Movement of Triboelectrically Charged Particles in Toner Display

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Abstract

The mechanism of toner display based on an electrical movement of black and white charged particles has been investigated. Two types of black conductive toner and white fused silica particles charged in the different electric polarity are enclosed between a two electrodes coated with charge transport layer. The particle movement is controlled by the external electric field applied between two transparent electrodes. The toner is fixed on the cathode by an electrostatic force across the CTL to display a black image. The toners can be put back to the counter electrode by applying a reverse electric field, and a white image is formed.

The black and white solid images are displayed by the switch of polarity of applied voltage in toner display cell. The polarity of charge and the value of charge to mass ratio of two particles were measured by observation of the particle separation on the surface-type electrodes and using q/m meter, respectively.

Introduction

Recently, an electronic document is distributed on the computer network and displayed on a monitor and printed out as a hard copy using an electronic printer. In order to read an electronic document, a development of a new paper like display, which has the convenience of the conventional hardcopy and a capability of access to digital information, is expected. The development a new display technology has been important. The thermal rewritable marking has been used practically as a rewritable card. A fatty acid-polymer composite type rewritable marking,[1,2] a leuco dye-polymer type rewritable marking,[3] an electrophoresis display using micro-capsule,[4,5,6] in-plain type electrophoresis display,[7] a twisting ball display,[8] photo-address electronic paper[9] and polymer dispersed liquid crystal electronic paper[10] are reported as rewritable technology. We had reported the principle and characteristics of toner display using the conductive toner, which is a familiar to us as an image formation material for a hardcopy.[11] The toner display using triboelectrically charged black and white particles was reported. [12]

In this paper, the polarity of charge and the value of charge to mass ratio of two particles were measured by observation of the particle separation on the surface-type electrodes and using q/m meter, respectively. We discuss the particle movement of triboelectrically charged black and white particles.

Toner Display

The structure of toner display device using the conductive toner and white particle 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 hole charge transport layer is coated on the each transparent electrode. The conductive toner and white particle are been built-in in this cell. The conductive toner and white fused silica particle were charged triboelectrically in negative and positive, respectively. The black toners and white particles move to the positive and negative electrodes, respectively. The device displays white or black pattern by the change of applied voltage caused by the movement of toner and white particle between two transparent electrodes.

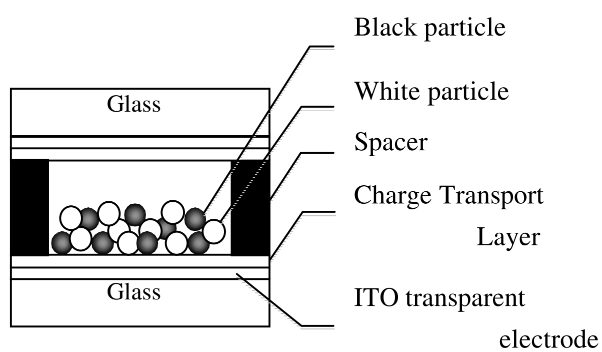


Figure 1. The structure of toner display device using the conductive toner and white particle.

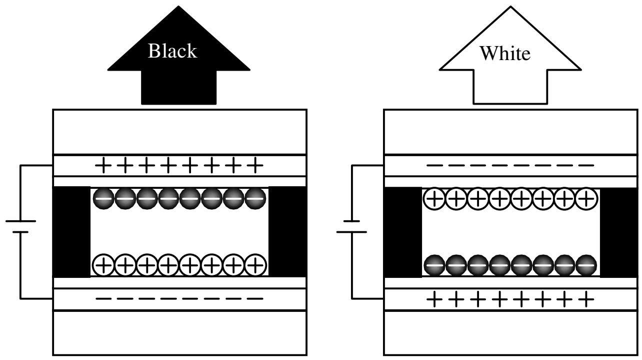


Figure 2. Black toner and white particle movements by applied voltage and display device black and white patterns.

The conductive toner and white particles are put in the cell. When the top electrode is applied by positive voltage, the negative charged conductive toners move to the top electrode due to the coulomb force between the toner charge and positive charge on the top electrode. The conductive toner is kept on the surface of CTL without applying voltage because the CTL acts on insulating layer due to the blocking contact between the toner and CTL. As the surface of the CTL on the top electrode is covered with the toners, the observer through the top electrode sees the black solid pattern. When the polarity of an applied voltage is reversed, the positive 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.

Experimental

Sample

The toner display cell consists of conductive toners, white particles, and charge transport layer. The mixture of conductive toner and white powder are sandwiched by the transparent electrode surfaces of two glass plates. The thickness of spacer is 500 µm and the size of one pixel is 10mm x 10mm. The usual magnetic conductive toner (Hitachi Metals, Ltd.) and fused silica (Japan Aerosil Co., Ltd.) were used for the black and white particles, respectively. The toner particle is almost spherical in shape and its size ranges from 5 to 30 µm; its median diameter is ca. 15 µm. The fused silica is elliptical shaped particle with a size of 1-20 µm and has a high electrical resistance.

The mixture the charge transport material, p-diethyl amino-benzaldehyde (diphenyl hydrazone) and polycarbonate polymer (PC, Teijin chemicals Ltd., Panlite k-1300) in a 1:1 weight ratio was coated on transparent electrode. The layer thickness of CTL is 3 µm. The response of the display to alterations in applied voltage was monitored with an optical microscope (Olympus Optical Co., Ltd., BH2-UMA), and the optical reflection density of the image was measured with a reflection densitometer (Ihara Electronic Ind. Co., Ltd., Ihac-11). The charge of toner was measured using by q/m meter (Trek Com.).

