Control of surface anisotropy by exposing linearly polarized ultraviolet light

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Abstract

We examine the surface alignment of liquid crystals (LC's) by a double linearly polarized ultraviolet (LPUV) light expose process. Exposing polarized light induces a surface anisotropy to polyimide (PI) layer surfaces and hence determines the alignment direction. LPUV exposes with angular difference of 45 ° between two polarization directions make LC director change.

1. Introduction

Although the rubbing of PI layers is the most widely used method for the large-scale production of liquid crystal displays (LCDs) now, problem caused by rubbing process, such as dust particles, static electricity or contamination on the rubbing cloth breakage will lower the yield of LCDs. It is also hard to acquire microscopic variation in director orientation for wide viewing angle LCDs. Photo-induced alignment such as cis-trans isomerizations [1] or polarization-sensitive chmical reactions [2] can be alternatives for rubbing.

It was reported the interplay between the effects of mechanical rubbing and subsequent photo-induced chemical reactions on PI films [4]. Anisotropy oriented by rubbing was modified by LPUV expose. In this study, we examine the interplay between two LPUV lights that have different directions of polarization as shown in Fig. 1. We measured the change of LC director by changing LPUV exposure time.

2. Experimental

A mixture of 0.2 g of H-PSPI (ETRI) , 1.0 g of 2-Butoxyethanol (Junsei Chemical, referred to as BC) and 4.0 g of γ- Butyrolactone (Junsei, referred to as γ-BL) was stirred at the magnetic stirrer and used for the alignment layer. PI films were spin coated at the rate of 1000 rpm for 10 sec and followed by the rate of 3000 rpm for 20 sec. The films were soft baked at 90℃ for 10 min, then hard baked at 160℃ for 1h. The films were exposed the LPUV light twice with angular difference of 45° from a Xe lamp (Stanford research system) power-driven at 1000W.

Fig. 2 shows schematically the instruments used for optical phase retardation measurements. We used a photoelastic modulator (PEM-100, Hinds Instruments). He-Ne laser was used for the light source. The photoelastic modulator (PEM) and sample cell were sandwiched between a pair of crossed polarizers. The polarizer and the analyzer are oriented at ±45° with respect to the PEM retardation axis. The PEM retardation axis defines 0° for the coordinate system. The sample cell prepared with photoalignment layers

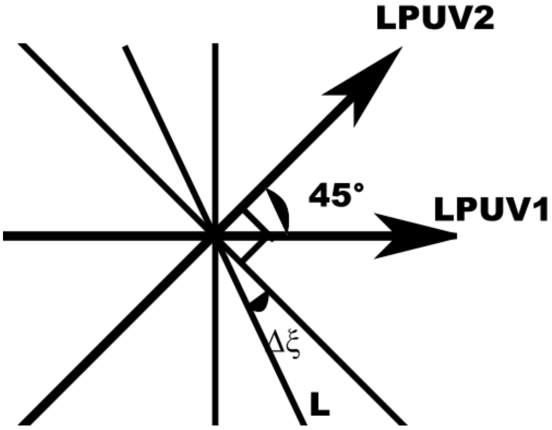


Fig. 1. Relationship between direction of LPUV (LPUV2) and the initially UV exposed direction (LPUV1). L is the easy axis and Δ ξ represents deviation of alignment direction.

