Measurement of anchoring strength of a photo-polymer for LC alignment

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Abstract

We have presented in the paper preliminary results on physical characteristic parameters of a photopolymer LPPF 301 CP. The weak azimuthal anchoring energy (~ 5.0×10^{-6} J/m^2) of a photopolymer was measured by using a simple optical method. High pretilt up to 30^o has been achieved in the photo-aligned cell by irradiating an obliquely incident UV light.

1. Introduction

Anchoring energy is not only a key parameter in the liquid crystal display (LCD) technology, but also plays an important role in understanding interfacial phenomena in LC physics. There are two kinds of surface anchoring for liquid crystals: the polar anchoring and azimuthal anchoring.[1,2] The former is anchoring with respect to the out-of-plane tilt of the liquid crystal (LC) director on the LC-substrate plane from the easy axis. The latter corresponds to deviations from the easy axis in the LC-substrate plane. Since the polar anchoring is related to the out-of-plane tilt of the LC director, TN-LCD. With a recent introduction of in-plane switching of liquid crystal molecules, the azimuthal anchoring becomes an important parameter for the display application.

Different methods based on Rapini-Papoular model for the surface free energy, have been extensively used to determine the polar anchoring energies. In the case of azimuthal anchoring, several attempts were reported. Sato et al[3] used a Cano wedge cell doped with a chiral materials. Iimura et al [4] used a method based the modulation in the polarization state of an incident light to the twisted nematic cells. Jiang et al [5] and Akahane et al [6] proposed an optical method by measuring an actual twist angle and optical retardation of the twisted or supertwisted nematic LC. however, not much methods are available. Li et al [7] introduced a method by measuring the width of the Neel wall of disclination lines for weak azimuthal anchoring energy. More recently, Saitoh et al[8] proposed a method using two different chiral dopant cells, and M. Vilfian et al [9] used dynamic light scattering measurements. Fonseca et al[2] proposed a simple method using a wedge cell of two symmetrical substrates.

Photo alignment technique was introduced as an alternative to the conventional running method for the LCDs [10]. It is therefore worthwhile to characterize the physical parameters for the photo alignment material.

In this paper, we use a wedge cell to measure the azimuthal anchoring energy. The method is based on the relation between the light transmission through a twisted cell, and cell thickness, wavelength, and the azimuthal anchoring strength.

2. Measurement principle

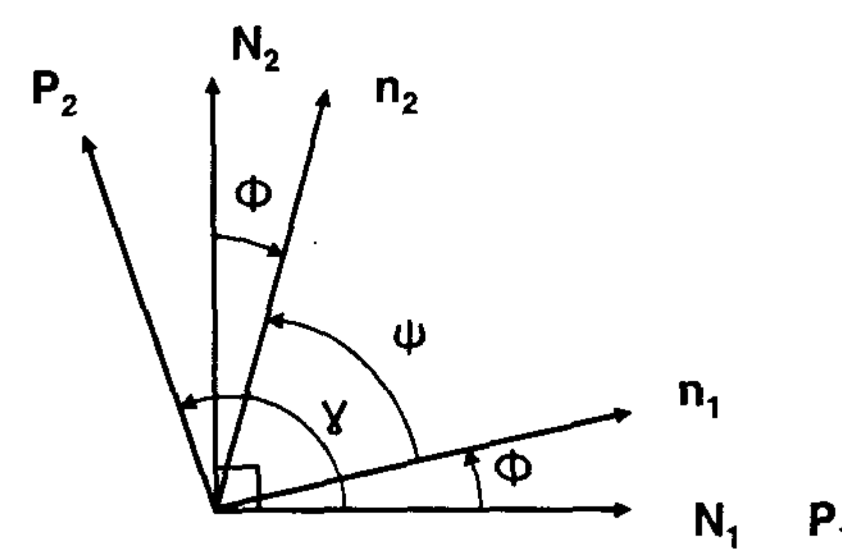

Fig.1. Schematic representation of symmetric twisted cell.

