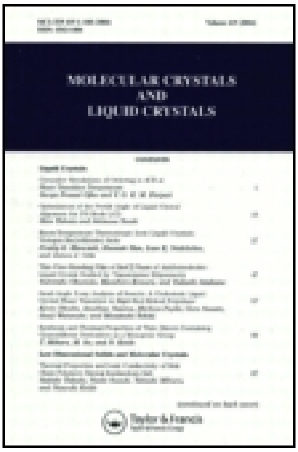

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Electrically Controlled Transparency of Salted Liquid Crystal

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Electrically Controlled Transparency of Salted Liquid Crystal

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We propose a new composite system consisted of micro-crystals of alkali halides dispersed in nematic liquid crystal (LC). We studied NaCl-particles dispersed in pentyl-cyanobiphenyl (5CB). LC doping with NaCl-particles does not change the macroscopic properties of LC. Strong interaction between LC molecules and the surface of the micro-crystals results in a strong light scattering by the suspension. Application of an electric field switches the material to a light transparent state due to director reorientation and matching of the refractive indexes of the LC domains and micro-crystals. The initial state recovers very quickly (< 1 ms) at field removing. We consider alkali halide suspensions very promising for IR applications since they are highly transparent in this spectral region.

Keyword: liquid crystal; heterogeneous LC systems; alkali halide particles; filled nematics.

INTRODUCTION

The structure, intermolecular interaction and physical properties of heterogeneous liquid crystal (LC) systems are the subject of intensive investigations now because of their promising applications and interesting science. Typical examples of these systems are polymer-dispersed liquid crystals (PDLCs) and suspensions of aerosil in nematic LC (filled nematics). These systems scatter light but become transparent when an electric field is applied[1-4]. Their switching is due to matching of the refractive indexes of the polymer and LC upon reorientation of the director in the droplets. PDLCs provide a fast response (~ 1-10 ms) and relaxation times (~ 10-50 ms), good contrast ratio (~ 1:100) and require relatively low operating voltages (~ 1-5 V/μm)[5]. The technology of the PDLC fabrication is rather delicate since the problems of matching of the refractive indexes of the polymer matrix and LC, solubility of LC, phase separation, thermal stability *etc* are complicated. The preparation of filled nematics with the same electro-optical properties is much simpler since a complicated phase separation process is not required. At the same time the structure of filled nematics and physical processes responsible for their switching in an electric field are very complicated and are still the subject of discussion. Therefore, development of simple, reliable and cheap heterogeneous LC systems is of the current interest. All previous heterogeneous compositions have been developed for operation in the visible range, limiting their application in telecommunication systems.

In this paper we propose a new IR-transmitting heterogeneous LC system consisting of a suspension of ultra-fine alkali halides particles dispersed in a nematic matrix. The mixture of micro-crystals of NaCl and 5CB possesses a fast electro-optical response, is simple to make and cheap.

EXPERIMENTS AND DISCUSSION

We used a suspension of NaCl powder (weight concentration $c = 45 \div 65\%$, initial particle size $d \approx 1$ μm) in the nematic LC pentyl-cyanobiphenyl (5CB, EM Industries). The NaCl powder was obtained by milling the crystals of sodium chloride obtained from Aldrich during 100 hours by Fritsch boll-mill. The suspension was prepared by shaking of the mixture of the powder and the LC in an ultra-sonic mixer.

We found that the salt does not dissolve in 5CB and essentially does not change the conductivity and phase transition temperature of 5CB. We measured the conductivity in *ac*-electric field (frequency, ν = 1 kHz) and the phase transition temperature of pure 5CB and salted 5CB. The measurement by a standard bridge method gave the values $\sigma_{5CB} \approx \sigma_{5CB+NaCl} = (1 \pm 0.05)\ 10^{-6}$ Ohm m^{-1}. The observation in the polarizing microscope of the textures of the samples which was put in a precise hot stage "INSTEK-HS-1 gave the values T_{5CB} = (37.53 ± 0.03)°C, $T_{5CB+NaCl}$ = (37.49 ± 0.03) °C. The fact that the clear point of 5CB is not changed when 5CB is salted means that the interaction of the components does not change the mesogenic properties of 5CB, and the role of the salt particles is to impose boundary conditions on the LC.

