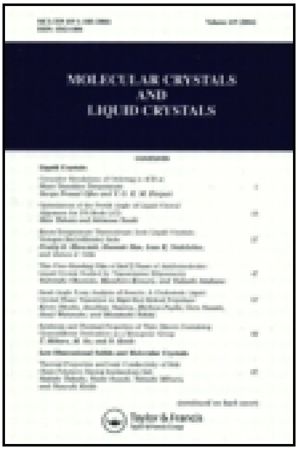

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Improving Electro-Optic Response in V-Shape Chiral Smectic Displays

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IMPROVING ELECTRO-OPTIC RESPONSE IN V-SHAPE CHIRAL SMECTIC DISPLAYS

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Addressing waveforms for reflective LCOS devices filled with V-shape chiral smectic liquid crystals, have been tested and optimised. Analogue greyscale generation has been tested on passive devices mimicking the behaviour in active matrix based devices. A comparative study of a number of experimental chiral smectic mixtures showing V-shape response has been carried out. Specific driving waveforms have been designed and optimised in order to improve the material's electro-optic response. This procedure is lengthy since every voltage level of the waveform ought to be separately optimised, and interdependences between the different waveform fragments lead to an iterative optimisation process. The effect of a short blanking pulse named well pulse has been particularly remarkable, thus forcing a thorough tune-up as a function of working temperature and video rate.

Keywords: addressing waveform; analogue greyscale; electro-optic response; V-shaped chiral smectic; well pulse

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INTRODUCTION

The interest on the peculiar electrooptic (EO) response of chiral smectic liquid crystal phases has been continuous along the two last decades. Both antiferroelectric or V-shaped liquid crystals have shown the possibility of generate images at 200 Hz rate. Driving waveforms for antiferroelectric liquid crystals has been reported and the use of well pulses in passive devices in order to enhance optical performance has been demonstrated [1,2]. Active matrix addressing of AFLCs has been demonstrated as well [3]. On the other hand, V-shape hysteresis-free thresholdless response shown by some chiral smectic mixtures has been found attractive for high-end displays [4]. Indeed, V-shaped materials show intrinsic analogue greyscale generation, in plane switching (IPS), excellent contrast ratio and remarkably fast electro-optic response. Analogously, suitable addressing waveforms for applying in devices with V-shaped liquid crystals have been proposed [5,6]. Advantages and constraints of employing antiferroelectric and V-shaped materials in active devices have been established in a comparative study [7].

In this work, further studies on design of addressing waveforms are shown. Specifically, it has been carried out a thorough study of well pulse optimisation for V-shaped liquid crystal addressing, similarly to the previous reported study on AFLCs.

DRIVING DEVICES BASED ON V-SHAPED LIQUID CRYSTALS

The basic addressing waveforms compatible with LCOS device technology has been presented elsewhere [5]. LCOS driving is made of a number of steps, as summarised in Figure 1.

Display *blanking* takes place when a *saturation* pulse is applied to the counter electrode. The pixel reaches the maximum optical transmission during that frame interval and the previous pixel data is erased. Simultaneously with blanking, data for the next frame are written onto the active matrix. Data *writing* obviously does not affect the LC since a saturating voltage is being applied to every pixel. Then, all pixels are eventually switched at the same time reaching different optical transmission level. This addressing scheme assumes that data stored in pixels are not affected by the addressing saturating pulse; otherwise corrections on data voltage levels may be implemented in advance. The saturating pulse is removed, and the display is *sequentially lighted* (R or G or B) along the frame time. The time the light is on must be a substantial fraction of the frame to avoid impairing the display brightness.

