Improvement of Particle Velocity of an Electrophoretic Display by Introducing Guide Blocks in a Display Cell

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Abstract

Electrophoretic display has been utilized for reflective display panel fit for e-book readers. However, its slow response speed is one of major weak points. We have focused on the liquid flow generated by particle movement when driving voltage is applied in a display cell. We suppose that the liquid flow affects to the particle movement and its possible turbulence probably prevents smooth particle movement expected under the applied electric field. We have tried to control the liquid flow in a display cell by introducing guide block structure in a display cell. We expected the guide blocks decrease the turbulence of the liquid flow and can improve moving speed of particles. We have prepared two types of display cell, with and without the guide blocks, and measured speed of particle movement in the display cells. As a result, we have found two times faster particle velocity when using the display cell with the guide blocks than when using the display cell without block. These results suggest that appropriate arrangements of display cell structure can effectively improve the response time of electrophoretic displays.

1. Introduction

Electrophoretic display[1), 2)] forms images by moving charged particles with controlling electric field. It is a promising display technology for electronic paper which requests reflective and nonvolatile display. Electrophoretic display has been utilized as e-book readers, however, its slow response speed has been pointed out as a major weak point. Besides, detailed characteristics of particle movement[3), 4)] in an electrophoretic display cell has not been clarified; it means there are no appropriate guide for improving the response speed of particle migration. We have focused on the liquid flow[5)] generated by particle movement when driving voltage is applied in a display cell. When particles move in a viscous liquid, driven by an electric field, liquid produce uni-directional flow as a result of drag force caused by the movement of the particles. Consequently, the produced liquid flow also affects behavior of the particles. The effect to the particle movement, however, has not been considered for the discussions of particle movement in an electrophoretic display cell.

A uniform liquid flow cannot be expected, as a result, in a closed area of the electrophoretic display cell. The particle movement must be affected by the turbulent flow in a cell; the particle moving speed must be reduced by the turbulence. Our supposition is that the particle moving speed can be improved by reducing the turbulence of liquid flow in an electrophoretic display cell.

In this study, we have tried a new cell structure for controlling liquid flow in a cell and evaluated the effect of the flow control by measuring particle speed in the cell.

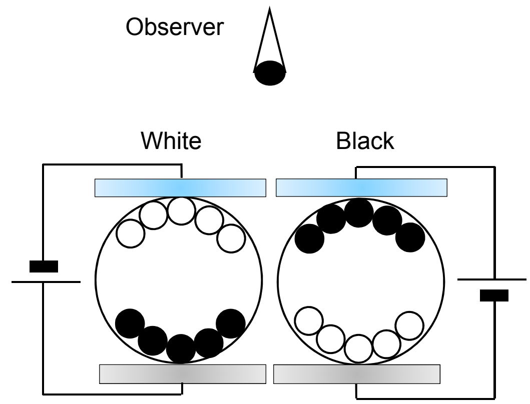

Fig.1 Principle of electrophoretic display

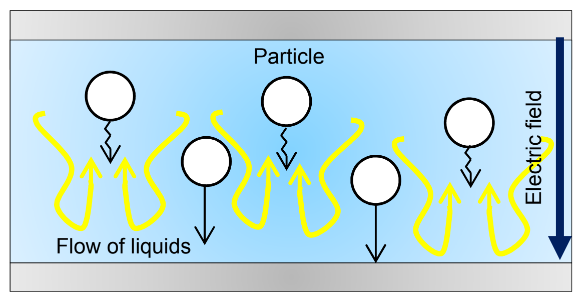

Fig.2 Supposed turbulent flow in an electrophoretic display cell

2. Experimental Methods

Figures 3 and 4 show two types of cell structures, in which we measured particle moving speed. Guide blocks are introduced in the cell (B) for the purpose of reducing turbulence of the liquid flow. Cell (A) is a conventional cell without the guide blocks between parallel electrodes. Details of the test cells and measuring conditions are shown in Table 1. Figures 5 and 6 show the appearances of the conventional cell (A) without guide blocks and special cell (B) with the guide blocks respectively.

We observed and recorded the behavior of particles in the cell under the conditions of applied voltage of 100 ~ 1000 V between the parallel electrodes in the cell.

