Polymer Layer Effects on Anchoring Strength and Surface Ordering in NLC, 5CB, by the Washing Process after Rubbing on the Polyimide Surfaces

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The liquid crystal (LC) aligning capabilities by the washing processes after rubbing on the two kinds of the rubbed polyimide (PI) surface were studied. The polar anchoring energy of 4-n-pentyl-4'-cyanobiphenyl (5CB) increased with the rubbing strength RS on the two kinds of the rubbed PI surface. The polar anchoring energy of 5CB on the rubbed PI surface with alkyl side chains is larger than the rubbed PI surface with CONH moiety. Also, the surface ordering of 5CB on the rubbed PI surface with alkyl side chains is larger than the rubbed PI surface with CONH moiety. Therefore, the surface ordering of 5CB strongly depends on the polymers and washing process.

Keywords : Nematic liquid crystal, Washing, Rubbing, Anchoring strength, Surface ordering

1. INTRODUCTION

Rubbed polymer surfaces have been widely used to align LC molecules. PIs are widely employed as orientation films since they have appropriate characteristics such as high transparency and uniform LC alignment. Even though the LC alignment mechanism is not fully understood. The thin film transistor (TFT)-LCD and super (S) TN-LCD are damaged by the induced electro-static charges produced during rubbing. Previously, H. Matsuda et al. reported the induced electro-static charges and pretilt angles of NLC on various rubbed PI surface as a function of rubbing strength[1]. In the practical fabrication of LCDs, a washing process is used to remove the dust and electro-static charges caused by rubbing.

The LC aligning capabilities and anchoring strength (energy) on treated substrate surfaces have been discussed[2-6]. In a previous paper, we reported the first measurement of the temperature dependence of the polar (out-of-plane tilt) anchoring energy of weakly rubbed PI surfaces in a 5CB[2]. We also reported the temperature dependence of the polar anchoring energy of 5CB on various PI-Langmuir-Blodgett (LB) surfaces[7]. Most recently, we reported the washing effect on the anchoring energy of 5CB on rubbed PI surfaces with side chain[8].

In this paper, we report the influences of alignment layers on the polar anchoring energy and the surface ordering in NLC, 5CB, by the washing process on the two kinds of the rubbed PI surfaces.

2. EXPERIMENTAL

The molecular structure of the polymer used is shown in Fig. 1. The PI films were coated on indium-tin-oxide (ITO) coated glass substrates by spin-coating, and were imidized at 250℃ for 1 hr. The thickness of PI layers was about 500Å. The PI films were rubbed using a machine equipped with a nylon roller (Yo-15-N, Yoshikawa Chemical Industries Co.). The definition of the rubbing strength RS was given in previous paper[9]. The rubbed PI surfaces were washed after for rubbing. The following washing materials are used : pure water, freon, and isopropylalcohol (IPA). The characteristics of washing materials are hydrophilic, hydrophobic, and amphiphilic, respectively. We used the wet method for 20 min. for the washing process. LC cells were assembled with the antiparallel to rubbing direction. The LC layer thickness was set to 60.0± 0.5μ m. To measure pretilt angles, we used the crystal rotation method. The measurement of pretilt angle was done at room temperature (22℃). Also, we measured the anchoring strength by using "high electric-field techniques"[2] as shown in Fig. 2. 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 optical retardation measurement system consists of a polarizer, an acousto-optic modulator, and an analyzer. The output signal is detected by a photo-diode. The electric capacitance of the LC cell is obtained by measuring the out-of-phase component of the current produced by changing the voltage which is applied to the cell. The extrapolation length d_e is determined by using the relationship between the measured values of the electric capacitance and the optical retardation [2]:

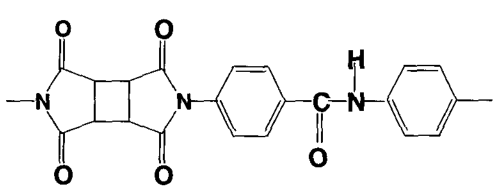
$$\frac{R}{R_0} = \frac{I_0}{CV} - \frac{2d_e}{d}, \text{ when } V \gg 6V_{th} \quad (1)$$

