A New Method for Measuring Azimuthal Anchoring Energy of Rubbed and UV-Exposed Polyimide Alignment Layers

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Abstract

Novel optical measurement systems and improved cell configurations for measuring of azimuthal anchoring energies were developed. The difference between the mechanical rubbing direction and the optical easy axis that caused errors in the previous azimuthal anchoring energy measurement was compensated. In addition, the measurement accuracy of the twist angle and therefore the azimuthal anchoring energy was greatly enhanced. As a result, we were able to obtain valid azimuthal anchoring energy values for different alignment layers.

1. Introduction

Anchoring energy is a key parameter representing anchoring force of liquid crystal at the surface of the alignment layer. There are two types of surface anchoring energy in a liquid crystal cell, polar anchoring energy and azimuthal anchoring energy. The former is the anchoring force with respect to the out-of-plan tilt of the liquid crystal director on the surface from the easy axis and the latter is that with respect to the in-plane tilt.

Many methods of measuring the polar anchoring strength have been reported[1-6], for a long time, so called surface disclination, Freedericksz transition, high field method and etc.

The methods of measuring azimuthal anchoring energies may be divided into two groups according to whether an external perturbating field is applied (field-on techniques) or not (field-off techniques). The field-on method using the twist deformation produced by a magnetic(or electric) field[7-9] requires a complex system to apply extra-high magnetic field and needs non-linear curve fitting between experimentally obtained optical data and simulation results based on the elastic theory of liquid crystal. So this method is difficult to utilize and the accuracy of anchoring energy is not good.

Nowadays the torque balance method using elastic power of liquid crystal has been widely used and is categorized as field-off technique. The critical issue in determining the anchoring energy using the torque balance method is how to measure the actual cell thickness and twist angle precisely.

Recent studies[10-16] of azimuthal anchoring measurement using the torque balance method have assumed that the rubbing axis is same as the optical easy axis, such as 90° or 0°. However, it would cause measurement errors because there is a difference between an easy axis and an actual rubbing direction in a real case. The measurement error of the anchoring energies is worse in a strong anchoring alignment layer than in a weak anchoring alignment layer because of the non-linear relationship between the twist angle and the azimuthal anchoring energy. (Fig. 2) Therefore, the designs of optical configuration and cell structure are very important for measuring actual twist angle.

In order to overcome these problems, we here adopted novel optical measurement system and improved cell configuration which are able to compensate the discord between upper and lower optical axes.

2. Experimental

In order to evaluate the azimuthal anchoring energy A by the torque balance method, the twist angle Θ and cell gap d were measured using novel optical measurement system.

The azimuthal anchoring A can be described, using a torque balance equation, as[10]

$$A = \frac{2K_{22}}{\sin 2\phi_s}\left(\frac{2\pi}{P_0} - \frac{\theta_1}{d_1}\right) \quad (1)$$

K_{22} is the twist elastic constant, P_0 is the chiral pitch, d_1 is the cell gap, and Φ_s is the deviation angle of the director at the surface from the easy axis.

In case of a 90 degree TN cell, the azimuthal anchoring energy A can be obtained from the relation of $90^\circ - \Theta_1 = 2\Phi_s$ by measuring twist angle Θ. While in case of an anti parallel (or parallel) cell, the azimuthal anchoring energy A can be obtained from the relation of $\Theta_1 = 2\Phi_s$. These calculations are valid only when the rubbing axis is the same as the optical easy axis. (Fig. 1.(a)) But in the real process, there exist manufactured errors in the alignment of the upper and lower substrates, and therefore deviation angle Θ_0 between the rubbing directions and the actual easy axes, as shown Fig. 1.(b). These errors prevent precise anchoring energy measurement. Fig. 2 shows that the error of one degree in the twist angle is very serious if the anchoring energy, A is expected in the range of 10^{-4} J/㎡.

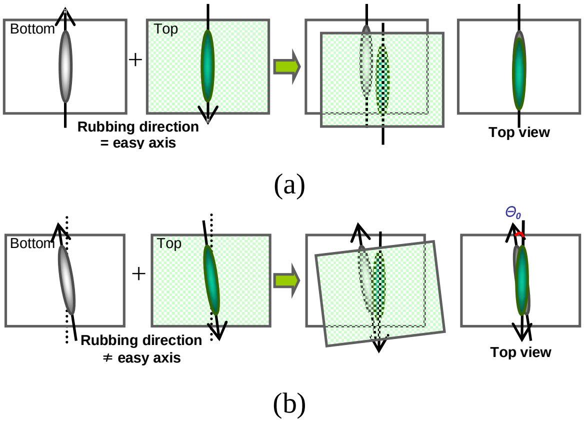

Fig. 1. Schematics of anti parallel LC cells (a) Ideal case, rubbing direction and easy axis are same (b) Real case, rubbing direction (solid line) and easy axis(dashed line) are different.