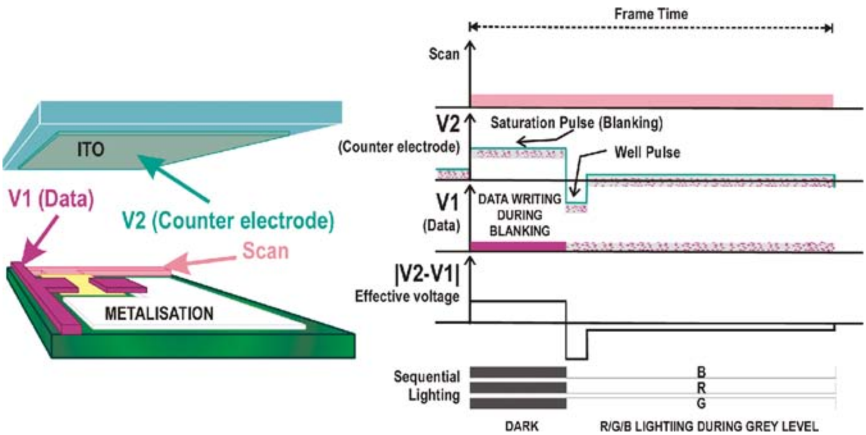

FIGURE 1 Addressing scheme in an active device based on V-shaped chiral smectic liquid crystal. (See COLOR PLATE XXII)

Well Pulse Design

The waveforms previously proposed also include a well pulse. *Well pulse* is a voltage pulse that is included after the saturation pulse with opposite sign. The scope of this pulse is to speed up the selection of the grey level in the following frame. The amplitude and time duration of the well must be carefully optimised because it determines some performance parameters of the display such as contrast ratio and brightness.

EXPERIMENTAL SET-UP

Experiments were carried out with experimental V-shape mixtures provided by the Military University of Warsaw. The same manufacturing protocol with slight changes was used in several cell batches. Surfaces of cells were conditioned with a cured and rubbed spin-coated polymer, Nylon 6 at different concentrations.

The characterisation system allows optical and electrical measurements. The optical system was composed of a Nikon POL2 polarising microscope, a fibre bundle and a Hamamatsu H5783–01 photomultiplier. The electric system consisted of a Tektronix TDS420A digital oscilloscope and a DS345 Stanford Research arbitrary waveform generator to produce the addressing waveforms. The whole experimental set-up is controlled by a PC via GPIB. The temperature was controlled with a programmable hot stage (Mettler FP-80).

Measurements based on checking electro optical responses under triangular waveforms at saturation voltages were carried out in order to reveal the correlation between the manufacturing protocol and the anchoring strength between the liquid crystal and surfaces. Temperature was modified during experiments. After that, cells were addressed with the waveform under study and relaxation times were checked in the worse case, that is, transition time between optical saturation and darkest grey level.

RESULTS AND DISCUSSION

Correlation Between Fabrication Protocol and Optical Response

Figure 2 shows evolution of optical transmission when a triangular waveform is applied over some cells with different manufacturing protocols. Working temperature is modified as well.

As seen in the Figure 2, protocol b gives cells with higher saturation voltages than protocol a. This result is attributed to a higher anchoring energy in the first case. Indeed, the concentration of the polymer precursor is twice higher in protocol b than in protocol a. The temperature variation reveals that voltage threshold before reaching optical saturation, decreases as temperature increases. This result implies that the greyscale shall be corrected to lower voltage levels in addressing waveforms as temperature increases.

