Fabrication of a Flexible Cholesteric Liquid Crystal Display based on Pixel Isolation Method

Ki Sun Kwon** and Daeseung Kang*

Abstract

A flexible reflective cholesteric liquid crystal display (ChLCD) is fabricated on plastic substrates by using the pixel isolation method. The polymer walls between pixels and the polymer layers in the pixels are formed by two-step UV irradiation. Electro-optical response of the ChLCD with polymer wall and layer is studied and compared with conventional bistable ChLCD cells.

Keywords : cholesteric, LCD, polymer wall, pixel isolation

1. Introduction

Polymers are widely used in cholesteric liquid crystal displays (ChLCD)s. They are generally used to stabilize the ChLC texture by forming anisotropic polymer networks or to imbed the ChLC molecules by polymer dispersion. Polymer stabilized cholesteric texture (PSCT), and polymer dispersed ChLC are typical examples, and their modes have been extensively studied by many researchers [1~6].

Recently, an application of mode using phase-separated polymer wall was introduced [7~9]. The polymer walls in LC cells are useful in flexible display devices due to their ruggedness against normal stress and self-sustaining structures. Several methods for the formation of polymer walls have been reported so far. Y. Kim et al [7] and E.Y. Park et al [8] introduced a method for forming polymer walls through the segregation of liquid crystal molecules into pixel by applying a patterned electric field during phase separation, followed by UV irradiation to form polymer walls in the interpixel regions of a cell. This method induces phase separation due to the difference of molecular arrangement, controlled by the field gradient and alignment layer. J. L. West et al used the fabricated internal polymer columnar structures in LC cells by thermally-induced phase separation of LC/polymer mixture [9]. Q. Wang et al used the method to fabricate flexible plastic LCDs [10]. Other methods employ photomask [11], [12] or flexographic printing [13] through which selective areas (interpixel) are irradiated with UV light to induce phase separation. In this spatial photo-polymerization method, the degree of polymer wall formation depends on the irradiation time and intensity of UV light.

V. Vorflusev et al reported a method for forming polymer layer on top of liquid crystal layer in the cell [14~15]. This method is called phase separated com- posite films (PSCOF) and causes upper polymer layer to form near the substrate faced to UV light source. Due to the UV intensity gradient in a cell, UV-induced phase separa-tion forces LC molecules to diffuse away from the source, eventually forming a horizontal polymer layer.

R. Penterman et al [16] reported the photo-enforced stratification LCD technology using a directionally controlled photo-polymerization-induced phase separation of liquid crystal and polymer-forming material. By using high intensity UV radiation of 400 nm wavelength and subsequent low intensity UV of 340 nm, polymer walls and vertical stratification were realized. J.-W. Jung et al [17] recently coined pixel isolated liquid crystal (PILC) mode that incorporates PSCOF with regularly patterned polymer walls. They fabricated plastic LCDs for mobile phone using PILC cells, where LC molecules are isolated in pixels. The device showed good alignment stability against external pressure and bending even at ferroelectric LC samples.

In this paper, we used upon the above directional

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phase separation scheme of PILC in order to fabricate a reflective ChLC display. A two-step photopolymerization was used. Polymer walls and horizontal polymer layers were formed by the two successive irradiation of UV light. The resulting horizontal polymer layers and vertical polymer walls were found to isolate ChLC molecules in pixels from their surroundings.

2. Experiments

The ChLC mixture, which is used herein, is a mixture of non-chiral nematic ZLI-6000-100 (Merck, n_o=1.5082, n_e=1.6589) and chiral additive S-811 (Merck Co.). The mixture of nematic LC with chiral additive (27.5 wt%) appeared green in planar states, showing peak reflectance wavelength of approximately 544nm due to Bragg reflection. Two PES (polyether sulphone) substrates with a thickness of 200 µm and coated with ITO (Indium Tin Oxide) were prepared. One was treated with nylon 6/6 and the other one was used as received. The nylon 6/6 film was deposited by spincoating on clean PES substrates at 350 rpm for 8 seconds, and then, at 3700 rpm for 10 seconds. The coated films were then baked at 115 °C for 90 minutes. To achieve planar alignment, rubbing process was carried out. For the polymerization, a commercially available prepolymer NOA65 (Norland UV epoxy) was mixed with the ChLC mixture. This prepolymer exhibits a maximum optical absorption in the 350~380nm range. The concentration of polymer in the ChLC/polymer composite was 40% in weight. The silica sphere spacers were placed between two ITO PES substrates and nominal thickness of the cells was 3.5 µm. The cell was placed on a hot plate heated up to 100 °C, with the untreated substrate facing a UV light source.