Figure 1 shows the schematic representation of our twisted cells. The nematic director $\mathbf{n}_1$, $\mathbf{n}_2$ at two substarate interface deviate from easy axes $\mathbf{N}_1$, $\mathbf{N}_2$ respectively, because of competition between the surface anchoring strength and the volume elastic torque. Then the actual twist angle ψ is less that the cell twist angle (90 degree). Using Fonseca's simple method [2], we deduce the azimuthal anchoring energy:

$$E_a = K_{22}\frac{D\sin 2\phi}{\pi - 4\phi} \qquad (1)$$

where, K_{22} is the Frank elastic constant for the twist deformation, D is cell thickness, ϕ is surface deviation angle. So, a fit on the experimental data $D(\phi)$ yields the azimuthal anchoring energy.

3. Experimental

The linearly photo polymerized (LPP) material used was LPPF 301 CP obtained from Rolic, which was further diluted in cyclopentanone. The photosensitivity of the LPP was around 280 – 330 nm, which corresponds to the characteristic wavelength of UVB lamp. The photopolymer was deposited by spin-coating on clean glass substrates. The coated LPP films were then prebaked at 150 °C for 10 minutes. After the prebaking, the films were exposed to linearly polarized UV(LPUV) light from the UVB lamp, incident normal to the substrate. Glan-Thomson prism was used to render the UV light linearly polarized. The intensity of the UV light was about 1.9 mW/cm^2.

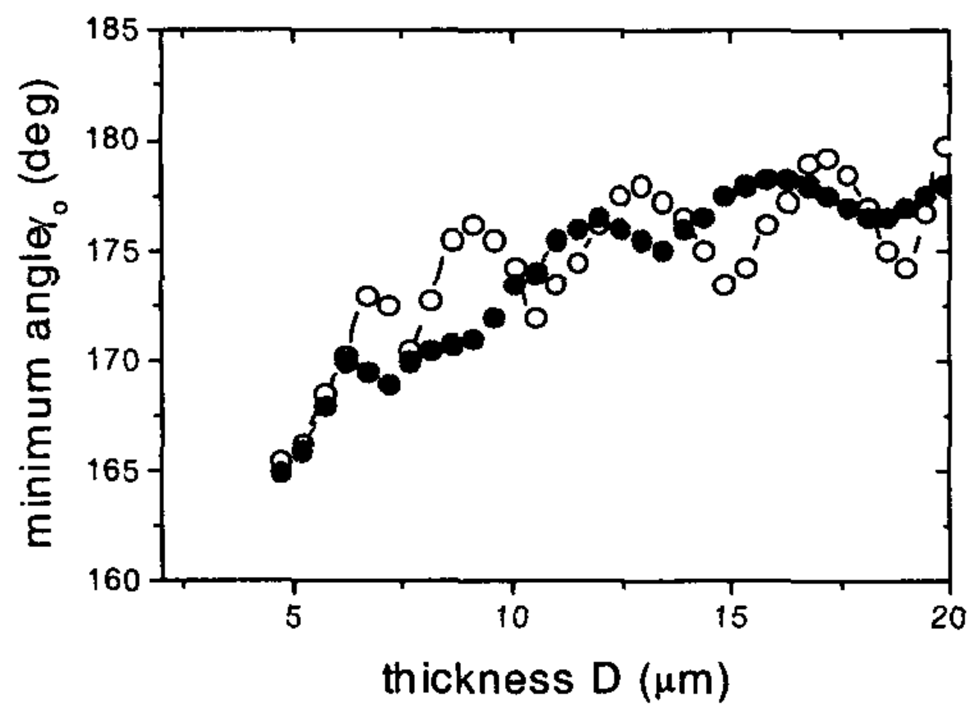

Fig.2. Minimum transmission angle of analyzer (γ_o) versus cell thickness (D). The open and solid dots indicate data obtained from a monochromatic light (534.5nm) and the white light, respectively.

In order to measure azimuthal anchoring energy, symmetric twisted wedge cells were fabricated using two LPP films exposed by perpendicularly LPUV light. About 20 μm mylar spacer was inserted between two glass substrates only on one side to form a wedge shape. The wedge angle and thickness of the cell were accurately determined by interferometric method. Figure 1 illustrates the angle diagram for the twisted wedge cell.

To measure the pretilt angle, two antiparallel substrates were prepared. Both substarates are tilted 45 degree with respect to the incident UV light. Autronic 107 TBA was used to determine the pretilt angle.

The liquid crystal used in the experiment was ZLI-5900-000 from Merck and used as received without further purification.

