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A NEW METHOD TO ALIGN LIQUID CRYSTAL MOLECULES BY LINEAR PHOTO-POLYMERIZATION FOR LIQUID CRYSTAL DISPLAY*

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A new technique to uniformly align liquid crystal molecules is presented. The technique is based on producing an anisotropic surface on the glass substrate coated with photo-polymers by photo-polymerization of linear polarized UV-light. The orientation of liquid crystal molecules is governed by the direction of the polarized vector of UV-light. Using this method, we have studied the photo-polymer PSi-CM aligning LC 6710A molecules. The liquid crystal microscopic texture between crossed polarizers, optical retardation from liquid crystal layers and electro-optical properties of twisted nematic liquid crystal display cell are obtained, which was prepared with one side -photo-alignment and the other side-rebbed substrate.

Keywords: liquid crystal, photo-polymerization, orientation, alignment
PACC: 6130, 6845

I. INTRODUCTION

Production of uniformly aligned liquid crystal (LC) molecules is of primary importance for both their basic studies and application.[1] Many techniques[2-9] have been developed to produce planar and homeotropic alignment of liquid crystals. All these techniques are based on the surface orientation of liquid crystal. At the same time, surface alignment of liquid crystal is one of the key technologies to fabricate liquid crystal displays (LCDs). Among these studies, the establishment of rubbing-free technique to control LC alignment is an important target due to several shortcomings of the rubbing method for mass-production, such as the generation of electrostatic charge and dusts during the process. Recently, progress of photo-alignment control of LC molecules on photo-sensitive polymer films enables us to believe that the photo-alignment technique will be a hopeful candidate for rubbing technique.

In this paper, we report on the results of photo-alignment control of liquid crystal molecule orientation on the photosensitive material PSi-CM film, using polarized optical microscopy. The optical retardation from LC 6710A cell between cross polarizers as a function of exposure time is measured. The electro-optical properties of twisted nematic liquid crystal display (TNLCD) cell are obtained, which was produced with one side -photo-alignment and the other side -substrate rubbed (PAS-RTNLCD).

II. SAMPLE PREPARATION

The chemical structure of the polymer material PSi-CM used is shown in Fig.1. The polymer material PSi-CM(5wt%) was spin-coated on the cleaning glass substrate, and heated at 150°C for 2h.

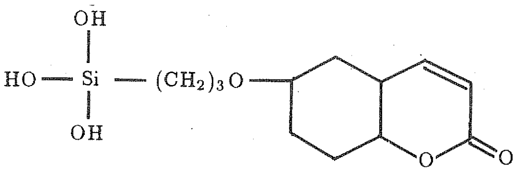

Fig.1. The chemical structure of PSi-CM.

The experiment setup of the photochemical reaction for polymer PSi-CM is shown in Fig.2, where the light source is 1000W I-Ga lamp. The UV-light will become polarized while the parallel light passes through the G-F prism. The temperature on the surface of polymer substrate is detected with a temperature detector.

