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Investigation of washing process on surface liquid crystal alignment and polar anchoring energy in NLC on rubbed polyimide surfaces

논 문
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Abstract

In this work, the influences of washing processes on the surface liquid crystal (LC) aligning capability on rubbed polyimide (PI) surface with CONH moiety were investigated. The induced optical retardation from non-washing process on rubbed PI surface was larger when compared with the washing processes. The pretilt angles in 4-n-pentyl-4′-cyanobiphenyl (5CB) decreased by the washing process. The polar anchoring energy of 5CB decreased by the washing processes on weakly rubbed PI surface ; the washing effects are clearly observed. The surface order parameter S_S of 5CB strongly depends on the rubbing strength and washing materials. Consequently, we suggest that the LC aligning capability is strongly attributed to the characteristic of the polymer and washing processes.

Key Words(중요용어) : Nematic liquid crystal(NLC), polyimide, rubbing strength, washing Process, anchoring strength, surface ordering

1. INTRODUCTION

Pretilt angle prevents the creation of reverse tilt disclinations in twisted nematic (TN)-liquid crystal display (LCD). The generation of pretilt angle in NLC on polyimide (PI) layers by unidirectional rubbing has been demonstrated and discussed by many investigators[1~5]. Rubbed PI 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, uniform LC alignment, high charge retention and good thermal stability.

TN-LCDs have been fabricated by using mechanical rubbing to align LCs, but it generates dusts and electro-static charges. The thin film transistor (TFT) - LCD is damaged by the induced electro-static charges produced during rubbing. Previously, Matsuda et al. reported the induced electro-static charges and pretilt angle generation of NLC on various rubbed PI surface as a function of rubbing strength[6]. In practical fabrication of LCDs, the washing process is used to remove the dust and electro-static charges after the PI surfaces are rubbed.

The anchoring strength (energy) between the LCs and the alignment layers on treated substrate surfaces has been demonstrated and discussed by many investigators[7~9]. In a previous work, we reported the first measurement of the temperature dependence of the polar (out-of-plane tilt) anchoring strength of weakly rubbed PI surfaces in 5CB[10]. We also reported the relationship between the surface order parameter and the polar anchoring energy in 5CB on weakly rubbed PI surfaces[11]. Most recently, we reported the washing effects on the pretilt angle, polar anchoring strength, and surface order parameter for 5CB on rubbed PI surface with side chain[12].

In this work, we report the influences of washing processes on the pretilt angle gen-

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eration, the anchoring strength, and the surface order parameter in NLC, 5CB, on rubbed PI surfaces with CONH moiety.

2. EXPERIMENTAL

The molecular structure of the used polymer material 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 (Y_0-15-N, Yoshikawa Chemical Industries Co., Ltd.). The definition of the rubbing strength RS was given in previous papers[2,3]. 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. The LC layer thickness was set to $60.0\pm0.5\mu m$. To measure pretilt angles, we used the crystal rotation method for values up to 10° and the magneto capacitive null method for values above 10°. The measurement of pretilt angle was done at room temperature (22℃). Also, we measured the induced optical retardation on rubbed PI surface with side chain. Next, we measured the anchoring strength by using "high electric-field techniques"[7,8]. 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 de is determined by using the relationship between the measured values of the electric capacitance and the optical retardation :[7,8]

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

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 $K=K_1\cos^2\theta_0+K_3\sin^2\theta_0$, where K_1, K_3, and θ_0 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 order parameter S_s was obtained by measuring the residual optical retardation induced on the polyimide surface above the nematic-isotropic transition temperature T_c[13].

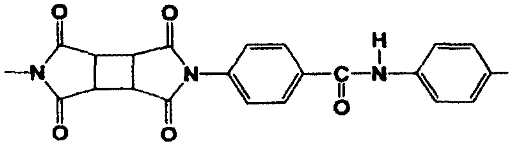


Fig. 1. Chemical structure of the polymer.

3. RESULTS AND DISCUSSION

Figure 2 shows the induced optical retardation on rubbed PI surface with CONH moiety for non-washing and washing processes as a function of RS. The induced optical retardation for non-washing process on rubbed PI surface increases with increasing the RS : it is attributed by the rubbing process. It is considered that the rubbing process gives rise to an enhanced orientation of polymer chains, thereby creating more anisotropy environment for the LC alignment. The induced optical retardation on rubbed PI surfaces decreased by the washing processes, which indicates the washing effects. In a previous work, the similar effects were observed by author group[12].

