PHOTOALIGNMENT OF LIQUID CRYSTALS ON CHALCOGENIDE GLASS $As_{20}Se_{80}$ SURFACE

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Photoalignment of nematic liquid crystals on the chalcogenide glass $As_{20}Se_{80}$ surface is studied by the digital processing of the optical textures of light-induced twist deformations of a liquid crystal (LC) in a cell irradiated with Gaussian polarized light. The original experimental method allowed obtaining the dependence of the light-induced twist angle for the $As_{20}Se_{80}$ surface on the exposure dose by the analysis of the only irradiated spot. The dependences of the light-induced twist angle on the exposure dose are found to be qualitatively different for LC 5CB and LC E7, which points on a possibility of different mechanisms of photoalignment on chalcogenide glass.

1. Introduction

The homogeneous monodomain alignment of liquid crystals (LCs) can be obtained by different methods such as the rubbing technique [1], application of Langmuir–Blodgett films [2], plasma-treatment [3], surface-mediated [4], and bulk-mediated photoalignment [5]. The first four methods involve the physical mechanisms that induce an anisotropy on the orientation surface. In particular, the surface-mediated photoalignment utilizes the irradiation of photosensitive polymer layers with polarized light to induce an anisotropy on its surface. In the case of the bulk-mediated photoalignment, the anisotropic aligning layer of dye molecules adsorbed from the LC bulk is formed at the irradiation of the LC by polarized light.

The orientation of LCs on the aligning surface is characterized by the anchoring energy and the easy orientation axis. The possibility to control the anchoring energy and the spatial distribution of the easy orientation axis makes the noncontact photoalignment of LC to be one of the most promising methods of LC alignment. Therefore, the development of new photoaligning materials is one of the main trends of the LC material science [6].

One of the new promising photoaligning materials is chalcogenide films, which reveal the strong photoinduced birefringence and the dichroism [7–9]. The photoinduced anisotropy on chalcogenide glass depends on the polarization of light and can be erased by irradiation with unpolarized light. Taking the exclusive chemical and thermal stabilities of chalcogenide films into account, one can expect their successful application as effective photoaligning materials.

For the first time, Kurioz *et al.* [10] observed a photoinduced alignment and a reorientation of the director of LCs on the chalcogenide As_2S_3 surface under the irradiation of an LC cell with the chalcogenide boundary surface with linearly polarized light. Later, Gelbaor *et al.* [11] showed that a chalcogenide As_2S_3 film tentatively irradiated with linear polarized light causes the orientation of LCs along a light polarization. The present paper is devoted to studying the photoalignment of a LC on a chalcogenide glassy film $As_{20}Se_{80}$. This material is interesting by the strong effect of a mass transfer in the gradient of a light field that was effectively used to form a microrelief and record diffraction holograms [12, 13]. The combination of this effect with the photoalignment of a LC can open new ways for the precise tuning of an LC alignment.

2. Experimental Method and Results

The experiments were carried out in a combined LC cell with the thickness $L = 20$ μm consisted of the reference substrate and the test substrate. The reference substrate was covered with a rubbed polyimide layer that provided a strong unidirectional planar alignment of LCs with a pretilt angle of about 1°. The test substrate was covered with a chalcogenide film $As_{20}Se_{80}$ 200 nm in thickness. The cell was filled with a LC pentyl-cyanobiphenyl (5CB) or LC E7 by capillary forces at room temperature in the nematic phase.

A planar alignment of the LC along the rubbing direction on the reference surface was observed in the filled cells. The stable homogeneous alignment of the LCs on the tested surface pointed on the formation of the anisotropic layer of adsorbed LC molecules on the chalcogenide surface with the easy orientation axis along the rubbing direction. The filled cells were irradiated with linear polarized light by a Gaussian laser beam ($\lambda = 532$ nm, beam radius $r_0 = 0.1$ mm, power $P_{\rm exc} \leq 30$ mW) from the side of the test substrate. The polarization of the exciting light, $\mathbf{E}_{\rm exc}$, made the angle $\pi/4$ with the rubbing direction on the reference surface.