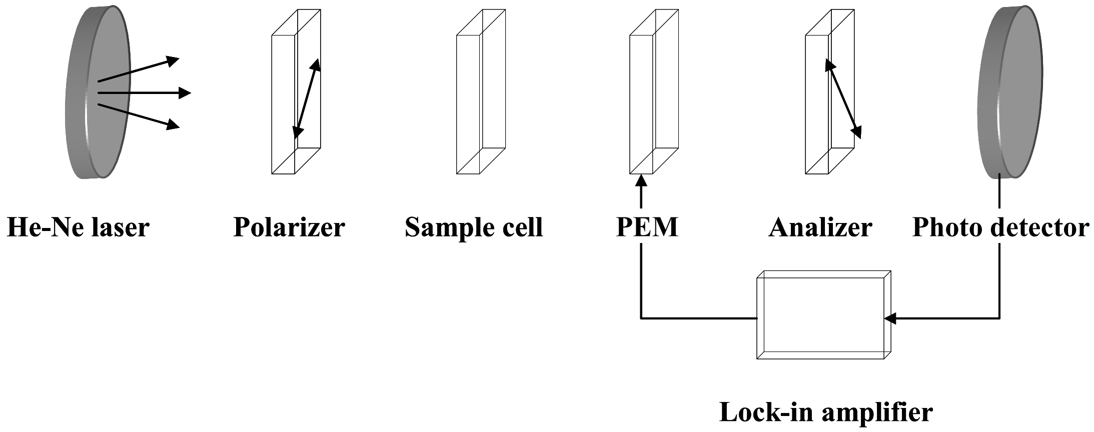


Fig. 2. Schematic drawing of the experimental settings for optical phase retardation measurements.

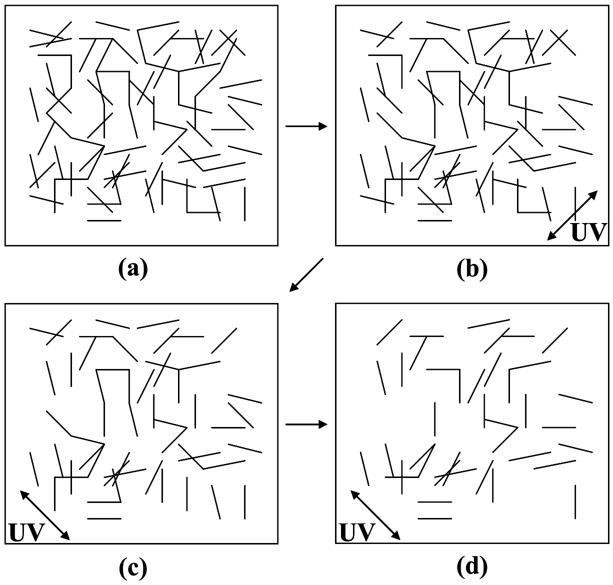
was placed between the polarizer and the PEM. The photodetector output was fed to a lock-in amplifier (Stanford research system) to detect the ac signal and a dc voltmeter to detect the dc signal. The lock-in amplifier was set to a modulation frequency of 50-kHz by the PEM. The laser beam was irradiated to the sample cell's surface. Rotating the sample cell, ac and dc signals were detected. Using the ratio of the first and second harmonic signals, we can find out the retardation of sample cell's surface [3]. In this study, this process was done by a computer program and has been made with a resolution of 5° .

3. Results and discussion

As shown in Fig. 1, optical anisotropy of the surface was measured after first LPUV (LPUV1) exposure. Exposure time was 45 min and 60 min for each experiment. Then the second LPUV (LPUV2) that makes an angle φ=45° with the first LPUV polarization direction was exposed to the substrate. This time, optical anisotropy was measured with LPUV exposure time of 0 min, 30 min, 60 min, 90 min, 120 min, 150 min, 180 min and 210 min.

Presumably, alignment direction caused by the first LPUV expose will be modified by the second LPUV expose. To check this, we modeled the time evolution of polymer chain alignment with increasing the LPUV exposure time [5] in Fig. 3. Although the angular difference between two LPUV orientation is 45° at the experiment, we set angular difference 90° in Fig. 3 to recognize the result easily. A Fourier Transform infrared study [6] has shown that the UV exposure dissociates photosensitive bonds that are parallel to the polarization direction [4] so that the alignment direction would be perpendicular to the UV polarization direction. From the Figure, we can think alignment direction would be perpendicular to the second LPUV direction eventually.

