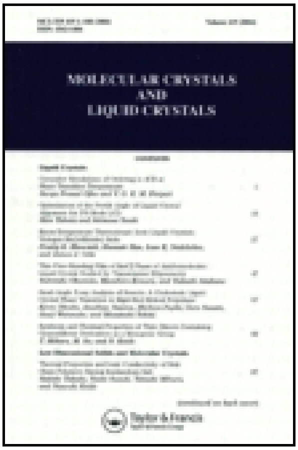

Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Azimuthal Anchoring Properties of Nematic Liquid Crystal on Non-Rubbed Polyimide Surfaces

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Azimuthal Anchoring Properties of Nematic Liquid Crystal on Non-Rubbed Polyimide Surfaces

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The study on the wetting properties of a liquid crystal (LC) on two types of polyimide (PI) films has been done for clarifying the azimuthal surface anchoring properties of LC adsorbed on the films. The results show that the PI showing high wettability of a LC phase gives a higher azimuthal anchoring energy and less temperature dependence of the anchoring energy than the PI with low wettability. We also show that long exposure of a LC phase to PI surfaces leads to a strong adsorption state of LC molecules, indicating the importance of the wetting properties to realize thermal-stable (strong azimuthal anchoring) surface LC alignment.

Keywords: Liquid Crystal; Azimuthal Anchoring Energy; Wettability

1. INTRODUCTION

Liquid crystal displays with an amorphous liquid crystal alignment structure (a-LCDs) are known to show wide and uniform viewing angle characteristics [1,2]. Since a-LCDs are free from any LC alignment treatment such as rubbing, the stability of the LC alignment may be strongly influenced by the adsorbed states of LC molecules on a polymer surface. Thus a detailed behavior of the adsorbed LC molecules is an important factor to determine the device-stability of a-LCDs. Previous investigations of LC molecules adsorbed on two types of polyimide (PI) surfaces demonstrated that the PI with high LC wetting properties showed good thermal stability of LC alignment [3].

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In this paper, the wetting properties of a nematic LC phase on two kinds of PI surfaces are studied with the aim of knowing how the wetting properties influence the azimuthal anchoring of LC molecules on a PI surface.

2. EXPERIMENTAL

Two kinds of organic-solvent soluble PIs, which were also used in a previous study [3], were used as LC alignment films. The chemical structures and surface tensions of the PIs are shown in Fig. 1 and Table I, respectively. The PI with high polarity is named PI-A while the PI with low polarity is referred to as PI-B. These PIs were coated on glass substrates and were baked at 180 °C for 1 hour. The film thicknesses of the PIs were controlled to be about 40 nm. The LC material used was 4′-n-pentyl-4-cyano-biphenyl (5CB), which shows a clearing point of about 35 °C.

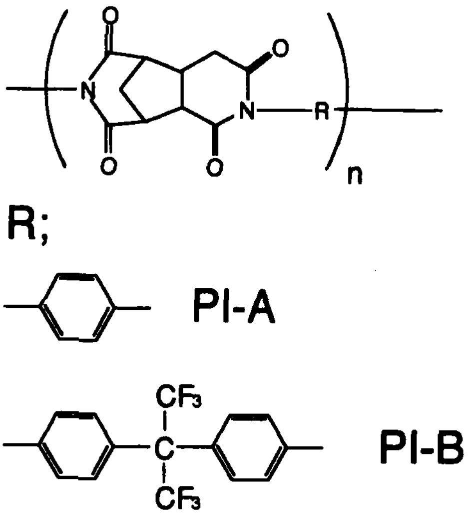

FIGURE 1 Chemical structure of polyimides used in this study

For investigating the azimuthal anchoring originated from LC molecules adsorbed on a PI surface, a one-side rubbed sandwich-type empty cell (5-μm thick) was placed in a uniform magnetic field of 10 kG (a magnetically aligned method: a MA method), where the direction of the applied magnetic field was set to be 85 deg. with respect to the rubbing direction of the opposite substrate surface. The cell was heated up to 60 °C in the field, and 5CB was injected into the cell via a capillary action in the isotropic phase. After the cell was gradually cooled down to room temperature at a cooling rate of 0.1°C/min., the applied magnetic field was switched off. By using this process, a twisted nematic (TN) sample with a twist angle of less than 85 deg. was fabricated.

