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Light-induced liquid crystal alignment on the non-organic isotropic surface

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Abstract

Light-induced planar alignment of nematic liquid crystal (LC) 4-*n*-pentyl-4′-cyanobiphenyl (5CB), on the isotropic surface of the fused quartz upon illumination with polarized UV light, is observed for the first time. The axis of LC easy orientation lies perpendicular to the direction of the incident light polarization. Such phenomenon is explained by proceeding from the photo-orientation of LC molecules adsorbed on a quartz. Activation energy of LC anchoring with the quartz surface is measured. © 1999 Elsevier Science S.A. All rights reserved.

Keywords: Liquid crystal alignment; Light-induced anisotropy; Adsorption

1. Introduction

Uniform alignment of liquid crystals (LCs) is a principle requirement for most LC display devices. LC alignment is usually produced on the polymer substrates. As a rule, before the cell fabrication and filling of LC, polymer surface is treated to acquire anisotropic properties. The anisotropy of polymer surface is usually created with rubbing [1] or photo-alignment [2] technique.

There are several methods of LC alignment on the isotropic polymer surface in the cell, which is already filled. For example, Ref. [3] reported about LC alignment on the isotropic polymer films after LC cooling below T_c under magnetic field action. This phenomenon takes place because LC molecules adsorb onto substrate preferably parallel with respect to the direction of the magnetic field.

The LC alignment on the isotropic polymer surface under the polarized light irradiation of the cell filled with azo-dye-doped LC was also observed [4]. This phenomenon was explained in a model of light-induced anisotropic adsorption of the dye molecules onto the polymer surface.

In all methods of LC alignment described above, polymer substrates for LC orientation were used. In this article, we report an effect of effective photo-alignment of nematic LC on a non-organic isotropic surface (surface of fused quartz) under the action of UV light onto the bulk of LC.

2. Experimental and discussion

In our experiments, nematic LC 4-*n*-pentyl-4′-cyanobiphenyl (5CB) was used. LC layer was placed between the quartz substrate and glass substrate covered with rubbed polyimide layer. A cell gap was 10–50 μm. Multidomain planar LC texture in a cell was initially observed.

A part of the sample was illuminated normally to the sample plane through the quartz plate with the collimated beam of polarized UV light. As a source of UV light, high-pressure Hg-lamp was applied. Glan prism was used for the polarization of UV irradiation. Time of illumination was 20 min at the integrated light intensity of 5 mW/cm^2. Illumination was done at different temperature conditions:

1. at room temperature (which corresponds to LC mesophase);
2. during the cooling to room temperature, when the samples were heated above $T_c = 36°C$; and
3. at the temperatures of isotropic phase close to T_c.

In all these cases, the exposure resulted in high-quality LC alignment in the illuminated area (Fig. 1). Both parallel and twist planar structures were obtained. Twist angle depended on the angle between the direction of rubbing of polyimide substrate and vector ***E*** of UV light, as well as on the exposure energy. In contrast to Ref. [4], easy axis on the quartz substrate was induced in the direction per-

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pendicular to the direction of the light polarization. In our experiments, easy axes direction was changed several times by the change of polarization direction of UV light.

The LC orientation induced on the quartz substrate is stable. The quality of the alignment at room temperature was not changed during the time of observation (2 months). Short-time heating of the sample over the clearing point, followed by cooling back to room temperature, also did not change the quality of the induced alignment. More detailed studies of the thermostability of the alignment showed that the alignment became weaker the longer the cell was maintained at the elevated temperature. The holding time τ_T at elevated temperature (time required for the disappearance of the light-induced alignment in illuminated area) depends on the curing temperature T. Dependence of τ_T on T is presented in Fig. 2. This curve can be described by an Arrhenius law with an activation energy $E_a = (45 \pm 15) k_B T_r$, where T_r is room temperature. This value is fairly high, which is an evidence of strong interaction between the anchored 5CB molecules and a quartz surface. However, this value is 1.5 times less than the corresponding value for the ‘LC-polymer’ interface measured in Ref. [5].

