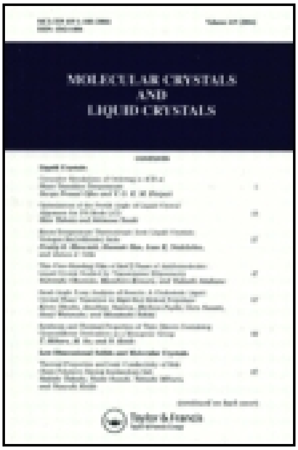


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# Multistable Alignment of LC Doped with Aerosil

A. Glushchenko [a] & O. Yaroshchuk [a]

[a] Institute of Physics of NASU, prosp, Nauky 46, 252022, Kyiv, Ukraine

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# Multistable Alignment of LC Doped with Aerosil

A. GLUSHCHENKO and O. YAROSHCHUK*

*Institute of Physics of NASU, prosp. Nauky 46, 252022 Kyiv, Ukraine*

Different types of alignment (planar, homeotropic and tilted) were observed in LC cell doped with aerosil. Alignment direction was controlled by means of magnetic and electric field. Stability of LC alignment after removing the field is explained as LC stabilization by oriented structure of aerosil.

*Keywords:* LC alignment; aerosil; multistability

## INTRODUCTION

In overwhelming majority of LC devices, oriented liquid crystalline layers are used. Alignment of LC is usually produced with special treated cell substrates. The surface of the substrates after such treatment acquires anisotropic properties. Procedure of rubbing of polymer layers is commonly used for this purpose [1]. In the last years photoalignment technique is developed [2-3]. In this case, anisotropy on the surface of polymer orienting layers is produced by illumination with polarized light. The main reason of the alignment in both cases is accepted to be dispersion interaction of LC molecules with oriented polymer units.

* Corresponding author. E-mail: <olegyar@marion.iop.kiev.ua>.

LC alignment can be also produced in the cell with random initial orientation. For example, in [4] it is reported about LC alignment on the isotropic polymer films after LC cooling below $T_c$ in magnetic field. The reason of the alignment is anisotropic adsorption; LC molecules adsorb onto substrate preferably parallel with respect to the direction of the magnetic field. In this way, anisotropic boundary conditions are created. LC alignment can be also reached by means of the cell illumination with polarized light [5].

Another approach is to use aligning surface spatially distributed in LC layer. Kobayashi et al [6] reported LC alignment by oriented polymer network produced in liquid crystalline matrix. In this experiment, LC layer containing monomer composition was oriented in magnetic field. Than sample was exposed to UV light. As result of photopolymerisation polymer network appeared which stabilized LC orientation. Light scattering in a cell was low because of small polymer concentration.

As a rule, in LC cell with anisotropic substrates only one sort of stable LC alignment can be realized. Same situation is observed for the alignment with Kobayashi method. In the present article, it is reported about multistable alignment of LC layer doped with aerosil.

## SUSPENSION "LIQUID CRYSTAL-AEROSIL"

A mixture "liquid crystal-aerosil" (filled LC) was proposed by De Jeu and Eidenschink in 1991 for the information recording and storage [7]. Layer of filled LC with the high aerosil concentration scatters intensively light because of many defects generated with aerosil particles. If the electric voltage to the layer of the suspension is applied, LC molecules orient in a field homeotropically. That is why defects disappear and system becomes to be transparent. Usually the transparent state is stable and does not relax after switching off the field. It is accepted to call this phenomenon as a memory effect. Transparent state can be erased by mechanical treatment or heating [8], or application of an electric field with a frequency above the crossover point [9].

From the microscopical point of view, the memory effect was explained as follow [10]. Aerosil particles agglomerate in liquid crystalline matrix. The nature of the agglomeration is a hydrogen-type interaction between primer particles. Because agglomerates form in anisotropic matrix, they acquire anisotropic shape. Application of the electric field leads to the reorientation of LC. Aerosil agglomerates are involved in such reorientation processes. Because the inter-particles hydrogen bonds are sufficiently weak the initial aerosil agglomerates will be broken and new one form in the oriented state of LC. Such oriented agglomerates fix orientation of LC after electric field is removed (Fig.1).

