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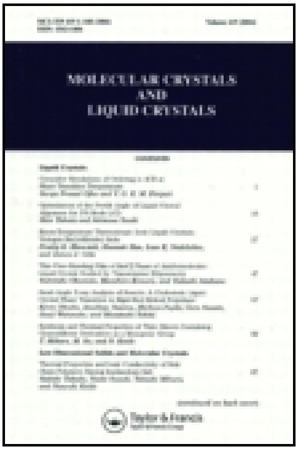
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Dielectric Anisotropy Effects on Pretilt Angle Generation for Nematic Liquid Crystals on a Polymer Layer

Dae-Shik Seo [a] , Jeoung-Yeon Hwang [a] , Sang-Keuk Lee [b] , Seung-Hee Lee [c] & Seung-Kwon Paek [d]

[a] Dept. of Electrical and Electronic Eng. (C-724), College of Eng. , Yonsei University , Seodaemoon-ku, Seoul, Korea

[b] Dept. of Electrical Eng., College of Eng. , Kwangwoon University , Nowon-ku, Seoul, Korea

[c] Dept. of Polymer Science and Technology, College of Eng. , Chonbuk National University , Chonju, Chonbuk, Korea

[d] Dept. of Electronic Eng., College of Eng. , Inje University , Kimhae, Kyungnam, Korea

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DIELECTRIC ANISOTROPY EFFECTS ON PRETILT ANGLE GENERATION FOR NEMATIC LIQUID CRYSTALS ON A POLYMER LAYER

Dae-Shik Seo and Jeoung-Yeon Hwang
Dept. of Electrical and Electronic Eng. (C-724), College of Eng., Yonsei University, 134 Shinchon-dong, Seodaemoon-ku, Seoul 120-749, Korea

Sang-Keuk Lee
Dept. of Electrical Eng., College of Eng., Kwangwoon University, 447-1 Wolgye-dong, Nowon-ku, Seoul 139-701, Korea

Seung-Hee Lee
Dept. of Polymer Science and Technology, College of Eng., Chonbuk National University, Chonju, Chonbuk 561-756, Korea

Seung-Kwon Paek
Dept. of Electronic Eng., College of Eng., Inje University, Kimhae, Kyungnam 621-749, Korea

Generation of the pretilt angle in nematic liquid crystal (NLC) with negative dielectric anisotropy and cyano (CN) mixtures on a rubbed polyimide (PI) surface was studied. The pretilt angle of negative type NLC generated was larger than that of the positive type NLC on the rubbed PI surface for homogeneous alignment. However, the pretilt angle of negative type NLC generated was lower than that of the positive type NLC on the rubbed PI surface for homeotropic alignment. The different mechanisms of LC pretilt angle for homeotropic and homogeneous alignment can be observed. The pretilt angle increases with cyano content on the rubbed PI surface for homogeneous alignment and then saturates with further addition.

Keywords: cyano LC; homeotropic alignment; negative dielectric anisotropy; nematic liquid crystal (NLC); pretilt angle

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Address correspondence to Dae-Shik Seo, Dept. of Electrical and Electronic Engineering (C-724), College of Engineering, Yonsei University, 134 Shinchon-dong, Seodaemoon-ku, Seoul 120-749, Korea.

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INTRODUCTION

Active matrix (AM)-liquid-crystal displays (LCDs) have been largely employed in flat panel display (FPD) applications because of high resolution and high image quality. LCDs require monodomain alignment and control of the pretilt angle of NLC molecules on the substrate surfaces. The commercial LCDs utilize rubbed PI surface to control LC alignment. The pretilt angle prevents the creation of reverse tilted disclinations in twisted nematic (TN) and vertical-alignment (VA) modes. The generation of LC pretilt angle on the rubbed PI surface for homogeneous alignment has been discussed by many researchers [1–10]. Recently, we have reported the $\pi - \pi$ interactions between the NLC molecular and polymer surface on pretilt angle generation [11]. The correlation between the perpendicular permittivity $\varepsilon_{\perp}$ of NLC and the pretilt angle on a rubbed PI surface has been reported by M. Nishikawa *et al.* [12]. Also, the pretilt angle generation in NLC by second harmonic generation (SHG) on a rubbed PI surfaces has been investigated [13]. However, the control of pretilt angle in NLC on the rubbed PI surface for homeotropic alignment is not reported yet. The details of the mechanism on pretilt angle generation in NLC for homeotropic alignment have not yet been understood. In this study, we report on the generation of the LC pretilt angle with negative and positive dielectric anisotropy and cyano mixtures on the various rubbed PI surfaces.

