Movement of Electrophoretic Particles between Two Electrodes in Electrophoretic Image Display System

Yuichi Nobusawa, Sakiko Nakamura, Nobukazu Miyagawa and Takashi Kitamura; Graduate school of Advanced Integration Science, Chiba University, Chiba, Japan

Abstract

Electrophoretic Image Display (EPID) based on the electrophoresis of charged particles in dielectric liquid is investigated to us for an electronic paper. In this paper, spatial distribution of electrophoretic TiO_2 particles under the reciprocation motion between two electrodes was observed by using an optical microscope. The drift velocity and mobility of electrophoretic particles were calculated by the observation of movement of particles between two electrodes.

Introduction

In order to read an electronic document, a development of electronic paper which has convenience of the conventional hardcopy and a capability of access to digital information, is expected. This development of a new display technology is important. Electrophoretic image display, toner display, a twisting ball display, photo-address electronic paper and polymer dispersed liquid crystal electronic paper are reported as rewritable technology. In particular, the application of EPID for the electronic paper is expected because EPID exhibits paper-like readability, wide viewing angle, long memory, high image contrast and low power consumption. EPID is reflection type image display based on the movement of particles in an insulating liquid.

In this paper, spatial distribution of electrophoretic particles was studied for analyzing the movement mechanism of electrophoretic particles. Mobility and zeta potential of electrophoretic particles were calculated by observation of electrophoretic phenomenon.

Principle

EPID

The structure of EPID is shown in Fig 1. This display device is sandwich type cell structure and suspension is enclosed in two ITO transparent electrodes. The black and white particles were charged negatively and positively in an insulating solvent respectively. When the voltage is applied to the display cell, black and white particles move to the positive and negative electrode, respectively. Black or white pattern is seen through the top electrode by changing of applied voltage.

The response speed of EPID depends on the mobility of electrophoretic particles. The mobility of particles is calculated by observation of the movement of particles.

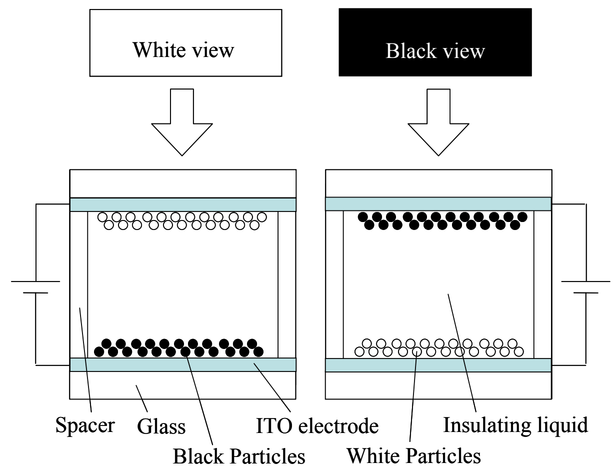

Figure 1. *Schematic illustration of EPID*

Zeta Potential and Mobility

The particle charge q is

$$q = 4\pi r^2 \sigma \tag{1}$$

where r, σ are radius and surface density of charge. The force F_1 caused by electric field E is

$$F_1 = qE \tag{2}$$

Viscosity resistance F_2 when the particle move at the constant speed v is given by Stokes' law:

$$F_2 = 6\pi\eta r v \tag{3}$$

where η is viscosity of insulating liquid. As the speed of particles in an insulating solvent is constant, mobility of the particle is as following equation.

$$\mu = \frac{v}{\mathrm{E}} = \frac{q}{6\pi\eta r} \tag{4}$$

Zeta potential ζ of the particle is

$$\zeta = \frac{q}{\varepsilon r} - \frac{q}{\varepsilon(r + 1/\kappa)} = \frac{q}{\varepsilon r(1 + \kappa r)} \tag{5}$$

where $1/\kappa$ is thickness of diffuse electric double layer. As the $1/\kappa$ in an insulating solvent is large, zeta potential ζ is as following equation.

$$\zeta = \frac{q}{\varepsilon r} = \frac{6\pi\eta}{\varepsilon \mathrm{E}} \cdot \mu \tag{6}$$

Experimental

Materials

The titanium dioxide particles were coated with 2-ethylhexyl polymer. The weight ratio of polymer to particle is 5.6wt% and the particle size is 450nm. The insulating liquid IsoparG (Exxon Ltd.) 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.

