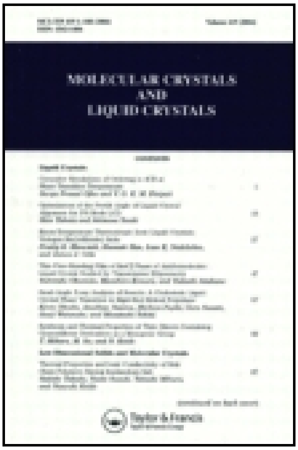

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Electro-Optical Properties and its Measuring Method for a Ferrielectric Liquid Crystal

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The electro-optical properties of the FELC, such as driving voltage, hysterisis, contrast, transmittance and response time, were investigated. The two times rubbed cell in polyamic acid and polyimide state showed smaller hysterisis and faster response time compared with that of the one time rubbed cell in polyimide state. The driving voltages of one time rubbed cells are almost the same regardless of the different rubbing strength. The contrast of FELC cell increased as the cell thickness decreased.

Keywords: ferrielectric liquid crystal; electro-optical properties; alignment

INTRODUCTION

To solve the problems for narrow viewing angle and slow response time of twisted nematic liquid crystal display (TNLCD), several display modes including surface stabilized ferroelectric liquid crystal (SSFLC)[1] and deformed helix ferroelectric liquid crystal (DHFLC)[2] switching using smectic LC instead of TNLC have been studied. Ferrielectric liquid crystal (FELC) is known to have the very fast response time (several hundreds μsec) and the wide viewing angle compared with the conventional twist nematic (TN)[3]. But the FELC has many problems to be solved for a successful display. Particularly, the low stability of aligned structure and contrast of the FELC is the week point for commercial display.

In this study, the electro-optical properties of the FELC cells, such as driving voltage, hysterisis, contrast and response time, were investigated by using the symmetric bipolar driving method and a new response time measuring method. And also the electro-optical properties according to the change of alignment condition were investigated.

EXPERIMENTAL

A mixtured FELC named M5 were used as a FELC material. The M5 has the following phase sequence; Isotropic – Smectic A (83°C) – Smectic C* (ferri phase: 72°C) – Crystal (below −30°C). The RN1199 (Nissan Chemicals) polyimide showing a low pretilt angle was used as an aligning film. Homogeneously aligned cells were prepared by rubbing the polyimide coated on glass plate with ITO electrodes. The one time rubbed cell was prepared by rubbing in polyimide state. In the case of the two times rubbed cell, the first rubbing was done at the room temperature after pre-baking for 5 minutes in the polyamic acid state at 70°C and the second rubbing was done at room temperature in the polyimide state. The thickness of the spin coated aligning film was 600Å. The thickness of the prepared cell was controlled by 1.25, 1.7 and 2.05 μm with spacer. The V-T curve of FELC was measured with triangular wave pulse and a square wave pulse of 30 Hz with linearly increasing its pulse amplitude with times (the symmetric bipolar driving method).

RESULTS AND DISCUSSION

Alignment Effect for Electro-Optical Properties

Figure 1 shows the V-T curve and the response time of one time rubbed cell (a) and two times rubbed cell (b). The V-T curve of FELC was measured with the symmetric bipolar driving method (a square wave pulse of 30 Hz with linearly increasing its pulse amplitude with time) and the response time was measured with applying from minimum voltage to maximum voltage, consecutively. The symmetric bipolar driving method is very useful to eliminate flickering of displayed image. The V-T curve of the one time rubbed cell showed big hysteresis as shown in Figure 1(a). The existence of hysteresis in a panel can be a cause of image sticking or change of color and decrease of contrast. In the case of two times rubbed cell (b), no hysteresis was shown. And the response time of the two times rubbed cell (b) was 25% faster than that of one time ubbed cell (a). In spite of the different response times of cell (a) and (b) in Figure 1, the driving voltage of the cells was almost same. The faster response time of cell (b) than that of cell (a) is a clue for the stronger anchoring force of two times rubbed polyimide than that of one time rubbed polyimide. The retardation value of the two times rubbed polyimide was 1.5 times of that for the one time rubbed polyimide[3].

Figure 2 shows V-T curve of cells with different rubbing nip. The driving voltages of these cells are almost same regardless of the different rubbing nip,

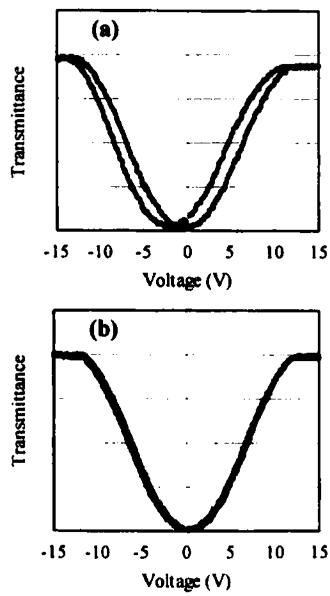


FIGURE 1. The V-T curves of (a) one time rubbed cell and (b) two times rubbed cell. The response time(μ s): (a) τ_r=147, τ_d=162, (b) τ_r=106, τ_d=153.

nip 10 (a), nip14 (b). Also the driving voltages of nip8, nip12 cells showed the same result of Figure 2. This result explains that the anchoring force depends on more alignment material state than rubbing strength.

