Dependence of Rewritable Characteristics on Media Thickness in Wax-based Electrophoretic Media

Takeshi Hasegawa*, Takayuki Sano** and Yasushi Hoshino*; *Nippon Institute of Technology; Saitama, Japan, **Tomoegawa Paper Co., Ltd.; Shizuoka, Japan

Abstract

A new rewritable printing media using electrophoresis and selective heating has been proposed to contribute to the reduction of paper consumption.

Wax-based electrophoretic rewritable media has been investigated based on their potential for having good preservation characteristics. Decreasing the thickness of rewritable media is very important in order to decrease the writing/erasing energy of wax-based rewritable media. In the present study, the thickness characteristic of rewritable media is investigated.

As a result, reflectance ratio of dyed-wax side and TiO_2 side is obtained as good condition around media thickness 0.075mm at proper wt ratio conditions of dye and TiO_2.

Introduction

With the rapid increase in information traffic associated with the development of computer and network technologies, the paper amount by electronic printing has increased rapidly. Electronic paper technology has been investigated as a means for reducing the paper consumption associated with hard copy printing and thereby reducing the environmental impact. There are two main approaches for realizing electronic paper. One approach has its origins in printer technology. In this approach, like printed media, the display medium has no addressable circuit. The other approach is based on display technology. In this approach, like display devices, the medium has an addressable circuit. Printer-based technologies are primarily rewritable media that utilize the reversible coloring reactions of leuco dye, e-ink, liquid crystal, dry toner motion, thermal magnetophoresis, and gyricon.[1, 2] Writing methods are classified into four main types: electrical, magnetic, light, and thermal writings. These are used with both kinds of electronic paper: paper-like displays and rewritable paper. The advantages and disadvantages of each type of electronic paper depend on the writing method and the components in the paper media.

A wax-based electrophoretic rewritable paper has been proposed. The major advantage of this wax system is the possibilities of modulating the melting temperature over a wide range and of realizing good preservation properties.[3–8] Such paper is expected to have a very high number of write/erase cycles because it employs a electrophoretic process. This rewritable mechanism involves melting the wax when writing or erasing. The energy consumed during writing and erasing is considered to be relatively high. Therefore, it is very important to make rewritable media thin. However, the thickness characteristics of wax-based electrophoretic rewritable paper have not been sufficiently understood.

The purpose of the present study is to clarify the thickness characteristics of rewritable media. The dependence of the rewritable characteristics on the dye and TiO_2 concentrations is measured and the thickness characteristics are discussed. Rewritability is tentatively confirmed by preparing an enlarged rewritable dot cell.

Experimental

Sample preparation

Samples were prepared by mixing dye, surfactant, and TiO_2 with wax. The wax is carnauba wax and its melting points is approximately 80 °C. Oil Black HBB (Orient Chemical Industries Co., Ltd.) was used as the dye and an anionic surfactant was used as the surfactant. The mean size of the TiO_2 particles was about 250 nm. If the particles are smaller than 250 nm, then their whitening ability will be weak, whereas if they are larger, sedimentation due to gravity cannot be ignored.

The materials were prepared using the ratios shown in Table 1. Mixing was performed as follows: wax, dye, TiO_2, surfactant, and a 9.5-mm-diameter nylon ball were bottled and the bottle was placed in a temperature-controlled box (Koyo Thermo System, KLΦ-45M) that was maintained at 120°C for 10 min. With the exception of the ball, the content of the bottle melted. The bottle was removed from the oven and was shaken by hand for 2 min. The bottle was then placed in the oven for a further 10 min. It was then removed from the oven and shaken using a paint shaker (Red Devil Inc.) for 10 min.