TABLE I Surface tension of two kinds of polyimide film used in this study

	γ *(dyn/cm)*	γ_p *(dyn/cm)*	γ_d *(dyn/cm)*
PI-A	58.7	19.6	39.1
PI-B	41.4	7.8	33.6

$\gamma = \gamma_p + \gamma_d$: Surface tension.

The fabricated TN cell was then stored for various periods at a room temperature, and the temperature dependence of the twist angle of the sample was measured by using the optical method [4].

3. RESULTS AND DISCUSSION

The contact angle of 5CB on PI-A was less than 1 deg., while that on PI-B was about 4 deg. This result indicates that a PI-A surface is almost perfectly wetted by 5CB and 5CB on a PI-B surface shows partially wetting properties. We previously showed that, in a coexisting temperature region of nematic and isotropic phases, PI-A gave a higher wettability of a nematic phase than PI-B [3], which means that the contact angle of a nematic phase on a PI-A surface may become smaller than that on a PI-B surface and thus the LC surface order parameter for PI-A is higher than that for PI-B [5]. Therefore, the contact angle results presented in this study are consistent with those reported in a previous paper [3].

Figure 2 illustrates the temperature dependence of the twist angle for two kinds of as-prepared MA TN cells with different PI alignment films. We also show the results for the corresponding samples that were stored for four days at room temperature. First, it is clear that the room-temperature storage of the sample significantly changes the temperature behavior, in particular, a large temperature variation of the twist angle observed in PI-B is drastically reduced. A detailed discussion of this reduction in the temperature dependence will be presented later. As for the as-prepared PI-A sample indicated by the open circles, the temperature dependence of the twist angle shows very little decrease (about 5 deg.) on approaching the clearing point, and the twist angle in this entire temperature range is about 70 deg. On the other hand, the twist angle of the as-prepared PI-B

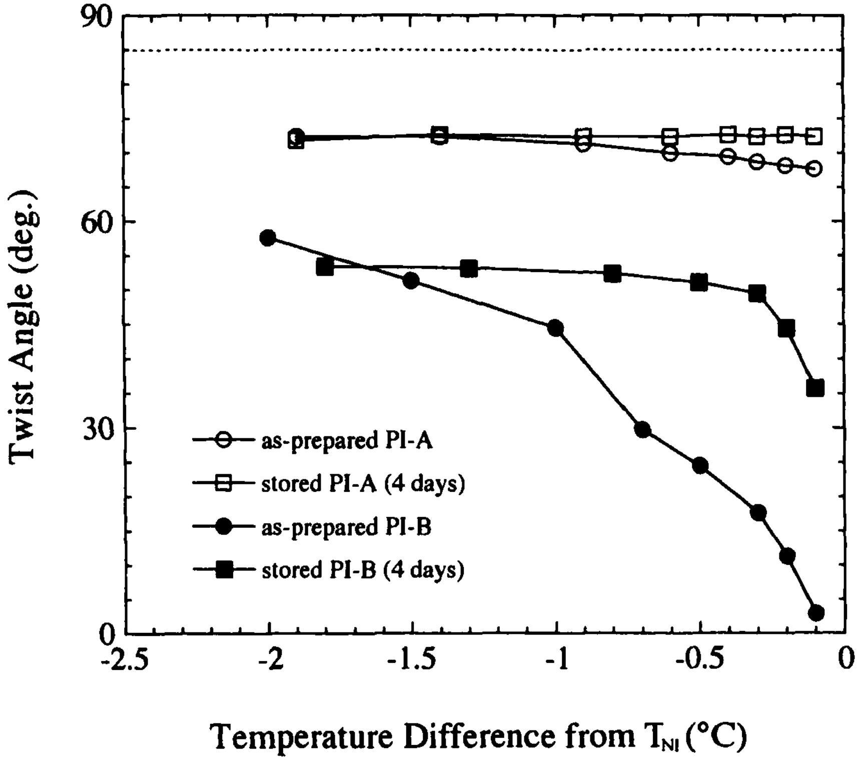

FIGURE 2 Temperature dependence of the twist angle for two types of as-prepared MA TN samples. For comparison, the results for stored samples for four days are also plotted

