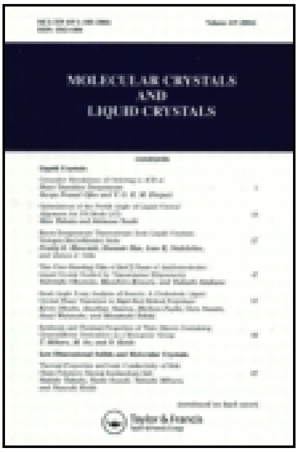

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# Bistable Switching in FLC Cells Aligned by Photoanisotropic Films

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# BISTABLE SWITCHING IN FLC CELLS ALIGNED BY PHOTOANISOTROPIC FILMS

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Abstract Long-term perfect bistable switching of 1,5μm thick Ferroelectric Liquid Crystal (FLC) cell oriented by photoanisotropic (PA) films was demonstrated even in case of a large spontaneous polarization $Ps=100nC/cm^2$. The condition of a good $SmC^*$ orientation quality was shown to be the existence of a nematic phase $N^*$. The bistability properties of PA-films aligned FLC cell, kept for a while in a short-curcuiting state, are easily restored, which is not observed in FLC cells oriented by usual rubbing technique.



## INTRODUCTION

Nowadays FLC screens with a high contrast and a relatively fast response were developed[1]. The main problems in their production are known to be the quality of a $SmC^*$ phase orientation, which provides a high contrast, required threshold properties and a long-term bistability switching. The phenomenon of a bistability degradation in FLC cells aligned by usual rubbing technique is well established[2]. To avoid this degradation several authors[3] propose to apply FLC mixtures with $Ps<20nC/cm^2$, to use polyimide (PI) Langmuir-Blodgett (LB) films[4] for the director orientation as well as rubbing of PI films doped with a charge-transfer complexes (CTC)[5].

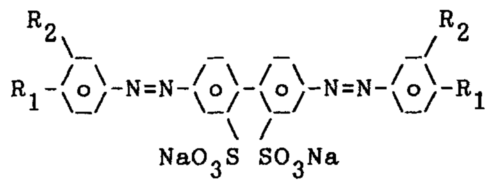
The present paper investigates bistable properties of thin (1,5μm) FLC cells with spin coated photoanisotropic (PA) films which used as aligning agents. The photoinduced anisotropy of these films was obtained by UV-illumination.

The rubbing technique was avoided. These films present a new type of orienting agents[6] which provide a specific electrooptical behaviour of FLC-cells.

## EXPERIMENTAL

Orienting films were made by spin-coating of the water solution of polyvinyl alcohol (PVA) in combination with azodye onto the substrate and subsequent drying and illumination of the substrates by a linearly polarized light.

The chemical structure of the azodye used was the following:



(1)

where $R_{1,2}$ were OH or COOH substituents.

The orienting agent was prepared as follows. The 2-3 drops of the water solution of the azodye (1) (5.0wt%) were mixed with 5 gramms of the saturated PVA solution. The resulting aligning mixture was spincoated onto the glass substrates with current-conducting layers (ITO) by rotating centrifuge (4000min$^{-1}$). The thickness of the formed PA-films was 500-600Å. After this the substrates were heated up to T=80$^{\circ}$C for 20 minutes. The spectral characteristics of the PA-films obtained in this procedure is shown in Figure 1. After heating the substrates were cooled to the room temperature and illuminated by a linearly polarized light from a high-pressure Mercury Lamp during 10 minutes. The polarizer was Glan-Tompson prism, no other filters were used. The illumination power was 8mWt/cm$^2$ at the wavelength $\lambda$=365 nanometers. The photoinduced anisotropy was controlled visually by a polarimeter, the kinetic of the process[7] was not measured. Two substrates coated with PA-films layers with parallel preferred directions of orientation were taken together to make a 1,5-2,0μm FLC cell.

