Control of Particle Movement for Color Toner Display

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Abstract

Toner Display is based on an electrical movement of charged particles in the air space. Two type of positively charged color and black particles with different amount of charge to mass ratio and negatively charged white particles are enclosed in the toner display cell. The particle movement is controlled by the external electric field applied between two transparent electrodes. The smaller charged black toner is collected to the electrode by an application of changing voltage slowly, and black solid image is displayed. The toners can be put back to the counter electrode by applying a reverse electric field, and white solid image is displayed. The yellow toner is collected the electrode by applying a reverse electric field, and yellow solid image is displayed. Yellow, black and white images are displayed by an application of voltage in the one pixel.

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, liquid crystal image display, a twisting ball display, photo-address electronic paper and polymer dispersed liquid crystal electronic paper are reported as rewritable technology.[1-6] The toner display using tribo-electrically 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 such as white, black and yellow particles.[7,8]

B/W Toner Display

The structure of toner display device using black and white particles is shown in Figure 1 and 2. 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.

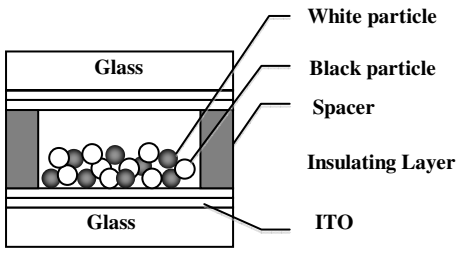


Fig. 1 Structure of toner display

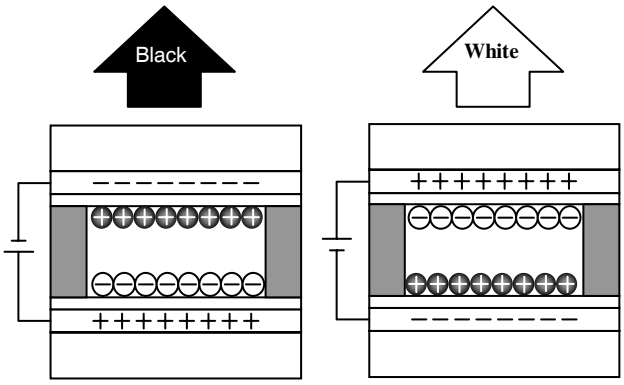


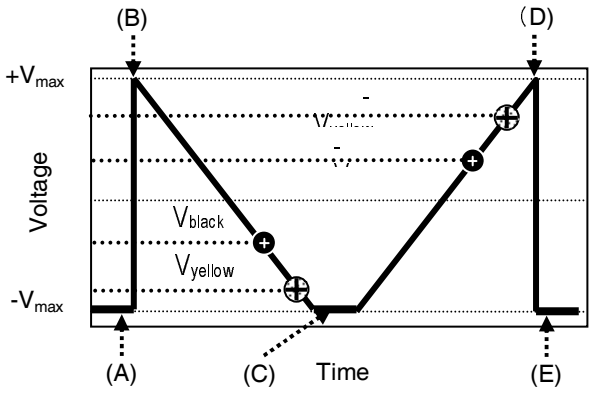
Fig. 2. Black toner and white particle movements by applied voltage and display black and white patterns.

Color Toner Display

It is possible to display color image in toner display with color filter. But white reflectance will be low because white image showed by mixing color lights through the color filter. Using white particles, we can keep a high optical reflectance in the white image area. By the 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 .Fig. 3. Particles with Three colors are built-in in this cell. White, black and yellow particles are built-in in the cell. Yellow and



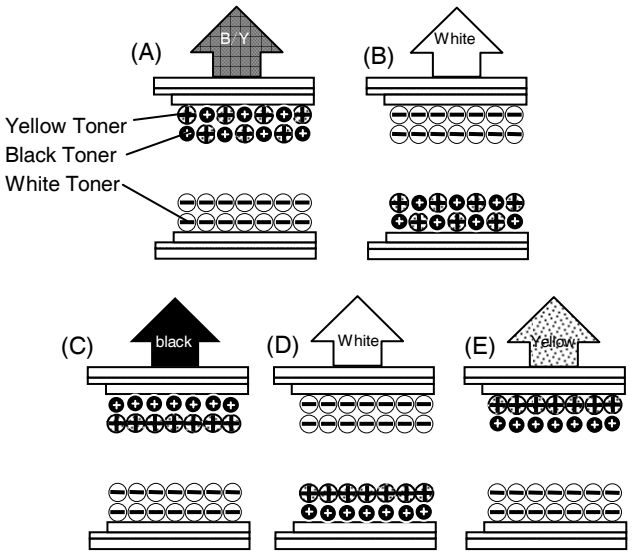


Fig. 3. Mechanism of color toner display using tree toners.

