

# New Electrochromic Materials and Prevention of Cross-talk in Passive Matrix Electrochromic Display

Chang Ho Noh \*, Jae Eun Jang, Jae Eun Jung, Ji Min Lee, Seog Jin Jeon, Rupasree Ragini Das, Jai Yong Han, and Jong Min Kim

Display Lab., Samsung Advanced Institute of Technology, Yongin 449-712, KOREA

TEL: 82-31-280-6768 , E-mail: chnoh@samsung.com

Seung Uk Son, So Youn Park, WALID S. A. MOUSTAFA

Department of Chemistry, Sungkyunkwan Univeristy, Suwon 440-746, Korea

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## Abstract

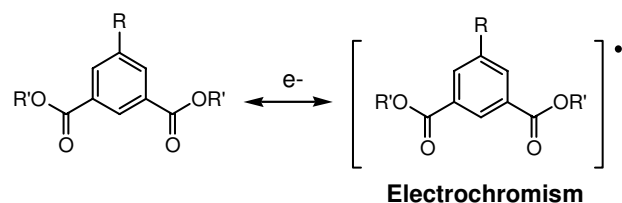
Here we describe the new structured electrochromic(EC) materials to improve the three primary colors (RGB). We also report the simply isolated electrochromic unit cell using gel type electrolyte and show cross-talk' free driving of EC display device.

## 1. Introduction

Electronic paper (E-paper) is an area of great interest for electronics since it has good ambient contrast, low-power operation and bistability, which means no electrical refresh is required once a display screen is drawn[1,2]. Among the technical candidates of E-paper, electrochromic material has various advantages such as low driving voltage, high reflective state [3, 4]. However, they showed relatively restricted properties in the electrochemically induced color and bistability. Electrochemical materials showing color changes from clear to the three primary colors (RGB) and bistability have been required to realize the full-color electronic paper. Here, new structured electrochromic materials have been prepared and studied to improve the three primary colors (RGB) and bistability. The diverse 5-substituted isophthalate compounds has been prepared and investigated to show their electrochromic behavior. Further, prototype electrochromic display (ECD) was also prepared for the electronic paper application. However, the device structure and the driving mechanism make current flow easily between unit cells through electrolyte, inducing 'cross-talk' state for device. The isolation of electrolyte within unit cell could be a solution for the 'cross-talk' problem. Here, we also report the simply isolated EC unit cell using gel type electrolyte and show 'cross-talk' free driving EC display device with ITO glass substrates.

## 2. Experimental

As far as we are aware, there is no report on the electrochromism of 1,3-isophthalates, which attracted our attention because functional groups can be easily introduced at the 5 position of them(Scheme 1).



Scheme 1. Electrochromism of 5-substituted isophthalate derivatives.

Diverse 5-substituted isophthalate derivatives used in this study were prepared via esterification of 5-substituted isophthalic acids or Suzuki coupling between 5-iodo isophthalate and diverse boronic acids. All compounds were fully characterized by <sup>1</sup>H and <sup>13</sup>C NMR and high resolution mass spectroscopy. The UV-visible spectra were recorded using Jasco V630 and Ocean Optics USB4000 spectrometer for the measurement of the displayed colors of isophthalate derivatives via supply of DC voltage.

The electrochromic cells were prepared using two ITO-coated glass electrodes which was sandwiched by Surlyn tape. The gel type electrolyte was formed using printing method to build the device between ITO electrodes within the unit cell area.

## 3. Results and discussion

Usually, the organic electrochromic materials show the color change via gaining or loosing the electron. In

many cases, the colored species correspond to anionic radical and cationic radical species. Generally, the radical species are relatively very reactive and unstable. To be long-lived devices, stabilization of the colored species is very important. Recently, we have found that 5-substituted isophthalate derivatives have electrochromism via one electron reduction. It was believed that the color species correspond to the anionic radical. The resultant colors were dependent on the functional group(R) on 5-position as shown in figure 1.

