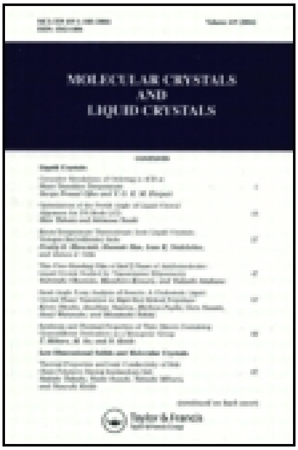

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Mesogenic Polymer-Stabilized FLCDs Exhibiting Asymmetric and Symmetric (V-Shape) Electrooptic Characteristics

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We have succeeded in fabricating a novel FLCD, which exhibits symmetric electrooptic (EO) characteristic called V-shape EO performance, by choosing an appropriate photocuring condition such as applied voltage waveforms and the concentration of photocurable mesogenic monomers. Our mesogenic polymer stabilized (MPS)-V-FLCD shows high contrast ratio owing to zig-zag defect free, continuous grayscale without accompanying switching domains, and good switchability with TFTs due to free from the value of the spontaneous polarization.

Keywords: FLCD; polymer stabilization; photocurable mesogenic monomer; V-shape EO characteristic

1. INTRODUCTION

There have been a number of reports of several ferroelectric liquid crystal display (FLCD) technological developments produced by different research groups over the past two decodes including surface stabilized (SS) bistable FLCD;[1] antiferroelectric (AF) LCD showing double hysteresis electrooptic (EO) characteristics;[2] an FLCD showing V-shape EO characteristics;[3,4,5] a mesogenic polymer stabilized (MPS) FLCD exhibiting asymmetric (diode) EO characteristics[6]; and an FLCD showing half V characteristics.[7] Some years ago, the authors' research group reported an electroclinic-like LCD by polymer stabilization.[8] In addition to these technological advances, we have succeeded in developing a new FLCD, which exhibits V-shape EO characteristics, by controlling the photocuring condition of the doped photocurable mesogenic monomers. We abbreviate this device as MPS-V-FLCD. The response times of this MPS-V-FLCD are τ_r=100 μs and τ_f=100 μs, and the device exhibits a high contrast ratio (100:1) owing to its zig-zag defect free nature and further the device is switchable with FETs owing to its freedom from the value of spontaneous polarization Ps; the actual value is 5-20nC/cm^2, whereas the traditional V-shape FLCDs are realized when Ps exceeds 100nC/cm^2.[3,4,5]

According to these analyses of historical developments of FLCDs, an FLCD that exhibits either half V-shape or V-shape characteristics is belonging to one of the following two classes: in the first group they are fabricated without polymer stabilization and the other includes those with polymer stabilization. We refer to the former as "intrinsic type" and the later as "extrinsic type".

In this paper, we report detailed characteristics of this new extrinsic V-FLCD (MPS-V-FLCD) in comparison with other existing FLCD technologies.

2. EXPERIMENTALS

The materials used in this research were as follows: the FLCs were FELIX-M4851/100 (Clariant) and CS-1014 (Chisso Petrochem.); the mixture of photocurable mesogenic monoacrylates were UCL-001 and UCL-003 (Dainippon Ink and Chemicals) that were doped with 1wt%

photoinitiator; and the LC alignment layers were polyimide RN-1199 (Nissan Chem. Ind.).

The relevant properties of FLC (FELIX-M4851/100) given by the data sheets are shown on Table I.

TABLE I Properties of FELIX M4851/100.

Properties	
Phase sequence	Cryst.(<-20)SmC*(67)SmA(71)N*(76)Iso. [℃]
Spontaneous polarization	-22.0 nC/cm^2(20℃)
Tilt angle	30.5° (20℃)
Switching time	38 μs (E=15V/μm, 20℃)

An FLC, which was doped with a mixture of photocurable monomers (6wt%), was injected into a cell with a gap of 1.6 μm, whose inner substrates were coated with rubbed polyimide films. And then the FLC medium was photocured with UV light source at 365nm for 4 min. under the simultaneous application of a triangular voltage wave, whose amplitude was ± 10 volts and the frequency at 2kHz, at the UV light intensity level of 2mW/cm^2, particularly at a temperature where the LC medium is in the SmC* phase.

The microscopic textures of the FLC cell fabricated by this method were observed with a polarizing microscope and its electro-optical characteristics were measured with several measuring systems.

3. RESULTS AND DISCUSSION

Figure 1 demonstrates an example of EO characteristics of newly developed FLCD, as transmittance vs. applied voltage at different temperatures.