black particle are charged positively with a different amount of charge. White particle are charged negatively. Yellow/Black and white pattern is seen like the case where white and black particle are used. Yellow/Black pattern is color mixture of yellow and black 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 black particle moves to the top electrode primarily and high charged yellow particle moves secondarily. Low charged black particle covers the surface of top electrode. Black pattern is seen. When the polarity of an applied voltage is reversed gradually, negative charged white particle covers the surface. White pattern is seen. Black 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. Black 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 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. Yellow toner (Toner-Y) and black toner (Toner-K) were used as the positive charged particles. White toner (Toner-W) was used as the negative charged particle. Average sizes of Toner-Y, Toner-K and Toner-W are 8 μm, 10 μm and 7 μm, respectively. The mixtures of Toner-Y, Toner-K and Toner-W are sandwiched by the transparent electrode surfaces of two glass plates. The thickness of spacer is 100 μm and the size of one pixel is 10 mm x 10 mm.

Results and Discussion

Display Characteristics using three particles

The mixture of Toner-Y, Toner-K and Toner-W mixed in a 1:1:2 volume ratio was enclosed in the display cell.

The cross sections of the cell at the condition of color displays were observed using the optical microscope. The distribution of the colored particle was obtained using the image processing software. The air void in the cell is not considered. Figure 4 shows the model of particle distribution and the photograph of the cross sections of the cell at the condition of black display. The particle layer ranged in the order of black, yellow and white particle from the negatively charged top to the positively charged bottom electrodes. The area ratio which the particle occupies is shown in Fig. 5. The vertical and horizontal axis show the distance from the positively charged bottom electrode and the area ratio of particles in the display cell. In the black display, the black particle occupies 70% of the area ratio and 30% of the area ratio were occupied by the white and yellow particles at the negatively charged top electrode. In the yellow display state, the yellow particle occupies 60% of the area ratio and 40% of the area ratio were occupied by the white and black particles at the negatively charged top electrode. This result agrees with the principle of three particles migration to display three colors on the Toner Display.

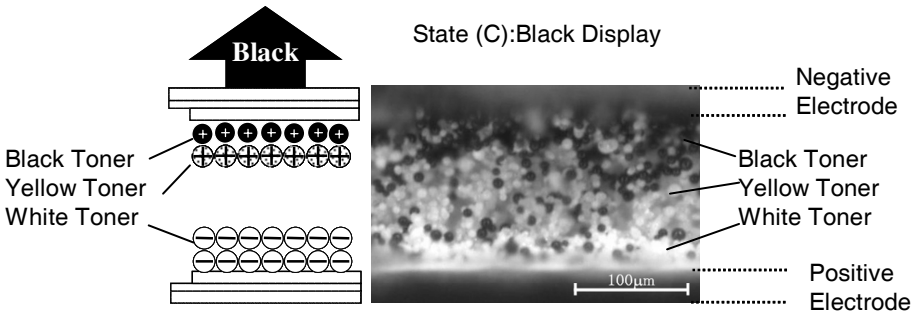


Fig.4 The model of particle distribution and the photograph of the cross sections of the cell at the condition of black display.

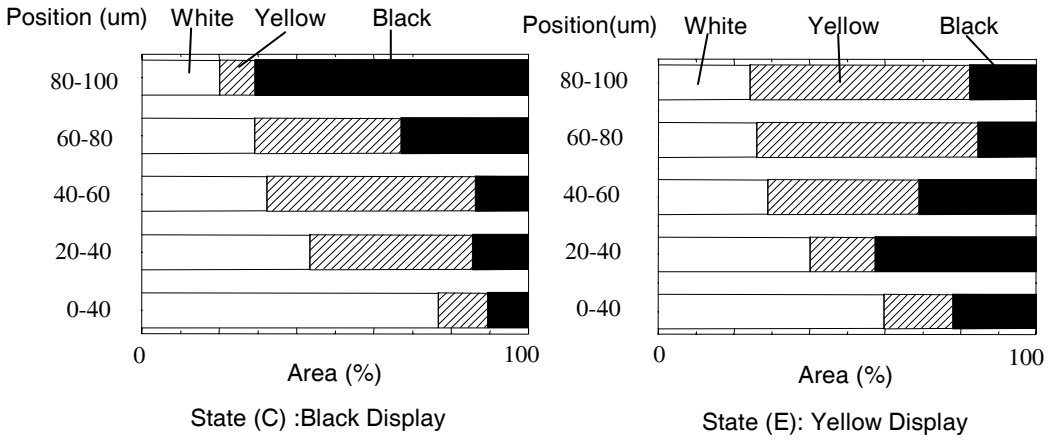


Fig.5 The area ratio which the particle occupies.

Summary

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, black, and yellow images were seen in this cell applying DC voltage and saw-tooth shaped voltage.

References

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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.