Evaluation of Particle Velocity in Mobile Fine Particles Display with Liquid Crystal

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Abstract

We propose a new type of display called Mobile Fine Particle Display (MFPD). The display is carried out by moving fine particles mixed with nematic liquid crystal, which are then applied to the electric field. The voltage dependence of mobile speed of particles, which is the basic properties of the MFPD, were measured, when material type and particle size of it were changed. The mobile speed appears to change more with a difference in particle size than a difference in material of particles. And, the behavior of the particles in the cell with the different electrode pattern was observed.

Introduction

Recently, some studies in the aim of paper-like displays using several kinds principles are reported from several research institutes and companies.[1-7]

We have proposed a Mobile Fine Particle Display (MFPD) that has a permanent memory in which the rewrite is possible in the display characteristics. The display image is obtained with the existence or without the existence of the group of fine particles, which are controlled and moved by the applied electric field in the pixel area.

From the viewpoint of stability and high contrast ratio of the display, we mainly investigate in respect of the in-plane-electrophoresis or in-plane-flowing-particles mode. This article describes the behavior of the group of fine particles in MFPD cells depending on the applied electric field, and the direction of movement of particles with different types of particles.

Behavior of Fine Particle

The flow is generated in the liquid crystal when the electric field of dc or alternating current adding dc offset is applied to liquid crystal cell. With this factor, it is considered that the fine particle is put in flow by the impurity ion in liquid crystal, by back-flow effect in liquid crystal with the switching, and moreover, by the electrification of fine particles which is made to draw them into the electrode (electrophoresis-like), etc.

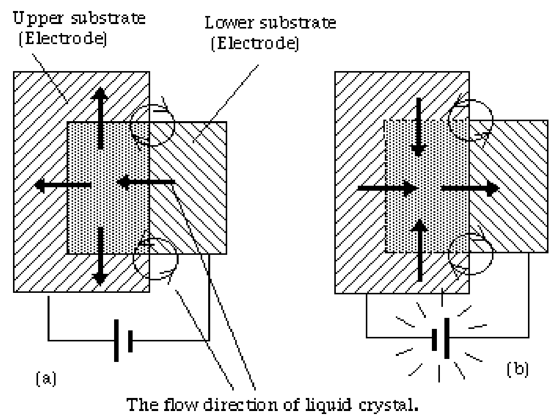


Figure 1. The flow direction of liquid crystal (particles) is dependent on the polarity of the electric field.

To begin with, in order to investigate how liquid crystal in our MFPD cell flows by the applied field, the observation was carried out under the polarizing microscope. The cell in which the top and bottom electrode (ITO) placed as shown in Figure 1, it injected only liquid crystal without fine particles. The cell thickness was 50 - 70 μm, without alignment layer on the cell surfaces. The nematic liquid crystal, ZLI-4318 ($\Delta\varepsilon < 0$), and ZLI-2232 ($\Delta\varepsilon > 0$) (Merck), which we used for this experiment showed the flow together shown in Figure 1, when dc electric field was continuously applied. In these liquid crystal materials, the stream can be considered flowing from the negative electrode to the plus electrode. In the current stage, the clear factor of this flow is not proven, and it may have been caused by the impurity ion in liquid crystal.

Furthermore, the experiment was carried out in order to find the difference in charge of fine particles of several kinds of composition, in the air, when fine particles were put between parallel electrode plates which applied high electric field, they moved whichever electrode was tested. Especially, movement by the multiplied effect with the flow of liquid crystal can be expected, when the fine particles were mixed with the liquid crystals as mentioned above, if the polarity of fine particles is easy to charge negative or negalective (very small). The other hand, if the charge of fine particles is positive, it is anticipated that the mobile speed of the fine particles slows down, since the direction of flow in the liquid crystal and direction in which fine particles intend to move are opposite-directional.

