Switching characteristics of a pixel-isolated bistable twist-splay nematic liquid crystal cell

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Abstract

We demonstrate a pixel-isolated bistable twist-splay namatic (PI-BTSN) liquid crystal (LC) cell which has two stable states of splay and π-twist. Each state is stabilized by a multi-dimensional anchoring effect of pixel-isolating polymer walls without any chiral additives. Polymer walls are formed around the pixel region by anisotropic phase separation between LCs and reactive mesogens. Switching between the two states is archived by using vertical and horizontal electric fields. The memory mode of the fabricated LC cell has shown infinity memory time.

1. Introduction

Bistable characteristics of a liquid crystal (LC) cell have received much attention due to their memory characteristics that enable low power consumption, which can be used in the optical switching or display technologies [1]. Recently, many bistable nematic LC modes such as Berremann's bistable twisted nematic (BTN) [2], bistable chiral splay nematic (BCSN) [3], *BiNem* [4], and zenithal bistable device (ZBD) [5] have been proposed. Each mode has its own switching and memory characteristics, which are related to the applied electric field, alignment surface, topological relation, and elastic free energy density of the two LC textures. Berremann's BTN LC mode has topologically equivalent two stable states of 0- and 2π-twist. It uses an adequate ratio of chiral additive in order to equalize elastic free energies of the two states. However, the retention times of the two states are short because a more stable intermediate π-twist state exists. Its switching is conducted by the waveform and amplitude of a vertical electric field. BCSN mode and *BiNem* have topologically inequivalent two stable states of splay and π-twist. They show excellent memory characteristics by using an adequate ratio of chiral additive for equalizing elastic free energies of the two states. BCSN mode uses transition nucleus formed by a horizontal electric field for switching, while *BiNem* uses polar anchoring breaking at an alignment surface by the waveform of a vertical electric field. ZBD uses two stable LC textures generated by changing the average pretilt angle of LCs at the micro-patterned surface with short pitch and deep profile. Its switching is generated by the polarity of an electric field.

In this work, we demonstrate a pixel-isolated bistable twist-splay nematic (PI-BTSN) LC cell that has two stable states of π-twist and splay. The two states are stabilized by not chiral additive but multi-dimensional alignment effect of pixel-isolating polymer walls. Switching between the two stable states is conducted by horizontal and vertical electric fields in three-terminal electrode structure.

2. Experimental

The proposed cell has pixel-isolating polymer walls formed by an anisotropic phase separation between LCs and UV-curable polymers. Figure 1 shows the fabrication process of the proposed bistable LC cell. The LC and the UV-curable polymer used in the experiment are ML-0223 (positive dielectric anisotropy, birefringence $\Delta n=0.0809$, Merck) and reactive mesogen (RM). Pixel-isolating polymer walls were formed by anisotropic phase separation of a mixture of LCs and RM. The cell was exposed to a Xe-UV light (Oriel) with a peak wavelength of 365 nm at the maximum intensity of about 5 mW/cm^2 for 60 min through a photomask. The photomask has dark square patterns with the pixel size of a 300 × 300 μm^2 and transparent boundaries of 30 μm in width for the irradiation of the UV light to the cell. During the UV light exposure, a vertical field was applied to the cell. The field plays an important role to control the tilt angle of LC molecules near the wall.

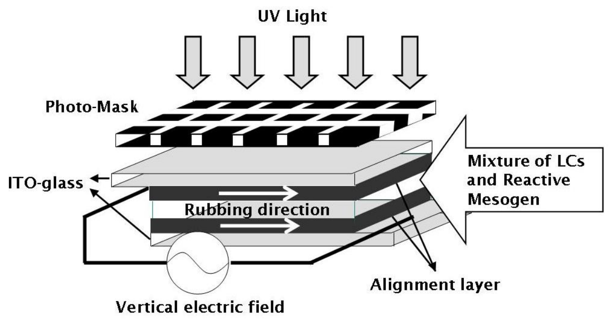

Fig. 1. Fabrication process of a PI-BTSN LC cell.