Figure 3 (a), (b), and (c) show the generation of pretilt angles in 5CB for non-washing and washing processes on rubbed PI surface with CONH moiety as a function of RS. The obtained pretilt angles for non-washing and washing processes on the rubbed PI surfaces increases with increasing RS, and then saturate. The pretilt angles of 5CB decreased by the washing processes at a strong RS region. It is considered that the generated pretilt angles of 5CB strongly depends on the washing process.

Figure 4 shows the extrapolation length of

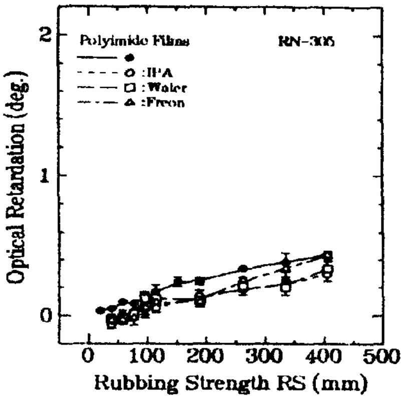
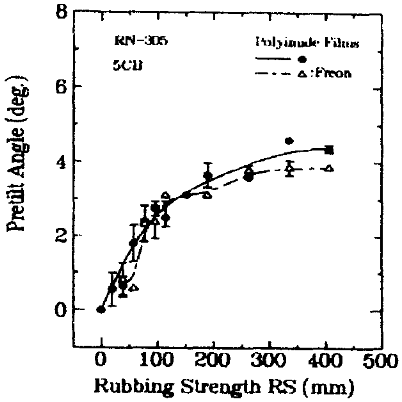
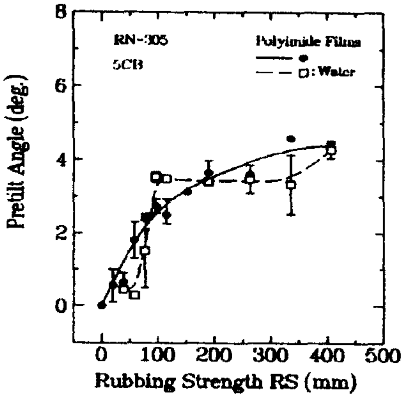


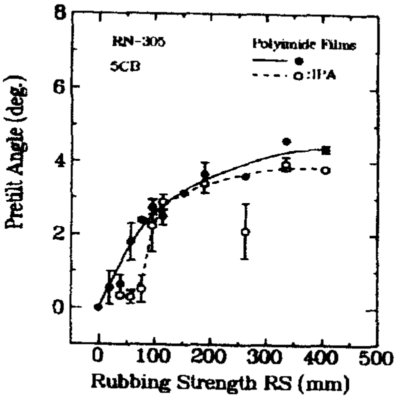
Fig. 2. Induced optical retardation for non-washing and washing processes on rubbed PI surface with CONH moiety as a function of RS.



(a)



(b)



(c)

Fig. 3. Pretilt angle of 5CB for non-washing and washing processes on rubbed PI surface with CONH moiety as a function of RS (a) Freon, (b) Water, (c) IPA.

de of 5CB for non-washing and washing processes on weakly rubbed PI surfaces with CONH moiety. The extrapolation length d_e of 5CB for non-washing and washing processes decreases with RS. The extrapolation length de of 5CB for all washing processes was larger than that on non-washing process. The washing effects on extrapolation length d_e of 5CB is cleary observed at weak RS region.

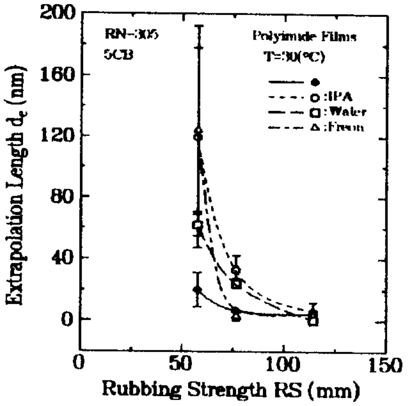


Fig. 4. Extrapolation length de of 5CB for non-washing processes on rubbed PI surface with CONH moiety as a function of RS.

The polar anchoring energy in 5CB for non-washing and washing processes on weakly rubbed PI surface with CONH moiety as a function of RS is shown in Fig. 5. The polar anchoring energy of 5CB for non-washing process on weakly rubbed PI surface is approximately 3×10^{-4} (J/㎡) at RS=57 ㎜ and then increases with increasing the RS. The anchoring strength of 5CB on rubbed PI surface is strongly attributed to the surface ordering due to the increase of LC aligning capability[11, 12]. Also, the polar anchoring strength of 5CB decreased by the washing process ; the washing effects are clearly observed. Recently, we reported the washing effects on the polar anchoring energy of 5CB on rubbed PI surface with side chain[12]. The polar anchoring energy of 5CB increased by the washing processes[12]. From these results, we consider that the washing effects on LC aligning capability strongly depends on the characteristics of the polymer.

