Color Toner Display Based on Control of Particle Movement

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Abstract

Toner Display is based on an electrical movement of charged particles. Two types of black toner and white particles charged in the different electric polarity are enclosed between two electrodes. The particle movement is controlled by the external electric field applied between two transparent electrodes. The toner is collected to the electrode by an electrostatic force across the insulating layer to display a black image. The toners can be put back to the counter electrode by applying a reverse electric field, and white solid image is displayed. We have studied on the movement of three color particles independently to display color image in Toner Display. Two positively charged color particles with different amount of charge to mass ratio and negatively charged white particles were enclosed in the toner display cell. Yellow, cyan and white images were displayed by an application of voltage.

Introduction

In order to read an electronic document, a development of electronic paper which has the convenience of the conventional hardcopy and a capability of access to digital information, is expected. The development of a new display technology has been important. An electrophoresis display using micro-capsule, in-plain type electrophoresis display, a twisting ball display, photo-address electronic paper and polymer dispersed liquid crystal electronic paper are reported as rewritable technology. The toner display using triboelectrically charged black and white particles was reported. We had reported an image contrast of display is improved by using newly designed white particle. In this paper we will discuss the color image of Toner Display using three particles, white particle, cyan particle and yellow particle.

Toner Display

The structure of toner display device using black and white particles is shown in Figure 1. The display device is the sandwich type cell structure that is enclosed in two ITO transparent electrodes using an insulating spacer. The black and white particles are been built-in in this cell. The black and white particles were charged tribo-electrically in positive and negative, respectively. The device displays black pattern due to movement of black particles to negative electrodes due to the Coulomb force between the particle charge and negative charge on the electrode. When the polarity of an applied voltage is reversed, the negative charged white particles move to the top electrode and covered on the top electrode and then the white pattern is seen through the top electrode. Black and white patterns can be changed by the polarity of applied voltage caused by the movement of toner and white particle between two transparent electrodes.

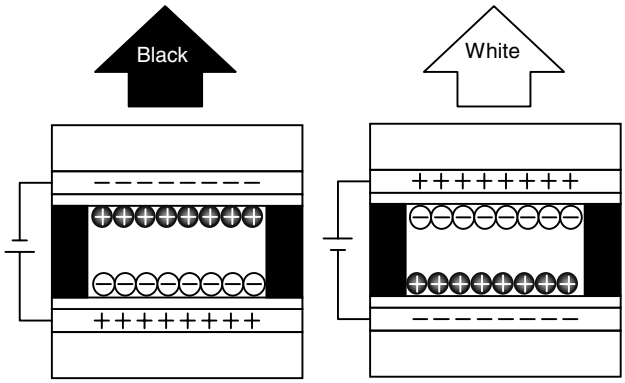

Figure 1. Black toner and white particle movements by applied voltage and display black and white patterns.

Objective

It is possible to display color image in toner display with color filter. But white reflectance will be low because white image is showed by mixing pigment colors. Using white particles, we can keep white reflectance high. And controlling several kinds of color particles, white, black, cyan, yellow and magenta, toner display can show the color image without sub pixel. Electronic charges of particles are important parameters on the movement of toners. We intend to control the movement of three particles with different amount of electronic charges independently.

Principle

Driving mechanism of Toner Display using three particles is shown in figure2. Particles with Three colors are built-in in this cell. White, cyan and yellow particles are built-in in Figure 2. Cyan and yellow particle are charged negatively with different amount of charge. White particle are charged positively. Green and white pattern is seen like the case where white and black particle are used. Green pattern is color mixture of cyan and yellow particle. Toner Display has threshold voltage. It is considered low charged particle has low threshold voltage because Coulomb force becomes low between negatively and positively charged particles. By raising negative voltage gradually, low charged cyan particle moves to the top electrode primarily and high charged yellow particle moves secondarily. Low charged cyan particle covers the surface of top electrode. Cyan pattern is seen. When the polarity of an applied voltage is reversed gradually, negative charged white particle covers the surface. White pattern is seen. Cyan particle moves primarily and yellow particle moves secondarily to the bottom electrode. An applied voltage is reversed again. But it is reversed quickly at this point. Cyan and yellow particles move to the top electrode at once. When they move to the top electrode, yellow particle covers the surface of top electrode because yellow particle

