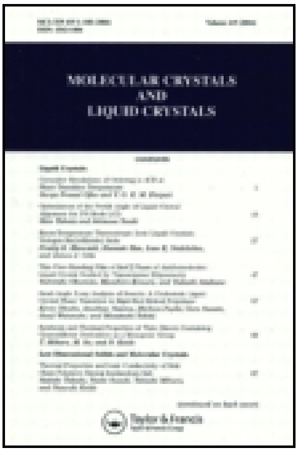


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# Peculiar Alignment Properties of Nematic Liquid Crystals with a Bicyclohexane Core

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# PECULIAR ALIGNMENT PROPERTIES OF NEMATIC LIQUID CRYSTALS WITH A BICYCLOHEXANE CORE

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Abstract A homogeneous alignment of nematic liquid crystals (NLCs) can usually be obtained on a rubbed polymer surface such as a polyimide, where the molecular orientation is parallel to the rubbed direction. Most of NLCs other than those having a bicyclohexane core also align parallel to the rubbing direction on a poly-hydroxyethyl methacrylate (pHEMA) surface. However, the latter having a bicyclohexane core align perpendicular to the rubbing direction on the pHEMA surface. When the NLCs are heated up to the clearing temperature and cooled down to the nematic phase, the alignment direction change from perpendicular to parallel to the rubbing direction

## INTRODUCTION

A uniform alignment of NLC on the substrate surface of LC cells is very important for LC display applications and is also of great interest for the study of interfacial phenomena. The most widely used alignment film is a mechanically rubbed polymer, such as a rubbed polyimide (PI), because of the high quality NLC alignment and the suitability for mass productions. Two phenomena have been considered to determine the homogeneous alignment of NLCs on the rubbed polymers, one is microgrooves on the surface[1] and the other is the orientation of main-chain molecules of the polymer.[2]

Recently, we have proposed a new nonrubbed aligning method of the NLC using UV cured polymer materials.[3,4] We have tried to rub these surfaces and to compare the alignment properties between rubbed and nonrubbed surfaces. In these processes, we found that one NLC aligned parallel and another NLC aligned perpendicular to the rubbing direction on the same polymer material.

In this paper, alignment properties of various NLCs which have different cores and terminal groups on the rubbed UV cured polymer surface are described and some peculiar properties of NLCs which have a bicyclohexane core are reported.

## EXPERIMENTAL

A monomer of hydroxyethyl methacrylate (HEMA from Nippon Kayaku Co., Ltd.) containing a photoinitiator of 3wt% was cured by the UV irradiation of 2 $mW/cm^2$ for 200 s at 25 °C on the indium-tin-oxide (ITO) coated glass substrate. Figure 1 shows a molecular structure of pHEMA. Its surface was rubbed using a polyurethane/nylon, cotton or pulp cloth.

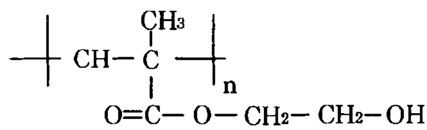


FIGURE 1 A molecular structure of pHEMA.

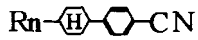
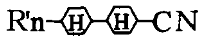
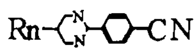
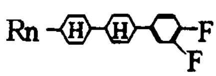
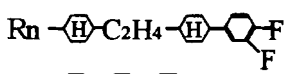
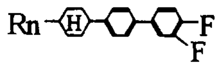
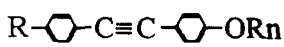
Many NLCs having different cores and terminal groups were prepared. Properties of the NLCs with a negative and a positive dielectric anisotropy were also discussed. Alignment directions of NLCs were determined by measuring the light absorption of guest-host cells or by observing the NLC droplets[5] on the rubbed polymer surface.

## RESULTS AND DISCUSSION

Table 1 shows molecular structures of NLCs and alignment directions on the rubbed pHEMA surface. It becomes clear that the alignment direction of NLCs depends on the structure of the core. CCH, FB-01 and FB-20 which have two cyclohexane rings align perpendicular to the rubbing direction. PCH does not uniformly align on the rubbed pHEMA. The other NLCs align parallel to the rubbing direction. The alignment direction is not affected by the terminal groups such as an alkyl chain, an alkenyl chain, a cyano substituted end or a fluorine substituted end. Two NLCs with a negative dielectric anisotropy align parallel to the rubbing direction because they have no bicyclohexane rings in main ingredients. All NLCs shown in Table 1 align parallel to the rubbing direction on the PI and polyvinylalcohol surfaces. Alignment directions shown in Table 1 are not affected by the kind of rubbing clothes if clean one is used.

