Shearing and Electro-optical Properties of Stressed Cholesteric Liquid Crystal Cells

Jung Min Lee and Daeseung Kang***

Abstract

The shearing effects on the electro-optical properties of a stressed cholesteric liquid crystal were investigated. A photopolymer was dispersed in the cholesteric liquid crystal cell. By carefully choosing the mixing ratio between the liquid crystal and the photoreactive monomer, and by applying suitable mechanical shearing on the substrates, a cholesteric liquid crystal display with a low threshold voltage and no alignment layer was demonstrated.

Keywords: liquid crystal, stress, cholesteric, photopolymer, shearing

1. Introduction

Liquid crystal (LC)-polymer composites have drawn a great deal of interest in the past decades [1]. Due to their fascinating superior electro-optical properties, various modes of them, such as PDLC (polymer-dispersed liquid crystal), PSLC (polymer-stabilized liquid crystal), and PSCT (polymer-stabilized cholesteric texture), have been explored [2, 3]. It was reported that the electro-optical properties of LC devices are highly dependent on the formation of an LC-polymer network created through the thermal or UV curing [2] of monomers. Depending on the concentration of the polymer in the composite and on the details of the phase separation process, many different types of LC network structures can be created.

Stressed liquid crystals (SLCs) made of interconnected micron domains of an LC in a stressed polymer structure, such as optical-phase array [4], non-mechanical beam steering [5], adaptive optical tip-tilt correction, and fast displays, are currently being utilized in the field. By applying physical shearing on the LC cells, the LC molecules tend to arrange in the direction of shearing, thereby producing better optical properties, simultaneously lowering the operating voltage and increasing the transmittance. A fast response time is achieved in thick cells. Furthermore, the additional rubbing procedure required for the conventional LC devices is not needed [6, 7].

In this paper, a stressed cholesteric liquid crystal (ChLC) cell was fabricated, and the shearing effect on the cell was investigated.

2. Experiment

Pure ChLC cells were prepared by mixing a host nematic LC (MLC-6000-100, Merck) with a chiral dopant (MLC-811, Merck). The mixing ratio was 66.6:33.4 in weight, and the pure ChLC exhibited a typical blue color upon reflection. The ChLC-polymer composite was prepared by mixing the ChLC and the photoreactive monomer NOA65 (Norland) at a weight ratio of 97:3. The LC cell was fabricated by sandwiching the mixture between two indium-tin-oxide-(ITO)-coated glass substrates. The substrates were separated by 4.5-μm fiber spacers. Note that there were no alignment layers on the substrates. To apply mechanical shearing on the cell, the two substrates were not tightly glued. The ChLC-NOA 65 mixture was injected into the cell via capillary force at an elevated temperature. The cell was then exposed under an unpolarized UV light for 20 min, at 30 mW/cm^2.

After UV exposure, the polymer network was formed with random ChLC domains. The top glass substrate was gently sheared while the bottom substrate was fixed, inducing the alignment of the ChLC domains. The shear distance

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* Member, KIDS; ** Student Member, KIDS
Corresponding author: Daeseung Kang
Dept. of Electrical Engineering, Soongsil University, Seoul 156-743, Republic of Korea
E-mail: dkang@ssu.ac.kr **Tel:** +82-2-820-0642 **Fax:** +82-2-817-7961

was controlled by adjusting the microscrew of a home-made shearing device mounted on the hot stage of a polarizing microscope (Fig. 1). An Ocean Optics S1000 UV-Vis spectrometer was used to measure the reflectance spectra for the stressed ChLC.

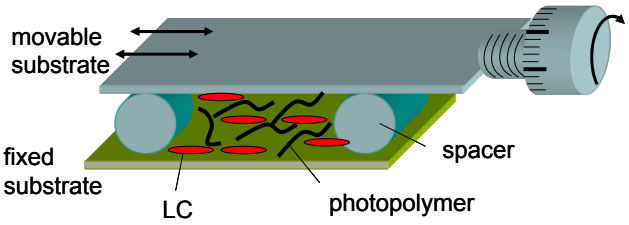

Fig. 1. Schematic diagram of a stressed LC cell.

3. Results and Discussion

Fig. 2 shows the microscopic textures of the ChLC cells with different shear distances. Pure ChLC cells (Fig. 2(a)) containing no polymer exhibit a typical planar texture, while ChLC cells dispersed with polymer show focal-conic textures due to the random mixing of the ChLC domains and polymer chains (Fig. 2(b)). As mechanical shearing was applied on the mixture cell, the focal-conic texture switched to a planar texture because the stressed polymer chains forced the LC molecules to align along the shearing direction. Fig. 2(c) and (d) show the mixed textures with planar and focal-conic domains. As the shear distance became larger, the planar state dominated the texture.

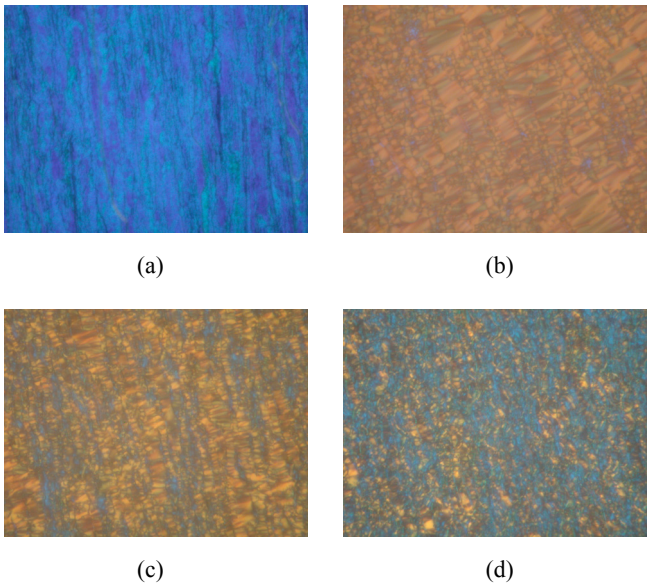

Fig. 2. Optical polarizing microscopic images of the ChLC cells at different shear distances: (a) pure ChLC; (b) 0 μm; (c) 100 μm; and (d) 200 μm.