The salted 5CB was pressed between two glasses coated with In_2O_3 (ITO). The cell's thickness was $L = 5 \div 20$ μm. LC cell strongly scatters light due to defects of LC orientation induced by NaCl particles. Application of the electric field caused increase in the transparency of the cell. The dependence of the transmittance of He-Ne laser beam through the cell as a function of applied *ac*-voltage for the different concentration of the particles is shown in Fig.1.

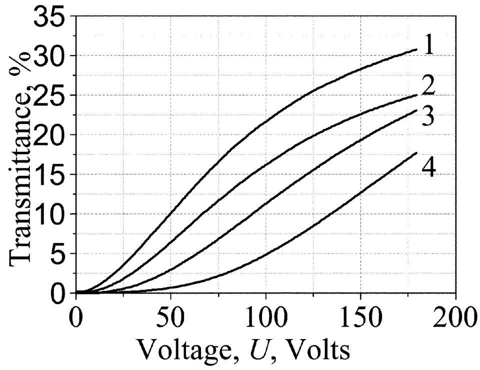

FIGURE 1. Dependence of cell's transmittance on applied voltage, f = 1 kHz: (1) 45 wt %, (2) 55 wt %, (3) 60 wt %, (4) 65 wt %.

The salted LC can be used not only for electrically controlled light switching but also for an electrically variable birefringent cell. We made the salted LC cell from two glasses, one of which was covered by an ITO electrode and the other one covered with an etched ITO pattern of lines with a width and period of 50 μm. Application of the electric field caused a spatially modulated birefringence of the cell and produced a diffraction grating due to reorientation of LC director. Figure 2 shows a schematic of the experimental set-up we used. We measured the light intensity of the first diffraction peak as a function of the applied voltage. Two maxima of the characteristic seeing in Fig.2 demonstrate that the phase retardation $\Phi \approx 2\lambda$ is produced by the application of the voltage $U \approx 400$V.

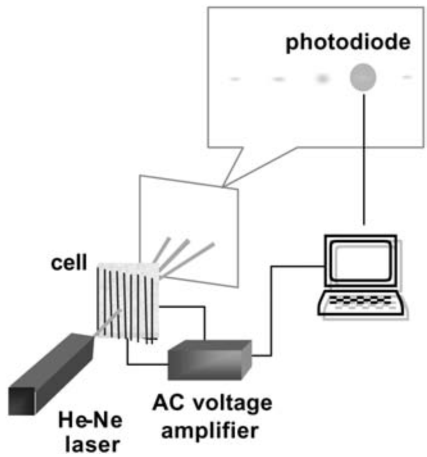

FIGURE 2. Experimental set-up for the measurement of characteristics of the spatially modulated birefringence of the cells.

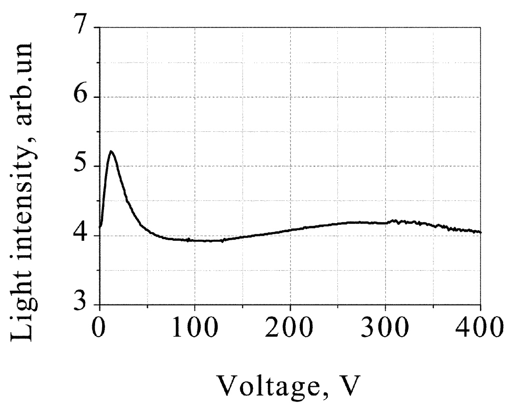

FIGURE 3. Light intensity of the first diffraction peak as a function of the applied voltage. $c_{NaCl} = 60\%$, L = 20 μm.

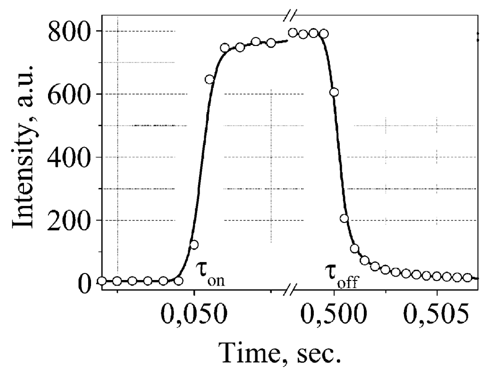

FIGURE 4. Dynamics of switching and relaxation of the cell with 5CB-NaCl mixture. $c_{NaCl} = 60$ %, $\tau_{on} = 0.9$ msec, $\tau_{off} = 1.6$ msec.

