Study on The Principle of Controlling Rewritability for Joule Heating by Electrode Type Wax-based Electrophoretic Media

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The wax-based electrophoretic rewritable media has been studied due to the expectation of good preservation property. In the previously proposed methods, external heating mechanism is required to melt the wax-based media. In this proposed method, joule heating by current flow at the lower electrode is used to melt the wax as an alternative heating method. It is confirmed that rewritability is possible by this method. Thermal characteristics of this proposed display is discussed.

Keywords: Rewritable media, Wax, Display property, Joule heating, Thermal characteristics

1. Introduction

Rewritable media technology has been studied because of preservation of environment. Rewritable media is associated with printer technology and display technology. Due to the implementations on rewritable media, electrophoretic display has been proposed. The wax-based electrophoretic media has been studied as it is supposed to show excellent preservation property. An electrophoretic display is an information display that forms visible images by arranging charged pigment particles using an applied electric field1-3). In wax-based electrophoretic media, titanium dioxide (TiO$_2$) particles which are white in color are dispersed in a dyed wax mixture along with surfactants. When the media is melted, the TiO$_2$ particles move electrophoretically to the plate bearing the opposite charge from that on the particles. When the particles are attached to the viewing side of the display, that area appears white and when the particles are located at the rear side, it appears black due to the dyed wax. This media is expected to have a very high number of write/erase cycles because it employs an electrophoretic process.

Since this rewritable mechanism involves melting the wax initially when writing or erasing, heating mechanism is needed. 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.

Studies4-11) have been carried out on wax-based electrophoretic rewritable media. In the particular studies, an external heating mechanism is used to melt the wax. As a different proposal for the heating mechanism, in this study, joule heating by current flow at the lower electrode is proposed. The principle of this type of self heating system was studied.

Concerning the characteristics of the proposed method, it is assumed that proposed type of display cells can be produced in the scale of large size. And also, display information is expected the characteristic of good preservation. For an instance, if a heavy vibration occurs in a situation like earthquake, the display information remains unchanged, different to the electronic displays as the information is displayed with liquid crystals. And also, another advantage can be introduced as it doesn’t require electricity while displaying. For the demerits of this type of displays, the wax rewritable speed is not fast. Further, the power consumption when writing and erasing is considered to be relatively high.
2. Experimental

2.1 Sample preparation

Samples were prepared by mixing dye, surfactant, and TiO₂ particles with wax. The wax is carnauba wax which has a melting point of approximately 80℃. Oil Black HBB (Orient Chemical Industries Co., Ltd.) was used as the dye and a nonionic surfactant (CHEMISTAT 1100) was used as the surfactant. Experiments have carried out for various mixing ratios in previous studies. The optimum mixing ratios are considered as follows. Dyed wax is prepared so as the dye concentration to be 0.3 wt%. The mixing ratio of TiO₂, surfactant and dyed wax is 5 : 0.5 : 94.5 wt%.

The mean size of the TiO₂ 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. Mixing was performed as follows: wax, dye, TiO₂, surfactant, and 9.5 mm diameter nylon balls were bottled and the bottle was placed in a temperature-controlled box (Koyo Thermo System, KL-45M) for 10 minutes time at the temperature of 120℃. The content of the bottle was supposed to be melted after keeping for 10 minutes and then the bottle was removed from the oven. It was then shaken by hand for 2 minutes, before it was placed in the oven for another 10 minutes. It was then removed from the oven and shaken using a paint shaker (Red Devil Inc.) for 10 minutes. Shake by hand was done to avoid monotonous mixing by paint shaker.

2.2 Methodology

When setting up the experimental system, rewritable media was sandwiched and 20 mm X 20 mm display cell was prepared. The experimental set-up is shown in Fig. 1. Switch 1 was used to turn the DC power supply on and off which helps to melt the rewritable media and switch 2 was used to change the polarity of the voltage applied to the cell.

