Influence of Dye Concentration on Display Characteristic in Wax-Base Electrophoretic Rewritable Media

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Abstract

Wax-based electrophoretic rewritable media has been studied with the expectation of good preservation characteristics. The thinning thickness condition of the rewritable media thickness is studied. The samples of dye concentration 0, 0.03, 0.07wt% against wax and weight ratio of TiO_2 2.5, 5 and 10wt% are prepared with the thickness of 0.1 and 0.2mm. Displaying characteristics are estimated. Concerning the dependence of dyed side on dye concentration, Lambert-Beer equations is applied and the absorption coefficient of dye is obtained. The thinning condition of rewritable media is discussed as the reflection ratio of dyed side and white TiO_2 side of the media can be realized to 10 at the condition of media thickness less than 0.1mm around dye concentration 0.1wt%.

Introduction

As a result of developments in rapid information technology recently, paper consumption for printing using electronic printers, such as electrophotographic printers and ink jet printers has increased dramatically. A certain amount of paper is used for data confirmation or document preparation. The electronic paper technology has originated[1] so as to decrease this paper consumption and consequently preserve forests. These are two main approaches to creating electronic paper from printers and display technology. The technologies are reversible coloring reactions of leuco dye[2]-[4], liquid crystal[5],[6], twisting ball[7],[8], dry toner motion[9]-[12], thermal magnetophoresis[13], and gyricon[14]. The writing methods are divided into four main method namely electrical, magnetic, light, and thermal writings, which are used with both categories of electronic paper (a paper-like display and rewritable paper). The advantages and disadvantages of each type of electronic paper depend on the writing method and the components in paper media[15].

A wax type electrophoretic rewritable paper is proposed[16]-[19] and the major advantage of this wax system is the possibility of modulating the transition temperature at a wide range. The number of writing and erasing cycles of some kinds of the dye complex material using a thermal head or bar capable of spot heating without affecting optical density could be only 100 times of usage. Eventhough this is important to make rewritable media efficient, it is said that the fundamental is not obtained yet.

In this study, the condition of making less than 0.1mm thickness media is discussed. Also the effect of dye and TiO2 concentration on obtaining thickness thinning condition is estimated.

Experimental

Sample preparation

The samples were prepared by mixing dye, surfactant and TiO_2. Two kinds of wax (carnauba wax and rice wax) were used in the experiment. 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.) was used as dye while an anionic surfactant was used as surfactants. The samples were prepared so as the dye concentration to be 0, 0.03 and 0.07 against wax and 2.5, 5 and 10 against TiO2 respectively. Two types of spacers were used where the thicknesses of 0.1 and 0.2mm.

The samples which were prepared according to the above mentioned weight ratios, were put in to bottles and they were heated in temperature-controlled box (Koyo THERMO Systems KLΦ-45M). The temperature of inside of the box is raised from room temperature to 120 ℃. When considering the exposure time, the carnauba wax was stirred for 30 minutes until got melted and 10 minutes for rice wax respectively. The materials of molten state were shaken by Paint Shaker (Red Devil, Inc.). Shaking time was 10 minutes. A measuring cell was fabricated by sandwiching wax mixture between two ITO glass substrates.

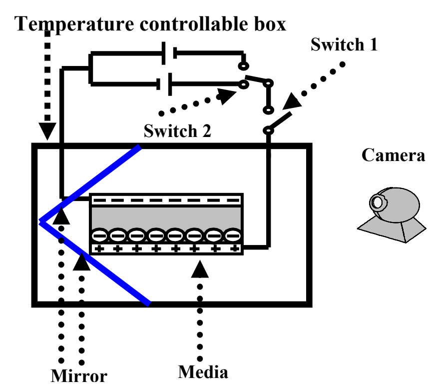

Figure 1. *Schematic diagram of experimental system.*

Measurement methodology

The schematic diagram of the experimental method is shown in Figure 1. Switch 1 was used for controlling ON/OFF of DC power supply (KENWOOD: PA500) and switch 2 was for polarity change of the voltage of measuring cell. The sample was kept in a temperature box (Koyo THERMO Systems KLΦ-45M); the temperature is raised from room temperature up to 100 ℃. After the wax is melted enough, switch 1 was put to ON. DC power supply voltage 100V was applied. Electric field was applied for

TiO_2 to move to lower side as an initial condition. Then, Switch 2 was changed for TiO_2 to move from lower to upper side. The voltage was applied during one minute and the reflectance of upper side of the sample was measured. Subsequently reverse polarity was applied to the sample and such a polarity change was repeated several times. Figure 2 shows the reflectance changes. After several times of polarity change, the sample was cooled to room temperature with the voltage applied state. Both sides of the sample were measured by spectrum colorimeter (MINOLTA CM-2022). Three points of the sample were measured and the average value was taken to consideration.