EXPERIMENTAL

In this experiment, various types of polymers were used:

PI-1: SE-7492, for high pretilt angle of homogeneous alignment (from Nissan Chemical Industries Co.)
PI-2: JALS-146-R34, for low pretilt angle of homogeneous alignment (from JSR Co.)
PI-3: JALS-146-R37, for low pretilt angle of homogeneous alignment (from JSR Co.)
PI-4: JALS-696, for homeotropic alignment (from JSR Co.)
PI-5: JALS-204, for homeotropic alignment (from JSR Co.)

The polymers were uniformly coated by spin-coating method on indium-tin-oxide (ITO) electrodes. The polymers were baked at 180°C for 1 hr on the PI-2, PI-3, PI-4, and PI-5 surfaces. Also, the polymer was baked at 220°C for 1 hr on the PI-1 surface. The thickness of the PI layer was set at 500Å. The substrate surfaces were rubbed by rubbing machine. Author

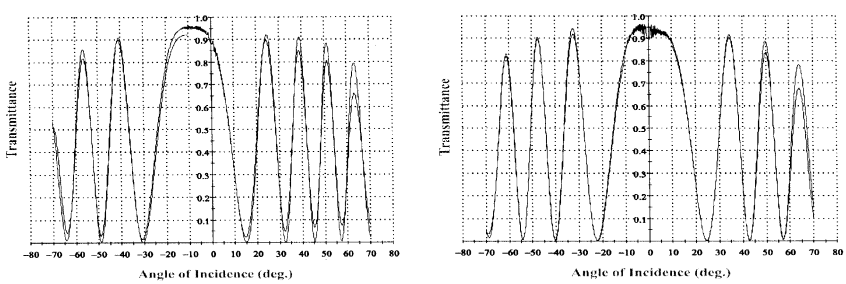
TABLE I NLCs Used in this Study.

NLCs	CN (%)	ε	$\varepsilon_{\perp}$	$\Delta\varepsilon$
LC-1	0	11.4	4.2	7.2
LC-2	5	11.7	4.4	7.3
LC-3	10	11.8	4.5	7.3
LC-4	15	11.6	4.4	7.2
LC-5	20	11.9	4.6	7.3
LC-6		3.7	7.6	−3.9
LC-7		9.6	3.4	6.2
LC-8		3.5	7.3	−3.8
LC-9		10.8	3.4	7.4

group in previous papers defined the rubbing strength (RS) [3–5]. The cell was fabricated as a sandwich type, and the thickness of the cell was 60 μm. After fabricating the cell, a mixture of NLC was injected in isotropic phases. LC cells were cooled to room temperature. Table I shows the NLCs used in this study. LC pretilt angles were measured using the crystal-rotation method at room temperature.

RESULTS AND DISCUSSION

Figure 1 shows the measurement of the tilt angle in the NLC on the rubbed PI surface with homeotropic alignment. A larger shift of symmetric point from point 0 was measured on the PI-4 surface with a medium rubbing strength, 187 mm, as shown in Figure 1(a). Thus, it is shown that a low tilt angle can be achieved. In the other words, a high pretilt angle of the NLC was measured. However, no shift of symmetric point from point 0 was



(a) PI – 4 (RS = 187 mm) (b) PI –5 (RS = 187 mm)

FIGURE 1 Measurement of the pretilt angle in NLC on the rubbed PI surface for homeotropic alignment.

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observed on the rubbed PI-5 surface with a medium rubbing strength, 187 mm, as shown in Figure 1(b).

