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Journal of Molecular Liquids 92 (2001) 147–152

journal of MOLECULAR LIQUIDS

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Electrooptical properties of filled chiral nematics

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The effective memory (non-reversible electro-optic response) is a characteristic feature of filled nematic liquid crystals (LC). Insertion of a chiral dopant in a filled nematic LC is suggested as a method for suppression of the memory effect. Destruction of the linking of aerosil aggregates with the twisting tension caused by chiral dopant is considered as the main reason of the reversible response. Aerosil structure causes stabilization of various intrinsic cholesteric textures. It makes the system perspective for multiplexed LC displays.

1. INTRODUCTION

Liquid crystal displays (LCD) usually utilize two famous effects peculiar to liquid crystals – electrically controlled birefringence and electrically controlled light scattering. The latter effect can be observed in heterogeneous systems containing LC. A new representative of this class is a filled liquid crystal – suspension of ultra small particles (usually aerosils) in LC[1–6]. The particles cause many orientational defects in LC matrix resulting in the intensive light scattering by filled LCs. On applying the electric field, the system becomes transparent due to the orientation of LC.

The effect of electrically controlled light scattering is similar to that observed in capsulated LCs. A specific property of the filled LCs is an essential residual transparency after the field is switched off (memory effect). This effect is determined by the stability of the aerosil structure in LC. Orientation of LC matrix in the electric field causes a destruction of the initial chaotic aerosil structure, and a new stable aerosil structure stabilizes the oriented state of LC after the field is turned off.

Memory effect is very attractive for many applications. At the same time, the use of the filled LCs could be essentially extended getting a reversible electro-optical response. Kreuzer *et al.* [3] eliminated the memory effect forming a polymer network in the filled LC. This network fixed the initial chaotic aerosil structure. We obtained a reversible electro-optical response using suspensions with a high concentration of aerosil when the aerosil system was very rigid and was not essentially changed during reorientation of LC [4].

A new method of suppression of the memory effect in the filled LC is reported herein. We consider the filled nematic LC doped with chiral agent. Such a chiral dopant causes a strong twisting tension in LC, which destroys the oriented structure (memory state) when

0167-7322/01/$ - see front matter
PII S0167-7322(01) 00187-8

the electric field is removed. Electrooptical characteristics of the filled chiral nematic LC are studied in a wide range of concentrations of aerosil and chiral agent. Possible applications of the studied compositions are discussed.

2. EXPERIMENTAL

2.1. Samples and measuring set up

In our experiments a suspension of aerosil R812 (Degussa) in nematic LC ZLI4803-100 (Merck) was studied. The chosen liquid crystalline mixture was characterized by a high dielectric ($\Delta\epsilon$=51.5) and optic (Δn=0.186) anisotropy. Concentration of aerosil varied within 2–10 weight %. Chiral dopant S812 (Merck) with the concentration of 1-15 weight % was added to LC before mixing with the aerosil. Small amount of spacers (d = 10 μm) was also introduced into the mixture to fix the thickness of the tested layers. The components were mixed at a temperature above clearing point, T_c = 68°C. The suspension was placed between two glass substrates covered with ITO layers from the inner side followed by the substrates that were pressed and glued. The electro-optic properties of the cells were studied by measuring the transmittance of the He-Ne laser (λ=0.63 nm) light with the collection angle of 2 deg. The transmittance-voltage (T-V) characteristics of the cells were measured at different concentrations of the suspension components and the frequency of the electric field. The T-V curves were measured for the increase and the following decrease of the amplitude of sine voltage.

2.2. Results and discussion

Let us first consider the change of the T-V curve at a fixed concentration of aerosil, c_a, and the increase of the concentration of chiral dopant, c_{ch}. In this case three different types of T-V curves can be selected. Samples without a chiral component as well as with a small c_{ch} demonstrate an effective residual transmittance (memory) (Fig.1a). The state of memory disappears as soon as c_{ch} reaches a threshold value c_{ch0}. At $c_{ch} = c_{ch0}$ the system relaxes to the initial turbid state when the applied voltage is completely removed. The increase of c_{ch} leads to relaxation of the residual transmittance even when the voltage is not decreased to zero (Fig.1b). It results in the decrease of the width of hysteresis loop of the measured T-V curve. Finally, at the concentration $c_{ch} = c_{ch1}$ the hysteresis practically vanishes (Fig.1c). So the increase of c_{ch} causes a qualitative transition from the first to the second and from the second to the third type of T-V characteristic. Besides, the steepness of the measured T-V curve gradually changes. The observed tendency does not change at the increase of aerosil concentration ca. In this case the threshold concentrations c_{ch0} and c_{ch1} quasilinearly increase with the increase of c_a (Fig.2).