Dispersion for observation of electrophoretic phenomenon was prepared as follows. 1wt% particles were mixed with IsoparG containing 0.5wt% Solsperse17000 and 0.5wt% Sorbitan Trioleate in an ultrasonic bath for 30 minutes.

Observation of Electrophoretic Phenomenon

Figure 2 shows the schematic diagram of measurement apparatus for electrophoresis of particles in the cell. The measuring cell is sandwich type with space of 25 μ m. The top electrode is parallel type ITO electrode with 1.2mm space, and bottom glass plate on the black plate due to observe the white particles. The dispersion consisted of 1wt% electrophoretic particles was injected into the cell, and movement of particles was observed through the space of two parallel electrode by using of optical microscope. The time resolution photographs were taken during the movement of particles between two parallel electrodes. The electric field strength is 25, 50, 75 and 100V/mm.

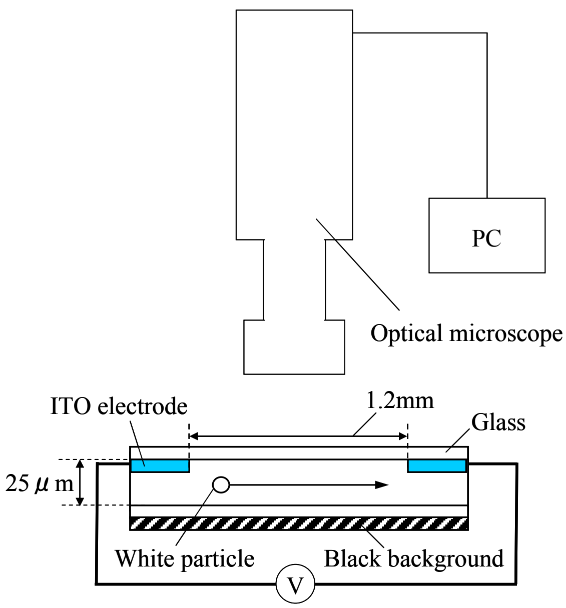

***Figure 2.** Schematic representation of electrophoretic cell for observation of electrophoretic phenomenon*

Results and Discussion

Photographs of the observation are shown in Fig 3. The white particles exhibited electrophoretic phenomenon, moved from anode to cathode. As the result, the white particle estimated to be positive charged.

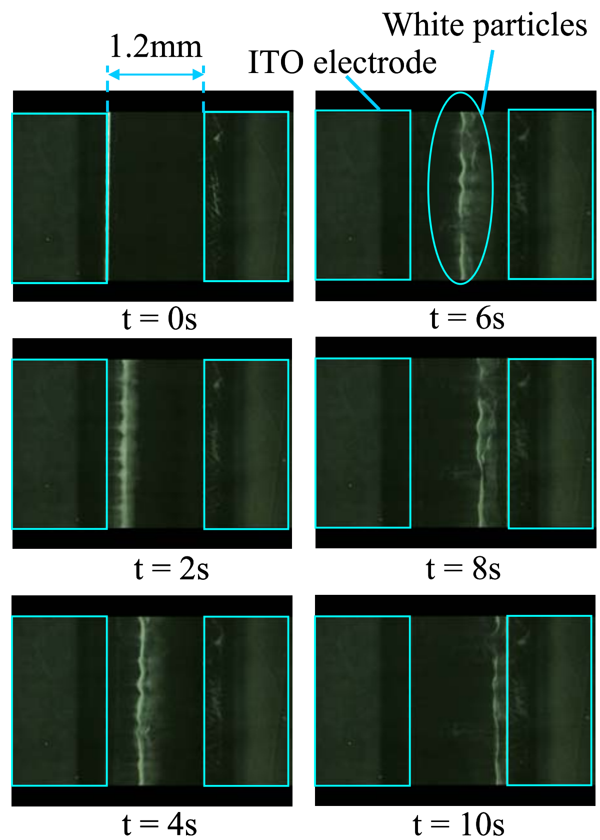

***Figure 3.** Photographs of spatial distribution of electrophoretic particles*

Fig 4 shows particle distribution profile calculated by image analysis of photographs of Fig 3. WinRoof (Mitani Corp) was used as image analysis software. It has been confirmed that relation between particle concentration and gray level is linear.

