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ELECTROOPTICAL EFFECTS IN THE POLYMER DISPERSED NEMATIC LIQUID CRYSTALS: RESPONSE TIMES

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Abstract The response times for two types of polymer dispersed liquid crystals (PDLC) with normally and tangentially anchored drops are studied experimentally. It is shown that the normal anchoring provides the shorter turn-on and turn-off times.

PDLC films, consisting of micron size liquid crystalline droplets, dispersed in a polymer matrix, have recently been reported as new electrically switched light shutters.[1] Electrooptical response strongly depends on the boundary conditions, viz., anchoring of the director on the polymer surface and the shape of the drops.[1-3] For example, it was predicted qualitatively,[2,4,5] that normally anchored drops might provide shorter response times than tangentially anchored ones. We report the response times for two corresponding types of PDLC films, with tangential boundary conditions (T-films) and normal ones (N-films). In T-films liquid crystalline drops (ZhK-807) were dispersed in polyvinyl alcohol. In order to prepare N-films with similar parameters, a small amount (0.01-

0.1 p.c. of weight) of lecithin was added at the final stage of T-film formation. As a result, film thickness, concentration and average radius of the drops ($R \approx 2\mu m$) were the same in both films. T- and N-films differed only in the drop structures: the former possesses bipolar structures and the latter possesses radial ones.

Fig.1 shows the responses of films to an applied rectangular AC (10kHz) pulse for light of He-Ne laser, normally incident on the film. N-film possesses shorter turn-on (t_{on}) and turn-off (t_{off}) times than T-film: t_{on}^N=2 ms, t_{on}^T=8 ms, t_{off}^N=5 ms, t_{off}^T=20 ms. It is convenient to discuss these inequalities for t_{off} only, because t_{on} is determined mainly by the field.

T-film

Due to the bipolar structure of drops, the dominant factor in the electrooptical response of T-films is a shape of these drops.[2-6] For spherical bipolar drops no restoring elastic torque exists and $t_{off}^T \to \infty$. However, nonspherical drops possess such torque due to the difference in the elastic energy F for different orientations of the structure.[2,6] Relaxation time is determined by balance of the elastic and viscous torque. As it was shown by B.-G.Wu et al.,[3]

$$t_{off}^T = \frac{\gamma R^2}{K(l^2-1)}, \qquad (1)$$

where γ is orientational viscosity, K is effective elastic constant, l=a/b is the aspect ratio of the droplet, a and b are the lengths of the minor and major axes. For $\gamma = 7 \cdot 10^{-2}$ P, $K = 10^{-11}$N, $R = 2 \cdot 10^{-6}$ m and l=1.5 one obtains t_{off}^T=22 ms. Shorter times may be achieved with larger l. However, increasing of l leads to

increasing of the threshold field.[2-6] The "passive" character of the restoring torque is a deficiency of T-films. In N-films this torque is active due to anchoring forces.

N-film

The transition between on- and off-states may be considered as a contraction of the flat disclination ring[2,4] with variable radius r in the equatorial plane of the spherical drop. As a result of the contraction in off-state we get a radial hedgehog. The latter is stable due to the surface anchoring. Equation for torques may be written as

$$\frac{4}{3}\pi\gamma R^3 \frac{d\beta}{dt} + \frac{dF}{d\beta} = 0, \qquad (2)$$

where $\beta=\arcsin(r/R)$, $F=8\pi K(R-r)+2\pi Kru$, $u=\pi\alpha(1+\ln(WR/2K))/2$, α is a geometrical parameter,[2] W is anchoring energy. Here we assume that the director distribution is uniform inside the sphere with radius r and radial outside this sphere. One estimates from (2) the time constant for the relaxation time

$$t^N_{off} = 2\gamma R^2/3K(u-4). \qquad (3)$$

For $\alpha=3$ (see Ref. 2), $W=2\cdot10^{-5}$ J/m^2, and earlier values for K, γ, R model yields $t^N_{off}=5$ ms. The shorter t^N_{off} may be achieved in N-films with stronger anchoring, rather than with deformations of the drops.

