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Electrically controlled light scattering effect in the emulsion "liquid crystal – isotropic liquid"

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New heterogeneous liquid crystal (LC) system with electrically controlled light scattering is suggested. It is an emulsion of isotropic liquid in the nematic LC. Electro-optical characteristics of such system are reported.

Keywords: heterogeneous liquid crystal medium, emulsion, electro-optical properties.

INTRODUCTION

Effect of electrically controlled light scattering is under investigation for different heterogeneous LC media. The "LC-polymer" systems with different morphology are especially well studied. The most investigated one is a capsulated LC [1]. At higher LC concentration, polymer network structure or polymer agglomerate structure in liquid crystal matrix could be formed [2,3]. Different types of LC displays, light shutters, sensors etc. based on the system "polymer-LC" are developed. Electrically driven light scattering in the LC introduced into porous membranes was studied in [4]. Recently, electro-optical properties of filled LCs- suspensions of small solid particles in LC were investigated [5,6].

All mention above heterogeneous systems are binary mixtures of liquid crystalline and solid phase. Alternative to such media is the binary mixture of two liquid components where at least one component is in LC state [7,8]. The

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aim of this work is to study the effect of electrically controlled light scattering in the emulsion "nematic liquid crystal-isotropic liquid".

EXPERIMENTAL RESULTS AND DISCUSSION

Sample preparation

As a LC component, nematic liquid crystalline material 5CB with $\Delta\varepsilon$=10 was used. We tried different isotropic liquids, namely, water, glycerine, engine oil and polymethylsiloxane (PMS) oil for the preparation of emulsion. Using different relative concentration of components, we tried to produce both dispersion of isotropic liquid in nematic LC and vice versa, dispersion of nematic LC in the matrix of isotropic liquid. The first type of emulsion was very unstable, so only the second one will be reported. The best dispersion of the isotropic liquid in a LC matrix was reached for PMS. It is naturally because polymethylsiloxane is a well known surface active material. A mixture of 5CB-PMS (with concentration of PMS about 40 weight %) was intensively stirred with the ultrasound mixer and placed between two glass plates covered with transparent ITO electrodes contacting with emulsion. Layer thickness was 10 μm. The samples just after preparation were quite turbid. Nevertheless, the samples become slowly increasingly transparent. Observation of the emulsion layers with the polarization microscope showed that initial size of the PMS droplets was less a 0.5 μm. Then the PMS droplets slowly flow together and larger PMS inclusions appear. Aggregation rate increases when the electric field is applied. A size of the droplets stabilizes after the droplet touched the walls of the cell. Therefore, the size of stable PMS droplets was 10 μm. Low intensity light scattering was observed in this case.

To prevent the inter-flow process small amount of photo-polymer composition (8 weight %) was added to the emulsion. The samples just after preparation were irradiated with the mercury lamp during 15 min. Integral intensity of the irradiation was 4 mW/cm^2. Irradiation leads to the formation of polymer network. In the "loops" of this network the PMS droplets are stabilized. The size of the droplets stabilized in such way was 1-2 μm. Droplet

size distribution was rather sharp. It was also observed that the application of an electric field does not change essentially the shape and size of the PMS droplets. Such emulsion layers stabilized with polymer network were used for the electro-optical measurements.

Electro-optical measurements

The experimental set up is described in our previous paper [6]. The intensity of the He-Ne-laser light beam transmitted through the sample, I_{out}, was measured within the cone of 2°. From these data the transmittance of the sample, $T=I_{out}/I_{in}$, was calculated (I_{in} is the intensity of the incoming beam). Transmittance consists of both direct T_{dr} and alternating T_{alt} components. Total transmittance T as well as components T_{dr} and T_{alt} was measured. Based on these data the transmittance-voltage and transmittance-frequency characteristics were obtained for the emulsion layers which have been investigated.

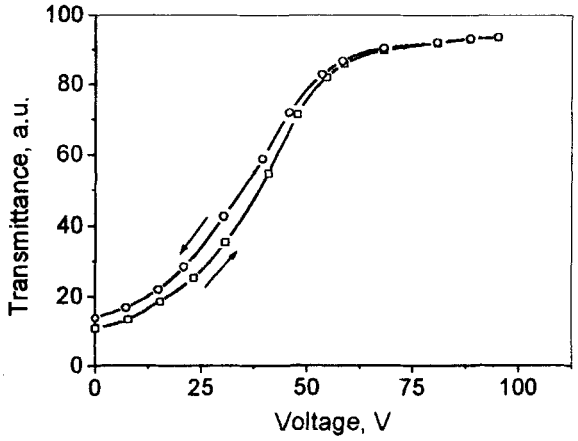


FIGURE 1. The transmittance-voltage curves for the emulsion 5CB-PMS for both increase and decrease of the applied field (f=1 kHz).

The transmittance-voltage curves ($T(U)$) for the emulsion 5CB-PMS for both increase and decrease of the applied field (f=1 kHz) are presented in

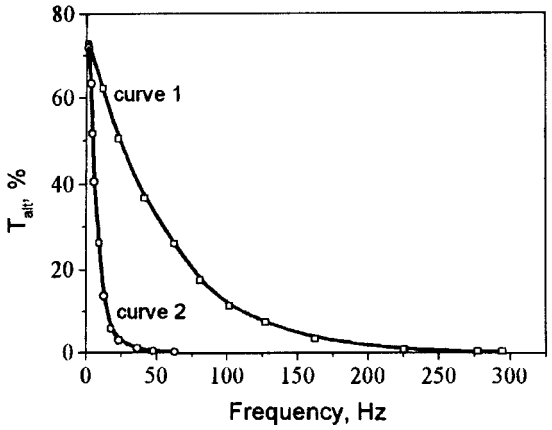
Fig.1. One can see that initial transmittance T_o=11% is low enough. Increase of the voltage leads to the increase of the cell transmittanse. A rise of the curve *T(U)* is not steep. Dependence *T(U)* saturates at the voltage of about 50 V. Saturated value of the transmittance is about T_s =94%. Curve *T(U)* is practically reversible but small hysteresis loop take place. Contrast ratio calculated as T_s/T_o is about 9.