At $c_{ch} > c_{ch0}$, the residual transmittance after removing the applied voltage was not observed at any frequency of the applied field in the range of $0.1 - 10^4$ Hz. This result is in strong contrast to the filled nematic LC where the efficiency of memory essentially increases at low frequencies. At the same time, the frequency of the applied field strongly effects the steepness of the T-V curve; the increase of the field frequency leads to the decrease of the steepness (Fig.3).

As it was detected for the compositions with $c_{ch} > c_{ch1}$, transparency at the zero field depends on the rate of the voltage decrease. When the voltage decreases quickly, the observed structure is planar. In turn, the structure is transformed into a focal conic

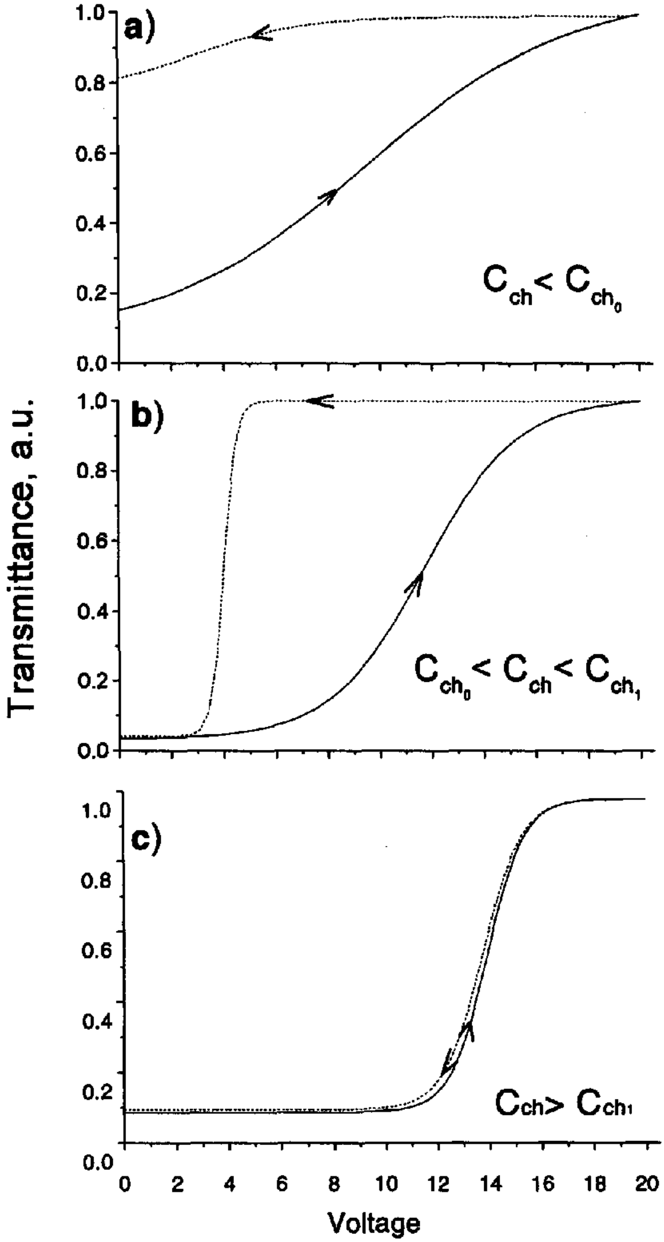

Figure 1. Types of measured T-V curves.

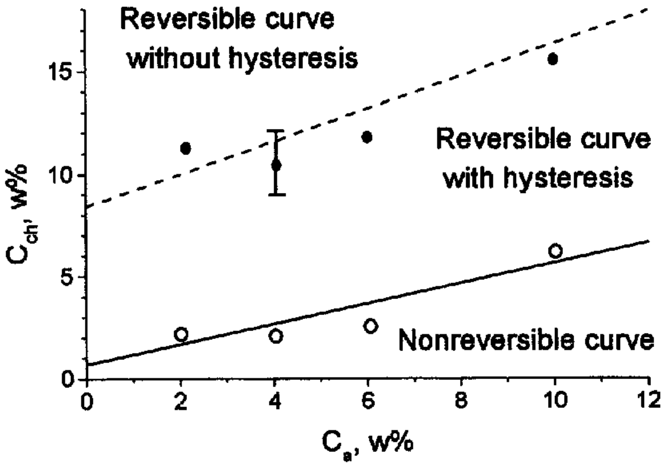

Figure 2. Types of T-V curves depending on the concentration of aerosil c_a and chiral dopant c_{ch}.

