Liquid crystal emulsions: new system for display and non-display applications

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Abstract: *New type of inhomogeneous liquid crystal systems –liquid crystal emulsions (LCE) are proposed as perspective materials for display and non display applications. This conclusion is made due to a study of thermo-optical and electro-optical effects in these objects. The results of such investigations are presented and discussed. The main advantages of LCE important for an application in display and fiber optic technologies are described*

Keywords: Liquid crystal emulsions; electrooptical and thermooptical effects; liquid crystal displays; fiber optics

Introduction

For the last years inhomogeneous liquid crystal systems (ILCC) were recognized as very interesting objects for both fundamental studies and practical applications [1, 2]. In particular, strongly confined LC systems (SCLCS) such as porous glasses, aerosils and aerogels were used to obtain a new deep insight into the nature of physical processes taking place at nano-scaled space confines [1]. Some types of ILCC, polymer dispersed liquid crystals (PDLC), for example, were successfully applied in display technologies [2]. They also were proposed as new perspective media for fiber optic applications [3]. Recently [4, 5] we reported the first experimental results of acoustical and optical studies of liquid crystal emulsions (LCE) which were devoted to the physics of phase transitions in SCLCS of such type. In this report we mostly focus on the physical effects interesting for possible display and non display applications of these new objects.

Liquid Crystal Emulsions: technology of a preparation and methods of a control

Liquid crystal emulsions consist of small LC droplets immersed in isotropic liquid. The chemical stable nematics (5CB and three nematic mixtures: ZhK440, ZhK1289 - NIOPiK production and N96 – Charkov production) were chosen as proper materials for LCE preparation. We used two possible technologies for a preparation of LCE samples well known for isotropic emulsions.

1. Ultrasonic mixing. This technology is well adopted to obtain micrometer and sub-micrometer droplets of a liquid crystal in a water. In our experiments we used a powerful ultrasound of frequency 25 kHz which provides the samples with a wide distribution of droplets on size. The segregation of the samples under gravity or by spinning enabled us to obtain a relatively narrow distribution of the droplets.

The quality of LCE samples were controlled by both microscopic observations and by dynamic correlation spectroscopy [6]. The examples of microscopic image of the samples and of their distribution on droplet`s sizes are shown in Fig. 1.

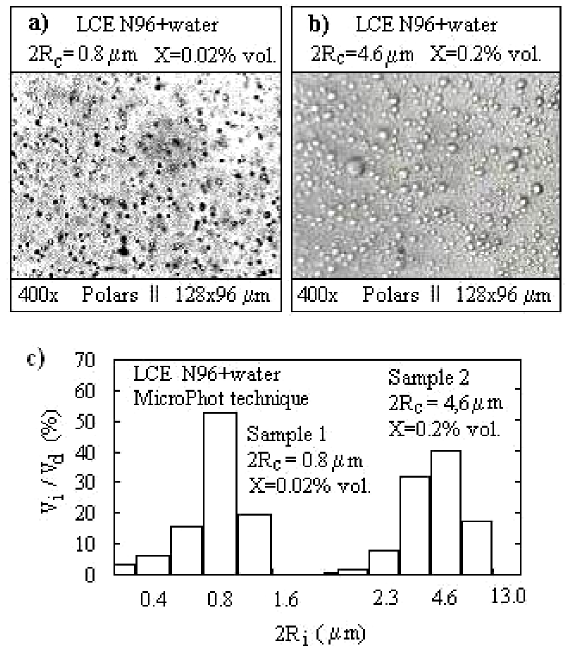

Figure 1. Microscopic images (a, b) of LCE samples with different average radius (R_c) of droplets. X – concentration of LC in water; c) - the distribution of droplets on sizes in samples (a, b) obtained by micro-photometrical technique. The height of each column represents the volume V_i of liquid crystal per into total volume V_d of LC in emulsion for drops with sizes indicated on the horisontal axis $R_{i.}$

We also used ultrasonic absorption measurements to control the clearing point of the samples [5]. Some decreasing of this parameter in the samples of water-LC relatively to the value obtained in bulk samples (see Fig. 2) can be partly explained by confine effects [1].

The braking of the binary solution LC – silicon oil under cooling was used as the way to obtain the samples with the temperature controlled sizes of droplets. Moreover the letter samples turned out to be very useful for electrooptical investigations as silicon oil can be considered as a good dielectric.

