Influence of alignment techniques on switching behaviour of SSFLC cells

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ABSTRACT

Dependence of SSFLC electrooptic switching characteristics and matrix addressing capabilities on cell materials was investigated. Four test cells were made with two FLC mixtures, ZLI 4851-000 and BDH SCE8, in combination with two alignment materials, rubbed polyimide (Nissan SE3140) and friction deposited teflon. The cells show a good bistability characterized by memory and symmetric switching. Delay and rise times have been measured and fitted using a uniform director model, allowing a determination of all parameters within this model. Based on this, computed regions of operation of normal and fast addressing modes are reported. For both mixtures, teflon aligned cells, compared to polyimide aligned cells, show higher elastic restoring torques in the model. For normal addressing modes, teflon cells feature a higher minimum and a lower maximum operating voltage. Furthermore, they allow higher addressing speeds for both normal and fast modes.

Keywords: surface stabilised FLC cells, alignment layers, addressing waveforms.

1. INTRODUCTION

Surface interactions between a ferroelectric liquid crystal (FLC) and the alignment layers are of fundamental importance for the operation of surface stabilised (SSFLC) bistable cells. Different FLC mixtures in combination with different alignment layers give different display performance depending also on which matrix addressing technique is used. Therefore, to optimise the overall performance of SSFLC devices, the best combination of FLC mixture, alignment layer and addressing method must be selected. Several cells made by different combinations of FLC mixtures with several rubbed polymers and evaporated alignment materials have already been characterised[1]. Recently polytetrafluoroethylene (i.e. PTFE or Teflon) has become an interesting material to align liquid crystals because of its highly ordered structure when deposited by friction on heated glass substrates, without any rubbing process[2]. Atomic force microscopy showed quite clearly a higher range of ordering than in the case of rubbed polymers and benefits were found in terms of better electrooptic switching behaviour in SSFLC cells[3]. This makes teflon a promising powerful yet low cost material to fabricate FLC displays. In order to model the alignment layer influence, SSFLC test cells have been prepared with two FLC mixtures, Merck ZLI 4851-000 and BDH SCE8, in combination with two alignment layers, Nissan SE3140 polyimide and teflon. Their switching characterisation has been made by measuring the delay and rise time of optical transmission as a function of amplitude of voltage steps[4]. Computer simulation of electrooptical response by using a uniform director model[5] requires different values for the cell parameters to fit experimental data and enlightens differences between cells using different alignment layers. Simulation with the same parameter values gives operating regions for several addressing waveforms, both of normal, i.e. low-voltage[6] and fast, i.e. high-voltage type[7].

2. MEASUREMENTS AND SIMULATIONS

The 4851-000 cells were 1.7 µm thick and SCE8 cells 2.1 µm. Both FLC mixtures had low spontaneous polarisation P_S in order to reduce sticking problems during addressing. Nissan SE3140 was deposited by spin coating and then rubbed. Teflon was deposited by hot friction at 180 °C, so that a thin layer of about 400 nm was obtained. Optical transmission response of the test cells between crossed polarizers was measured at 24 °C when driving the cells by the simple test waveform[4] shown in Fig. 1, repeated with alternating polarities at 1:100 duty ratio. The first two pulses provide dc compensation and a fully switched initial state at each occurrence, even for voltages above minimum switching time with monopolar pulses. The amplitude of the waveform was varied from 5V up to 95V while adjusting pulse time to a minimum value for clear switching.

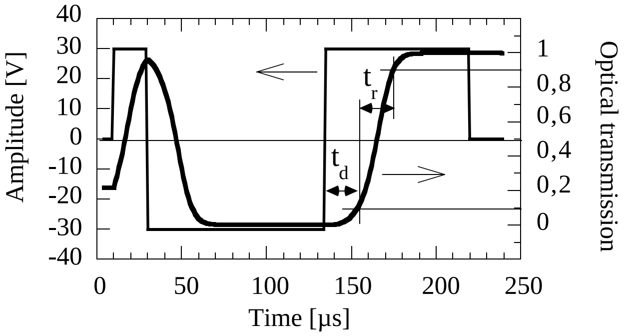

Fig. 1. Test driving waveform and SSFLC optical response, with definition of delay and rise time.

