Color Electrophoretic Image Display Based on Movement of Particles Using Two Driving Electrodes

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Abstract

We have proposed novel Color Electrophoretic Image Display, CEPID, based on the movement of white, black and color particles in an insulating liquid. There are non-electrophoretic white particles, negatively charged black particles and positively charged color particles in the cell. The movement of charged particles is controlled by the change of polarity of voltage applied to three electrodes. This CEPID cell displays black/white and color by changing polarity of voltage applied to driving electrodes. Both of black and color particles move to the driving electrodes when each driving electrode is applied to positive and negative voltage, we can see white image through the common electrode.

Introduction

An electronic paper is investigated as a next generation paper-like-display medium which has good features of both of hard-copy and soft-copy. Electrophoretic Image Display, EPID, is expected as one of the display technology with the feasibility in the electronic paper system. Although black and white EPID is developed in commercial available, Color EPID, CEPID, is yet in the study phase. Though, the CEPID using a color filter array is demonstrated, there is a problem with a low reflection light intensity at white view due to loss the light pass the color filter. In this paper, we have proposed the new method of a color display using three kinds of particles of black, white, and color, and two driving electrodes in the display cell.

Color EPID

Fig.1 shows the principle of operation of the newly proposed CEPID [1], [2], [3], [4], [5]. The display cell is made up with a pair of transparent glass substrates on which transparent electrode is coated. The full face of top glass is coated with transparent ITO electrode. The interdigitated electrodes which are patterned two electrodes alternately such as a comb are used for the driving electrodes. Thereby, one common electrode is on the top glass and two driving electrodes are on the bottom glass. The distance between pair electrodes is kept constant by spacer. Three kinds of particles, white, black, and color, are dispersed in an insulating liquid. We use white particles which are not charged in a solvent, and black and color particles are charged in positive or negative, respectively.

Black, white and color image can be displayed by controlling the movement of the charged particles within the cell by changing the polarity of voltage applied to two driving electrodes. The white image is displayed by applying positive and negative voltages to the driving electrodes, respectively. Thereby, positively charged color particles and negatively charged black particles move to the driving electrodes, respectively and white particles dispersed in the cell are observed through the common electrode. When negative voltage is applied to the both of two driving electrodes, positively charged color particles move to the driving electrodes and negatively charged black particles move to the common electrode, so the black image can be seen through the common electrode. The color image is displayed by applying positive voltage to the both of two driving electrodes because negatively charged black particles move to the two driving electrodes at bottom glass and positively charged color particles move to the top electrode.

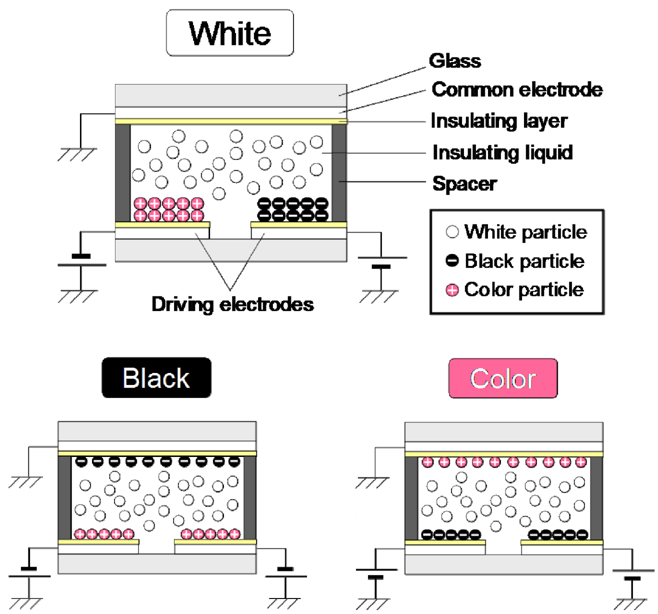


Figure 1 *Schematic illustration of CEPID cell*

Experimental

Materials

We used poly-vinyl-naphthalene (PVNp) [6], resin-coated black Ti(N, O_2), and resin-coated quinacridone pigment for non-electrophoretic white particles, negatively charged black particles and positively charged color (magenta) particles, respectively. Figure 2 shows the SEM image of PVNp. PVNp is the spherical particles of 450 nm of diameter, and has a high refractive index. Moreover, it has high dispersion stability in insulating liquid. The insulating liquid Isopar G (Exxon Mobil Corp.) was used for solvent, and surfactants Solsperse17000 (Avecia) and Sorbitan Trioleate (Wako Pure Chemical Industries, Ltd.) were used as charge control agent and dispersant agent.

