INFLUENCE OF FULLERENES C_{60} ON OPERATING CHARACTERISTICS OF LIQUID CRYSTAL MBBA

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Influence of fullerenes C_{60} on the threshold voltages of Freederickzs and Carr-Helfrich effects and switching times of the Carr-Helfrich effect in nematic liquid crystal 4-methoxybenzilidene – 4' – butylaniline (MBBA) are presented. It is shown that the clearing temperature and threshold voltage of both effects decreases at the additive of fullerenes. The threshold voltage of electrohydrodynamic instability at low frequencies and also critical frequency of disappearance of Williams' domains decrease. Moreover, the switching times of this effect also decrease. Experimental results are explained by increasing of elastic constant, suppression of conductivity and an increase in numbers of turbulence nucleation at the additive of particles.

Keywords: Liquid crystal; Freedericksz effect; Williams' domain; fullerenes
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INTRODUCTION

A series of contributions are devoted to influence of nanoparticles on electrooptic properties of liquid crystals. Particularly, the review on similar researches is resulted in [2]. There is a lot of works on liquid crystalline colloids based on fullerene derivatives, for instance, [3]. But influence of the pure fullerenes on electrooptic parameters of liquid crystals did not practically study.

The results of investigation of Influence of fullerenes C_{60} on electrooptic properties of liquid crystal 4-methoxybenzilidene – 4' – butylaniline is presented in the report.

EXPERIMENTAL

We used the nematic liquid crystal (LC) 4-methoxybenzilidene – 4' – butylaniline (MBBA) (NIIOPIK, Russia) as a matrix having negative anisotropy of dielectric permittivity. The fullerenes C_{60} (U.S. Research Nanomaterials, In.) was added into the liquid crystal with 0.5 wt.% and was shaken in a vortex mixer for 1 hour, followed by sonication for 4 hours.

The cell had a sandwich structure and consisted of two plane-parallel glass plates whose inner surfaces were coated with thin transparent and conductive indium-tin-oxide (ITO) layer. The initial configuration of both the LC and the colloid was homeotropic. The cell thickness was fixed with calibrated 20 μm polymer spacers for measurements. Both the colloid and the pure LC were injected into the empty cell by capillary action at the isotropic state.

A set-up for measurements of electro-optical parameters was assembled on the base of the Carl Zeiss polarization microscope. The electric impulses of the special form applied to the cell from the functional generator (model G6-28, Russia). A light, passing through the cell, fell on the photo diode and was registered by digital storage oscilloscope (model 6022BE, Hantek). Switching times were defined from an electro-optic response by application of unipolar rectangular impulses while threshold voltage was defined using unipolar triangular impulses in quasi-static regime. Besides, a value of the threshold voltage was supervised under the polarization microscope. Frequency dependence of the threshold voltage was registered by application of sinusoidal voltage. All measurements were carried out at temperature 23°C.

RESULTS AND DISCUSSION

Observation under the polarization microscope has shown that the presence of fullerenes in MBBA shifts the clearing point from 42.2°C to 41.6°C. It is qualitatively agreed to following expression from [3] for the spherical form and low concentration of isotropic particles:

$$T_c = (1- f)\, T_o$$

where f is the volume fraction of particles, T_0 is the clearing temperature of the pure LC.
Besides, it has been shown that the threshold voltage of Freedericksz effect also decreases from 3.7 V to 3,3 V. The threshold voltage at strong coupling is defined as follows [4]:

$$U_{th.F.} = \pi\sqrt{\frac{K_{33}}{\varepsilon_0 \Delta\varepsilon}}$$

where K_{33} is the bend elastic constant; ε_0 is electric constant; $\Delta\varepsilon$ is the dielectric anisotropy. Considering numerical values of dielectric anisotropy ($\Delta\varepsilon^{LC} = 0.50$; $\Delta\varepsilon^{col} = 0.99$ [5]) we may define the bend elastic constant for both the pure LC and the colloid which equals to $6.14 \cdot 10^{-12}$ H и $9.68 \cdot 10^{-12}$ H, correspondingly. Therefore, there is an increase of elastic constant in the colloid.

The frequency dependence of threshold voltage of Williams's domains formation as the pure LC and the colloid is shown in Fig.1.

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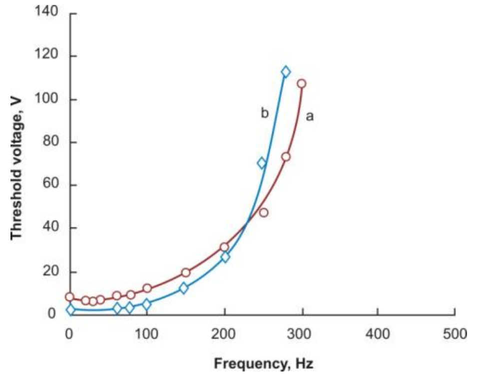

Fig.1. The frequency dependence of the threshold voltage of Williams's domains formation: (a) pure MBBA, (b) MBBA + fullerenes.

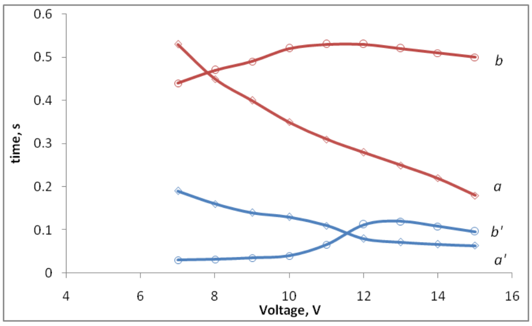

Fig.2. Voltage dependence of switching times: (a) a rise time of the pure MBBA, (a') a rise time of the colloid, (b) a decay time of the pure MBBA, (b') a decay time of the colloid.

Apparently, the threshold voltage of Williams's domains formation for the colloid is less than for the pure LC at low frequencies. Obviously, it is connected with an increase in numbers of turbulence nucleation at the additive of particles. The critical frequency of disappearance of Williams's domains in the colloid is also less. It is connected with conductivity reduction in the colloid [5].

The results of measurements of switching times for hydrodynamic instability (Williams's domains formation) of the pure LC and the colloid depending on the applied voltage are resulted in Fig.2.

Apparently, the additive of particles reduces both a rise time and a decay time that, basically, is connected with an increase in dielectric anisotropy and reduction of the threshold voltage. Actually, a rise time for the Carr-Helfrich effect is defined by following expressions [6]:

$$\tau_{on} = \frac{\beta \eta d^2}{U^2 - U_{th}{}^2}$$

where η is the translational viscosity, β is the parameter depending on material properties of the substance such as elastic constants and density, *d* is the cell thickness, *U* is the applied voltage. One can calculate the rotational viscosity for both samples. These calculations show that the viscosity increases at the additive of fullerenes.

As can be also seen from this Fig. 2, a decay time also decreases at present of fullerenes. In accordance with [6,7], a decay time is defined by following expressions:

$$\tau_{off} = \frac{\alpha \eta d^2}{\pi^2 K_{33}}$$

It is obvious that decreasing of decay time is connected with increasing in an elastic constant.

In summary, the additive of fullerenes in MBBA improves the operating characteristics of liquid crystal MBBA, namely, decreases the threshold voltages and switching times in the Carr-Helfrich effect.

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