Photoalignment of Cholesteric Liquid Crystals

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Abstract
We report on studies of photoalignment of cholesteric liquid crystals on photosensitive phenylon-based polymer. We found that reflective and electro-optical characteristics of cholesteric cells strongly depend on UV exposure doze. The optimized UV treatment of the polymer allowed us to obtain the same quality of alignment on standard rubbed polyimide orientants. At the same time, the photosensitive orientant possesses evident advantage of the effective control of cholesteric textures

1. Introduction
Operation of liquid crystal (LC) devices requires uniform orientation and reproducible pretilt of the LC director on aligning surfaces. Traditional methods of LC alignment involve mechanical rubbing of the aligning polymer surfaces [1]. Last decade, Gibbon et al., Reznikov et al, and Schadt et al. proposed alternative, photoaligning techniques [2-5]. Those techniques use polarized light to induce anisotropy in a photosensitive aligning layer. The light-induced anisotropy of the irradiated layer causes appearance of the easy orientation axis, ***e*** of LC director on a photosensitive surface.

The majority of studies of photoalignment technology were concentrated on alignment of nematic liquid crystals. Studies of photoalignment of smectics started recently [6]. To our knowledge, there were no systematic studies of photoalignment of cholesteric LC carried out till now. At the same time, application of photoalignment technology to cholesteric LC looks extremely promising since controlling direction of the easy axis and anchoring energy on the photosensitive aligning surface allows in turn, controlling characteristics of the cholesteric textures and electrically-driven transitions between bistable states of cholesteric cells.

In this paper we described electro-optical characteristics for the cholesteric LCD which was made by photo alignment technique.

2. Results
We investigated photoalignment of cholesteric mixture BL-118 from Merck on several photoaligning materials (fluorinated polyvinyl-cinnmate, cellulose-cinnamate and phenylon-based polymer). The phenylon-based polymer among them provided the best electro-optical characteristics. Therefore, below we present the results which we obtained for the phenylon-based polymer. The polymer films were produced by spin coating of the polymer solution in dimethylformamide (weight concentration was 15 g/liter) on a glass substrate covered with ITO. The centrifuge speed was 7000 rpm. After spin-coating, films were cured at 120$^?$C for 1.5 hour to remove the solvent and improve the mechanical properties of the films. After that the films were exposed with linearly polarised UV light from a Hg-lamp at normal incidence to the film surface. The IR-part of the lamp spectrum was cut by a water filter. The intensity of UV in the plane of the polymer film was about 110 mW/cm^2.

The alignment of the cholesteric LC was tested in the parallel combined cells made from a reference surface and a test surface. The reference surface was covered with rubbed polyimide layer. The test surface was made from the phenylon-based material irradiated with different exposure doze. Calibrated polymer spacers set the cell thickness L = 5.5 μm. Liquid crystal was filled into the cell by capillary effect at 85^o? and the cell was slowly cooled down to a room temperature.

The cholesteric textures were checked in a polarizing microscope. The quality of the alignment on the UV exposure doze was characterized by measuring the dependence of the intensity of scattering, I_{scat}, of the polarized beam of a YAG-laser (?=532 nm) from the test cell on the scattering angle. To do this, the cell was set perpendicular to the laser beam and the photodiode was rotated by a step-motor around the cell with a radius 30 cm. The cell was faced to photodiode by a tested layer, the back substrate was covered by a black tape and a lock-in modulation technique was used to collect the data.

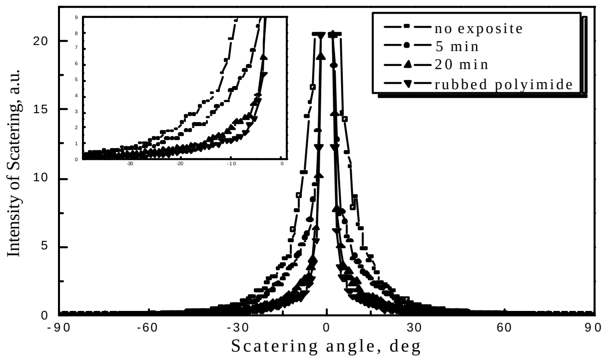

Figure 1. Dependence of the intensity of scattering from the planar cholesteric texture on the scattering angle at different exposure times. 0o-angle corresponds to the scattering normal to the cell. The fragment of the bottom of the plot is in the insertion. The experimental points around 0o-angle are not shown in because of a large scale of the plot.

