A New Type of Display for Electric Paper Using Fine Particles Dispersed in the Nematic Liquid Crystal Cell

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Abstract

We propose a novel display mode, which is called a Mobile Fine Particle Display (MFPD) with liquid crystal. In the MFPD cell, the fine particles are doped and dispersed within the nematic liquid crystal. The positions of the fine particles can be controlled by the direction of an applied electric field, which is DC field or AC field adjusted by applying DC, for obtaining optical changes in MFPD cell.

The MFPD shows excellent paper-like-display characteristics such as a high reflective ratio (approximately 50%), a high contrast ratio (more than 15), and a wide viewing angle. In addition, MFPD can rewrite when electric field is applied and sustain displayed information without electric field for a long time (over one month). These performances of the MFPD indicate that this new-type display is rather suitable for electric paper displays.

Introduction

In recent years, new types of paper-like displays have been brought to public attention, such as in-plane electrophoretic displays,[1,2] microencapsulated electrophoretic displays,[3,4] twisting ball displays,[5] and toner displays,[6,7] which have the ability to memorize and rewrite display images. It is required that such paper-like displays have improved characteristics in (1) memory function, (2) rewritability, (3) a high contrast ratio, (4) convenience (as like paper), (5) low cost performance, and so on. In order to approach this performance, we propose a novel MFPD (Mobile Fine Particle Display) using nematic liquid crystal doped and dispersed with special fine particles, enabling the achievement of paper-like displays with the improved characteristics.

In this paper, we describe the structures and basic electrooptical characteristics for our new display cells.

Principle of MFPD Mode

Figure 1 shows the example of MFPD cell. The nematic liquid crystal (ZLI-2231 ($\Delta\varepsilon > 0$), ZLI-4318 ($\Delta\varepsilon < 0$) (Merck Co., Ltd.)), which mixes about 10wt% with white color fine particles of several microns diameter are used for this display. The cell has 50-100μm thickness. As alignment films, PI-A (homogeneous) and RN-722L (homeotropic) (Nissan Chem. Ind. Co., Ltd.) are used. As other geometry of electrode except Figure 1, for instance, two-level crossing electrodes is formed on the top and bottom substrates, and electrodes divided by a slit is formed on only one side of the substrate, are examined.

The position of the fine particles-group in a pixel can be controlled by the direction of an applied electric field, which is DC field or AC field adjusted by applying DC. The details of how the fine particles-group can be controlled in such fields, has not been clarified yet, but we consider that both of fluidization phenomenon of liquid crystal and electrophoresis phenomenon of the particle are related to the behavior of the particle.

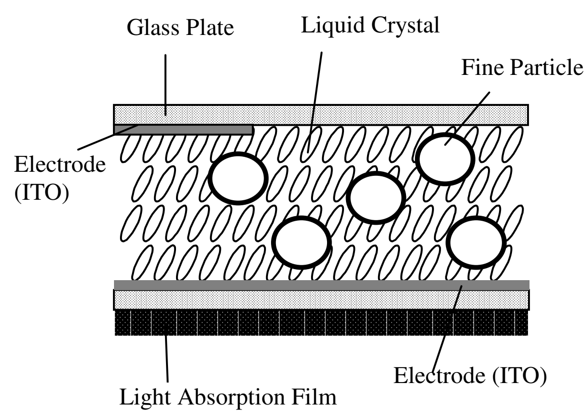


Figure 1. The structure of MFPD cell (side view).

In Figure 2, the microphotograph of MFPD cell is shown. It shows part of the slit, when applying an electric field, causing fine particles move out. It has been confirmed that the position of the fine particle is sustained over 1 month in the state of the microphotograph. Under the reflection mode, the white display image is caused by the light scattering of fine particles, when the fine particle group has entered the display pixel area, as seen in Figure 3 (a). Then, the black display image is caused by the light absorption film put on the cell, when the group has been out of the display pixel area (Figure 3 (b)).

