Response Time for Toner Display By Electrical Particle Movement

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Abstract

The toner display by an electrical movement of conductive toner has been investigated. The display device is the sandwich type cell structure that is enclosed in two transparent electrodes coated by the charge transport layer. The conductive toner and white particle are been built-in in this cell. The charge transport layer acts on the both of hole injection from the electrode to conductive toner and insulating layer to keep the conductive toner on electrode. The toner display is a reflective display based on an absorption and scattering of ambient light at image and non-image area, respectively. In this paper, the response time of the toner display is measured by using the photon counting technique. The value of response time is about 1 msecond. The response time of toner display depended upon applied voltage.

Introduction

Recently, an electronic document is delivered on the computer network and displayed on a monitor or 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 a digital information is expected. It is necessary for the development a new display technology to investigate the key-technology for the rewritable marking such as an electronic paper. 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, an electrophoresis display using micro-capsule[3,4,5], a twisting ball display[6], and dichromatic dye-liquid crystal composite type paper 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.[7]

In this paper, we discuss the response time to display the black and white pattern for the toner display measured by using the photon counting method.

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 device displays white or black pattern by the change of applied voltage caused by the movement of toners between two transparent electrodes.

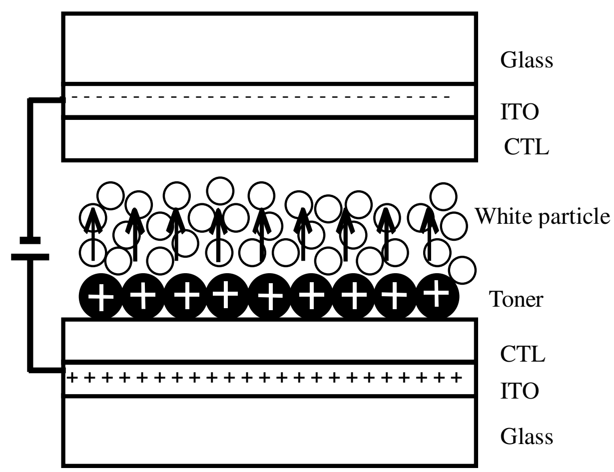

Figure 1. The structure of toner display device using the conductive toner and white particle.

The conductive toner and white particles are put in the cell is shown in figure 1. When the under electrode is applied by plus voltage, the conductive toners on the CTL are charged positively by the hole injection from CTL, and move to the top electrode due to the coulomb force between the toner charge and negative charge on the top electrode. The conductive toner is kept on the surface of charge transport layer without an applied voltage because the charge transport layer 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 black solid pattern is seen by the observer through the top electrode. When the polarity of an applied voltage is reversed, the conductive toners are moved and covered on the opposite electrode and then the white pattern is seen through the top electrode by covering the toner layer with the white particles.

Experimental

Sample

The mixture of conductive toner and white powder are sandwiched by the two transparent ITO glass plates. The thickness of spacer is 100μm. The mixture the charge transport material, p-diethyl amino-benzaldehyde(diphenyl hydrazone) and polycarbonate polymer (Teijin chemicals Ltd., Panlite k-1300) in a 1:1 weight ratio was coated on transparent electrode. The layer thickness of CTL is 5μm. The ordinarily magnetic conductive toner (Hitachi metals Ltd.) and fluoride carbon (Nihon carbon Co.) were used as black and white particles, respectively.

Measurement of Response Time

The measurement of response time to display white and black pattern was carried out by using the photon counting method. Figure 2 shows the measuring apparatus for the reflective light intensity from the sample surface. He-Ne laser illuminated to the sample and the light reflected from the sample was introduced into the photomultiplier. The change of light intensity was measured by exclusive signal processor as a photon number. The voltage variation of an applying the voltage to the sample was used as an outside trigger.