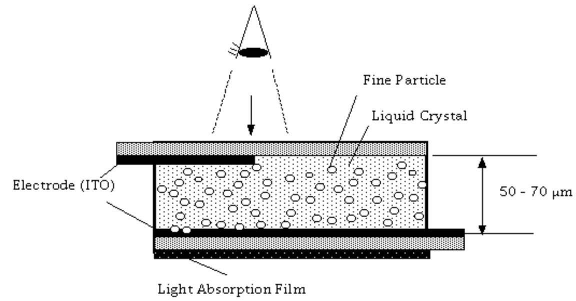
From the results, this experiment and characteristics of the dispersiveness to liquid crystal, the fine particle of inorganic material and organic material was respectively selected. Selected materials have the characteristics which are easy to take slightly in the negative charge for the organic material, and the inorganic material has the characteristics which show the negalective polarity.

The Mobility of Fine Particle

The moving behavior of the particle in the cell that applied the electric field was observed, the example is shown in Figure 2, they are photographs of the part in the cell in which the fine particle moves rectilinear. The structure of electrode in the cell is as shown in Figure 1. It is proven that the movement of the fine particle can be controlled by the polarity of the applied field.

Then, applied voltage dependence of the mobile velocity of the fine particle group (average velocity) was measured by carrying out the observation mentioned in Figure 2 for each type, respectively, inorganic material and organic material selected by the method for describing in advance. The fine particle was mixed in the liquid crystal ZLI-4318 ($\Delta\varepsilon$ - 2) amount of about 10wt% was used. The substrate surfaces were coated with polyimide film RN-722 (Nissan Chem. Ind.) that achieved the vertical alignment of liquid crystal molecules. The measurement result is shown in Figure 3, in case of the particle size (diameter) is about 6 •m and different materials of particle. It is seen that the moving speed of the particle made from the organic material is faster than that of the inorganic material, under the same application of voltage. This seems to be the effect by the charge of particles, furthermore it also considers the effect of surface stat and specific gravity of the particle.

The characteristics, as the particle size is made to change with the 3, 6, 10 μm in the organic material are shown in Figure 4. It shows that the moving speed is faster when the particle size is smaller even in the same material. It seems that it is not as effective on the resistance force, which particles receive from the fluid, if they move by carrying the flow of the liquid crystal. That is to say, it seems to also include the electrophoretic-like behavior of particles since they were charged, except for the flowing effect of liquid crystal.



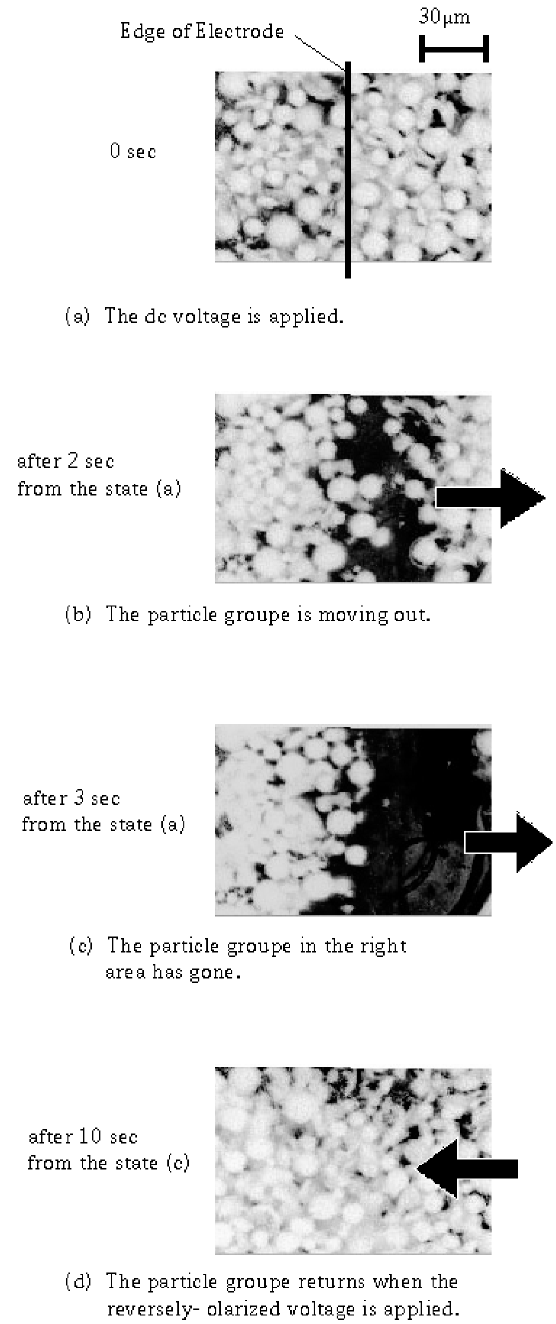


Figure 2. The mobility of fine particle under applying dc electric field. (It was measured by the reflection mode.)