To our mind, it is reasonable to compare studied emulsion with the filled LC. Indeed, filled LC is a dispersion of small solid particles (usually aerosils) in liquid crystalline matrix [5]. Studied system is a dispersion of isotropic liquid in LC, so one can say that *it is liquid crystal filled with liquid phase*. In filled LC the solid particles generate orientational defects in anisotropic LC matrix. In the emulsion, the isotropic droplets are the sources of LC defects. It is a reason for the light scattering in the initial state. Like in the case of filled liquid crystals, orientation of LC molecules in electric field leads to disappearing the defects and so to the transparent state. Irreversible electro-optical response of filled LC was earlier explained as stabilization of LC oriented state with the structure of anisotropic agglomerates of solid particles [6]. Accordingly, reversible character of the curve *T(U)* could be explained proceeding from the sphere-like structure of liquid inclusions.

Total transmittance T of the emulsion did not practically not depend on the field frequency. However, the components T_{dr} and T_{alt} essentially depend on the f. Frequency dependence of the amplitude of T_{alt} is presented in Fig.2 (curve 1). Transmittance T_{alt} decreases with the increase of frequency. This decrease is sharper than in case of filled LC 5CB (curve 2) [6]. Let us introduce the frequency of relaxation f_r corresponding to decrease of T_{alt} in e=2.7 times in comparison to the value of T_{alt} at 0.1 Hz. The value of f_r for the emulsion 5CB-PMS is 25 Hz wile for the filled LC 5CB-aerosil A300 f_r=200 Hz.

Switching on and switching off time for the emulsion 5CB-PMS are correspondingly τ_{on} =15 ms and τ_{off} =100 ms. As was previously measured

FIGURE 2. Frequency dependence of T_{alt} for the LC-aerosil system (curve 1 [6]) and for the LC-isotropic liquid system (curve 2).



[6], corresponding parameters for filled LC 5CB-aerosil 300 are τ_{on} =3 ms and τ_{off} =20 ms.

The measured values f_r =25 Hz and τ_{off}=100 ms roughly satisfy the equation f_r=1/τ_{off} because they reflect the same relaxation processes in the system. Application of the electric field causes orientation of LC domains confined between neighbor droplets. In the alternative field, LC domain reorients following the swinging of the field. But for the frequencies higher than f_r it can not reorient in time with the field changes. It is the reason why the amplitude of T_{alt} decreases. Sharper decrease of the curve $T_{alt}(f)$ for the emulsion 5CB-PMS than for the filled LC 5CB-aerosil300 takes place because of larger size of LC domain. Reorientation time in an electric field for an individual LC domain having the characteristic dimension d can be evaluated as

$$\tau \approx \frac{\eta d^2}{\pi K}$$

where η is the orientational viscosity, K, the Frank constant. For the size of the droplets in the emulsion setting the values K=5 10^{-7} dyn, η=1 P, τ_{off}=100 ms one can obtain d=1 μm. This value is in good agreement with the inter-droplet distance measured with polarization microscope. For the field LC

5CB-PMS setting the value τ_{off}=20 ms the inter-agglomerate distance d=0.3 μm can be obtained.

Conclusions

So, this study enlarges the range of heterogeneous LC systems with the electrically controlled light scattering effect. Electro-optical properties of the layers of the emulsion "nematic LC(5CB)-isotropic liquid (PMS)" are first investigated. The intensity of the light scattering as a function of electric field parameters was measured. Samples where characterized with controlling voltage about 50 V, contrast ratio near 10 and low multiplexity of the transmittanse-voltage curve. Electro-optical response with only direct component of the transmittance was observed in a very wide frequency range (20 Hz-20 kHz). The measured electro-optical dependences are explained proceeding from the microscopic structure of the system.

References

[1.]Wu B.-G., West J.L. Doane J.M. *J.Appl.Phys.*, **62**, 925 (1987).

[2.]H.Takatsu, K.Takeuchi and Y.Umezu. *Mol.Cryst.Liq.Cryst.*, **225**, 81 (1993).

[3.]Y.K.Fung, D.-K.Yang, S.Ying at al. *Liquid Cryst.*, **19**, 797 (1995).

[4.]G.P.Crawford, J.W.Doane. *Modern Phys.Lett.B.*, 7, 1785 (1993).

[5.]M.Kreuzer, T.Tschudi and R.Eidenschink. *Mol.Cryst.Liq.Cryst.*, **223**, 219 (1992).

[6.]A.Glushchenko, H.Kresse, V.Reshetnyak, Yu.Reznikov, O.Yaroshchuk. *Liq.Cryst.* **23**, 241 (1997).

[7.] P.Poulin, H.Stark, T.Lubensky, D.Weitz. *Science*, 275, 1770 (1997).

[8.]C.Casagrande, P.Fabre, M.A.Guedeau, M.Veyssie. *Europhys. Lett.*, **3(1)**, 73 (1987).