Measurement methodology

Figure 1 shows a schematic diagram of the experimental method. Switch 1 was used to turn the DC power supply (Kenwood, PA500) on and off and switch 2 was used to change the polarity of the voltage applied to the measurement cell. The sample was kept in a temperature-controlled box (Koyo Thermo Systems, KLΦ-45M). The temperature was raised from room temperature to 100°C. After the wax had melted sufficiently, switch 1 was turned on. A DC voltage of 100 V was applied to the lower electrode. This electric potential was applied to move the negatively charged TiO_2 particles to the lower side initially. Switch 2 was then turned on to move the TiO_2 particles from the lower to the upper side. The voltage was applied for 1 min and the reflectance of the upper side of the sample was measured. Subsequently, the polarity of the voltage applied to the sample was reversed. The polarity was reversed several times. Figure 2 shows the changes in the reflectance. After several times polarity changes, the sample was cooled to room temperature while applying a voltage. Both sides of the sample were measured using a spectrophotometer (Minolta, CM-2022). Three points on the sample were measured and the three values obtained were averaged.

Writing/erasing was performed at an applied voltage of 100 V and a temperature of 100°C.

A dot cell was prepared, as shown in Figure 2. The dot cell is 3 mm in diameter and the rewritable medium is 0.1 mm thick. The cell contains rewritable medium with 5 wt% TiO_2 and 0.3 wt% dye. Writing/erasing was performed at an applied voltage of 100 V and a temperature of 100°C.

Table 1 Mixing ratio of material.

Samples number	TiO_2 [wt%]	Surfactant [wt%]	Dyed wax [wt%]	wt% ratio wax:dye
1				100:0
2				100:0.03
3				100:0.07
4	2.5	0.5	97	100:0.15
5				100:0.3
6				100:0.6
7				100:0.9
8				100:0
9				100:0.03
10				100:0.07
11	5	0.5	94.5	100:0.15
12				100:0.3
13				100:0.6
14				100:0.9
15				100:0
16				100:0.03
17				100:0.07
18	10	0.5	89.5	100:0.15
19				100:0.3
20				100:0.6
21				100:0.9

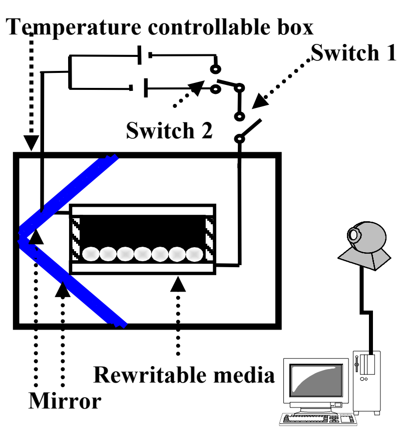


Figure 1 Schematic diagram of the experimental system.

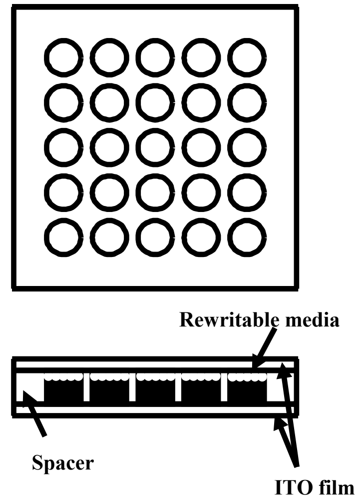


Figure 2. Experimental cell structure of rewritable media.

Result and Discussions

Figure 3 shows the dependence of the reflectance at a wavelength of 550 nm (which the human eye is highly sensitive to) dependence on the dye concentration. The reflectance decreases with increasing dye concentration and increases with increasing TiO_2 concentration. The reflectance of dyed wax side decreases rapidly till dye concentration 0.1wt%, however, the reflectance of TiO_2 side shows a little bit decrease. The decrease of dyed wax side is due to the light absorption by dye. The decrease of TiO_2 side is due to dying of TiO_2 and entering dyed wax into the space between TiO_2 particles.

Figure 4 shows the dependence of reflectance difference between TiO_2 side and dyed wax side with respect to dye concentration. The difference in the reflectances of the white side (i.e., the TiO_2 side) and the black side (i.e., the dye-wax side) increases with increasing dye concentration because the dye absorbs light, whereas TiO_2 reflects light till the dye concentration 0.2wt%. However, over the dye concentration 0.2wt%, the difference decreases a little bit due to the decrease of the reflectance of TiO_2 side.

Figure 5 shows the dependence of logarithm of the reflectance ratio between TiO_2 side and dyed wax side on the medium thickness.