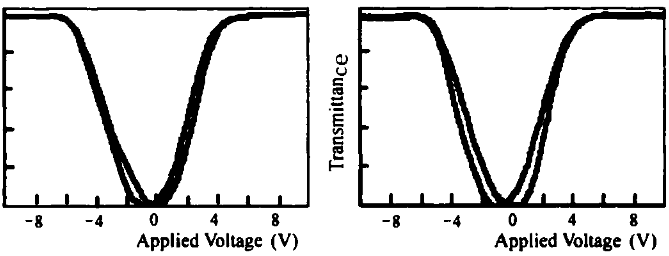


FIGURE 2. The V-T curves of the cells with different rubbing, in the case of one times rubbed cell.

Electro-Optical Properties and Its Measuring Method

Figure3 shows the response time measuring method for the FELC cell. The response time is measured by applying from arbitrary starting voltage through arbitrary end voltage between maximum and minimum voltage points, where the voltage sign for two voltage point should be opposite, for example, from –5V through +5V, +5V → -5V, –7V → +5V, and +5V → -7V. This new method of measuring the response time compared with the conventional TN method is the best way to explain how the panel works.

Figure 4 shows the V-T curve and the response time with applying various cells with different thickness. The driving voltage of cells with different cell thickness was almost the same. But the response time, transmittance and the contrast of cells changed with the cell thickness. In the case of 2.05 μm cell (c), the falling time is very slow compared with any other cases. In the case of one side rubbed cells of FELC, the response time of the thick cell thickness will be slow, because the effect of alignment surface (anchoring force) will decrease, as the cell thickness increases.

The equation on the response time (τ) is given by $\tau = \eta / Ps\,E$, $E = (\pi / d)^2 K$, where K is a Frank elastic constant and Ps is a spontaneous polarization. If the cell thickness (d) increases, applied voltage (E) decreases, and then τ increases. The contrast is in inverse proportion to the cell thickness. But the reason is not clear. We are investigating the aligned structure of FELC to clear the

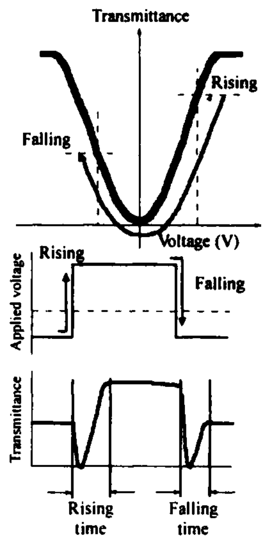


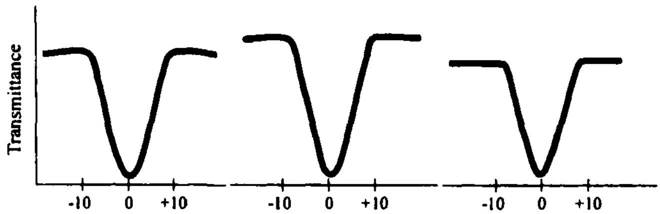
FIGURE 3. The new measurin method for the response time.

reason.

The transmittance of cells was calculated from the following equation.

$$T \propto \sin^2 2\theta \cdot \sin^2(\pi \Delta nd/\lambda)$$

The equation shows the maximum transmittance when ($\Delta nd/\lambda$)=1/2 and the wavelength of incident light is about 5800Å, Δn=0.15. So we get the highest transmittance when the cell thickness is nearly 1.7 μm among those three cell thickness (1.25, 1.7, 2.05 μm),



a) 1.25μm
Driving Voltage: ±7.7V
Rising tme: 82μsec
Falling time: 176μsec
Contrast: 263

b) 1.70μm
Driving Voltage: ±7.4V
Rising time: 134μsec
Falling time: 113μsec
Contrast: 194

c) 2.05μm
Driving Voltage: ±7.4V
Rising time: 118μsec
Falling time: 452μsec
Contrast: 174

FIGURE 4. The V-T curve and the response time of cell having different cell thickness.

CONCLUSION

The electro-optical properties of the FELC cells, such as driving voltage, hysterisis, contrast and response time were investigated. The effects of the alignment surface for electro-optical properties were investigated by changing the rubbing method and strength. The two times rubbing method was effective for electro-optical properties, such as hysterisis, contrast and response. The large value of rubbing nip was not effective for the control of electro-optical properties of FELC.

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