Behavior of Fine Particles Dependent on Cell Structures in Mobile Fine Particle Display Cells

Taiju Takahashi*), Kazunori Shimoyama *), Susumu Saito*), and Yasuo Toko**)
****)Department of Electronic Engineering, Kogakuin University, Tokyo, Japan***
*****)R&D Laboratory, Stanley Electric Co., Ltd., Kanagawa, Japan***

Abstract

A Mobile Fine Particle Display (MFPD) which was proposed in a first place by our group is based on the electrophoresis effect of fine particles in nematic liquid crystal that used as an anisotropic solvent. In the MFPD cell, the images are displayed due to control the amount of fine particles in a pixel area by an applied voltage. Since the displayed images are permanently memorized, the MFPD has a possibility to be utilized as an electronic paper.

In the present stage, the contrast ratio obtained in MFPD is not sufficiently high enough, since MFPD needs an accumulation space of fine particles in a pixel. In this study, a three-layered structure is newly proposed to improve the contrast ratio of MFPD cells.

Introduction

In recent years, electronic paper displays have attracted attention. Various displays are proposed as a mode of the electronic paper displays, such as an in-plane electrophoretic display [1,2], a microencapsulated electro phoretic display [3,4], a twisting ball display [5], and a toner display [6,7]. It is required that such electronic paper displays are characterized by display memory function (for obtaining low power consumption), rewritability, convenience (as like paper), low manufacturing cost and high legibility. We previously proposed a novel display mode, which is called a Mobile Fine Particle Display (MFPD) [8,9]. In the MFPD cell, fine particles are dispersed in a nematic liquid crystal and the fine particles are moved to a horizontal direction for switching the display by an applied electric field.

Principle of MFPD Modes

Figure 1 shows a cross section of our MFPD cell for conventional type. The nematic liquid crystal (LC) having positive dielectric anisotropy, which is mixed at 10-25 wt% with white color fine particles, is used for this display. The cell has 50-100 µm thickness. As alignment films, SE-1211 (homeotropic orientation for LC molecules: Nissan Chem. Ind. Co.) are used.

The position of a group of fine particles in the pixel can be controlled by the direction of an applied electric field, which is a DC field or an AC field adjusted by applying DC. Figures 2(a)-(b) show display switching principle of the MFPD cell. In the MFPD cell, the fine particles are moved to a horizontal direction for switching the display images by the applied dc or a biased ac electric field. Fine particles are migratable by the synergistic effect of the flow of LC and the electrophoresis of the fine particles; the Coulomb's force acting on the charged fine particles. Under the

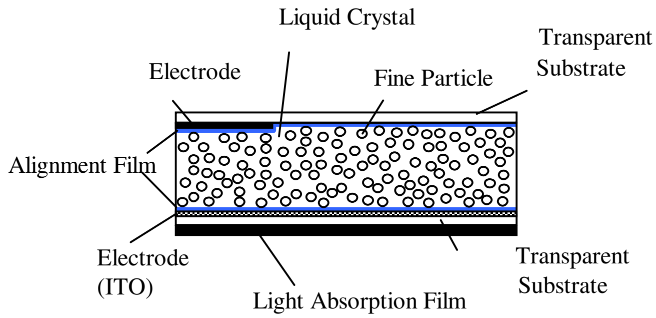
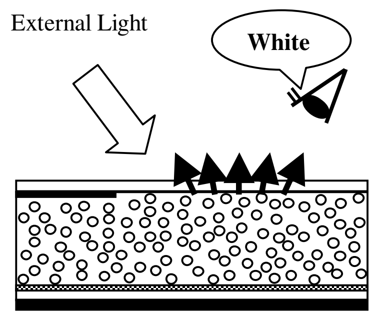
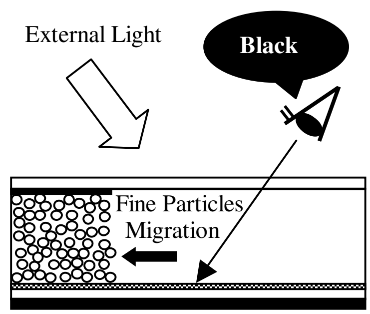


Figure 1. Fundamental structure of MFPD cell.