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

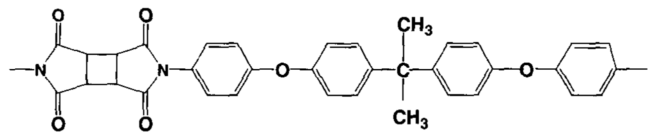
The polar anchoring energy A is obtained from the following relation:

$$A = K / d_e, \quad (2)$$

where K is the effective elastic constant which is given by $K = K_1\cos^2\theta_o + K_3\sin^2\theta_o$, where K_1, K_3, and θ_o stand for the elastic constants of the splay and bend deformations, and the pretilt angle, respectively. We used the measured elastic constants in this work. The surface ordering of 5CB was obtained by measuring the residual optical retardation induced on the PI surface above the nematic-isotropic transition temperature T_c[10].



(a) PI-1



(b) PI-2

Fig. 1. Chemical structure of the polymer.

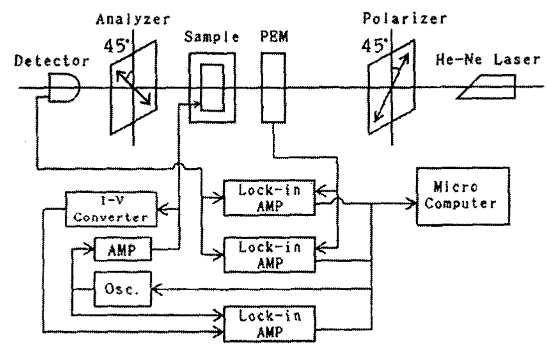
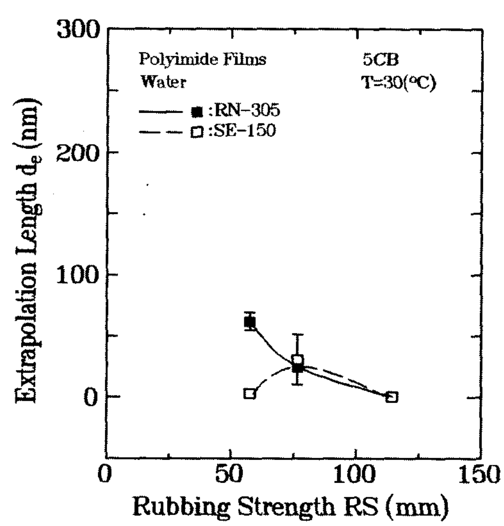


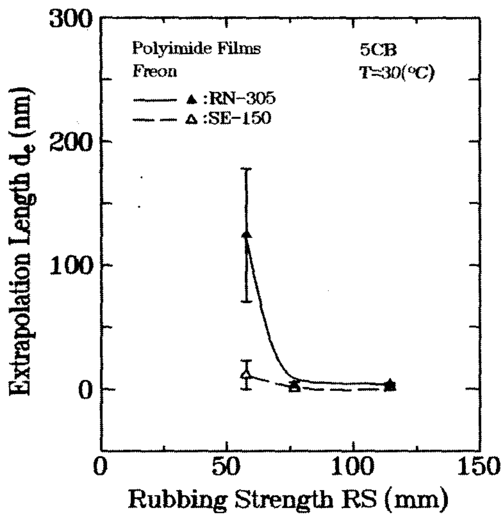
Fig. 2. Measurement system of polar anchoring strength.