Observation of textures in a polarizing microscope showed that UV irradiation on the polymer resulted in the orientation of initially random planar-oriented domains in a direction which was determined by the polarization of the incident UV-light. Increase of the exposure results in improvement of the domain ordering; at $t_{exp} > 10$ min the irradiated areas revealed a high-quality mirror reflection in a green part of visible spectrum.

The UV doze dependence of the angular selectivity of the photoaligned planar cholesteric structure is depicted in Figure 2. The angular selectivity of the planar texture was determined by a width of the angular distribution at I_{scat}=1/40 of the distribution maximum. The data for standard rubbed polyimide cell are also presented in the figure. One can see that increase of the exposure time, t_{exp},, that is equivalent to increase of the irradiation doze, results in an essential contraction of the angular selectivity which becomes close to the angular selectivity of the texture on the rubbed polyimide surface at $t_{exp} > 20$ min.

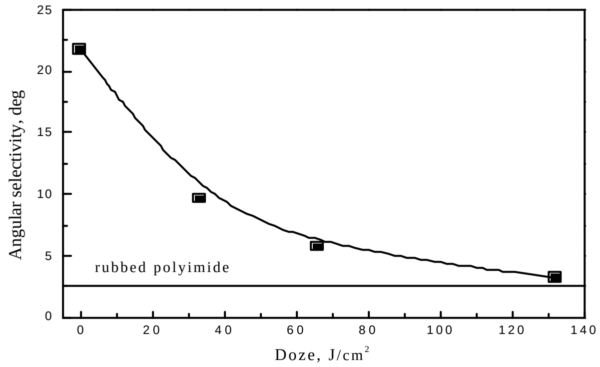

Figure 2. Dependence of the angular selectivity of the photoaligned cholesteric texture on the UV-doze. The solid line corresponds the angular selectivity of the cholesteric planar structure aligned by rubbed polyimide surface.

The UV exposure doze dependence on the reflectivity of the planar photoaligned cholesteric structure is shown in Figure 3. The reflectivity of photoaligned cholesteric structure at 100J/cm^2 is equivalent to rubbed polyimide surface.

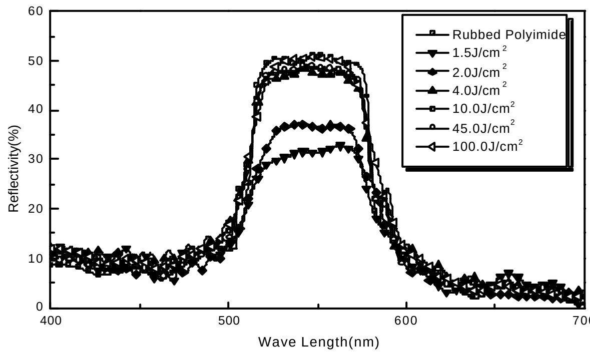

Figure 3. Dependence of reflectivity of the photoaligned cholesteric texture at different exposure energy.

The electro-optical switching of the cell depending on the exposure time was studied. 50Hz AC-voltage was applied to the planar cell during 1s. After 3s the voltage was switched off and the intensity of the reflection was measured. The following measurement cycle was carried out after recovering of the initial planar structure by application of 45 V during 1s. We found that at $t_{exp} > 10$ min the transition was almost the same as the characteristics of the rubbed-aligned planar structures. Shorter exposure times resulted in decrease of the reflectivity of the textures but the driving voltage characteristics for planar – focal-conic transition and the transition to homeotropic texture remained constant (Fig. 4).

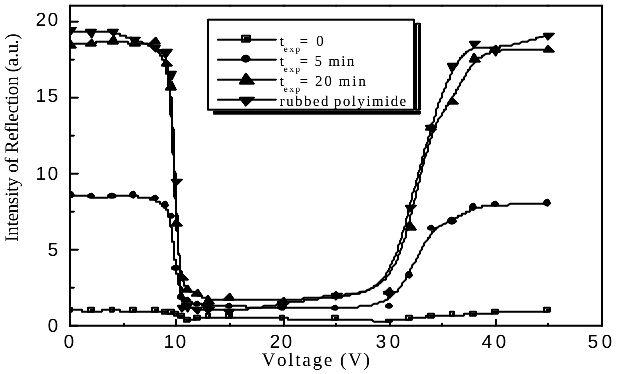

Figure 4. . Dependencies of the intensity of the light reflection from the cholesteric structure on applied voltage.