It is well known that the optical properties of the stressed LC cell depend highly on the concentration of the polymer network [1]. The mixing ratio of the photoreactive monomer NOA65 was chosen by the optimal shearing condition on the nematic-polymer mixture. In the case of 20-μm thick, stressed nematic LC cells with a mixture of nematic LC 5CB and the monomer NOA65, the mixing ratio was 90:10, while the optimal mixing ratio in the ChLC cell and NOA65 was 97:3 in weight. The concentration of the monomer was lower in the case of the stressed ChLC cells compared to the stressed nematic LC cells. Fig. 3 shows the transmittance spectra of the stressed nematic LC cells and the reflectance spectra of the stressed ChLC cells.

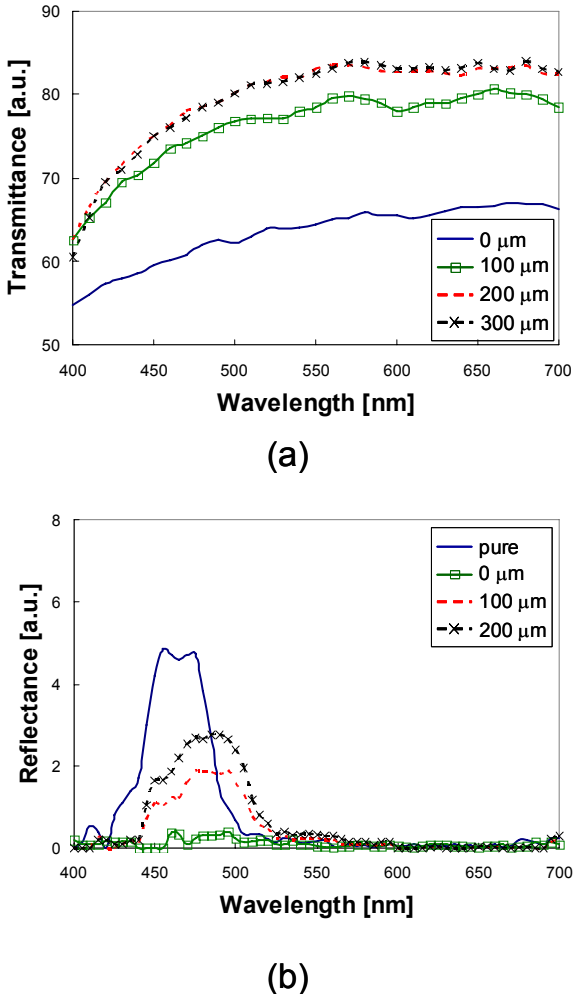

Fig. 3. (a) Transmittance spectra of a stressed nematic LC cell. (b) Reflectance spectra of a stressed ChLC cell.

Before applying shearing, both cells showed strong light scattering due to the irregular dispersion of the polymer chains and LC domains. The cells gradually became transparent, however, when shearing was applied. In the case of the nematic cells, when the shear distance reached 200 μm, the transmittance became saturated. In the case of the ChLC cells, a small shift of the peak wavelength was observed in the reflectance spectra, mainly because the helix axes of stressed ChLC cells tend to tilt away from the normal to the substrate.

Fig. 4 shows the switching properties of the stressed ChLC cells. The reflectance at the peak wavelength (~ 460 nm) was measured 10~15 sec after applying the voltage on the cells. Before each measurement, a high reset voltage (>80 V) was applied on the cell to set the initial state of the ChLC to a quasiplanar state. As shown in Fig. 4, the polymer-dispersed ChLC cell exhibited a lower threshold voltage from the planar to the focal-conic domains compared to the pure ChLC cell. As the shear distance became larger, the threshold voltage from the focal-conic to the homeotropic domains was further lowered in the case of a shear distance over 100 μm. The decrease in the threshold voltages is as cribed to the lower elastic energy of ChLC due to its helical structure [8].

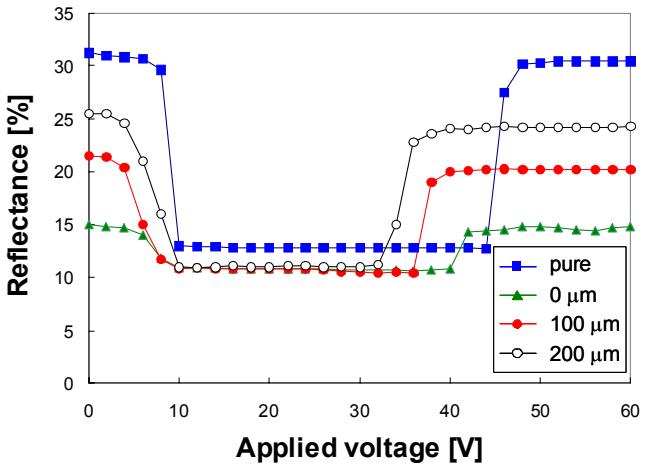

Fig. 4. Reflectance vs. applied voltage of the ChLC cells.

4. Conclusion

In conclusion, mechanical shearing was introduced to ChLC cells. The threshold voltages from the planar to the focal-conic domains and from the focal-conic to the homeotropic domains were reduced at higher shear distances. The employment of shearing on the ChLC cells significantly improved their electro-optical properties. Moreover, it is expected that this method can be applied to single-substrate ChLC devices. Work in this direction is in progress.

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