

A Dual In-Plane Electrode Structure for Better Brightness in a Helix-Deformed FLCD

Doo Hwan You, *Student Member*, Sin Doo Lee, *Member*, Ju Hyun Lee, *Member* and Do Jun Na

Abstract

We propose a dual in-plane parallel electrode structure of a vertical configuration of a helix-deformed ferroelectric liquid crystal (HDFLC) mode for better brightness than a single in-plain electrode case. This structure provides high brightness in addition to the analog gray scale capability, fast response, and wide-viewing characteristics. In contrast to a conventional HDFLC in a planar geometry, smectic layers arrange themselves parallel to the substrates and thus extremely uniform alignment of molecules in a large area is naturally achieved in our new configuration.

Keywords : Dual in-pane electrode, vertical alignment, wide-viewing, fast response

1. Introduction

Currently, the market of liquid crystal displays (LCDs) is rapidly expanding. Especially, the fast response and the wide viewing characteristics are key aspects of high-performance LCDs. Recently, we developed a vertical configuration (VC) of a helix deformed ferroelectric liquid crystal (HDFLC) mode as one of the wide-viewing technologies [1]. The VC-HDFLC mode exhibits fast response, analog gray scale capability, high contrast, and wide viewing characteristics. However, this mode exhibits relatively low brightness compared to the conventional TN mode. This results from the curvature of an applied electric field present along the surface normal of the VC-HDFLC cell.

In order to reduce such field curvature, we introduce a dual in-plane parallel electrode structure into the VC-HDFLC mode for better brightness. It is found that our new electrode structure indeed gives high transmittance through VC-HDFLC cell.

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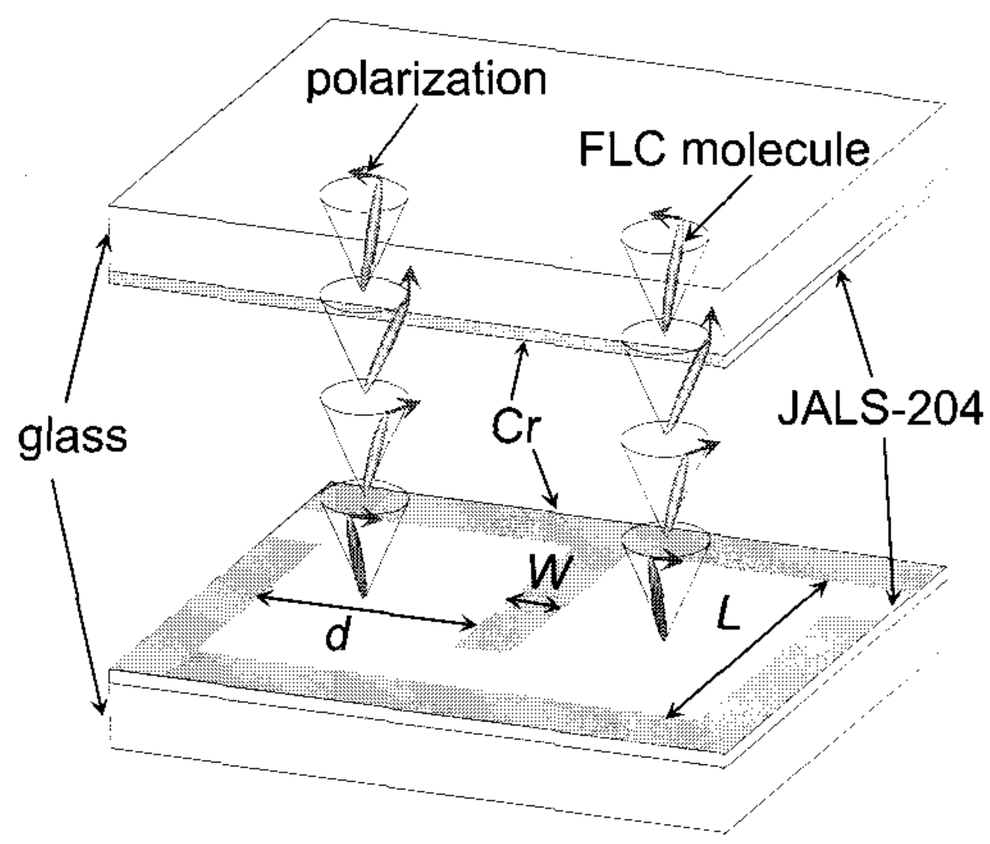
2. Theory

Fig. 1 shows schematic figure of the on and off states of the single and dual in-plane electrode structure of VC-HDFLC cell. The off states of single and dual case are the same but the on states have different electric field distributions.

