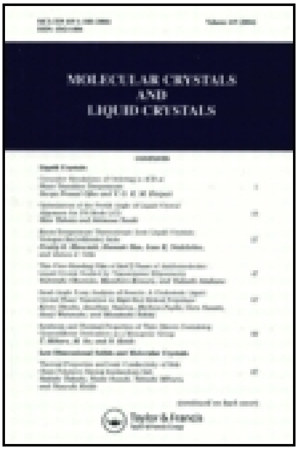

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New Design Technique for Driving Antiferroelectric Liquid Crystal Displays in Passive Matrix Using a Predetermined V-T curve

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NEW DESIGN TECHNIQUE FOR DRIVING ANTIFERROELECTRIC LIQUID CRYSTAL DISPLAYS IN PASSIVE MATRIX USING A PREDETERMINED V-T CURVE

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We propose a new voltage-transmittance (V-T) curve suitable to determine the driving pulse shapes. There are three alternating periods in the multiplex driving scheme; a selecting period, a holding period and a resetting period. Holding pulse shape and holding period affect the switching behavior of AFLCs. In this paper a new V-T characteristics of AFLCs applicable in the design of multiplex driving scheme is examined, where a square pulse is used for both selection and holding voltages.

Keywords: delayed response time; new V-T characteristics; passive matrix driving

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INTRODUCTION

Antiferroelectric liquid crystals (AFLCs) [1,2] have been extensively studied because they are suitable for fast switching electrooptic light modulators and displays. Fast response time, steep threshold, and symmetrical hysteresis loop of AFLCs allow passive matrix driving that has many advantages such as low power consumption, low fabrication cost and simple manufacturing process. Multiplex driving of AFLCs has already been investigated from the standpoint of application [3,4]. To design the multiplex driving, the hysteresis loop of AFLC materials should first be investigated. In general, V-T curves are obtained using triangular pulses. However when multiplex driving is performed, the threshold and steepness are quite different. The V-T characteristics under square pulses were studied by Hitoshi Hayashi *et al.* [5]. However under square pulse whose width is shorter than its response time, the transmittance or reflectance peak appears some time later [6]. This makes possible for the passive matrix driving to achieve its full transmittance or reflectance in a high-resolution condition where the selection pulse width is shorter than its response time. In the multiplex driving scheme, there are three alternating periods [3,4]; a selecting period, a holding period and a resetting period. Figure 1 represents the pulse shape used in experiments [7] and shows these periods.

In multiplex driving the maximum transmittance or reflectance peak occurs during the holding period though the selection period is already over. So in the actual driving condition, switching behavior of AFLCs is affected by holding pulse shape, and the transmittance or reflectance value of AFLCs will be changed by the holding pulse shape.

In this work, we study new V-T characteristics which are obtained by applying square pulses for both selection and holding voltages, and confirm

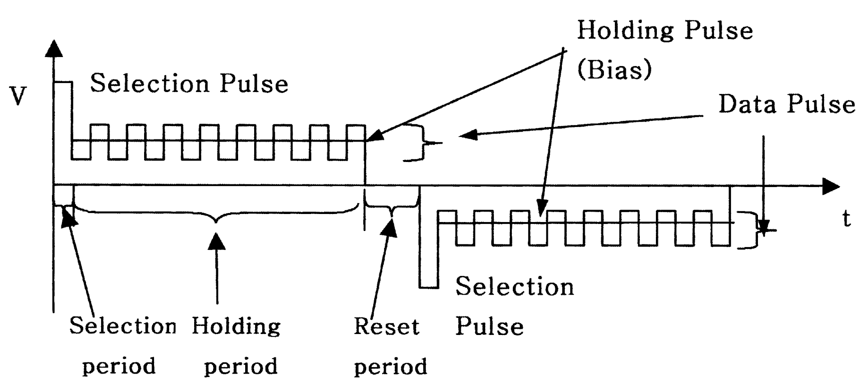

FIGURE 1 Waveform employed in the experiments.

the relationship between the new V-T characteristics and the values of driving pulse in passive matrix driving.

EXPERIMENTAL

An optical configuration of a reflective AFLC is shown in Figure 2. This configuration is composed of a polarizer, an AFLC cell, an achromatic quarter wave film, and a metallic diffuse reflector. Though the inherent tilt angle of an AFLC material should theoretically be 22.5°, in the experiments, the AFLC material has an inherent tilt angle of 24° and Δnd of 550 nm. Solid arrows indicate the transmission axis of the polarizer, the optic axis of the AFLC cell, and the slow axis of the achromatic quarter wave film. Open arrows express the polarization direction of the light passing the cell. The rubbing direction of the AFLC cell is parallel with the transmission axis of the polarizer, and oriented at 45° with respect to the optic axis of the quarter wave film. The dark state and the bright state are obtained with antiferroelectric-state (AF-state) and ferroelectric-state ((+)F-state or (−)F-state), respectively. The experimental set-up is schematically depicted in Figure 3. To remove glare light, we inclined the He–Ne laser

