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Short Note

Tilt Angle Generation for Nematic Liquid Crystal on Blended Homeotropic Polyimide Layer Containing Trifluoromethyl Moieties

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A decrease in tilt angle generation for a nematic liquid crystal (NLC) with negative dielectric anisotropy on a blended homeotropic polyimide (PI) surface containing trifluoromethyl moieties was investigated. The decrease in tilt angle (below 90°) of NLC on the blended PI surface containing a homogeneous PI structure having a high tilt angle was measured, and the tilt angle of the polymer was found to decrease as the rubbing strength increased. However, the decreases in tilt angle (about 90°) of NLC on the blended PI homeotropic surface containing two kinds of homogeneous PI structure having a low tilt angle were not observed. The tilt angle of NLC generated was about 73° and the drop of tilt angle is attributable to the trifluoromethyl moiety attached to the lateral benzene ring in the backbone structure on the blended homeotropic PI surface. Therefore, the drop of the tilt angle of NLC to below 90° of NLC can be achieved using the blended homeotropic PI surface. [DOI: 10.1143/JJAP.42.1713]

KEYWORDS: blended homeotropic polyimide, nematic liquid crystal, rubbing strength, tilt angle

Homogeneous alignment of LC molecules can be achieved using rubbed PI films,[1–5)] by oblique evaporation of SiO,[6)] and using Langmuir-Blodgett films.[7)] The pretilt angle prevents the formation of reverse tilted disclinations in TN- and VA-LCDs. Previously, the tilt angles of nematic liquid crystals (NLCs) on a rubbed PI film for homogeneous alignment have been discussed by many researchers.[1–5)] Moreover, we have reported the generation of the tilt angle in NLC on various rubbed PI films containing trifluoromethyl moieties for homogeneous alignment.[8,9)] However, the control of the tilt angle in NLC on a rubbed PI film for homeotropic alignment has not been reported yet.

In this paper, we report the generation mechanisms of a high tilt angle in NLC with negative dielectric anisotropy on a blended PI surface containing trifluoromethyl moieties.

In this experiment, five types of polymers were used:
- PI-1: PI for homeotropic alignment (from JSR Co.)
- PI-2: PI for homeotropic alignment (from JSR Co.)
- PI-3: PI for homogeneous alignment (from JSR Co.)
- PI-4: PI for homogeneous alignment (from JSR Co.)
- PI-5: PI for homogeneous alignment (from JSR Co.)

The molecular structures of the three polymers (PI-3, PI-4, PI-5) used in this study are shown in Fig. 1.[8,9)] Table I shows the compositions of the six types of blended homeotropic polymer used in this study. The six types of polymer were uniformly coated on indium-tin-oxide (ITO) electrodes by a spin-coating method, and imidized at 180°C for 1 h. The thickness of the PI film was set at 500 Å. The substrate surfaces were rubbed with a rubbing machine. The rubbing strength (RS) has been defined in previous papers.[3–5)] The cell was fabricated as a sandwich type with an anti-parallel structure, and the thickness of the cell was 60 μm. After fabricating the cell, a mixture of NLCs was injected in isotropic phases. LC cells were cooled to room temperature. The NLCs had a negative dielectric anisotropy ($\Delta\varepsilon = -4$, from Merck Co.). The pretilt angles were measured by the crystal-rotation method at room temperature.

The NLC tilt angles on the PI-1 and PI-2 surfaces for homeotropic alignment as a function of rubbing strength shows that the tilt angle of NLC generated was about 86° on the rubbed PI-1 and PI-2 surfaces for the strong-rubbing region ($RS = 125$ mm). The tilt angle of NLC generated on the rubbed PI-1 and PI-2 surfaces decreased with increasing rubbing strength. Also, the tilt angle of the NLC generated on the PI-1 surface was lower than that on the PI-2 surface.

The tilt angles of NLCs on the three kinds of soluble PI surface containing trifluoromethyl moieties for homogeneous alignment as a function of rubbing strength are shown

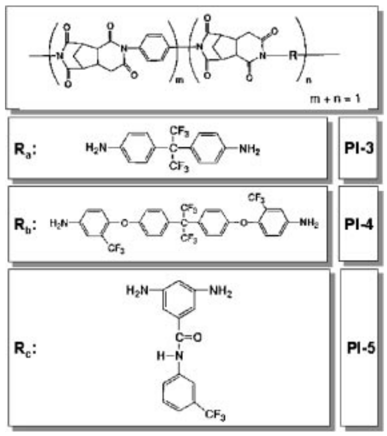

Fig. 1. Molecular structure of three kinds of homogeneous PI containing fluorine group.

Table I. Composition of six types of blended polymer.

