Electrophoretic Characteristic of TiO_2 Particle in Melted Wax

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Abstract
A new rewritable printing media using electrophoresis and selective heating has been proposed to contribute to the reduction in paper consumption by printers. The mechanism is that when a heated part of the rewritable media is melted, white particles in that part of the media are able to move by electrophoresis. The media is initialized by heating its entire surface under the condition of voltage application and imaging is carried out by selective heating under the condition of an applied reversed-polarity voltage. The relation between Electrophoretic characteristic of TiO_2 and the viscosity of the melted wax is discussed.

Introduction
The printing technology has realized remarkable progresses. Due to the increase of paper consumption, environmental problem are arising. Rewriteable paper has been considered. The rewritable display has two approaching methods that are printing and technologies. Both technologies are called as the electronic paper[1]. The technologies are the reversible coloring reaction of leuco dyes[2,3], dry toner motion[4,5], thermal magnetophoresis[6] and gyricon[7], and so on.
The electrophoresis has the possibility of display characteristic like a paper.[8, 9, 10] In this work, we estimated the viscosity in melted wax and measured the mobility of TiO_2 in the melted wax. The difference of mixing method is studied and also carnauba and rice waxes are compared.

Proposed Rewritable Printing Media
The rewritable printing media is shown in Fig. 1.
1) Initialization: the media is melted by heating under the condition of voltage application, so that one side becomes colored and the other side becomes white.
2) Imaging: under a reversed-polarity voltage, the area of the media where the reflectivity is to be changed is melted by selective heating. Because of reversed-polarity voltage application, white particles move to the other side of the media only where the media is melted. Selective heating can be carried out using heating elements for thermal printing and is also considered to be possible by laser beam scanning. When conventional one-dimensionally arranged heating elements are used, the rewritable media is passed over a heating element and selective heating can be accomplished in the same way as in a thermal printer.
The rewritable printing media utilizes electrophoresis and the media is stable solid at its storage temperature, which is usually room temperature, so excellent visibility and stability are expected.

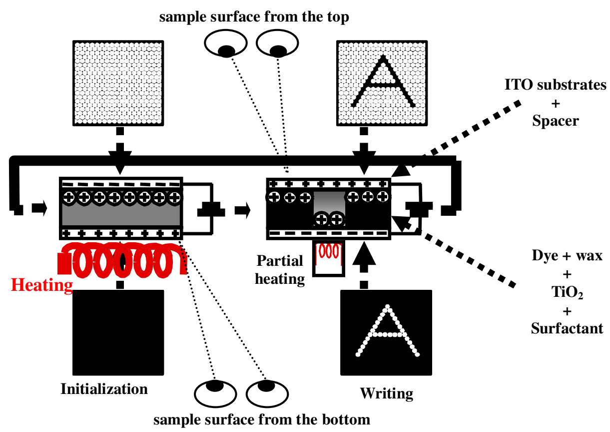

Figure 1. Proposed Rewritable Printing Media.

Experimental
Two kind of wax (carnauba wax and rice wax) were studied. They are mixed with dye, surfactant and TiO_2. The mixing is carried out by stirrer and paintshaker to compare the effect of mixing method. The melting points of carnauba wax and rice wax are about 80°C and 44°C, respectively. OIL Black HBB (Orient Chemical Industries Co., Ltd.) is used as dye. A measuring cell is fabricated by sandwiching wax mixture between two ITO substrates. A space of two substrates is kept 0.2 mm by using an insulator. The measurements were carried out at the temperature of 100°C. Applied to the cell and the reflectance change was measured. The reflectance change was observed by digital camera (Minolta: DiMAGE Z1). Operating in the Motion JPEG mode at 30 frames/s, with 640x480 dots, after the reversed-polarity voltage is applied. Two mirrors were analyzed both side reflectance change simultaneously as shown in Fig. 2.
The viscosity of wax is estimated from the free fall motion

of ball. The experimental schematic is shown in Fig. 3. The ball is dropped into the wax melted by heat and its motion is observed by digital camera. The falling speed of the ball is obtained from the image captured by the camera. The ball used is steel ball which diameter is 3.1 mm. The falling speeds of carnauba wax and rice wax were observed to 0.3m/s and 0.42m/s, respectively. Their viscosity constants were estimated to 1.3p and 0.9p, respectively.

