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Surface Dependent V-Shaped Switching in a Chiral Smectic Liquid Crystal

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We have extensively studied the influence of the substrate surface on the V-shaped switching in thin planer cells of a chiral smectic liquid crystal and found that the substrate surface plays a major role in the emergence of V-shaped switching: namely, thick alignment layers and less polar surfaces are ideal for V-shaped switching. It was also found that, instead of using a thick alignment layer, ideal V-shaped switching could be achieved by using a thin alignment layer with a less polar insulating layer.

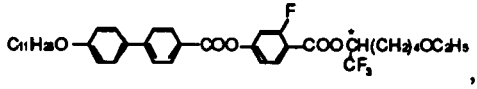
Keywords: V-shaped switching, chiral smectic liquid crystal, insulating layer, alignment layer, surface effect

1. INTRODUCTION

The thresholdless and hysteresis-free V-shaped switching was first observed by Inui et al. in thin homogeneous cells of an apparent AFLC mixture, suggesting potential for active matrix addressing in display devices[1-3]. In our previous paper[4], we reported the suitability of using a thick alignment layer for V-shaped switching. However, when the alignment layer becomes thicker, a higher driving field is necessary. This may be a disadvantage from an application point of view. In this paper, we report the suitability of a thin alignment layer together with a less polar insulating layer for V-shaped switching with low driving voltage.

2. EXPERIMENTAL

The liquid crystalline material used was 4-[(1-trifluoromethyl-5-ethoxy)-pentyloxycarbonyl-3-fluoro]phenyl 4'-(n-undecyloxy)biphenyl-4-carboxylate,



the phase sequence of which is Iso (83.4°C) Sm A (80.2°C) Sm X*. This material shows V-shaped switching in thin planer cells as well as in the bulk state in the phase designated as Sm X*. It has a large spontaneous polarization of 260 nC/cm^2 and a tilt angle of 41° at 25 °C. In the present study we chose the polyimides PI-4 (Nissan Chemical) and PI-6 (Toray, SP550) among the list summarized in ref. [4]. Particular attention has been paid not only to the effect of the thickness, polarity and capacitance of the alignment layer but also to the effect of an insulating layer on V-shaped switching. Three PI-4 films of different thicknesses, 2250 Å, 1360 Å and 600 Å, were used, and the contact angles of water on each surface were 59°, 59° and 55°, respectively. The fabrication of the liquid crystal cells and the measurements of optical transmittance and switching currents were done as described in our previous paper[2].

3. RESULTS AND DISCUSSION

Thickness Dependence

Figure 1(a) compares the optical transmittance measured at 40 °C and 50, 100 and 1000 mHz for the cells coated with PI-4 of three different thicknesses. Good V-shaped switching was observed for 2250 Å and 1360 Å films and W-shaped switching for 600 Å film at all frequencies. The bottom line (abscissa) of all the figures given in this article corresponds to the complete dark state when no light goes to the photomultiplier tube. Figure 1(b) compares the V-shaped switching measured at a frequency of 1 Hz and 25 °C, 55 °C and 70 °C

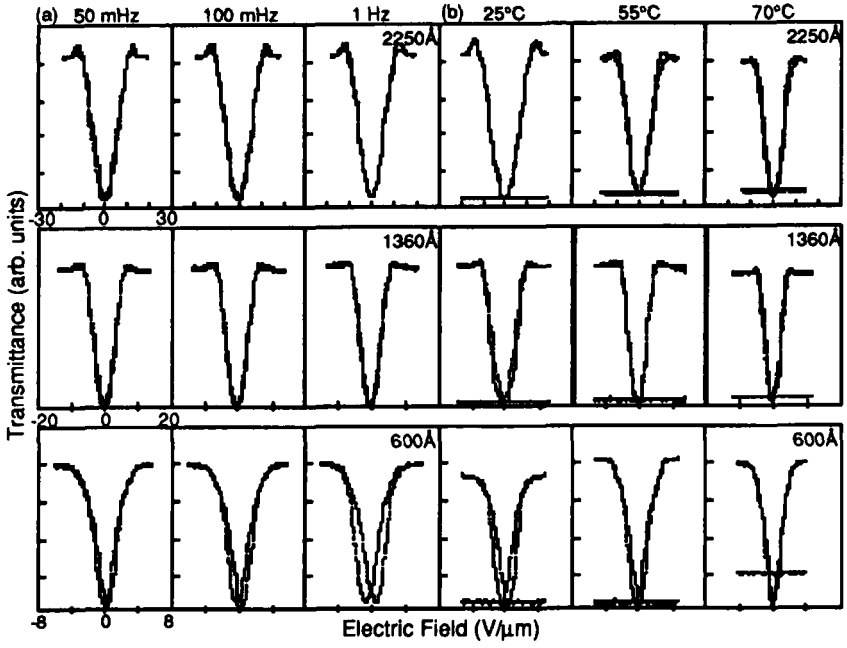


FIGURE 1. Electrooptic behavior (a) at 40 °C and (b) at 1 Hz for cells with PI-4 films of three different thicknesses.

temperatures for three different PI-4 film thicknesses. The solid straight line in each figure shows the transmittance when the field is switched off. For all the three thicknesses the transmittance retains at low level when the field is off, unless the temperature is high (70 °C) and the PI-4 film is thin (600 Å). Thus thicker alignment layer assists to achieve V-shaped switching.