Figure 2 shows the LC pretilt angles with dielectric anisotropy on the rubbed PI surface for homogeneous alignment. The pretilt angle of the rubbed PI-1 surface for all NLC was higher than that of the rubbed PI-2 and PI-3 surface on a homogeneous alignment. It is considered that the high pretilt angle in NLC is attributed to steric interaction between the LC molecular and the side chain of polymer on the rubbed PI-1 surface. Also, the pretilt angle of negative type NLC was higher than that of the positive type NLC for medium rubbing strength on the three kinds of PI surface of homogeneous alignment. Generally, the negative type NLC has fluorine moiety in side chain of phenol. We can consider that the steric interaction between the NLC molecular and the polymer surface increases with increasing perpendicular component of permittivity of the NLC. The high pretilt angle in NLC can be attributable to steric interaction between the fluorine moiety and the NLC molecular. We think that steric interaction is one cause in generation of tilt among the many other interactions.

Figure 3 shows the LC pretilt angles with dielectric anisotropy on the rubbed PI surface for homeotropic alignment. The pretilt angle of the rubbed PI-4 surface for all NLC was higher than that of the rubbed PI-5 surface region on a homeotropic alignment. It is considered that the high pretilt angle in NLC is attributable to side chain of the polymer. Also, the pretilt angle of positive type NLC was higher than that of the negative type NLC on a homeotropic PI surface. This behavior for homeotropic alignment

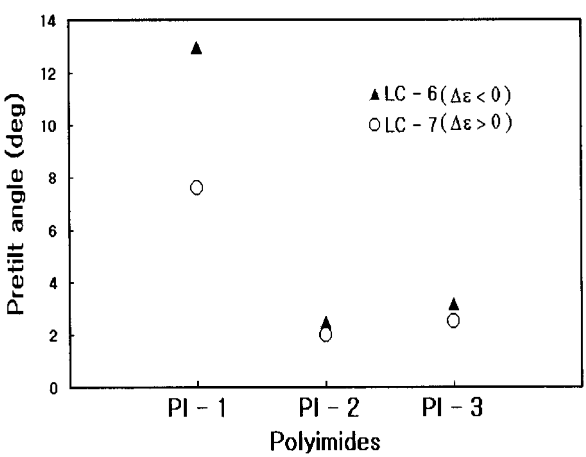

FIGURE 2 Pretilt angles in NLC with dielectric anisotropy on the rubbed PI surface for homogeneous alignment.

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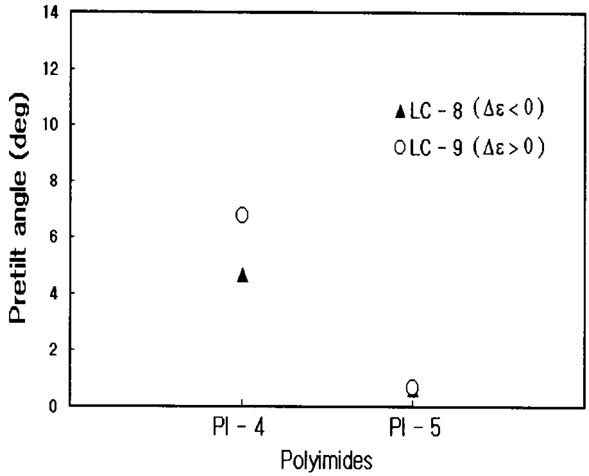

FIGURE 3 Pretilt angles in NLC with dielectric anisotropy on the rubbed PI surface for homeotropic alignment.

is different from the one for homogeneous alignment. Generally, the LC pretilt angle generated is attributable to steric interaction between the LC molecular and the polymer surface on the rubbed PI surface for homogeneous alignment [2,5,12]. Consequently, the different mechanisms of the LC pretilt angle for homeotropic and homogeneous alignment were observed.

The LC pretilt angles on the rubbed PI-1 surface as a function of perpendicular component of permittivity of the NLC were shown in Figure 4. The LC pretilt angle generated was about 8 degree in 4.6 of perpendicular permittivity of the NLC on the rubbed PI-1 surface. However, the high pretilt angle in NLC was observed about 12 degree in 7.6 of perpendicular permittivity of the NLC. The LC pretilt angle increased with increasing of perpendicular permittivity of the NLC. Previously, M. Nishikawa *et al.* have reported the correlation between the pretilt angle and the perpendicular permittivity of the NLC for positive NLC on the rubbed PI surface [12]. It is shown that the pretilt angle increases with increasing perpendicular permittivity of the NLC on the rubbed PI surface [12]. Consequently the LC pretilt angle generated can be attributable to steric interaction between the LC molecular and the polymer surface on the rubbed PI surface for homogeneous alignment. We think that steric interaction is one cause in generation of tilt among the other many interactions.

