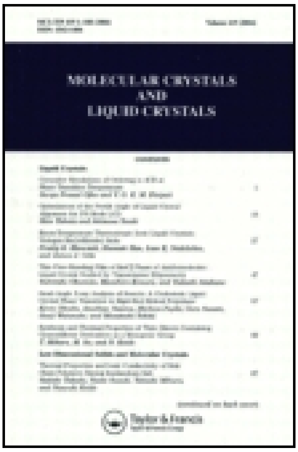

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Screening Effect of a-C:H Alignment Layer and its Influence on Characteristics of LC Cells

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Screening Effect of a-C:H Alignment Layer and its Influence on Characteristics of LC Cells

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The influence of the hydrogenated carbon alignment layer electrostatic screening effect on characteristics of dual frequency nematic liquid crystal was investigated. The screening effect was declined as the result of the threshold voltage reduction from 6 V to 1 V connected with the fourfold decrease in alignment layer thickness. The pretilt angle rising and the phase retardation reduction were observed at the same time. It is shown that hydrogenated carbon alignment layer application is able to change electrical properties of the cells as well as to accelerate the switching time at the wavelength of 1.55 μm.

Keywords amorphous hydrogenated carbon; alignment layer; pretilt angle; switching time

Introduction

One of the new materials used for the liquid crystals (LCs) alignment is amorphous hydrogenated carbon (a-C:H), produced by the chemical vapor deposition in plasma. The investigations of a-C:H alignment layers have increased considerably recently, and methods of the surface anisotropy forming of these layers are improved. These methods are based on the non-contact technology of the surface treatment by ions [1] or the scanning beam of plasma [2], as well as an action of polarized or non-polarized UV radiation [3]. The relevance of LCs cells with a-C:H alignment layers investigation is connected with the development of devices for the telecommunication systems [4, 5].

It is known that the thickness and electrical properties of an alignment layer affect on the voltage drop on the LCs layer. The screening effect of the alignment layer increases in thin LC cells [6]. Decreasing of cells thickness up to 8 μm has lead to considerable rising of the electro-optical splay-effect threshold voltage of the dual-frequency nematic liquid crystal (DFNLC). It has been contributed to screening of the applied voltage by the dielectric a-C:H alignment layer [5]. The aim of this experiment is to observe the screening effect and the influence of the a-C:H alignment layer thickness changing on characteristics DFNLC cells in detail.

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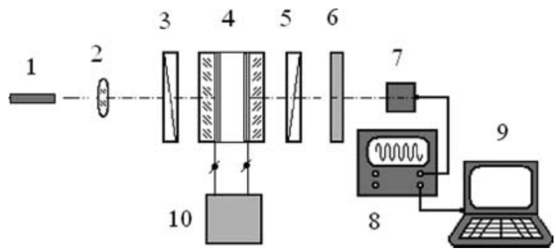

Figure 1. The scheme of the electrooptical characteristics measurements LC cells. 1—semiconductor laser module, 2—collimator, 3—polarizer, 4—LC cell, 5—analyzer, 6—system of filters, 7—photodiode, 8—oscilloscope, 9—computer, 10—pulse generator.

Experimental Details

The experiments were carried out on the electrically controlled sandwich type LCs cells fabricated from two polished glass substrates 35 mm in diameter covered by a transparent electrode layer based on the tin-doped indium oxide and the a-C:H alignment layer. The a-C:H layers have been prepared by the chemical deposition of acetone vapors using the direct-current glow discharge under a room temperature with a pressure of 0.05 Pa and a discharge power of 0.4 W in the vacuum chamber. Substrates were located into plasma oblique to electrodes at the angle of 20 degrees. The oblique arrangement of substrates into plasma allows preparing the a-C:H layers, which orient LC molecules homogeneously without any additional processing [7]. The thickness of the a-C:H layers varied by changing a deposition time and was measured using the interferometer.