The exposure resulted in the LC director reorientation on the chalcogenide surface and the formation of a twist structure in the irradiated area, which were observed with a polarizing microscope. Under our experimental conditions, the Mauguin regime for the propagation of a visible light was realized [14]. Therefore, the polarization, $\mathbf{E}_{\rm test}$, of the income testing beam of a microscope, which was set in parallel to the director on the reference surface, followed the LC director in the cell, and the polarization of the beam on the test surface coincided with the direction of the director of this surface, i.e. with the twist deformation angle, ψ. Because of the Gaussian spatial distribution of the light intensity $I_{\rm exc} = \frac{P_{\rm exc,0}}{\pi r_0^2} \exp(-(r/r_0)^2)$, and the dependence of the twist angle on the light intensity $\psi(I_{\rm exc})$, the value of ψ depended on the distance from the center of the irradiated area. Therefore, the comparison of the dependences $I_{\rm exc}(r)$ and $\psi(r)$ allowed us to recover the dependence of the light-induced twist angle on the exciting light intensity $\psi(I_{\rm exc})$.

To determine the dependence $\psi(I_{\rm exc})$, we first recover the spatial distribution $\psi(r)$ in the irradiated area by the processing of a set of digitized images of this area at various positions of the polarizer of a microscope. Specifically, the LC cell was placed between the polarizer and the analyzer of a polarizing microscope, and the reference surface was faced to the light source of a microscope. The axis of the polarizer was parallel to the rubbing direction on the reference surface, and the angle between the axes of the polarizer and the analyzer $\beta = 0$. The images of the light-induced structures in the plane of the chalcogenide test surface were projected by the microscope lens on the 8-bit 570×720-pixel CCD-matrix, which provided the optical resolution of the digitized images of about 3 μm. A set of images with a step of 4° from $\beta = 0$ to $\beta = 180^\circ$ were recorded and digitized.

The monochromatic light intensity in a given pixel reads

$$I_{\rm out} \approx E_{\rm in}^2(\cos^2(\beta - \psi) + \phi \sin^2(\beta - \psi)\cos\Delta), \qquad (1)$$

where $E_{\rm in}$ is the light intensity that comes in the cell from the side reference substrate, φ is the small angle between the input polarization and the rubbing direction on the reference surface, which can be not equal to zero due to the experimental mismatching. In the case of the broadband spectrum of a microscope lamp, the integral intensity is

$$\langle I_{\rm out} \rangle_\lambda = E_0^2 \cos^2(\beta - \psi). \qquad (2)$$

To get the spatial distribution of the twist angle over the irradiated area, $\psi(x, y)$, the experimental dependences $I_{\rm out}(\beta)$ were fitted by function (2) for each pixel, and the angle ψ corresponded to the minimum of the fitted curve. This procedure allowed measuring the twist angle to within 0.3° in each pixel. The calculated distributions of the twist angle $\psi(x, y)$ in the cells with 5CB and E7 are presented in Fig. 1,*b*. These distributions were compared with the Gaussian intensity distributions also presented in Fig. 1,*c*, which resulted in the dependences $\psi(I_{\rm exc})$ shown in Fig. 2.

One can see that the dependences $\psi(I_{\rm exc})$ for LC 5CB and LC E7 are qualitatively different. The sign of the twist deformation of the director of 5CB is changed from the positive (reorientation of the director toward $\mathbf{E}_{\rm exc}$) to the negative one (reorientation from $\mathbf{E}_{\rm exc}$), as the light intensity $I_{\rm exc}$ increases. Only a negative twist deformation was observed for LC E7. Therefore, we can conclude that the molecular structure of LC molecules is a crucial factor that determines the photoalignment on the chalcogenide glass. In addition, we can state that the starting point of the processes which result in the photoalignment is the light absorption of the chalcogenide layer. This conclusion is based on the fact that both LCs are transparent at $\lambda = 532$ nm, and the $As_{20}Se_{80}$ layer 200 nm in thickness absorbs about 70% of light. According to [15], there are two primary mechanisms of photoalignment on chalcogenide surfaces. The first one is related to the light-induced anisotropy on the chalcogenide surface and results in the easy orientation axes of a LC to be parallel to the polarization of the incident light. The second mechanism is attributed to the energy transfer from the dichroic units after the light absorption to the LC molecules adsorbed on the chalcogenide surface. The transferred energy causes the polarization-sensitive desorption of LC molecules from the chalcogenide surface and the light-induced easy orientation axis of a LC per-