(closed circles) gradually decreases with increasing the sample temperature and, near the clearing point, the twist angle of the sample becomes about 0 deg., which is much smaller than that of the intended twist angle of 85 deg. It is known that the twisted structure formed in a MA sample is kept only by the azimuthal anchoring force originated from unidirectionally-aligned LC molecules adsorbed on a polymer alignment film, and thus the twisted structure of the sample depends strongly on the adsorbed state of surface LC molecules. For understanding the difference in the twist angle of the two samples, two factors may be important; one is the direction of an easy axis at a non-rubbed (NR) polymer surface that coincides with the adsorbed direction of the surface LC molecules, and the other is the surface LC ordering near a NR polymer surface. From these two factors and the facts that the wettability of a LC phase and the thermal stability of LC alignment in the PI-A sample is better than those in the PI-B sample [3], a larger twist angle observed in PI-A than in PI-B indicates that the LC direction adsorbed on a NR PI-A surface is not significantly deviated from the direction of a magnetic field applied during the sample fabrication (that is, 85 deg.) and that the surface LC ordering near a NR polymer surface in PI-A is higher than that in PI-B. On the other hand, a large temperature dependence of the twist angle in PI-B can be understood by considering that, with increasing the sample temperature, the LC direction adsorbed on a NR PI-B surface is gradually approaching the rubbing direction on the counter polymer surface and the LC surface ordering near a NR PI-B surface has a larger temperature dependence than the bulk LC ordering.

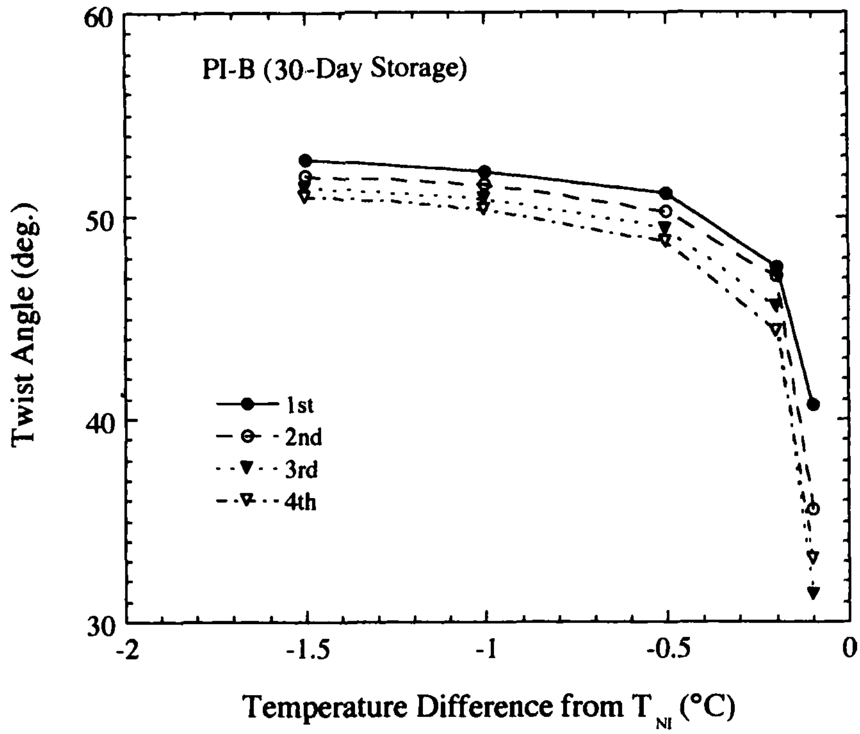

FIGURE 3 Temperature dependence of the twist angle of the PI-B sample stored for thirty days. The measurements were successively conducted four times

It is noted that, in contrast to a conventional rubbed sample, the easy axis in a NR polymer surface is varied as the direction of surface LC molecules adsorbed on the surface is changed. In Fig. 3, we shows the temperature dependence of the twist angle of the PI-B sample stored for thirty days, where the measurements of the twist angle were conducted four times, and the each measurement was done just after finishing the preceding measurement. From this result, the temperature dependence of the twist angle is not exactly reproduced after the measurement, and the magnitude of the twist angle becomes smaller, which may indicate the movement of the easy axis at the PI-B surface. This change in the easy axis direction on NR polymer surfaces was also observed by Xuan et al [6].

