5.3: Novel Design for Color Electrochromic Display

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Abstract
We have developed a technology for a new full-color reflective electrochromic display (ECD) based on the subtractive color mixing model. This improves display brightness and color reproducibility. Additional advantage is simple production process. An active matrix driving of the full-color reflective ECD has been demonstrated successfully.

1. Introduction
Electronic papers are increasing in commercial mainly using black and white reflective display. But bright full-color reflective displays are now still under development. Without its own light source it is difficult to achieve bright color. This is because light use efficiency is too low when using Red/Green/Blue color filter such as conventional liquid crystal displays (LCD). Therefore, several full-color display technologies without using color filter have been developed.

The first is cholesteric liquid crystals (ChLCs) technology [1]. This device is based on stacked three kinds of ChLCs display units* (*display unit = display layer sandwiched by a pair of substrate with transparent electrode). The three kinds of ChLCs show each red, green, blue color by selective reflections. But the light use efficiency of this device is poor because it consists of six (or four) substrates and six electrodes. And colors are created by light interference control of ChLCD, so it have theoretical limit (50%) of reflectivity and viewing angle issue. Additionally the device cost is high by composition of stacked three display units. The second is In-plane electrophoretic technology [2]. This device can show colors by moving the several color particles. But in order to make full-color pictures it needs at least two display units. As a result of it is costly. The third is electrochromic technology. Electrochromic compounds turn into a coloration state from transparence reversibly by applied the voltage. Full-color performance was expected by stacked three display units* using cyan, magenta and yellow colors [3].

We have been developed a new full-color reflective display (multi layered electrochromic display = mECD) consisting of one display unit [4]. In this paper we will present a possibility of brightly full-color reflective display based on the mECD technologies and demonstrate an active matrix (AM) driving of the mECD.

2. Electrochromic compounds
Electrochromic materials that change in color on application of a potential. (Fig. 1) Color changing can be operated efficiently by injecting charge current with using those electrochromic compounds adsorbed in nano-TiO2 film formed on a transparent electrode [5]. New electrochromic compounds which color can be reversibly changed from transparent to each cyan, magenta and yellow, are successfully synthesized. The electrochromic compounds were adsorbed on the surface of nanostructured titanium oxide on transparent electrodes, and they were colored

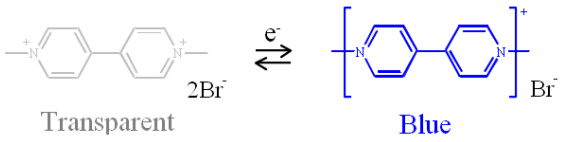

Figure 1. Examples of electrochromic compound.

by applying voltage. All of new electrochromic compounds were colored less than -2 volts (vs Ag/Ag+) voltage. The absorption spectra corresponding to the colored state of three electrochromic compounds are shown in Fig.2.

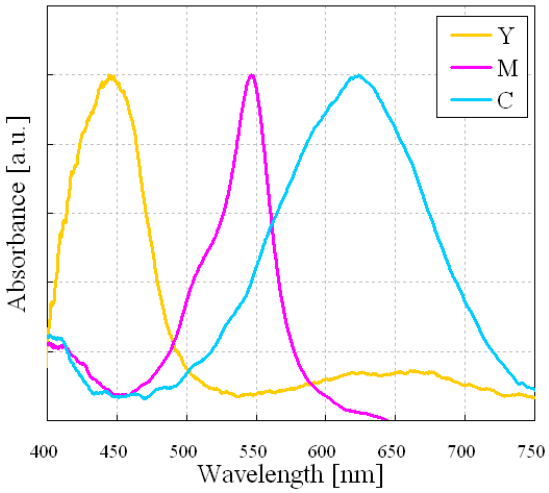

Figure 2. Absorption spectra of the new organic electrochromic compounds (cyan, magenta, yellow).

