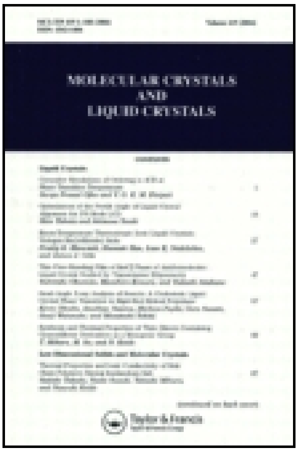

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PDLC Systems in Elliptical Capillaries

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PDLC Systems in Elliptical Capillaries

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Large liquid crystal droplets have been obtained in capillaries with elliptical cross-section by photopolymerization-induced phase separation method. The liquid crystal alignment inside droplets has been studied. The preliminary studies of electrically-tunable waveguide properties of such structure have been done.

Keywords Confined liquid crystals; PDLC; capillaries; phase separation; waveguiding

INTRODUCTION

Liquid crystals (LC) confined in capillaries of different size, apart of fundamental research[1,2], are studied due to their possible applications, connected with fiber optic systems. The first of them are sensor systems[3], while the second one are electrically driven devices designed for fiber optics[4], especially for polarization controlling. Capillaries with elliptical cross-section are often used recently because they allow to obtain LC alignment similar as that one observed in a planar cell[5]. The aim of the present work was to obtain, by phase separation method, large droplets of LC embedded in a polymer matrix inside a capillary with an elliptical core and to study their essential properties. In this way, the necessity of sealing the ends of a capillary containing LC could be avoided. Moreover, composite systems allow to obtain LC droplets with other director configuration than in case of bulk LC, depending on the system used, and elongated LC structure thinner than capillary diameter what can reduce the number of guided modes. For instance, the system studied can be considered as a quasi-monomode one (in elliptical cross-section of used capillary the shorter axis length is comparable to wavelength of propagating beam).

Because typical polymer-dispersed liquid crystal (PDLC) composite systems strongly scatter incident light, LC droplets should be much larger than the wavelength of light used. Moreover, driving voltages are much less in case of large LC droplets.

EXPERIMENTAL

The most of studies have been done for capillaries having elliptical core with transversal axes of 18x4 μm. Well known UV-curable polymercaptoester NOA-65 (Norland) has been used as a prepolymer for polymer binder, while nematic mixture W-765 (Institute of Chemistry MUT), specially designed for this particular binder, has been chosen as LC material.

At first a mixture of a prepolymer and a LC mixture (1:1 b.w.) has been prepared. The capillary has been filled with this mixture under lowered or elevated pressure. It has been found that the former method is faster and more efficient in case of the system used.

After filling the capillary, the system has been illuminated by low-intensity UV flux (order of 0.1 W/cm^2) from 10 to 60 minutes. Typical length of the illuminated part of the capillary has been from 5 to 10 mm. As the effect, large elongated LC droplets (with cross-section close to the capillary transversal size) emerged in the cured polymer binder. The long time of photopolymerization-induced phase separation allowed diffusion of LC from initial prepolymer-LC mixture to the droplets. The UV illumination has been usually performed in room temperature, however in some cases the process temperature has been decreased to $10^{o}C$ to extend the curing rate of the prepolymer. The illumination usually has been done through the grating mask to obtain LC droplets in “bright” spots and to allow easier diffusion of LC from “dark” spots. In this way the nucleation of small LC droplets has been avoided and the amount of LC in cured polymer was lower than 5 % b.w. This percentage has been found from the refractive index vs. composition characteristic using interference method (see Fig. 1).

Obtained systems have been observed in polarized light in different planes to find the director configuration inside droplets.

The preliminary studies on waveguiding properties of obtained systems have been done. The samples of different length cut out from the capillary have been placed between glass plates with ITO layer and connected to input and output optical fibers. The latter fiber has been connected to the detecting system. The optical properties of LC droplets have been changed by an application of bias electric field to the glass plates. The change of those properties has affected parameters of the passing beam. In particular, polarisation characteristics of the guided beam have been tested.

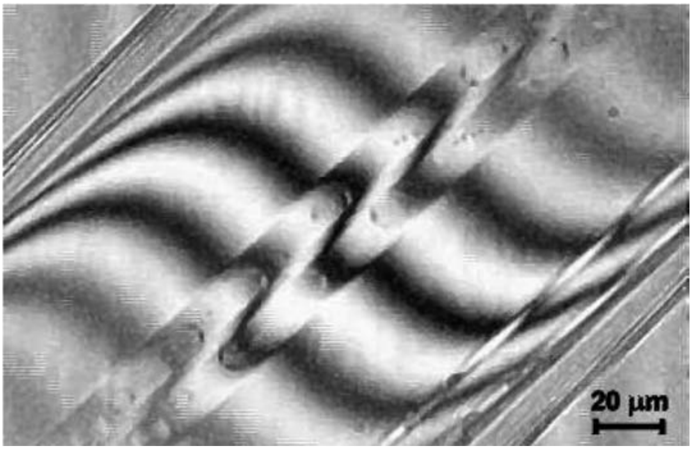

FIGURE 1. Interference stripe field obtained in white light with double-splitted image of capillary with cylindrical hole dipped in immersion liquid (ethyl acetate + cedar oil)

