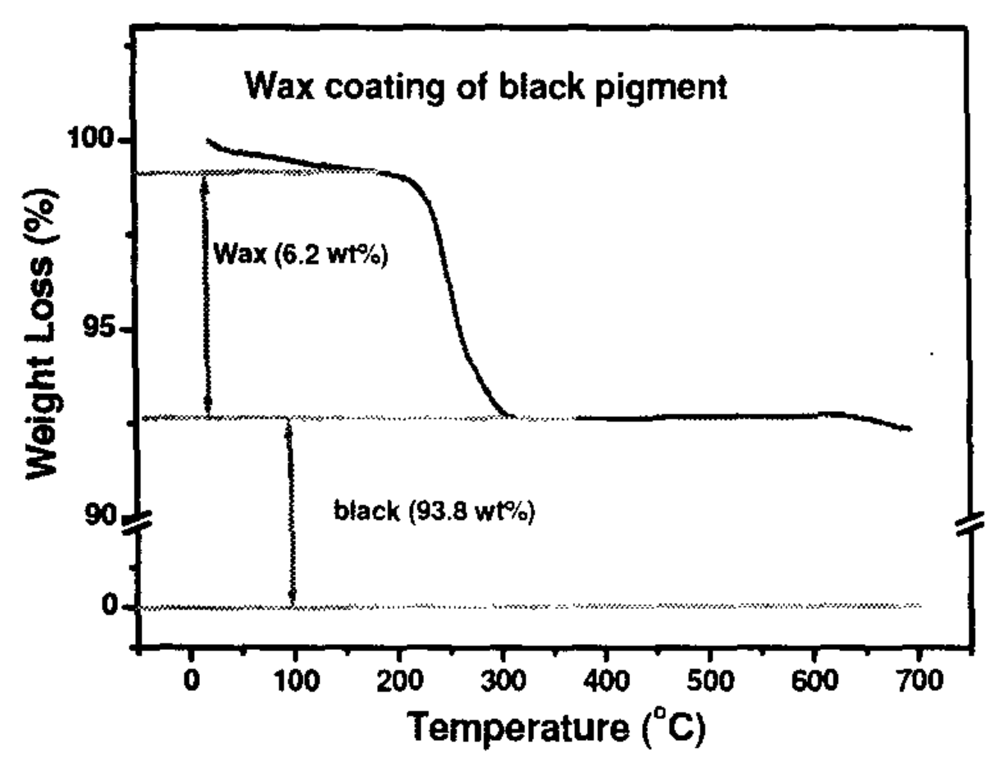

Figure 5. Thermogravimetric analysis of wax coated black pigment.

The PMMA dispersion polymerization method followed the Table 2 recipe solved the problems of thickness and size controls. As shown in Figure 6, nano sized black pigment was polymerized to give <1 μm black particles. The approximated density of the black particle could be calculated from TGA graph in Figure 7. It has <2 g/mL density similar to that of suspending fluid and bistability of the particles could be realized by thickness control.

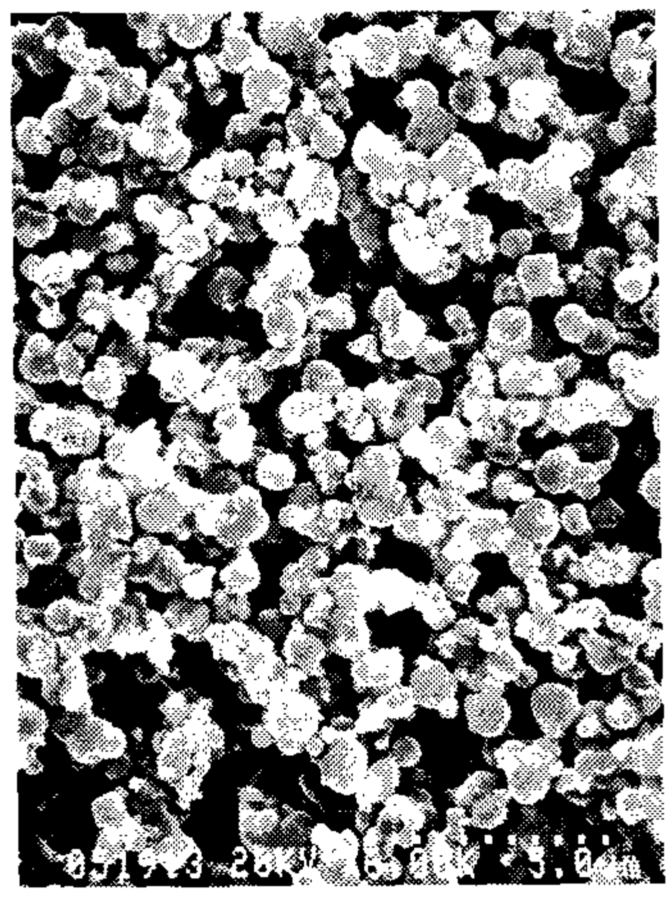

Figure 6. Scanning electron microscopy photograph of PMMA dispersion polymerized black pigment.

