AIP | Applied Physics Letters

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Citation: Appl. Phys. Lett. **66**, 1753 (1995); doi: 10.1063/1.113356
View online: http://dx.doi.org/10.1063/1.113356
View Table of Contents: http://apl.aip.org/resource/1/APPLAB/v66/i14
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Study of surface alignment of nematic liquid crystals on polyimide Langmuir–Blodgett films

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(Received 22 August 1994; accepted for publication 17 January 1995)

The orientation effect of liquid crystal and polyimide molecules on the Langmuir–Blodgett (LB) films was studied. The orientation degree of polyimide chain in the LB films is less than that in the strong rubbing films. This result may be due to bad linear structure of polyimide. The 9 or 11 LB film layers may well align liquid crystals, but the orientation effect of liquid crystals on the polyimide LB films is worse than that on the strong rubbing films. The surface azimuthal anchoring energy of liquid crystals on the polyimide LB films was measured by a torque balance method proposed by our group. The intermolecular interaction between liquid crystal and polymer molecules is considered to be very important for aligning liquid crystals on the polymer surface. © *1995 American Institute of Physics.*

The surface alignment of liquid crystals (LCs) is not only a key technology of preparing LC displays, but also an important branch of the LC physics. Many alignment methods such as oblique evaporation,[1] rubbing,[2] and LB films[3] are being used, and in which rubbing on a polymer coating is a simple and practical method to take homogeneous alignment, but the mechanism of LC alignment on a rubbed surface is not yet fully understood. Recently there has been much more interest in polyimide (PI) LB films as nonrubbing alignment layers for LC displays.[3,4]

Geary *et al.* reported on the orientation of polymer molecules in an alignment layer due to rubbing.[5] To investigate the mechanism of LCs on the polymer further, in this letter, the PI LB films were prepared and the orientation effect of LCs and PI molecules on the LB films was studied. The azimuthal anchoring energy of nematic LCs on the PI LB films was measured and discussed.

The structure of PI for the LB films is shown in Fig. 1. The PI LB films were cured 1 h at 300 °C.

The degree of alignment of PI molecules may be estimated by measuring the optical retardation. In this work Senarmont ellipsometry was used, which is a very sensitive method of measuring the optical retardation. Figure 2 shows the principle of the measurement setup. Laser light passing through the first polarizer is linearly polarized at an angle of $\pi/4$ and it becomes elliptically polarized due to the retardation δ of the sample. After passing through the $\lambda/4$ plate with axis rotated at $\pi/4$, the light changed again into linearly polarized light at an angle $(\pi/4)+\alpha$. We can determine this angle by rotating an analyzer perpendicular to it so that the transmission becomes minimum. The retardation can be calculated by

$$\delta=(\alpha/\pi)\lambda, \tag{1}$$

where λ is the wavelength of laser light. In this work $\lambda=632.8$ nm.

Figure 3 shows the measured results of retardation of PI LB films. It indicates the optical retardation of the PI LB films is increased with increasing film layers. For a comparison, the retardation of rubbed PI films was measured and the results are shown in Fig. 3 also. The rubbing strength was expressed in precious paper.[6] The retardation of the rubbed films increased according to the rubbing strength, and the retardation is larger for the strong rubbing than for the LB films. It indicates that the orientation degree of PI chain is better for rubbing than that in the LB films. This result may be due to worse linear structure of PI.

In order to study the effect of LC alignment on the LB films, the 90° twist cell was prepared. The observed phenomena under cross polar microscope show that there is no LC alignment on 1 and 3 LB film layers, there is very weak alignment on 5 layers, and there is good alignment on 9–11 layers but there are some disclinations. To study the reason of making the disclination, the pretilt angle of LCs on the LB

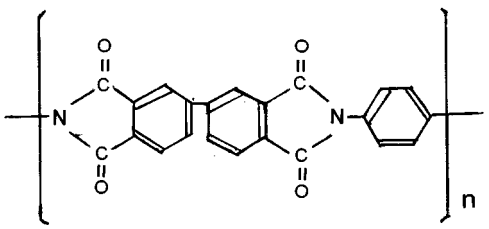

FIG. 1. The structure of PI for the LB films.

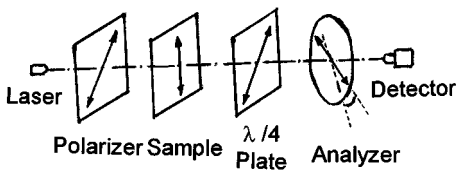

FIG. 2. The measurement setup for the optical retardation.

