P-133: Enhancement of Memory Characteristics in Bistable Chiral Splay Nematic Display Mode

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Abstract
We report an enhancement of memory characteristics in a bistable chiral splay nematic (BCSN) display mode with reactive mesogens (RMs). The polymerized RMs give rise to hindrance to relaxation in a memory mode and thus a memory retention time is significantly improved in the BCSN mode.

1. Introduction
In the present age of the rapid spread of the digital information, the significance of the individual mobile display has being emphasized. Among the various display technologies for mobile applications such as subcompact laptop, multifunctional smart phone, and multimedia player with other functionality, a concept of the dual mode liquid crystal displays (LCDs) mentioned to bistable chiral splay nematic liquid crystal (BCSN) mode comes into the spotlight due to their viable functionality [1-4]. The BCSN mode is switchable between dynamic and memory modes. The dynamic mode is performed by the optically compensated bend switching with fast response and the memory mode is obtained by the bistability of the bounded LC cell with a chiral dopant [5-7]. In this dual LC mode, the memory mode has been focused due to the power consumption issue.

In the memory mode of the BCSN configuration, where splay and π-twisted configurations exhibit dark and bright states, respectively, the memory retention time is limited by the stability of π-twisted LCs arrangement [8]. The multidimensional alignment method was attempted to increase the π-twisted alignment state corresponding to the memory retention time of BCSN-LC mode [9,10]. However, This approach was rather limited because the fabrication process was incorrigible in comparison with that for conventional LC cell. Actually, it is hard to achieve the permanent memory retention time in BCSN mode for the low power consumption.

In this work, we propose BCSN mode with an improved retention time in memory mode by polymerizing reactive mesogen (RM) in the π-twist state. After generating the π-twisted state in the BCSN mixed with RMs by an electric field treatment, the BCSN cell was exposed to the UV light in the condition of the optimized wavelength and intensity. In the condition of π-twisted LC configuration, the RM monomers were polymerized and grew following the ordered direction of LC molecules from the substrate adjacent to the UV light source. This polymer network structure formed according to the π twisted arrangement acted as an obstructor that disrupts the return to the initial splay state. Eventually, we could obtain BCSN device with the improved memory retention time.

2. Experiment
Figure 1 is the schematic diagram of the proposed BCSN cell structure in cross section by using the RM network structure. Polyimide (PI) alignment layer (AL22620, JSR Inc.) for LC alignment parallel to the substrates was spin-coated on substrates evaporated indium tin oxide (ITO) and soft-baked to evaporate solvent under 100 °C for 10 min followed by hard-baked to polymerize under 210 °C for 1h. We rubbed the alignment layer for a unidirectional alignment of the LC molecules. For an initial splay state, two rubbed substrates were assembled parallelly with the cell gap uniformity using by 5 μm ball spacers. Nematic LCs (ZKC-5085XX, Chisso) and chiral dopant (R-811, E. Merck) with the right-handed helical molecular sense were mixed to get tendency of twist formation on LC molecules. The proportion of cell gap to pitch (*d/p*) is 0.15 which is more stable in splay state than in energy boundary condition in which *d/p* is 0.25 between splay and π-twisted state. Photo-initiator (1.4 wt.%, Irgacure651, Ciba Specialty Chemicals) and RM (6.4 wt.%, E. Merck) were added in LC mixture. The BCSN mixture was stirred in an isotropic phase for 24 h to make the composite uniformly

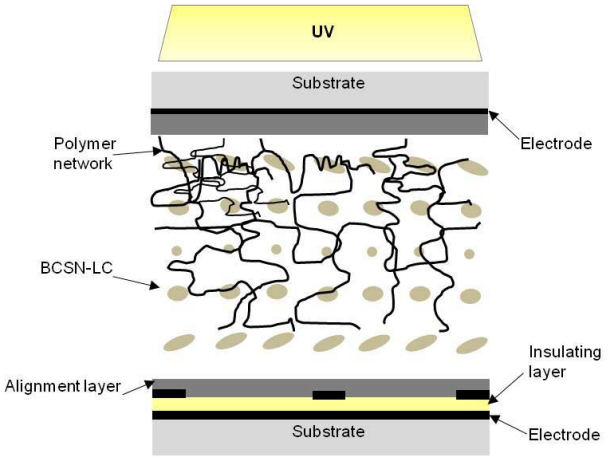

Figure 1. The schematic diagram of the cross section of the proposed BCSN-LC cell structure.