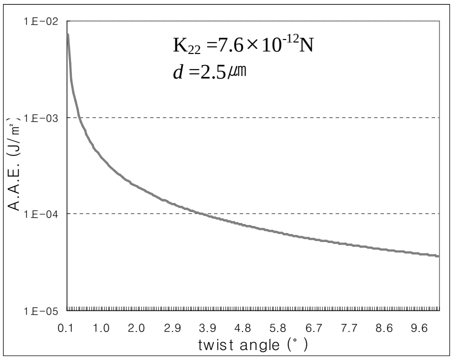

Fig. 2. Relationship between the actual twist angle and the azimuthal anchoring energy.

We assemble a double-sized cell using two ITO substrates, and then cut it into two cells. Then we inject liquid crystals of the same type but with different chiralities into each cell. Twist angle Θ_1, Θ_2 and cell gap d_1, d_2 of etch cell are measured with optical measurement system. Φs is given by

$$\phi_s = \frac{\theta_1 - \theta_0}{2} \quad (2)$$

where Θ_0 is the original twist angle between upper and lower optical axis. Both cells have the same Θ_0 and anchoring energy, and therefore

$$\frac{1}{\sin(\theta_1 - \theta_0)}\left(\frac{2\pi}{P_0} - \frac{\theta_1}{d_1}\right) = \frac{1}{\sin(\theta_2 - \theta_0)}\left(\frac{2\pi}{P_0} - \frac{\theta_2}{d_2}\right) \quad (3)$$

The Θ_0 can be calculated by solving eq. (3) and then anchoring energy A is obtained using eq.(1), (2).[17] With this method the difference between mechanical rubbing direction and optical easy axis that caused azimuthal anchoring energy measurement errors could be compensated.

We used four types of polyimide alignment materials, two of which (UV-1, 2) are exposed by linearly polarized UV light and two of which (Rub-1, 2) are rubbed in order to align liquid crystals.

3. Results and discussion

Our system shows that the measurement errors of the twist angles are within a ±0.05° repetitively and within a ±0.1° reproducibly. Compared with the error range of about ±0.5° in the previous system[11,14-16], our method is greatly improved for the measurement of twist angles. Twist angles and therefore azimuthal anchoring energies were measured for two rubbed and two UV-exposed polyimide alignment layers. As shown in Fig. 3, the azimuthal anchoring energy increases in order of UV-1→UV-2→Rub-1→Rub-2 and there are distinct differences between them.

As mentioned in the experimental section, the previous method can't compensate the Θ_0, the angle difference between the upper and the lower rubbing axes, and therefore gives an inaccurate value of the twist angle. For example, the twist angles of Rub-1 measured with a previous method with a liquid crystal blended with a left-handed chiral agent were very scattered and the azimuthal anchoring energies were far away from the actual values (Fig. 4 (a)). By measuring the twist angles with our method, we could obtain the accurate anchoring energies with small deviation because we could reflect the actual Θ_0 value (0.36°). (Fig. 4 (b))

4. Summary

We made an improved measurement system of the azimuthal anchoring energy by adopting novel optical configuration and new cell structure which can compensate the discord between the upper and lower rubbing axis. We could accurately measure the values of anchoring energies of two rubbed and two UV-exposed polyimide alignment layers. Especially, the anchoring energy of the UV-2 alignment layer is close to those of rubbing alignment layers. We expect that our new method will play an important role in the liquid crystal alignment layer study.

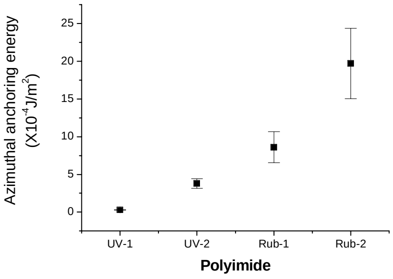

Fig. 3. Azimuthal anchoring energy($\times 10^{-4}$J/㎡) of UV-exposed PI and rubbed PI.

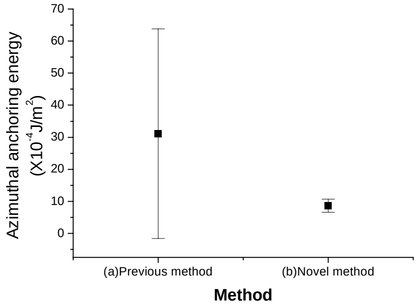

Fig. 4. Azimuthal anchoring energy($\times 10^{-4}$J/㎡) of Rub-1 (a) Using a previous method. (b) Using a novel method.

5. References

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