# Reflective Paper-Like Display using Opposite-Charged Two Particles

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## Abstract

*Reflective paper-like display (PLD) using two types of particles having different electric polarity has been developed. A positive-charged particle has $TiO_2$, polymer and charge control agent (CCA), while a negative-charged particle consists of carbon black, polymer and CCA. We achieved fast response time (~0.2 msec) and passive matrix driving addressing. These methods can easily be adapted to complete a large area display and flexible display.*

## 1. Objectives and Background

In reflective paper-like display systems, there are toner displays[1], electrophoretic displays[2], twisting ball displays[3] and a cholesteric-type display[4] and so on.[5] Among them, the toner display using charged particles is the most promising candidate because it offers advantages such as fast response time and passive matrix driving addressing.[6, 7] The critical technology in toner displays is the development of particles having good movement property and electric polarity characteristic. In our experiment, a positive-charged particle has $TiO_2$, polymer and CCA (+), while a negative-charged particle consists of carbon black, polymer and CCA (-). These particles have good fluidity by additive of nano-sized silica. Using these materials, we demonstrated display panel that has 120×120 array of pixel driven by passive matrix addressing.

## 2. The operation principle and panel

The operation principle of our toner display device is simple as follows. The white particles are charged positively and the black particles negatively. When negative voltage is applied to the upper electrode, the white particles move toward the upper substrate and the black particles move toward the opposite direction, the bottom substrate. As a result we can see the white image on the upper substrate. When the polarity is reversed, we can attain black image. Figure 1 shows the structure of toner type PLD device.

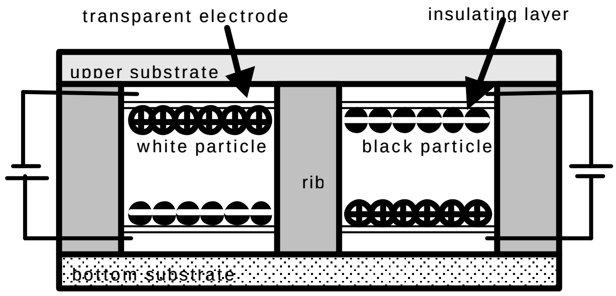


**Figure 1: The structure of the toner type PLD device**

The PLD device is comprised of an upper substrate, bottom substrate, insulating layer, two transparent electrodes, ribs, and two opposite-charged two particles. The toner particles are filed up in the cell surrounded by ribs. The height of the ribs is 50 to 100 um and their width is 20 to 40 um. Ribs are located at the space between both upper and bottom substrates. Figure 2 shows SEM photography of mesh-shaped rib. We used ITO (Indium-Tin-Oxide)-coated glass for upper and bottom substrates, and the transparent ITO electrode layers are patterned by photo-lithography method for passive matrix addressing.

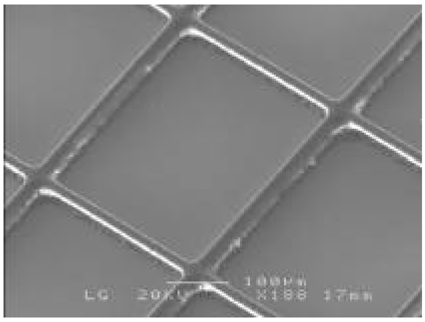

**Figure 2: SEM photography of mesh-shaped rib**

The upper electrodes are same shape as the bottom ones, but two electrodes are cross right angle to each other. Figure 3 is basic driving scheme of toner-type PLD. Scan pulse signals are sequentially applied from $S_1$ (Scan 1) to $S_N$ (Scan N) and data signals are simultaneously applied to show some images. The voltage applied to either scan electrode or data electrode must be lower than the threshold voltage for passive matrix addressing. Once a driving voltage is applied, the last image is maintained for a long time without supplying an additional voltage. We call it memory effect. Therefore our device with memory effect needs an erase pulse corresponding to sum of scan and data voltage to make a white background image before signal is applied to scan and data electrodes.