(a) White image in the MFPD pixel



(b) Black Image in the MFPD pixel

Figure 2. Display switching principle of MFPD.

reflection mode, the white display image is caused by the light scattering of fine particles, when the group of fine particles has entered into the pixel area, as seen in Fig.2 (a). Then, the black display image is caused by the light absorption film put on the cell, when the group of fine particles has been out of the pixel area (Figure 2 (b)).

Flow of LC and Behavior of Fine Particles in MFPD Cell

The optical microscopic observation was carried out using a polarizing optical microscope to investigate the flow generated in the MFPD cell. Only LCs containing no fine particles was injected into the cell with a gap of 50 to 70 µm. The LC flow patterns observed under the DC voltage application are depicted in Fig.3 by arrows together with the top- and bottom-electrode patterns. The direction of flow coincides with the direction of electric force acting on the negative charge with the LC which is used in our experiments.

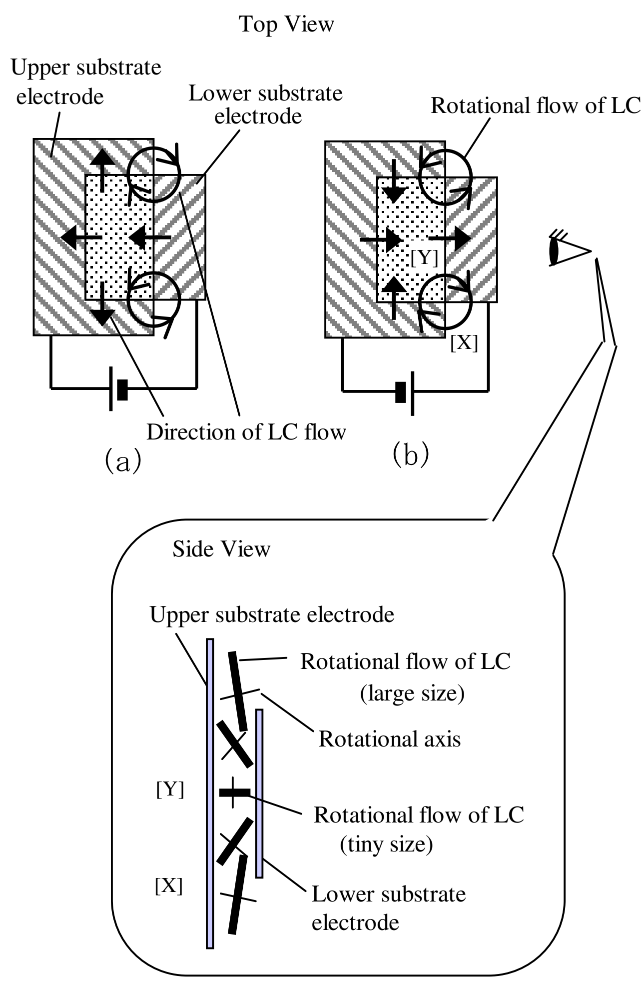


Figure 3. Dependence of flow direction of liquid crystal ($\Delta\varepsilon>0$) on polarity of the applied voltage.

When the LC including fine particles with negative charges was injected into the cell, the flow directions observed using a polarizing optical microscope coincided with the results observed in the case when only LC was injected.

In the case of the solvent that has been widely used in electrophoretic displays, the particles also moved; however, the migration distance is much shorter than that in the case of using nematic LCs.

