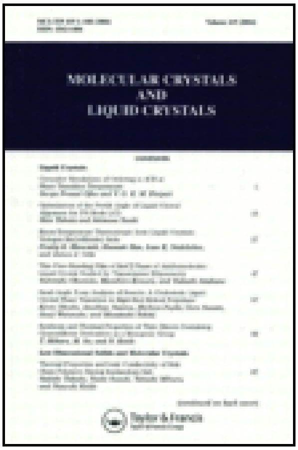

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In this paper we present a new possibility to obtain analogue grey level in surface stabilized ferroelectric liquid crystal displays (SSFLCD). Our simulation results show that the switching time under a certain applied voltage can be changed by varying the surface anchoring coefficient. Consequently, the percentage of the FLC switching area according to the applied data voltage can be controlled by a certain distribution of the surface anchoring strength within a single pixel. Since the optical transmission is the integral of the whole pixel, by applying appropriate addressing schemes, analogue grey levels become possible. This is confirmed by our simulation and experiment results.

Keywords: surface anchoring; analogue grey level; hysteresis loop

INTRODUCTION

Ferroelectric smectic C* liquid crystals are known to be one of promising LC materials for applications in new generation of devices. On the one hand, fast switching, bistability, wide viewing angles and simple construction allow video rate and resolution in large passive matrix displays, on the other hand, display of more than few gradations is difficult. In FLC passive matrix displays, digital grey scale proved so far to be the most straightforward technique to achieve a limited number of grey levels. However, with increasing number of grey levels, it requires faster switching and an extended number of connections and drivers. Analog methods would be a better choice if only grey levels could be created in a reproducible way over the whole display area. In a single pixel area, gradations can be addressed by means of mixtures of microdomains[11]. Many efforts have been devoted to modifying the basic SSFLC structure and to overcome the problems encountered with mixed microdomains, but they turn out to be very difficult to control.

In this paper we propose a new possibility to generate analogue grey level in SSFLC by varying surface anchoring strength within a single pixel. The goal is to control the switching process by making use of the influence of the surface anchoring strength when a certain combination of selection and data voltage is applied.

THEORETICAL APPROACH

We have developed a dynamic director switching model in SSFLC with a rigid chevron structure to efficiently analyze electro-optical effects in SSFLC cells[4]. The configuration of our model is shown in Figure 1. In the bulk, there are four main torques acting on the FLC director during switching - a ferroelectric torque, a dielectric torque, an elastic torque and a viscous torque. We solve the equation of motion for the FLC-directors

$$\eta \frac{\partial \varphi}{\partial t} = C_{elast} + C_{ferro} + C_{dielec}$$

$$C_{elast} = \alpha \frac{\partial^2 \varphi}{\partial x^2}, \quad C_{ferro} = EP \sin\varphi \cos\delta$$

$$C_{dielec} = \frac{\varepsilon_0 E^2}{2}\{(\Delta\varepsilon \sin^2\theta - \delta\varepsilon)\sin 2\varphi\cos^2\delta - \frac{\Delta\varepsilon}{2}\cos\varphi\sin 2\delta\sin 2\theta\}$$

where η is the rotational viscosity, α is the elastic constant, E is electric field $\Delta\varepsilon=\varepsilon_3-\varepsilon_1$, $\delta\varepsilon=\varepsilon_2-\varepsilon_1$.

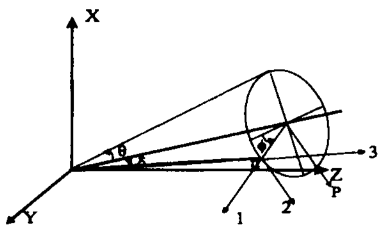


FIGURE 1 The orientation of the smectic cone, the director and the coordinate axes.

At the interfaces with the alignment layers, we calculate the interaction of FLC molecules and alignment layers by a classical approach with non-polar and polar contributions, defined as γ_1 and γ_2, respectively. The boundary condition is expressed as:

$$\alpha\varphi_x\big|_{x=x_s} = \gamma_1\{\mp\cos^2\delta\sin^2\theta\sin 2\varphi_s - \frac{1}{2}\sin 2\vartheta\sin 2\delta\cos\varphi_s\} + \gamma_2\cos\delta\sin\varphi_s$$

with the minus sign at the top interface and the plus sign at the bottom interface. For the moment we neglect γ_2 and concentrate on γ_1.

