

네마틱 액정의 표면 액정 배향에 관한 폴리이미드막의 분자 구조의 효과
Effect of the Molecular Structure of Rubbed Polyimide Films for
Surface Liquid Crystal Alignment of Nematic Liquid Crystal

서 대 식*

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We have investigated the effect of molecular structure of polymer of rubbed polyimide (PI) films for surface liquid crystal alignment. To obtain surface alignment effect of polymer molecular structure, we measured the polar (out of plane-tilt) anchoring strength and surface ordering of 5CB on rubbed PI surfaces. We have found that the polar anchoring strength of 5CB is depend on the polymer molecular structure of these unidirectionally rubbed PI surfaces.

1. Introduction

The unidirectional uniform alignment of liquid crystals (LCs) on treated substrate surfaces is very important in LC science and technology.¹⁾ Interfacial properties between the LC and the alignment surface are the key to understand the alignment mechanism of LCs. To align LC molecules, unidirectionally rubbed polymer surfaces have been widely used, but the detailed mechanism of LC alignment is not yet fully understood. Also, the anchoring strength and the surface ordering between the LC and the surface are very important in understanding the LC alignment. Previously, Yokoyama et al. reported the measurement of polar (out of plane-tilt) anchoring strength of 5CB on obliquely evaporated SiO surfaces.^{1,2)} In previous papers, we have reported the polar anchoring

strength of 5CB on weakly rubbed polyimide (PI) surfaces.^{3,4)} Previously, the surface ordering of the nematic (N) LCs on alignment layers was demonstrated and discussed by some investigators.^{1,2,3)} K.Miyano and J.C.Tarczon have previously reported the surface order parameter of 5CB on various alignment layers, by measuring residual optical retardation near the clearing temperature (Tc).⁶⁾ Recently, we reported the surface order parameter of NLCs on PI Langmuir-Blodgett (LB) surfaces.⁷⁾

In this paper, we report the effect of the molecular structure of polymer of rubbed PI surfaces with trifluoromethyl moieties on polar anchoring strength and the surface ordering of 4-n-pentyl-4-cyanobiphenyl (5CB).

2. Experimental

The molecular structures of polymer used in this study are shown in Fig. 1.

This PIs with trifluoromethyl moieties (Japan Synthetic Rubber Co., Ltd.) were coated on indium-tin-oxide (ITO) coated glass substrates by spin-coating, and were imidized at 180°C for one hour. The PI films were unidirectionally rubbed using a machine equipped with a nylon roller (Yo-15-N,

Yoshikawa Chemical Industries Co., Ltd.). The definition of the rubbing strength, RS, was given in previous papers.^{8,9)} The sandwich-type cells were assembled by keeping the rubbing directions antiparallel to each other with a cell thickness of 60 ± 0.5 μ m.

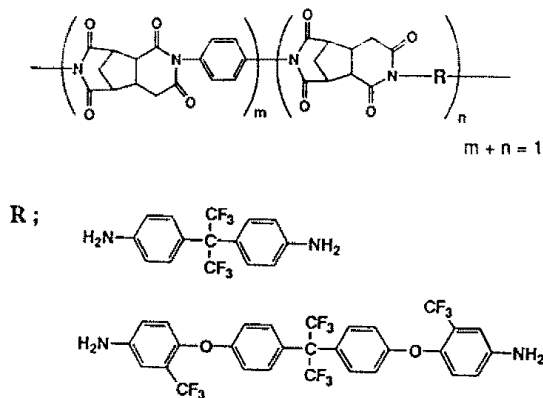


Fig. 1. Used molecular structures of the polymer

We measured the optical retardation (R) and the electric capacitance (C) as a function of applied voltage (V). In order to determine the polar anchoring strength, the "high-electric field technique" by Yokoyama et al.,²⁾ was used. For optical retardation measurements, a He-Ne laser (632.8nm) with 2-mW output power was used as the light source and the system consists of a polarizer, an acousto-optic modulator, and an analyzer. The output signal was detected with a photodiode. The electric capacitance of the LC cell was obtained by measuring the out-of-phase component of the current produced by changing the applied voltage across the cell. The extrapolation length, d_e , was evaluated using the relationship between the measured values of the electric capacitance and the optical retardation :

$$\frac{R}{R_0} = \frac{I_0}{CV} - \frac{2d_0}{d}, \text{ when } V \gg 6V_{th} \quad (1)$$

where I_0 is a proportional constant depend on the LC materials; and V and d stand for the applied voltage and LC medium thickness, respectively.

The polar anchoring energy A is obtained from the following relation :

$$A = \frac{K}{d_e}, \quad (2)$$

where K is the effective elastic constant given by K

$= K_1 \cos 2\theta + K_3 \sin 2\theta$, with K_1 , K_3 , and θ are the elastic constants for the splay and bend deformations, and the pretilt angle, respectively. We used the measured elastic constants in this work.