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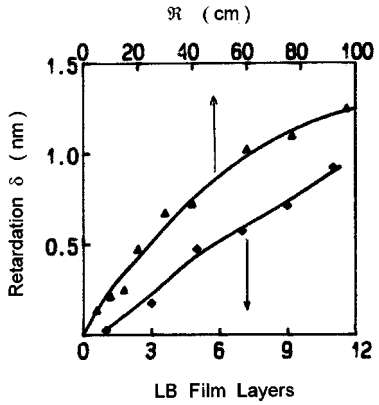

FIG. 3. The measured results of retardation of PI LB films and rubbed PI films.

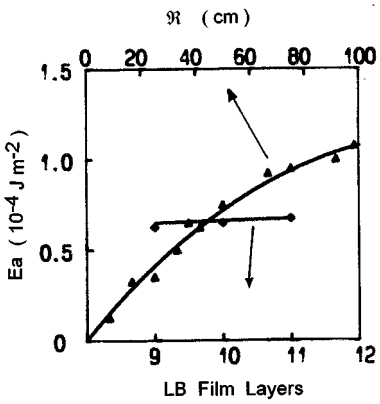

FIG. 5. The experimental results of E_a for the PI LB films and rubbed PI films.

films was determined and it is shown in Fig. 4. In the experiment 4-*n*-pentyl-4′-cyanobiphenyl (5CB) was used. The pretilt angle for the 9–11 LB film layers is same and it is about 0.1°. No doubtness, so small pretilt angle reduces disclinations in the 90° twist cell. Being difference with LB film, as shown in Fig. 4, the strong rubbing may get about 1.2° of the pretilt angle and it may be used to prepare a good 90° twist cell in which there is no disclination. This result proves also that rubbing is a better process for preparing 90° twist cell than the LB technique.

The azimuthal surface anchoring energy was measured by a torque balance method proposed by our group.[6] According to the Frank elastic theory, the direction of the surface LC orientation in the twist cell deviates from the rubbing direction due to a spontaneous twisting elastic power of LCs. This deviated angle is determined by the balance between the elastic twist power of LCs and the azimthal anchoring energy. From this deviated angle the azimuthal anchoring energy can be given by the following formula:

$$E_a = 2\ K_{22}\ \Psi_a / [d\ \sin(2\phi_s)], \tag{2}$$

where E_a, K_{22}, Ψ_a, d, ϕ_s are the azimuthal anchoring energy, the twist elastic constant, the actual twist angle of the LC director in the cell, the cell gap, the deviation of the director at the surface from the rubbing direction, respectively. The relation between Ψ_a and ϕ_s can be expressed by the following equation:

$$2\ \phi_s = \Psi_r - \Psi_a \tag{3}$$

here Ψ_r is the angle between the two rubbing directions on the both substrates.

Figure 5 shows the experimental result of E_a. In the experiments 5CB was used. There is nearly no differ for 9–11 LB film layers. For a comparison, the anchoring energy of the rubbed PI films was measured and the result is shown in Fig. 5 also. It is clear that the anchoring energy for strong rubbing is larger than that for the LB films. This result proves also that the orientation effect of LCs on the PI LB films is weaker than that on the strong rubbed films.

In other side, there is not any groove on the PI LB films and the anchoring energy of LCs on the PI LB films is one magnitude bigger than that on the evaporated SiO.[7] It shows the orientation mechanism of LCs on the polymer surface stems from the intermolecular interaction between LC and polymer molecules.

In conclusion, the surface alignment and the surface azimthal anchoring energy of LCs on the PI LB films were studied. The experimental results show that the 9–11 LB film layers may well align LCs, but the orientation effect of LCs on the PI LB films is worse than that on the strong rubbing films. The intermolecular interaction between LC and polymer molecules is considered to be very important for aligning LCs on the polymer surface.

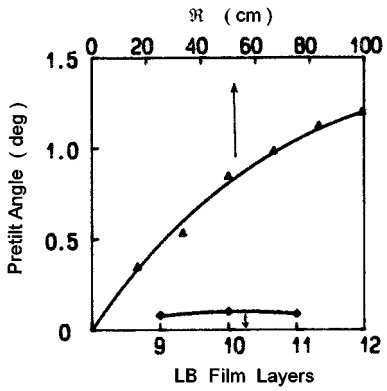

FIG. 4. The pretilt angle of LCs on the PI LB films and rubbed PI films.

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