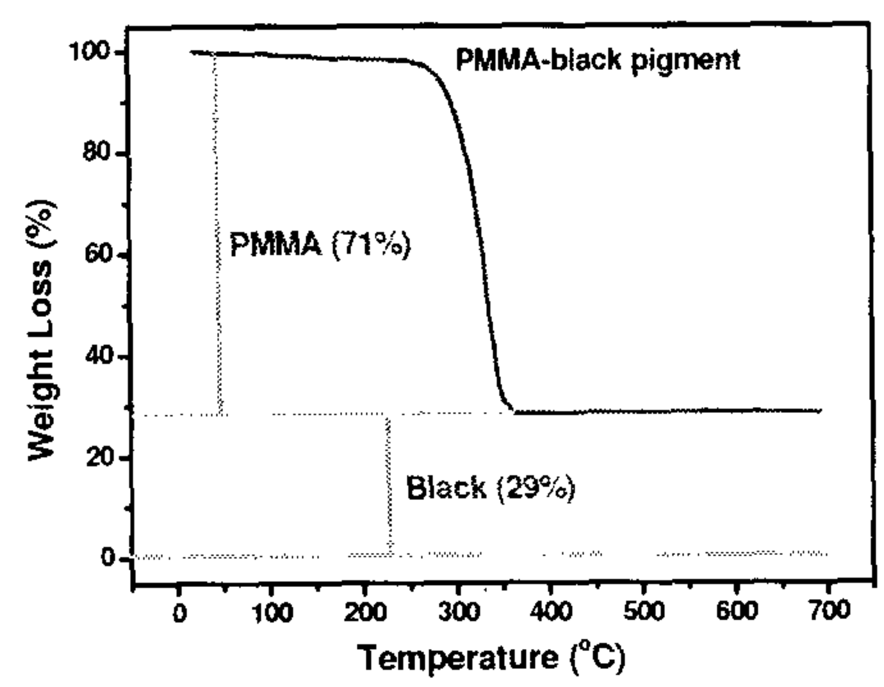

Figure 7. Thermogravimetric analysis of PMMA dispersion polymerized black pigment.

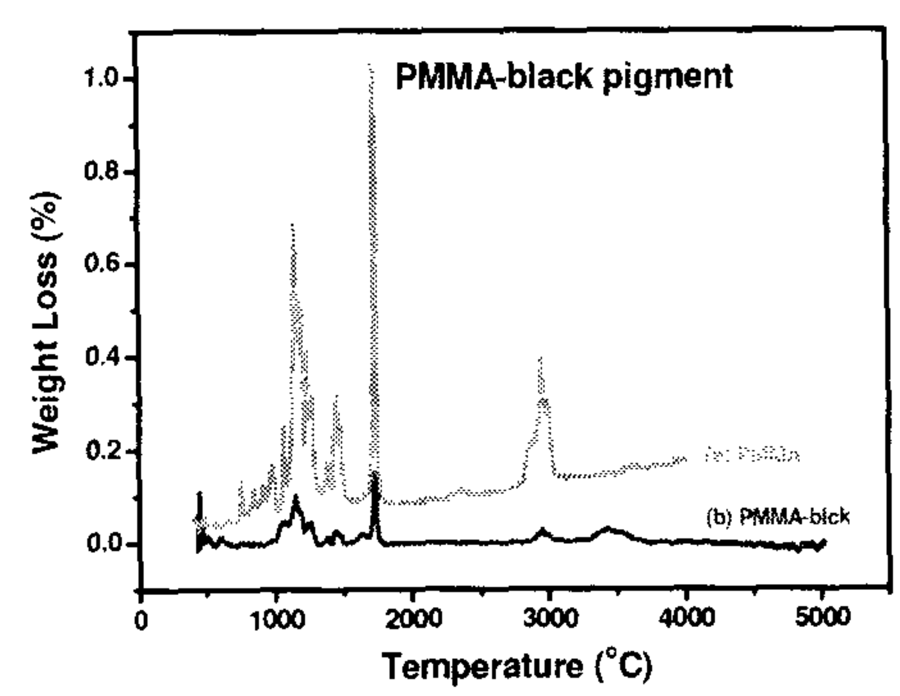

Figure 8. (a) FT-IR of PMMA. (b) FT-IR of PMMA dispersion polymerized black pigment.

One another evidence of PMMA coating was shown in Figure 8 FT-IR spectrum, the peaks of PMMA-black particle were matched with PMMA characteristic peaks.

3. Conclusion

In this study, we have investigated a process of preparation of charged black particles by physical or chemical coating with functionalized polymer for the flexible low-cost paper-like display. We will discuss, especially, the implementation of bistable pigment providing high mobility by using unique charge control agent and also optical and electrical properties of polymer coated black particles and two particle-type microencapsulation in the future.

4. Acknowledgements

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5. References

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