Polar Anchoring Strength and Surface Ordering in NLC by the Washing Process on Rubbed Polymer Surfaces Containing Trifluoromethyl Moiety

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The polar anchoring strength and surface ordering in a NLC, 4-n-pentyl-4'-cyanobiphenyl (5CB), on a rubbed polyimide (PI) surface containing trifluoromethyl moiety were studied. The large extrapolation length d_e of 5CB for washing process of water was measured at RS=114 mm. The polar anchoring energy of 5CB on the rubbed PI surface is decreased by the washing process. Also, the polar anchoring energy of 5CB increases with the rubbing strength on the PI surface. The surface ordering of 5CB for all washing processes is smaller than the non-washing process; it is attributed to the washing process.

Keywords : Nematic liquid crystal, Washing, rubbing, Anchoring strength, Trifluoromethyl moiety

1. INTRODUCTION

Recently, thin film transistor (TFT) - liquid crystal display (LCD) are widely utilized for the information display device. The LC alignment mechanism is not understood completely, rubbed polymer surface are widely used as an alignment film in practical applications. TFT-LCD is damaged by the induced electrostatic charges produced during rubbing process. Previously, H. Matsuda et al. reported the induced electrostatic charges and pretilt angle generation of NLC on various rubbed PI surface as a function of rubbing strength[1]. In the practical fabrication of LCDs, the washing process is used to remove the dust and electrostatic charges after the PI surfaces are rubbed.

The LC aligning capabilities and anchoring strength (energy) on treated substrate surfaces have been discussed[2-7]. In a previous study, we reported the first measurement of the temperature dependence of the polar (out-of-plane tilt) anchoring strength of weakly rubbed PI surfaces in a 5CB[3]. We also reported the temperature dependence of the polar anchoring strength of 5CB on various PI-LB surfaces[8].

In this paper, we report the washing effects on the polar anchoring strength and the surface ordering in NLC, 5CB, on rubbed PI surfaces containing trifluoromethyl moiety.

2. EXPERIMENTAL

The molecular structure of the polymer (from Nissan Chemical Industries Co.) 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 500 Å. 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 a previous paper[9]. The rubbed PI surfaces were washed after for rubbing. The following washing materials are used: isopropylalcohol (IPA), pure water, and freon. The characteristics of washing materials are amphiphilic, hydrophilic, and hydrophobic, respectively. We used the wet method for 20 min. for the washing process. LC cells were assembled with the antiparallel to rubbing direction. We measured the anchoring strength by using "high electric-field techniques"[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 as shown in Fig. 2. The optical retardation measurement system consists of a polarizer, an acousto-optic modulator, and an analyzer. The output signal is detected by a photodiode. 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]

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

where I_o 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 Tc.

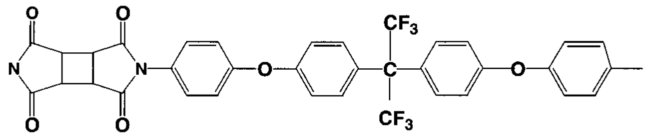


Fig. 1. Chemical structure of the polymer.

