

## The Control of Electrostatic Characteristics in Toner Type Paper-like Display

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### Abstract

The toner type paper-like display (PLD) has been developed with two polymer particles having opposite polarity composed of polymer, colorant and external additives (nano-sized silica). Nano-sized silica with triboelectric charge was used for the charge control agent (CCA) and influenced on the electrostatic properties of the silica-coated polymer particles. The surface morphology and the cohesiveness of silica-coated polymer particles were changed with the silica coating time. From these results, it was verified that the PLD cell using silica-coated particles (200 seconds) shows a good white appearance and low driving voltage.

**Keywords** : toner type paper-like display, paper-like display(PLD), toner display, electronic paper, silica coating

### 1. Introduction

Many types of electronic papers such as a toner type display, an electrophoretic display, a twisting ball display, an in-plane type electrophoretic display, a cholesteric-type display and so on have been demonstrated recently<sup>1-3</sup>. Among them, the toner type paper-like display (PLD) is the most powerful candidate because it has high reflectivity, fast response time, paper-like image, low power consumption and passive matrix driving<sup>4-5</sup>.

The basic principle of the PLD is based on the movement of oppositely charged particles under the electric field. When two particles having opposite charge contact with each other, the electrons in the polymer particles migrate to equilibrate the Fermi-level due to the difference in work function. As a result of the electron migration, the two particles change into positive and negative polymer particles. Fig. 1 shows the structure of the toner type PLD. The charged particles are kept in the space surrounded by substrates and polymer ribs. When the positive voltage is applied to the upper electrode, the negative particles are attached to the upper electrode while opposite particles move downward. As a result, we could see the color of

polymer particles on the upper electrode<sup>6</sup>.

In general, the electrostatic characteristics of polymer particles are mainly determined by the CCA. In previous work, we have reported that nano-sized silica having triboelectric charge greatly affect physical and electrical properties<sup>7</sup>.

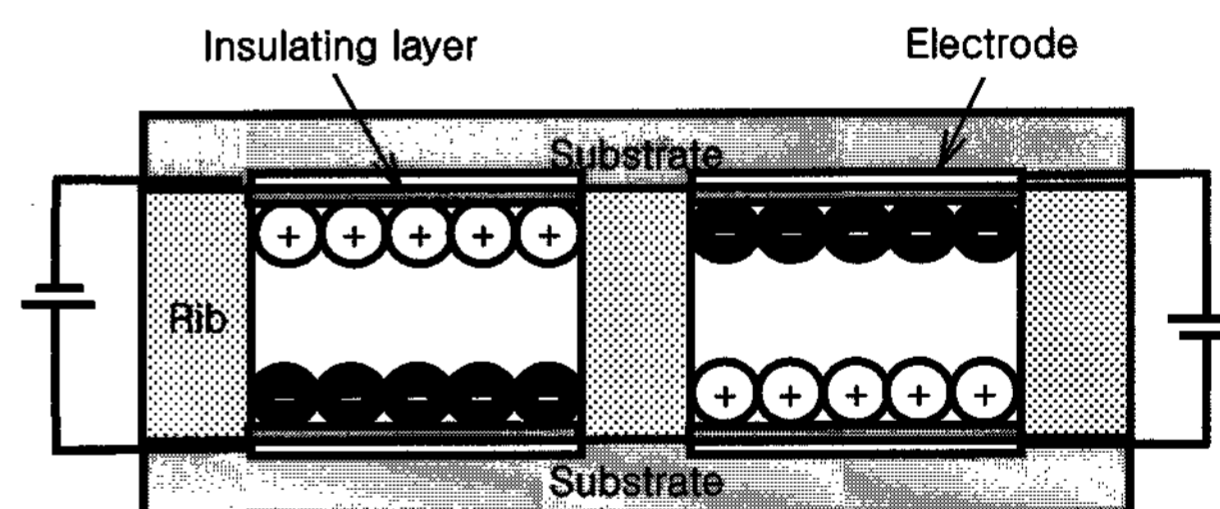


Fig. 1. The structure of a toner type PLD.

In this paper, the electro-optical properties of the silica-coated polymer particles were affected when the coating condition was changed. The surface morphology and the cohesiveness of the silica-coated particles were observed for the effect of the silica coating time.