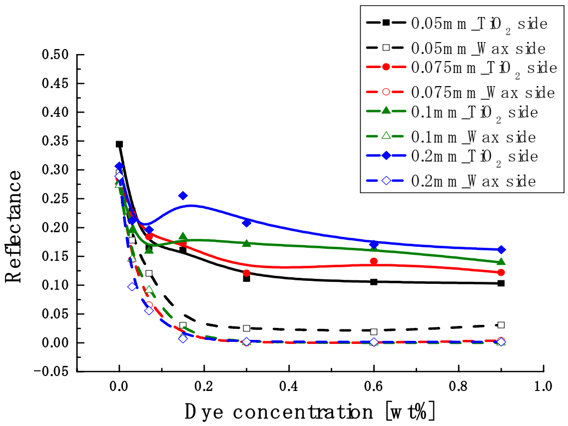
The logarithm of the reflectance ratio LR is expressed as

$$LR = \log_{10}\left(\frac{R_{TiO_2\ side}}{R_{dyed\ wax\ side}}\right) \quad (1)$$

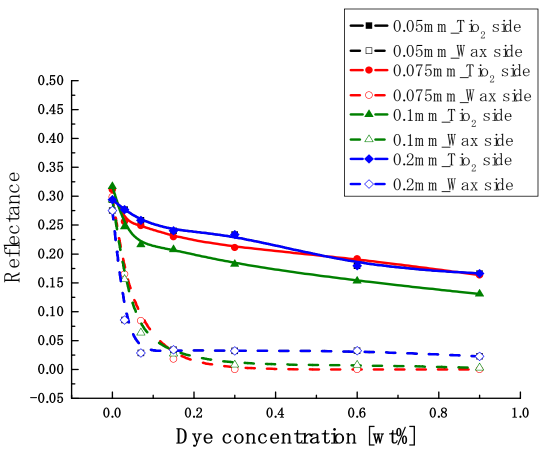
where LR(Logarithm reflectance) is logarithm of the reflectance ratio of TiO_2 side and wax side. $R_{TiO2\ side}$ means the reflectance of TiO_2 side and $R_{Wax\ side}$ is the reflectance of wax side.

From the Figure 5, it is found that the reflectance ratio shows peak at the wax layer thickness 0.07- 0.1mm and the peak becomes clear above the dye concentration 0.3wt%.

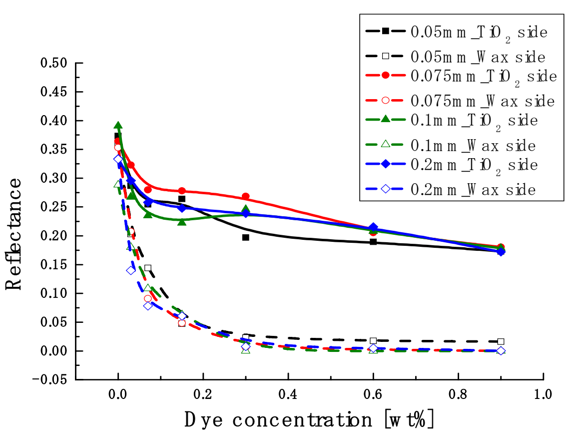
Rewritable characteristics are experimented preliminary. The conditions are dye 0.3wt%, TiO_2 5wt% and layer thickness 0.1mm. The results are shown in Figure 6.



(a)

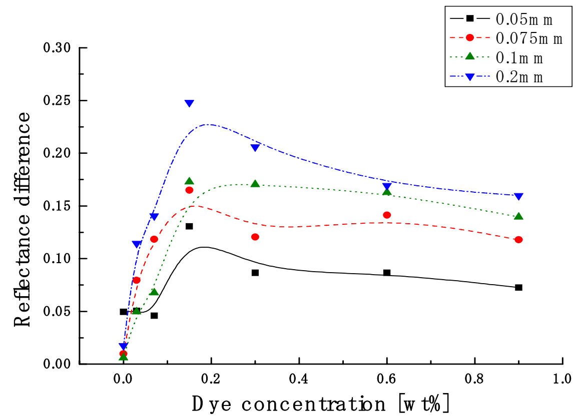


(b)