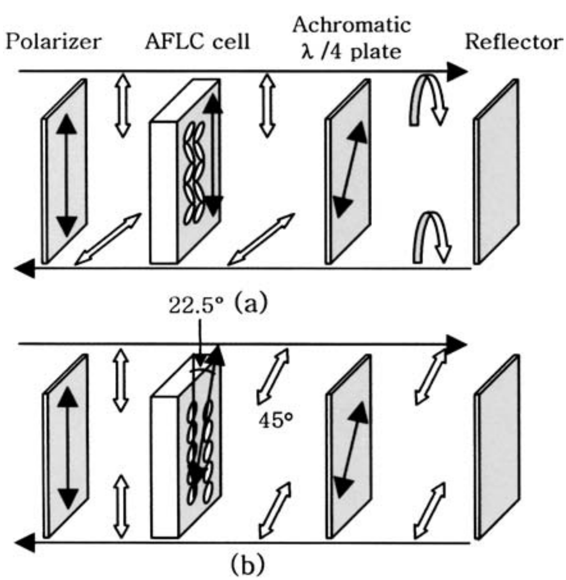

FIGURE 2 The configuration and polarization states of a single polarizer reflective AFLCD ((a)dark state, and (b)bright state).

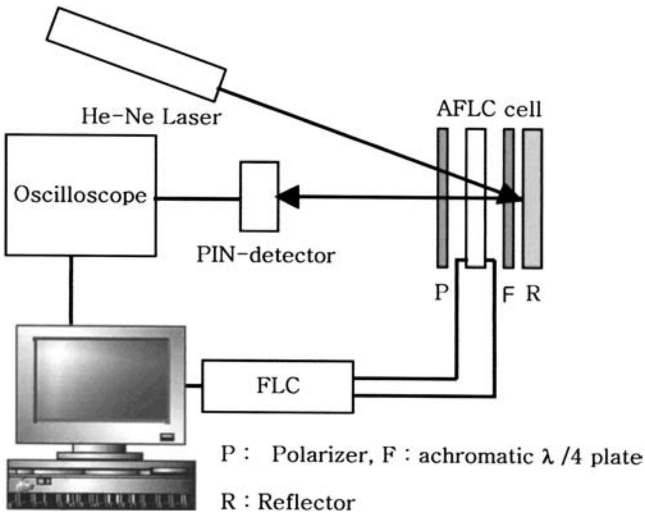

FIGURE 3 Experimental set-up.

source about 30°. The reflected light was measured by a PIN photodiode and an arbitrary waveform generator, WFG500 (FLC electronics) was used. Both the applied voltage and the output of the photodetector were simultaneously monitored by a digital storage oscilloscope (LeCroy, 9354AL). However, for CCD observation, an AFLC cell was located between the crossed polarizers.

DISCUSSION

Under the square pulse whose width is shorter than its response time the reflectance peak appears some time later [6]. This delayed response time of AFLC is shown in Figure 4(a). Here the maximum value of the reflectance is obtained during the holding period in the multiplex driving. Figure 4(b) shows that the transmittance value of AFLCs is changed by the holding pulse value, through the selection pulses are the same.

The delayed response behavior is presumed due to the propagation fingers in AFLC which appear during the phase transition from AF-state to F-state [8]. Delayed response time is defined as the time that micro domains propagate. CCD pictures of the domain growth during the phase transition from AF-state to F-state are shown in Figure 5. The rubbing direction of the AFLC cell is in the vertical direction and smectic layers are in the horizontal direction. Domain growth proceeds along the horizontal direction.

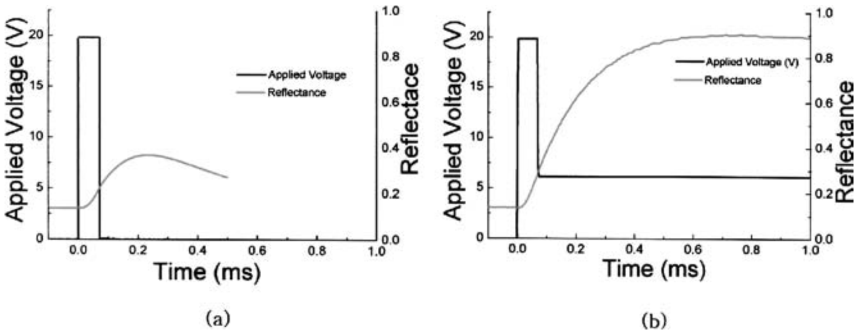

FIGURE 4 Reflectance based on (a) the square pulse (70 us), and (b) the square pulse (70 us) with holding pulse (16 ms).

