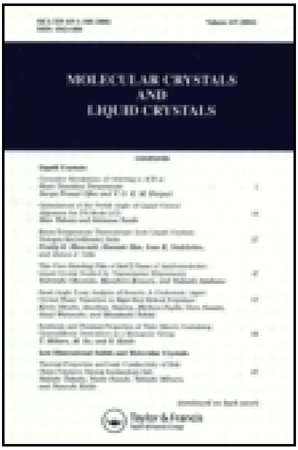

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Light Induced LC Alignment on the Isotropic Non-Photosensitive Surface

G. Magyar [a], J. West [a], Yu. Reznikov [b] & O. Yaroshchuk [b]

[a] Liquid Crystal Institute, Kent State University, Kent, OH, 44242, USA

[b] Institute of Physics of National Acad. of Sci., prospect. Nauky 46, Kyiv, 252022, Ukraine

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Light Induced LC Alignment on the Isotropic Non-Photosensitive Surface

G. MAGYAR[a], J. WEST[a], YU. REZNIKOV[b] and O. YAROSHCHUK[b]*

[a]*Liquid Crystal Institute, Kent State University, Kent, OH 44242, USA and*
[b]*Institute of Physics of National Acad. of Sci., prospect. Nauky 46, Kyiv 252022, Ukraine*

We observed planar alignment of nematic liquid crystal (LC) 5CB on a fused quartz surface upon illumination with polarized UV light. The axis of easy orientation is perpendicular to the polarization of the incident light. The value of the anchoring energy increases with increase of the illumination dozes up to 10^{-4} erg/cm^2. We propose that the phenomena observed results from light-induced rearrangement of the LC layer adsorbed on the quartz surface.

Keywords: liquid crystal alignment; photoalignment; adsorption

INTRODUCTION

Uniform alignment of liquid crystals is crucial for most LC studies and applications. Homogeneous LC alignment is usually reached with anisotropic polymer films deposited on glass substrates. Anisotropy can be induced in polymer surfaces using several methods.

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* Corresponding author. E-mail: olegyar@marion.iop.kiev.ua

Mechanical rubbing of polymer layers is the most common method to achieve uniform alignment of LCs[1]. Rubbing produces anisotropy on the polymer surface, and liquid crystal molecules uniformly align on the surface due to the anisotropic intermolecular interaction between polymer and liquid crystal molecules.

Anisotropic polymer surface can be also obtained by illumination of some photosensitive polymers containing dichroic absorption centers with polarized UV light. Photoalignment is of the great interests last decade because of its obvious advantages; non-contact method and the possibility of effective control of the basic anchoring parameters – easy axis direction and anchoring energy[2-5].

There are also methods of LC alignment on isotropic polymer substrates in the cells already filld. For example, Hiroshima[6] reported on LC alignment on the isotropic polymer films after cooling a LC below the clear point, T_c, with a magnetic field applied. The origin of this effect is the anisotropic adsorption of LC molecules onto the substrate parallel to the magnetic field.

Similar effects can be achieved by illumination of dye-doped LCs with polarized light[7-8]. The anisotropic adsorption of the excited dye-molecules onto the initially isotropic polymer surface is postulated to be the origin of this type of photoalignment.

In all methods mentioned above LC orientation was produced on the polymer substrates. We report an effect of effective photoalignment of non-dyed nematic liquid crystal on the isotropic surface of bare quartz under the action of UV light onto the bulk of liquid crystal. Possible orientation mechanisms will be considered.

EXPERIMENT

The experiments were performed with a combined sandwich cell filled with a 4'-n-pentyl-4-cyanobiphenyl (5CB or K15 from Merck). Thickness of the cell was controlled by cylindrical spacers and varied in the range of (10-50) μm. One substrate consisted of glass covered with a rubbed polyimide layer. The other substrate was made from bared fused quartz. The aligning polyimide surface determined the preferable planar orientation of LC in the cell parallel to the rubbing direction. The cell was filled with LC in the isotropic state (T=100°C) and cooled down slowly to room temperature to avoid a possible alignment in flow. The alignment was poor and a many defects localized on the quartz surface can be observed with polarizing microscope.