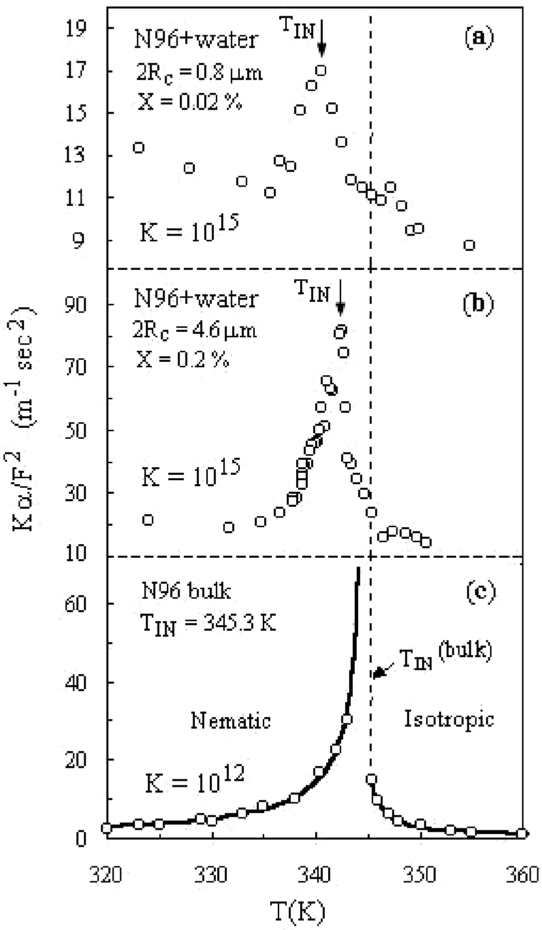

Figure 2. The temperature dependence of ultrasonic absorbtion (α) at frequency F=2.7 MHz (points) for LCE samples with $2R_c$=0.8 μm (a) and $2R_c$=4.6 μm (b); K – dimensionless coefficient. The data for the bulk N96 reference sample are also shown in (c). Solid lines represent the power-law approximation.

Experimental technique

We used both polarizing microscopy technique for a detail analysis of local optical properties of LCE and measurements of the integral intensity of the light passed through the LCE sample placed between crossed polarizers. The experimental set-ups for such measurements are shown in Fig. 3, 4. The second set-up is made on a base of the spectrometric complex KSVU-23M (LOMO production) which provided measurements at different wavelengths. The experimental technique enabled us to fulfill measurements at different temperatures and under electric fields.

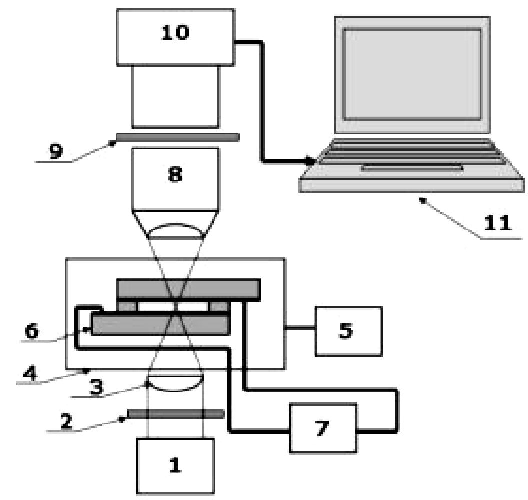

Figure 3. The block diagram of microscopic setup: 1 - source of light , 2 - polarizer, 3 - lens, 4 - thermostat, 5 - thermo regulator, 6 - acoustic-optical cell, 7 – low frequency generator 8 - objective of the microscope, 9 - analyzer, 10 - digital video camera, 11 - computer.

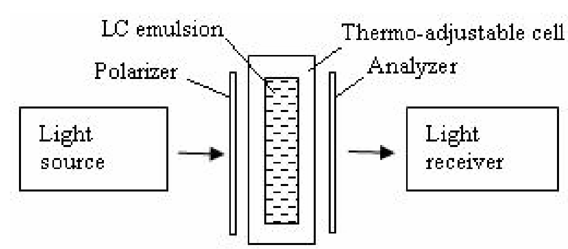

Figure 4. The scheme of optical measurements of integral intensity of light passed through LCE.

Experimental results

Thermal-optical effects. There are to ways to change the optical properties of LC emulsions interesting for practical applications. The mostly pronounced effects were obtained under temperature variation. The microscopic images of LCE (ZhK440-silicon oil) at two temperatures corresponding to nematic and isotropic phases are shown in Fig. 5. Due to the analysis of these images (Fig. 5 c) we have revealed a slight shift of phase transition temperature even for LC droplets of relatively big sizes (10…60μm). This shift becomes more pronounced for droplets with sizes lower than 5μm (see fig. 6). It is of importance for practical applications that relatively large changes of light intensity (about 50%) induced by temperature variations can be obtained at a proper choice of the concentration of LC and of the technology of a preparation even in LCE samples of small thickness (about 50 μm).