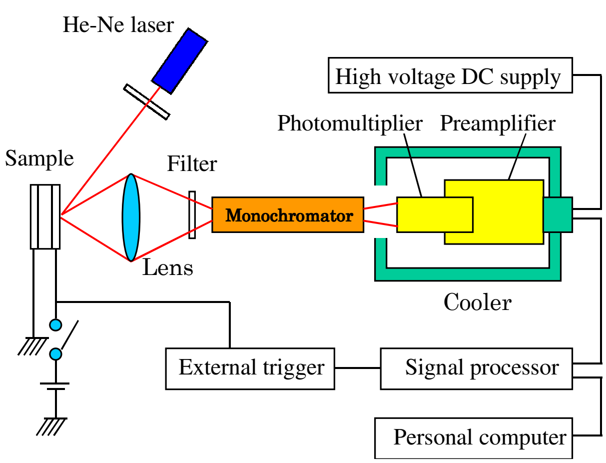

Figure 2. Schematic diagram of measuring apparatus for response time using photon-counting system.

Results and Discussion

The changes of light intensity reflected from the surface of sample which displays the two cases of the white to black pattern and black to white as are shown in figures 3 and 4, respectively. The distance between two electrodes is 100 μm and applied voltage is 500V for the sample.

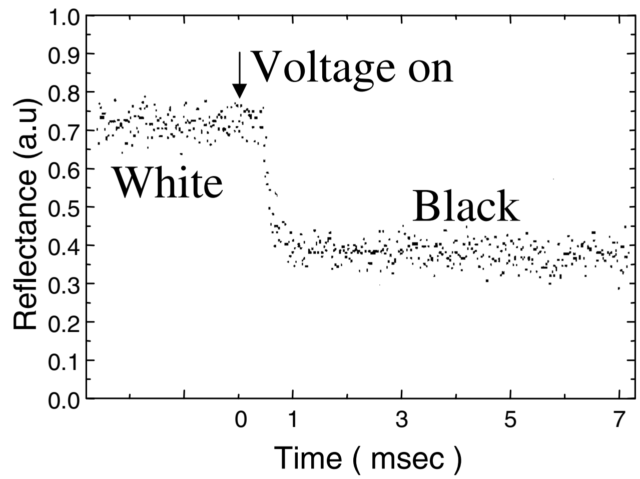

Figure 3. The response curve at the change from white to black display at applied pulse voltage of 500V.

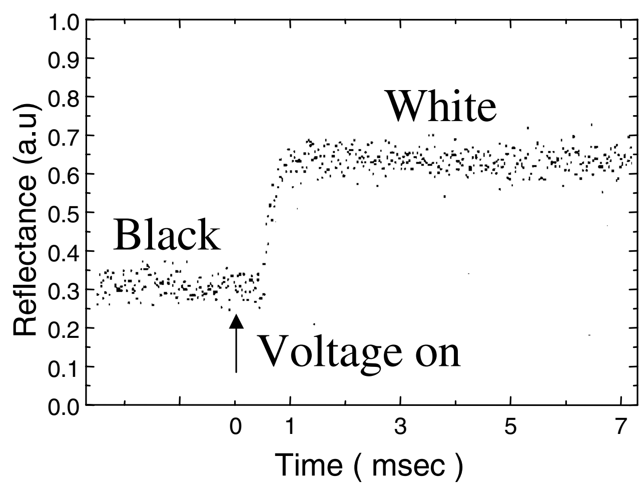

Figure 4. The response curve at the change from black to white display at applied pulse voltage of 500V.

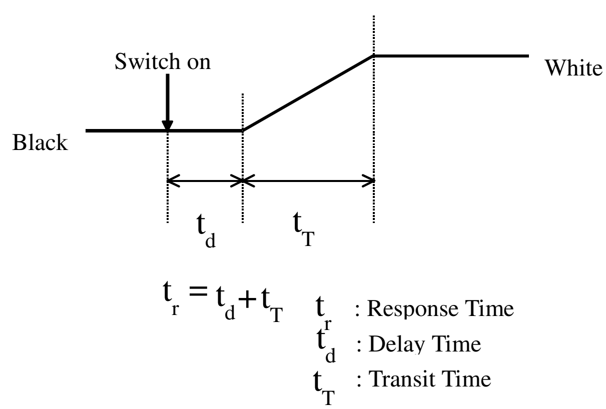

Figure 5. Typical response curve at applied pulse voltage

The typical response curve for display to the applied voltage show a little delay, linear increase and constant value as it is shown in figure 5. The response time tr is defined the time from starting time to the time shows the constant value.