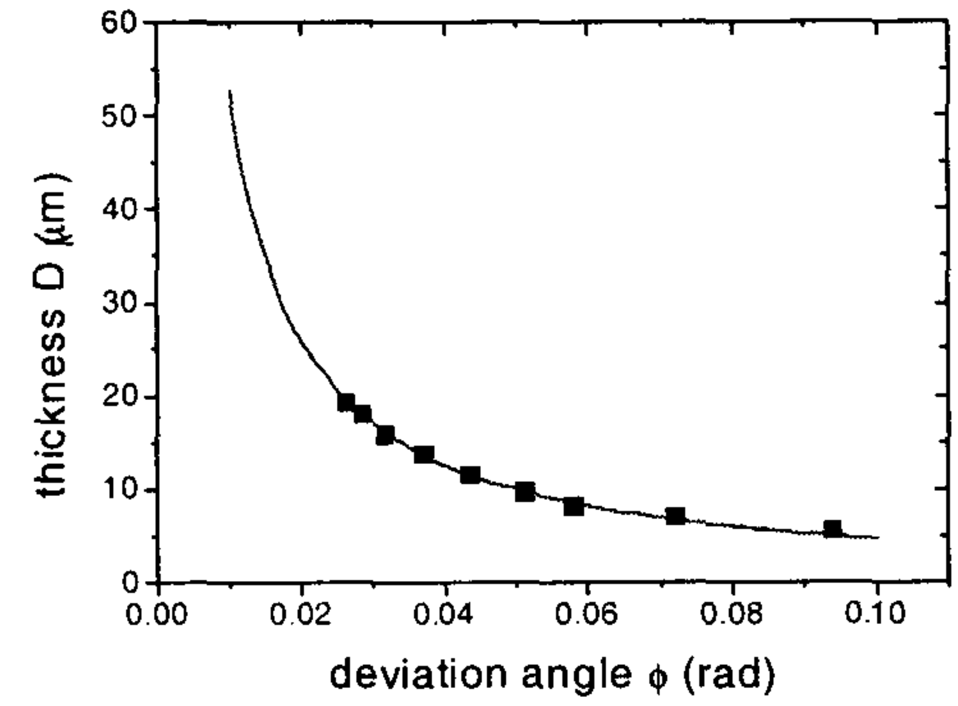

Fig.3. Cell thickness vs. deviation angle for the photopolymer. Solid line is the fit using Eq. (1).

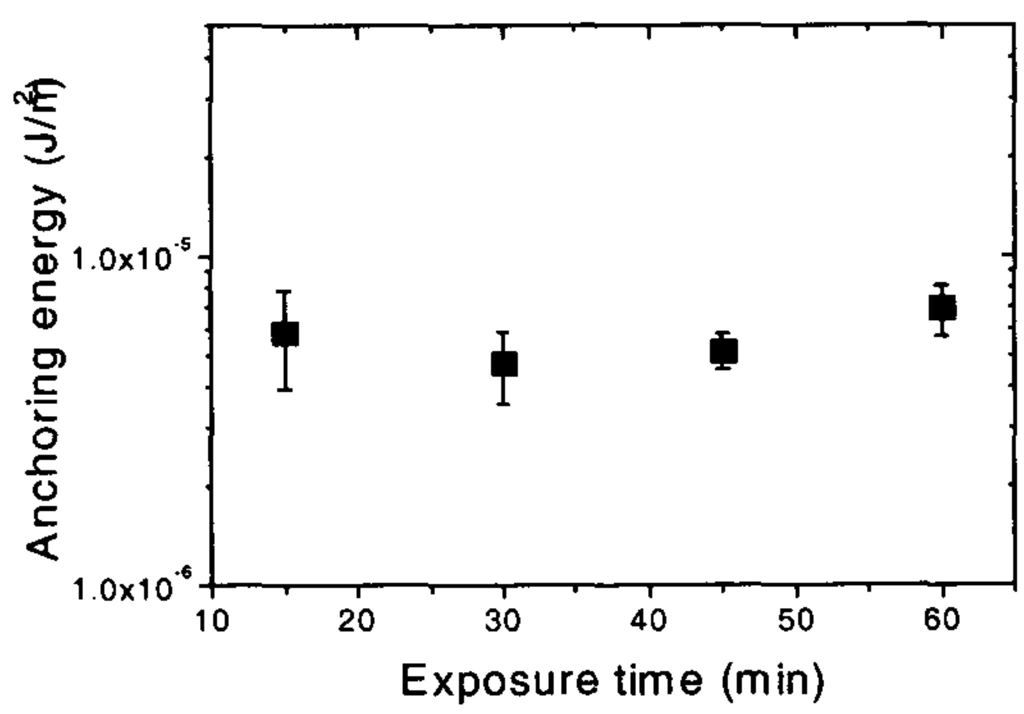

Fig.4. Azimuthal anchoring strength vs. UV exposure time for the photopolymer.