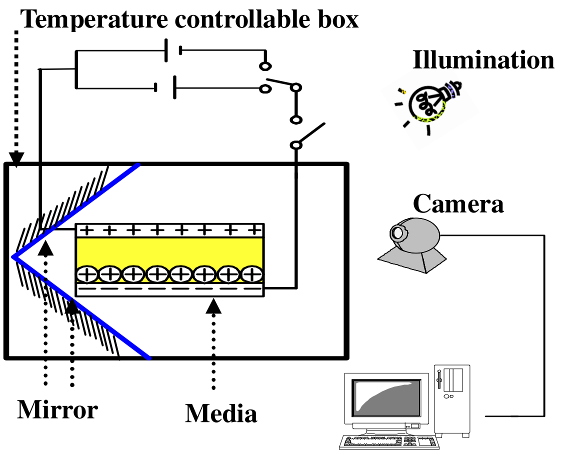

Figure 2. Schematic diagram of experiment.

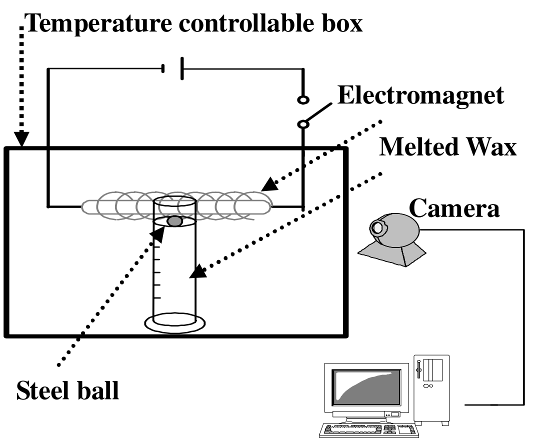

Figure 3. Schematic diagram of viscosity estimation.

Results and Discussions

The reflection change by voltage application is shown in Figure 4. It is observed that the reflection of one side increases and the reflection of other side decreases after the application of the voltage. The increase and the decrease are reversed when the voltage polarity is reversed.

The response time of reflection change is defined as shown in Figure 5. This definition means the time needed for half change after the voltage application. The inverse of the half change time is plotted as the applied voltage in Figure 6-9. Figure 6 and 7 show the electric field dependence of carnauba wax and Fig.8 and 9 show the electric field dependence of rice wax. It is found that there is the difference between TiO_2 moving upward time and moving downward time in both waxes. The difference is possibly because of gravity force.

Concerning the mixing methods, it is found from the comparison between Figure 6 and Figure 7, and also the comparison between Figure 8 and Figure 9 that the differences of response times between upward motion and downward motion smaller when mixing is carried by shaker instead of stirrer.

Concerning the wax, it is found that rice wax shows high speed response compared with carnauba wax. The reason is considered due to the difference of viscosity and TiO_2 particle charge.

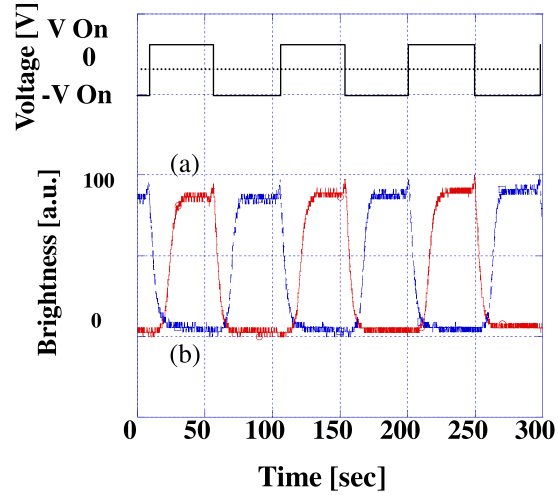

Figure 4. Reflection response against voltage pulse. (a)up,(b)down.

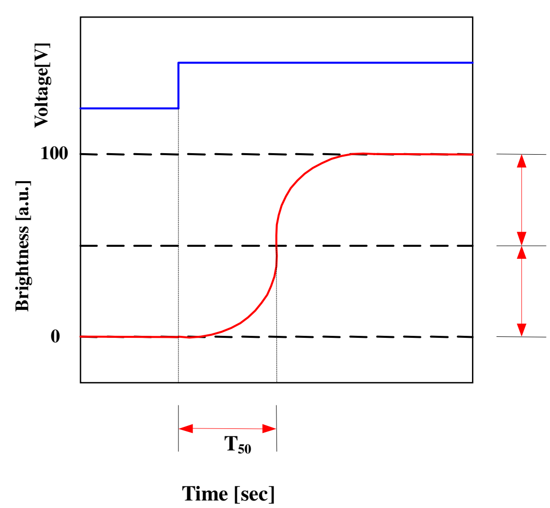

Figure 5. Response time of reflection change.