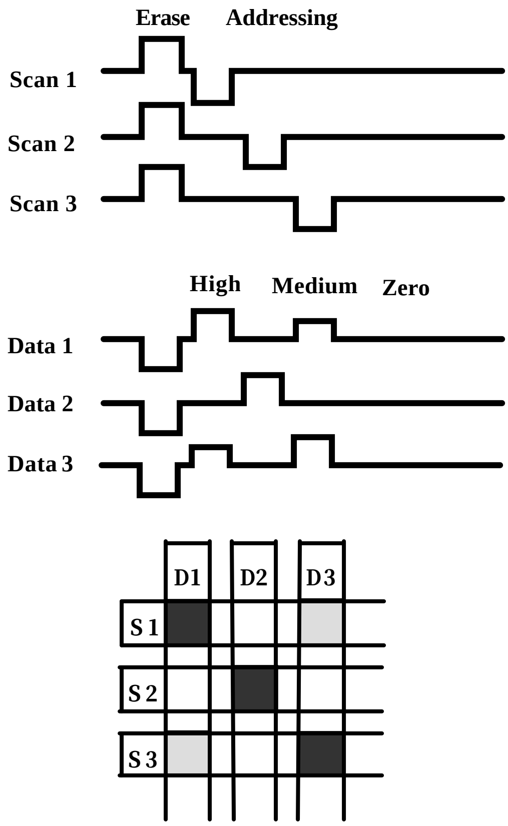


**Figure 3: The driving scheme of PLD**

Gray scale is controlled by voltage level of data electrode. High voltage level makes black image, and medium voltage level makes gray image and zero voltage makes the pixel unchanged white background image.

### 3. Measurement and discussion

We used photo-reflectivity measurement equipment (LMS EOA) system for measuring reflectivity and response time (Figure 4). These two measurement principles are as follows. We irradiate light on the reflective PLD panel with changing driving voltage and time, respectively. Then its reflective light from the panel is detected by the PMT (Photo Multiplier Tube). PMT converts voltage-varying and time-varying luminescence data of some area on the panel into analog voltage signal. The analog signal is digitalized and processed using personal computer to determine the response time and reflectivity.

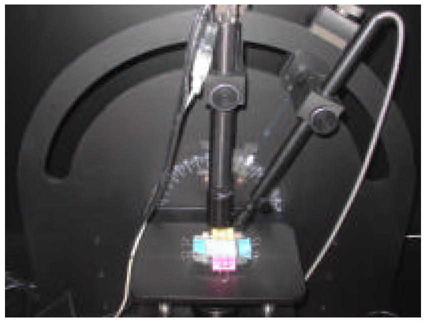

**Figure 4: Photo-reflectivity measurement equipment for PLD**

Figure 5 show that our panel achieves response time about 0.2 msec. The response time of 0.2 msec shows that our display panel is faster than electrophoretic type panel of 15~30 msec.[8] This response time is fast enough to display 120×120 array of pixel, so it takes only 24.2 msec to change 1 flame image including erasing time.

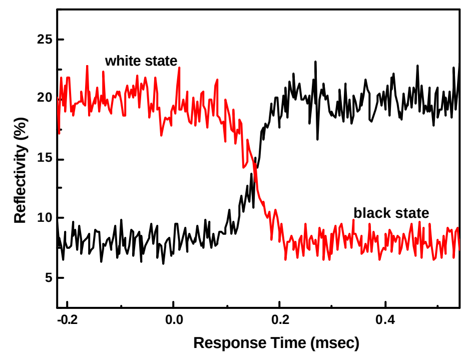


**Figure 5: Response time of the toner type PLD device**

Figure 6 shows 21% in reflectivity even though our experiment is at the beginning point. We think there are many chances to improve reflectivity through modifying components of particle resin, mixture ratio of each particle, panel structure and so on.

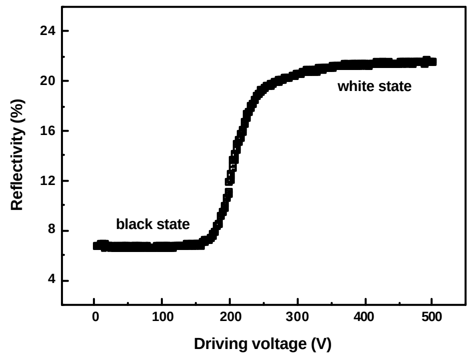


**Figure 6: Reflectivity change with varying applied voltages**

Figure 6 also shows the sharp inclined curve variation, allowing passive matrix addressing. If there is not the critical voltage level initiating movement of particles in the cell, PLD device cannot use passive matrix addressing. In case of active matrix addressing needs TFT (Thin-Film-Transistor) arrays to operate each cell. TFT is unfavorable to make large-sized display panel because of its high cost and complex manufacture process. We demonstrated 120×120 array of pixel, 2.4-inch size panel with passive matrix addressing as shown in Figure 7. The response time of 0.2 msec is enough to give natural image during updating. These images were maintained over 6 months due to a high memory effect of the PLD device.

**Figure 7: 120×120 array of pixel, 2.4-inch panel image of the toner type PLD device**

## 4. Conclusions

Our toner-type PLD panel has a threshold voltage that enables passive matrix addressing. Response time is 0.2 msec and reflectivity is 20%. Also, the panel has memory effect. To maximize these advantages of our panel, we anticipate that our panel is applied for ultra-large sized panel as like E-Poster and commercial advertising board.

## 5. Reference


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