Figure 5 shows the LC pretilt angles on the rubbed PI-1 surface as a function of CN content. The LC pretilt angle gradually increases with

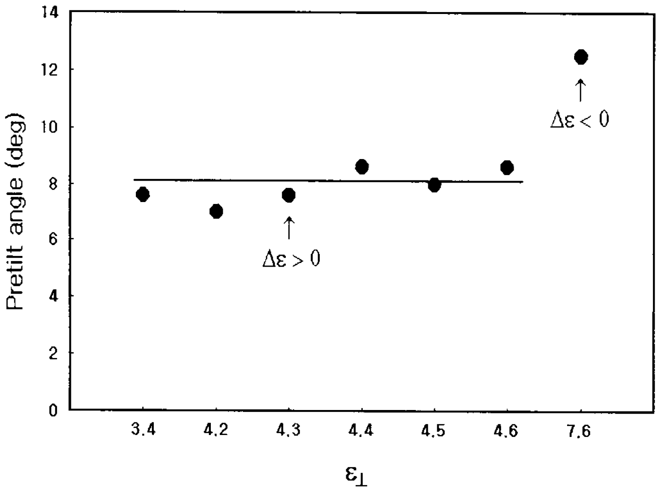

FIGURE 4 NLC pretilt angles on the rubbed PI-1 surface as a function of perpendicular component of permittivity of the NLC.

increasing CN content on the rubbed PI-1 surface. Also, the LC pretilt angle was saturated above 15% of CN content on the rubbed PI-1 surface. The correlation between the rubbing-induced azimuthal orientational distribution of the LC monolayers and the resulting LC bulk pretilt angle

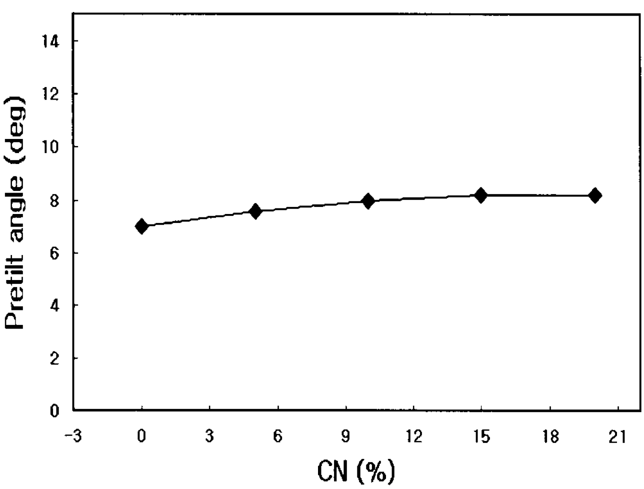

FIGURE 5 Pretilt angles in NLC on the rubbed PI-1 surface as a function of CN content.

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has been reported by M. Barmentlo *et al*. [13]. Therefore, the LC pretilt angle generated can be attributable to surface-induced LC monolayer orientation by previous paper of M. Barmentlo *et al*. Also, we can be considering that the dipole-dipole interaction for NLC increased by increasing of CN content. Therefore, we think that the generation of pretilt angle in NLC is one cause in the dipole-dipole interaction on the rubbed PI-1 surface with side chain.

CONCLUSION

In conclusion, the control of the LC pretilt angle with dielectric anisotropy and cyano mixtures on the various rubbed PI surface was investigated. The pretilt angle of negative type NLC generated was larger than that of the positive type NLC on the rubbed homogeneous PI surface. However, the pretilt angle of negative type NLC generated was lower than that of the positive type NLC on the rubbed homeotropic PI surface. The different mechanisms of LC pretilt angle for homeotropic and homogeneous alignment were observed. The LC pretilt angle generated increases with CN content on the rubbed PI surface and then saturates with further addition. Finally, the generation of LC pretilt angle is attributable to dipole-dipole interaction on the rubbed PI surface for homogeneous alignment.

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