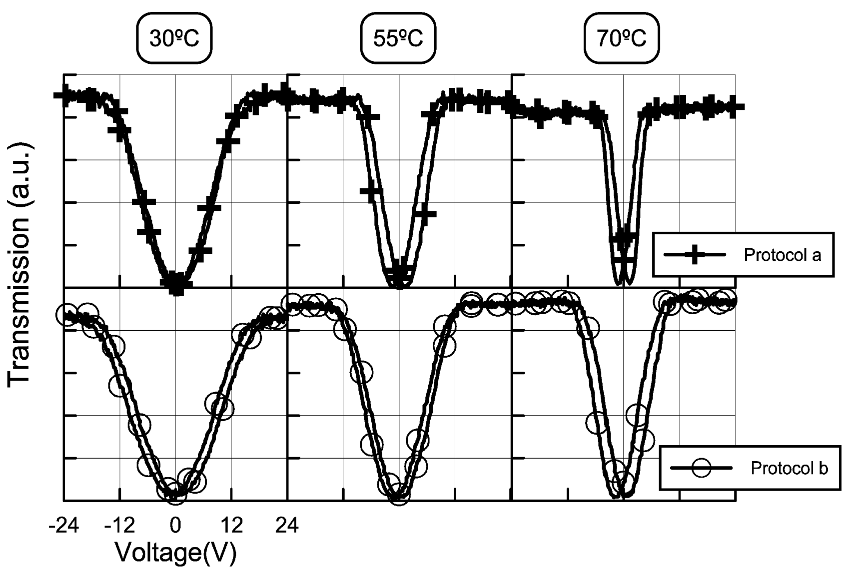

FIGURE 2 Alignment protocol and temperature dependence of saturation voltage for two cells manufactured under alignment protocols a and b.

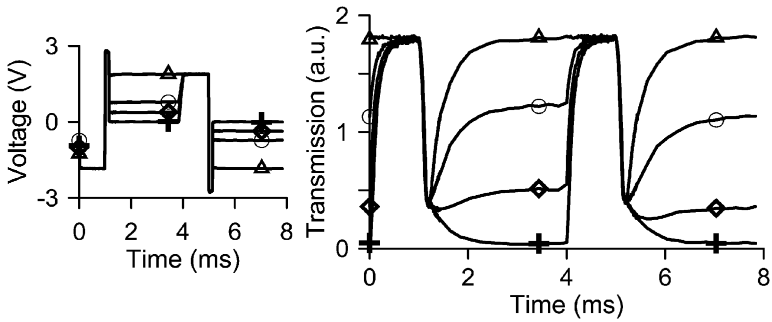

FIGURE 3 Effects on optical transmission for blanking and well pulses.

Relaxation Time

Fast response of V-shape liquid crystal, hundreds of microseconds, may be exploited in display applications. The response time is limited by the ferroelectric to antiferroelectric relaxation time. In this sense, a detailed study of relaxation times was carried out considering three parameters, width and amplitude of the well pulse, and temperature.

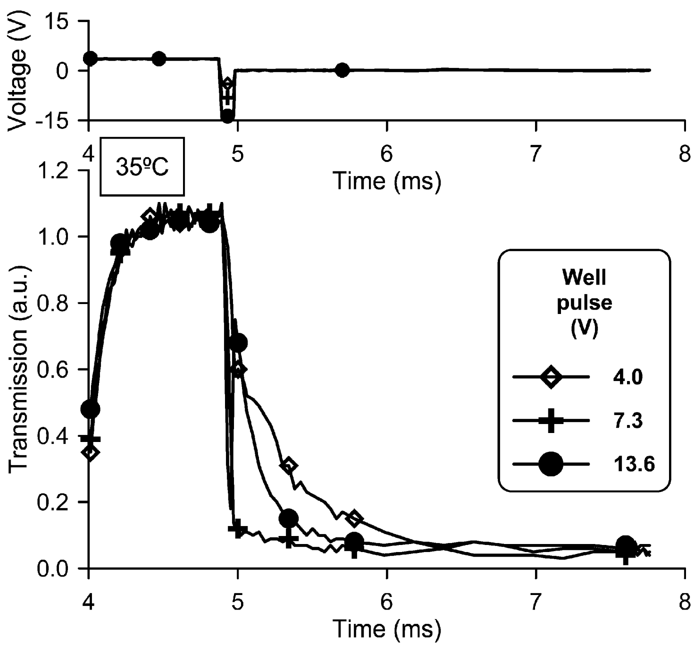

FIGURE 4 Amplitude well pulse dependence of relaxation time.