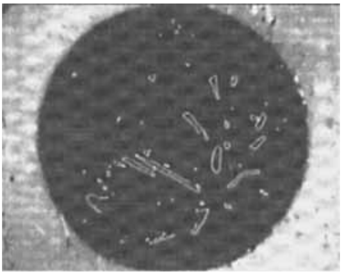

FIGURE 1 Photograph of the illuminated cell placed between the crossed polarizers.

A part of the sample was illuminated through the quartz substrate with polarized UV light. A high-pressure Hg-lamp or Xe-lamp was used as a source of UV. The integrated light intensity was about of 5 mW/cm^2 and the exposure time was up to 50 min. We illuminated the cell either at room temperature or while cooling from the isotropic phase and in isotropic phase near T_c. In all cases, the exposure results in uniform planar LC orientation in the illuminated area (Fig.1). The orientation of the light induced easy axis is perpendicular to the polarization of the incident light, ***E***; twist structures were obtained at the ***E*** parallel to the direction of rubbing on PI surface.

The twist angle, θ_{test}, depended on the exposure time. This dependence is caused by the dependence of the azimuthal anchoring energy W on the exposure time τ_{exp}. The values of θ_{test} and W are related according to the following equation[8]

$$\xi \sin 2\left(\theta_{test} - \bar{\theta}\right) = 2\theta_{test}, \qquad (1)$$

where $\xi = Wd/K$ is the anchoring parameter, $\bar{\theta}$ is the angle between the light-induced easy axis and the easy axis on the rubbed substrate.

The experimental dependence $\theta_{test}(\tau_{exp})$ for $\bar{\theta}=45^{\circ}$ one is shown in Fig.2. The calculated dependence $W(\tau_{exp})$ at the parameter $d/K = 1{,}8\ 10^{-4}$ cm^2/erg (d=20 μm) is also presented in Fig.2. The anchoring energy goes

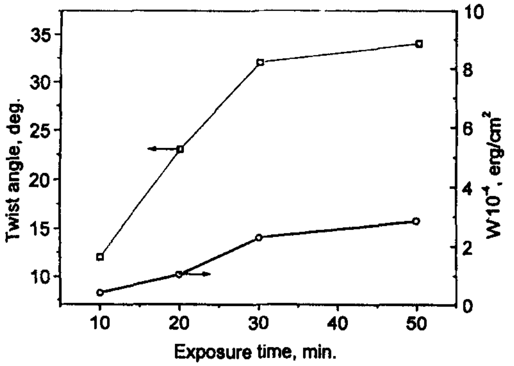

FIGURE 2 Dependencies $\theta_{test}(\tau_{exp})$ and $W(\tau_{exp})$.

up quasi-linearly with the exposure time (illumination doze). The maximum energy we achieved is of the order of 10^{-4} erg/cm^2. This value is typical for photoaligned and 1-2 order less of the anchoring on rubbed polymer film[3,9].

LC orientation induced on the quartz substrate is stable. Heating the sample over the clearing point followed by cooling back to room temperature did not change the induced alignment. More detailed studies of the thermostability of the alignment showed that the alignment gets weaker the longer the cell maintained at elevated temperature. We observed a decrease in the twist angle, θ_{test}, after thermal treatment. The time τ_{twist} at elevated temperature required for the disappearance of the light-induced twist structure depends on the curing temperature T. Dependence of τ_{twist} on T is presented in Fig.3. This curve can be described by an Arrhenius law with an activation energy E_a=(45±15) k_BT_r, where T_r is room temperature. This value highlights the strong interaction between the anchored 5CB molecules and a quartz surface. However, the measured

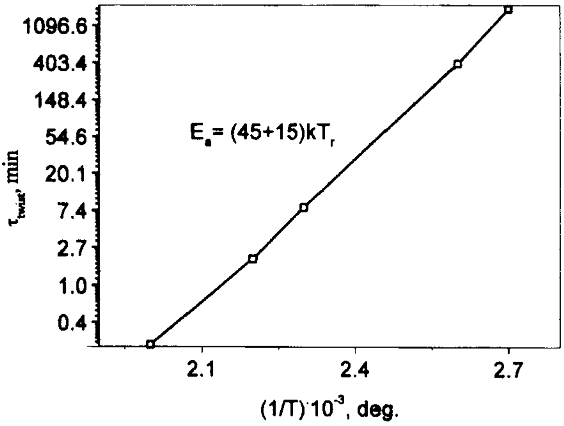

FIGURE 3 Temperature dependence of the holding time τ_{twist}.

value of the activation energy is lower than that one measured by Ouchi et all value $E_a = 80\ k_B T_r$ for LC layer adsorbed on the polymer surface[10].