Figure 2 compares the switching current peaks measured at 1 Hz and 55 °C for three PI-4 films of different thicknesses. When the film becomes thicker the current profile becomes broader and resembles to the characteristic current profile of V-shaped switching consistent with the Langevin type switching[4]. From the measurement of contact angle it is clear that all the three surfaces have weak polarity.

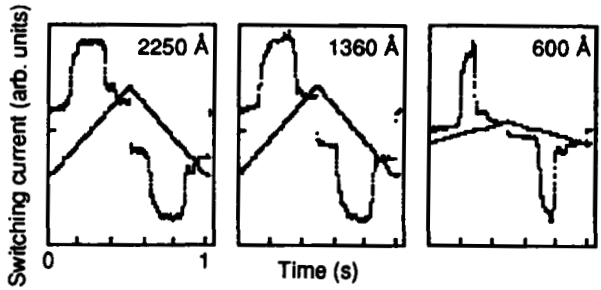


FIGURE 2. The switching current peaks measured at 1 Hz and 55 °C for three film thicknesses of 2250 Å , 1360 Å and 600 Å of PI-4.

Effect of Insulating Layer

In order to further investigate the influence of the surface of the LC cell on V-shaped switching, the effect of an insulating layer was examined. It was shown that good V-shaped switching is observed, if the polyimide (PI) film is thick. Instead of using a thick PI film we tried to decrease the capacitance by using a thin PI film (600 Å) together with an insulating layer. We used TaO_x of 900 Å thickness as an insulating layer, of which the dielectric constant was 20 and the contact angle was 36°.

Figure 3(a) compares the optical transmittance measured at 40°C and at different frequencies for polyimide PI-6 (600 Å) with and without the insulating layer. As the PI-6 film is relatively thinner (600 Å) it gives rise to W-shaped switching without an insulating layer. When TaO_x was used as the insulating layer with a thin PI-6 good V-shaped switching was observed. Figure 3(b) illustrates the temperature dependence of the optical response measured at 1 Hz frequency for the cells with and without the insulating layer. The transmittance in the field off state became very low when the insulating layer was used. From this figure it is clear that good V-shaped switching can be achieved when TaO_x is used as an insulating layer together with thin PI-4 at all temperatures and frequencies.

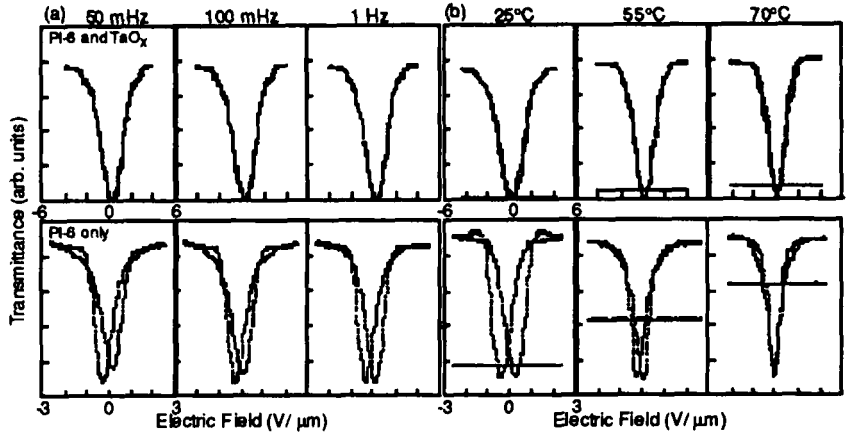


FIGURE 3. The optical transmittance as a function of applied electric field measured at (a) 40 °C and (b) 1 Hz for PI-6 with and without the TaO_x insulating layer.

SiO_2 was also examined as an insulating layer. SiO_2 layer decreases the capacitance of the cell more than TaO_x does, since it has a smaller dielectric constant of 4.2. However, the effect was not remarkable when compared with the TaO_x layer. The reason is not clear at present, although a very strong polar surface of SiO_2 (contact angle; 3°) may be responsible for the unexpected result. Thus, less polar TaO_x which has a high dielectric constant favors V-

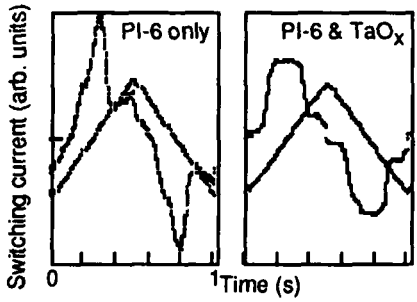


FIGURE 4. The switching current peaks measured at 1 Hz and 55 °C for PI-6 with and without the insulating layer, TaO_X.

shaped switching by decreasing the capacitance of the cell to some extent.

Switching current behavior also shows the similar trend, as shown in Fig. 4. Broad current peaks were observed in the cell with TaO_x layer, which exhibits V-shaped switching, while relatively sharp peaks were observed in the cell with only PI-6, which exhibits W-shaped switching.

4. CONCLUSION

The alignment layer plays a major role in the emergence of V-shaped switching. Thick alignment layers or thin alignment layers with a less polar insulating layer are ideal for V-shaped switching. Instead of using a thick polyimide film, the use of a thin polyimide film with a TaO_x insulating layer serves as an ideal surface realizing ideal V-shaped switching with low electric field.

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