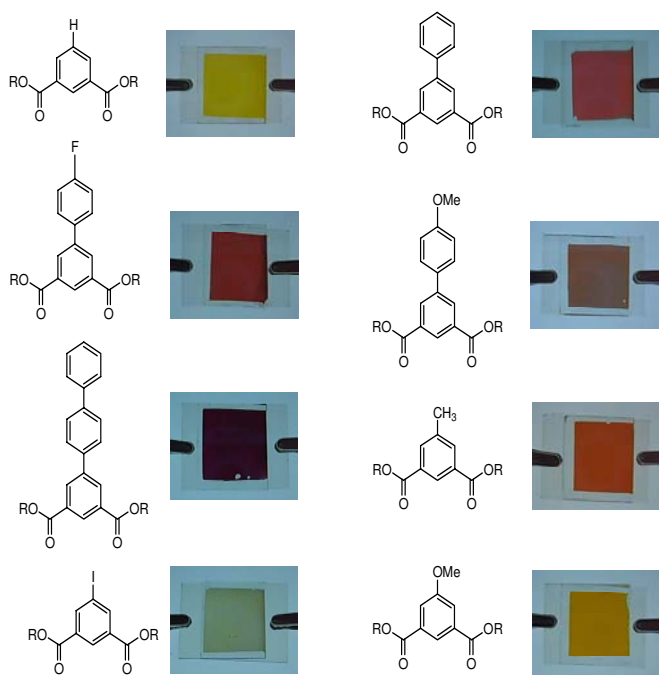


Figure 1. Electrochromism of 5-substituted isophthalate derivatives

As expected, isophthalate derivatives displayed diverse colors. It is evident that a functional group in the 5-position has a significant influence on the electronic surroundings of the reduced species. When the 5-functional groups were H, Me and OMe, the colored species showed maximum absorption peak at 450, 449 and 445 nm, respectively. When the 5-functional groups were monoarenes (phenyl and fluorophenyl), the maximum absorption peaks were red-shifted to 510 nm, 512 nm. The colored species by biphenyl showed the maximum absorption peak at 568 nm. Considering the length of conjugated system, the trend of the resultant color could be rationalized; as the conjugated system is longer, the maximum absorption peak is more red-shifted as shown in figure

2. Based on this speculation, we believe that the color can be controlled by properly choosing a functional group at 5-position.

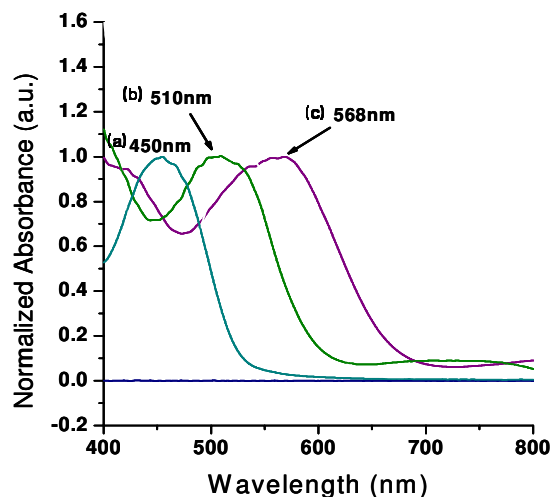
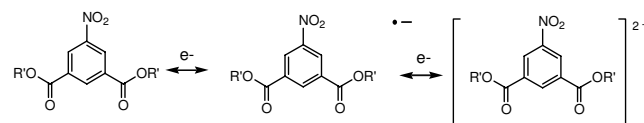


Figure 2. Color transition depending on the functional group(R) on 5-position ; (a) H, (b) phenyl, (c) biphenyl.

Next, we introduced a nitro group at the 5- position. Anionic radicals of aromatic nitro compounds have been a very important electrochemical research subject, in part because of their role in the unique functions of organic aromatic nitro compounds. Until now, it has been known that two reduced species can be generated step by step with two electrons as shown in scheme 2. The first reduced species is an anionic radical that can undergo further reduction to form the dianion.



Scheme 2. The reduction process of 5-nitro isophthalate.

In the case of 5-nitro isophthalate, vivid blue, then red appeared at 4.17 and 5.19 V, respectively (figure 3). The reason why two distinct colors were generated is unknown at this stage and further work on the computational approach is needed. However, we believe that this discovery opens the door not only to diverse spectroelectrochemical approaches for the study of nitro radicals and dianions academically, but also to the development of multi-color display devices.