### 2. Experiment

#### 2.1 Preparation of the silica-coated particles

The two oppositely charged polymer particles having different color were required for the toner type PLD. The

Manuscript received October 10, 2006; accepted for publication March 15, 2007.

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toner particles were composed of poly methyl methacrylate (PMMA), colorant and nano-sized silica. These particles were synthesized by the suspension polymerization method. White particles had titanium oxide and black particles had carbon black inside polymer particles. The mean diameter of white and black particles was about 5  $\mu\text{m}$ . The charge polarities of white and black polymer particles were positive and negative, respectively.

Nano-sized silica A and B were served as a function of the CCA. Silica A is 12 nm in diameter and has a positive polarity, silica B is 16 nm and has a negative polarity. Nano silica was coated by a blade mixer with a rotation speed of 5000 rpm and polarity between polymer and silica was the same. In this experiment, the 5 wt% silica relative to a polymer weight was coated on the polymer surface. And nano-sized silica was coated for 200, 400 and 600 seconds to control the physical and electrical properties.

Fig. 2 shows the structure of a silica-coated polymer particle. Nano-sized silica was embedded into the polymer surface by a blade mixer.

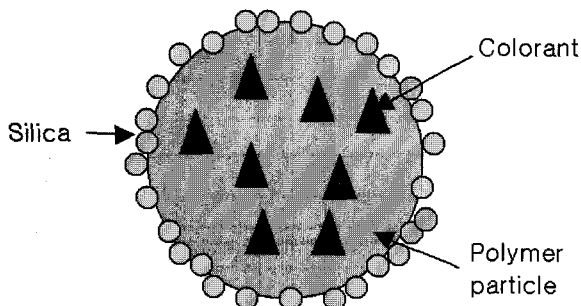


Fig. 2. The schematic structure of a silica-coated polymer particle.

### 2.2 The cohesiveness of the silica-coated particles

A sieving method was developed to measure the cohesiveness which is relevant to the interaction between the particles. Three types of meshes were applied and these were stacked from 38  $\mu\text{m}$  to 53  $\mu\text{m}$  in turn as shown in Fig. 3.

The measurement process is as follows;

1. Shake polymer particles for a while
2. Pour 4 g particles into 53  $\mu\text{m}$  mesh
3. Cover the top and fix the equipment
4. Vibrate for 30 seconds with 900 rpm
5. Measure the rest particle weight on each mesh

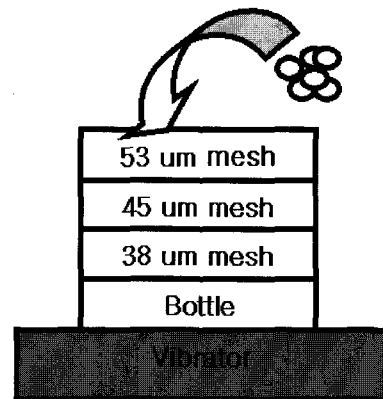


Fig. 3. The schema of cohesiveness measurement.

Each weight data was inserted in equation (1).

$$\text{Cohesiveness} = 50 \times \text{powder weight}(53 \mu\text{m}) + 30 \times \text{powder weight}(45 \mu\text{m}) + 10 \times \text{powder weight}(38 \mu\text{m}) \quad (1)$$

### 3. Results and Discussion

Two white and black particles having same coating time were used for PLD cells. Fig. 4 shows the reflectivity changes of PLD cells with increased voltage. As the silica coating time, the electro-optical properties of PLD cells dramatically changed. The 200s and 600s PLD cells showed the reflectivity of white appearance over 30% and the contrast ratio over 5:1. The driving voltage of these cells was lower than 400s PLD cell.

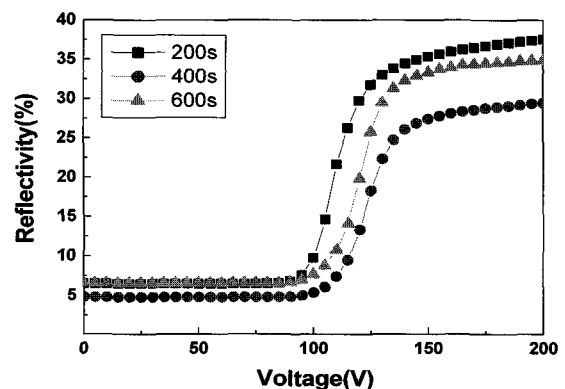


Fig. 4. The reflectivity changes with applied voltage. The silica coating time: (-■-)200s, (-●-) 400s, (-▲-) 600s.