We used DFNLC ZK-1001 (NIOPIK, Moscow) for our investigations. The gap thickness of cells we obtained from an empty cell capacity measuring was about 8 μm. Dependences of capacitances and resistances of cells are measured on a handmade scheme by applying the electric field with a frequency 1 kHz. Optical characteristics and switching times of the LC cells were measured using the electrooptical scheme shown in Figure 1 at 0.65 μm and 1.55 μm wavelengths described in detail elsewhere [8]. The LC cell mounted between the polarizer and the analyzer in such a way that the long axis of the molecules lay in the plane of its rotation and made an angle of 45° with the plane of polarization of the incident light. The maximum phase retardation $\Delta\Phi_{max}$, the pretilt angle θ_p, and the threshold voltage U_{th} of cells were determined from experimental dependences of its transmission on the bias voltage with a frequency 1 kHz, which were measured using methods described previously [9]. The characteristics of the LC cells are shown in Table 1.

Results and Discussions

The threshold voltage of the cell was equal to 6 V when the thickness of the a-C:H alignment layer was about 130 nm and reduced up to 1 V, after fourfold decrease in the deposition time of a-C:H layer as can be seen in the table. Lowering of the threshold voltage was accompanied by increasing of the pretilt angle θ_p from 17° up to 44° and reducing of the phase retardation as shown in Fig. 2 [5].

The increase of the pretilt angle could be caused by a reduction of an anchoring energy LCs with a-C:H layer surfaces. The change of interphase interaction could be caused by a formation of a space charge under the application of an electric field to LC cell and adsorption of ionic charges by the dielectric a-C:H alignment layer surface. The

Table 1. LC cells characteristics

No cells	Cell thickness, μm	Deposition time of a-C:H layer, min	U_{th}, V	θ_p, degree	$\Delta\Phi_{max}/\pi$ $\lambda = 0.65\ \mu$m	$\Delta\Phi_{max}/\pi$ $\lambda = 1.55\ \mu$m
1	7.8	20	6	17.5	5.3	2.3
2	8.3	5	1	44	3.1	1

experimental dependences of the resistance R and the capacitance C on voltage applied to cells No 1 and No 2 are shown in Figs 3 and 4. Number of curves in Figures corresponds to the numbers of cells in the table. The dependencies of R and C were changed non-linearly in case of the cell No 1 where the layer thickness was about 130 nm (curves 1 on Figs. 3 and 4). The capacity did not change it up to 3.5 V. This indicates that the screening effect of the a-C:H alignment layer took place in the LC cell. On the contrary, the dependencies of R and C varied smoothly for cell No 2 (curves 2 on Figs. 3 an 4). The reducing of thickness of the alignment a-C:H layer modifies significantly the electrical characteristics of the LC cells.

The response times of LC cells were analyzed at the wavelength of 1.55 μm. Devices for telecommunication application should provide phase retardation no less than one π. DFNLC comprises a mixture of molecules with positive and negative anisotropy of the dielectric permittivity. Due to the permittivity sign inversion, DFNLC based devices can be switched from the on state to off state by the electric fields with different frequencies.