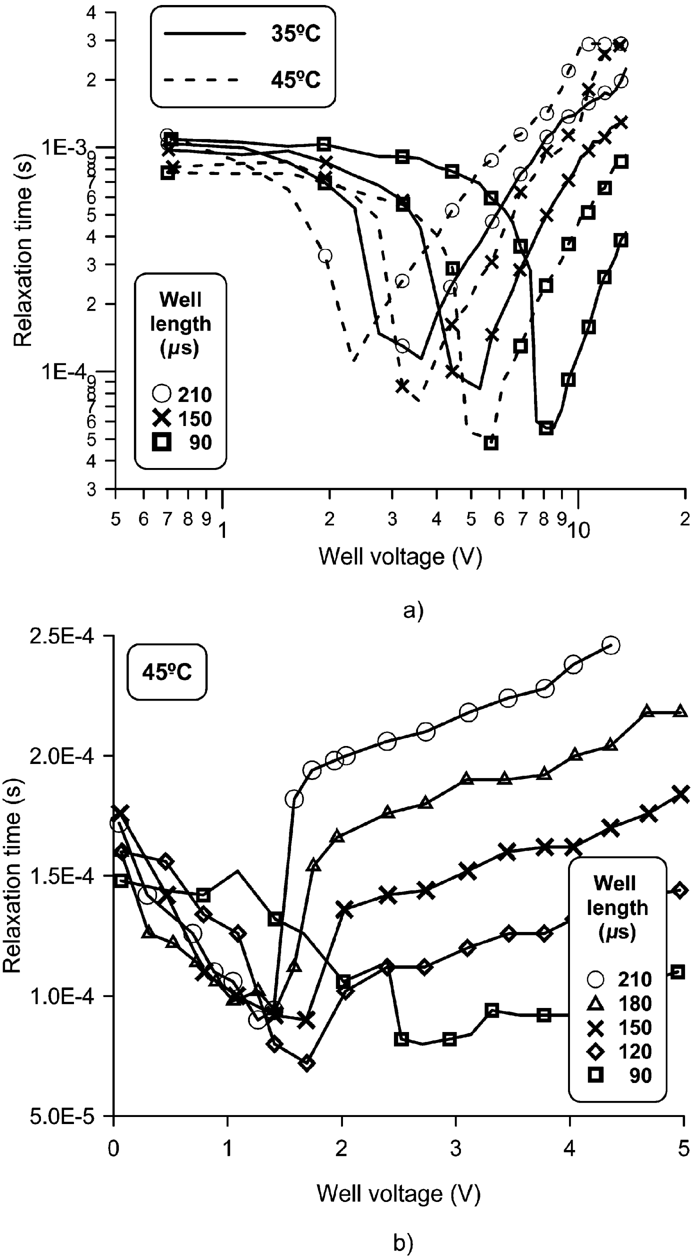

FIGURE 5 Relaxation time in V-shaped test cells (Note that axis are in logarithmic units in a), but axis are lineal in b)) a) Weak anchoring b) Strong anchoring.

Results of the evaluation may be summarised as follows:

- Saturation blanking and well pulse forcea **a known state** previous to the next grey level (Fig. 3).
- Wells lower than optimum produce **slow relaxations** while higher wells **increase transmittance for overswitching** (Fig. 4).
- **Higher temperatures** needs **lower well amplitudes** to get the optimum relaxation time and **higher well lengths** require **lower amplitudes** for reducing relaxation time (Fig. 5a).
- The alignment protocol is decisive in optical response of liquid crystal when well pulse is applied. The **efficiency of well pulse is enhanced** when **anchoring strength is weak**. Indeed, relaxation time may be reduced in more than one order of magnitude, as seen by comparing the relaxation times shown in Figures 5(a) and (b). The anchoring in the cell shown in Figure 5(b) is strong enough for relaxation times to be similar with and without well pulse.
- Optimised well pulses **improve contrast ratio** because light leakage at darkest states is avoided.

CONCLUSIONS

Well pulse has been added to waveforms designed for addressing devices. It speeds up the relaxation time from ferroelectric to antiferroelectric state. Moreover, a suitable well leads to darker transmittance in off state. So, contrast ratio and brightness may be improved.

It has been observed that there is a direct relationship between the manufacturing protocol and the optimisation of well pulse, specifically with the thickness of the alignment layer as induced by concentration of polymer in the precursor solution. In fact, the manufacturing procedure strongly determines the shape of the low-frequency EO response, and its temperature dependence. Therefore the whole design of driving waveforms is determined by the fabrication process. In this sense, the action of well with thin thickness alignment layers, that is weak anchoring, is maximised. There is a drawback, however: weak anchoring often leads to poor electro-optic responses, as W-shape response is usually promoted.

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