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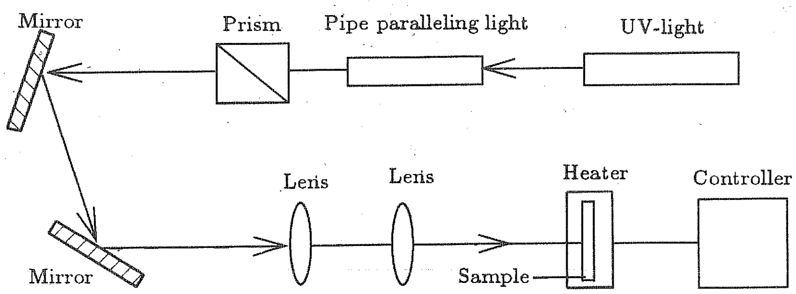
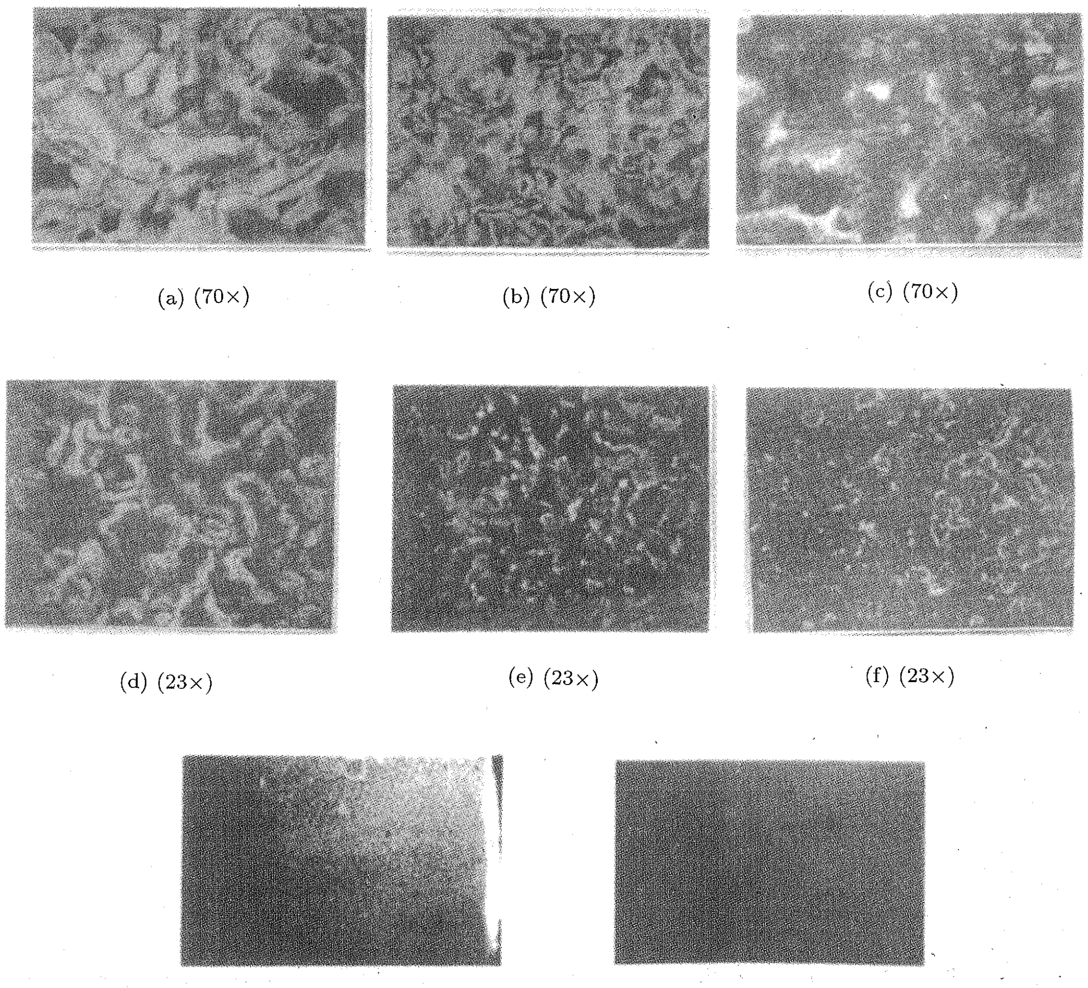


Fig.2. The experimental setup of photo-alignment LC by polarized UV-light

An I-Ga lamp with 1.5 mW/cm^2 power intensity is used to polymerize the photosensitive polymer molecules in the alignment layer, and the direction of the polarized UV-light is fixed 45° against wave normal direction. The time of illumination on the substrate surfaces is set at 30, 60, 120, 180, 240, 300, 420, 600 min, separately. We have observed the textures of liquid crystal alignment between two cross polarizers with 'antiparallel' exposure direction. The cell gap is 30μm. The liquid crystal 6710A is injected into the cell at 85°C ($T_{N\to I} = 70$°C), and then cooled to room temperature.

Ⅲ. EXPERIMENTAL RESULTS AND DISCUSSION



(a) (70×) (b) (70×) (c) (70×)

(d) (23×) (e) (23×) (f) (23×)

(g) (40×) (h) (40×)

Fig.3. The optical micrographs of LC alignment between two cross polarizers (a) 30min, (b) 60min, (c) 120min, (d) 180min, (e) 240min, (f) 300min, (g) 420min, (h) 600min.

The optical micrographs of textures are shown in Fig.3. From these pictures, we can see, the liquid crystal molecules are aligned when the irradiated time of the polarized UV-light is held up to 120min. At the same time, we can measure the optical retardation from the liquid crystal layers. The schematic experimental setup is shown in Fig.4, where the compensator is a quartz phase compensator, whose thickness is adjustable.

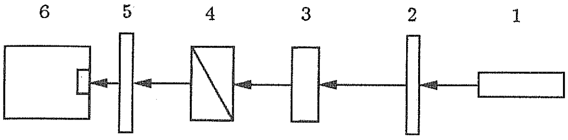


Fig.4. Schematic of experimental setup for measuring optical retardation of LC cell 1.Laser 2. Polarizer 3. Sample 4. Compensator 5. Polarizer 6. Detector.

The linear polarized light, whose polarized vector is at 45° azimuthal angle against the direction of easy direction of LC (the direction of polarized vector of the linear polarized UV-light), irradiates vertically through the LC cell. The rates of spread between the parallel and perpendicular to the easy direction are different because of the uniaxial character of LC molecules. The optical path difference is

$$\Delta = |n_{\perp} - n_{\|}| \cdot d, \qquad (1)$$

where d is the thickness of LC layer. The phase difference is

$$\delta = \frac{2\pi}{\lambda}\Delta = \frac{2\pi}{\lambda}|n_{\perp} - n_{\|}| \cdot d. \qquad (2)$$