We determined the surface order parameter by measuring the temperature dependence of the residual optical retardation near the clearing temperature T_c .⁶⁾

3. Results and Discussion

Figure 2 shows the extrapolation length of 5CB on weakly rubbed PI surfaces as a function of temperature. It is clear that the extrapolation length of 5CB diverges near the clearing temperature for both kinds of rubbed PI surfaces, and this is due to the decrease of the surface order near the clearing temperature. A similar behavior in polar^{2,3)} and azimuthal¹⁰⁾ anchoring strengths has been observed previously in 5CB on obliquely evaporated SiO₂ surfaces, and attributed to the manifestation of the reduced orientational order of the LC near the interface.⁶⁾ Therefore, it is expected that the polar anchoring strength of 5CB decrease rapidly due to the decrease of the surface order near the clearing temperature. Also, the extrapolation length of 5CB on rubbed F2 PI surfaces is large compared with rubbed F1 PI surfaces near the clearing temperature. This indicates that the polar anchoring strength of 5CB is strongly depends on the molecular structure of the polymer used.

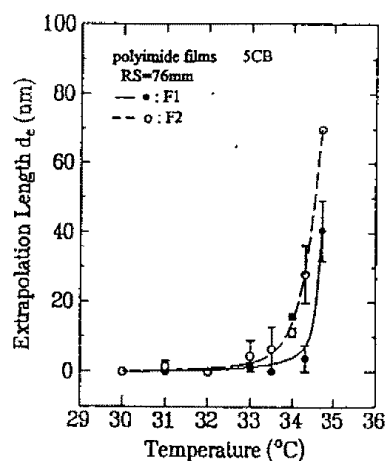


Fig. 2. Temperature dependence of extrapolation length of 5CB on weakly rubbed F1 and F2 PI surfaces with trifluoromethyl moieties.

Figure 3 shows the surface order parameter of 5CB on rubbed F1 and F2 PI surfaces as a function of RS.

It is clear that the surface order parameter increases with RS and then saturates for F1 PI surface, F2 PI surface, very small values of surface order parameter is observed for all the values of RS. It is expected that the anisotropic dispersion force effect on rubbed F1 PI surfaces is larger than that on rubbed F2 PI surfaces. By comparison of Fig.2 with Fig.3, we can see a that the good correlation between the polar anchoring strength and the surface order parameter in 5CB. It is clear that the polar anchoring strength of 5CB strongly depends on the surface order of the rubbed PI surface. Therefore, it is expected that the the polar anchoring strength of 5CB is strongly contributed to the anisotropic dispersion force between the LCs and the surfaces.

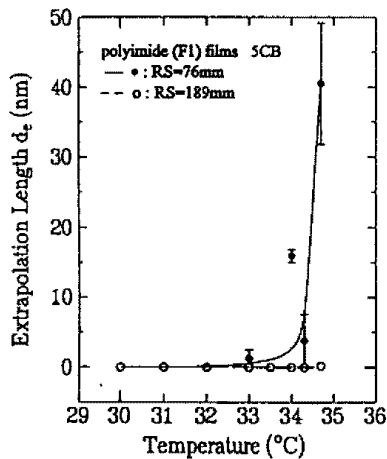


Fig. 3. Temperature dependence of extrapolation length of 5CB on two kinds of weakly rubbed PI surfaces with trifluoromethyl moieties.

4. Conclusion

We have investigated the effect of polymer molecular structure of PI films for surface alignment of liquid crystals by measuring polar anchoring strength and surface ordering on rubbed PI surfaces. The effect of the molecular structure of polymers of weakly rubbed PI surfaces with trifluoromethyl moieties on polar anchoring strength and surface ordering is clearly observed. It is expected that the polar anchoring strength of 5CB is contributed to the molecular structure of polymer of the rubbed PI surface. Also, we obtained that the polar anchoring strength of 5CB strongly depends on the surface order of the rubbed PI surface.

References

- 1) H.Yokoyama, *Mol.Cryst.Liq.Cryst.* 165, 269(1988).
- 2) H.Yokoyama, S.Kobayashi, and H.Kamei, *J.Appl.Phys.* 61, 4501(1987).
- 3) D.-S.Seo, Y.Iimura, and S.Kobayashi, *Appl.Phys.Lett.* 61, 234(1992).
- 4) D.-S.Seo, T.Oh-ide, and S.Kobayashi, *Mol.Cryst.Liq.Cryst.* 214, 97(1992).
- 5) D.-S.Seo, H.Matsuda, T.Oh-ide, and S.Kobayashi, *Mol.Cryst.Liq.Cryst.* 224, 13(1993).
- 6) J.C.Tarczon and K.Miyano, *J.Chem.Phys.* 73, 1994(1980).
- 7) D.-S.Seo, S.Kobayashi, D.-Y.Kang, and H.Yokoyama, *Jpn.J. Appl. Phys.* 34, 3607(1995).
- 8) D.-S.Seo, K.Muroi, and S.Kobayashi, *Mol.Cryst.Liq.Cryst.* 213, 223(1992).
- 9) D.-S.Seo, S.Kobayashi, and M.Nishikawa, *Appl.Phys.Lett.* 61, 2392(1992).
- 10) S.Faetti, M.Gatti, V.Palleschi, and T.J.Sluckin, *Phys.Rev.Lett.* 55, 1681(1985).