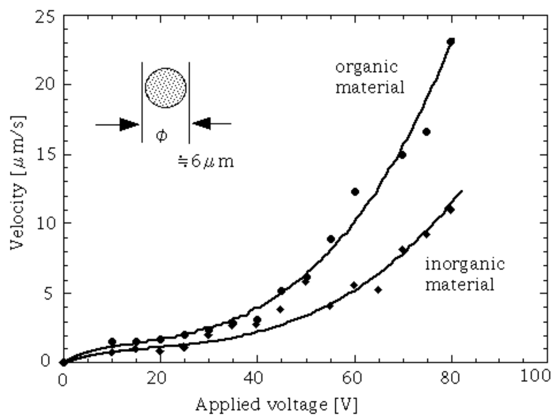


Figure 3. Characteristics of velocity of the group of fine particles.

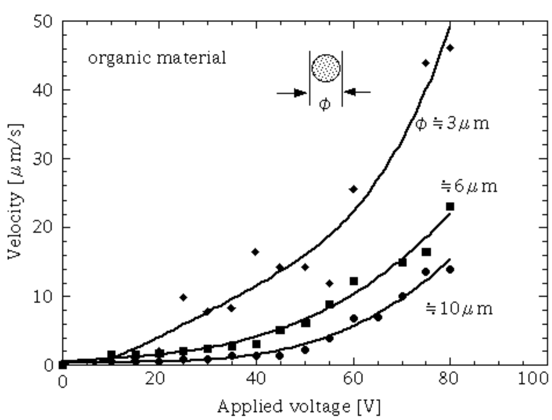


Figure 4. Characteristics of velocity of the group of fine particles.

Electrode Patterns and Behavior of the Fine Particle (Applications)

We are investigating displays with the matrix electrode pattern for our MFPD, and here, the example of the other electrode patterns are shown. In order to use as a display, not only controllability of the particle by the applied field but also optical characteristics (color, reflection characteristic, contrast characteristics of the fine particle, etc.) have to be considered.

In the material which we selected, the organic material was inferior to inorganic material in optical characteristics, such as a visual observation and properties of the inorganic material which is disperse in liquid crystal and the uniformity for the movement of the fine particle in the switching are also more excellent than those of organic material. (These are problems of the surface of fine particle). Here, this experiment was carried out using the inorganic particle with diameter 6 μm. The liquid crystal is ZLI-4318, the dosage of particles is 10wt%, and electrodes in the cell are made of the metal molybdenum.