The model for mechanism about the migration of fine particle is shown in Fig. 4. For example, the particles having negative surface charge are caught and held at the electrode with positive polarity by the Coulomb's force. (at areas A, B, C)

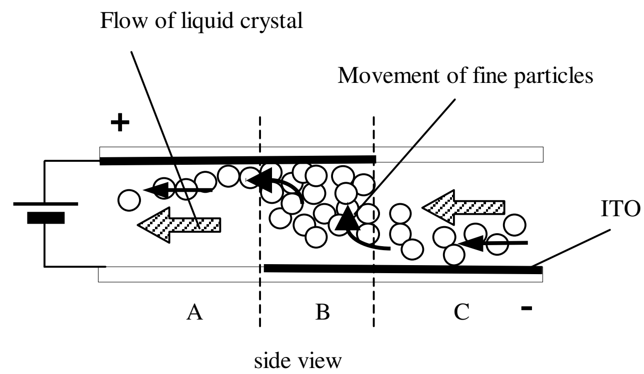


Figure 4. The mechanism of migrating fine particles around the area [X] in Fig.3.

At the area with only one side electrode (areas A or C), the flow of LC occurred due to the oblique electric field. The force acting on particles by this flow was stronger than the Coulomb's force, so fine particles were migrated together with the LC flow. By this flow, fine particles, existing at the area C, were tucked into the area A, and fine particles stocked at area the B were pulled out to the area A.

Improvement of Structure of MFPD Cells

MFPD pixels show the display memory characteristics for reasons as mentioned above. However, display contrast ratio is not always good, because all of the fine particles are not sometimes hidden under the opaque electrodes which is a storage area for particles, if the opaque electrodes are narrow. The other hand, if the storage area is wide, aperture ratio of pixel is low. Furthermore, there is the inflow of the fine particles and/or the LC from the next pixel in the MFPD cell shows in Fig.1.

Then, novel type of pixel structure is proposed, which has a storage shed with a circumvallated structure to storage the fine particles and to avoid the causing interference from other pixel.

©2006 Society for Imaging Science and Technology

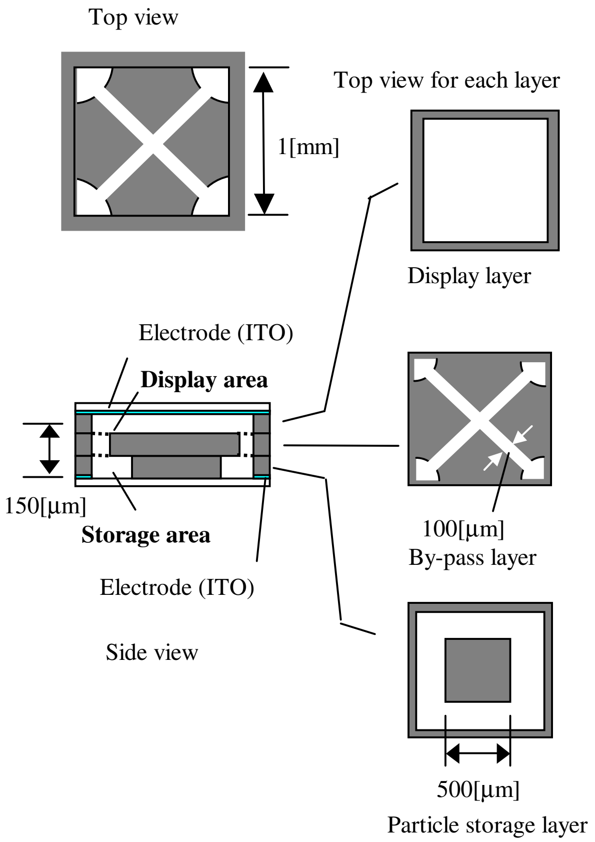


Figure 5. Fundamental structure of novel type of MFPD pixel.

The fundamental structure was used for the experimental to confirm behavior of the particles and LC. Figure 5 shows the novel fundamental MFPD pixel structure, which is configured with three layers; a display layer, a by-pass layer, and a particle-storage layer. Each layer (film) has 50μm thickness. And in order to improve the movement of fine particles, the display area has an X-shaped groove, and this groove hinder for the display, it works as a dead area. Under ordinary circumstances, this groove should be very narrow or be formed without display area, for the improvement of contrast ratio.