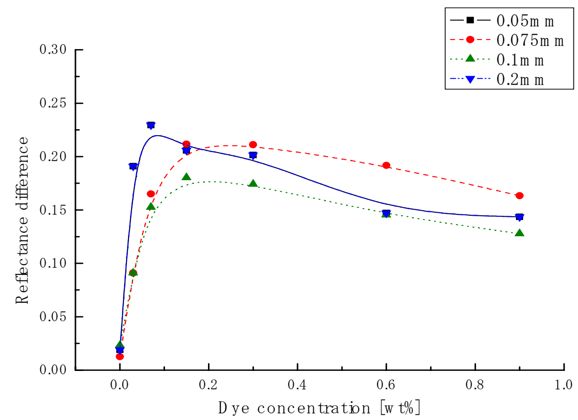


(c)

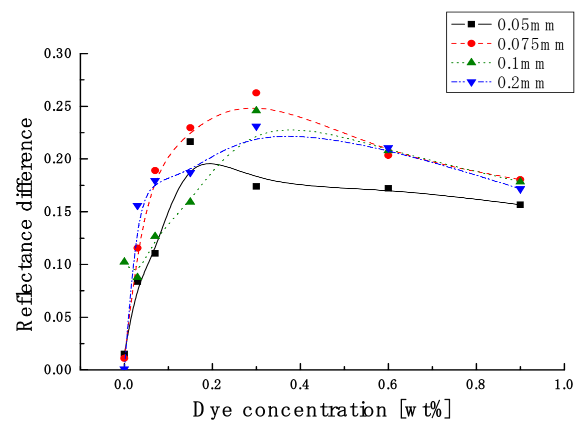
Figure 3 Plots of reflectance at 550 nm of the TiO_2 side and the dyed wax side with respect to dye concentration in carnauba wax. (a) TiO_2 2.5 wt%, (b) TiO_2 5 wt%, (c) TiO_2 10 wt%.



(a)

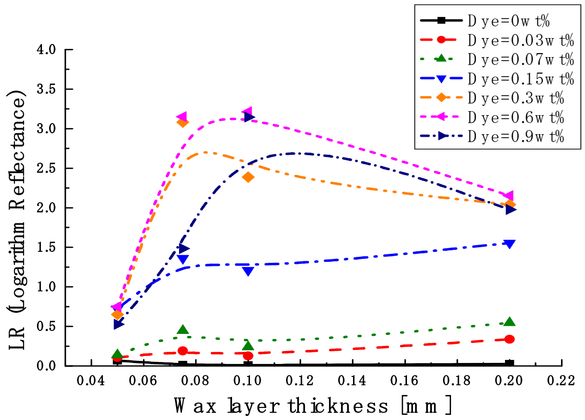


(b)

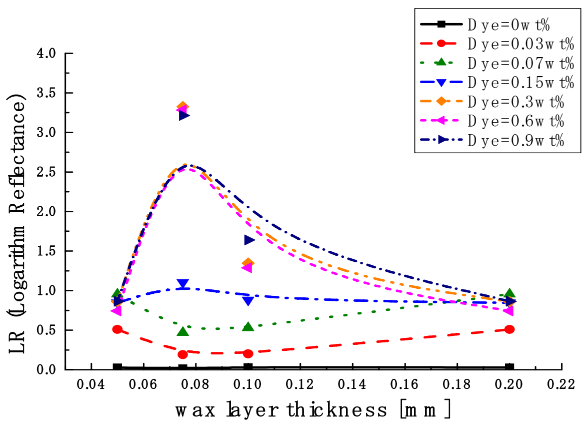


(c)

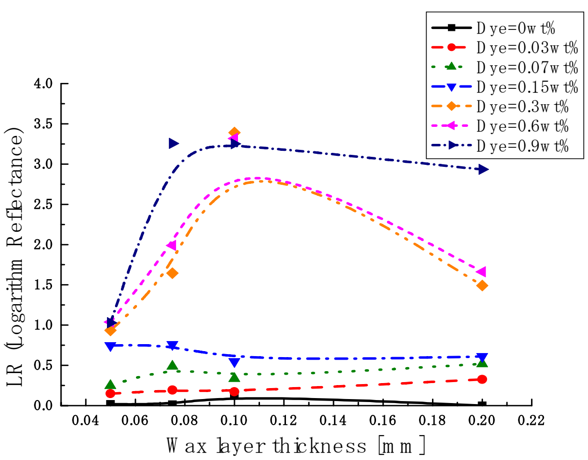
Figure 4 Reflectance difference between TiO_2 side and dyed wax side with respect to dye concentration in carnauba wax. (a) TiO_2 2.5 wt%, (b) TiO_2 5 wt%, (c) TiO_2 10 wt%.