This phenomenon might be explained as light-induced reorientation of LC molecules adsorbed on the quartz surface. As we know, mechanisms of photo-reorientation in the adsorbed organic layers were not being investigated. To our mind, it is a difference in principle in the light-induced reorientation processes in the LC bulk and in the LC layers adsorbed on the substrate. In the bulk of LC, the photo-reorientation is usually caused by the light-induced Frederiks effect [6]. This mechanism hardly plays an important role in our case because of high effective viscosity of adsorbed LC layers. Indeed, estimated value of activation energy $E_a = (45 \mp 15) k_b T_r$ is close to the value $E_a = (40 \mp 15) k_b T_r$ corresponding to light-induced anisotropy in polymer films [7]. It could be an evidence of similar layer rigidity. Considering it, we can assume the photo-selection mechanism of the proper reorientation to polymer films [8]. An optical dipole moment of the 5CB molecule is oriented approximately along its long axis [9]. So, probability of absorption depends on the angle between vector $\boldsymbol{E}$ of the light and long molecular axes; LC molecules oriented along vector $\boldsymbol{E}$ of the exciting UV light will absorb the light more intensively then molecules oriented perpendicular to $\boldsymbol{E}$. As result of angular-dependent absorption, initial angular distribution of 5CB molecules adsorbed on the quartz surface can be changed; orientation axes of the induced structure will lie in the plane of adsorbed LC layer perpendicular to the direction of polarization of UV light. Arranged in such way, adsorbed 5CB layers determine orientation of LC in a bulk.

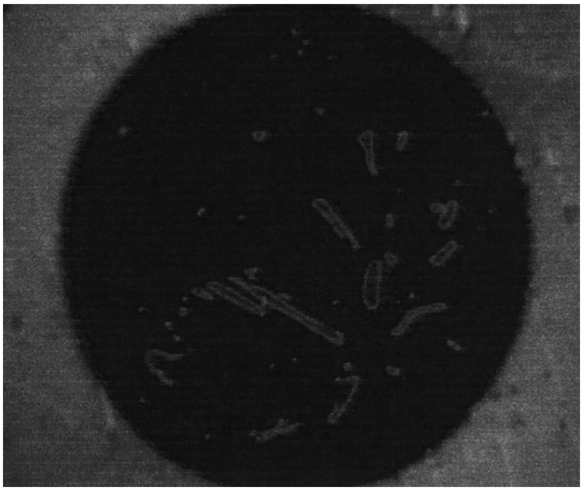

Fig. 1. A photograph of the cell in crossed polarizers. Black square in the middle part of the cell corresponds to the irradiated area.

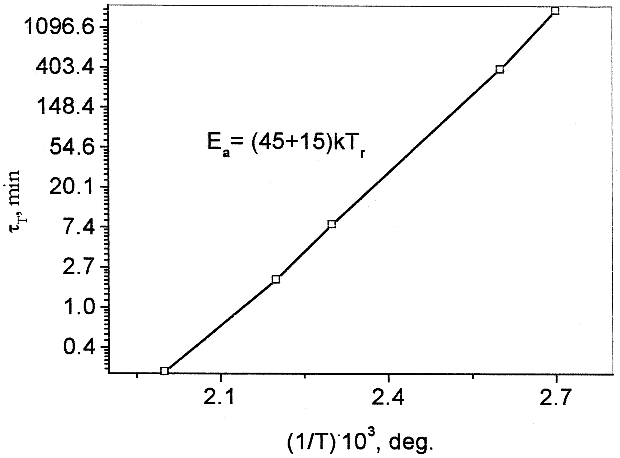

Fig. 2. Relaxation time τ_T of the light-induced alignment as a function of temperature.

Following our consideration, the problem of the photo-alignment of LC can be transformed to the problem of photo-orientation of the adsorbed LC layers. LC adsorption is a common phenomenon; it takes place in different types of substrates. Hence, LC photo-alignment in *different* substrates (not only polymer substrates) can be realized. On the other hand, quality and thermostability of the induced alignment should depend on the anchoring between substrate and LC. It was admitted above that thermostability of the LC alignment induced on the quartz surface was 1.5 times lower than for the surface of polymer.

3. Conclusion

Thus, photo-induced orientation of the dye-free LC on the isotropic non-organic substrate (bored quartz substrate) was realized. This phenomenon could be explained by assuming photo-induced ordering of LC molecules adsorbed on quartz surface. Oriented LC layer adsorbed on the rigid substrate can determine LC orientation in the bulk. These results induce to reconsider the common accepted conception, which is based on the important role of polymer layers in LC alignment.

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