and homogeneously. By capillary action in the isotropic phase, the BCSN mixture was injected the assembled cell. The LC molecules in our experimental cell are aligned in the splay state by the parallel rubbed PI surface condition. In such configuration, it is necessary to apply a voltage of 20 V (square waveform, 1 kHz) for 10 s to transform from the initial splay to the high bend states. After the vertical electric field is applied over the level of applied voltage for the high bend state, it was removed to derive reorientation of the π-twisted state with topologically same phase with the high bend state by the LC relaxation [11]. In the π-twisted state, UV light (365 nm wavelength, 0.12 mW/cm^2 intensity for 30 min) was irradiated onto the experimental cell to compose polymer network structure for stabilizing the π-twisted state in LC mixture.

3. Results and Discussion

In our concept, the polymer network structure formed by UV irradiating process in the π-twisted state of BCSN cell was expected to function as special supporter for the enhanced memory retention time. Figure 2 shows the field emission scanning electron microscope (FESEM) images of a cross section and the surface of the RM network structure formed by UV irradiation in the π-twisted state of BCSN device after the LC molecules were washed off with hexane for 24 h. By the phase separation and the polymerization of the RM monomers, the coarse polymer network with 2.0 μm thickness is formed from the substrate adjacent to UV light source. This RM network structure generates local anchoring force to retain the π-twisted LC arrangement in partially small bulk region. Thus, we could manufacture the BCSN cell with the improved memory retention time.

The retention time in memory mode of fabricated BCSN cells with/without polymerized RMs network structure are shown in Fig. 3. The retention time was determined through measuring the transmittance of the π-twisted state as a function of the elapsed time after forming the π-twisted state (no applied voltage). In the initial splay state with the rubbing direction coincided with the transmission axis of the crossed polarizers, both BCSN cells with/without the RM polymer networks exhibit dark state. By the regulation of the external voltage (dropping voltage after applying voltage for the high bend state with topologically same phase with the π-twisted state), the π-twisted state (bright state) could be achieved. We measured the time conserving the uniform transmittance of the π-twisted state. In the BCSN cell with the polymerized RM network structure, the retention time was significantly improved rather than that of the conventional BCSN cell without RMs as shown in Fig. 3.

We fabricated a prototype of a 2-inch BCSN cell. Figure 4(a) shows the polarizing microscope textures of the fabricated prototype. The initial splay state has the dark state which is no transmission of light under crossed

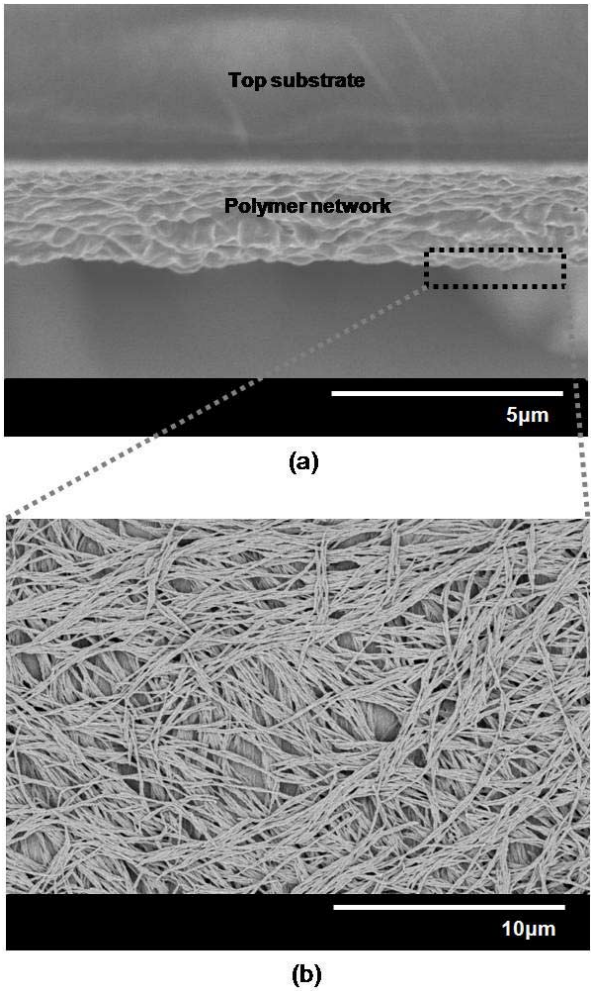

Figure 2. The FESEM images of the polymer networks formed in our BCSN-LC cell: (a) the cross section and (b) the surface.