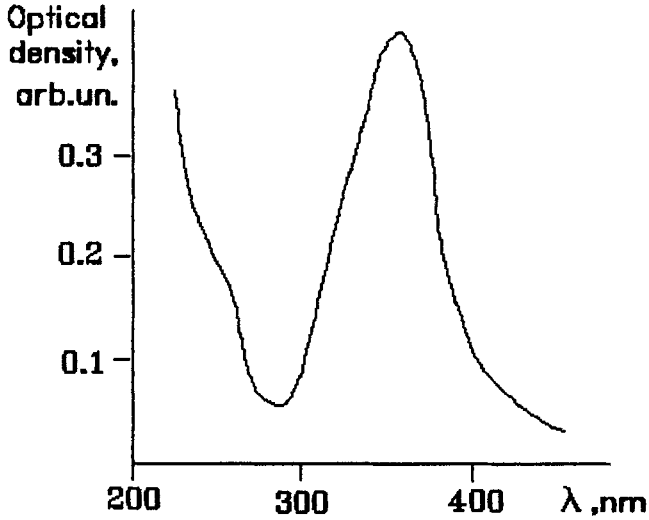



FIGURE 1 Absorption spectrum of the PA-film, based on PVA-azodye solution

We used in experiment two FLC mixtures ZhKSM-224 and ZhKSM-1009 developed in NIOPIK with characteristics given in Table 1.

TABLE 1 FLC mixtures, used in experiment

| | ZhKSM-224 | ZhKSM-1009 |
|---|---|---|
| Phase sequence | $Cr \rightarrow SmC^* \rightarrow SmA \rightarrow I$ | $Cr \rightarrow SmC^* \rightarrow SmA \rightarrow N \rightarrow I$ |
| Spontaneous polarization, Ps, $nC/cm^2$, $T=25^oC$ | 105 | 30 |
| Helix pitch in $SmC^*$, μm | 5 | 15 |
| Tilt angle θ, deg, $T=25^oC$ | 23 | 23 |

The $SmC^*$ cell was filled at the temperature of the isotropic phase $T=110^oC$. The bookshelf structure of ZhKSM-224 was obtaining by training in an electric field with the amplitude $\pm 10V/\mu m$. All the electrooptic measurements was made using the polarization microscope POLAM-P-311 at T=23°C.

## RESULTS AND DISCUSSION

To study the capability of photoanisotropic films based on PVA-azodye solution to orient $SmC^*$ phase we used FLC mixture with a nematic $N^*$-phase (ZhKSM-1009, Figure 2) and without nematic phase (ZhKSM-224, Figure 3). The quality of orientation is evidently better in the first case, when a uniform director texture with a memory angle $\theta_m$=12° is formed. In the latter case (ZhKSM-224, Figure 3) the PA-films aligned FLC texture also exhibits a preferred direction, however the texture quality in general is worse and the contrast of electrooptic switching in square-wave

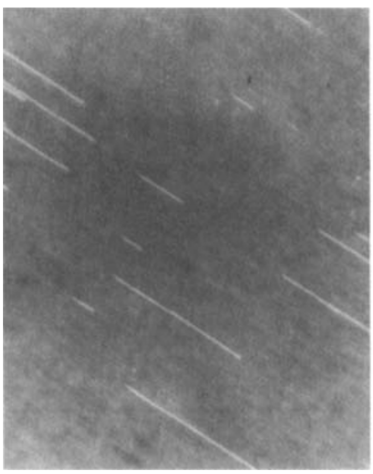


FIGURE 2

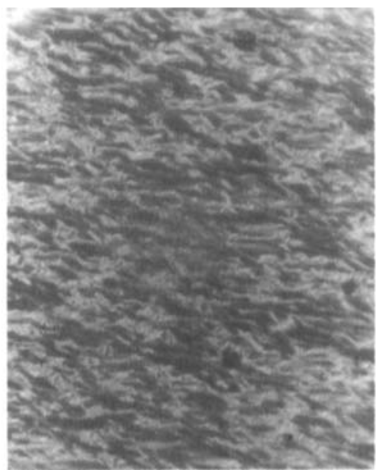


FIGURE 3

FIGURE 2 FLC texture quality for FLC mixture with $N^*$-phase for the chevron structure of smectic layers.

FIGURE 3 FLC texture quality for FLC mixture without $N^*$-phase and for the bookshelf structure of smectic layers.

voltage pulses hardly achieves the values of 3 or 4. We have also to note, that in case of normal incidence of the orienting UV-light illumination on PA-films the chevron structure of ZhKSM-1009 is characterized by the presence of zig-zag defects.

One of the main problems to be solved to better FLC display applications proves to be to avoid the bistability degradation in thin (1,5μm) FLC cells. This degradation phenomenon was explained[2] by the action of the near-electrode layers formed by impurity ions, which were placed at the orienting substrates and "kick-off" one of the bistable states. To recover the bistability behaviour is not possible.