(a)

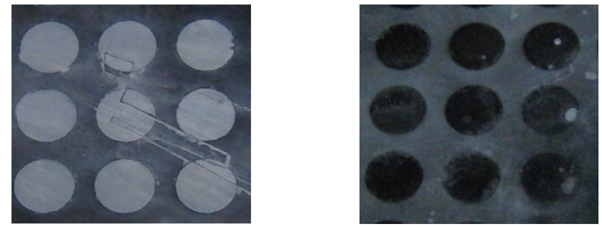


(b)



(c)

Figure 5 LR(Logarithm reflectance) dependence on wax layer thickness. (a) TiO_2 2.5wt%, (b) TiO_2 5wt%, (c) TiO_2 10wt%.



(a) (b)

Figure 6. Photographs of written and erased dots: (a) TiO_2 side when TiO_2 moved to the upper side; (b) dyed side when TiO_2 moved to the bottom side.

Conclusion

The effect of dye concentration on rewritable characteristic was studied with the purpose of obtaining the optimum condition of the dye concentration in wax.

It is found that the reflectance ratio shows peak at the wax layer thickness 0.07- 0.1mm above the dye concentration 0.3wt%. The optimum condition of the rewritable media is obtained at the media thickness 0.075mm of TiO_2 5wt% and dye concentration 0.3-0.9wt%.

The rewriting characteristics is confirmed at the 0.1mm thick wax layer of TiO_2 5wt% and dye 0.3wt%.

References

[1] D. A. Hays, J. Electrost. 51, 57 (2001).

[2] N. K. Sheridon, "The Gyricon as an electronic paper medium", Proc. Pan-Pacific Imaging Conference / Japan Hardcopy, p.83-86, (1998).

[3] Y. Hoshino, M. Ogura and T. Sano, Japanese J. Appl. Phys. 43, 7129 (2004).

[4] S. Noppakundilograt, S. Phattanarudee, S. Kiatkamjornwong, R. Kumekawa, M. Ogura, Y. Hoshino, "Imaging Parameters Influencing the Rewritable Process of Titanium Dioxide Electrophoresis", J. Imaging Sci. Technol. 51, 190-195, (2007).

[5] R. Kumekawa, T. Hasegawa, T. Sano, and Y. Hoshino, "Estimation of TiO_2 Particle Electrophoresis by Measuring Reflectance Response", Proc. IS&T's NIP 21 (IS&T, Springfield, VA, 2005) p56-59(2005).

[6] T. Hasegawa, R. Kumekawa, Y. Hoshino and T. Sano, "Electrophoretic Characteristic of TiO_2 Particle in Melted Wax", Proc. IS&T's NIP 22 (IS&T, Springfield, VA, 2006), p477-480(2006).

[7] T. Hasegawa, T. Sano, and Y. Hoshino "Influence of Dye Concentration on Display Characteristic in Wax-Base Electrophoretic Rewritable Media", Proc. IS&T's NIP 26 (IS&T, Springfield, VA, 2010), p516-519(2010).

[8] T. Hasegawa and Y. Hoshino, "Dependence of rewritable characteristics on dye and TiO_2 concentrations in wax-based electrophoretic thin media", to be published in J. Imaging Sci. Technol. 55, Sept. /Oct. (2011).

Author Biography

Takeshi Hasegawa received his B.S Degree in Systems Engineering from Nippon Institute of Technology of Japan (2005). He received his M.S Degree in Systems Engineering from Nippon Institute of Technology of Japan (2007). Since 2009, he began to study as a Doctor course student in Nippon Institute of Technology. His theme for PhD is electronic paper.