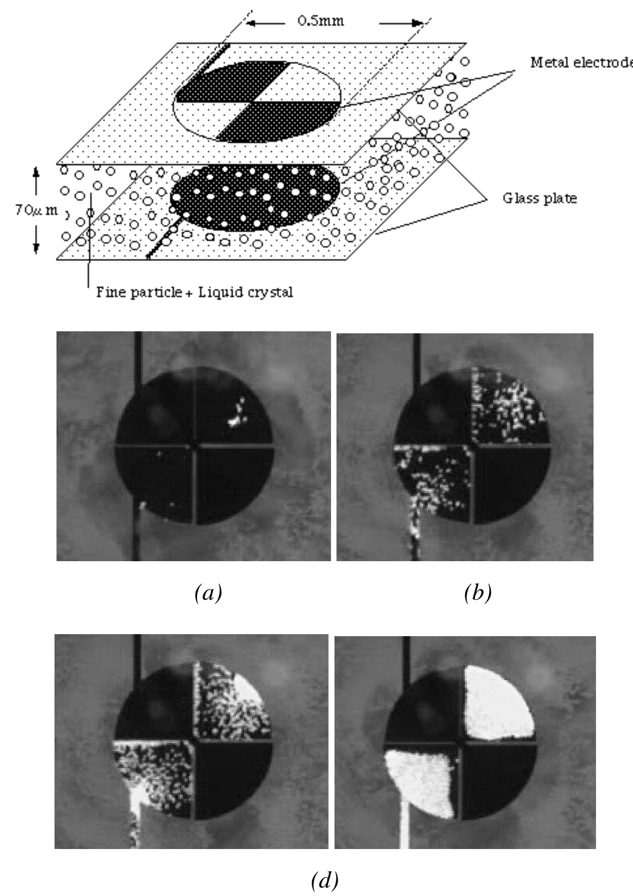
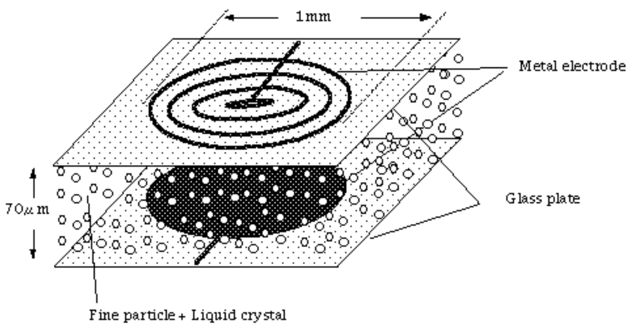
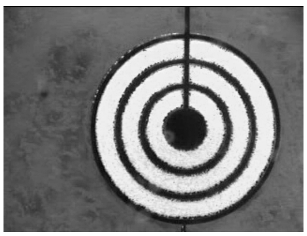
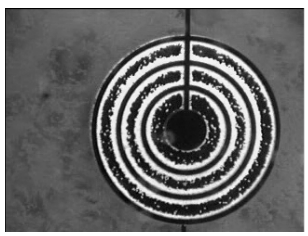


Figure 5. Moving condition of the fine particle in the MFPD cell. (the sectorial electrode pattern)

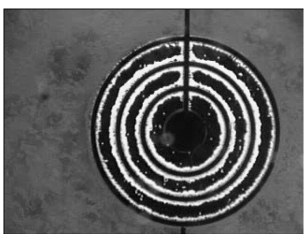
In Figure 5, when the electric field (80V) is applied, the condition changes to the (d) from initial state (a) through the (b) and (c), for 4 sec. In the (d) condition, fine particles have been hidden under the sectorial metal electrode. When the polarity of the electric field is inverted, the particles return to the initial condition (a).

In Figure 6, when the 80V is applied, the condition changes to the (a) to (c), for 1.5 sec. Of course, it returns to the (a) condition, when the polarity of the field is reversed. In Figure 6, the comparison in case of Figure 5, the movement of the fine particles is almost the same regardless of the place, because the electrodes are formed in the concentric circular. So, this electrode style has a possibility to take a quick response time for switching. The structure of this electrode style may also correspond to the large size pixel, if the width of electrodes is optimized and the number of concentric circle electrode is increased.



(a) *(b)*



(c)

Figure 6. Moving condition of the fine particle in the MFPD cell. (The concentric circle electrode pattern)

Conclusions

In the moving force of the fine particles in the MFPD cell, it seems that there is not only the effect by the flow with liquid crystal but also the effect by the electrophoretic with charging particles. It is necessary to carry out further experiments with the particles of which the charge differs.

The mobile speed appears to change more so with a difference in particle size than a difference in material of particles.

By using concentric circular as the electrode pattern, it is shown that there is a possibility of also corresponding to the large pixel.

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Biography

Taiju Takahashi received the B.S. degree in Electronic Engineering in 1989, and the M.S. degree in Electrical Engineering in 1991 from Kogakuin University, respectively, and he received the Ph.D. degree from Nagaoka University of Technology in 1998. He has worked as a postdoctoral researcher at the Liquid Crystal Institute of Science University of Tokyo in Yamaguchi from 1998 to 2000, and he is a lecturer at Kogakuin University from 2000. He has engaged in liquid crystal displays and their applications.