The situation is different in case of PA-films as orienting agents[9]. After cooling down to a room temperature the perfect bistability is observed (Figure 4b). When short- curcuiting of the cell in one of the stable states, e.g. at $I_{min}$ transmission (Figure 4b), the state with $I_{max}$ transmission degrades, like for the cell prepared by the usual rubbing technique (curve 1, Figure 4c). However after this a totally complete "recovery" of bistable properties is taken place (curves 2,3, Figure 4c), which is not observed in the FLC cell with rubbed substrates. Such a bistability "recovery" is also taken place in a chevron FLC cell with ZhKSM-1009.

One of the possible explanations of the phenomenon could be as follows. In case of a PA-film oriented surface the number of surface states capable to absorb ions is considerably lower then for the surfaces, coated with a rubbed layer. Consequently, the charge is not absorbed on the surface. When the simulating voltage pulses (Figure 4a)are applied the conditions of surface charge formation disappear, the ions come to the bulk and bistable switching is restored.

The mentioned surface states[10] could arise during the procedure of rubbing, which results in a sharp increase of

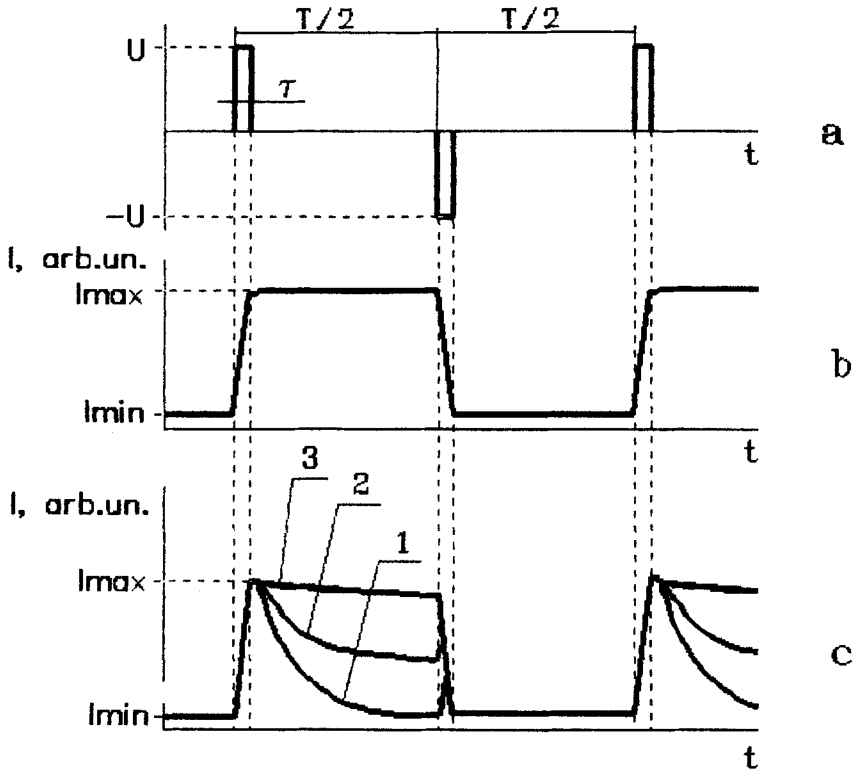



FIGURE 4 (a) Voltage pulses applied to FLC cell; T-pulse period, τ-positive and negative pulses duration, U-amplitude.
(b) Optical response of the newly prepared FLC cell; in experiment T/2=200ms, U=15V, τ=50μs, ZhKSM-224 (Ps=105nC/cm$^2$, d=1,5μm).
(c) Optical response of the same FLC cell after keeping two hours in a short-curcuiting state and subsequent application of voltage pulses, shown in Figure 4a, at $t=t_o$.
Curve 1 - FLC cell response at $t=t_o$
Curve 2 - FLC cell response at $t=t_o$+10min
Curve 3 - FLC cell response at $t=t_o$+20min.

the surface roughness[11]. We do not observe the restoration of the bistability properties in FLC cells with a rubbed PA orienting layer, the same which so easily promotes bistability recovering in case of being UV-illuminated.


## SUMMARY

Photoanisotropic (PA) orienting films based on PVA-azodye solution provide a good quality of $SmC^*$ phase, provided that FLC mixture possesses a nematic $N^*$ phase. In thin (1,5μm) FLC cells the bistability properties are easily restored even in case of a high spontaneons polarization $Ps=100nC/cm^2$. This phenomenon could be explained due to the difference of charge absorption in UV-illuminated orienting PA-layers and rubbed orienting films.



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