After the cell was infiltrated with the ChLC/polymer mixture through capillary action, it was subjected to Xenon UV light (Oriel Instrument) irradiation with photomask to induce polymerization for polymer walls at 100 °C for 90 minutes (Fig. 1). The photomask film that was used had rectangular cells with the dimension 100 µm x 300 µm separated by 30 µm spacing at both directions (Fig. 1(a)). The cell was then cooled to room temperature at a rate of 2 °C/min. After confirming the formation of polymer walls, we irradiated the cell with weak UV light without photomask at elevated temperature for 30 minutes to induce

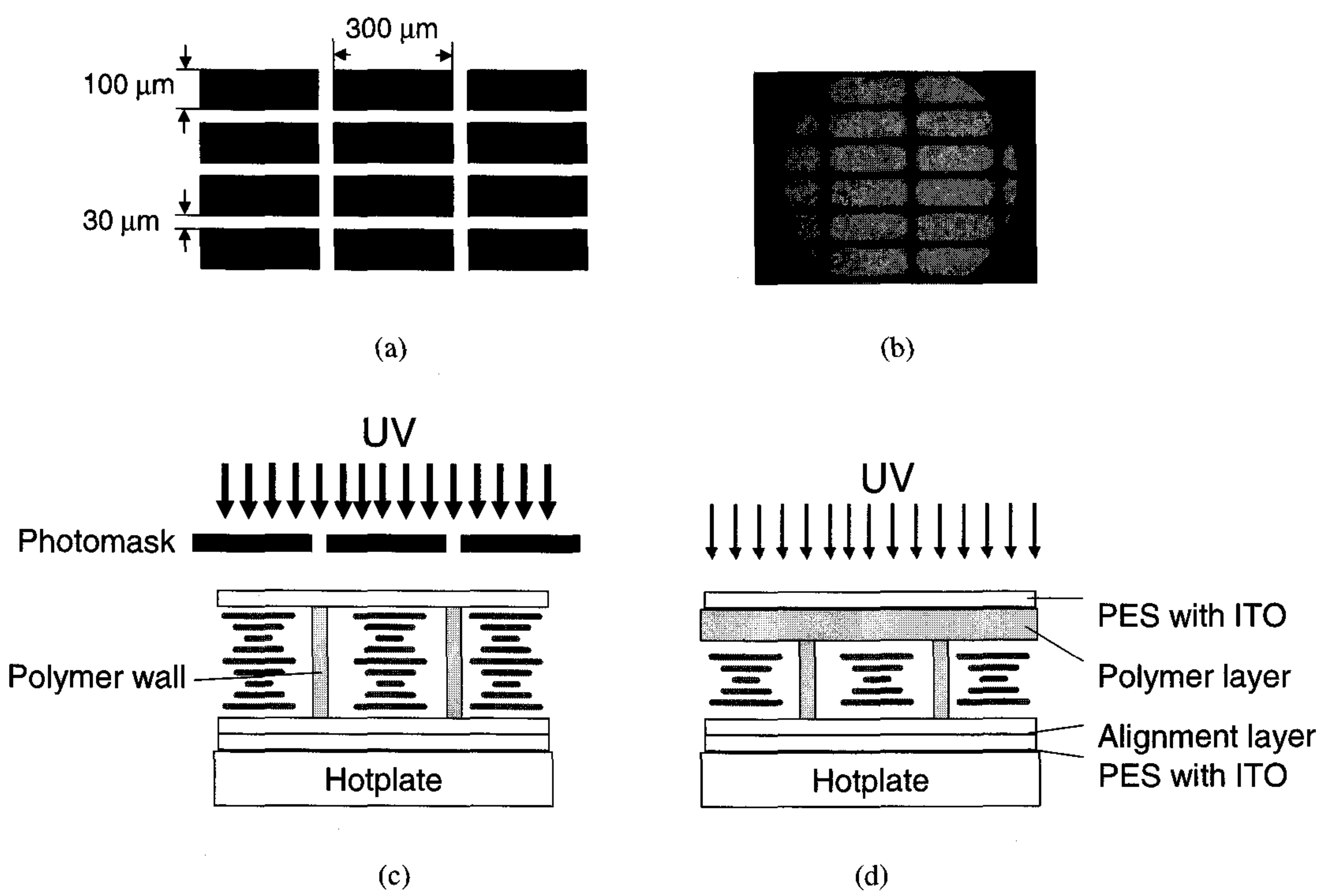

Fig. 1. Schematic representation of the two-step photopolymerization scheme.
(a) photomask, (b) a typical optical micrograph of ChLC cells with polymer wall,
(c) 1st UV irradiation with a photomask, and (d) 2nd UV irradiation without the photomask.

phase separation in vertical direction. Note that polymer layer is formed on untreated top substrate (Fig. 1(d)).

The cells manufactured through the above procedure were then disassembled carefully and examined by optical polarizing microscope to check polymer walls and polymer layer.

Ocean Optic S2000 spectrometer was used to characterize the reflective properties of the cells. For comparison, two kinds of cells were prepared: (cell1) a typical bistable cholesteric display (BCD) cell filled with ChLC without polymer and (cell2) pixel isolated ChLC (PIChLC) cell with ChLC/polymer mixture.

Electro-optical experiments were performed in the reflective mode with the back of cells covered with a black plate to enhance contrast between planar and focal conic states. For the light source, a green He-Ne laser (λ=543.5nm, Melles Griot) was used.

3. Results and discussion