Fig. 4 shows measured optical anisotropy (birefringence) with increasing the second LPUV exposure time. The first LPUV exposure time is 60 min. The filled circles, open circles, filled triangles, open triangles and filled squares represent the second LPUV exposure of 0, 30, 60, 90 and 120 min,



(a) (b) (c) (d)

Fig. 3. The time evolution of polymer chain alignment with increasing the LPUV expose time. The arrows indicate the increase in expose time. (a) initial arrangement of polimer, (b) after first LPUV expose (c), (d) after second LPUV expose

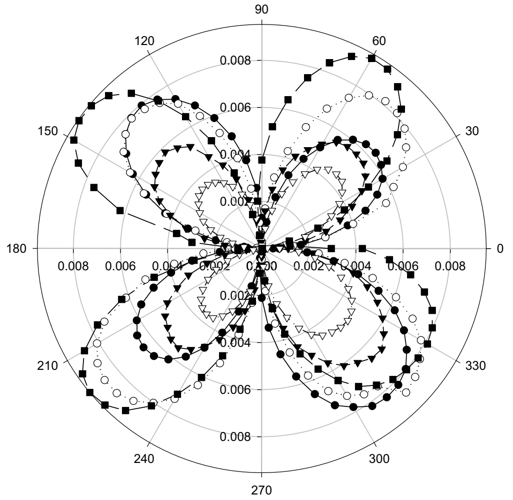


Fig. 4. The angular dependences of optical anisotropy for initially exposed to LPUV for 1h. The filled circles, open circles, filled triangles, open triangles and filled squares represent exposure of 0, 30, 60, 90 and 120min, respectively.

respectively. From this figure, we can find out the change in the LC director by the effect of the second LPUV exposure. It is known that the optical anisotropy is a function of the UV exposure time [5]. In this figure, optical anisotropy decreases for 90 min after the second LPUV exposure. Then after 120 min, optical anisotropy increases.

Fig. 5 represents the angle of deviation, Δξ, with the second LPUV exposure time. The first LPUV exposure time is 45 min and 60 min, respectively. The deviation Δξ, the angle between easy axis and the direction perpendicular to the polarization of the second LPUV, decreases with increasing exposure time. The sample, the first LPUV exposed for 60 min, changes alignment direction slower than the one LPUV exposed for 45min, since more photosensitive bonds are aligned perpendicular to the polarization of the first LPUV. If stronger anchoring is made from the first LPUV, it will take longer exposure time of the second LPUV to change the easy axis.

4. Summary

We have studied the interplay between two LPUV exposure with the different angles. Schematic model of change in alignment on PI films of the double LPUV exposure process. In this study, the alignment direction of the already photo-aligned layer can be modified by the subsequent LPUV exposure with different polarization. Anchoring strength varies with LPUV exposure time. Photo-aligned PI surfaces show weak anisotropy, so it takes much time to align the surface for LCDs. Also, different type of photo-sensitive layer shows different changing rate of alignment direction. The precise tuning of LC alignment can be meet by adjusting the first and the second LPUV exposure time, changing intensity of the UV light or using different type of photosensitive alignment layer. It deserves further research to know physical and chemical reaction related with photo-induced alignment and get more accurate models.

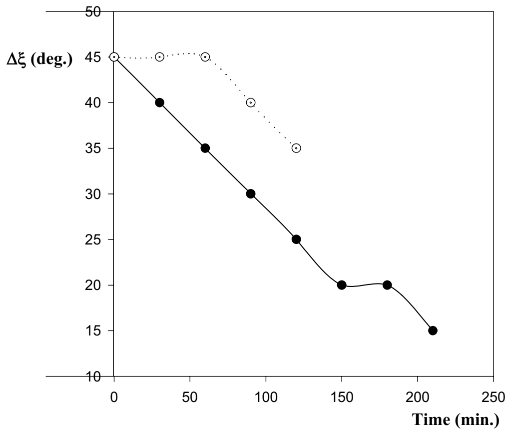


Fig. 5. Angle of deviation, Δ ξ with LPUV(2) exposure time. Filled circles and open circles represents LPUV(1) exposure time of 45 min and 60 min.

5. References

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