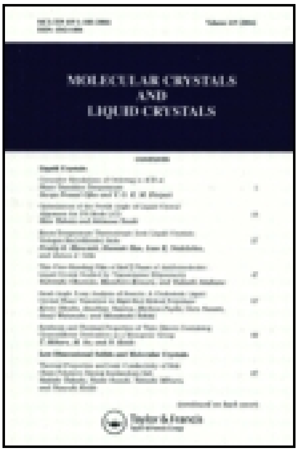
MOLECULAR CRYSTALS AND LIQUID CRYSTALS

Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

Electrically Controlled Light Scattering of the Aerosil-Liquid Crystal System

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Version of record first published: 24 Sep 2006.

Mol. Cryst. Liq. Cryst. 1994, Vol. 251, pp. 303–309
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Printed in the United States of America

ELECTRICALLY CONTROLLED LIGHT SCATTERING OF THE AEROSIL-LIQUID CRYSTAL SYSTEM

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Abstract. Optical and electro-optical characteristics of a silica suspension in a liquid crystal were studied. Their possible applications in different electro-optical devices are analyzed.

INTRODUCTION

Heterogeneous liquid crystal (LC) systems form a new class of materials that are intensively studying last decade. Among them it should be noted such systems as "LC-polymer matrix"[1], "LC-pored glass"[2], and "polymer-LC matrix"[3]. They present a fascinating physical object with strongly developed surface and are attractive for a lot of applications. Such systems are particularly possessing a very strong effect of electronically controlled light scattering. It gives the opportunity to develop new types of displays and light shutters which need not polarizers and aligning technique.

Authors[4] provided investigations of a new such system that was called "filled nematics" (FN) -- a suspension of small silica particles in a nematic LC. These small particles lead to a network formation due to the interparticle interaction and a multiple defect origin what result in a strong light scattering in an initial state. The reorientation, transformation and disappearance of a

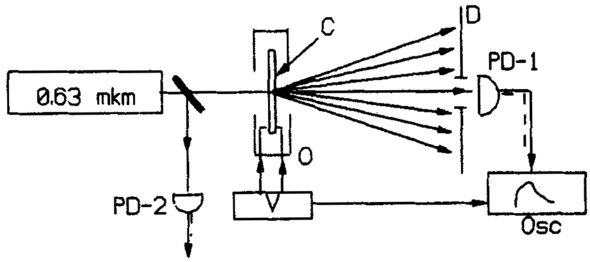
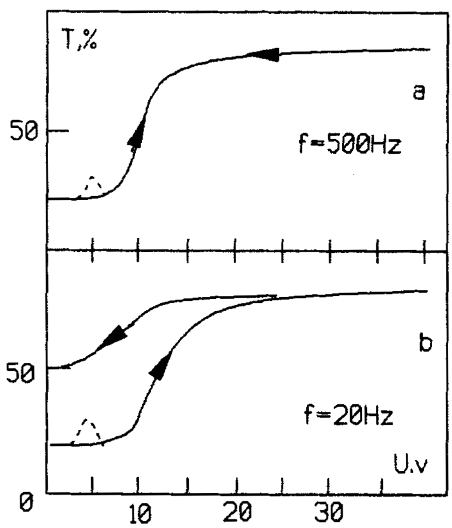


Fig.1. Experimental set-up.



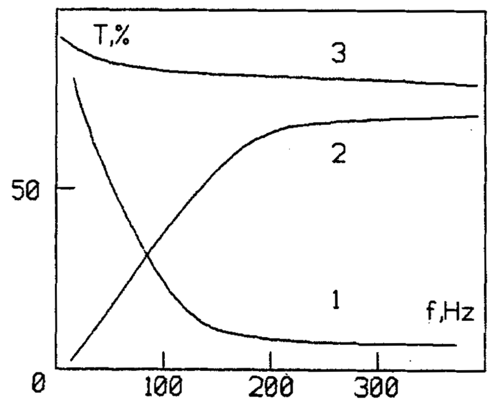


Fig.2. **T(U)** contrast vs voltage dependency.

Fig.3. Frequency dependency of the constant **T_-**, varying **$T_\sim$** and total **T** cell transparency.

part of them under the electric field action as well as the turn of LC molecules in non-defected areas along electric field cause a strong media enlightenment. It was observed in an irreversible decrease of light scattering in FN under applying of a low frequency electric field and analyzed different ways of a system recovery to the initial state. The aim of this work is an investigation of optical and electro-optical features of the similar FN system, which is differed from the described above one by other types of silica particles and nematic matrix that results in some specific system characteristics.

SAMPLE PREPARATION AND EXPERIMENTAL SET-UP

A nematic mixture of cyanobiphenyles and cyclohexan carbon acid esters (LC-1289, Institute of Single Crystals, Kharkov, Ukraine) was used as LC matrix. It possesses a positive dielectric anisotropy ($\Delta\varepsilon = 12$) and high birefrigence ($\Delta n = 0.2$).

A highly dispersed pyrogenic silica A-300 with particle dimension of 100-150 Å was inserted into a matrix. To exclude a possibility of a chemical reaction of particle surface with LC molecules and to decrease their aggregation and agglomeration together silica was treated with octomethylcyclotetrasyloxane according to Reference[5].

Milk-white mixture of LC and aerosil was made by ultrasonic stirring with optimized aerosil concentration about 2-4 weight percentage. Cells were assembled from 20x30 mm ITO glass plates with teflon strips of 20 µm thickness between them. Plates were fixed by epoxy adhesive.