DISCUSSION

The nature of the observed effect deserves further studies. We will consider the most probable origin of the phenomena. We speculate that the underlying mechanism of the effect is re-arrangement of the adsorbed LC layer under the action of UV-light.

It is well-known that the alignment memory effect of cyano-biphenyl LCs can be rather strong[10,12]. Therefore, the formation of a stable adsorbed layer of 5CB molecules on the quartz surface after cell filling is reasonable to assume. The initial angular distribution of the adsorbed LC molecules should be anisotropic due to the general alignment of LC given by the rubbed PI; the anisotropy axis is lined up parallel to the direction of rubbing. The order parameter of the adsorbed molecules is determined by the order parameter of the LC and the strength of the interaction between the LC molecules and the quartz surface.

Polarized light action can modify the initial angular distribution of the adsorbed molecules. Indeed, molecules of 5CB are strongly dichroic. It results in the angular selective absorption in the adsorbed LC layer. Depending on the mechanisms of the light action, the following ordering processes could be expected:

- *Photo-induced transformation of adsorbed LC molecules.* For example, decomposition of LC molecules under the action of short wave-length UV irradiation should result in the anisotropical angular distributions of the initial and photo-transformed molecules under the action of polarized light. The origin of this anisotropy is that LC molecules absorb light preferably being parallel to this polarization because of their large absorption dichroism.

Photo-induced changes of the LC – quartz surface interaction. It is reasonable to suggest that the excitation of LC molecules can provoke drastic changes of their interaction with quartz surface resulting in a new stable state of LC molecules onto the surface. For example, it is possible to presume appearance or disappearance of the H-bonds between 5CB molecules and OH-groups of the quartz surface. In this case absorption dichroism of LC molecules results in the surface anisotropy like described above.

Light-induced desorption. Absorption dichroism of LC molecules could result in anisotropic desorption of molecules from the surface. It results in anisotropy of the adsorbed LC layer. The following adsorption process is probably to be also anisotropic. Therefore, a stationary anisotropic angular distribution of the adsorbed molecules may appear in this case.

Light-induced reorientation of the adsorbed molecules perpendicular to the polarization of the incident light. The effects of the molecular reorientation perpendicular to the vector ***E*** of the light wave are well known; they were studied in azo-polymer and polyvinyl-cinnamate films (see, for example[13-15]. Ichimura at all [16,17] found in-plane reorientation of LC on a quartz surface modified with azobenzene and cinnamic units. These effects are explained by the tran-cis-trans- isomerisation of photosensitive fragments perpendicular to the vector ***E***. This model includes a sharp increase in the rotation mobility of the photosensitive fragments during trans-cis isomerisation and strong positive dichroism of trans-isomers. The increase of the rotation mobility leads to changes of the fragment orientation during trans-cis isomerisation. If a photosensitive fragment is oriented perpendicular to the vector ***E***, it is trapped because it does not absorb light in this orientation. As a result, the molecular angular distribution is enriched with the molecules oriented perpendicularly to ***E***. Molecules of 5CB also possess strong absorption dichroism but do not reveal trans-cis isomerisation. At the same time, the increase of the rotation mobility of molecules under the light absorption should be a general phenomenon. Therefore, we presume that this mechanism could be responsible for the production of the anisotropy axes on the quartz surface and LC alignment.

Depending on the mechanism of the anisotropy producing, the deterioration of the alignment at the elevated temperature should be determined by desorption of the molecules from the quartz surface or/and by the rotation diffusion of the oriented molecules. Both processes are usually described by an Arrhenius law that corresponds to our observation.

CONCLUSION

We observed homogeneous planar alignment of nematic liquid crystal (LC) 5CB on a fused quartz surface upon illumination with polarized UV light. The axis of easy orientation is perpendicular to the polarization of the incident light. The value of the anchoring energy increases with increases on the exposure dozes up to 10^{-4} erg/cm^2. The activation energy of the photoalignment deterioration is E_a=(45±15) k_BT_r. We propose that the phenomena observed result from light-induced re-arrangement of the LC layer adsorbed on the quartz surface.

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