On the contrary, 400s PLD cell showed poor electro-optical characteristics such as reflectivity, driving voltage

and threshold voltage. Fig. 5 shows the white appearance of 400s PLD cell after driving. Although the PLD cell displayed white image, there were some black defects. This phenomenon was caused by aggregation of white and black particles. The reason for this result was that nano-sized silica might influence on the electro-optical characteristics of toner particles.



Fig. 5. The white appearance of 400s PLD cell.

To confirm the assumption, we observed the surface morphology and the cohesiveness of the silica-coated polymer particles. The surface morphology changes of silica-coated white particles depending on the silica coating time are shown in Fig. 6. The degree of the silica coating increased with the silica coating time. Fig. 6(right) shows the schema of the state of silica coating. The 200s particle was weakly bounded with nano silica. Nano-sized silica of 400s particle was coated homogeneously on the polymer surface. When the silica coating time was 600s, the surface of the silica-coated particle was rough since some silica particles were stuck in polymer bulk. These morphology variations with the increasing coating time were found to be dependent on the increasing number of collision.

The cohesiveness of each white particle is listed in Table 1. Compared with the silica-coated particles, the bare particle had high cohesiveness because the friction force between the particles was so strong. On the other hand, nano-sized silica of the silica-coated particles put some distance between the particles. This function of nano-sized silica reduced the friction force and the cohesiveness.

In the silica-coated particles, the cohesiveness of the 400s particles was greater than the 200s and 600s as shown in Table 1. This result suggests that the cohesiveness of the silica-coated particles was dominated by electrostatic force rather than friction force<sup>8</sup>. It means that the silica-coated

