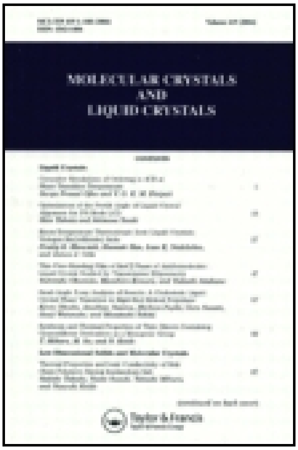

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Novel Orientation States Transitions in Liquid Crystal Induced by Microtextured Substrates

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Novel Orientation States Transitions in Liquid Crystal Induced by Microtextured Substrates

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Substrate induced alignment of liquid crystal is well established for electro-optical applications. In most of these cases it results in strong anchoring of liquid crystal, however, tuning of effective anchoring is well desired. Some of the photopolymers, under exposure to polarized UV light, induces the alignment in adjacent liquid crystals and offers the way to control the alignment on local basis. Here, we show a method of tuning the effective anchoring energy on patterned photopolymer with mixed alignment potential (resulting in planer and tilted orientation) of constant periodicity. The effective anchoring is weak and associated with first order transition of orientation state as a function of temperature. The phenomena observed here might be exploited for application purposes by local heating or by applying an electric field.

Keywords: Liquid Crystal; Anchoring Transition; Photo-polymer; Microtexturing

Introduction

Liquid crystals (LC) are used as electro-optic materials in variety of applications such as display and light modulator etc. For these applications, LC molecules are needed to be oriented in uniform direction on the substrate, in prior, before applying the electric field. Here, the substrate induced alignment of LC is a crucial factor for applications where weak surface forces are used to orient the LC[1]. In most of these cases the alignment of LC remains pinned to the surface induced orientation depending on the substrate condition. In some of applications, for better performance of devices, the use of liquid crystal in electro-optics desires the control of director (average LC molecular orientation) over local area with any arbitrary angles between 0^{o} to 90^{o} that director forms with the substrate.

In case of weak anchoring, either on uniform substrates[2] or substrate with modified uniform potential by co-adsorbed molecules[3,4] the anchoring transition occurs, where LC orientation state is the continuous function of temperature. It has been reported that a case of weak anchoring could be the way to control the LC alignment for an arbitrary angle[2]though it was not persuaded and exploited for application purposes. Recently, under the framework of finite elastic correlation length Quian et al.[5] have predicted the possibility of orientation transition in liquid crystal on microtextured substrate with mixed alignment potential. It has been reported that microtexturing may offer the approach to continuously vary the anchoring strength from the strong (far away from the transition point) to the weak (close to the transition point).

To the best of our knowledge, the first experimental evidence of the novel orientation states associated with first - order orientation transition of liquid crystal as function of temperature on microtextured substrate with spatially mixed alignment potential of constant periodicity is reported in this paper. The phenomena is observed on weak strength photopolymer polyvinyl cinnamate (PVCi) with azimuthal anchoring ~ 10^{-7} j/m^2 used as an aligning agent. However, same substrate microtextured with similar alignment potential (planer and twisted) does not give the orientation transition as a function of temperature. The phenomena reported here might be exploited in tuning the effective anchoring energy for application by using the local heating for a 'light control light' liquid crystal device or by applying an electric field based on field induced effect.

Experiment

Our approach of patterning the substrate with mixed alignment potential is based on the photoalignment technique for orientation of LC[6,7]. Here, 2wt% of chloroform solution of polyvinyl cinnamate was spin coated on ITO coated glass for uniform thickness. The films were baked and subsequently, irradiated with polarized ultra violet light (LP UV) for 30 min. At 10mW/cm^2. The cell was assembled using 10μm spacer and filled with LC and PVCi mixture (in 99:1 weight ratio) in isotropic phase and cooled slowly. The resulting orientation is the uniform planer orientation. The liquid crystal used here is RDN-91207-1 (Dannipon inc. Japan) with $\Delta\varepsilon = -2.5$, $T_{NI} = 70^{0}C$. To achieve the patterned structure of mixed alignment potential, a metallic grating mask with pitch 400μm was placed over the cell (having prior uniform planer orientation of LC) and irradiated with linear polarized UV light parallel to the planer alignment direction of the LC while heating the cell near by but a few degree above the nematic-isotropic transition temperature of LC.

Result & Discussion

After exposure, we have observed the reorientation of LC with tilt on the non masked area with director normal to the initial direction (Fig.1).

In optical micrograph Fig1 there are domain boundaries seen on the tilted region due to double degenerate alignment state of PVCi and the

FIGURE 1 Optical micrograph of the cell rotated by 45^{0} under cross Nicole (See Color Plate VIII at the back of this issue)

the directors are tilted in opposite direction from domain boundary after reorientation.