Fig. 1 shows the schematic of the phase separation using a photomask. In order to form polymer walls followed by adjacent horizontal polymer layer, we performed the two-step photo-polymerization. In the first step, a strong UV light was irradiated on the cell through the photomask. This process resulted in the formation of walls. In the second step, weaker UV light was irradiated on the cell in order to form a horizontal polymer layer. In the second exposure, UV light was shined on the entire area of the cell after the photomask was removed. The resultant structure of PIChLC cells is illustrated in Fig. 1(d).

Fig. 2 shows the optical micrographs taken from a dissembled cell after the two-step polymerization. 30 μm thick polymer walls can be clearly seen in the interpixel regions (dark stripes). As shown in Figs. 2 (b)-(c), inter-pixel regions have the same optical characteristics between two polarizing films, exhibiting birefringence due to slight deformation when the cell was peeled off. Fig. 2(a) and (d) show the micrographs of top and bottom substrates. Fig. 2(d) shows only faint smudge of polymer wall on the bottom substrate. Fig. 2(a) and (d) show that horizontal polymer layer is formed on the top substrate which is closer to the UV source. From this, we can conclude that by performing two-step photopolymerization, ChLC/polymer mixture in a cell becomes PSCOF structure with pre-patterned polymer walls. We could also confirmed the horizontal polymer layers by measuring the electrical resistance of both substrates.

To investigate the optical properties of our ChLC display, we compared the reflection spectra of the conventional bistable cholesteric display (BCD) cell and pixel isolated ChLC (PIChLC) cell in planar state. As shown in Fig. 3, the reflection spectra of the planar texture