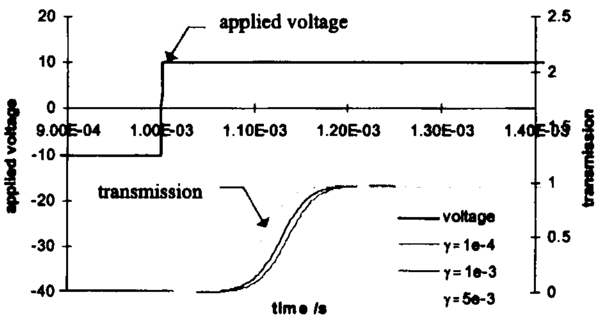
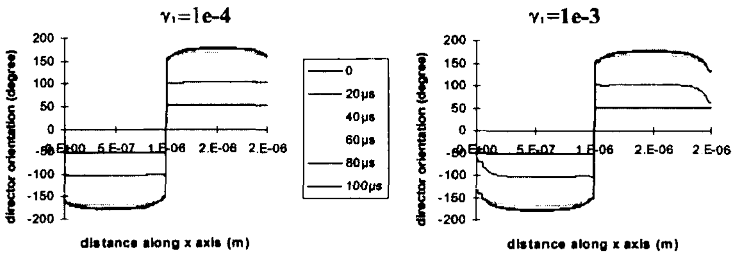


FIGURE 2 Influence of γ_1 on FLC switching.



(a) (b)

FIGURE 3 Simulation results of time evolution of director profile. In (a) the alignment constant γ_1 is small, the molecules switch rather homogeneously, while in (b) γ_1 is large, the molecules at the boundaries cannot follow the switching of those in the bulk region.

We keep all other parameters unchanged and vary only γ_1 to investigate its influence on the switching process. From Figure 2, we see that the switching time varies if the surface anchoring coefficient varies. When the surface interaction is weak, with a certain applied voltage, the FLC molecules at the interface of alignment layers can switch just as those in the bulk. This leads to a rather homogeneous director profile during switching between $\varphi=0$ or $\varphi=\pi$(see Figure 3(a)). On the contrary, if the surface anchoring is strong, the molecules at the boundaries tend to stick to a certain position determined by surface interaction and do not switch together as bulk molecules(see Figure 3(b)). When the polarity of the applied voltage is reversed, the ferroelectric torque is smaller for small surface anchoring, which results in a larger delay time. We see in figure 2 that the larger γ_l is, the shorter the delay time.

In Maltese's addressing schemes, a pulse phase modulation (PPM) method is used to generate grey levels[2]. Since the switching is influenced by surface anchoring, a certain data signal in combination with the row signal can result in different switching behavior and hence different optical transmission if the surface anchoring coefficient γ_l varies. This effect is illustrated in figure 4. Here we use the CROM4 addressing scheme with a selection voltage of 47V, data voltage of 25V and a control window of 71.3μs. For the moment, the influence of ion transport is not taken into account.

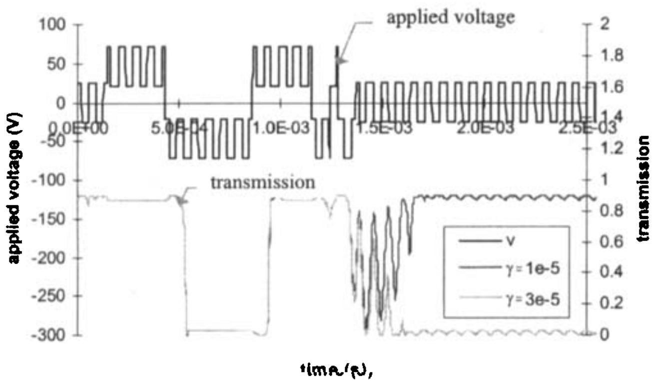


FIGURE 4 The effect of different surface anchoring strength on switching.

From Figure 4 we see that there exist threshold values of γ_1 above which a certain voltage signal can switch the molecules while below which it cannot. If γ_1 has a certain distribution within one pixel, with a certain applied signal, some part where γ_1 is above threshold switches, while the other part where γ_1 is below threshold does not switch. By this means, grey level is made possible. We have found these threshold values by simulating a cell filled with FELIX-M4851-000 using above addressing signals. The results are given in Figure 5 where the threshold values of γ_1 are represented as a function of the data signal (5 to 11)[2]. If we could make a pixel within which γ_1 is a function of position, in principle we could switch different percentage of the whole pixel by applying different data signals.

