Optically compensated bend cell with pixel-isolating polymer wall for a flexible display application

Seong Ryong Lee, Joong Ha Lee, Hong Jeek Jang, Jin Seok Jo, Tae-Hoon Yoon and Jae Chang Kim
School of Electrical Engineering, Pusan National University, Busan 609-735, Korea
TEL:82-51-510-1700, e-mail: mengmol@pusan.ac.kr.

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Abstract

We fabricated an optically compensated bend cell with pixel-isolating polymer wall. The polymer wall was formed by phase separation of LCs and UV-curable polymer. The fabricated cell had initially π-twist state. It showed low driving voltage, wide viewing angle and fast response properties. Also, polymer wall provided the mechanical stability preventing distortion of a display image from pressure.

1. Introduction

Because of the fast switching and wide viewing angle properties, the optically compensated bend (OCB) mode[1-3] has attracted a fair amount of attention as one of the candidates for many portable display applications such as mobile phone, portable multimedia players and car-navigations. An OCB cell is composed of a pi cell and some retardation films. The pi cell has the fastest response speed among all nematic LC modes since the switching is not involved backflow[1-2]. However, the conventional pi cell has the splay state initially and should be bend-aligned for high speed operation[4-5].

Recently, some structures of pi cell were proposed, which employed polymer-induced structure to solve the uniform splay-to-bend transition problem[6]. The polymer network also provided the mechanical stability against the pressing and bending of the cell. However, demonstrated cells had poor transmittance and contrast due to the index mismatching between the LCs and polymers. Also, they showed relatively slower on-off response time than conventional pi cell because the LC relaxation was disturbed by polymer network[4].

Most recently, we demonstrated an initially π-twist nematic liquid crystal (NLC) cell with pixel-isolating polymer wall by incorporating UV-curable fluorinated polymer [7]. Due to the inherent immiscible property of the fluorinated polymer, excellent anisotropic phase separation between the LCs and polymer was achieved. And, each pixel could be a π-twist as the initial state by the anchoring of the polymer wall[7]. So, the fabricated cell does not need any kind of disclination nucleus which is necessary for the bend transition.

In this paper, we demonstrate a pixel-isolated OCB cell composed of the initially π-twist NLC cell and several retardation films which has been proposed for a wide viewing angle properties[8]. And, the electro-optical properties and enhancement of the mechanical stability were measured and compared to a conventional OCB cell.

2. Experimental

The fluorinated polymer wall was formed by a phase separation of a mixture of LCs and UV-curable pre-polymers with a 10:90 wt%. The LC and pre-polymers used in the experiment were MLC-6265-100 (Merck) and fluorinated acrylates, respectively. Firstly, an alignment layer of AL-90101 (JSR Corp.) was spin-coated on the ITO-glass substrates. And, the cell was assembled with parallel rubbing directions of the two substrates. The cell-gap was maintained as 5.6 ㎛ by using silica spacers. Then, the mixture of LC and pre-polymer was injected into the empty cell. To crosslink the pre-polymer and isolate a pixel, the cell was exposed to an UV light through a photo-mask. The photo-mask has dark square patterns of a 300×300 ㎛^{2} pixel size and transparent boundaries of 30 ㎛. The intensity of light source was 30 mW/cm^2 with a peak wavelength of 365 nm. During the UV light exposure, a vertical electric field (1.5 V/㎛, 1 Khz) was applied between the two ITO-substrates. After the UV light exposure and formation of the polymer wall, the bend state is relaxed into the π-twist state and stabilized as soon as the electric field is removed. Figure 1 shows the fabrication process of the initially π-twisted NLC cell with a fluorinated polymer wall.

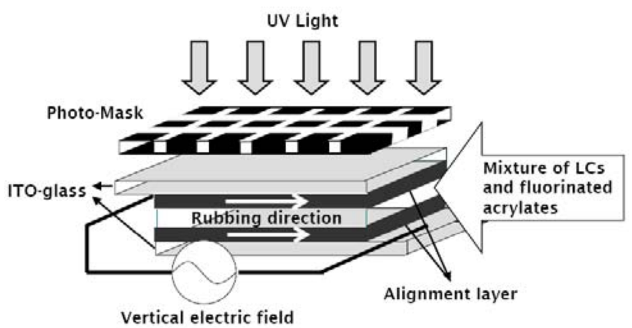

Fig. 1. Fabrication process of an initially π-twisted NLC cell.