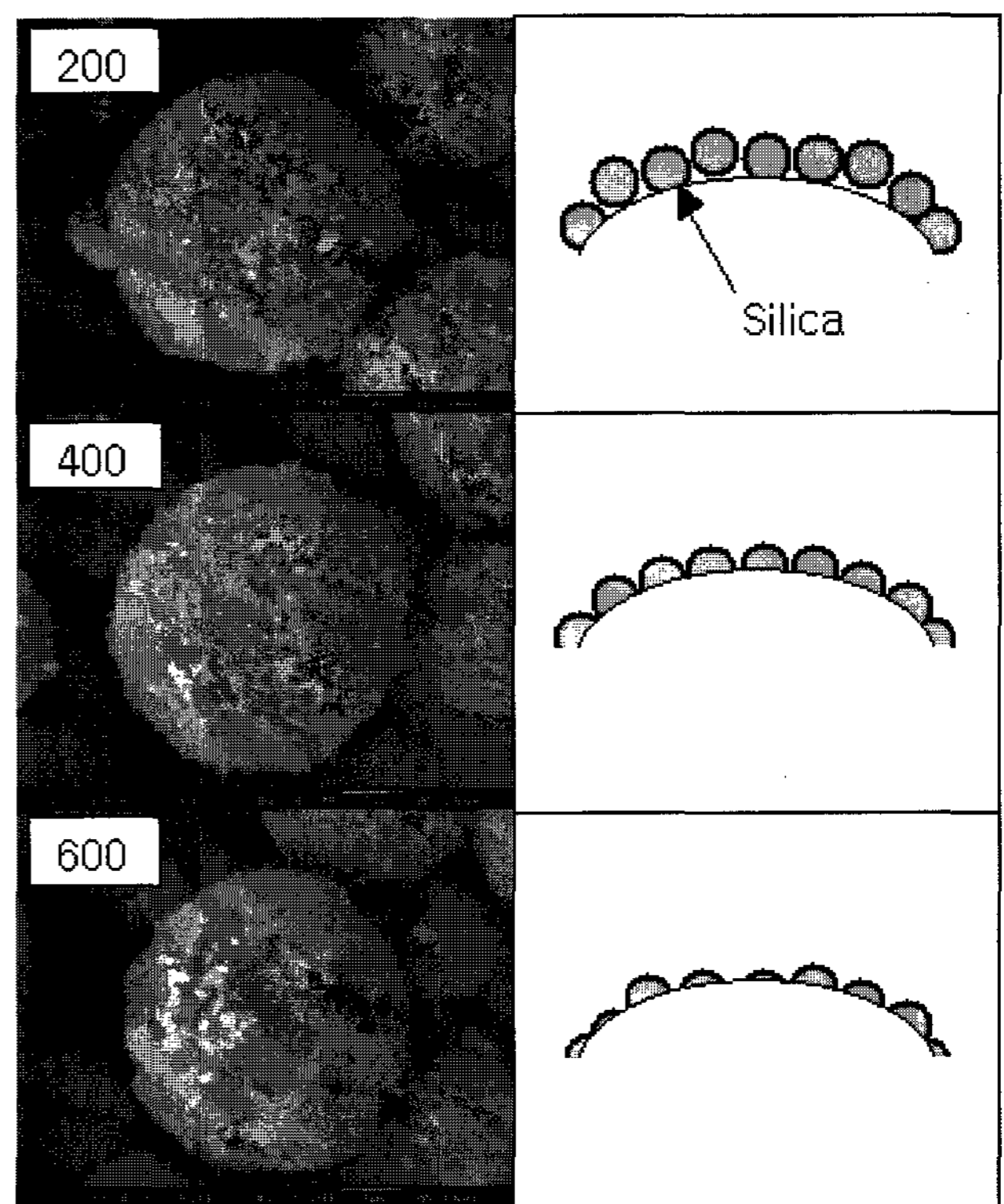


Fig. 6. The surface morphology of the silica-coated polymer particles with the silica coating time.

particles were electrified by triboelectric charge of nano-sized silica and had repulsive force between the polymers due to the same polarity of silica charge. The electrification efficiency of the silica-coated particles was dependent upon the degree of the silica coating. When the nano-sized silica was weakly (200s) or strongly (600s) adhered on the polymer surface, the cohesiveness was low due to low repulsive force. The 400s particles having high electrification efficiency showed high cohesiveness that was caused by strong repulsive force between particles. From these results, the 400s PLD cell had particle aggregation and low electro-optical properties (Fig. 4).

Table 1. The cohesiveness of bare and silica coated polymer particles.

Coating time	Bare particles	200s	400s	600s
Cohesiveness	149.3	91.7	96.2	80.3

The surface morphology was changed by the silica coating time. With increasing time, the degree of the silica

coating was increased and this influenced the cohesiveness of the silica-coated polymer particles.



**Fig. 7.** The image of 5.7 inch PLD panel with 320×240 array of pixels.

Fig. 7 shows 5.7 inch PLD panel with glass substrate, which has a 320×240 array of pixels. The silica-coated particles for 200s were used. This display shows good image quality, a paper-like image as well as a high memory effect. The reflectivity of white appearance was about 35% and the contrast ratio was about 6:1. The driving voltage of the PLD panel was 125V.

#### 4. Conclusion

In our toner type PLD, nano-sized silica was used for the charge control agent (CCA) and coated on the polymer surface by the mechanical mixing method. The surface morphology and the cohesiveness of the silica-coated polymer particles were varied according to the silica coating time.

The degree of the silica coating was to affect on the electrostatic properties. The silica-coated polymer particles were adapted to the 5.7 inch PLD panel successfully.

#### References

- [ 1 ] B. Comiskey, J. D. Albert, H. Yoshizawa, and J. Jacson, *Nature*. **394**, 253 (1998) .
- [ 2 ] R. Hattori, S. Yamada, *SID 04 Digest*. **35**, 136 (2004) .
- [ 3 ] G. Crawford, *SID 05 Short Course*. **S-1**, 51 (2005) .
- [ 4 ] S. H. Kwon, S. G. Lee, W. K. Cho, B. G. Ryu, and M. B. Song, *IMID 05 Digest*. 423 (2005) .
- [ 5 ] R. Hattori, S. Yamada, *SID 03 Digest*. 846 (2003) .
- [ 6 ] W. K. Cho, S. H. Kwon, S. G. Lee, N. J. Kim, B. G. Ryu and M. B. Song, *JID*. **6**, no.3 (2005) .
- [ 7 ] S. G. Lee, S. H. Kwon, W. K. Cho, B. G. Ryu and M. B. Song, *Asia Display/IDW 05*. **1**, 903 (2005) .
- [ 8 ] R. Freeman, W. Malvern, *Labplus international*. **18**, no.1 (2004).