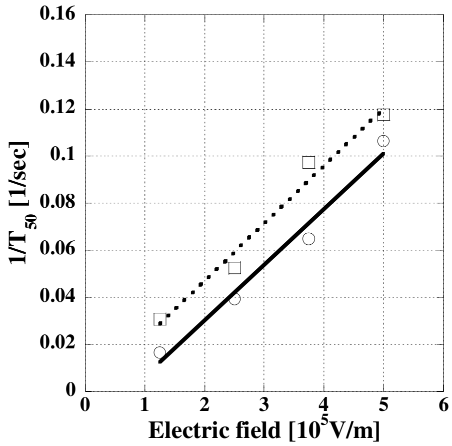

Figure 6. Inverse of response time dependence on electric field (Carunauba wax, Mixing method: stirrer)

□*: Downward motion ,* ○ *: Upward motion*

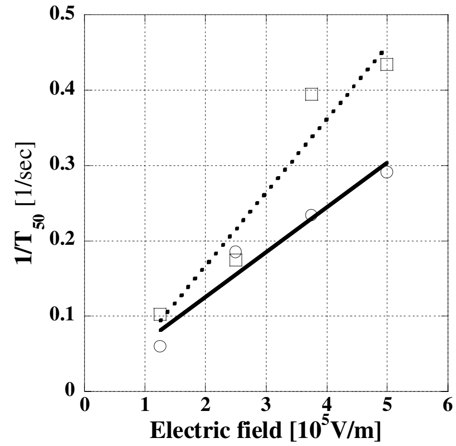

Figure 8. Inverse of response time dependence on electric field (Rice wax, Mixing method: stirrer)

□*: Downward motion ,* ○ *: Upward motion*

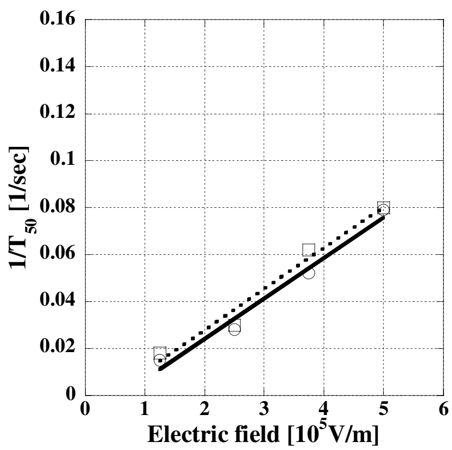

Figure 7. Inverse of response time dependence on electric field (Carunauba wax, Mixing method: Paintshaker)

□*: Downward motion ,* ○ *: Upward motion*

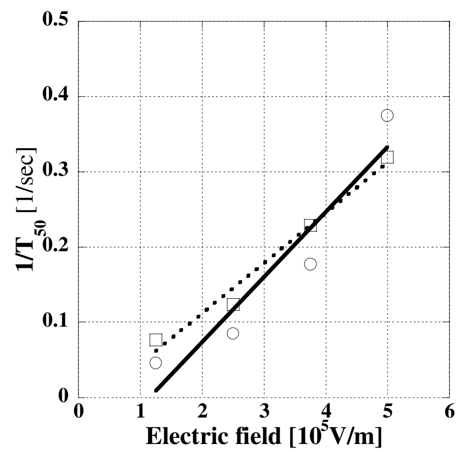

Figure 9. Inverse of response time dependence on electric field (Rice wax, Mixing method: Paintshaker)

□*: Downward motion ,* ○ *: Upward motion*

Conclusions

Reflection response by the voltage application was measured. From the response, the electrophoretic characteristics of TiO_2 in the melted carnauba and rice waxes were estimated. It is found that the reflection response of rice wax is quicker than the one of carnauba wax. Concerning the mixing method, stronger mixing force decreases gravity direction dependence of TiO_2 motion.

Acknowledgements
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Biography
***Takeshi Hasegawa** is graduate course student of Nippon Institute of Technology. He gained Bs. Degree from Nippon Institute of Technology and is now studying a new rewritable printing media in Hoshino laboratory of Nippon Institute of Technology. E-mail:1014345@sstu.nit.ac.jp*

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