The pitch (p) of the grating was chosen as 400μm i.e. P >>Δ so that director may respond to the spatial texturing where parameter $\Delta = (LC/B^2)^{1/2}$ is the elastic correlation length over which the order parameter can vary significantly, and L, C & B are the usual phenomenological constants expressed in the Landau-deGenns equation of free energy for the uniaxial LC phase. Fig.2 shows the temperature dependence of the transmission of the two regions respectively. It appears that the bulk director lies in the YZ plane as the optimal twist elastic energy configuration[5].

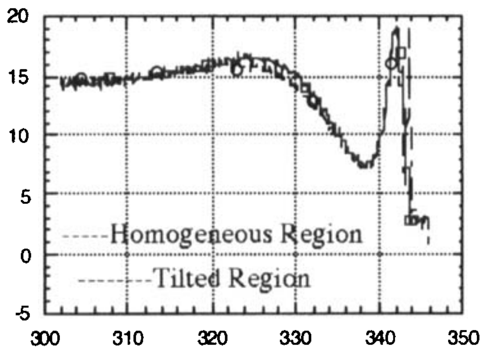

FIGURE 2 Intensity (i, in arbitrary units) plotted as the function of temperature.. (See Color Plate IX at the back of this issue)

The variation of orientation states near the transition temperature is quite pronounced as shown in the transmission curve of Fig.2 and in the optical micrograph of Fig.3. From a certain temperature 331K to 338K the director started tilting away from the substrate as the apparent birefringence changes sharply as shown in optical micrographs of Fig.3 (a), (b) and (c) and as of the sharp transmission curve Fig.2. At 332.8K, Fig. 3(a) change of birefringence in tilted region (YZ state) begins, at 338.3K Fig. 3(b) birefringence in both region begins, whereas in Fig.3(c) at 338.9K the change in birefringence is more pronounced in both region.

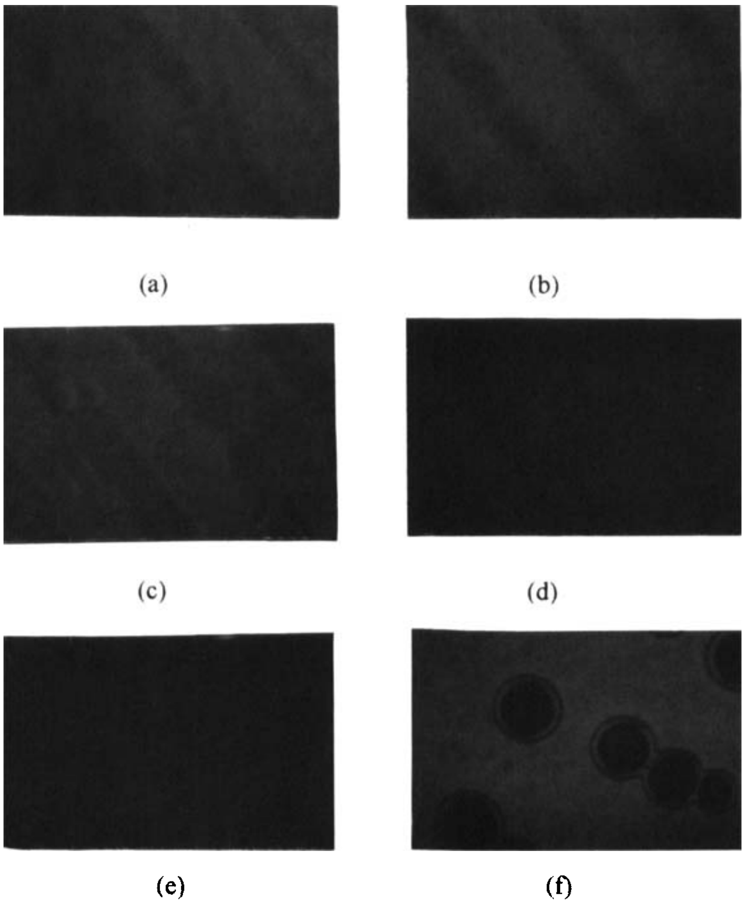

FIGURE 3 Optical micrographs of the cell rotated by 45° under cross Nicole at different temperature. (See Color Plate X at the back of this issue)

But before going to isotropic phase, at critical temperature 338.9K, the director in the bulk jumps from the YZ state to the XZ state as seen from optical micrographs Fig.3(d) & (e) and over the transmission curve. At 339.8K, Fig 3(f) the cell goes to random homogenous orientation and onset of nematic-isotropic transition begins The jump of the director from the YZ state to the XZ state might be associated with the first-order orientation transition between two states as boundary layer energy is overcome by strong uniform surface potential at critical temperature 338.9K.

Conclusion

Thus microtexturing with mixed alignment potential offers a method of continuous variation of effective anchoring strength from the strong (far away from the transition point) to the weak anchoring (close to the transition point). The orientation states are reversible over temperature cycle nematic-isotropic-nematic and we believe that the approach enhances the possibility to explore the microtexured controlled tuning of effective anchoring energy on various class of substrates.

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