3. Results and discussion

Figures 2(a) and 2(b) show transmission characteristics of a conventional and proposed pi cell with crossed polarizers, respectively. For the conventional pi cell, when the transmission axis of one polarizer was parallel to the rubbing direction of the cell in a splay state, it has no transmission of light through the crossed polarizers as shown in Fig. 2(a). On the contrary, in the pixel-isolated cell, light is transmitted under the same condition except in the regions of the polymer wall as shown in Fig. 2(b). From those observations, we can confirm that the initial state of the pixel-isolated cell is not a splay state but a π-twist state. Also, an excellent phase separation was achieved as shown in Fig. 2(c).

We fabricated the OCB cells using a conventional pi cell and an initially π-twisted NLC cell to compare the electro-optical properties. Two OCB cells have the same cell-gap, pretilt angle and film-compensating scheme. The structure of the OCB cell is shown in Fig. 3. It consists of two crossed polarizers, two quarter wave plates (QWPs), two biaxial films and a pi-cell. The rubbing direction of pi cell is parallel to the angle of 0°. The absorption axes of the polarizer and the analyzer are set at the angle of 90° and 0°, respectively. And, the optic axes (OAs) of the lower and upper QWPs are set at the angle of 45° and 135°, respectively. Biaxial film is used to suppress the light leakages of dark state at an oblique viewing angle [8]. The parameter, $R_o=(n_x-n_z)d$ and $N_z=(n_x-n_z)/(n_x-n_y)$, of the biaxial films was optimized as 50nm and 0.147, respectively.

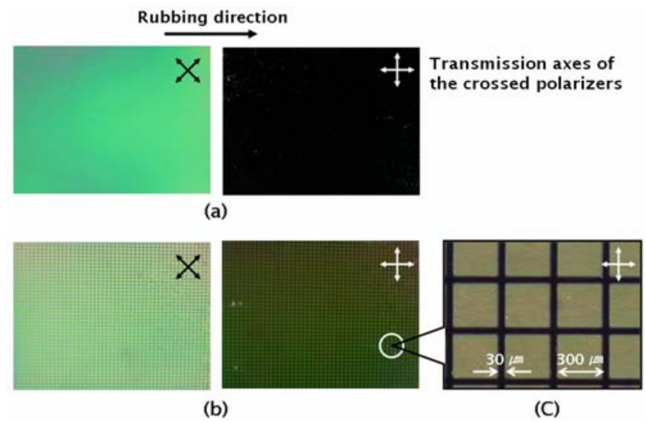

Fig. 2. Transmission characteristics of (a) a conventional pi cell, and (b) an initially π-twisted NLC cell, and (c) a polarizing electron microscopy images of initially π-twisted NLC cell.

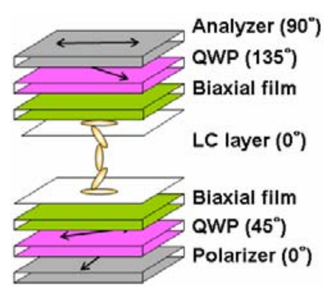

Fig. 3. Structure of a fabricated OCB cell.

We measured the optical characteristics dependent on the applied voltages of the fabricated cells in Fig. 4(a). The pixel-isolated OCB cell shows much lower dark voltage of 7 V than that of the conventional OCB cell. Also, the bias voltage of 2.4 V for sustaining the bend state in the pixel-isolated cell is lower than 3.2 V needed in conventional cells. Lower driving voltage of the pixel-isolated cell was caused by LC molecules near the polymer wall. Average pretilt angle of LC molecules at the edge of the pixel is supposed to be higher than main LC part by the anchoring of the polymer wall. Moreover, the interaction between LCs and fluorinated polymer was weak[7]. So, the retardation value of the edge is supposed to decrease faster than that of main LC part by the electric field.

Response time in the transition between dark and bright states was measured by applying 1-kHz square-wave pulse in Fig. 4(b). The pixel-isolated OCB cell showed 0.7 ms of turn-on time which was as fast as that of the conventional OCB cell. The turn-off time of the pixel-isolated cell was 2.1 ms, which was slightly slower than that of the conventional cell, 1.8 ms. The slower turn-off time is supposed to be caused by the weak anchoring of the polymer wall. However, total response time is sufficiently fast in comparison with those of other nematic LC modes such as twisted nematic (TN), in-plane switching (IPS) and vertical aligned (VA) modes.