The pictures of experimental pixel are shown in Fig.6. LC materials and fine particles were same as those used in the conventional type of MFPD. The white and black image were obtained by moving fine particles in the display area when the polarity of applied voltage was switched, of course, pixel had memory characteristics. Furthermore, to obtain the reproducible switching results, the pixel structure needs the route for LC-stream; the fine particles are caught and held at the electrode by the Coulomb's force, and the LC (solvent) without fine particles are circulated through this route.

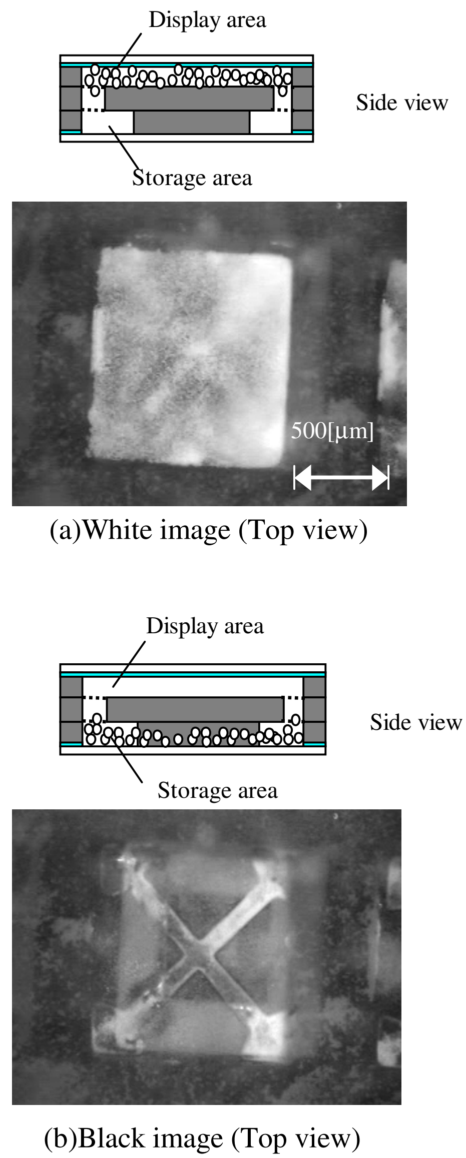


Figure 6. Photos of the pixel with white and black images in the novel type of MFPD pixel.

Conclusions

The novel type of MFPD cell structure was proposed to improve the contrast ratio. Optical microscopic observations were carried out for movement of fine particles and flow of LC in sample cells under the application of electric field. However, at the present stage, usefulness of the newly proposed cell structure for improving the contrast ratio has not been experimentally confirmed yet. Further, investigations on the optimization of cell structure will be required to sufficiently improve the contrast ratio of MFPD cell. But, for electronic papers, the pixel or cell structure is unsuitable to become complicate.

References

1. E. Kishi et al., SID'00 DIGEST, p. 24 (2000).
2. S. A. Swanson et al., SID'00 DIGEST, p. 29 (2000).
3. B. Comiskey et al., SID'97 DIGEST, p.75 (1997), and Nature, 394, p. 253 (1998).
4. H. Kawai and N. Kanae, SID'99 DIGEST, p. 1102 (1999).
5. N. K. Sherdon and M. A. Berkovitz, Proceedings of the S.I.D., 18/3&4, p. 289 (1977).
6. G. Jo et al., IS&T NIP15/International Conference on Digital Printing Technologies, p. 590 (1999).
7. K. Shigehiro et al., Proceedings of Japan Hardcopy 2001, p. 135, (2001).
8. Y. Toko et al., Proceedings of the 21st IDRC in conjunction with the 8th IDW, p. 265 (2001).
9. T. Takahashi, S. Saito and Y. Toko, JJAP, 43, No. 10, p.7181 (2004).

Author Biography

Taiju Takahashi received the Ph.D. degree from Nagaoka University of Technology in 1998. He has worked as a post-doctoral researcher at the Liquid Crystal Institute of Science University of Tokyo in Yamaguchi from 1998 to 2000. He is a lecturer from 2000 to 2005, an associate professor from 2005 at Kogakuin University. He has engaged in liquid crystal displays and their applications.

©2006 Society for Imaging Science and Technology