As a rule, electrooptic response of PDLC contains two components: fast, that was discussed above, and slow. Slow component manifestes in a hysteresis of the transmittance vs voltage curves, Fig. 2. N-film possesses smaller hysteresis than T-film. Analysis of

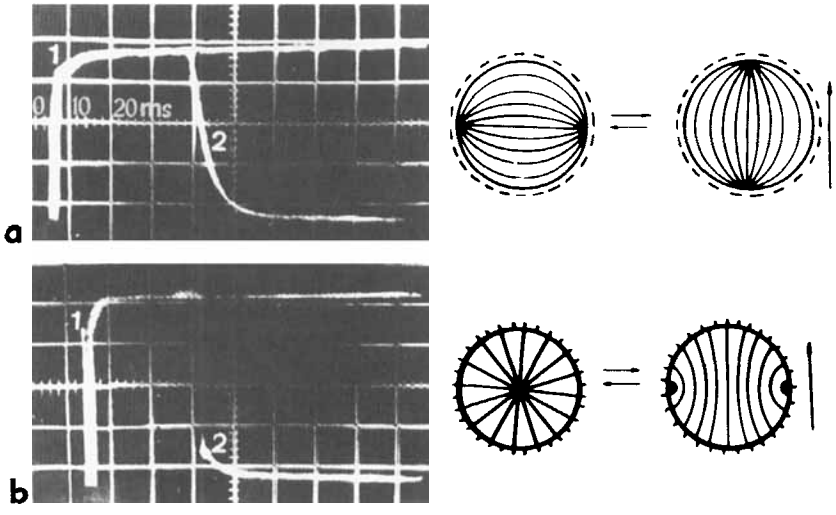

FIGURE 1 Light transmittance of T (a) and N (b) films during (1) and after (2) an applied 100 V driving AC pulse. Right side: corresponding types of structural transformations in drops.

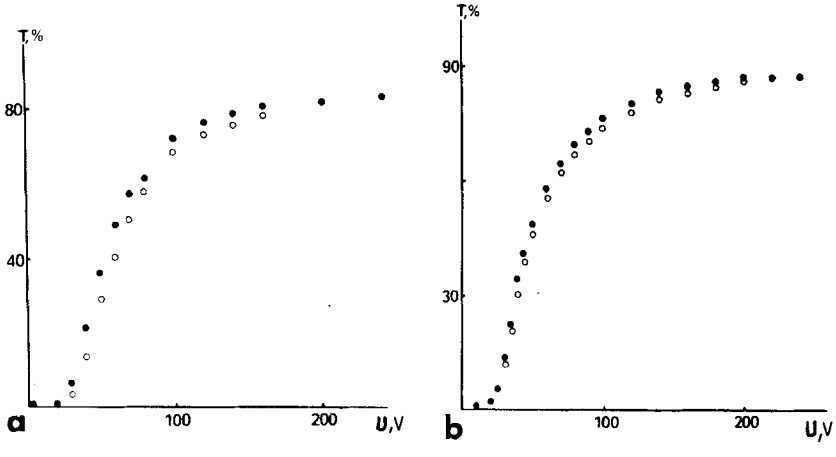

FIGURE 2 Transmittance vs voltage curves for T (a) and N (b) films. ○ increasing voltage, ● decreasing voltage.

this effect is possible within the scope of above mentioned models.

Real shape of the drops may be more complicated in comparison with the simply elongated or flattened drops and corresponds to a few minima of elastic energy rather than one. In T-films when the field is removed relaxation of the structure axis may be hindered by local "traps" of the drop shape. In N-films the relaxation is caused by active anchoring force and histeresis is smaller. Remaining hysteresis may be caused by surface pinning of disclination rings.

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