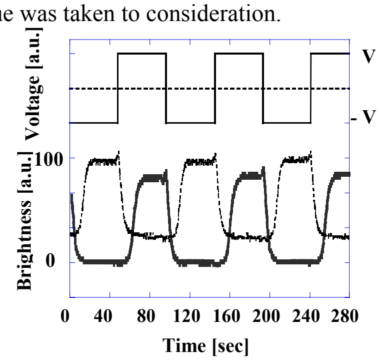

Figure 2. *Response of reflection against rectangular voltage.*

Results

Figure 3 illustrates the reflectance dependence on wavelength for concentrations of 0, 0.03 and 0.07 for wax and TiO2 as well. Figure 4 shows the comparison results when only the wax and dye were used. IT is observed that the media becomes white by TiO_2 addition. Reflectance at 550nm, of which wavelength human eye have high sensitivity, are plotted and shown in Figure 5.

It is found that the logarithm of the reflectance decreases on a straight time against the increase of the dye concentration.

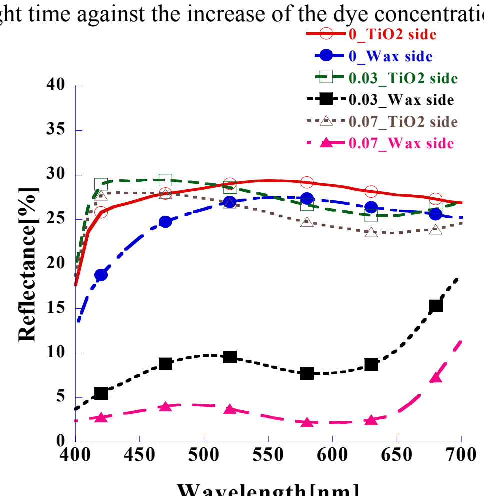

Figure 3. *Reflectance spectra of TiO_2 side and dyed wax side of test media on dye concentration of 0, 0.03, 0.07wt%.*

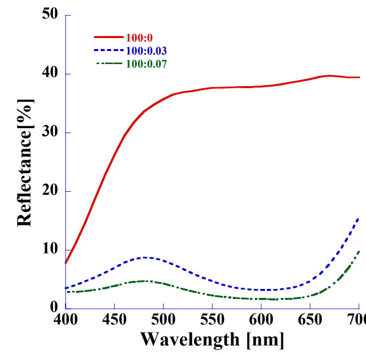

Figure 4. *Reflection spectra of wax of dye concentration 0, 0.03, 0.07. TiO_2 is not included.*

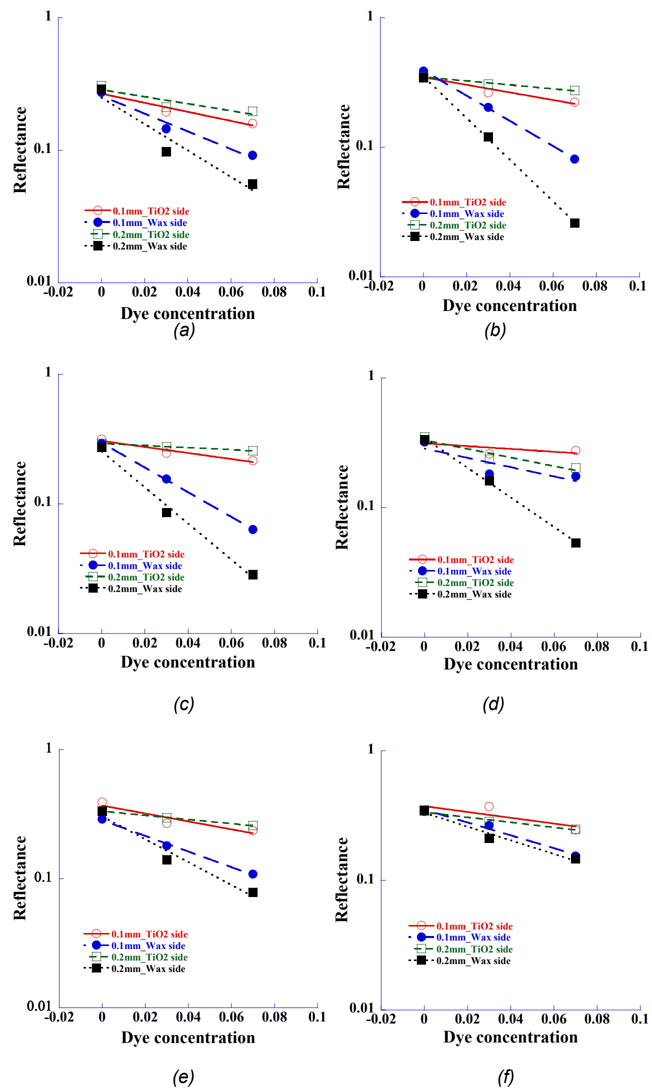

Figure 5. *Semi-logarithm plots of reflection at 550nm of TiO_2 side and dyed wax side versus dye concentration.(a) TiO_2 2.5wt%, carnauba wax, (b) TiO_2 5wt%, carnauba wax, (c) TiO_2 10wt%, carnauba wax, (d) TiO_2 2.5wt%, rice wax, (e) TiO_2 5wt%, rice wax, (f) TiO_2 10wt%, rice wax.*