Fig. 2 shows simulation results for the electric field strength in three different electrode structures, i.e., a single in-plane, a dual in-plane, and an ideal parallel electrode structures. We assumed that the distance between electrodes is 7 μm, cell thickness is 5 μm and applied voltage is 40 V.

The electric field strengths in the three cases are very different; in a single in-plane electrode case, the field is not uniform, and in a dual case, it is quite uniform and close to the ideal case. Moreover, the dual in-plane electrode case has a higher electric field strength than the single case over the whole cell. The electric field distribution is similar to any cell thickness. We are interested in the electric field distribution according to the electrode structure and not in cell thickness.



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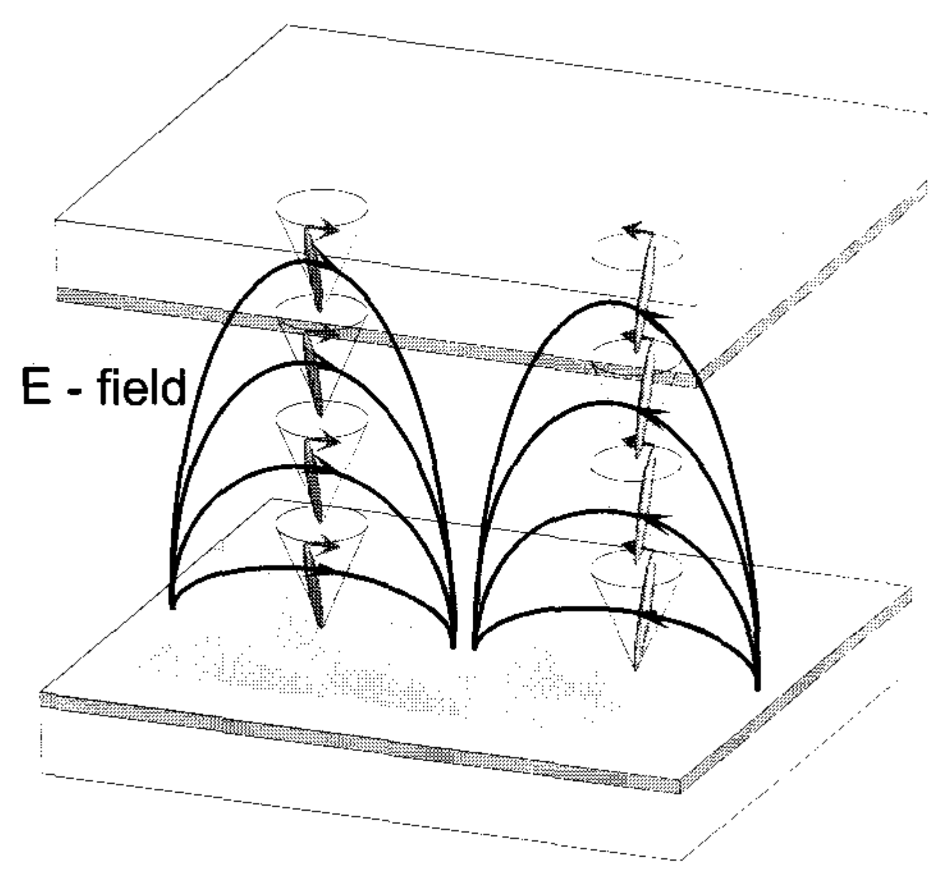