We measured traveling time of the fastest group of particles which across the channel area between the parallel electrodes. We then got the particle velocity, which is divided value of the particle moving distance by the travelling time of the particles. Mobility of particles μ was finally calculated by the following equation using the particle velocity v and electric field E from the parallel electrodes.

$$\mu = v/E \quad (1)$$

Table 1 Detail of cell and conditions of measurement

Items	Details
Cell	Glass plate
Cell gap	0.5 mm
Electrodes	Aluminum (0.5 mm thick)
Distance of the electrodes	2 mm
Guide blocks	Poly vinyl chloride (0.5 mm thick)
Seal	Epoxy adhesive
Particle	Plus charged (magenta)
Applied voltage	DC 100~1000 V
Electric field	50~500 V/mm
Particle observation	Digital micro scope

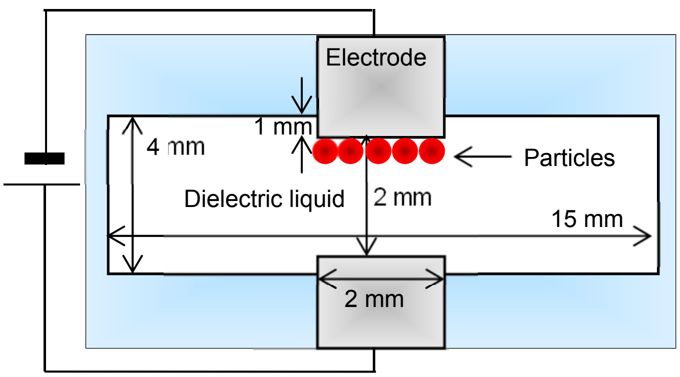

Fig.3 Structure of a cell without blocks: cell (A)

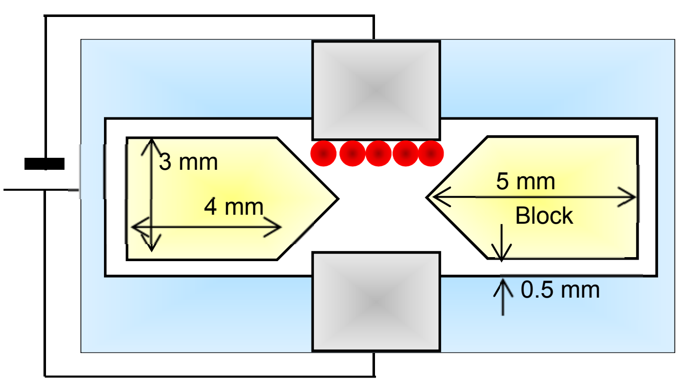

Fig.4 Structure of a cell with blocks: cell (B)

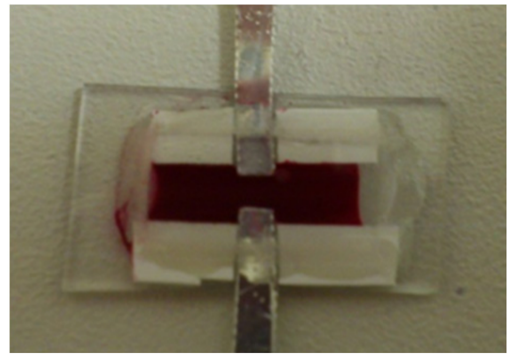

Fig.5 Cell (A) without blocks

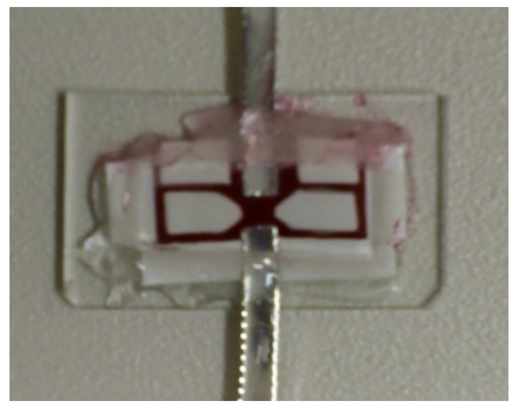

Fig.6 Cell (B) with blocks

3. Experimental Results

Figure 7 and 8 show measured results. Figure 7 shows the relation between the particle velocity and the applied voltage. The cell (B) with blocks showed two times larger value of particle velocity than that of the cell (A) without guide blocks. The cell (B) also showed two times larger mobility than that of the cell (A) in Figure 8.