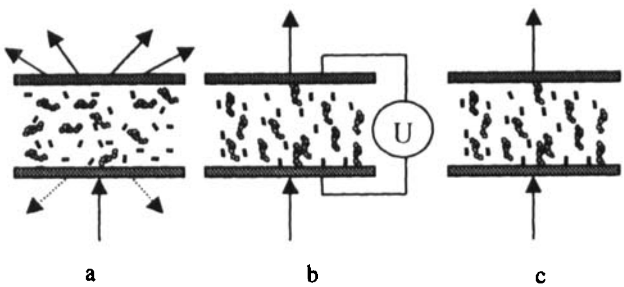


FIGURE 1 Structure of filled LC in the initial state (a), in the electric field (b) and when the electric field is removed (c).

Thus, in contrast to another heterogeneous LC media containing solid state (LC in porous media, LC with a polymer network etc.) a structure of the solid phase can be changed by the reorientation of LC. New-formed aerosil structure stabilizes orientated state of LC. One can suppose that aerosil agglomerates can stabilize not only homeotropic orientation, as in experiments with the memory effect, but any LC orientation given by external field. This idea will be searched below.

## EXPERIMENT AND DISCUSSION

### Sample preparation

Nematic liquid crystal 5CB (Merck) with a dielectric anisotropy $\Delta\varepsilon=7$ and magnetic anisotropy $\Delta\chi=1.76\cdot10^{-7}$ CGS units was used for the investigations. Aerosil R812 (DEGUSSA, Germany) was chosen as solid component [11]. Suspensions with various aerosil concentrations $c_a$=1-10 weight % ($c_a=m_a/(m_a+m_m)$, where $m_a$ and $m_m$ are the weight of both the aerosil and the mixture, respectively, were prepared by mingling the components in an ultrasonic mixer.

Both magnetic and electric field were used for the orientation of LC. Samples were produced as follows. A droplet of the suspension was placed between two glass plates covered with transparent ITO-electrodes in such a way that electrodes contacted with LC. Thickness of the suspension layer equal to 10-50 μm was given by spacers. Cell was pressed and glued with epoxy glue.

### Results and discussion

For the LC orientation magnetic field with intensity B=10 kG was used. Cells with initial planar multidomain LC structure were placed between magnetic poles in the position needed to provide planar, homeotropic or tilted LC orientation. At first, samples were brought in the field at room temperature. It did not result in the change of LC alignment after switching off the field.

Then the samples were heated above $T_c$=36$^0$C and cooled down to room temperature in magnetic field. This procedure resulted in fairly good LC alignment in the samples with $c_a$=1-3 weight %. Observation in polarization microscope showed that LC orientation is planar, tilted or homeotropic depending on the sample position in the magnetic field. In spite of oriented state of LC, slight light scattering in the cells was observed. The reason of it could be light dispersion on the large aerosil agglomerates and on the LC orientational defects in the close vicinity of aerosil particles. Observations with polarization microscope were accompanied with identification of the alignment direction with crystal rotation method [12].

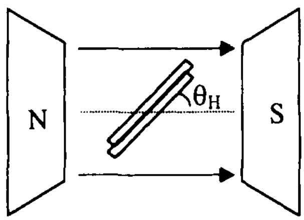


FIGURE 2. Sample position in the magnetic field

Transmittance-rotation angle curves for different sample positions in magnetic field (different values of $\theta_H$ (Fig.2)) are presented in Fig.3. In case of $\theta_H$=0$^0$ and $\theta_H$=90$^0$ curves T($\varphi$) are symmetrical one with respect to $\varphi$=0$^0$. It means that zero pretilt planar and homeotropic LC alignment is, respectively, realized. In the intermediate case when $0^0<\theta_H<90^0$ center of the curve is shifted to some value $\varphi_p\neq0$. It is evidence of tilted orientation.