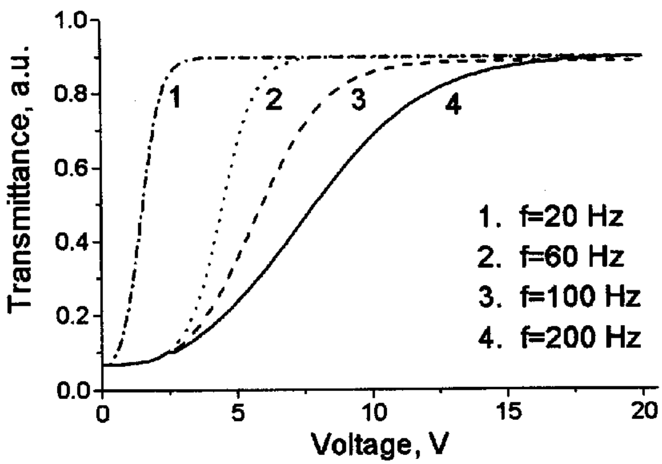

Figure 3. T-V curves for various frequencies of applied field.

structure when the voltage decreases slowly. The planar and the focal conic structure cause, respectively, a transparent and a scattered state of the sample when the applied voltage is removed. Both structures are stable. Similar bistability in the zero field was observed in case of cholesteric LC with polymer network [7].

It is reasonable to suppose that different types of the T-V curves are determined by three types of force in the system: 1) the elasticity of the aerosil structure; 2) the twisting tension in LC caused by chiral dopant; 3) the applied electric field. Assuming it, the destruction of the memory state takes place when the twisting energy of the chiral dopant is equal to the linking energy of aerosil agglomerates. The twisting energy could be described as

$$W_{\text{twist}} = K_{22}\left(\frac{2\pi}{p}\right)^2, \tag{1}$$

where K_{22} is an elastic modulus of the twist, p – is a helical pitch in the absence of the field. The aerosil linking energy W_a can be estimated as

$$W_a \approx Vnc_a, \tag{2}$$

where V is an energy of hydrogen bonding per one bond, n – average number of links belonging to one aerosil particle, c_a – concentration of aerosil particles. Using typical values $K_{22} = 10^{-6}$ dyne [8], $p = 0.5$ μm, $V = 10^{-13}$ erg [2], $c_a = 10^{16}$ cm^{-3} [9] and taking $n = 3$ one can obtain $W_{\text{twist}} \approx W_a$. It means that our assumption regarding the destruction of the oriented aerosil structure with a twisting tension is reasonable. Relaxation of the residual transmittance at the non-zero voltage at $c_{ch} > c_{ch0}$ means that the twisting energy is higher than the coupling energy of aerosil aggregates and it is partially compensated by the energy of the electric field.

Bistable properties observed for the studied compositions are also related to the cholesteric component. The difference with pure cholesteric LC lies mainly in stabilization of various textures intrinsic to the cholesteric phase.

The wide stable hysteresis of the T-V curves and bistability in a zero field make the compositions studied very promising for multiplexed displays without the use of an active matrix. Such LCD are characterized by high brightness, high information content without limitation in the number of scanning lines [10]. We believe that the filled cholesteric LCs are much more suitable for these applications if compared with the pure cholesteric LC because of the enhanced stability of the bistable states. Along with the electrical addressing, laser addressed LCD can be constructed based on the studied compounds [11]. To this end, compositions with T-V curve without hysteresis (Fig.1c) could be applied in the active matrix LCD in the way it was discussed earlier for PDLC [10].

3. CONCLUSION

Thus, the insertion of a cholesteric dopant in the filled nematic LC leads to the destruction of the quasihomeotropic (memory) state effected by the electric field. On the other hand, the intrinsic cholesteric textures can be well stabilized with an aerosil. It leads to several bistabilities, which can be applied for the construction of multiplexed LCD.

4. ACKNOWLEDGEMENT

We gratefully acknowledge the financial support by INTAS Foundation (grant No 97-1315).

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