Surface sliding effect of nematic liquid crystals on soft- polymer

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Abstract

Recently, study on the weak interaction energy between the soft polymer surface and liquid crystals has been a primary topic for new LC device applications. In this paper, to understand the switching property of nematic liquid crystals (LCs) at the interface with a weak anchoring boundary, we investigate experimentally the rotation property of surface nematic director by electric field on non-treated Poly-Methylmethacrylate (PMMA, T_g=110°C, Sigma Aldrich) film observed under various temperatures including the glass transition temperature (T_g) of the polymer layer.

1. Introduction

The specific properties of nematic liquid crystals with a weak anchoring strength on an interface have a special attraction for new LC applications [1-5]. Currently, the weak anchoring interaction between the soft polymer surface and liquid crystals has a primary function for the fundamental LC device research [6-8]. It is very basic research area including the nematic director reorientation mechanism on the polymer surface at the liquid crystal (LC) devices [9]. We studied on the nematic liquid crystal director gliding at the interface between the soft-polymer and the nematic LC in the horizontal electric or magnetic field. Gliding effect has been studied by many researchers who generally used two kinds of polymers as LC alignment layers of each substrate, such as the combination of dye molecules and polyimide (PI) or PVA (polyvinyl alcohol) [5, 10], polymethylmethacrylate (PMMA) and PI, polyethylmethacrylate (PEMA) and PI [1], etc.. Surface properties of these materials were mainly dominated by thermal conditions and electric [11, 12] or magnetic field strength.

In this paper, we demonstrate the rotation of surface nematic directors by electric field on the non-treated Poly-Methylmethacrylate (PMMA, Tg=110°C, Sigma Aldrich) film observed under various temperatures including the glass transition temperature (Tg) of polymer chains. Above all things, rearrangement of the surface director by in-plane electric field directions will open up an intriguing opportunity for functional LC alignment. Figure 1 shows the general structure of PMMA polymer with weak LC interaction used in this experiment.

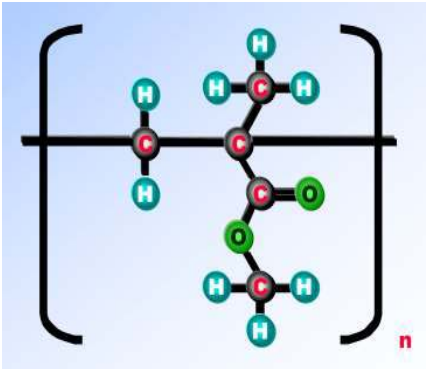

Fig. 1 Structure of PMMA polymer.

2. Experimental

Aluminum layer of about 200 nm thickness evaporated on glass substrate is patterned as an electrode for applying horizontal electric field, by wet etching process with the photo-lithography. 5 wt% PMMA solution with 95 wt% toluene was solvent spin-coated on the substrates at 3000 rpm (revolutions per minute) for 30 sec, and then baked on the hot-plate at 150 °C for 40 min. There was no mechanical treatment and rubbing process on the PMMA polymer surface in this process. The LC material was filled into the cell by the capillary effect after the general sandwich cell was assembled with the cell thickness of 5.5 ㎛ using the glass bead, and then the LC cell was sealed by the UV curable sealant. The material parameters of the nematic LC (ZKC-5085XX) used in the LC cell are shown in Table 1.

Figure 2 shows schematic diagrams of LC cells which have two different types of patterned electrodes. The electrode structure is composed of a circle electrode with 120 ㎛ diameter on the bottom substrate and an electrode with the hole of 300 ㎛ diameter on the top substrate. The circular patterned electrode structure provides the radial electric field from the center ring type electrode as shown in Fig. 2 (a).

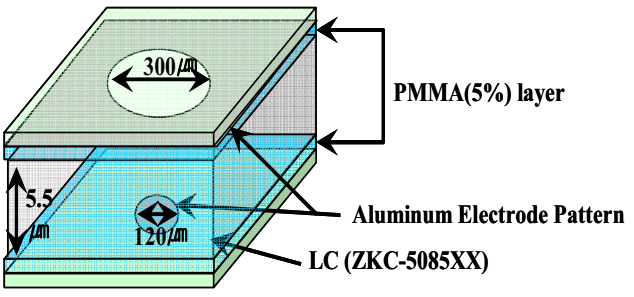

Fig. 2 Schematic diagrams of LC cell which has patterned electrode for LC reorientation.

3. Results and discussion

As expected, Fig. 3 (a) shows that polarizing optical microscope texture has many disclinations because there is no initial treatment of the polymer surface for LC alignment. By the way, we know that the nematic directors were aligned to the electric field directions (radial direction) when the electric field (0.2 V/㎛, 1KHz) was applied to the LC cell at near the T_g as shown in Fig. 3 (b) because dark states occurred only at the field direction coincident with the optic axis of two polarizers in the radial field. Subsequently, after cooling down slowly the temperature of the hot stage, when the electric field is removed the electric field, we obtained the aligned stable state of the nematic director on the PMMA surface at 40°C as shown in Fig. 3 (d). The surface nematic LCs maintains the new orientation after field off because there is no excess free energy by deformed LC elastic state at bulk. Even though we rotate the sample stage, we cannot find any optical change under two crossed polarizers, which indicates that LCs are aligned definitely to the radial direction. As a result, the easy axis of the surface nematic director can be reoriented by the action of the in-plane electric field due to weak LC surface anchoring.