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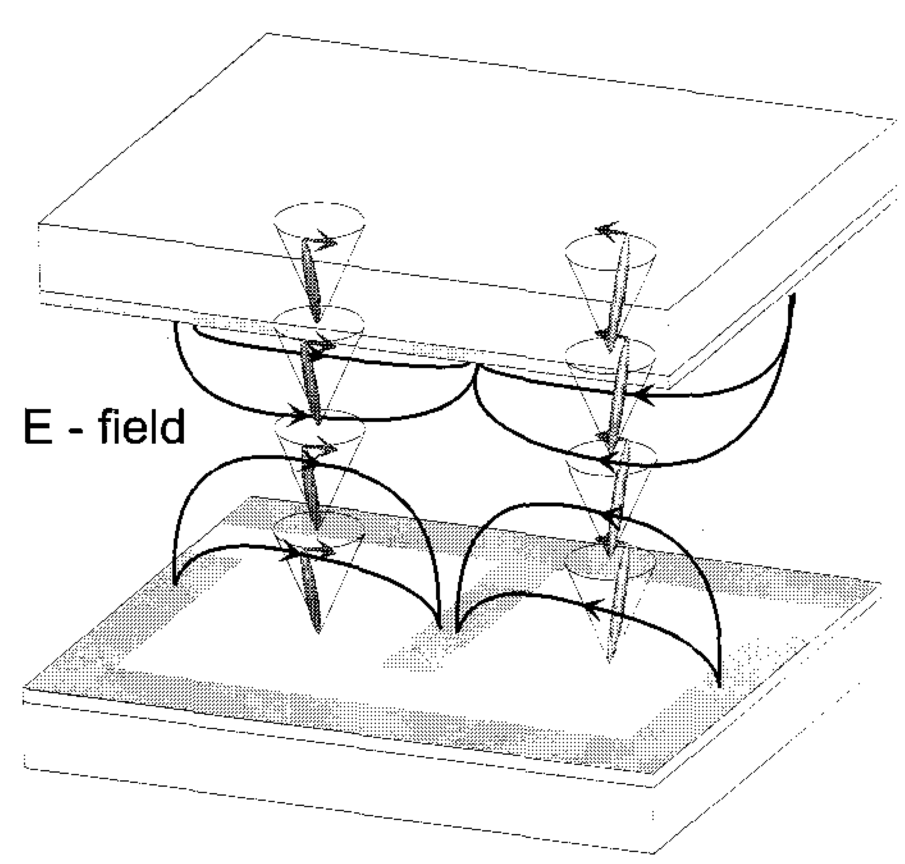


(c)

Fig. 1. The on and off states of the single and dual in-plane electrode structure of VC-HDFLC cell; (a) off state, (b) on state of single electrode, and (c) on state of dual in-plane electrode structure.