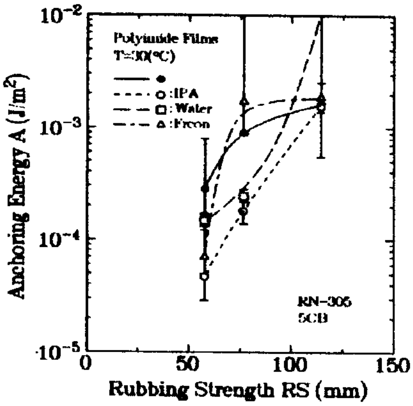
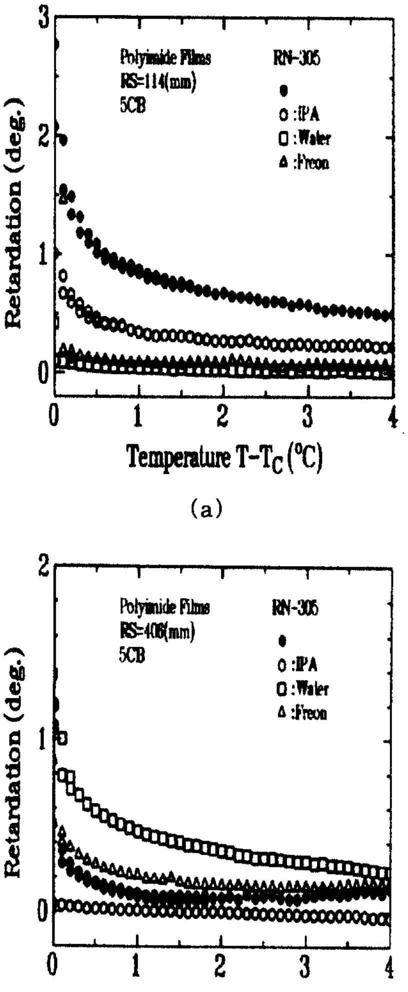


Fig. 5. Polar anchoring energy of 5CB for non-washing processes on rubbed PI surface with CONH moiety as a function of RS.

Figure 6 (a) and (b) show the residual optical retardation of 5CB for non-washing and washing processes on rubbed PI surface above the clearing temperature. The surface ordering of 5CB for all washing processes is small than the non-washing process on rubbed PI surface at weak RS region (RS=114㎜) as shown in Fig. 6 (a). However, the surface ordering of 5CB for washing processes (water and freon) is larger than that on non-washing process as shown in Fig. 6 (b).

The surface order parameter S_S of 5CB for non-washing and washing processes on rubbed PI surface with CONH moiety as a function of RS is shown in Fig. 7. The surface order parameter S_S of 5CB for non-washing process on rubbed PI surfaces increases with increasing the RS and then decreased above the RS=114㎜. The different behavior of surface order parameter S_s

in 5CB was observed. Therefore, the surface order parameter Ss of 5CB strongly depends on the rubbing condition and washing materials. Consequently, we suggest that the pretilt angle, anchoring strength, and surface order parameter are strongly attributed to the washing effects.



(a)

(b)

Fig. 6. Residual optical retardation in 5CB for non-washing and washing processes on rubbed PI surfaces with CONH moiety above the clearing temperature.
(a) RS=114㎜, (b) RS=406㎜.

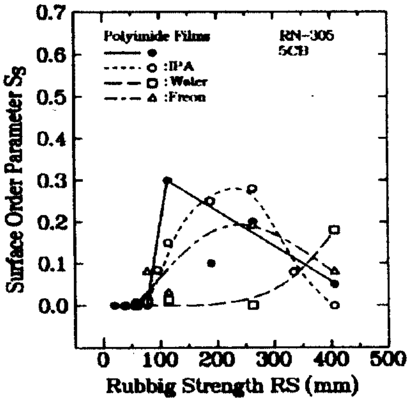


Fig. 7. Surface order parameter S_S of 5CB for non-washing and washing processes on rubbed PI surface with CONH moiety as a function of RS.

4. CONCLUSION

In summary, the influences of washing process on the LC aligning capability for NLC, 5CB, on rubbed PI surface with CONH moiety was successfully investigated. The induced optical retardation for non-washing process on rubbed PI surface was larger than the washing process. The pretilt angles in 5CB decreased by the washing processes. The polar anchoring energy of 5CB decreased by the washing processes on weakly rubbed PI surfaces. The surface order parameter S_S in 5CB depends on the rubbing condition and washing materials. Consequently, we suggest that the LC aligning capability is attributed to the washing process and PI materials.

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