After all, we can also know that several stable states can be obtained by various electrode couple in a new electrode system. We confirm that the easy axis of the surface nematic director is reoriented by the action of the in-plane electric field through the circular electrode system. Therefore, if the surface director can be controlled satisfactorily by the LC system with the soft-polymer surface by a desirable electrode which produces various LC states, this approach may be used as the LC device with the new multi-stability. Moreover, it would be useful for LC applications such as LC devices without mechanically rubbing treatment on the polymer surface because good alignment uniformity may be achieved by this simple method.

ZKC-5085xx	
K_1	9.2 [10^{-12} N]
K_2	6.9 [10^{-12} N]
K_3	16 [10^{-12} N]
N_e	1.654
N_o	1.503
Δn	0.151
$\Delta\varepsilon$	9.8
$\varepsilon_{\parallel}$	13.6
$\varepsilon_{\perp}$	3.8
Γ	265.9 [mpa*s]
T_c	120°C

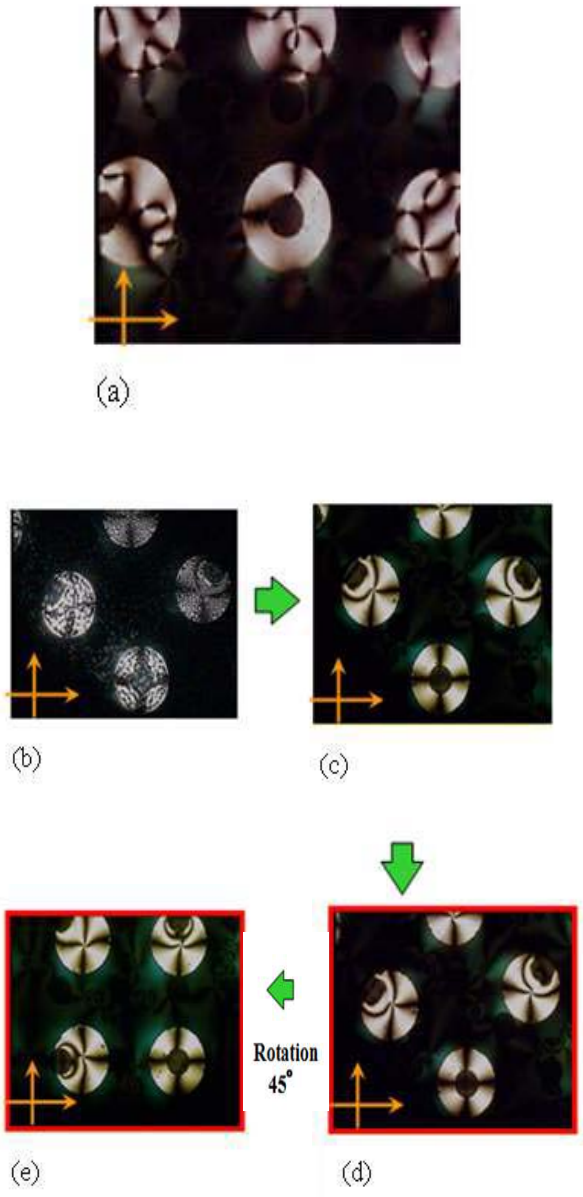

FIGURE 3 The polarizing microscopic images of the LC cell with the circular patterned electrode : (a) texture under crossed polarizers after injecting the LC material by the capillary effect (b) electrically aligned image at near 118 °C under applied radial type electric field strength of 0.2 V/㎛ (c) electrically aligned image at cooled down to about 40°C under applied radial type electric field strength of 0.2 V/㎛ (d) image under removed electric field at 40 °C (e) texture after rotating the sample about 45°.

4. Summary

We have developed the simple fabrication method for switching LC director on the soft-polymer surface. In this configuration, the easy axis of the nematic LC on the surface is reoriented by the action of the in-plane electric field due to weak surface anchoring strength. This enables the electric field direction to control the easy axis of the LC on the soft-polymer surface at 40°C lower than the glass transition temperature (T_g) of PMMA chains. Nematic LC on the soft-polymer surface maintains the new orientation after removing the electric field because there is no excess free energy by deformed LC elastic state at bulk. Several surface LC states changed by several field directions are reversible. Therefore, the surface director can be controlled satisfactorily by the LC system with the soft-polymer surface and a desirable electrode which produces various LC states by controlling various field directions. This result would be used as the LC device with the new multi-stability.

5. Acknowledgement

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6. References

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