RESULTS AND DISCUSSION

Microscopic images of LC droplets obtained in depolarized light after external coating removal are presented in Fig. 2. As one can see, it is possible to obtain large LC droplets in capillary without significant number of coexisting small droplets. Fig. 2b shows the LC droplets obtained in decreased temperature and without grating mask. In this case larger number of small LC droplets has been nucleated. The transversal dimensions of droplets have been limited by the size of the capillary core, 18x4 μm in the presented case, while their length has been from 10 to 20 μm, depending on the parameters of phase separation process. All large droplets has got the same thickness close to the capillary thickness (shorter transversal axis) what have been found as the uniform interference colour (see Fig. 3).

a) b)

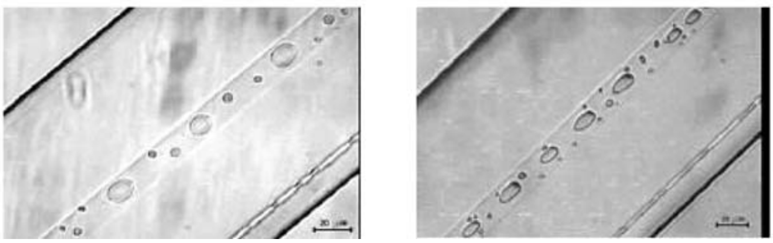

FIGURE 2. Images of LC droplets inside capillary; a) obtained by an UV illumination through the striped mask, b) obtained by an UV illumination at decreased temperature.

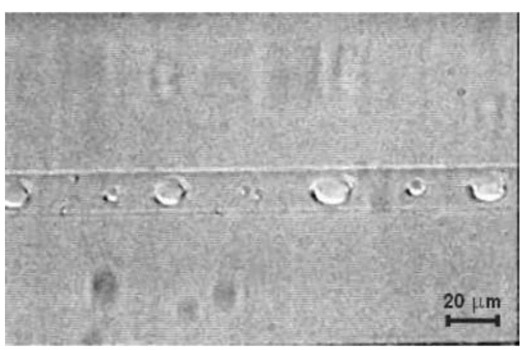

FIGURE 3. Microscopic confirmation of the homogeneous optical thickness of LC droplets; in original image droplets have the uniform colour.

In some applications it may be purposeful to enlarge the LC-to-polymer ratio inside the capillary. This effect could be achieved using better tailored LC-prepolymer systems with proper phase separation parameters, and grating mask with the smaller period.

Obtained structures have been observed in crossed polarizers to determine the LC director orientation. Observations have been made for different orientation of polarizers and in different directions with respect to the capillary axis. In Fig. 4 the image of LC droplets obtained in crossed polarizers, perpendicular to the longer axis of the capillary cross-section, is presented.

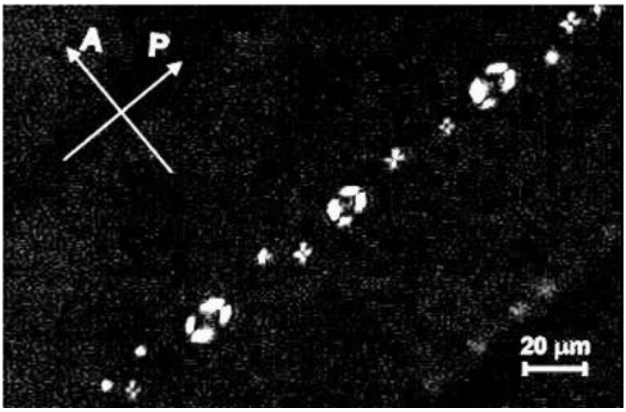

FIGURE 2. The image of LC droplets in crossed polarizers P and A.

As one can see, the LC alignment is the same in all large droplets. The observed image suggests tangential (homogeneous) alignment of LC inside droplets in the presented case. This observation is consistent with the observations of the cells containing NOA-65 – W-765 PDLC system. Another kinds of alignment could be obtained for other systems.

In preliminary studies we observed the effect of external electric field applied to the system on polarisation characteristics of waveguided beam. The switching voltage (160 Hz) depended on droplet size and varied from 20 for larger droplets to 30 V for smaller droplets, i.e. about 10 μm long. Polarisation changes have been observed for the systems containing one or more LC droplets. More pronounced effects have been observed, as predicted, for a single droplet. However, if the period of droplets along capillary will be optimised, such alignment can enhance this effect, also. The observed polarization effect strongly depends on the orientation of the linearly polarized input beam. The largest effect has been observed for input beam linearly polarized at the Π/4 angle with respect to the capillary elliptical cross-section axes. In off-state (without external electric field) only classic geometrical anisotropy is observed in waveguide structure due to the LC bipolar tangential alignment inside droplet. An application of bias field results in a reorientation of LC and the large additional material birefringence is observed. As the effect, the state of polarization different from linear has been observed.

Those studies have been only qualitative and will be continued. The main attention will be paid to decrease driving voltage and to improve LC alignment inside droplets. We expect that proper adjustment of longitudinal, periodic droplets distribution will introduce grating element characteristic and enhancement of polarization dependences described above.

CONCLUSIONS

1. Photopolymerization induced phase separation is a very convenient method to obtain inside capillary large LC droplets of uniform size and alignment.
2. Such systems are closer to bulk LC than to classic PDLC composites from the optical point of view.
3. It is possible to drive polarisation characteristics of such systems by external electric field as well as droplets alignment.

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