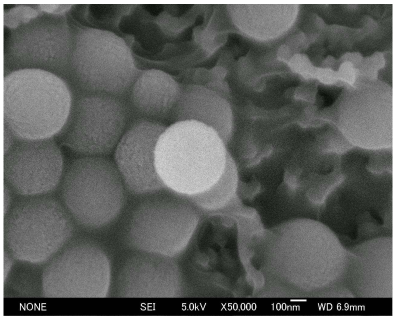


Figure 2 *SEM image of PVNp.*

Measurement

The structure of CEPID cell is shown in Figure 3. Glass substrate coated with ITO electrode (display area is 1cm × 1cm) and glass substrate coated with interdigitated ITO electrodes were sealed at gap distance of 100 micrometers and dispersion liquid was injected into the cell. Reflectance measurement and optical reflection spectra measurement were done. Light was irradiated at the cell set in the black box (A9665, Hamamatsu Photonics K. K.) through the optical fiber from spot light source (L8333, Hamamatsu Photonics K. K.), and reflectance measurement was performed by detecting reflection light with photonic multi channel Analyzer (PMA-11 C7473, Hamamatsu Photonics K. K.).White reflectance standard (Certified Reflectance Standard labsphere, Edmund Optics Japan Ltd.) was equated with 100 %, and evaluated samples by relative reflectance. Zeta potential measurement was performed with Zeta potential and particle diameter measurement equipment (ZETASIZER 3000HS, Malvern Instruments). This equipment uses the laser Doppler method for measurement of Zeta potential.

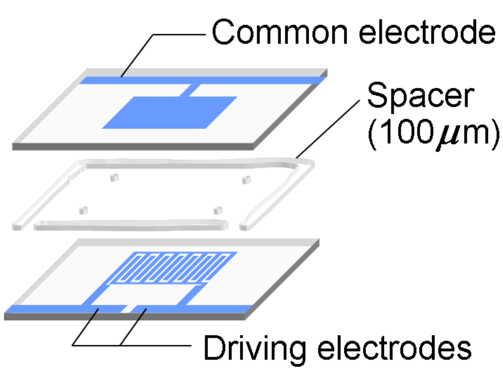


Figure 3 Structure of CEPID cell.

Results and Discussion

Particle Concentration

In order to determine the particle concentrations of black particles and color particles used for 3 particles dispersion liquid, the relation between particle concentration and reflective density was investigated for black particles and color particles. The mixture of particles and two kinds of surfactants of 0.5 wt% each in solvent, were stirred using magnetic stirrer and with ultrasonication. The samples which contain particles from 0.4 wt% to 2.2 wt% were prepared. 30 V was applied between the common electrode and both of two driving electrodes by DC power source (PMC 500-0.1A, Kikusui Electronics Corp.), and particles were deposited on the common electrode. Reflectance in 550 nm in black particles dispersion liquid and color particles dispersion liquid was measured where white reflectance standard was put on the back. Then the value of reflectance was changed into reflective density.

The relation between particle concentration and reflective density is shown in Figure 4. The sufficient reflective density 1.5 was obtained by 0.8 wt% of particle concentration about black particles and 1.3 wt% of particle concentration about color particles.

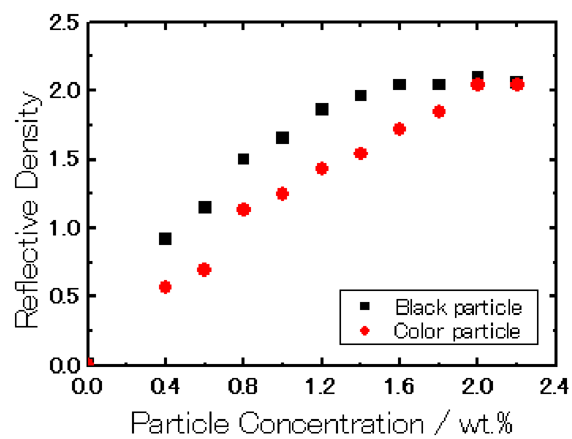
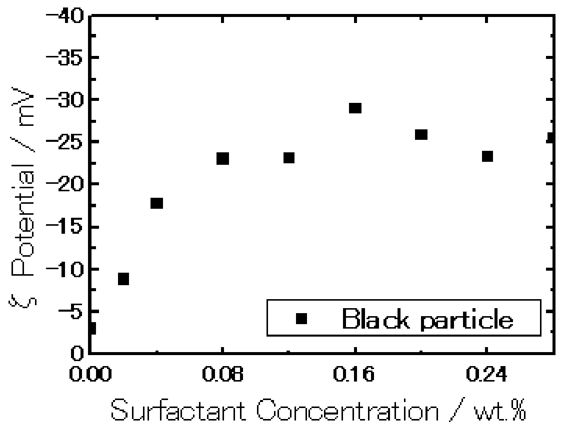