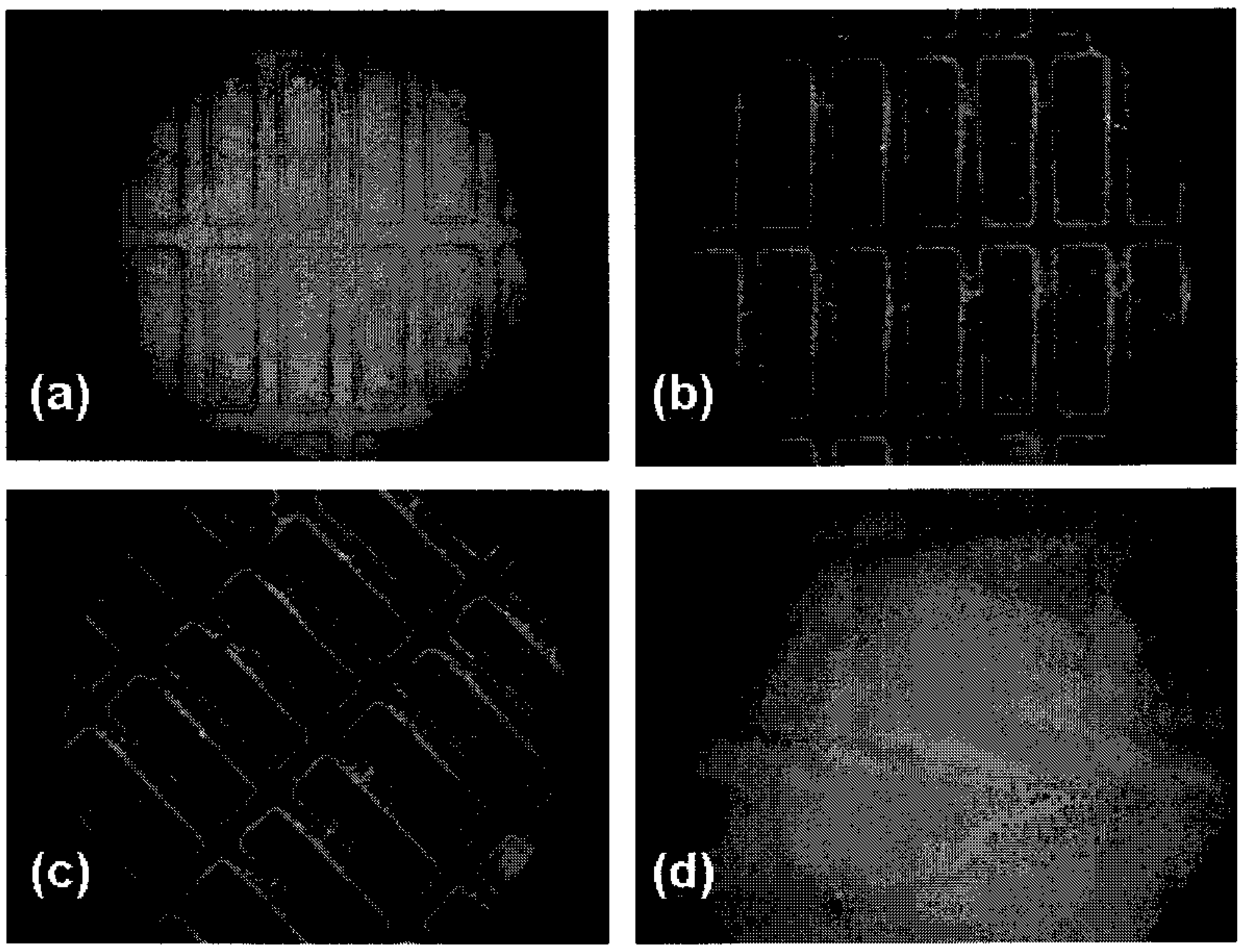

Fig. 2. Polarizing optical micrographs of top substrate peeled off from the PIChLC cell (a) in reflection mode, (b)-(c) in transmission mode. (d) Polarizing optical micrograph of bottom substrate in reflection mode.