We show the V-T curves in Figure 6 for the conventional triangular pulses (0.08 Hz) and square pulses studied by Hitoshi Hayashi *et al.* [5] and for both selection and holding voltages proposed by us. To compare

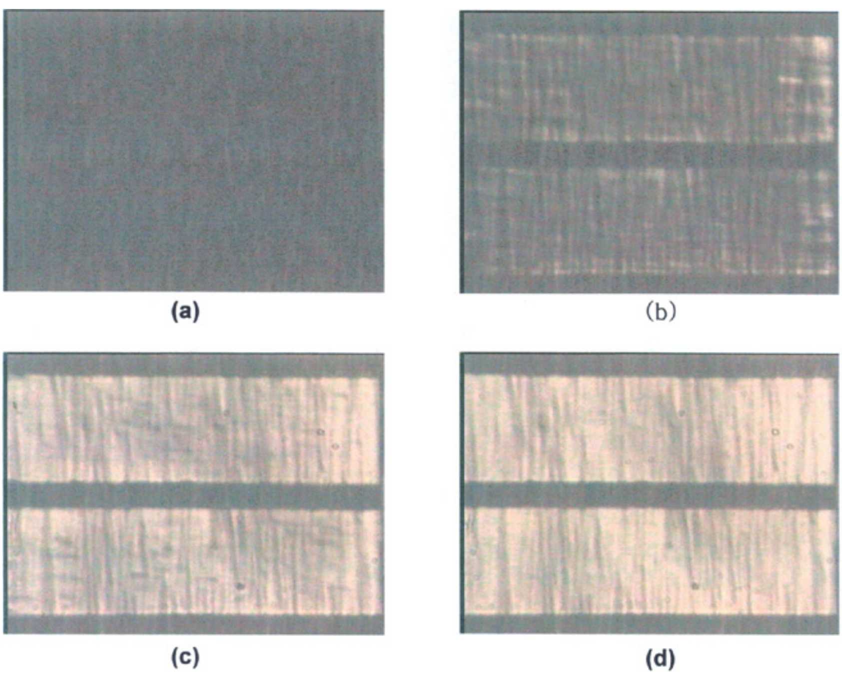

FIGURE 5 CCD pictures of the domain growth in the phase transition: (a) AF-state, (b) and (c) transition state, (d) F-state. (See COLOR PLATE XIX)

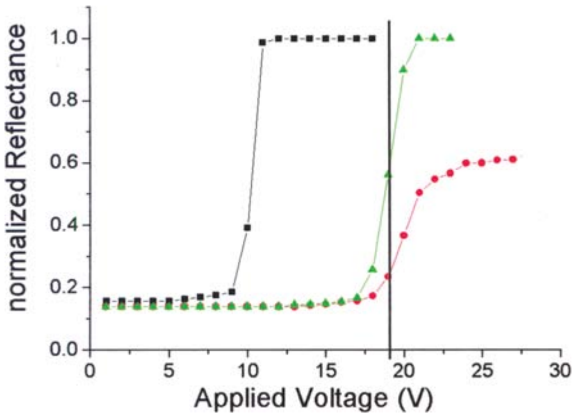

FIGURE 6 V-T characteristics based on the triangular pulses (■), square pulses for both selection and holding voltages (▲), square pulse for only selection voltage (●). (See COLOR PLATE XX)

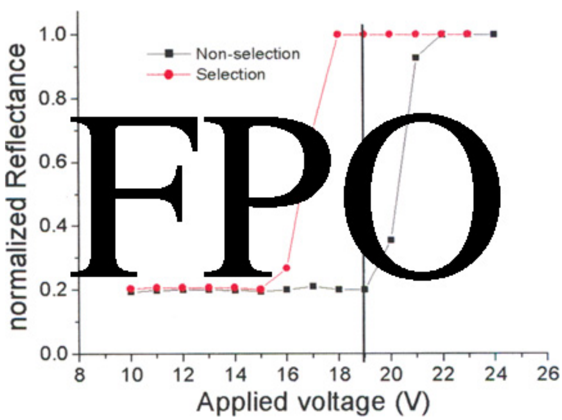

FIGURE 7 Gray scale evolution according to non-selection pulses and selection pulses whose width is 70 us (QVGA 320 × 240). (See COLOR PLATE XXI)

each V-T characteristics, the gray scale evolution according to non-select pulses and select pulses whose pulse width is 70 us (QVGA 320 × 240) is achieved with data pulse of 2 V in Figure 7 [9]. The V-T curve obtained by triangular pulses is similar in steepness to Figure 7. However threshold voltage is quite different. In the V-T curve obtained by square pulses, the steepness is quite different from Figure 7, though the threshold voltage is the same.

The V-T curve drawn by the square pulses for both selection and holding voltages is coincident not only with selection pulse region but also with threshold voltage, saturation voltage and the steepness of the selection/non selection curve. For multiplex driving this V-T curve we propose is very useful to determine the driving pulse values and we can easily confirm whether its driving pulse values are reasonable or not.

CONCLUSION

For multiplex driving, the new V-T curve we propose is very useful to determine the driving pulse values and with this curve, we can easily confirm whether its driving pulse values are reasonable or not in the passive matrix driving. In this curve, scan pulse value is unique and simply determined. The gray scale can be directly designed using this V-T curve.

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