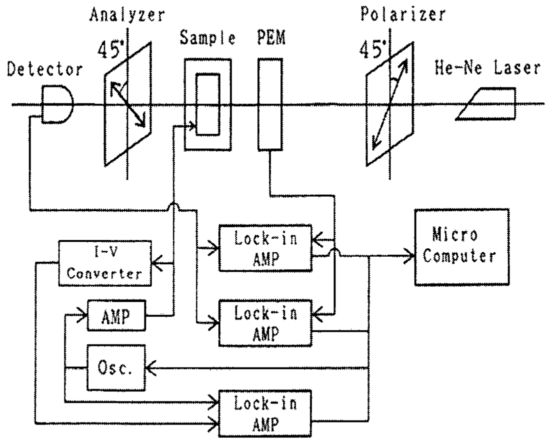


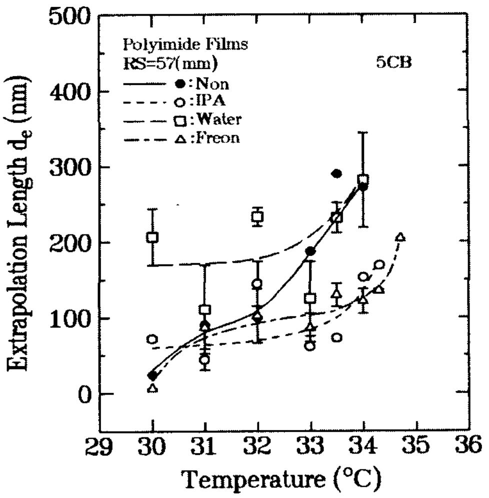
Fig. 2. Measurement system of polar anchoring strength.

3. RESULT AND DISCUSSION

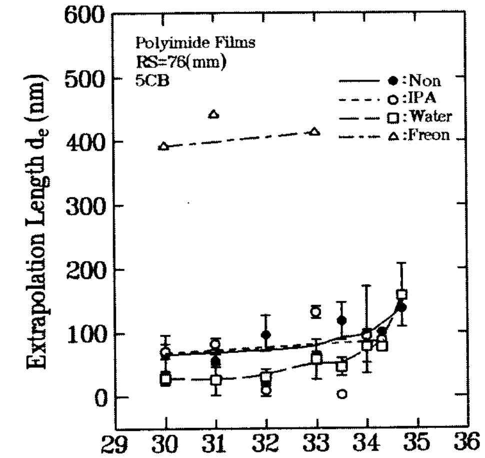
Figure 3 shows the temperature dependence of the extrapolation length d_e of 5CB for non-washing and washing process on the rubbed PI surface containing trifluoromethyl moiety. The extrapolation length d_e of 5CB for non-washing and washing on the rubbed PI surface increases with increasing the temperature. It is considered that the extrapolation length de of 5CB on the rubbed PI surface increased due to the decreasing of surface ordering[2,8].

Figure 4 shows the extrapolation length de of 5CB for non washing and washing processes on the rubbed PI surface containing trifluoromethyl moiety as a function of rubbing strength RS. The extrapolation length d_e of 5CB for non-washing process on the rubbed PI surface at RS=114 mm was obtained about 0, it is indicates the strong anchoring strength. The extrapolation length d_e of 5CB for all washing processes on the rubbed PI surface is larger than the non-washing process. The weak anchoring strength of 5CB for all washing processes on the rubbed PI surface was obtained.

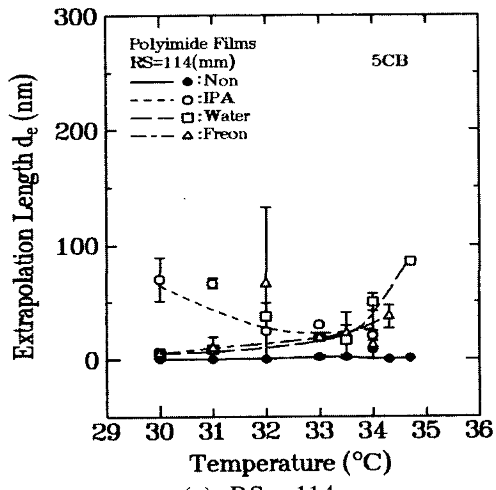
Figure 5 shows the temperature dependence of the polar anchoring energy of 5CB for non-washing and washing process on the rubbed PI surface containing trifluoromethyl moiety. The polar anchoring energy 5CB for non-washing and washing on the rubbed PI



(a) RS = 57 mm



(b) RS = 76 mm



(c) RS = 114 mm

Fig. 3. Temperature dependence of the extrapolation length d_e of 5CB for non-washing and washing processes on the rubbed PI surface containing trifluoromethyl moiety.