The experimental set-up is depicted in Fig.1. The beam of He-Ne laser passed through the cell **C** and the diaphragm **D**. The diaphragm was viewed from the cell plate with the angle 2°. The photodiode **PD-1** was placed behind the diaphragm and measured the intensity I_{out} of the transmitted beam. The photodiode **PD-2** monitored the intensity **I** of a laser beam. Signals from both photodiodes were displayed on the two-beam oscilloscope **Osc**. The cell was placed in the temperature-controlled oven **O** with the 0.1 ^oC accuracy. Alternative or constant voltage was applied to the cell from electrical signal generator **V** in the oven **O** in order to change its transmittance.

EXPERIMENTAL RESULTS

Temperature dependence of a system transmittance.

System transmittance $T = I_{out}/I_{in}*100\%$, (I_{in} and I_{out} are input and output beams' intensity, respectively) as a function of a temperature was measured during a slow heating of the cell in the thermostabilized oven. Cell transmittance is apparently temperature independent except of the narrow temperature region near the clearing point, where the scattering ability of the system drastically increases, i.e., a value **T** falls down. The cell being in an isotropic phase is totally translucent ($T \approx 100\%$) what testifies that the main contribution to the light scattering is made by orientation defects of LC caused by small particles, while the contribution from these particles themselves and their assemblies are negligible.

System light transmittance against voltage and its frequency dependence.

A system possesses a strong electrically control enlightenment effect that is the system transmittance is increased with the rise of applied electric field.

The results for the cell with silica weight concentration $c = 2\%$ are presented in Fig.2. It is shown that the essential rise of a light transmittance begins at the achievement of some threshold value of applied field (U_{th} =(5-8)**V**) and the transmittance saturation is observed at the high voltage ($U_{sat} \approx$ (20-30)**V**).

A small splash of the system transmittance appeared sometimes under a small applied voltage (dotted curves). It could be explained as a formation of a new texture with a higher transparency, which is destroyed with the following voltage growth.

The fact that cell transmittance are saturated under the value of applying voltage of **U = 20 V** testifies that LC-director have been already oriented parallel to the electric field. Under these conditions electric field -- LC-molecules interaction energy is comparable with LC elastic energy, determined in terms of director-particle surface anchoring energy **W** as:

$$\varepsilon \cdot \varepsilon_o \cdot E^2 \approx W \cdot n_p \cdot S_p$$

where n_p -- particle concentration, S_p -- area of a one particle surface. From the experiment conditions ($n_p \approx 10^{16}$ cm^{-3}, $S_p \approx 1.2\ 10^{-12}$ cm^2, $E = 10^4$ V/cm^2) we find that a surface energy value $W \approx 2\ 10^{-3}$ **erg/cm**^{2}. This value is in good agreement with available data[6].

The parameters of enlightenment effect are strongly depend on a frequency **f** of an applied electric field. The influence of a relatively high frequency field (**f**=(500-1000)**Hz**) results in reversible cell transmittance changes (Fig.2a). In the case of a low frequency (**f**=(10-50)**Hz**) the influence of an electric field caused the sufficient irreversible decrease of the initial scattering and transmittance-voltage dependence demonstrates the hysteresis behavior (Fig.2b). As this takes place the following action of an electric field of any frequency does not result in the change of initial value **T(V=0)**. In this sense we can speak about the memory of the system to the influence of an external field of low frequency. Overheating of the cell to the isotropic phase of LC during 15 - 20 min. appeared to recover a high scattering state of the system*).

The photodiode signal, which is proportional to the intensity I_{out}, consists of as a permanent as a varying component. The variable constituent of the light transmittance is strongly dependent on the frequency of applied voltage. Measurements of a varying $T_{\sim}$ and a permanent T_{-} component of the total value $T = T_{\sim} + T_{-}$ were provided in a wide frequency band ($f = 1 - 10000$ Hz) to investigate this dependency. The cells initially were exposed to the influence of a low frequency electric field so the irreversible component did not act on the experimental results. The data are shown on Fig.3 (1 -- $T_{\sim}(f)$, 2 -- $T_{-}(f)$, 3 -- $T(f)$). The value of $T_{\sim}$ is asymptotically decreases up to zero with an increasing voltage frequency while increasing T_{-} makes the main contribution to T. The latter is not dependent upon applied voltage frequency and apparently equals to that of a constant voltage influence.

<u>Transmittance kinetics.</u>

П-shape voltage pulses were applied to the cell to study light transmittance kinetics. Measured switching on and off times are respectively about some tens and hundreds of milliseconds for the cell thickness about 20 μm.

It should be mentioned that some specific splashes were sometimes observed in the beginning of the cell switching-on and in the end of the switching-off processes. They are analogous to that observed in a transmittance vs voltage experiment. As they appeared under the same voltages we can make a conclusion that they are caused by a system structure transition.

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*) For the first time the similar effect was ovserved in the Reference[4]. It should be noted that on the contrary to our results the irreversible regime was found for relatively high frequences ($f \geq 400$ Hz).

CONCLUSIONS.

The following features of the system could be useful to put into practice:

i) *Irreversible changes of light transmittance under the application of a low frequency field.* It might be used for the information storage.

ii) *Abrupt alterations of the system transmittance during transition to an isotropic phase of LC.* It could find an application in a highly efficient thermooptical light shutter. Working temperature is easily shifted by the choice of a liquid crystalline material.

iii) *Reversible alterations at high frequencies.* This phenomenon makes it possible a creation of an electro-optical light shutter based on FN and a development of a new type of heterogeneous medium for LC-displays. All working parameters of our cells (except contrast ratio) are at least not less then that of devices based on polymer dispersed liquid crystals[1]. We have no doubts that further optimization of the system parameters (e.g., layer thickness, silica particle concentration, their size and surface treating, etc.) will result in a strong improvement of mentioned above features.

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