LC alignment direction in our cells was many times changed and controlled by the heating the samples above $T_c$ and the following cooling in magnetic field in the corresponding position. Alignment direction was roughly controlled in polar as well as in azimuthal plane. Application of the electric voltage (U=5-10 V, f=1kHz) to the cell aligned in magnetic field resulted in homeotropic reorientation of LC. However, these orientation changes were reversible one; initial orientation restored after switching off the electric field. Like in the case of magnetic field, electric field action at the cooling from isotropic state led to stable homeotropic LC alignment.

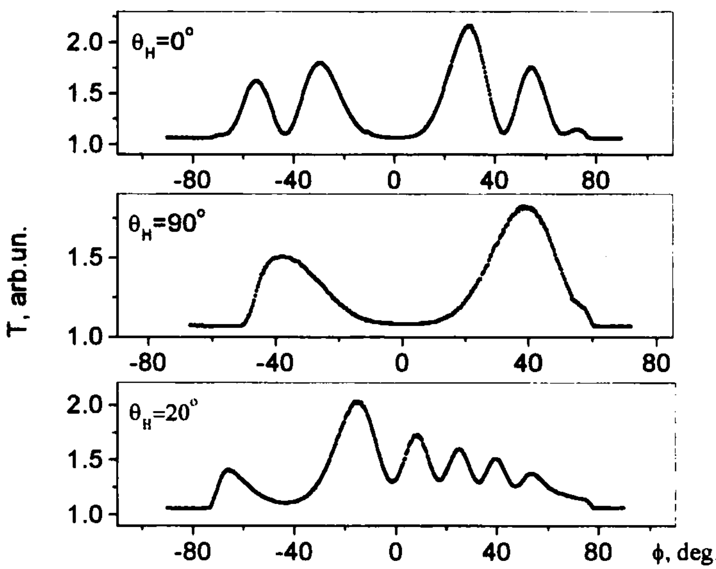


FIGURE 3 Transmittance-rotation angle curves for the cells aligned in magnetic field measured with crystal rotation method [12]; $\theta_H$=0$^0$(a), 20$^0$(b), 90$^0$(c).

In experiments described above LC alignment was changed by means of magnetic or electric field only by overheating the samples above $T_c$. It could be explained taking into account essential influence of the cell substrates on the orientation. Indeed, in such samples competition of two orientation factors take place; they are surfaces of cell substrates and spatial distributed surface of aerosil phase. First factor causes reversible orientational response on the action of the field. Second factor leads to the irreversible response and possibility to control alignment direction. As it was earlier established [10], at $c_a$<3 weight % first factor is dominant wile for $c_a$>8 weight % the second one. Thus, in our case ($c_a$<3 weight % ) orientational influence of the cell substrates should be dominant. Direction of the LC alignment could be determined by orientation of adsorbed LC molecules as well as aerosil agglomerates interacting with cell substrates. Last factor seems to be determinative, because effect of controlled alignment was not observed in LC cells without aerosil. From this point of view to change the LC alignment state aerosil structure should be destroyed not only in the bulk but also on the cell substrates. It is realized by heating above $T_c$. New aerosil structure forming under the cooling in magnetic field stabilizes new alignment state of LC.

To avoid orientational influence of the cell substrates and realize switching between different alignment states without heating the samples above $T_c$ concentration of aerosil should be increased. Intensity of the magnetic field in our experiments was quite low to reorient LC in samples with $c_a$>3 weight %. We do not see any limitation for realization of this effect. It is only question of field strength. As an evidence is qualitative homeotropic alignment realized in cells with $c_a$=8-10 weight % by means of electric field applied at room temperature.

## CONCLUSION

In conclusion, different types of monodomain alignment (planar, homeotropic and tilted) were realized in LC cell doped with aerosil. Switching between different types of orientation was provided by magnetic or electric field. LC orientation after switching off the field is fixed by oriented aerosil structure. Obtained LC cells with multistable alignment can be used in display technologies and information storage systems.

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