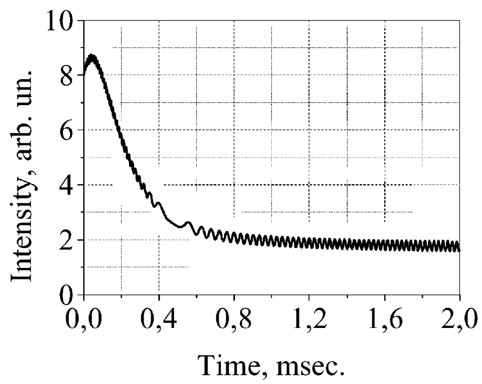

FIGURE 5. Dynamics of relaxation of diffraction intensity. $c_{NaCl} = 60\%$, $\tau_{off} \approx 0.5$ msec.

The salted 5CB responds in about a millisecond. The dynamics of the switching-on and -off of the cell upon application and removal *ac*-voltage $U = 180$V, $f = 1$ kHz is depicted in Fig.4. The relaxation of the intensity of the diffraction is shown in Fig.5. The dynamic characteristics of the salted 5CB do not depend on the cell's thickness in the range of 5-20 μm.

Frolova *et al*[6] showed that monocrystals of alkali halides impose stable alignment on nematic LCs along certain crystallographic axes. This indicates strong interaction between the LC molecules and the particle surface. The analyses of the IR spectra of salted 5CB (Fig.6) confirms this fact. CN- (2200 cm^{-1}) and CC- (1600 cm^{-1}) of the salted 5CB are much wider and shifted to longer wavelengths compared with the same bands of pure 5CB. These peculiarities of the spectra of the salted 5CB can be attributed to a strong interaction of 5CB monomers and dimers with both the NaCl surface itself and water adsorbed by the particle surface.

Assuming the strong anchoring of the 5CB on the NaCl surface, we estimated a characteristic spatial scale of LC inhomogeneity by the formula [7]

$$\bar{d} = \sqrt{\frac{\pi \tau_{off} K}{\eta}}\,.$$

For $\eta = 0.25$ P, $\tau_{off} = 0.5$ msec and $K = 7 \cdot 10^{-7}$ dyne we obtained the reasonable value $\bar{d} = 0.5$ μm, which is of the order of size of the NaCl particles.

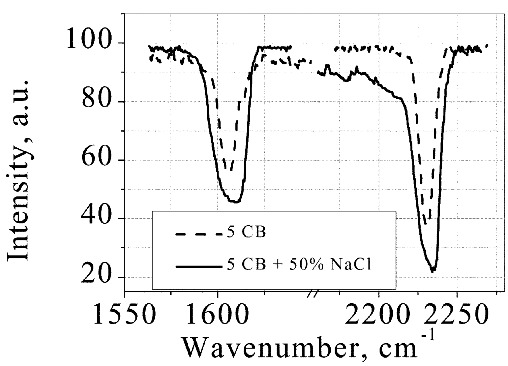

FIGURE 6. Fragments of IR spectra of pure 5CB and suspension 5CB + NaCl.

CONCLUSIONS

Ultra-fine NaCl-particles dispersed in nematic 5CB does not change essentially mesogenic properties of 5CB, and the role of the salt particles is to impose boundary conditions on the LC. The transmittance and the birefringence of the suspension can be effectively controlled with the electric field. The electro-optical response of the suspension is very fast; τ_{on} and τ_{off} are of the order of a millisecond. The advantages of this dispersion compared with known heterogeneous LC systems is its transparency in IR region. We emphasize that this system is the example of suspensions of alkali halides in nematic LCs. Our tentative experiments with the suspensions based on KBr and CaF particles showed that these systems have the same electro-optical effects. We plan to continue our studies to develop effective and fast electro-optical media operating in the visible and IR regions.

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