The plots of Fig. 2 show experimental points corresponding to measurements carried out on test cells and solid lines computed from the model by using the best fit parameters (Table 1), chosen to reproduce positions, slopes and shape of the measured curves, for given θ, η, P_S and measured d. Delay and rise time as well as total switching time, equal to their sum, are plotted along the vertical axis versus voltage. All characteristic times decrease with voltage down to a minimum and then increase at high voltages where dielectric torques become significantly strong. The most significant difference between simulation parameters related to teflon cells and those related to polyimide cells is found in the value for the relaxation time T_r which is inversely proportional to the elastic torque. Table 1 shows that the best fits were obtained by using larger values of T_r in the two cells with polyimide than in those with teflon. It follows that the highest elastic restoring torque acts in teflon cells. Hence, higher anchoring strength is induced by teflon than by polyimide. This effect is likely related to the fact that teflon is more highly oriented[3].

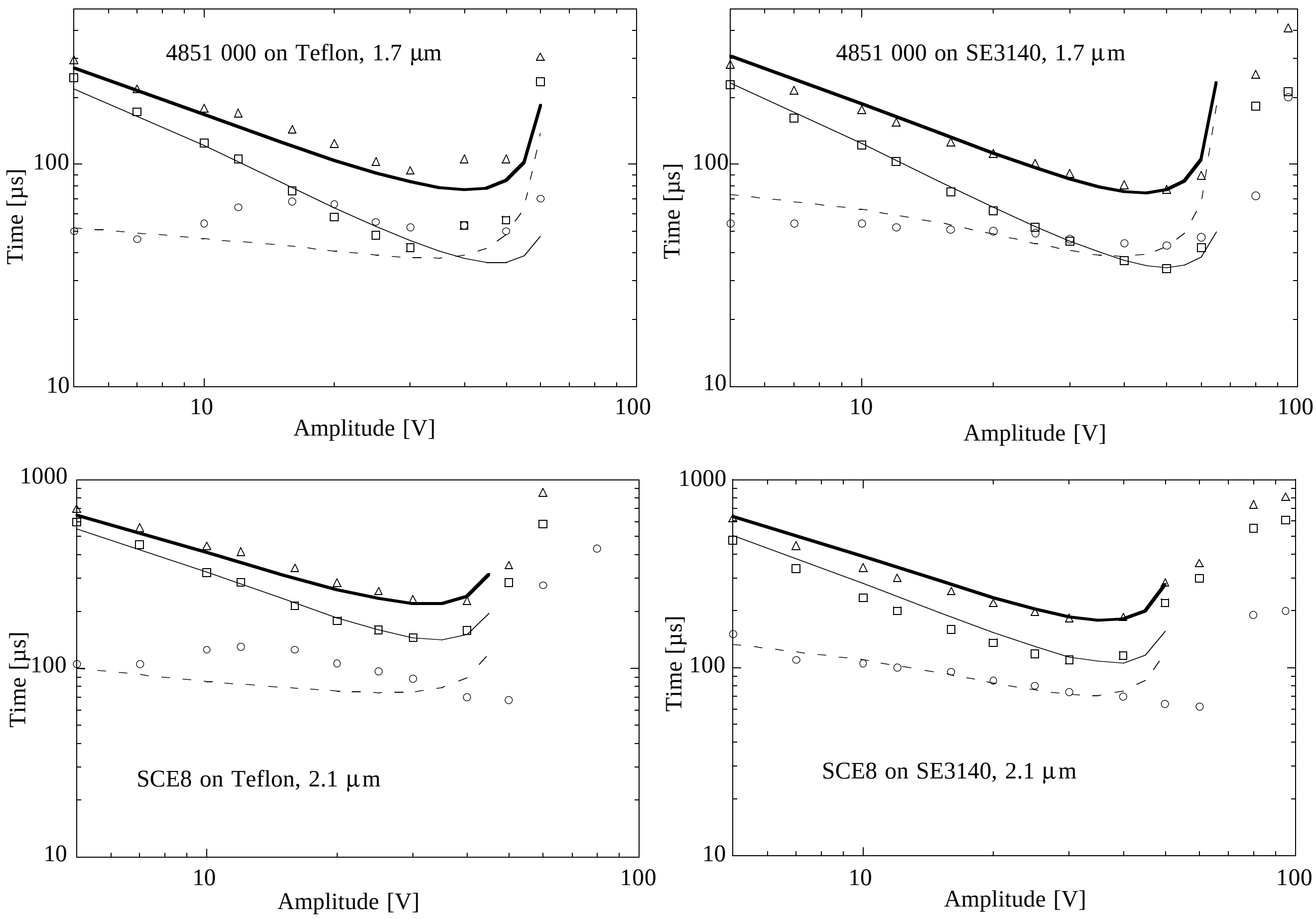

Fig. 2. Measurements and corresponding fitting in the four test cells: o delay (measured), □rise (measured), switching time (measured), - - delay (simulated), —— rise (simulated), ━━ switching time (simulated).