4. Results and discussion

Figure 2 shows typical measurements of cell thickness as a function of minimum transmission angle γ_0 obtained by rotating the analyzer axis. For a monochromatic light, the minimum angle shows oscillation with respect to cell thickness, but for white light the oscillation is significantly reduced because of averaging effect. Figure 3 represents cell thickness versus deviation angle that is deduced from the relation $\gamma_o = \pi - 2\phi$. By fitting the data using Eq. (1) and K_{22}=2.38×10^{-12} N, the anchoring strength was 7.0

$\times10^{-12}$ J/m^2. Figure 4 shows azimuthal anchoring strength versus UV exposure time. In our experiment time range, the azimuthal anchoring energy ranged from 4.8 – 7.0×10^{-6} J/m^2, which corresponds to intermediately weaker strength compared to rubbed polyimide (10^{-4} ~ 10^{-5} J/m^2).

Figure 5 shows the dependence of pretilt angle on UV exposure time at parallel cells that are tilted 45 degree from the UV light propagation axis. At about 20 minutes, the pretilt angle reached 31°. For longer UV exposure time, the pretilt angle decreases.

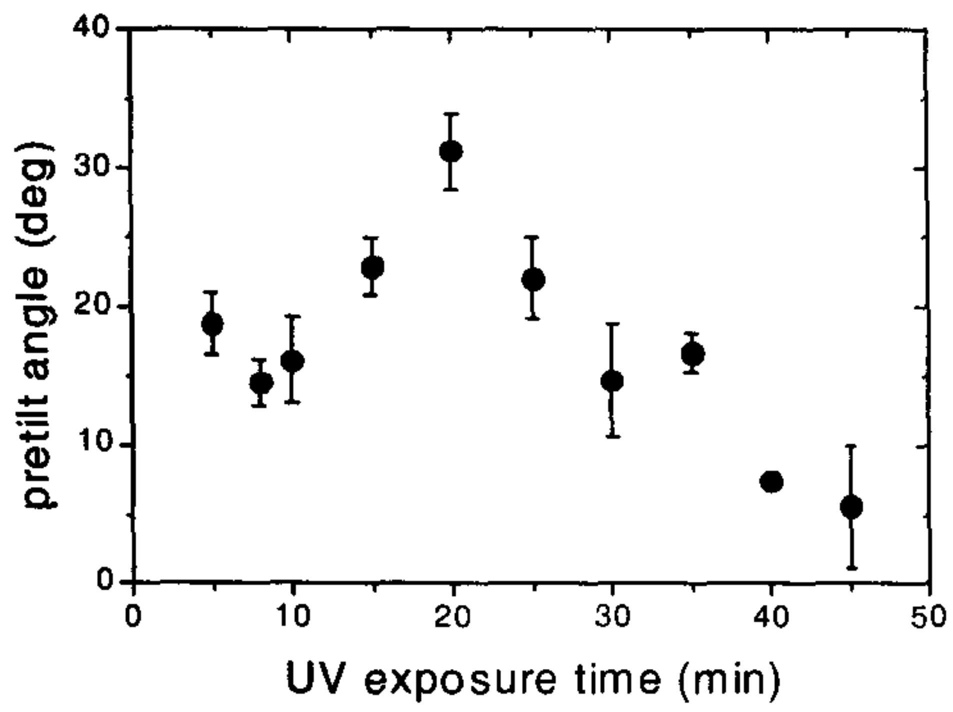

Fig.5. Pretilt angle vs. UV exposure time for the photopolymer.

5. Conclusion

In summary, we have used a simple evaluation method with an optical method for azimuthal anchoring strength for a photopolymer. The evaluated azimuthal anchoring energy was about 5.0×10^{-6} J/m^2, which is weaker than that of rubbed polyimide. High pretilt up to 30° has been achieved by irradiating an obliquely incident UV light.

7. References

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