Discussion

To obtain the condition of making rewritable media thin, the dependence of reflection on dye and TiO_2 concentration is measured. Following two points of dye concentration dependence in wax and effect of TiO_2 concentration on rewritable characteristics are discussed.

Dye Concentration Dependence in Wax

From Figure 5, it is found that the reflectance decreases exponentially as the dye concentration increases. So, the reflectance dependence on dye concentration is suggested to the application of Lambert-Beer's law. The light is absorbed by dye dispersed in wax and is reflected by TiO_2 particle layer as shown in Figure 6. The light is considered to be absorbed twice in dyed wax layer. So absorption coefficient of dye is estimated as Eqs. (1), (2).

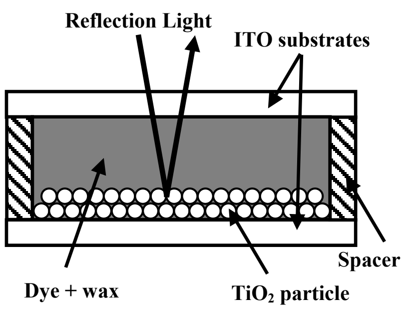

Figure 6 *Light reflection model.*

$$R_c = 10^{-2acd}, \qquad (1)$$

$$a = Log_{10}(R_0/R_{0.03})/2d(c_1 - c_0), \qquad (2)$$

Where R_c is reflection at the dye concentration c, a is absorption coefficient of dye and d is thickness of the wax layer. It is found the absorption coefficient has the dependence on wax, thickness and TiO_2 concentration.

Effect of TiO_2 concentration on rewritable characteristics

TiO_2 has role of light reflection in the rewritable media. To obtain the optimum condition of TiO_2 concentration, the rewritable characteristics are measured by changing the TiO_2 concentration.

By considering the Figures 7 and 8, dyed wax side absorption coefficient of dye is obtained. The reason for the absorption coefficient decrease according to the TiO_2 concentration increase is considered as,

1) TiO_2 absorbs dye and TiO_2 is dyed.
2) Dyed wax enters the space between TiO_2 particles.

It is also considered that the thickness of TiO_2 layer increases as the TiO_2 concentration increases and light path decreases.

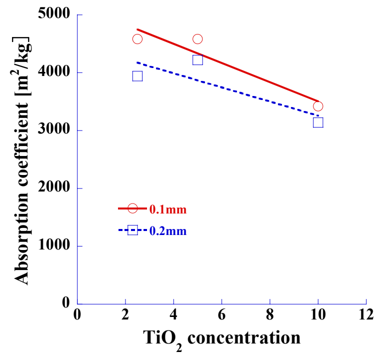

Figure 7 *Calculated result of the absorption coefficient dependence on TiO_2 concentration in carnauba wax.*

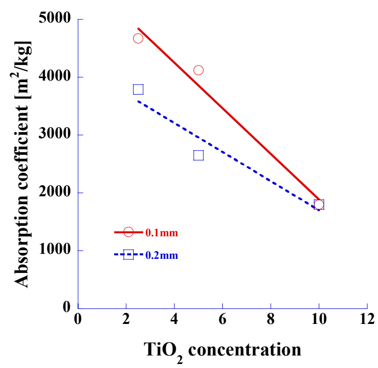

Figure 8 *Calculated result of the absorption coefficient dependence on TiO_2 concentration in rice wax.*

Conclusion

The effect of dye concentration on rewritable characterizes was studied so as to obtain the optimum condition of dye concentration for thin rewritable layer.

As the increase of dye concentration, it is found that reflectance of the colored side of the medium decreased exponentially. The decrease is explained by Lambert-Beer's law and the absorption coefficient of dye in the wax are obtained as 4.6. From the absorption coefficient the necessary dye concentration can be estimated for the expected thickness of the medium.

For carnauba wax, TiO2 5wt% concentration case and 0.1mm thickness, dye 0.12 wt% in OD (Optical Density) = 1.0 can be estimated.

These data is useful for advancing the development of the rewritable medium of the wax system.

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Author Biography

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