3. RESULT AND DISCUSSION

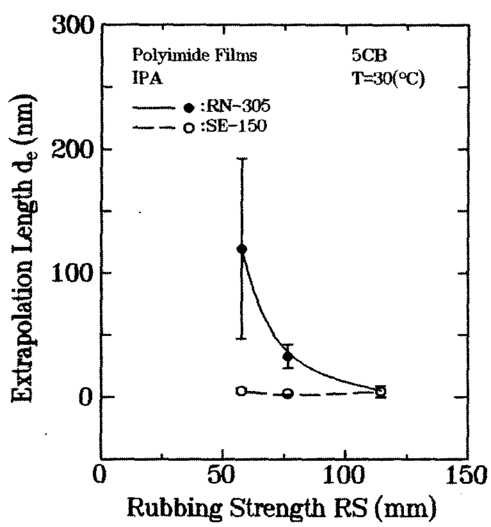
Figure 3 shows the extrapolation length d_e of 5CB for the washing processes on the two kinds of the rubbed PI surfaces as a function of rubbing strength RS. The extrapolation length de of 5CB decreases with increasing the rubbing strength RS. The extrapolation length d_e of the rubbed PI-1 surface with CONH moiety for all washing processes is larger than the rubbed PI-2 surface with alkyl side chains. The washing effects on extrapolation length d_e of 5CB is clearly observed at weak RS region.



(a) Water



(b) Freon

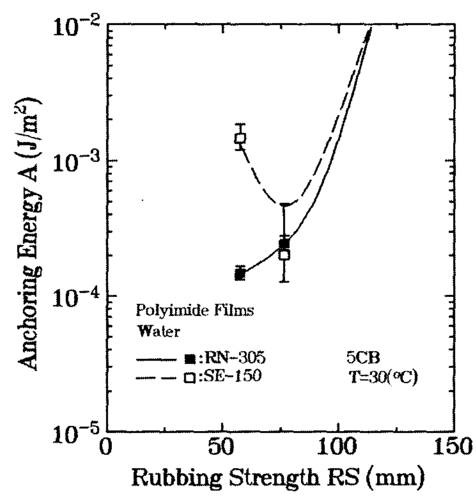


(c) IPA

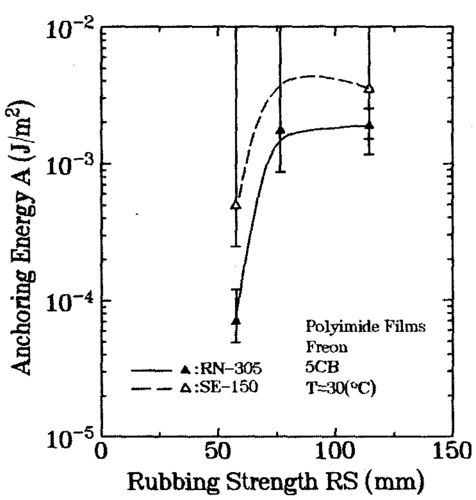
Fig. 3. Extrapolation length d_e of 5CB on the two kinds of the rubbed PI surfaces as a function of rubbing strength RS.

The polar anchoring energy of 5CB for washing processes on the two kinds of the rubbed PI surfaces as a function of rubbing strength RS is indicated in Fig. 4. In Fig. 4 (a), the polar anchoring energy of 5CB on the weakly rubbed PI-1 surface with CONH moiety is approximately 1.5× 10^{-4} (J/m^2) at RS=57 mm and then increases with increasing the RS. The polar anchoring energy of the rubbed PI-2 surface with alkyl side chains is larger than the rubbed PI-1 surface for all washing processes as shown in Fig. 4. The anchoring energy of 5CB on rubbed PI surface is strongly attributed to the surface ordering due to the increase of LC aligning capability[7,11]. From these results, we consider that the washing effects on LC aligning capability strongly depends on the characteristics of the polymer.