Figure 6 shows the relationship between the response time tr and applied voltage. The response time decreased with an applied voltage. In this figure, square marks indicate from black to white display change and circles indicate from white to black display change. The response time from black to white display change is 1.7ms, from white to black display change is 1.6ms in applied voltage 200V, respectively. The response time from black to white display change is 1.1ms, from white to black display change is 1ms in applied voltage 500V, respectively.

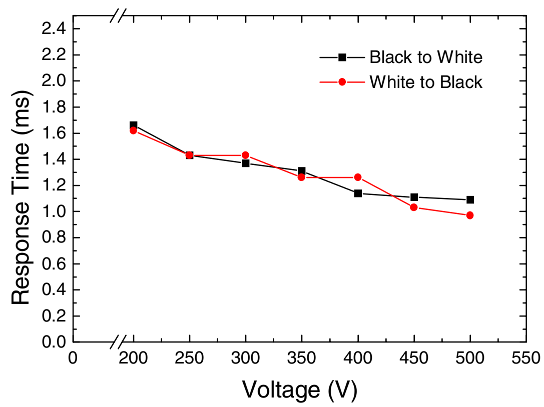

Figure 6. Voltage dependence of the response time for toner display.

The response time from white to black display change is correspondent to the time in which the black toners migrated from under electrode to upper electrode through the white particle layer. The other hand, the response time to display black to white pattern is correspondent to the time in which the black toner migrated from the upper electrode to the white particle layer. It is expected that response time for the change from white to black display is longer than that from black to white display. The two response times showed an almost equal value as is shown in Fig. 6. Although the delay of the response time which corresponds to the time in which the black toner migrate through white particle layer is expected, there was no difference between response curves as is shown in Figs 3 and 4. It is expected that there are air space exists in the cell and the black toners and white particle layer separate across air gap at two electrodes.

The relationship between the response time and the amount of white particle is shown in figure 7. As previously description, it is an almost equal value of response times from the white to black display and from the black to white display change. The response time increased with the amount of white particles in the range of the amount above 3mg. This experimental result indicated that it is necessary for the migration of toner through the white particle layer to keep the space of air in the display cell.

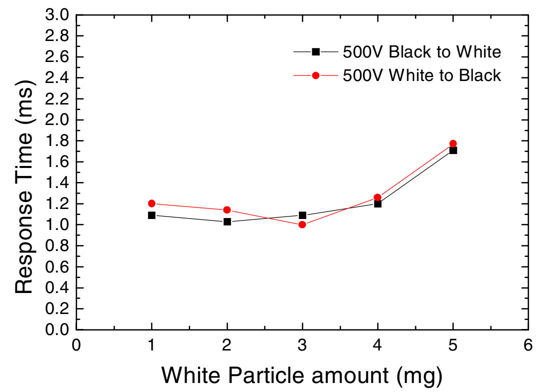

Figure 7. The relationship between the response time and the amount of white particle.

Conclusions

The response time is about 0.97 msecond at change from white to black pattern display for toner display measured by photon-counting method. The response time showed voltage dependence caused by the migration of toner particles between two electrodes.

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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. He was a Research Associate at Chiba University from 1970 to 1985, doing work on Electrophotography. He was a Associate Professor from 1985 to 1997 and has been Professor in Information and Image Sciences Department, Chiba University since 1997. His research interests are in Physics of Organic Photoconductor, Laser Thermal Transfer, Rewritable Imaging and Electronic Paper. He is a board member and a member of Technical Committee in the Imaging Society of Japan. He is a member of IS&T, U.S.A.