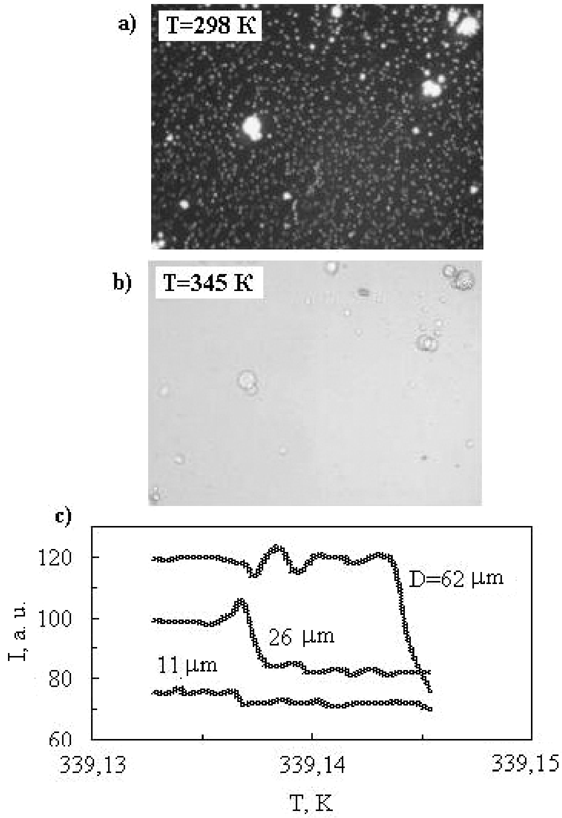

Figure 5. The microscopic images of LCE (ZhK440-silicon oil) at two temperatures: a) – nematic phase, crossed polarizers; b) – isotropic phase without polarizers; c) – brightness of light corresponding to droplets of different sizes.

Electrooptical effects

We have observed the most pronounced electrooptical effects in the samples LC-silicon oil. The examples of images at different electric voltages for LCE samples of different sizes of LC droplets are shown in Fig. 6. It is obvious from the time dependences of light intensity shown in Fig. 6 c), d) that characteristic times and the value of light intensity modulation (about 50-80%) are suitable for display applications.

Perspectives for display and non display applications of LCE

The thermo-optical and electro-optical effects presented above make LCE perspective for both display and non display applications. We can point out on the essential differences between LCE and PDLC which can be considered as the analog of these new materials.

1. The sizes of LC droplets can be effectively changed *after the preparation* of LCE samples. It provides a possibility to control the spectral characteristics of scattered light. This property is essential for display technologies (a control of color) and for fiber optics (thermally controlled filters).

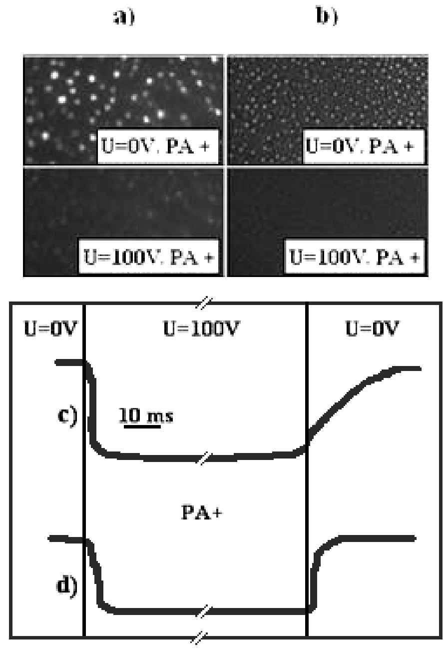

Figure 6. The microscopic images of LCE (8% ZhK1289 - silicon oil) in crossed polarizers without field and in electric field: droplet size about 20 µm (a) and about 10 µm (b); c) and d) – oscillograms corresponding to a) and b).

2. In principle there is a possibility to obtain three states of LCE with different optical properties: a) optically homogenious binary solution LC-isotropic liquid; b) microemulsion: nematic droplets in an isotropic liquid which is characterized by strong light scattering controlled by electric field; c) emulsion: droplets of isotropic phase of LC in isotropic liquid with isotropic scattering of light. These properties can be essential for applications in 3D displays of large sizes. The state a) is highly transparent media which is essential for fiber optics applications (low losses).

3. There is a lot of ways to control integral and local properties of LCE by variation of concentration, temperature and usage of proper technology of preparation for liquids of different types.

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