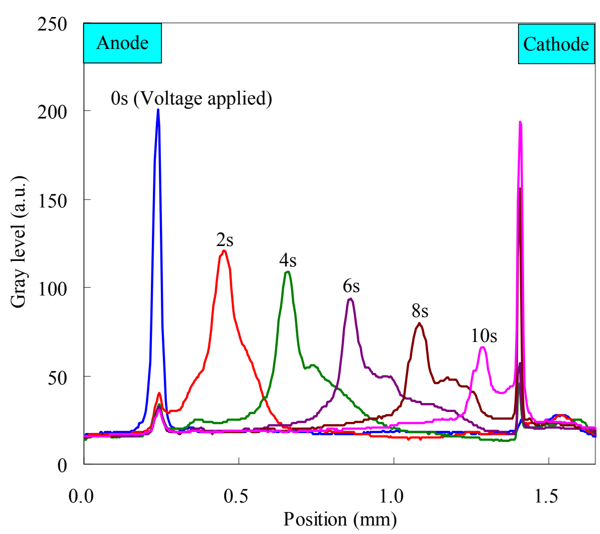

***Figure 4.** Spatial distribution of electrophoretic particles.*

Fig 5 shows relationship between peak position of particles distribution and time. The experimental results indicated that the drift speed of particles constant. The mobility of particles is calculated to be $1.26\times10^{-9}m^2/Vs$ by gradient of the line. Zeta potential is calculated to be 59.3mV by using equation 6.

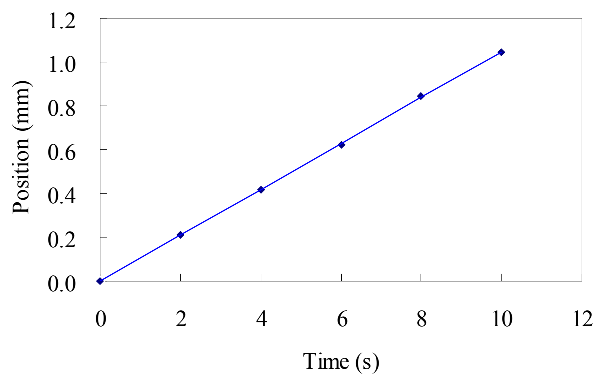

Figure 5. *Peak position of particles distribution vs. time*

Fig 6 shows peak positions of particles distribution as the function of the strength of electric field. Mobility and zeta potential was calculated in the same way. As a result, it's confirmed that mobility didn't depend on electric field strength, as shown in Table 1.

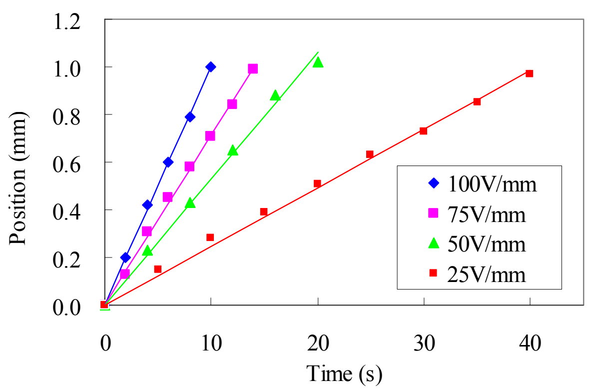

Figure 6. *Peak positions of particles distribution as the function of the strength of electric field*

Table 1. Electrophoretic mobility and Zeta potential as the function of electric field strength

Electric field (V/mm)	Mobility (m^2/Vs)	Zeta potential (mV)
25	1.18	55.6
50	1.27	59.9
75	1.14	53.7
100	1.20	56.5

Conclusion

Spatial distribution of electrophoretic TiO_2 particles under the reciprocation motion between two electrodes was observed by using an optical microscope. The mobility of electrophoretic particles was calculated by the observation of movement of particles between two electrodes.

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Author Biography

Yuichi Nobusawa received the B.S. degree in department of electrical and electronic systems from Saitama University in 2008. Since then he has been a student in Graduate School of Advanced Integration Science, Chiba University. He is a member of ISJ.