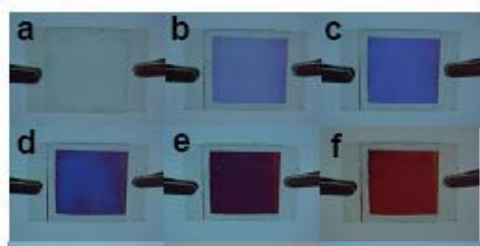


Figure 3. Multicolor display of 5-nitro isophthalate derivative with a supply of DC voltage; before voltage application (a), colors of first reduced species (b-c), second reduced species (d-f).

For practical use, all-solid-state devices are preferable to the solution-based ones due to the technical problem such as leakage of electrolyte solution. Thus, we fabricated the quasi-solid devices using polymer gel electrolyte. Figure 4 shows the schematic diagram of cells structure and the photograph of test sample without electrolyte isolation.

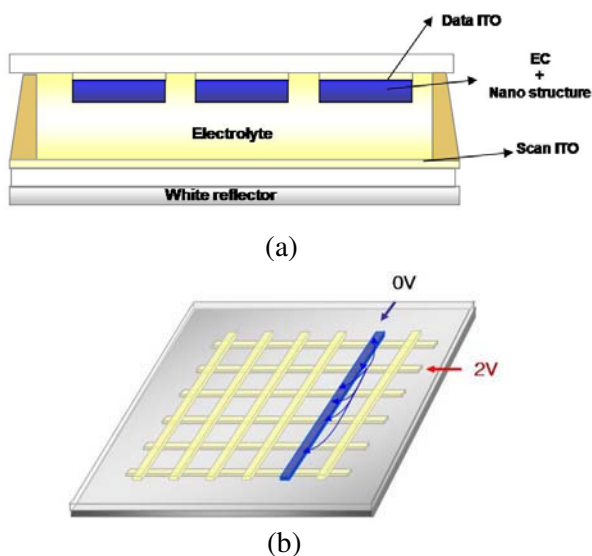


Figure 4. Schematic diagram and 'cross-talk' problem of test sample: (a) Cross-section view of EC device (b) 'cross-talk' makes line type 'On' state by current flows through electrolyte.

Although data line and scan line are selected for 'point-on' state, the current can flow from selected scan line ( $\sim 2V$ ) to all data line (ground state) through electrolyte. Therefore, all unit cells on the data line have electrochromic reaction and the states make 'line

type' color change, not 'point' driving. The isolation of electrolyte within unit cell could be a solution for the 'cross-talk' problem. In order to eliminate the 'cross-talk', gel type electrolyte is applied using printing method to build the device. The gel type electrolyte structure is just formed between ITO electrodes within the unit cell area. The backside glass with white reflector is assembled with precise alignment. Finally, the device is sealed using polymer resin (figure 5).

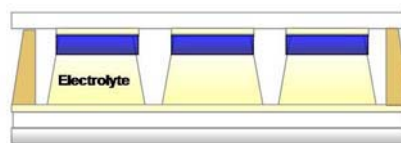


Figure 5. 'Cross-talk' free sample structure.

The isolation of electrolyte structure within each unit cells allows the current to flow directly to the selected cells only. A little current can flow to other cells by complicated paths formed by data electrodes, scan electrodes, and electrolytes. However, the current level is too low, compared to the main current flow on the selected unit cell, so that the current does not make enough electrochromic reaction to be visible. Figure 6 shows a driving image of EC test device by passive matrix mode. The electrolyte isolation and electrical floating states of non selected scan and data lines show a good image without 'cross-talk' state.



Figure 6. Electrochromic test device.

#### 4. Summary

Here, new structured electrochromic materials of 5-

substituted isophthalate derivatives have been studied to improve the three primary colors (RGB). The colors from Red to Blue were controlled by the change of functional group on 5-position of isophthalate derivatives. Further, prototype electrochromic display (ECD) was also prepared for the electronic paper. Gel type electrolyte is printed and isolated, which solved cross-talk problem of PM driving EC system. The simple fabrication process, easy driving method and good visual properties of the device prove that EC display is one of attractive candidates for reflective mode display system.

### **Acknowledgements**

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### **5. References**

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