3. Device structure
The multi layered electrochromic display (mECD) is a display technology which is designed to mimic the appearance of ordinary ink on paper. In most color printing, the primary ink colors used are cyan, magenta, and yellow. Combinations of different amounts of the three inks can produce a wide range of colors. The structure of mECD is shown below (Fig. 3). The frontplane includes three transparent electrodes having an electrochromic layer thereon each and insulating layers are also formed between each electrode. The electrochromic layers are based on three kinds of organic electrochromic compounds; cyan, magenta or yellow dye. Furthermore a white reflecting layer is formed on the frontplane. The frontplane is assembled to the backplane having counter electrode(s) together with electrolyte. The electrolyte is

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infiltrated into between the frontplane and the backplane. In order to reduce process complexity, pattering in small pixels is formed only on the backplane. The mECD is developed to be simple, easy to manufacture. Consists of one display unit, therefore result in sufficient brightness for the display.

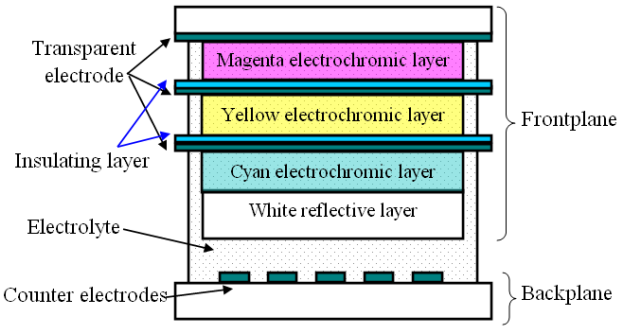


Figure 3. Schematic image of the multi layered electrochromic display (mECD).

4. Driving scheme

Example of the mECD driving scheme is shown in Figure.4.

1st step; White Image

Each electrochromic layer is turned to colorless clear by applying charge current.

2nd step; Magenta Image

Anode line is connected to the transparent electrode of magenta electrochromic layer. And cathode line is connected to pixels of counter electrode according to the picture. Then apply charge current that required for each pixel. At this time, other transparent electrodes are opened.

3rd step; Yellow Image

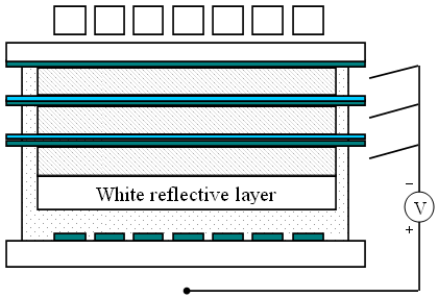
Anode line is connected to the transparent electrode of yellow electrochromic layer. And cathode line is connected to pixels of counter electrode according to the picture. Then apply charge current that required for each pixel. At this time, other transparent electrodes are opened.

4th step; Cyan Image

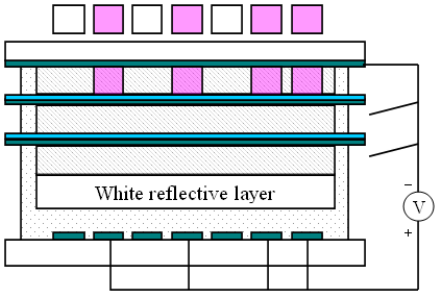
Anode line is connected to the transparent electrode of cyan electrochromic layer. And cathode line is connected to pixels of counter electrode according to the picture. Then apply charge current that required for each pixel. At this time, other transparent electrodes are opened.

Following those steps, the mECD operates any desired image. A color image can remain on-screen after the power is turned off. Finally full-color image is shown.

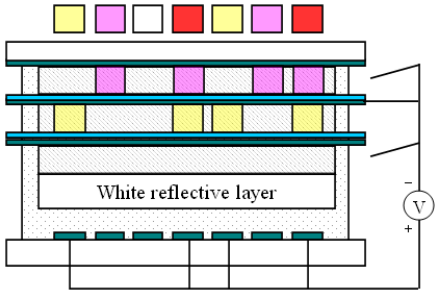
1st step; White Image



2nd step; Magenta Image



3rd step; Yellow Image



4th step; Cyan Image

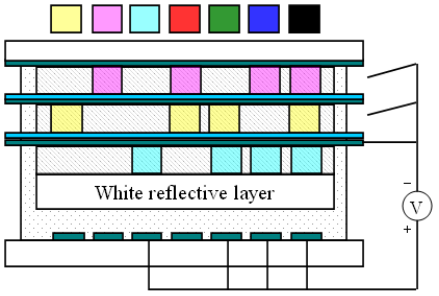


Figure 4. Driving scheme of the mECD

Note that this is a simplified example for explanation.