polarizers due to the rubbing direction parallel to the transmission axis of one of two polarizers. Applying a vertical voltage and removing, the LC configuration is transformed from the vertical to the π-twisted state. To

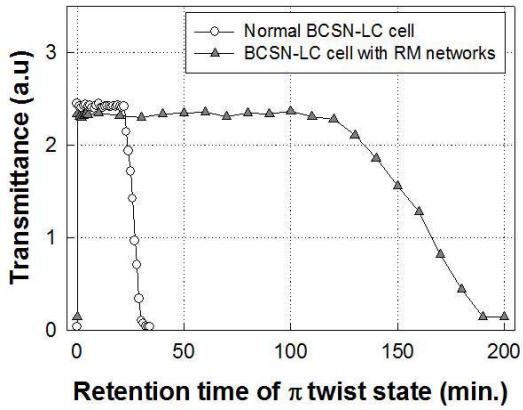

Figure 3. The measured retention time of π twist state in BCSN-LC device with/without RM network structure.

transform from the π-twisted to the splay states, the in-plane field was applied. Note that in the actual BCSN mode, the initial splay state exhibits bright state due to rotating the rubbing direction by 45° with respect to the polarizer. Here, to emphasize the switching textures between the splay and the π-twisted states, we use the optical configuration that the rubbing direction is parallel to the polarizer. Figure 4(b) shows a photograph of a 2-inch BCSN prototype with the directly electrode-patterned characters "HYU" and "DDLAB". On the patterned electrodes with these characters, the bright state as the π-twisted state could be maintained for about 120 min.

4. Conclusion

In this work, we proposed a BCSN mode with the enhanced retention time of the π-twist state in the memory mode operation. The BCSN mode proposed here could be operated in memory mode with more stable π-twisted LC arrangement by the RM network structure and thus shown the enhanced retention time of the memory mode. The novel technology improving the memory retention time in BCSN mode could be useful to overcome the limitation of parameters such as d/p, cell gap, and elastic constant of LCs considering the driving properties in both dynamic and memory modes.

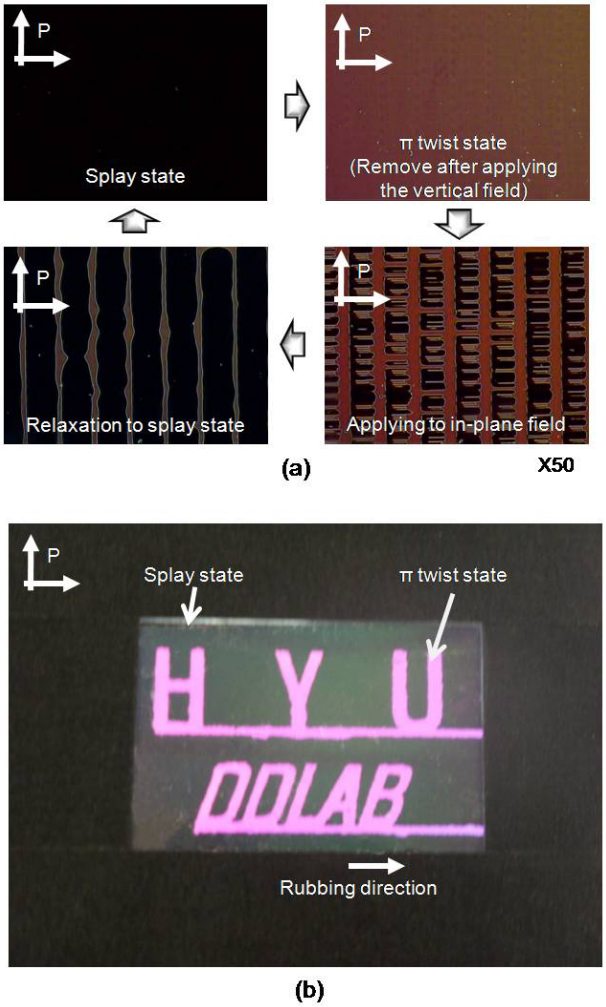

Figure 4. The visual results of bistable characteristics in fabricated BCSN-LC mode: (a) microscopic textures of the driving property between two stable states and (b) camera texture of the 2 inch BCSN-LC prototype coexisting with two of different states.

5. Acknowledgements

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