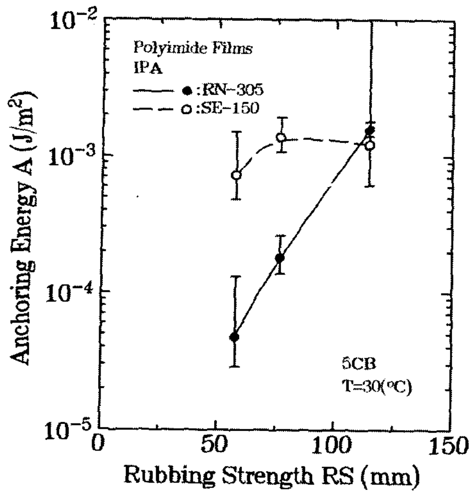
Figure 5 shows the residual optical retardation of 5CB for non-washing and washing processes on the two kinds of the rubbed PI surfaces above the clearing temperature. The surface ordering of 5CB for all washing processes is smaller than the non-washing process on rubbed PI-1 surface with CONH moiety at weak RS region (RS=114mm) as indicated in Fig. 5 (a). However, the surface ordering of 5CB for all washing processes on the rubbed PI-2 surface with alkyl side chains is larger than the non-washing process as shown in Fig. 5 (b). The different behavior of surface ordering in 5CB is observed as indicated in Fig. 5. The dusts on the PI surface removed by the washing process. The stable surface ordering of 5CB on the rubbed PI-2 surface with alkyl side chains can be achieved by the washing process. Therefore, the surface ordering of 5CB strongly depends on the rubbing condition and washing materials.



(a) Water

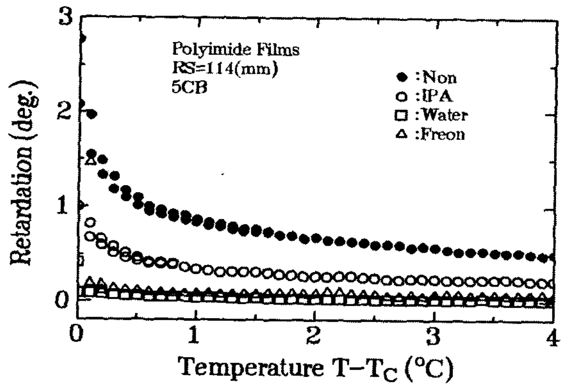


(b) Freon

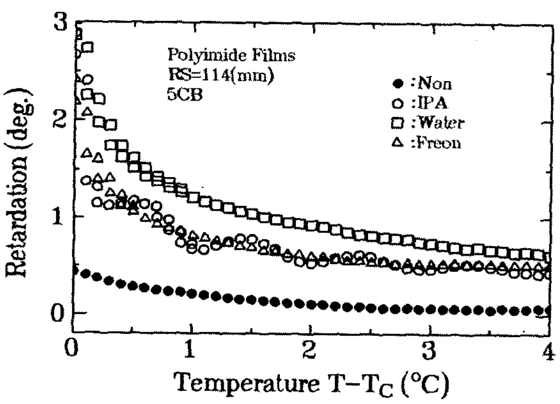


(c) IPA

Fig. 4. Polar anchoring energy of 5CB on the two kinds of the rubbed PI surface as a function of rubbing strength RS.



(a) PI-1



(b) PI-2

Fig. 5. Residual optical retardation in 5CB for non-washing and washing processes on the two kinds of the rubbed PI surfaces at weak rubbing (RS=114mm) above the clearing temperature.

4. CONCLUSION

In conclusion, the anchoring strength and surface ordering in 5CB by the washing processes after rubbing on the two kinds of the rubbed PI surface were studied. The polar anchoring energy of 5CB increased with the rubbing strength on weakly rubbed PI surfaces. The polar anchoring energy of 5CB on the rubbed PI surface with alkyl side chains is larger than the rubbed PI surface with CONH moiety. Also, the surface ordering of 5CB on the rubbed PI surface with alkyl side chains is larger than the rubbed PI surface with CONH moiety. The surface ordering of 5CB strongly depends on the polymers and washing materials. Consequently, we suggest that the LC aligning capability is strongly attributed to the characteristics of the polymer and washing processes.

ACKNOWLEDGEMENTS

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