Parameter	Symbol	Unit	4851/ Teflon	4851/ SE3140	SCE8/ Teflon	SCE8/ SE3140
memorised director position at V = 0	Φ_m	rad	0.3	0.3	0.4	0.4
tilt angle	θ	rad	0.42	0.42	0.357	0.357
chevron angle	δ	rad	0.34	0.36	0.275	0.34
biaxiality	$\delta\varepsilon$	-	0.155	0.155	0.4	0.4
anisotropy	$\Delta\varepsilon$	-	-1	-1	-5	-3
rot. viscosity	η	mPa s	90	90	450	450
spontaneous polarisation	P_S	nC/cm^2	2.8	2.8	5.0	5.5
relaxation time	T_r	µs	120	200	200	500
thickness	δ	µm	1.7	1.7	2.1	2.1

Table 1. Parameters used for simulating the four test cell response.

3. OPERATING REGIONS FOR ADDRESSING MODES

Normal driving modes have been used to get more insight into the switching behaviour of the SSFLC cells at low voltages for which elastic torques have largest influence. A useful evaluation tool is the operating region in the plane [line addressing time - total voltage across the cell] for specific addressing waveforms. Fig. 3 shows computed contours of operating regions for the normal voltage addressing mode X231[6]. For both mixtures teflon alignment requires a higher minimum driving voltage but also gives slightly higher addressing speed at higher voltages. The cells with teflon operate faster than those with SE3140, when voltages range between 0.3V and about 15 V in the case of FLC mixture 4851-000 and between about 1V and about 13V in the case of SCE8. These differences between teflon cells and SE3140 cells are a consequence of the higher strength of the anchoring forces at the teflon/FLC interface. A short operating voltage range can be widened by using mixtures with higher P_s which then also increases the switching speed[5].

Fast addressing waveforms are interesting because they can drive low P_S FLC's in a much faster way by exploiting the dominant effect of dielectric torques. The plots of Fig. 4 show operating regions of a series of fast addressing modes[7] computed for the four test cells. The names of the ROM driving waveforms are defined here as follows: [ROM][2°writing pulse width]_[selection_data voltage ratio]. In the case of ZLI 4851-000 all operating regions for teflon are downshifted with respect to SE3140, which means that the teflon cell is faster than the SE3140 cell. In the case of SCE8 the shapes of all regions are influenced by the alignment layer, in particular, the SDS waveform has a wider operating region for the teflon cell.

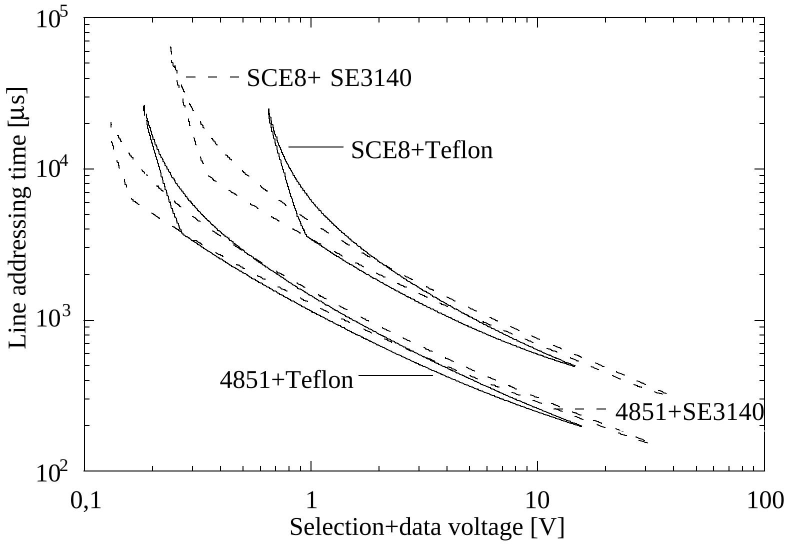

Fig. 3. Computed operating regions of normal addressing mode X231 with 3:1 selection/data voltage ratio.