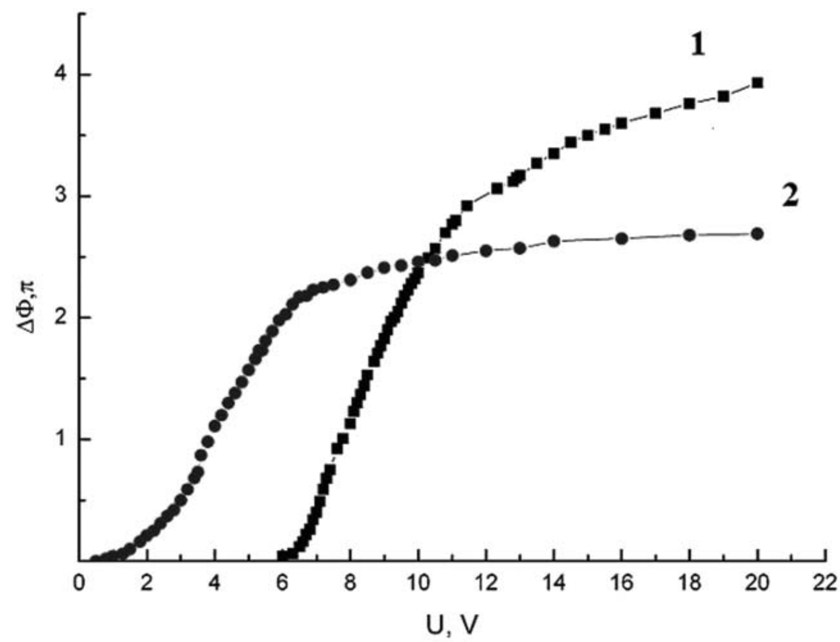

Figure 2. The dependences of phase retardation on voltage for cells No 1 and No 2 at a wavelength of 0.65 μm. Total achievable phase retardation for the cell No 2 is decreased due to the reduce of the a-C:H layer thickness.

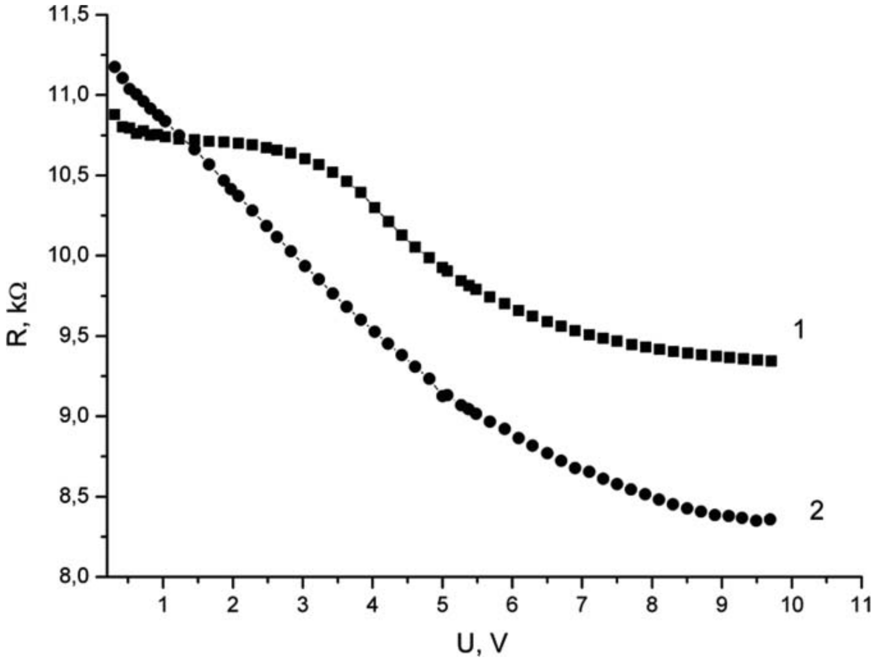

Figure 3. The experimental dependences of a resistance of compered cells on voltage applied with frequency of 1 kHz.