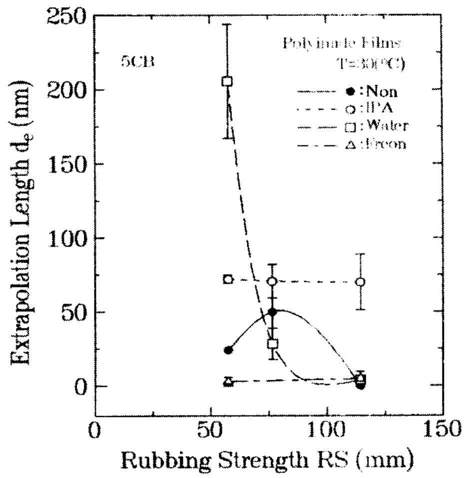
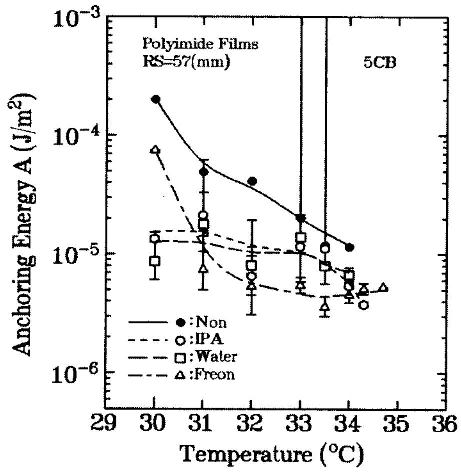


Fig. 4. Extrapolation length d_e of 5CB for non-washing and washing processes on the rubbed PI surface containing trifluoromethyl moiety as a function of rubbing strength RS.

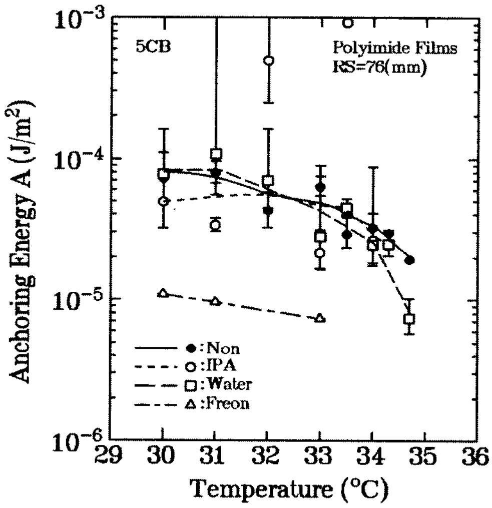
surface increases with increasing the temperature. The polar anchoring energy of 5CB for non-washing process on the rubbed PI surface is approximately 1× 10^{-3} (J/m^2) at 30℃ as shown in Fig. 5 (c). The polar anchoring energy of 5CB for non-washing process on the rubbed PI surface is larger than the all washing processes at all temperature region.

Figure 6 shows the polar anchoring energy of 5CB for non-washing and washing processes on weakly rubbed PI surface with trifluoromethyl moiety as a function of rubbing strength RS. The polar anchoring energy of 5CB for non-washing process on weakly rubbed PI surface is approximately 2× 10^{-4} (J/m^2) at RS=57 mm and then increases with increasing the RS. The polar anchoring energy of 5CB on rubbed PI surface is strongly attributed to the surface ordering due to the increase of LC aligning capability[8,10]. Also, the polar anchoring energy of 5CB is decreased by the washing process; the washing effects are clearly observed. In a previous work, the polar anchoring energy of 5CB on weakly rubbed PI surface with alkyl side chains is increased by the washing process[11].

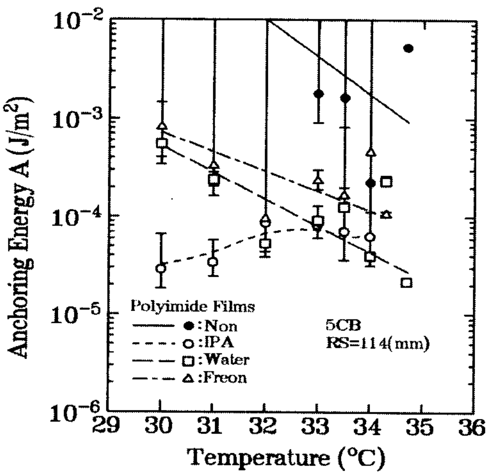
Figure 7 (a) and (b) show the residual optical retardation of 5CB for non-washing and washing processes on rubbed PI surface containing trifluoromethyl moiety above the clearing temperature. The surface ordering of 5CB for all washing processes on rubbed PI surface containing trifluoromethyl moiety is smaller than the non-washing process. The surface ordering of 5CB on the rubbed PI surface containing trifluoromethyl moiety is decreased due to the variation of surface characteristics by the washing process. Consequently, we suggest that the polar anchoring



(a) RS = 57 mm



(b) RS = 76 mm



(c) RS = 114 mm

Fig. 5. Temperature dependence of the polar anchoring energy of 5CB for non-washing processes on rubbed PI surface containing trifluoromethyl moiety.