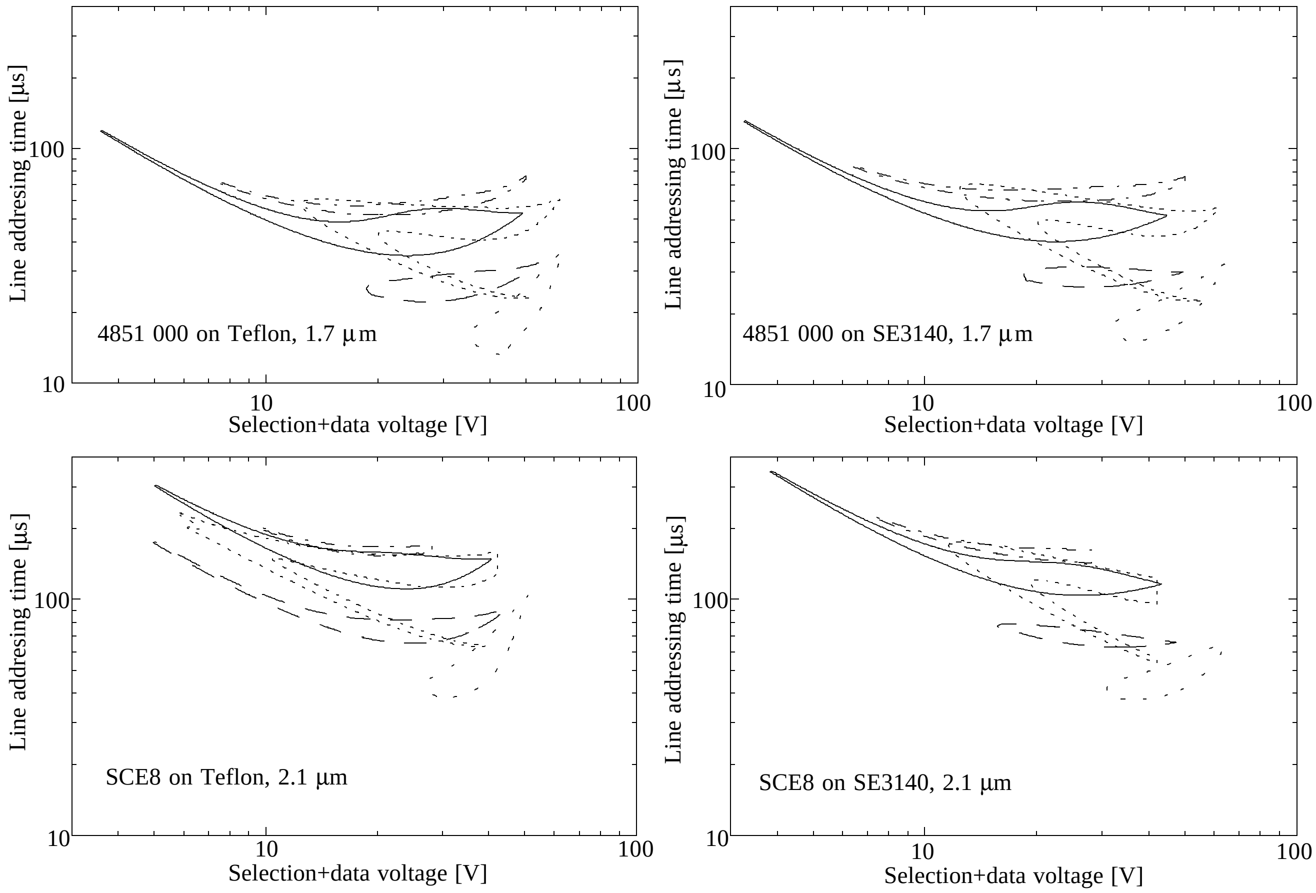

Fig. 4. Operating regions for fast modes in the four test cells: ROM1.25_2.8_1, SDS_2.5_1, ROM0.75_1_1, - - - ROM2.25_3.5_1, - - - - CROM4_2_1.

4. CONCLUSIONS

Simulation parameters of four SSFLC cells have been computed by fitting the experimental data on rise and delay times. Computed regions of operation have been reported for normal and fast addressing modes in 4851-000 and SCE8 cells. Fast modes are found to operate at much lower voltages than previously reported for ZLI 4655-000[7]. Teflon induces a higher elastic restoring torque than rubbed polyimide and for both of the used FLC mixtures teflon cells can be addressed at higher speeds. When fast addressing modes are used, comparable speeds are found for both coatings with SCE8 while teflon gives higher speed with 4851-000.

5. REFERENCES

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