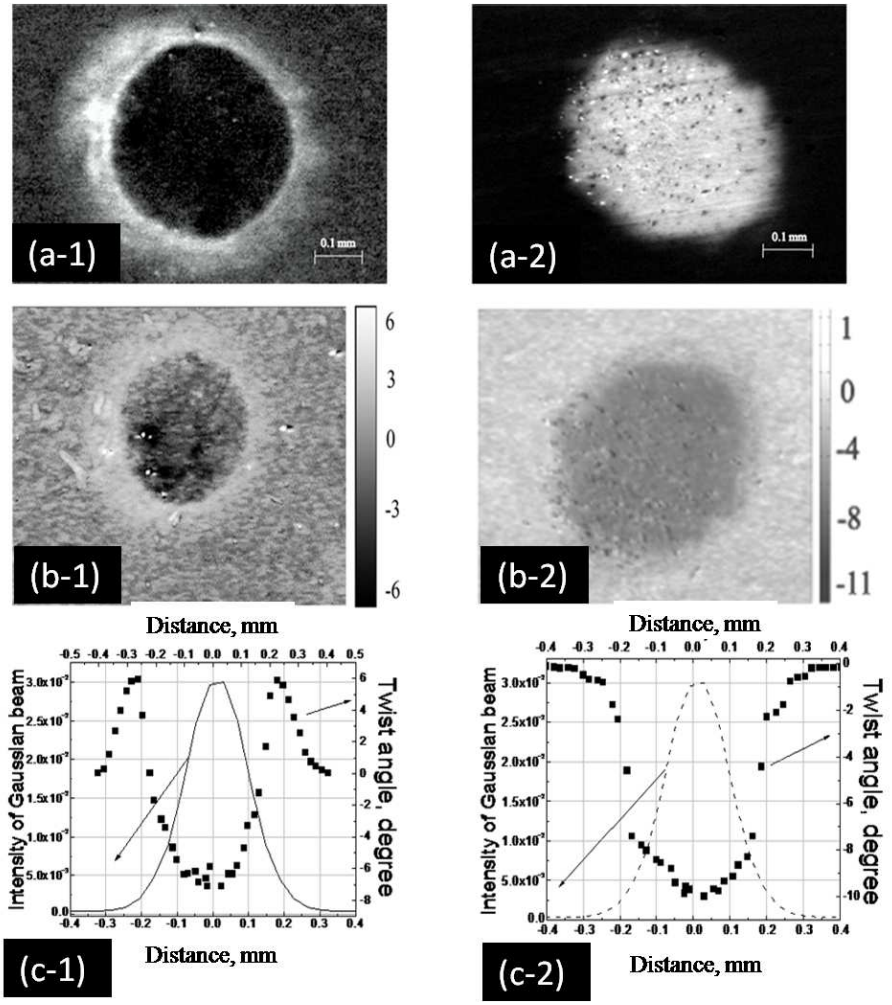

Fig. 1. *a*) Images of twist structures in the crossed polarizers. $\tau_{\exp} = 30$ min (a-1) LC 5CB, (a-2) LC E7. *b*) spatial distributions $\psi(x, y)$ in the cells with LC 5CB (b-1) and LC E7 (b-2). *c*) The cross section of the spatial distribution of $\psi(x, y)$. The profiles of the exciting polarization beam with the Gaussian intensity distributions. (c-1) LC 5CB, (c-2) LC E7