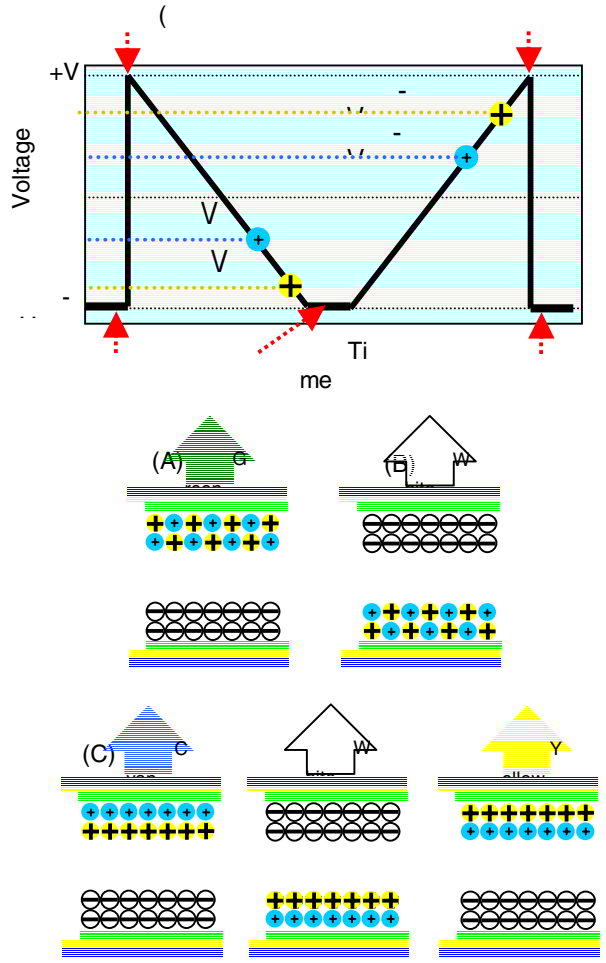

Figure 2. Mechanism of Toner Display using three particles

was near the top electrode before the voltage is reversed. Therefore yellow pattern is seen. As for this wave-form, it is understood that the saw tooth-shaped form is shown.

Sample

The toner display cell consists of positive and negative particle. Cyan toner (Toner-C) and yellow toner (Toner-Y) were used as the positive charged particles. White toner (Toner-W) was used as the negative charged particle. Average sizes of Toner-C, Toner-Y and Toner-W are 9 m, 8 m and 7 m, respectively. The mixtures of Toner-C, Toner-Y and Toner-W are sandwiched by the transparent electrode surfaces of two glass plates. The thickness of spacer is 100 m and the size of one pixel is 10 mm x 10 mm.

Results and Discussion

Charge to mass ratio

The electronic charges of Toner-C, Toner-Y and Toner-W were measured by q/m meter. Toners were mixed with carrier beads. Toner and carrier beads are charged by tribe-electrification when they are mixed and collide to each other. The value of q/m is shown in Table 1. Q/m of Toner-C, Toner-Y and Toner-W are + 4.9 C/g , + 8.9 C/g and - 13.6 C/g respectively. Toner-C and Toner-Y are charged positively. And Toner-W is charged negatively. Toner-Y charged twice compared with Toner C.

Table 1 Charge to mass ratio

Particle	q/m (μC/g)
Toner-C	+ 4.9
Toner-Y	+ 8.9
Toner-W	- 13.6

Comparison of voltage responses between high and low charged particle

Responses to voltage were measured using Mixture of Toner-C and Toner-W and mixture of Toner-Y and Toner-W. The mixture of Toner-C and Toner-W in a 1:1 Volume ratio was enclosed in the Toner display cell (sample A). Toner-Y and yellow Toner-W was mixed and enclosed similarly (sample B). Applying triangular wave voltage sample A and B were compared. Using triangular wave voltage, voltage responses of toner display cells could be measured from the viewpoint of time. 20 Hz and ± 400 V triangular wave was used. Incident lights of sample A and B shared 470 nm and 650 nm respectively through the monochromater. And the reflectances of Toner Display cells were measured.

Comparison of responses to voltage is shown in figure 3. The difference of response times was 3.5 msec when the color images changed to white images. And the difference of voltages was about 100 V. The voltages of sample A and B were about + 250 V and + 350 V when the color images 63 % changed to white images. Using positive charged particles with different amount of charge, difference of voltage responses was seen.