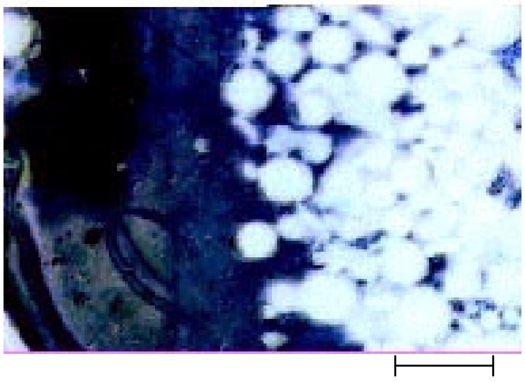
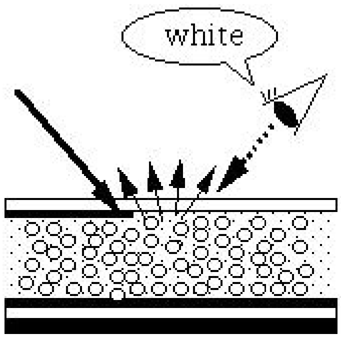
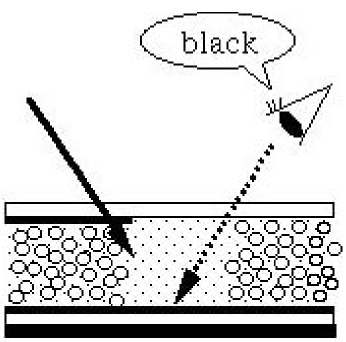


Figure 2. The microphotograph of MFPD cell.



(a) White state



(b) Black state

Figure 3. Display switching principle of the MFPD cell.

Basic Performance of MFPD

Velocity of Particles in MFPD

Figure 4 shows the characteristics for velocity of particles versus applied voltage in our MFPD cells of the electrode geometry shown by Figure 1 with homeotropic aligned liquid crystal ($\Delta\varepsilon < 0$).

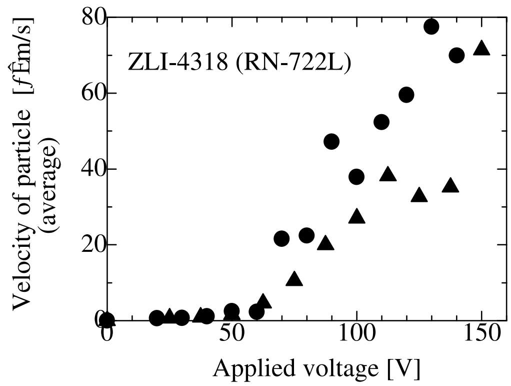


Figure 4. Velocity of particles versus applied voltage in the MFPD cells (the marks ● and ▲ describe the properties in other cells, but of same type).

In the MFPD cell, as shown in Figure 4, the mobile speed also increases with the rise in applied voltage, when about 50 V is exceeded.

Display Characteristics of MFPD

In Figures 5 (a) and (b), the microphotographs of MFPD cell are shown. In this cell, two-level crossing electrodes (top and bottom) of the molybdenum are used and the clearance of the crossing electrodes are correspondent to the display pixel area. By applying the DC bias (+80V) to the top electrode, fine particles gather in the display pixel area, and the white state is obtained (Figure 5 (a)). On the other hand, by applying the DC bias (+80V) to the bottom electrode, fine particles move under the electrodes, and the black state is obtained (Figure 5 (b)).

Figure 6 shows the measurement of reflective-viewing characteristics of the display pixel area in the MFPD cell. The 100% level is a reflection of the standard white plate. On measurement, the incident light was irradiated from the direction that tilted 30 degrees from normal of the cell, and the angle of the detector was changed from 0 degrees to 50 degrees in the opposite side of the incident light.

Figure 6 shows that the high reflective property (white state) and excellent dark condition (black state) are obtained through the entire region of measured viewing angle. Characteristics of Figure 6 indicate that a display having excellent visibility that is equal to the paper can be realized in MFPD.