The experiment was carried out to observe how long will take to heat/cool the system. Voltage was applied by switch 1 to heat the system until 120℃ in the condition of without wax. The temperature was observed by a digital thermometer (RX-450K) and when it reached to 120℃, switched off the S1. The time to reach 120℃ and time to return to the room temperature was observed. The applied voltage was varied from 40 V to 60 V to investigate the temperature rising speed.

In the next step, the reflectance of the black and white displays was observed respectively and the time durations for rewriting were investigated. After the wax melted sufficiently, the voltage supplied for joule heating was reduced so as to maintain the wax media in the melted status. It is assumed that the negatively charged TiO₂ particles were attached to the lower electrode initially. A voltage of 100 V was then applied in between the electrodes through switch 2 where as the upper electrode gets the positive polarity. Therefore, when the switch 2 was turned on, the TiO₂ particles move from the lower to the upper side as the particles attract to opposite polarity. The voltage was applied for 1 minute and the reflectance of the upper side of the sample was measured by a spectrophotometer (Minolta, CM-2022). Subsequently, the polarity of the voltage applied to the sample was reversed for several times and the display was observed repeatedly.

3. Results and discussions

The time response of the temperature of wax media is important, because the wax get melted/cooled to liquid/solid state with the specific conditions of proposed heating mechanism. Therefore, experiments were carried out to investigate the dependence of time duration for heating and cooling on exposure to the environment by attaching an Aluminium plate beneath the lower electrode. The dependence of temperature on time for the cases where with and without Aluminium plate, is shown in Fig. 2. It can be noticed that, the lower time duration for heating is observed when the higher voltage is applied. Also, it can be observed that the time duration for warming up till 120℃ has increased when 40 V is applied for the case where Aluminium plate is attached. For the cases where 50 V and 60 V are applied, time durations for reaching the 120℃ are almost same. But the cooling rate differs for the case where Aluminium plate was used, in every case. When the half period of graph is considered, it can be understood that, the cooling rate for the case where Aluminium plate was used, is higher than that of without the Aluminium plate. This can be assumed as a result of the area of exposing to air is increased which helps to release the heat rapidly. As another method of decreasing the time duration for heating, it is proposed that the power applied to the lower electrode is increased, as a
By analyzing the reflection dependence on time, it was observed that the time durations for changing the display from black to white and vice versa, was approximately 2.5 seconds (see Fig. 3). A significant time difference between the changes of black and white images, is not observed. This is assumed to be, the gravitational forces and frictional forces are negligible, comparative to the electric force.

The well-known basic theory of attracting particles bearing opposite charges, could be confirmed by this experiment. The negatively charged TiO₂ particles move to the upper electrode when the voltage is applied such as the upper electrode takes the positive polarity. Therefore, when the TiO₂ particles attached to upper electrode, the display becomes white in color and on the other hand, when they are attached to the lower electrode, the display shows the black color. The photographs of black and white solid images are shown in Fig. 4.

The controlling method of matrix of pixels is briefly discussed. A model of square type 3x3 display cell is shown in Fig. 5. For an instance, when the line 1 electrode is heated and the wax is melted, if the positive, negative and positive voltages are applied to the row A, B and C electrodes respectively, the pixel B1 only becomes black as shown in Fig. 5. Before applying voltage for line 2, 3 pixels, the wax is solid and black solid images are displayed. Therefore, it is considered that, every pixel is addressable by this simple matrix circuit.

4. Conclusions

An electrophoretic display without external heating mechanism is proposed. In this proposed method, heating mechanism is used to melt the wax through joule heating by current flow at the lower electrode. Thermal characteristics of this proposed display is discussed. When a higher DC voltage is applied in between the electrodes, the joule heating speed is increased. And also when the cooling mechanism is improved, it affects the efficiency of the display cell. At this stage, response time of temperature control is too long. The improvement of minimizing the response time is important in the next step. For that, further studies on thermal head and thinning conditions of wax are to be carried out.
References


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