The FLC cell exhibits the symmetrical EO characteristic for bipolar applied voltages without threshold. This characteristic is referred to as V-shaped EO characteristic. We call this new mode "mesogenic polymer stabilized V-shaped FLCD (MPS-V-FLCD)". The contrast ratio is equal to or more than 100:1 at an amplitude voltage of above 10 volts of the static drive. As shown in Fig.1, this device maintains to show V-shaped EO characteristics even at the elevated temperature to just below SmC*-SmA* transition temperature of this FLC material without doping monomers. The decline of the transmittance of the light state as rising the measurement temperature may be explained by the decrease of the cone angle of the FLC material with the rise of temperature. Therefore, it is necessary to explore new FLC materials that show wide temperature range.

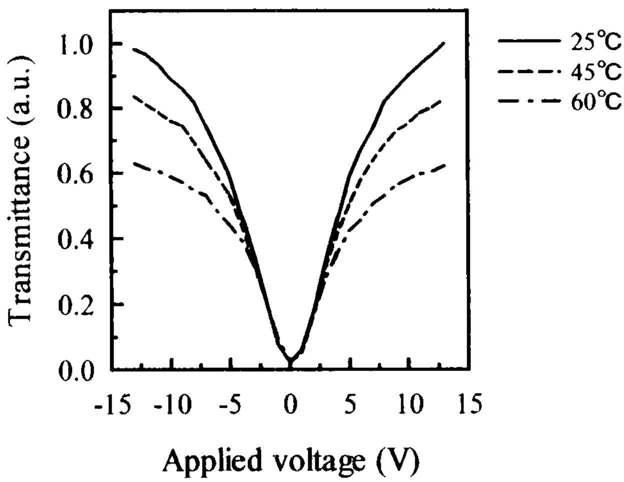

FIGURE 1 Transmittance vs. applied voltage for MPS-V-FLCD at several measurement temperatures.

Figure 2 shows the measured values of apparent tilt angle of this FLC medium, which is shown by full dots, as a function of applied voltage at 25°C. These values were obtained by finding the extinction condition under the cross-nicol condition with a polarizing microscope.

In addition to this, we obtained the calculated values of tilt angle or deflection angle, Φ, which is represented by a solid line by using the formula:

$$I = I_0 \sin^2(2\Phi)\sin^2(\pi\ \Delta nd/\lambda),$$

where we used the experimental data of transmittance given in Fig.1; in this calculation, we fixed the values of I_0 and $\pi\ \Delta nd/\lambda$.

The value of Φ is an angle between the projected director of FLC molecules on the substrate and the central line that is parallel to the rubbing direction. As shown in Fig.2, the agreement between the measurement and the calculated values are fairly good. Therefore, the apparent behavior of the FLC molecules is supposed as follows: when the applied voltage is zero, the FLC molecules align in the direction of the central line of the cone that coincides with the rubbing direction; and as the applied voltage increases,

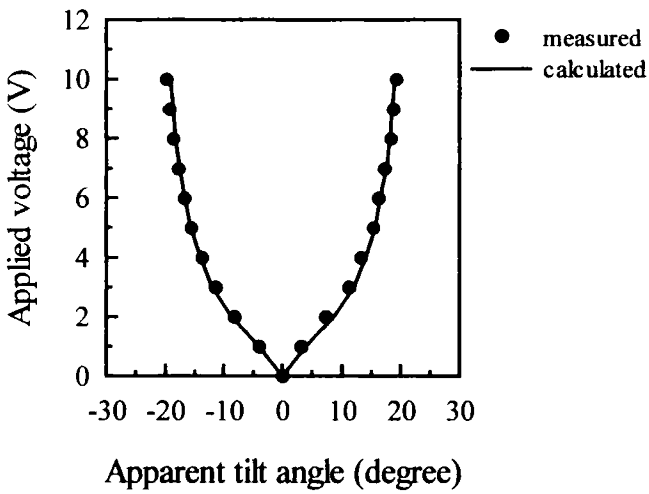

FIGURE 2 Applied voltage vs. apparent tilt angle of MPS-V-FLCD.

the FLC molecules rotate departing from the central line to the off directions depending on the applied voltage, where the sign of rotation direction is determined by the relationship between the polarity of the electric field and the sign of spontaneous polarization of the FLC molecule. Thus the medium produces a symmetric EO performance if the cell is properly fabricated. The curve shown on Fig.2 is supposed to be a potential curve having a single minimum owing to the side chain polymer stabilization, whereas an ordinary FLC、 which is not be subjected to the polymer stabilization, has a set of two minimum (double minima) before the polymer stabilization as discussed by Furue et al in the extrinsic type half V-FLCD.[9]

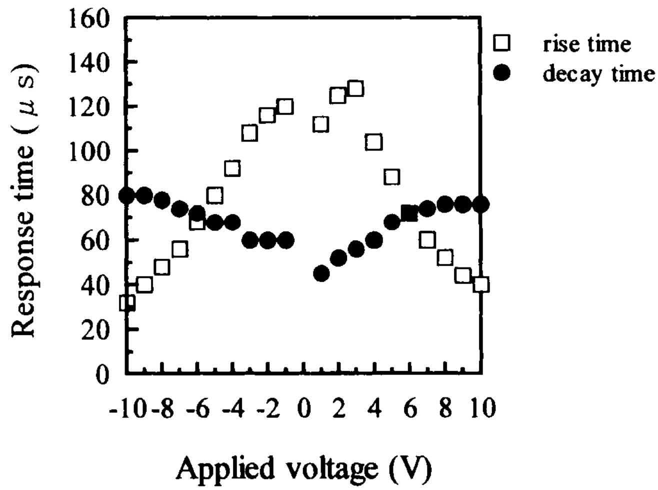

FIGURE 3 Response times of MPS-FLCD under various voltages.