We found that non-polarized UV-light also affects characteristics of cholesteric textures on phenylon-based layer. The pictures of planar textures for the cells which were partially irradiated with polarized light and non-polarized light are presented in Figure 5. Here, the UV exposure time and UV doze are set as t_{exp} = 30mim and I = 110 mW/cm^{2}. The non-irradiated areas of cholesteric cells are also presented in the photos. One can see that the area irradiated with non-polarized light looks brighter than non-irradiated area and polarization of UV-irradiation improves the reflectivity of the textures drastically.

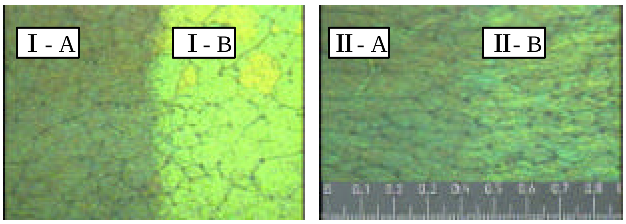

Figure 5. The picture of planar cholesteric textures with I -A), II -A) : non-irrediated area, I -B) : polarized UV irradiation area, II -B) : non polarized UV irradiation area. Width of the photos is 0.9mm.

Quantitative characteristics of the light scattering from the textures produced by irradiation of polarized UV-light, non-polarized UV-light and non-irradiated textures are presented in Figure 6. One can see that the angle dependencies of reflection for non-irradiated surface and for the surface irradiated with non-polarized light are virtually the same at the reflection angle $\theta > \pm 2^{o}$, and the angle range of the reflection are much wider then for polarized irradiation.

At the same time, the scattering at the small angles $-2^{o} < \theta < 2^{o}$ are different for non-polarized irradiation and no irradiation cases. For instance, for $\theta = 1.5^{o}$ the ratio of the scattering intensity for different treatment $I_1 : I_2 : I_3 = 1 : 1.8 : 122$ (here I_1; I_2 ; I_3 are the scattering intensity in the case of no irradiation, irradiation with non-polarized light and irradiation with polarized light correspondingly).

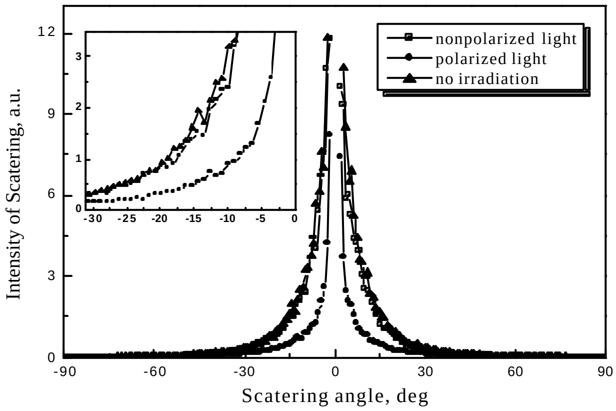

Figure 6. Dependencies of intensity of light scattering on the scattering angle

Angular dependence of scattering in a planar texture of cholesteric LC is determined mostly by the angular dependence of the axes of cholesteric spirals in domains and by the size distribution of cholesteric domains. We did not find essential changes in the domains sizes on the polymer surface after irradiation. Therefore, the difference in the scattering is determined mostly by the difference in the angular distribution of the orientation of the cholesteric spirals. Decrease of the pretilt angle of the director on the polymer surface after irradiation might cause the observed constriction of the angular dependence of scattering, but the pretilt angle of the nematic component of cholesteric mixture was found to be zero for both surfaces.

We believe that the difference in angular scattering dependence is caused by changes in efficiency of adsorption of LC molecules after irradiation of the polymer surface. Adsorbed LC molecule layer plays a role to stabilize the distribution of cholesteric spirals in a LC cell. UV Irradiation on the polymer is supposed to encourage a formation of this adsorbed layer which promotes a planar alignment of the director. It should result in increase of the anchoring energy of cholesteric LC that in turn, encourages planar orientation of the spirals and constriction of the angular scattering dependence.

3. Conclusion

Obtained results showed that photoalignment technology would be successfully applied for aligning cholesteric liquid crystals. Strong exposure doze dependence of the width of the angular selectivity of the planar textures allows to control the reflectivity of the cholesteric cells effectively. Photoalignment technology, where curing temperature is much lower than that of conventional rubbed polyimide, would be very promising for plastic LCD applications.

4. Acknowledgements

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5. References

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