Figure 4 *Relation between particle concentration and reflective density.*

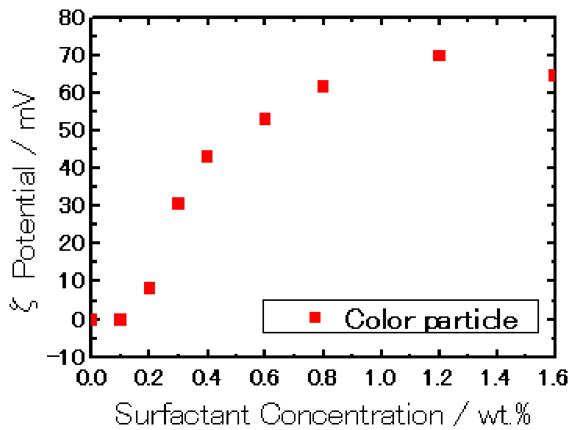
Zeta Potential

Zeta potential which shows the amount of electric charge of particle was measured. The samples which are the mixture of 1 wt% of particle, 0.5 wt% of Sorbitan Trioleate and some amount of Solsperse17000 each in solvent, were stirred with ultrasonication and using mixing rotar. The samples were diluted by solvent and their particle concentration became 0.005 ~ 0.01 wt%.

The results of zeta potential measurement are shown in Figure 5. By the quantity of addition of Solsperse17000, black particle showed negative charge, and color particle showed positive charge. And white particle had no charge even if it increased the quantity of Solsperse 17000.



(a) Black particle

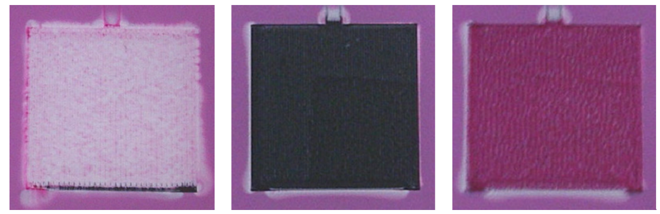


(b) Color particle

Figure 5 Zeta potential of black and color particles.

Reflection Spectra

The optical reflection spectra of the display cell were measured when the positive and negative voltages were applied to the two driving electrodes. The sample contained white particles, black particles, color particles and two kinds of surfactants in insulating liquid. Figure 6 shows the photographs of CEPID cell. Figure 7 shows the reflection spectra of sample. Magenta color was displayed when +15 V was applied to both of two driving electrodes. The waveform of magenta color showed the optical reflectance of 20 %, 1 %, 26 % at 410 nm, 540 nm and 640 nm, respectively. Black image was displayed when -15 V was applied to both of two driving electrodes. The waveform of black showed the optical reflectance of 3 – 5 % in whole optical range. When +15 V and -15 V were applied to each driving electrode, it has the reflectance more than 35 % on the whole, and it can be regarded as a white image. The optical spectrum of white image decreased at near 550 nm wavelength because a small number of magenta color particles were deposited on the surface of top electrode at white display state. These optical spectra exhibit black, white and magenta color, so it can be said that the image of white, black, and color was obtained by the change of polarity of voltage applied to driving electrodes.



(a) White state (b) Black state (c) Color state

Figure 6 Photographs of CEPID cell.

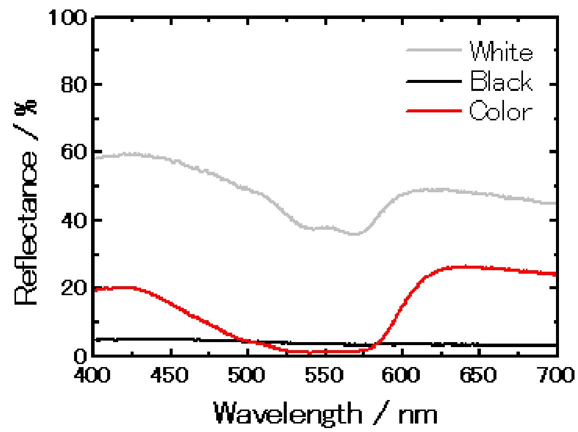


***Figure 7** Reflection spectra in white state, black state and color state.*

Conclusion

Color Electrophoretic Image Display, CEPID, based on movement of particles using two driving electrodes was investigated. Using non-electrophoretic white particles, negatively charged black particles and positively charged color particles, CEPID cell was prepared. White, black and color images were obtained by the change of polarity of voltage applied to driving electrodes of this CEPID cell.

References

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Author Biography

Hiroshi Endo received the B.S. degree in information engineering from Chiba University in 2007. Since then he has been a student in Graduate School of Advanced Integration Science, Chiba University. He is a member of ISJ.