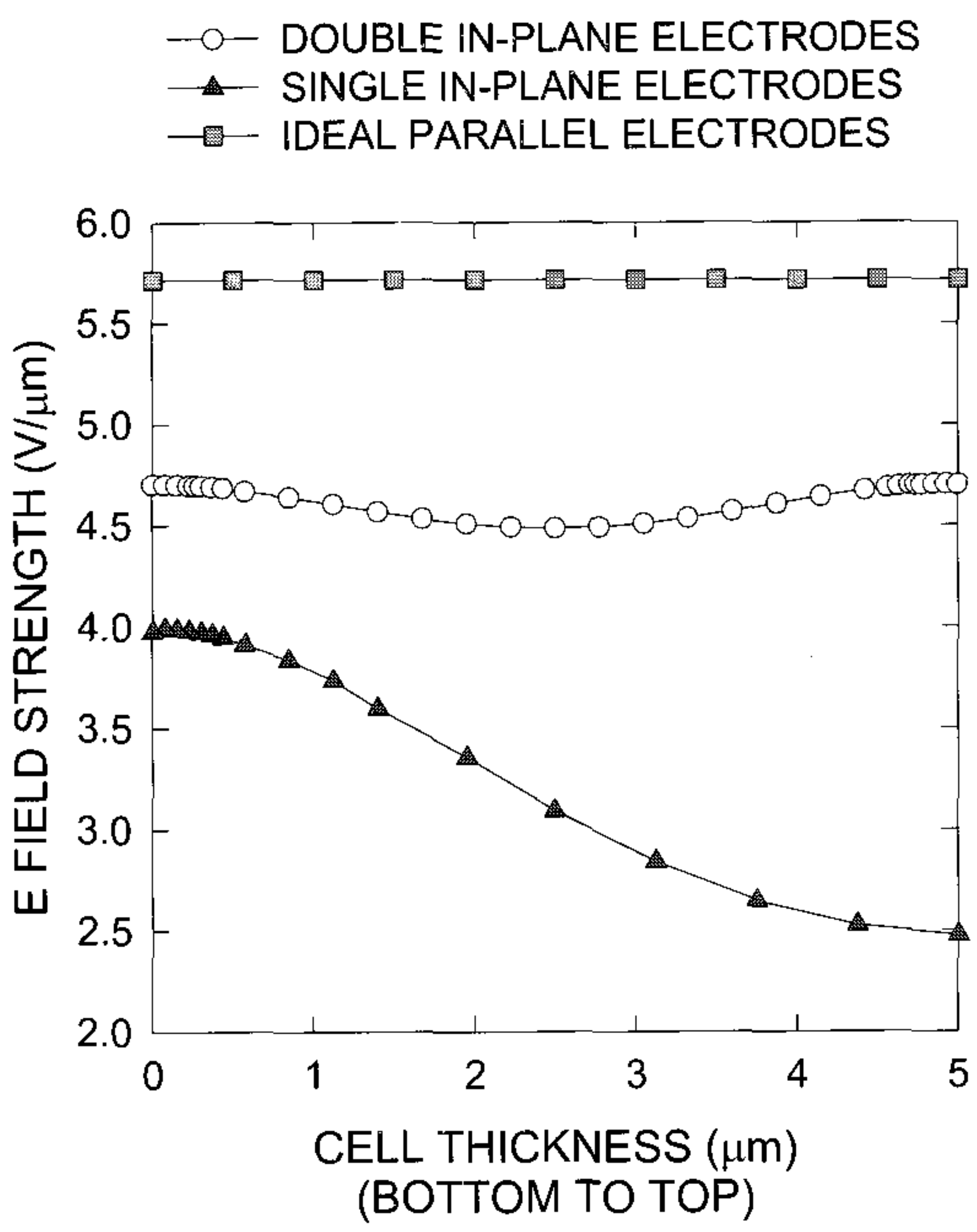


Fig. 2. The simulation results for the electric field strength in three different electrode structures, i. e., a single in-plane, a dual in-plane, and an ideal parallel electrode structures.

3. Experiment

The VC-HDFLC cell was made using two glass substrates, both of which were coated with a metal (Cr). Parallel electrodes, separated by 10 μm, were patterned on the Cr coated substrate. The polyimide (PI) layer of JALS-204 (Japan Synthetic Rubber Co.) was prepared on the two substrates to promote vertical alignment. It should be noted that no rubbing process was carried out. The cell thickness was maintained using glass spacers of about 7.8 μm. The FLC material used in this work was DC-F101 of Chisso Petrochemical Corp. The phase transition sequence was as follows: isotropic → (71 °C) → cholesteric → (69 °C) → smectic A → (58 °C) → smectic C* → (-34 °C) → crystal. The physical parameters of DC-F101 are shown in Table 1 [2].

Using our VC-HDFLC cell, we measured the electro-optic (EO) transmittance as a function of the applied electric field using a bipolar square waveform at 60 Hz. For the dynamic response, a unipolar square waveform was used. For the measurements of the EO properties, a He-Ne laser of 543 nm and a digitizing oscilloscope (TDS420, Tektronix) were used. For obtaining the iso-contrast maps, the LCD characterizing system (Autronics) was used. All the measurements were carried out at room temperature.

TABLE 1. The physical parameters of DC-F101.