Alignment layer	Blended polyimide		Blending ratio
	homeotropic	homogeneous	Homeotropic : homogeneous
Blended PI-1	PI-1	PI-3	1 : 1
Blended PI-2	PI-1	PI-4	1 : 1
Blended PI-3	PI-1	PI-5	1 : 1
Blended PI-4	PI-2	PI-3	1 : 1
Blended PI-5	PI-2	PI-4	1 : 1
Blended PI-6	PI-2	PI-5	1 : 1

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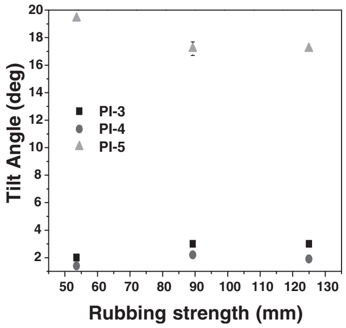
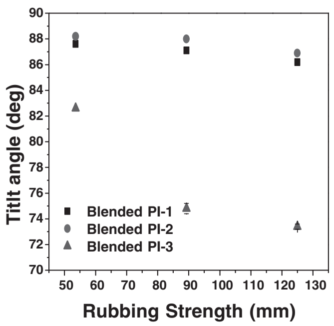


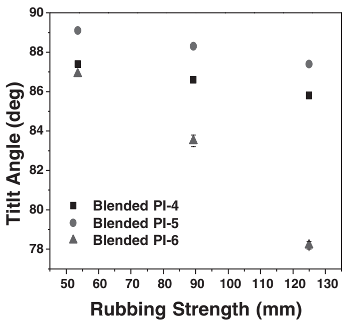
Fig. 2. NLC tilt angles on three kinds of soluble PI surface containing trifluoromethyl moieties for homogeneous alignment as a function of rubbing strength.

in Fig. 2. The tilt angle of NLC generated was about 2° on the PI surface with PI-3 and PI-4 structures for all rubbing strengths. However, the tilt angle of NLC generated was about 19° on the the PI surface with PI-5 structure for all rubbing strengths. The tilt angle of NLC generated decreases with increasing rubbing strength on the PI surface with the PI-5 structure. This large tilt angle of NLC generated on the PI-5 surface is due to the trifluromethyl moieties attached to the lateral benzene ring. It is considered that the high tilt angle in NLC on the rubbed PI surface with the PI-5 structure is attributable to the trifluoromethyl moiety in the backbone structure.[8,9)]

Figure 3 shows the NLC tilt angles on the blended PI surfaces containing trifluoromethyl moieties as a function of



(a) Blended PI-1~PI-3



(b) Blended PI-4~PI-6.

Fig. 3. NLC tilt angles on blended PI surfaces containing trifluoromethyl moieties as a function of rubbing strength. (a) blended PI-1–PI-3; (b) blended PI-4–PI-6.

rubbing strength. The tilt angle of NLC generated on the homeotropic alignment decreases with increasing rubbing strength as shown in Fig. 3(a). That is, the tilt angle of NLC generated on the homeotropic alignment decreases with increasing rubbing strength. Moreover, the tilt angle of NLC generated on the blended PI-3 surface with a homogeneous PI structure having a high tilt angle is lower than that on the blended PI-1 and blended PI-2 surfaces containing homogeneous PI structure having a low tilt angle. The drop of the NLC tilt angle (below 90°) on the homeotropic alignment was measured to be about 73° on the blended PI-3 surface containing a structure PI-5 with a high tilt structure at a high rubbing strength ($RS = 125$ mm). The same results were obtained for blended PI-4 to PI-6 surfaces as shown in Fig. 3(b). It is considered that the drop of the NLC tilt angle on these blended PI surfaces is attributable to the trifluromethyl moieties attached to the lateral benzene ring such that these PI polymers in NLCs generate a high tilt angle. However, the tilt angle of NLC is unaltered on the rubbed PI surfaces with trifluoromethyl moieties attached to the polymer backbone such that these PI polymers in NLCs generate a small tilt angle. Furthermore, the drop of tilt angle of NLC on the blended PI surface is attributed to the homeotropic alignment layer with a lower tilt angle between PI-1 and PI-2. Therefore, it is considered that the tilt angle on the blended PI depends on the location of trifluoromethyl moiety in the backbone generating the tilt angle in NLC, and is due to homeotropic alignment layer with a lower tilt angle.

In conclusion, we investigated the drop of tilt angle generate in NLC on the homeotropic blended PI surface containing trifluoromethyl moieties. Tilt angles of the NLC on the blended PI surface having a high tilt angle were lower than that on the blended PI surface having a low tilt angle. Finally, the drop of tilt angle in NLC generated on the blended PI surface is attributable to the location of the trifluoromethyl moiety attached to the lateral benzene ring in the backbone.

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