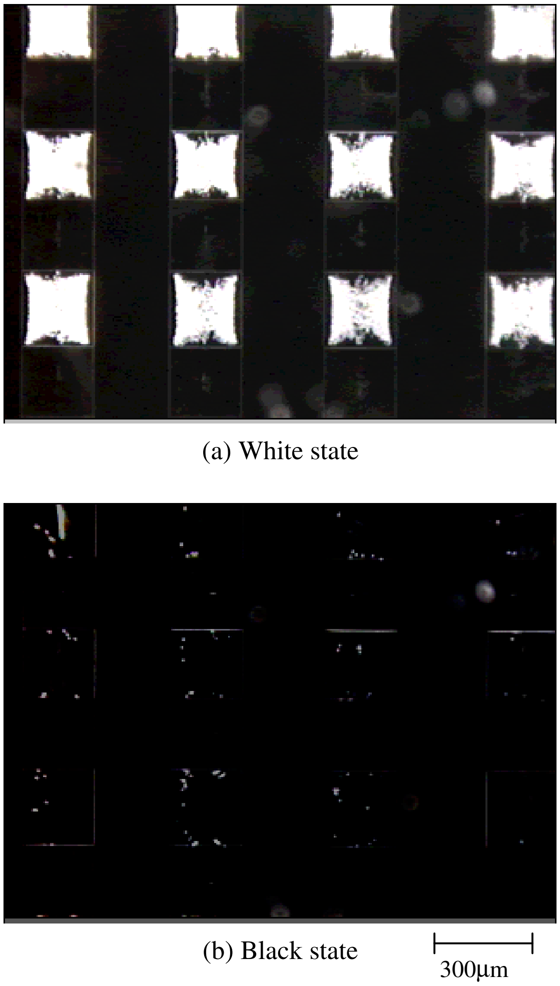


Figure 5. Microphotographs of the MFPD cell.

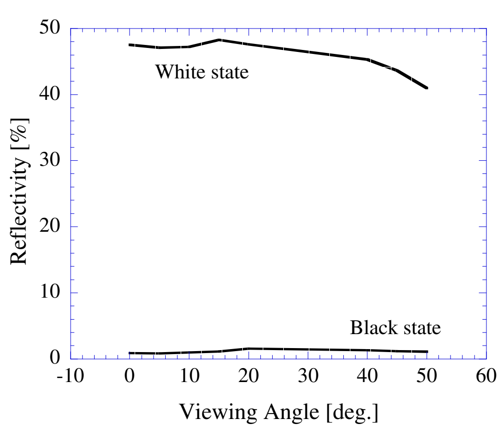


Figure 6. Viewing angle characteristics of the MFPD cell.

Figure 7 shows reflective characteristics and contrast ratio of the MFPD cell as a function of applied electric field time. In this cell, slit electrodes (1200µm gap) is formed on one side of the substrate, and fairly low electric field was applied (80V/cm) between the slit electrodes. As seen in Figure 7, reflective characteristics and contrast ratio gradually change with the applied electric field time. Therefore, gray display image can be represented by the change of the amount of fine particles in a pixel. It is supposed that the response characteristics of the MFPD is improved by the optimization of the electric field application condition, the electrode geometry, the cell configuration and the constituent materials.

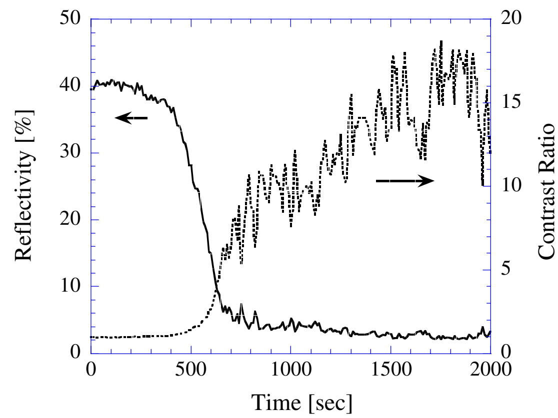


Figure 7. Applied electric field time dependence of reflectivity and contrast ratio in the MFPD cell.

Conclusions

The new display called a Mobile Fine Particle Display (MFPD) is shown, which exhibits the following excellent characteristics: a high reflective ratio; a high contrast ratio; a wide viewing angle, as it can be comparable to the paper; a long time memory of displayed information without electric field. These characteristics of the MFPD indicate that this novel-type display is rather suitable for electric paper displays.

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Biography

Yasuo Toko received his B.S. degree in Electrical Engineering from the Hiroshima University in 1985 and a Ph.D. in Electrical Engineering from Nagaoka University of Technology in 1998. Since 1985 he has worked in the R&D laboratory at Stanley Electric Corporation in Yokohama. His work is research and development of the display device technology mainly on liquid crystal.