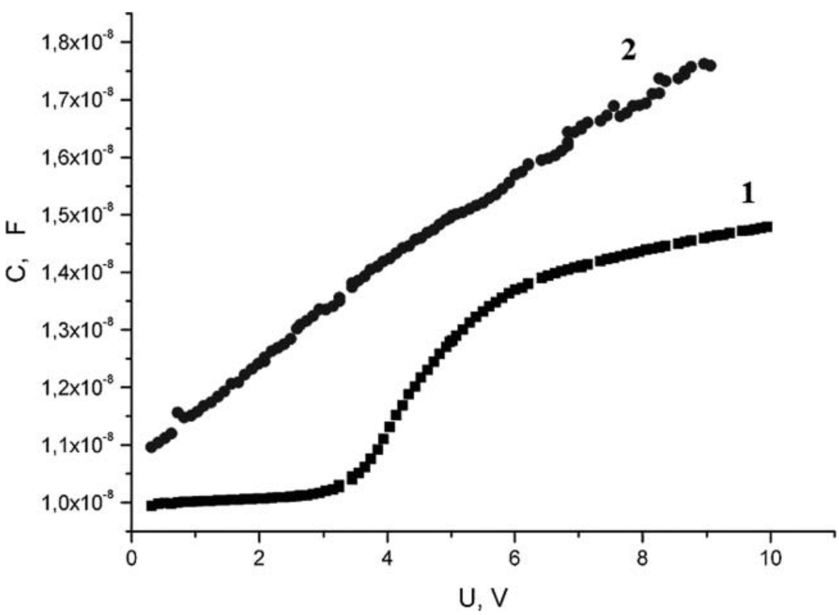

Figure 4. The experimental dependences of a capacitance of compered cells on voltage applied with frequency of 1 kHz.

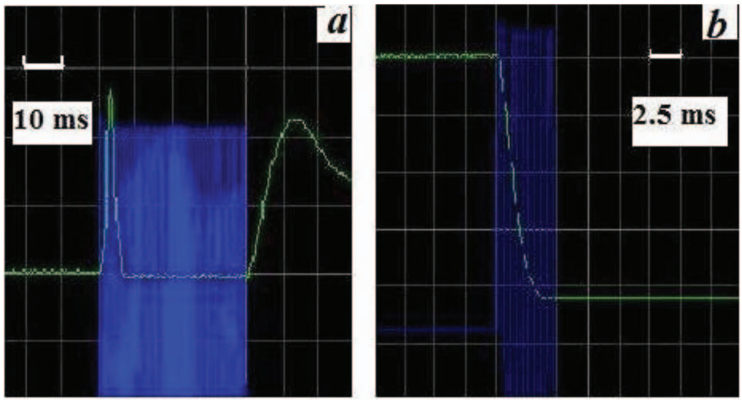

Figure 5. The electrooptical responses of cells No 1 (*a*) and No 2 (*b*) at a 1.55 μm wavelength controlled by applying to cells a packet of square waveform oscillations with frequency of 1 kHz and amplitude equal to 60 V. The electro-optical response of the cell No 2 was quickly compared with one of the cell No 1, but its phase retardation was less and the pretilt angle was bigger due to reducing of the a-C:H layer thickness and lowering of the screening effect.

Switching time τ_{on} to state on as the result of splay deformation for molecules DFNLC with a positive dielectric anisotropy was controlled by applying to cells a packet of square waveform oscillations with low frequency 1 kHz. Switching time τ_{off} from state on to state off was controlled by applying to cells a packet of square waveform oscillations with a high frequency 30 kHz. Amplitude of a packet of square waveform oscillations equals 60 V. The phase retardation of cell No 1 was about 2π, $\tau_{on} = 5$ ms (Fig. 5a) and τ_{off} equal to 30 ms. While the phase retardation of cell No 2 was only π, because higher pretilt angle (table), but switching was faster and $\tau_{on} = 1.2$ ms (Fig. 5b) at the same control regime as for the cell No 1. We got the acceleration of splay deformation, but lost the phase retardation in the result of lowering the screening effect by reducing of a-C:H layer thickness.

Conclusion

We analyzed the influence of the alignment a-C:H layers thickness on the characteristics of DFLNC cells. It was shown that the reducing of the a-C:H alignment layer thickness could decrease the threshold voltage and the screening effect seriously. These changes could be caused by the influence of a space charge field on an anchoring energy of the LCs with the alignment surface. Reducing of the threshold voltage by the dielectric a-C:H alignment layer thickness resulted to decreasing of a cell resistance and led to the acceleration of the splay-deformation LCs in the electric field. It was shown that the phase retardation about one π on the wavelength 1.55 μm could be obtained for the response time about 1.2 ms.

The experimental results show the influence of a thickness of the dielectric a-C:H alignment layer not only on the screening effect but on optical and electrical properties and switching times of LC cells. In order to improve the response time of LC cells (i.e., to reduce τ_{on} and τ_{off}) and ensure a phase retardation no less than one π, it is necessary to optimize not only LC layer thickness but the thickness of dielectric alignment layer as well. These results are helpful for optimizing LC devices characteristics developing for the telecommunication applications.

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