Display Characteristics using three particles

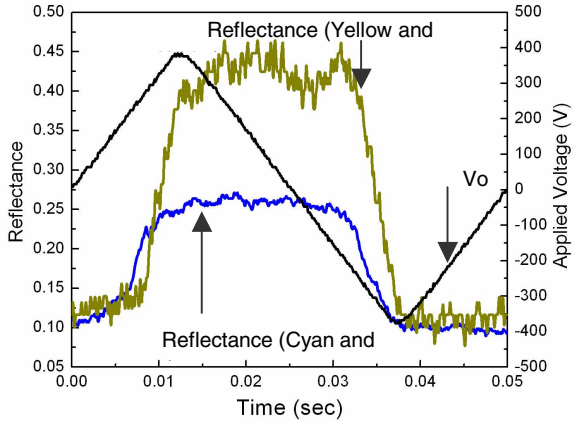

Figure 3. Comparison of the responses to triangular wave voltage between high and low charged particle

The mixture of Toner-C, Toner-Y and Toner-W mixed in a 2:1:1 Volume ratio was enclosed in the display cell. White and green images were displayed by the application of ± 400 Voltage. Green image was mixing colors of Toner-C and Toner-Y. Saw-tooth wave voltage (20 Hz, 400 V, 25 cycle) was used to display Toner-C and toner Y independently. Applying saw-tooth wave voltage rising from + 400 V to - 400 V gradually, Toner-C covered the top electrode. And applying the voltage rising from + 400 V to - 400 V quickly, Toner-Y covered the top electrode. Figure 4 shows reflection spectra of the cell. The reflectances of white at 550 nm, cyan at 650 nm and yellow at 450 nm are 40 %, 6 % and 12 %, respectively. It shows that three particles were moving independently to the top electrode. Figure 5 shows the photographs of the cells.

Summary

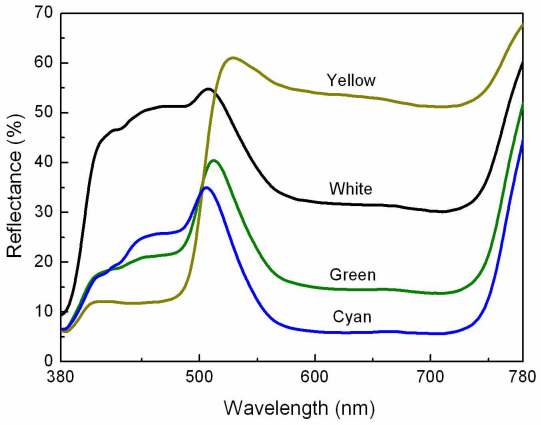

Figure 4. reflection spectra of Toner Display with three particles

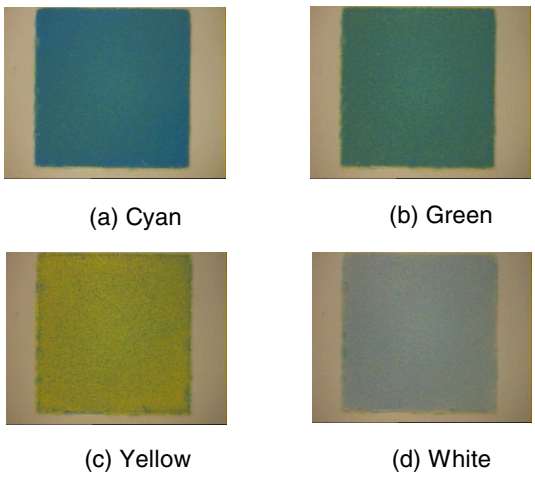

Figure 5. Photograph of Toner Display cell

Toner Display using three particles was investigated. Color particles with the same polarity and different amount of the electronic charges showed different responses to the voltage. Toner Display cell was prepared these positive charged color particles and negative charged white particle. White, green, cyan yellow images were seen in this cell applying DC voltage and saw-tooth shaped voltage.

References

[1] B. Comiskey, J. D. Albert, H. Yoshizawa, J. Jacobson, Nature, 394, 16, p. 253 (1998)

[2]H. Kawai, N. Kanae, Proceedings of Japan Hardcopy'99, p. 237, (1999).

[3] N. K. Sheridon, PPIC/JH'98, pg. 83, (1998)

[4] G. Jo, K. Sugawara, K. Hoshino and T. Kitamura, IS&T NIP15/International Conference on Digital Printing Technologies, p. 590 (1999)

[5] G. R. Jo, K. Hoshino and T. Kitamura : "Toner Display Based on Particle Movements" , Chem. Mater. , Vol.14, p. 664 (2002)

[6] Y. Yamaguchi, K. Shigehiro, Y. Machida, M. Sakamaki and T. Matsunaga, Asia Display/IDW01, p. 1729 (2001)

[7] T. Kitamura "Movement of Tribo-electrically Charged Particles for Electronic Paper", Asia Display/IDW04, p. 1721 (2004)

Author Biography

Takashi KITAMURA received the B.S. and M.S. degrees in graphic engineering from Chiba University in 1970 and 1972, respectively, and the Dr. Eng. Degree from Tokyo Institute of Technology in 1983. I was a Research Associate at Chiba University from 1972 to 1985, doing work on Electrophotography. I was a Associate Professor from 1985 to 1997 and have been Professor in Information and Image Sciences Department, Chiba University since 1997.

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