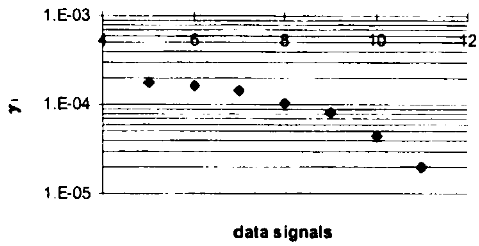


FIGURE 5 Threshold values of γ_1 for different data voltage signals.

EXPERIMENTS

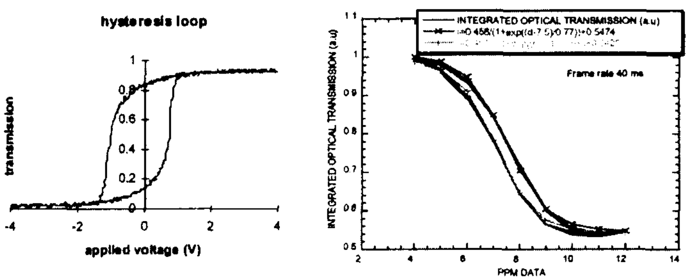
In our director switching model[4], the total free energy, f, of an SSFLC cell can be expressed as following:

$$f = -EdP\cos\delta\cos\varphi - \gamma_1(2\cos^2\varphi\sin^2\theta + 2\cos^2\theta\cos^2\delta + 2\sin^2\varphi\sin^2\theta\sin^2\delta)$$

where E is the electric field, d is the thickness of the cell and P is the spontaneous polarization. For simplicity we neglect the dielectric energy term and the chevron tip interaction. The two states where $\varphi=0$ and $\varphi=\pi$ are stable when $\partial f/\partial\varphi_{(\varphi=0,\pi)} = 0$ and $\partial^2 f/\partial\varphi^2{}_{(\varphi=0,\pi)} > 0$. In this way we obtain the threshold voltages for switching between the two bistable states

$$V_{th} = \pm\frac{4\gamma_1\sin^2\theta\cos\delta}{P}$$

Therefore we can measure γ_1 by measuring the width of the hystereis loop. Our test cell is filled with FELIX-M4851-000 (same as used in the simulations) with nylon as alignment layer. The cell is placed between crossed polarisers at an angle θ with the polariser axis. We use a He-Ne laser as light source in order to measure different points of the pixel. We apply a triangular voltage of $\pm$4V, 0.01Hz to guarantee a "static" condition. Figure 6(a) shows an example of our measurements.



(a) (b)

FIGURE 6 (a) An example of hysteresis loop to measure γ_1.
(b) Measured grey scales with hysteresis.

We have measured different points of the pixel and have found out that γ_1 varies from 1.47 10^{-5}N/m to 5.15 10^{-5}N/m, which approximately coincide with our simulation results.

The grey level is measured by applying the same addressing scheme as used in the simulations with PPM (Pulse Position Modulation[2]) data. We apply a step up-step down data cycle and the measurement setup has been published before[3]. The results are given in Figure 6(b).

We notice that the measured grey scales appear as a hysteresis loop, which indicates that they depend not only on the data signal within the control window, but also on the previous state of the pixel. This has been considered as one of the main obstacles in obtaining a good grey scale performance[4]. One of the probable reasons is the accumulation of ions at the interface between the FLC and the alignment layers, which creats an ionic field. It deforms the internal electric field, and consequently influences the switching process, hence the optical transmission[4].

CONCLUSIONS

Using our dynamic switching model, we have investigated the influence of the surface anchoring on the switching process. From the simulation and measurement results, we conclude that grey scale can be realized with a certain distribution of the surface anchoring strength within one pixel. However, the achieved grey levels depend not only on the data signal within the control window, but also on the history it has experienced. This is probably due to the transport of ions in the FLC which influences the internal electric field. This will be a subject of our future investigation.

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References

[1] P. Maltese, J. Dijon, T. Leroux and D. Sarrasin, *Ferroelectrics*, **85**, 265 (1998).
[2] P. Maltese, F. Campoli, A. D'Alessandro, V. Foglietti, A. Galbato, A. Galloppa, G. Rafaelli and M. Wnek, *Ferroelectrics*, **179**,153 (1996).
[3] P. Maltese, R. Beccherelli, F. Bernardini, M. Wnek, F. Zuliani, *Ferroelectrics*, **178**, 27 (1996).
[4] E. De Ley, V. Ferrara, C. Colpaert, B. Maximus, A. De Meyere, F. Bernardini, *Ferroelectrics*, **178**, 1 (1996).