We also measured the switching speed under various applied voltages. Rectangular waveform voltages were applied to the cell in this measurement. The results of rise times and decay times at 25℃ are shown in Figure 3. We confirmed that our MPS-V-FLC mode has very short response times of the order of 100 μ s. The rise time decreases with the increase of the applied voltage. This behavior may be in accordance with a theory that predicts that the rise time constant is inversely proportional to the applied field intensity. On the other hand, the decay times are always below 100 μ s and increases with the decrease of the applied voltage. Regarding the dynamic behavior of our MPS-V-FLCD, we suggest that the fairly strong interaction between the FLC molecules and side chain mesogenic moieties in polymer network may govern the dynamics of the molecules and hence the speed of the molecular switching in our MPS-V-FLCD.

Figure 4 shows the microscopic textures of MPS-V-FLC for different applied voltages. In these textures, continuous switching without accompanying switching domains is confirmed. This behavior indicates that switching is being done with grayscale capability. Not only in the quiescent condition but also in the energized condition, the MPS-V-FLCD fabricated in our method does not contain any zig-zag defect; this is owing to the favorable nature of polyimide RN-1199 (Nissan Chem. Ind.) used in this research; this results is in agreement with our previous research.[10] This defect-free situation results in very good dark state at the quiescent condition, thus in turn, produces very high contrast ratio.

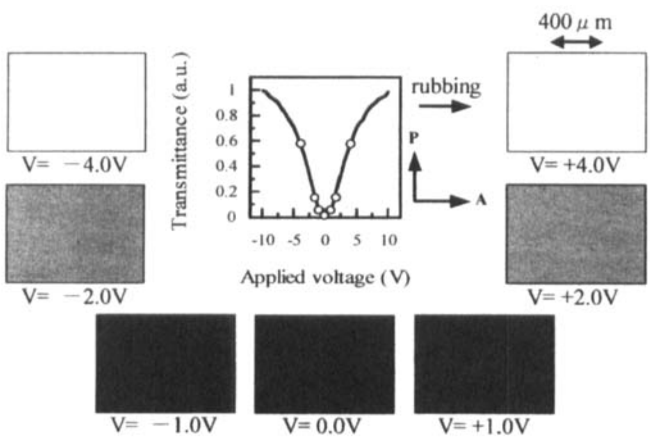

FIGURE 4 Textures of grayscales in MPS-V-FLCD

We confirm that MPS-V-FLC mode LCD can be also fabricated by using any other commercially available FLC materials such as TA-C100, CS-1014 (Chisso Petrochem.), and FELIX-4654/100 (Clariant) as well as FELIX-M4851/100 (Clariant) by doping photocurable monomers and by choosing appropriate curing condition. As far as we know, the existing intrinsic type V-FLC that reveals V-shape response only when the value of spontaneous polarization Ps exceeds 100 nC/cm^2 and the thickness of alignment layers have appropriate thickness. [3,4,5] Contrary to this our MPS-V-FLCD is free from the restriction of the value of Ps. This kind of flexibility is also one of the advantages of our MPS-V-FLCD.

Our MPS-V-FLCD will be utilized for displaying moving video full-color images using either color filters or adopting field sequential technique by taking advantage of fast response speed.[11]

More detailed description of fabrication process will be published elsewhere.[12]

4. SUMMARY

We have succeeded in fabricating a novel FLCD that exhibits V-shaped EO characteristic with grayscale capability without threshold and without having zig-zag defects and very short response times around 100 μ s. We call this LCD mode "mesogenic polymer stabilized V-shaped switching FLC (MPS-V-FLC) mode". As an example, we used an FLC material (FELIX M4851/100, Clariant) that has been stabilized by UV photocure of doped photocurable mesogenic monomers at the SmC* phase temperature by choosing appropriate concentration of monomers (actually it is 6wt%) and by applying particularly triangular AC electric field. Further, we confirm that V-shaped EO response is also revealed by using other commercially available FLC materials.

Another advantage of this device is that our MPS-V-FLCD will be driven with active matrix without modifying active matrix driver for ordinary TN-LCD.

This novel FLCD will be effectively utilized for displaying moving color video images either using color filters or by adopting field sequential technique by taking advantage of its fast response.

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