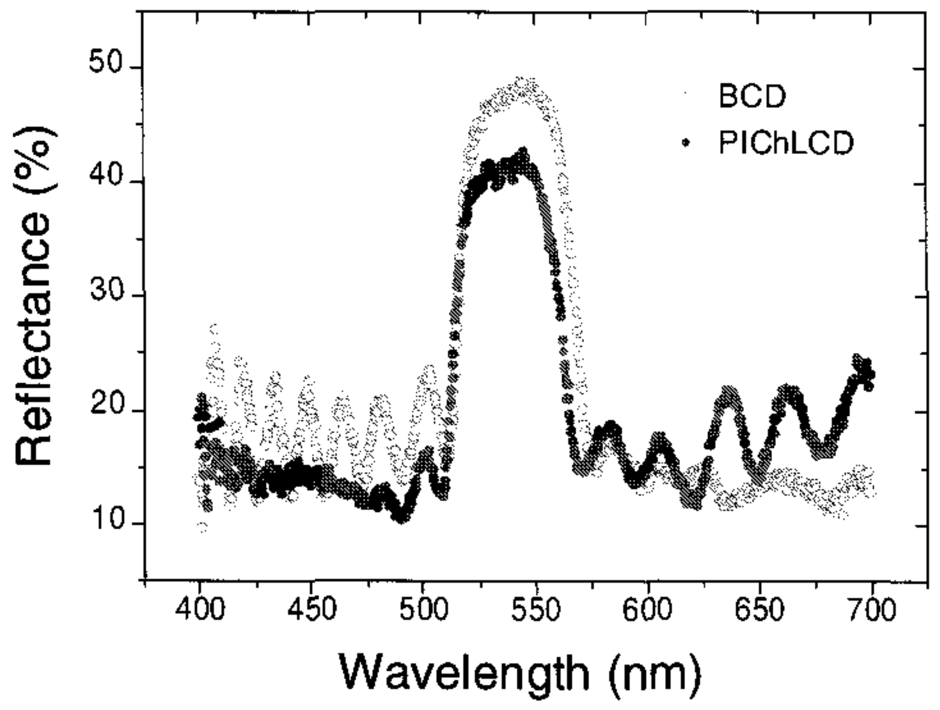

Fig. 3. Reflection spectra of BCD cell (open) and PIChLC cell (solid).

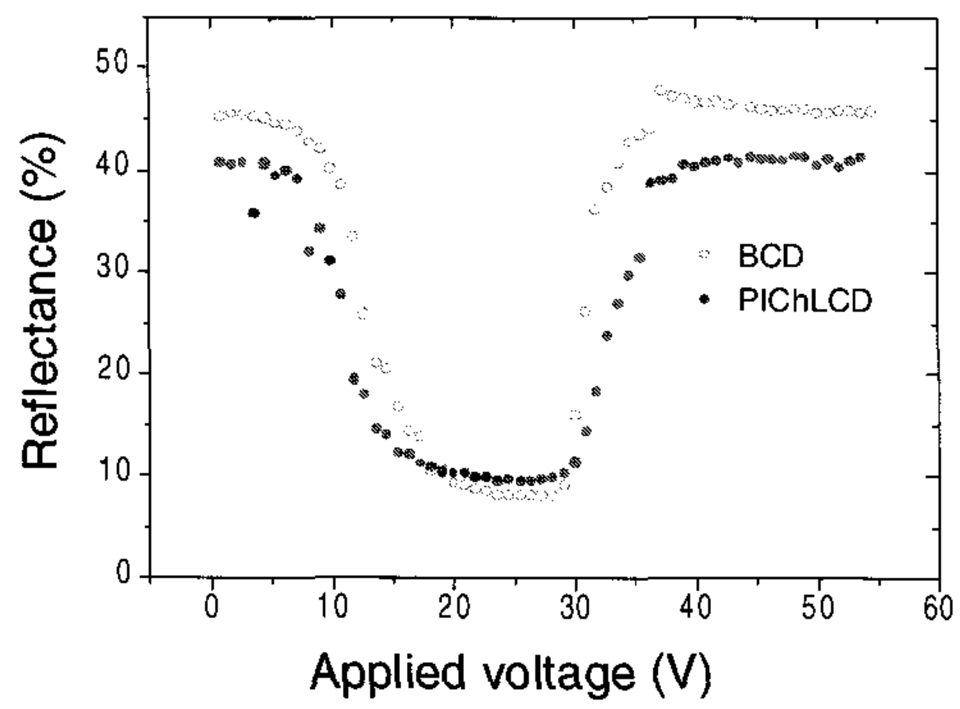

Fig. 4. Reflectance vs applied voltage in BCD cell (open, cell1) and PIChLC cell (solid, cell2). Prior to applying switching pulse, the cell is in planar state by high reset pulse.

is almost the same in both cells. The slight decrease of reflectance in the pixel isolated cells is due to the scattering of polymer walls and the remaining prepolymer after phase separation. To further examine the electro-optical properties of the PIChLC display, we performed reflectance measurement and measured the reflectance vs applied voltage. As shown in Fig. 4, the characteristic bistability between planar and focal-conic textures is maintained in the PIChLC cells. Threshold voltage to focal-conic state is lower in the PIChLC, but reset voltage (planar to homeotropic state) is slightly higher than BCD cells.

4. Conclusions

By performing the two-step photopolymeri zation, we successfully fabricated a flexible ChLC display with good bistablity and strong mechanical stability due to polymer wall and pixel isolation. We confirmed the existence of polymer walls in the interpixel regions and horizontal polymer layers inside the pixels through optical microscope. Lastly, it was confirmed that polymer walls and horizontal polymer layers formed by the two successive irradiation of UV light could isolate ChLC molecules in pixels from surroundings.

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