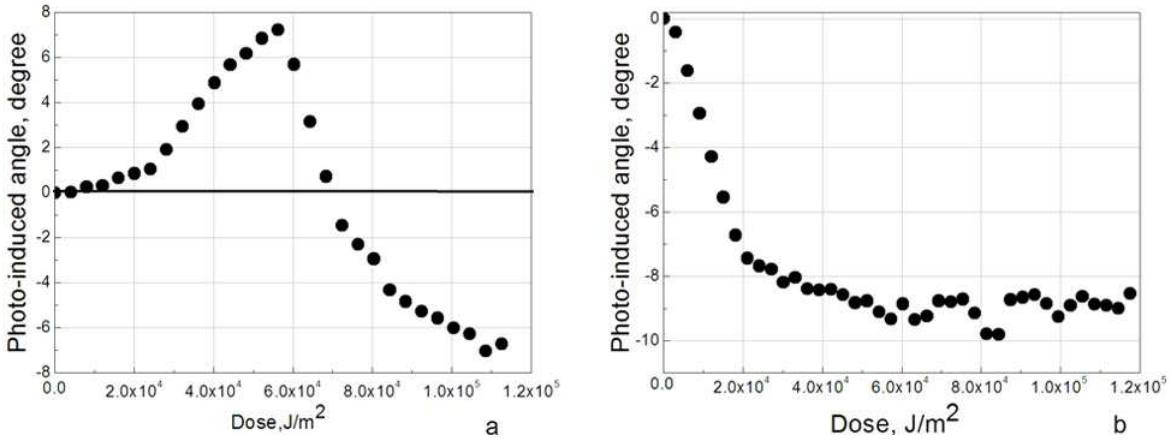

Fig. 2. Dependence of the photoinduced reorientation of the directors of LCs 5CB (*a*) and LCs E7 (*b*) on the irradiation on chalcogenide glass $As_{20}Se_{80}$

pendicularly to the incident light polarization. The competition between these mechanisms determines the direction of the easy axis with the exposure. It is evident that the efficiency of the energy transfer from the dichroic units to adsorbed LC molecules strongly depends on the chemical structure of LC molecules. This explains the difference between the exposure dependences $\psi(I_{\rm exc})$ for LCs 5CB and E7.

3. Conclusions

The photoalignment of nematic liquid crystals on the chalcogenide glass $As_{20}Se_{80}$ surface are studied by the digital processing of the optical textures of light-induced twist deformations of a liquid crystal (LC) in a cell irradiated with Gaussian polarized light. The original experimental method allows obtaining the dependence of the light-induced twist angle on the $As_{20}Se_{80}$ surface on the exposure dose by the analysis of the only irradiated spot. The dependences of the light-induced twist angle on the exposure dose are found to be qualitatively different for LC 5CB and LC E7, which points on a possibility of different mechanisms of photoalignment on the chalcogenide glass.

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ФОТООРІЄНТАЦІЯ РІДКИХ КРИСТАЛІВ НА ХАЛЬКОГЕНІДНІЙ СКЛЯНІЙ ПОВЕРХНІ $As_{20}Se_{80}$

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Р е з ю м е

Вивчено фотоорієнтацію нематичних рідких кристалів на поверхні халькогенідного скла $As_{20}Se_{80}$. Було оцифровано оптичні текстури світлоіндукованих твіст деформацій рідкого кристала (РК) у комірках, які опромінювались поляризованим світлом з гаусовим розподілом. Цей оригінальний експериментальний метод дозволив отримати розподіл світлоіндукованого кута повороту директора РК на поверхні $As_{20}Se_{80}$ від дози опромінення при аналізі лише однієї опроміненої області. Залежності світлоіндукованого кута повороту від дози опромінення дозволяють зробити висновок, що для РК 5ЦБ та Е7 можливі якісно різні механізми фотоорієнтації.