Results and Discussion

Display Characteristics

The conductive toner and white particle were mixed in a 1:1 weight ratio, was enclosed in the display cell. Figure 3 shows relationship of reflection density and an applied voltage. The density of 0.95 is for a mixture of the conductive toner and fused silica. The conductive toners move firstly to front electrode when an applied voltage was 80V. When an applied voltage is higher than 300V, the toners were enough charge up and shown difference of reflection density, 0.77. The difference of reflection density for the two particles movement type display cell is larger than the one particle movement type display cell.

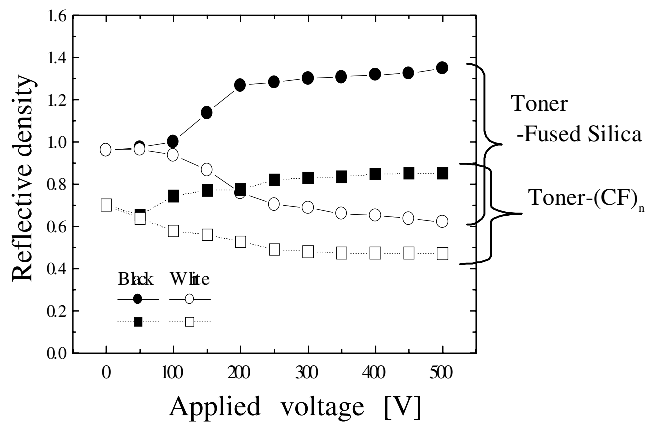


Figure 3. Reflection density vs applied voltage.

Particle Movement on the Surface Type Electrodes

Both particles of toners and fused silica may be charged by rubbing to each other. In order to affect of the mixing time on the triboelectric charge of particles, the separation of two particles on the surface type electrodes by applied electric field was observed using optical microscope. The surface type ITO electrodes was coated with insulating polymer layer. Toners and white particles are moved to positive and negative electrode separately by applied voltage, respectively, as is shown in Table-1. Two particles can be separated each other by applied voltage higher than 200V. The boundary of two particle layers becomes clearly with the increasing of mixing number due to the increasing the amount of particle charge.

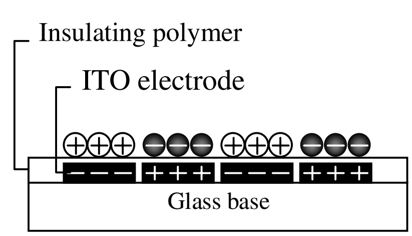
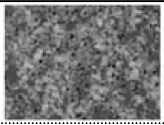
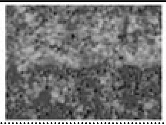
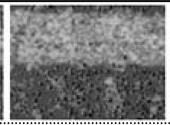
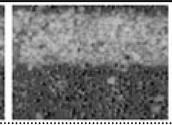
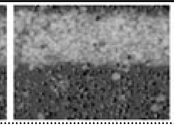
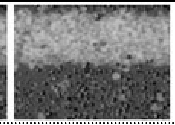
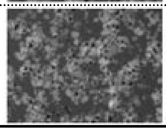
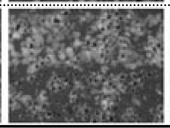
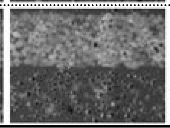
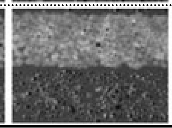
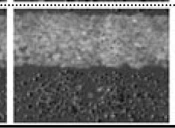
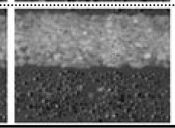


Table 1. Separation of two particles by applied voltage as the function of mixing time.

Mixing number	Applied voltage [V] 0	100	200	300	400	500
5						
200						

Charge to Mass Ratio

The electronic charges and weight of black toners and fused silica deposited on the two electrodes after opening the sandwich type display cell were measured using q/m meter.

The value of q/m is shown in Table 2. The toner and fused silica particle are charged negatively and positively, respectively. The two particles is charged by tribo-electrification when two particle are mixed and collide to each other in the display cell. The values of q/m are smaller than one of toner for electrophotography. The two particles may be coupled weakly each other after mixing before display operation. By application of external voltage to display cell, the two particles of black and white can be separated each other to move the both electrode.

Table 2 Charge to mass ratio

Particle	q/m [μC/g]
Conductive Toner	-2.73
Fused Silica	3.39

7 Segments Numeral Display

The display sample could be made using black toners and fused silica in toner display. The seven segments can be controlled by the external voltage supply.

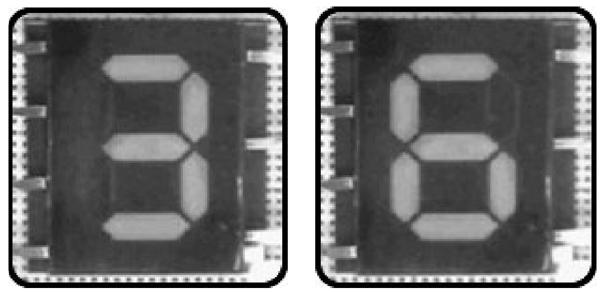


Figure 4. 7 segments numeral display.

Conclusion

The toner display based on the movement of both of black and white charged particles exhibits good display contrast ratio. The black toner and white particle were charged negatively and positively after mixing of both particles, respectively.

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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.