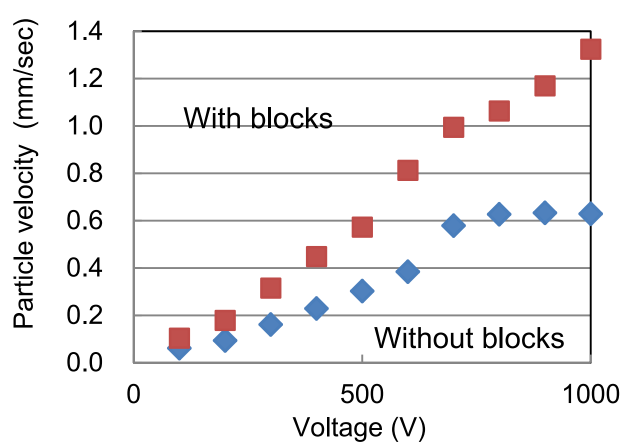

Fig.7 Relation between voltage and particle velocity

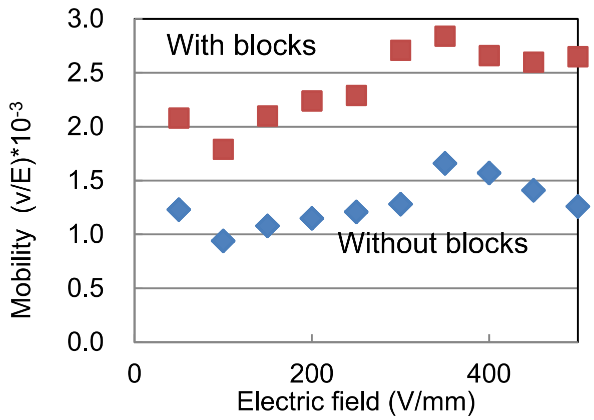

Fig.8 Relation between electric field and particle mobility

4. Discussion

Our experimental results suggests that the introduction of the guide blocks is effective for improvement of the particle velocity in the cell. Figure 9 shows illustrations of liquid flow supposed in the two types of cells. Turbulent liquid flow is supposed in the cell (A) without guide blocks. A smooth liquid flow is, in contrast to the cell (A), supposed around the guide blocks in the cell (B). We regard the guide block is effective for offering special route for the returning liquid flow, which is supposed as the cause of turbulence in the conventional cell (A) without blocks.

A typical strength of electric field is assumed as around 300 V/mm in the commercial products of electrophoretic displays (assuming driving voltage 50 v and distance of the parallel electrodes 50 μm). The range of electric field strength, 50 ~ 500 v, used in our experiment is thus regarded as practical conditions to evaluate the flow control effect of the guide blocks.

Our result indicates that the liquid behavior in the electrophoretic cell has a great influence to the particle velocity. Appropriate design of cell structure, including the introduction of guide blocks as a example, is thus suggested as a promising way of improving the slow response speed of electrophoretic display.

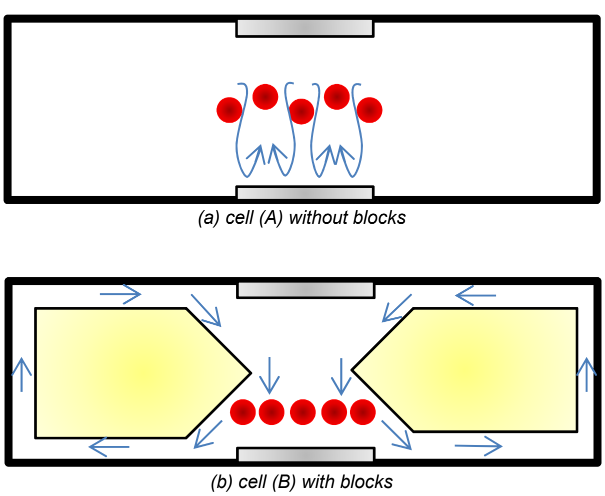

Fig.9 Supposed liquid flow in a cell.

5. Conclusion

We evaluated effects of cell structure to particle velocity in an electrophoretic display cell. Essential results are as follows:

1) A new cell structure with guide blocks showed two times lager particle velocity and mobility than that of the traditional cell structure without the guide blocks.
2) The guide blocks are regarded as effective for offering special route for returning liquid flow, which is supposed as the cause of turbulence in the conventional cell without blocks.

These results suggest that an appropriate designing of display cell structure can effectively improve the response time of electrophoretic display.

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Author Biography

Kotaro Sato was born in 1990. He received his B.E. degree in 2013 from Tokai University. He is expected to receive his M.E. degree from the graduate school of Tokai University in 2015. He is now engaged in a study of electrophoretic display.