Electronic Ink using the Electrophoretic High Mobility Particles

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Abstract

The black/white electronic ink containing high mobility white nano particles and the organic black pigment particles dispersed in dielectric fluid were prepared. A charge control agent affects the electrophoretic zeta potentials of white particle, which show the maximum value in zeta potential. The electronic ink panel fabricated with the charged white particles and the black particles exhibits more than 15:1 contrast ratio at 10V.

1. Introduction

The electronic paper that possesses reversibility, bistability, flexibility, and low cost to manufacture, has been pay attention to people. One of the electronic paper display technologies, the electrrophoretic display is a non-emissive device based on the electrophoresis phenomenon of charged pigment particles suspended in a dyed solvent. It was first proposed by Ota et al. in 1969 [1]. Due to the passive of the display, the near Lambertian scattering of the pigment, the electrophoretic display devices exhibit excellent contrast over a wide range of viewing angles. The colloidal suspension is the most crucial part of an electrophoretic display device. The composition of the suspension determines to a contrast ratio and response times of the device. A major consideration for the colloidal stability in the electrophoretic suspension is the contribution of a high electrophoretic mobility. The electrophoretic mobility of a particle in suspending liquid is given by [2]:

$$\mu = \varepsilon\zeta/6\pi\eta = v/E \,. \qquad (1)$$

Hence, liquids with the highest ε/η ratio should be chosen for fast display operation.

This study describes the preparation of the electrophoretic suspensions with charged white particles, showing above 100 mV zeta potential.

2. Experimental

Synthesis of pigment particles. As the white pigment particle (TiO_2/PS particles), TiO_2 (MT-500B, Avg. dia = 0.35 μm, Advanced Polymers Co.) were coated with a crosslinked poly(styrene-co-acrylic acid) copolymer through a two-stage dispersion polymerization technique. The color particles were obtained from Soken Chemicals Co. (Japan) and DPI Solutions Co. (Korea).

Preparation of the electrophoretic suspension. The electrophoretic suspension was prepared by suspending TiO_2/polymer hybrid particles, as the charged white pigment, and two different color particles respectively in a clear dielectric fluid. Suspensions were prepared by ballmilling using ceramic grinding balls. The procedure was to first dissolve the charge control agent in the suspending liquid. The white pigment was then added, and the mixture was ballmilled for several hours to make stock solution-typed suspension. The concentrated black suspensions were prepared the same method. To make the electrophoretic ink suspension, the concentrated white stock solution and the black stock solution were mixed, then it was diluted to the fixed concentration and was exposed to sonication. Routine testing of suspensions were done in simple test cells and measurements of the contrast, response times, and conductivity were performed. It was examined that the kinds of charge control agents and the concentration of the charge control agent influence the contrast ratio and response time in the electrophoretic cells, as a consequence, the quality of the device. The electrophoretic cells structured two 4 cm x 4 cm transparent plates with electrodes placed opposing each other, leaving a 150 μm distance in between by using spacers.

Each microcapsules containing the polymer-coated TiO_2 (negative polarity) and each color particles (positive polarity) suspension as a core material, were manufactured. Based on the color particle movement results in the electrophoretic cell tests, we prepared each color microcapsules which are improved the dispersion stability, the optical responses, and response time.

3. Results and discussion

Zeta potentials of electrophoretic white pigment particle suspensions that are composed the white pigment and dielectric fluid, were measured through Zetasizer 2000 (Malvern Instruments). Figure 1 represents the surface charge characteristics of TiO_2/PS.

The particles were dispersed in the isoparaffin oil with oil soluble surfactants as a charge control agent. Span grade surfactants showed different HLB, The HLB of Span-85 was the lowest for three different grades. Zeta potentials of the particle suspension were affected by HLB of the surfactant. The lower HLB of the suspension represented the higher zeta potential. The zeta potentials increased with surfactant concentrations at low concentration range, but it showed the maximum value then decreased. Surfactant concentrations for maximum value depended on the HLB of surfactant.

Therefore, the electrophoretic ink suspension to fabricate the display device was prepared with Span 85. 20 vol% white particles dispersed in 0.5 vol% of Span 85 concentrated isoparaffin oil was blended with 5 vol% of black particle suspension, then sonicated for 1 hr. The contrast ratio of the electrophoretic ink suspension was calculated using reflectivity in +10V vs. that in -10V through a test cell with thickness 150 μm. Figure 2 presents the performance of a black/white electrophoretic ink suspension in the cell after applying 10 V. We measured the reflectivity values of the black/white electrophoretic suspension cell using a chromater (CS-100, Minolta Co.). The white state shows 211 cd/m^2 and the black state is 11 cd/m^2. The contrast ratio (CR) of the black/white electrophoretic suspension in the cell is measured to be 19:1 with operating time of nearly 5 sec. Figure 3 shows a completed sheet of electronic ink panel (total thickness ~ 0.5 mm and contrast ratio ~ 4:1. The reduction of the contrast ratio at a microencapsulated electronic ink panel may come from the microscopic voids among the microcapsules and the dead microcapsules which are not operated.

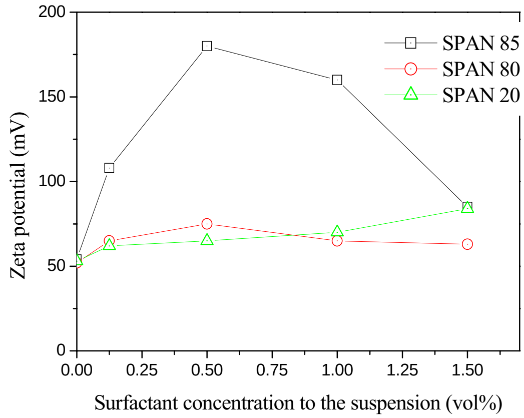

Fig. 1. Zeta potential of TiO_2/PS electrophoretic particle suspension with three different surfactants.

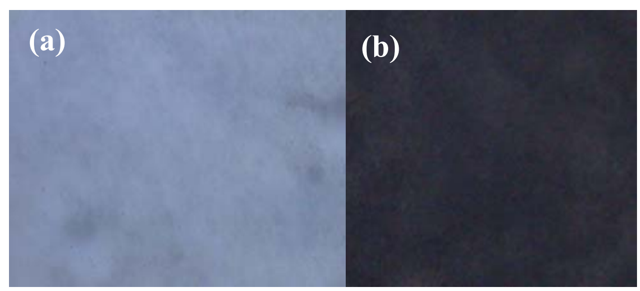

Fig. 2. Photomicrographs of the black/white electrophoretic ink suspension cell in power-on state. (a) is +10V applied on the front electrode, and (b) is -10V applied on the front electrode.

Fig. 3. Photographs of A4-sized electronic ink panel with an electrophoretic ink microcapsule diameter 50 ± 10 μm in power-on state.

(a) is +10V applied on the front electrode, and (b) is -10V applied on the front electrode.

4. Summary

We have developed the high contrast ratio electrophoretic ink suspension which can be fabricated the noticeable electronic paper display. The effects of the charge control additives were significant. The appropriate additions of charge control additives results in an increase in electrophoretic mobility.

5. Acknowledgements

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6. References

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