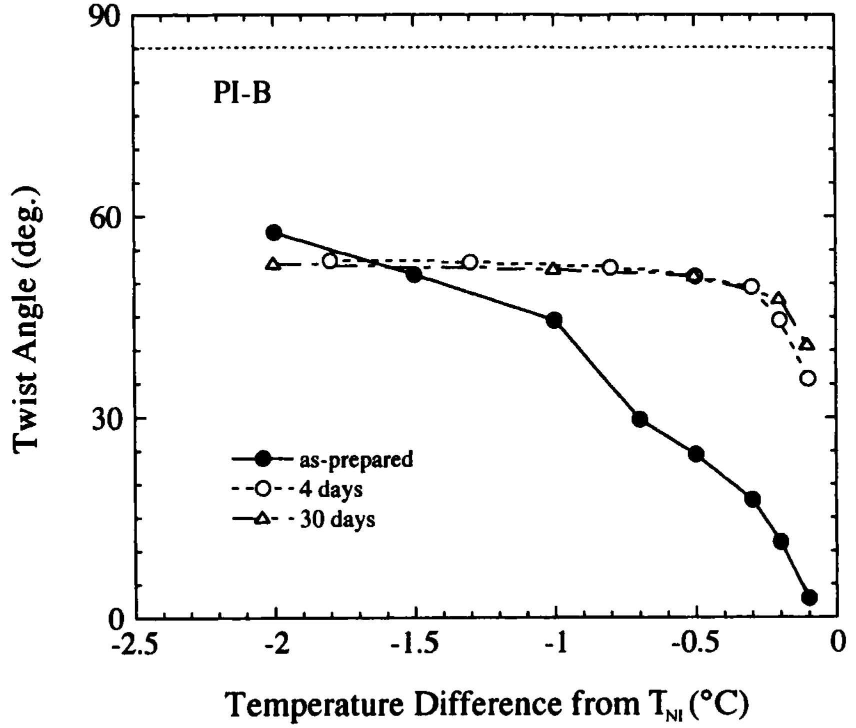

FIGURE 4 Effect of the room-temperature storage of MA samples on the temperature dependence for the PI-B sample

As shown in Fig. 2, the temperature variation of MA samples strongly depends on the storage time at room temperature. A detailed results for the PI-B sample is shown in Fig. 4. After room-temperature storage for four days, the temperature variation of the twist angle is not observed in a low temperature range (<-0.3 °C). but a further approach of the sample temperature to a clearing point induces a sudden change of the twist angle. It is also seen that these temperature behaviors of the twist angle are not changed significantly with a further storage of the sample, which may indicate the saturation in the strength of the adsorption state of surface LC molecules. As discussed in Fig. 2, the change in the twist angle with the temperature is determined by two factors, that is, the change in the easy axis direction originated from the alignment direction of the adsorbing LC molecules on a polymer surface and the surface order parameter. And thus the less temperature dependence of the twist angle for the stored sample than for the as-prepared one suggests increasing adsorption strength of surface LC molecules and surface ordering with exposing LC molecules to a polymer surface, which may result in the improvement of the wettability of a LC phase to a polymer surface.

4. CONCLUSION

The effect of the wettability of 5CB on two types of polyimide films on the azimuthal surface anchoring was studied for using magnetically-aligned TN samples. The results showed that the PI showing high wettability of a LC phase gives a higher azimuthal anchoring energy and less temperature dependence of the anchoring energy than the PI with low wettability. We also showed that long exposure of a LC phase to PI surfaces led to a strong adsorption state of LC molecules and the increasing surface ordering. These results indicate the importance of the wetting properties of LCs to realize thermal-stable surface LC alignment.

Finally, we should stress that, for obtaining the strong azimuthal anchorage of LCs on a polymer surface, the wettability of LC on the polymer surface is one of the important factors even in a photoalignment method [7].

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