3. Results and discussion

We measured the electro-optical characteristics of a PI-BTSN LC cell. To compare with the proposed cell, a BCSN LC cell was fabricated without polymer wall. The BCSN LC cell has the same alignment layer, rubbing condition, cell-gap, and LC material except that the two stable states are stabilized by chiral additive. Figure 2 show the polarizing microscope images of a BCSN LC cell and a PI-BTSN LC cell, respectively. For the BCSN cell, when the transmission axis of one polarizer was parallel to the rubbing direction of the cell, it had no transmission of light through the crossed polarizers. It indicates that the splay state was stabilized. On the contrary, the light was transmitted through the PI-BTSN LC cell under the same condition except in the regions of the polymer wall. We can confirm that the π-twist state was stabilized in the PI-BTSN LC cell.

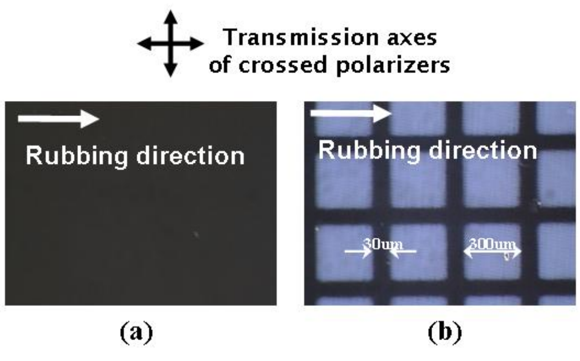

Fig. 2. Polarizing microscope image of (a) BCSN and (b) PI-BTSN LC cells.

Figure 3 shows texture transition of a PI-BTSN LC cell depending on the applied voltage. When a vertical electric field was applied to the LC cell, the π-twist state is switched to the bend state. After the field is removed, the bend state is relaxed back to the π-twist state. If a horizontal electric field is applied to the LC cell, the π-twist state will be switched to the splay state. The splay state can return to the π-twist state via the bend state by using a vertical electric field.

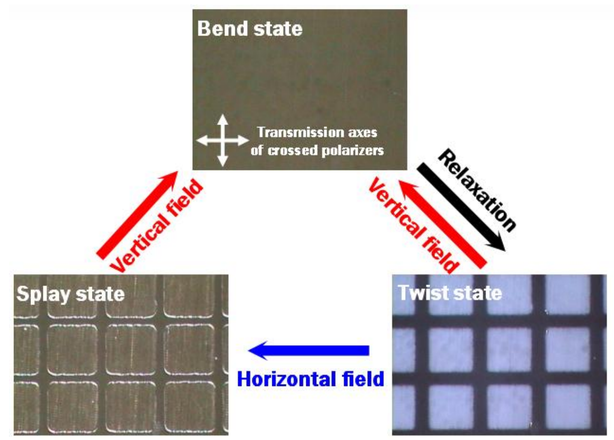

Fig. 3. Switching mechanism of a PI-BTSN LC cell.

Figure 4 shows switching characteristics from the π-twist to the splay states. A PI-BTSN LC cell shows transition time of 400 ms, which is much faster than 4000 ms of a BCSN cell. It is supposed that vertically aligned RM molecules within polymer walls play the role of the transition nucleus for uniform and fast switching between π-twist and splay states.

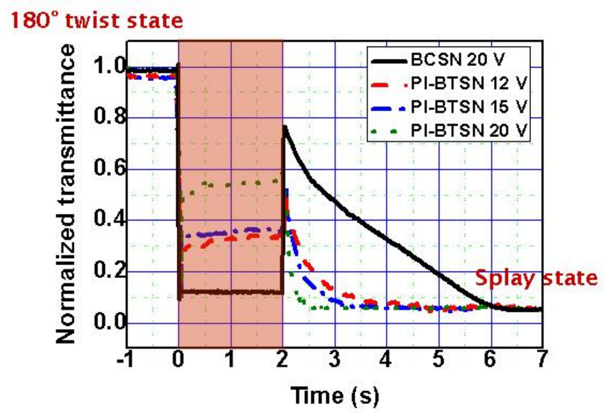

Fig. 4. Switching time characteristics of a BCSN and a PI-BTSN LC cell.

4. Summary

We demonstrated a bistable LC cell whose two stable states are sustained by pixel-isolating polymer walls without any chiral dopant. The proposed cell has the lower driving voltage for switching and the fast transition time compare to a BCSN cell. Moreover, it is expected that the polymer wall can provide mechanical stability and prevent distortion of display images from the external pressure.

5. Acknowledgement

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6. References

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