Alignment properties are very sensitive to the contamination on the rubbed pHEMA surface. Especially, PCH and FB-20 tend to align parallel to the rubbing direction on the contaminated surface.

TABLE 1 NLC molecular structures and alignment directions

| NLC | structure | rubbing direction/ alignment direction |
|---|---|---|
| **p-type** | | |
| 5CB |  | // |
| PCH |  n=3,5,7 | — |
| CCH |  n=2~5 | ⊥ |
| PE |  n=5,7 | // |
| PECH |  n=3,5 | // |
| PP |  n=5,7 | // |
| A-1 |  n=5,7 | // |
| FB-01 |  n=2,3,5 | ⊥ |
| FB-20 |  n=2,3,5 | ⊥ |
| FB-30 |  n=2,3,5 | // |
| **n-type** | | |
| MBBA |  | // |
| RDN-91207-1 (mixture) |  50% | // |

R: alkyl chain, R′: alkenyl chain
*: from Chisso Co., Ltd. **: from Rodic Co., Ltd.

Alignment directions of mixtures of 5CB and CCH were examined on the rubbed pHEMA surface to compare the effect of the benzene ring to that of the cyclohexane ring. Figures 2(a) ~ 2(e) show polarized microphotographs of NLC droplets under the crossed polarizers. In Fig. 2(a), a disclination line which is perpendicular to the rubbing direction, that is perpendicular to the alignment direction of 5CB, is observed in the droplet. The disclination line through the center of the droplet always appears perpendicular to the NLC alignment.[5] Then, the disclination line parallel to the rubbing direction as shown in Fig. 2(e) indicates that molecules of CCH align perpendicular to the rubbing direction. Moreover the droplet always spreads elliptically of which long axis is coincident with the alignment direction of CCH.

In the droplet of the mixture (5CB/CCH = 90/10), narrow dark regions due to the flow-induced alignment are shown in the longitudinal direction as shown in Fig. 2 (b). Such a texture is shown in the NLC droplet on the weak azimuth anchoring surface.[5] Width of the dark regions in the transverse direction decreases and that in the longitudinal direction increases as increasing the concentration of CCH, as shown in Figs. 2(b) ~ 2(d), and Fig. 2(c) shows that the NLC aligns radially on the rubbed surface in the droplet of the mixture (5CB/CCH = 57/46). When the mixing ratio of CCH becomes larger than that of 5CB, the easy axis of the mixture changes to be perpendicular to the rubbing direction. These results with other mixing ratios are shown in Fig. 3.

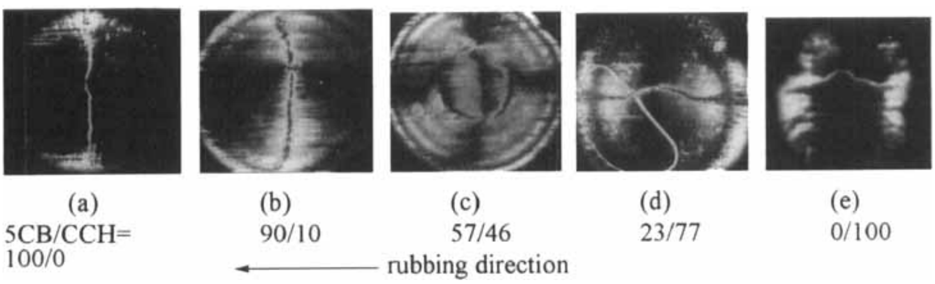



FIGURE 2 Polarized microphotographs of 5CB/CCH droplets on the rubbed pHEMA surface under the crossed polarizers.

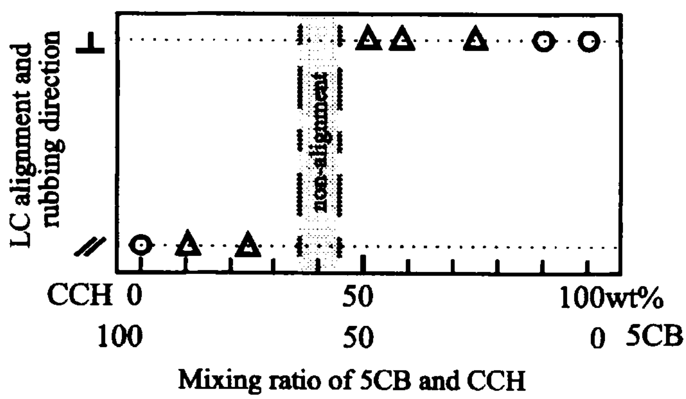



FIGURE 3 Relationships between mixing ratios of 5CB/CCH and their alignment directions. Symbols of "○" and "△" show a strong and a weak anchoring alignment, respectively.