If we put the optical phase compensator into the optical pathway, then we can get Eq.(3) when phase difference δ is equal to $2m\pi$

$$\begin{aligned}\delta =& \delta_{\mathrm{LC}} + \delta_{\mathrm{C}} = \frac{2\pi}{\lambda}(n_{\perp} - n_{\|})_{\mathrm{LC}} \cdot d_{\mathrm{LC}} \\ &+ \frac{2\pi}{\lambda}(n_{\mathrm{o}} - n_{\mathrm{e}})_{\mathrm{C}} \cdot d_{\mathrm{C}} = 2m \cdot \pi, \qquad (3)\end{aligned}$$

where δ_{LC} and δ_{C} are phase differences of liquid crystal layer and the quartz crystal, respectively; and m=1,2,... So we can obtain δ_{LC} as

$$\begin{aligned}\delta_{\mathrm{LC}} =& \frac{2\pi}{\lambda}(n_{\mathrm{o}} - n_{\mathrm{e}})_{\mathrm{LC}} \cdot d_{\mathrm{LC}} = 2m \cdot \pi - \delta_{\mathrm{C}} \\ =& 2m \cdot \pi - \frac{2\pi}{\lambda}(n_{\mathrm{o}} - n_{\mathrm{e}})_{\mathrm{C}} \cdot d_{\mathrm{C}}. \qquad (4)\end{aligned}$$

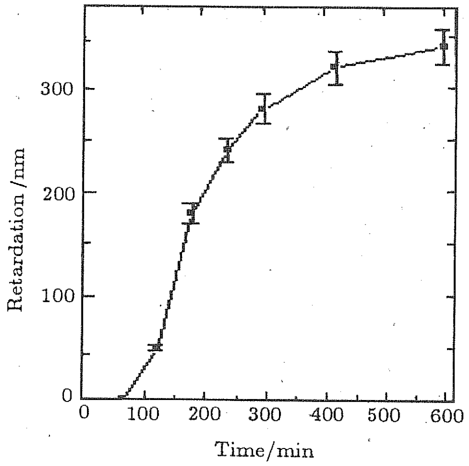


Fig.5. Optical retardation of LC cell vs time of exposure.

The experimental results are shown in Fig.5. From this figure we can see that the optical retardation could be measured when the irradiated time of the polarized UV-light is held up to 120min. And the retardation is augmenting with the time of illumination on the substrate surfaces. The generation of the optical retardation is based on liquid crystal molecules alignment. So the results in Fig.5 are consistent with the results in Fig.3.

The curves of the electro-optical properties of TNLCD and STNLCD cells produced with one side-photo-alignment and the other side-the substrate rubbed (PAS-RLCD) are shown in Fig.6 and STNLCD cell with twisted angle 240°. The gap of PAS-RTNLCD cell with twisted angle 90° are 7.0μm. The liquid crystal CP9001LA (by Merck) was injected into the cell at 85°C, then was cooled to room temperature. Here we can see the curves of electro-optical of the PAS-RLCDs are the same as conventional LCDs'.

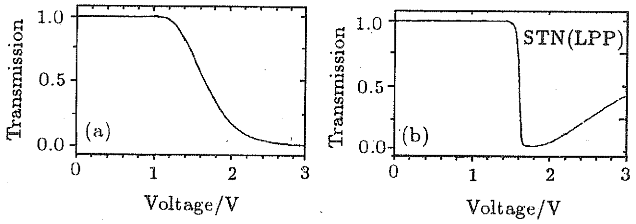


Fig.6. Electro-optical properties of PAS-RLCD (a) LPP-TNLCD, (b) LPP-STNLCD.

IV.THE GENERATION OF PRETILT ANGLE AND MECHANISM OF LC ALIGNMENT

We considered that LC molecules alignment on the substrate and the generation of LC pretilt angle are dependent on the power and direction of polarized UV-light.

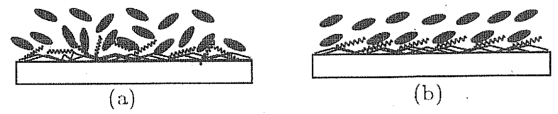


Fig.7. The LC alignment model on the polymer surface before (a) and after (b) exposure by polarized UV-light.

The surface of the photo-polymer is disordered and isotropic before the polarized UV-light illuminates on the surface (Fig.7(a)). Here, the pretilt angle of LC molecules is not produced by the polymer molecules. Alignment direction of the LC molecules is stochastic. The change of photo-polymer surface after the illumination on the substrate is shown in Fig.7(b). The substrate of LC alignment is in-order, anisotropic, and the pretilt angle of LC molecules could be induced. In this way, LC molecules are aligned, resulting from interactions between LC molecules and polymer molecules on the surface of the substrate.

V. CONCLUSION

We have studied the photo-alignment control of liquid crystal molecules orientation on the film of photosensitive material PSi-CM, using polarized optical microscopy. It is proved that the liquid crystal molecules are aligned on the photo-polymer film by photo-polarization using the linear polarized UV-light. The anisotropic properties of the film of aligned LC molecules are controlled by the exposure time and direction. The optical retardation of LC layers could be measured when the irradiation time of the polarized UV-light is held up to 120min with 1.5mW/cm^2 power intensity. And the retardation is augmenting with the time of illumination on the substrate surfaces. The curves of the electro-optical properties of PAS-RLCDs are the same as conventional LCDs'.

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