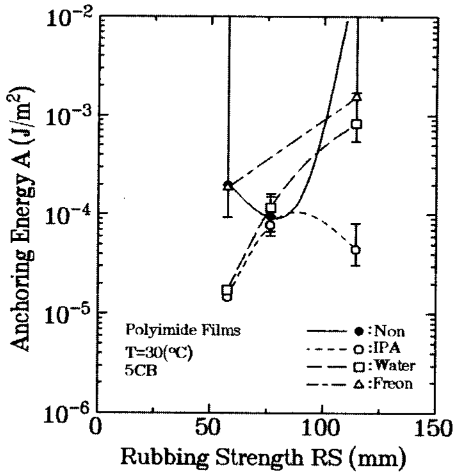
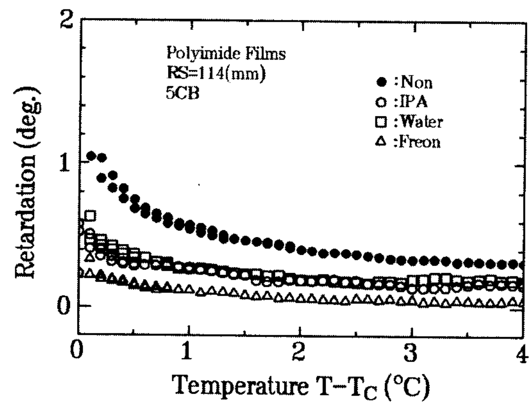
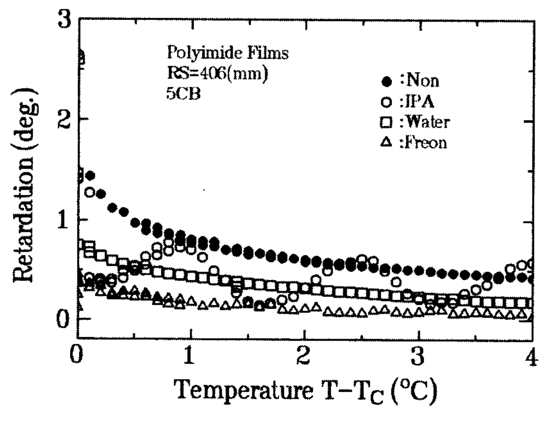


Fig. 6. Polar anchoring energy of 5CB for non-washing and washing processes on the rubbed PI surface as a function of rubbing strength RS.



(a) RS = 114 mm



(b) RS = 406 mm

Fig. 7. Residual optical retardation in 5CB for non washing and washing processes on rubbed PI surfaces containing trifluoromethyl moiety above the clearing temperature.

strength and surface ordering are unstabilized by the washing processes; LC aligning capability is largely attributed to the washing effects.

4. CONCLUSION

In summary, the polar anchoring strength and surface ordering in 5CB by washing process on the rubbed PI surface containing trifluoromethyl moiety were studied. The extrapolation length d_e of 5CB on the rubbed PI surface decreases with the rubbing strength. Also, the large extrapolation length d_e of 5CB for washing process of IPA was measured at RS=114 mm. The polar anchoring energy of 5CB on the rubbed PI surface is decreased by the washing process ; the washing effects are clearly observed. Also, the polar anchoring energy of 5CB increases with rubbing strength on the PI surface. The surface ordering of 5CB for all washing processes is smaller than the non-washing process; it is attributed to the washing process. Finally, the polar anchoring strength and surface order parameter in 5CB is largely attributed to the washing effects.

ACKNOWLEDGMENTS

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