After the NLCs having bicyclohexane core were heated up to their isotropic phase and cooled down to the nematic phase, we found that their alignment direction changed from perpendicular to parallel to the rubbing direction on the rubbed pHEMA surface. Clearing temperatures of CCH and FB-01 are 84°C and 112.5°C, respectively, and a glass transition temperature of pHEMA is 55°C. On the other hand, NLC still aligns perpendicular to the rubbing direction after the rubbed pHEMA was annealed over the clearing temperature of the NLC and then the NLC was put on its surface. These results show that the phase transition of the NLC or the NLC in the isotropic phase cause the change of the pHEMA molecular conformation. Moreover, there is a possibility that impurities in the NLC might be adsorbed on the pHEMA surface during the phase transition and the interfacial state changes.

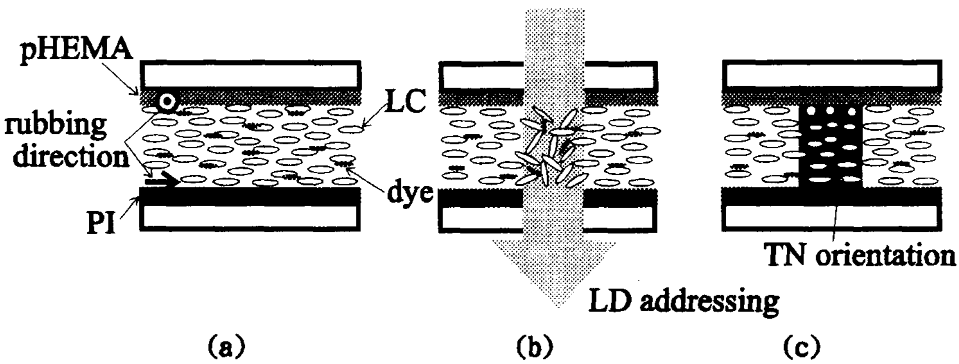



FIGURE 4 (a) Thermally addressed cell with the homogeneous orientation is constructed using the rubbed pHEMA and PI substrates and the CCH. (b) The laser beam is irradiated and (c) the addressed region becomes the twisted nematic orientation.

In order to confirm this phenomenon, we demonstrated a thermal addressing in the LC cell. The homogeneously aligned LC cell was constructed using the combination of pHEMA and PI coated substrates, of which rubbing directions intersect at right angles. The CCH containing a dye of 0.5wt% (IRP-101 from Nippon Kayaku) in the nematic phase was injected in the empty cell, then the homogeneous orientation was obtained as shown in Fig. 4 (a). The thermal addressing was done using a laser diode ($\lambda$=780 nm) and the CCH was heated up to the isotropic phase and the addressed region became the twisted nematic orientation as shown in Figs. 4 (b) and (c). Figure 5 shows the polarized microphotograph of the thermally addressed cell under the parallel polarizers. The addressed region appears dark and the disclination line is also observed due to the reveres twist.

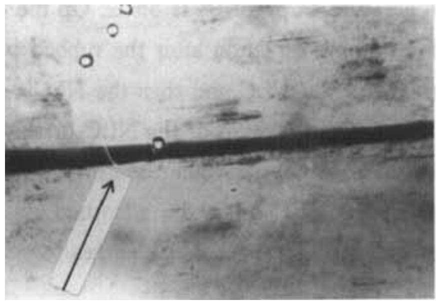


FIGURE 5 The polarized microphotograph of the thermally addressed cell under the parallel polarizers. The addressed line with the TN orientation appears dark. An arrow shows the disclination line due to the reverse twist.

## CONCLUSIONS

Alignment properties of various NLCs which have different cores and terminal groups have been investigated on the rubbed pHEMA surface. Most of NLCs align parallel to the rubbing direction, except those having the bicyclohexane core which align perpendicular to the rubbed direction. The alignment direction of NLCs with the bicyclohexane core changes from perpendicular to parallel to the rubbing direction after the NLCs are heated up to Tc and cooled down to the nematic phase. We have successfully demonstrated the thermal addressing in the cell constructed using the rubbed pHEMA and PI substrates and the CCH. The addressed line with the TN orientation can be obtained in the homogeneously oriented cell.

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