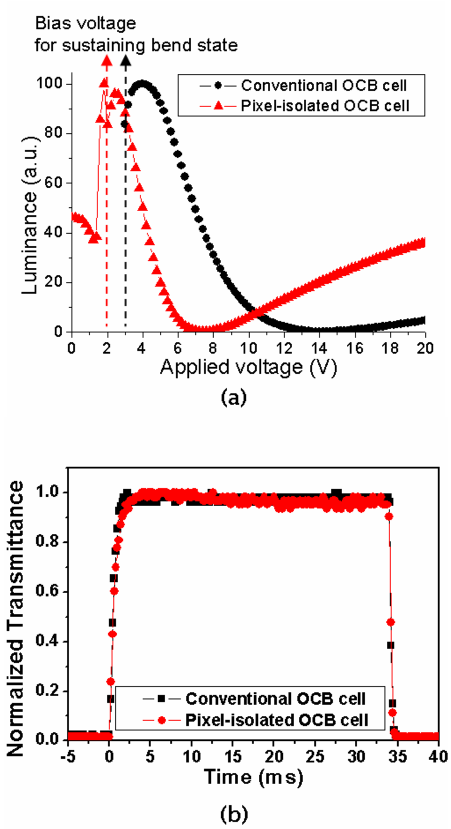

Fig. 4. The electro-optic characteristics of the conventional and pixel-isolated OCB cells: (a) voltage-transmittance curves, and (b) response properties.

Figures 5(a) and 5(b) show the viewing angle characteristics of the conventional and pixel-isolated OCB cell, respectively. The pixel-isolated cell has the viewing angle characteristics more than 140° (CR>10) in both the horizontal and vertical directions, which is almost same as those of the conventional one.

Finally, we tested the enhancement of the mechanical stability of the pixel-isolated cell in comparison with the conventional one. Figures 6(a) and 6(b) show the images of the OCB cells with and without an external point pressure. The pixel-isolated cell shows much lower image distortion than conventional one.

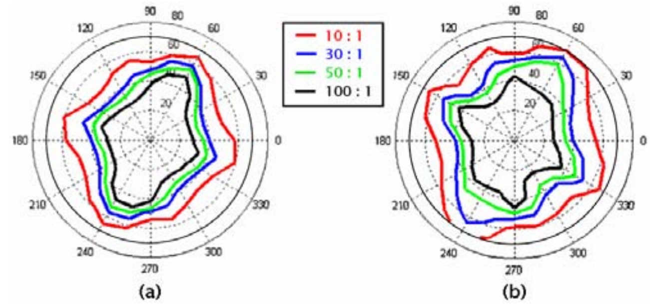

Fig. 5. Viewing angle properties of (a) a conventional OCB cell, and (b) a pixel-isolated OCB cell.

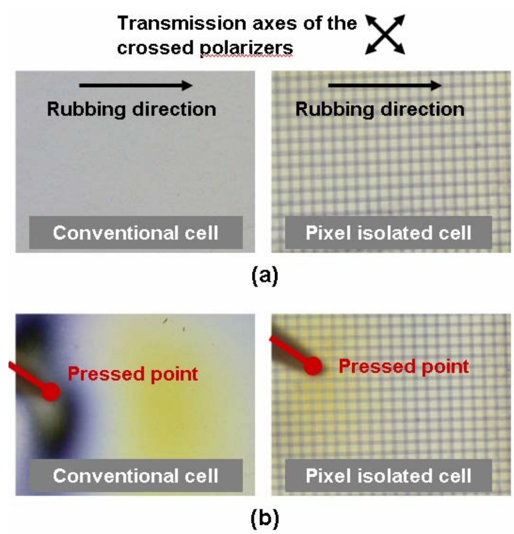

Fig. 6. Image distortion of the fabricated cell by pressure: (a) with and (b) without an external point pressure.

4. Summary

We proposed a pixel-isolated OCB cell which needs no nucleus for the transition from splay to bend state. The pixel-isolated cell shows low driving voltage, wide viewing angle and fast switching properties. Also, it showed enhanced pressure resistance preventing distortion of a display image in comparison with a conventional cell.

5. Acknowledgement

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