DC-F101 Physical Parameters	Value [unit]
Spontaneous polarization [*Ps*]	-28.6 [nC/cm^2]
Tilt angle [θ_t]	22.6 [deg]
Helical pitch [p_0]	≤ 0.2 μm

4. Results and Discussion

The EO properties of the two VC-DHFLC cells with a single and a dual in-plane electrode structures were measured under crossed polarizers. In the absence of an electric field, no light can be transmitted through the cell and thus excellent contrast can be achieved. The active area becomes bright with continuously increasing electric field.

Fig. 3 shows the EO characteristics of the single and the dual in-plane electrode cases. The threshold voltage of both cases are nearly the same but the EO transmittance of the dual in-plane electrode case is about twice higher than the single electrode case in the field range we studied.

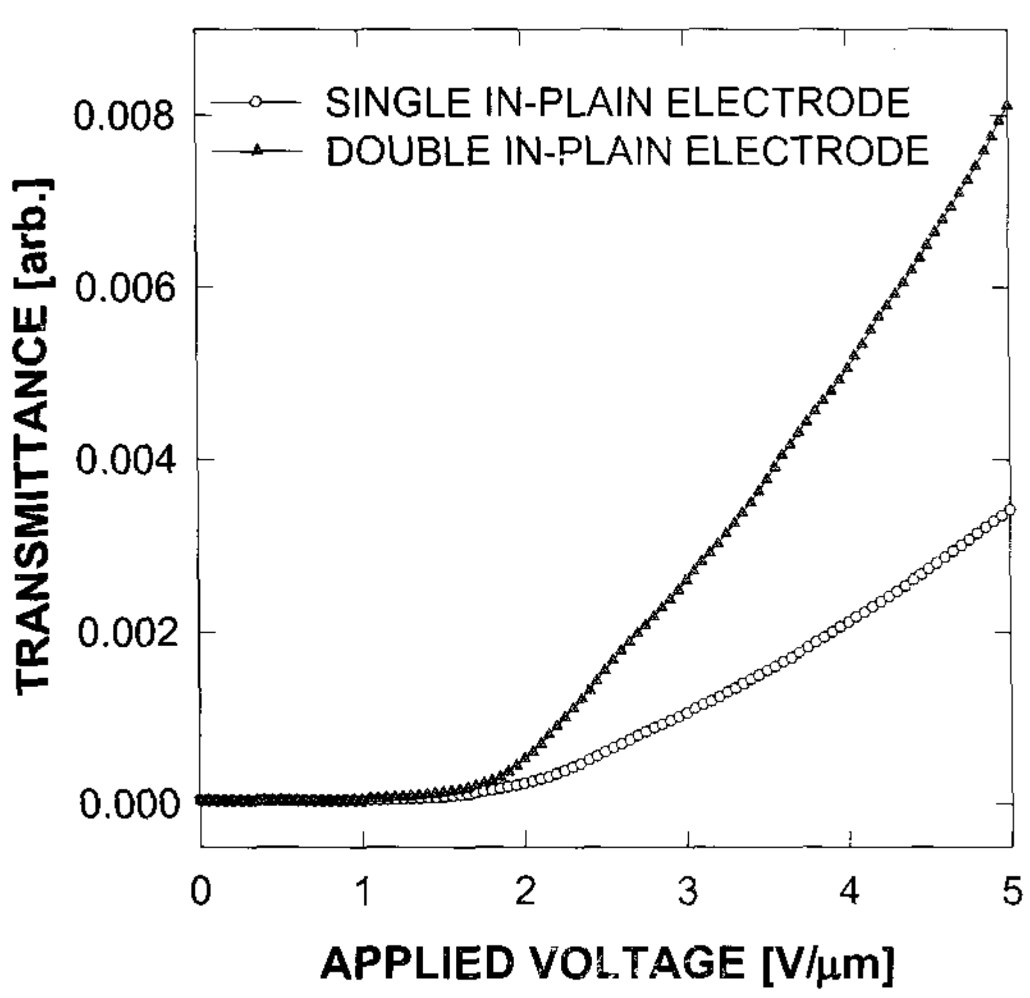
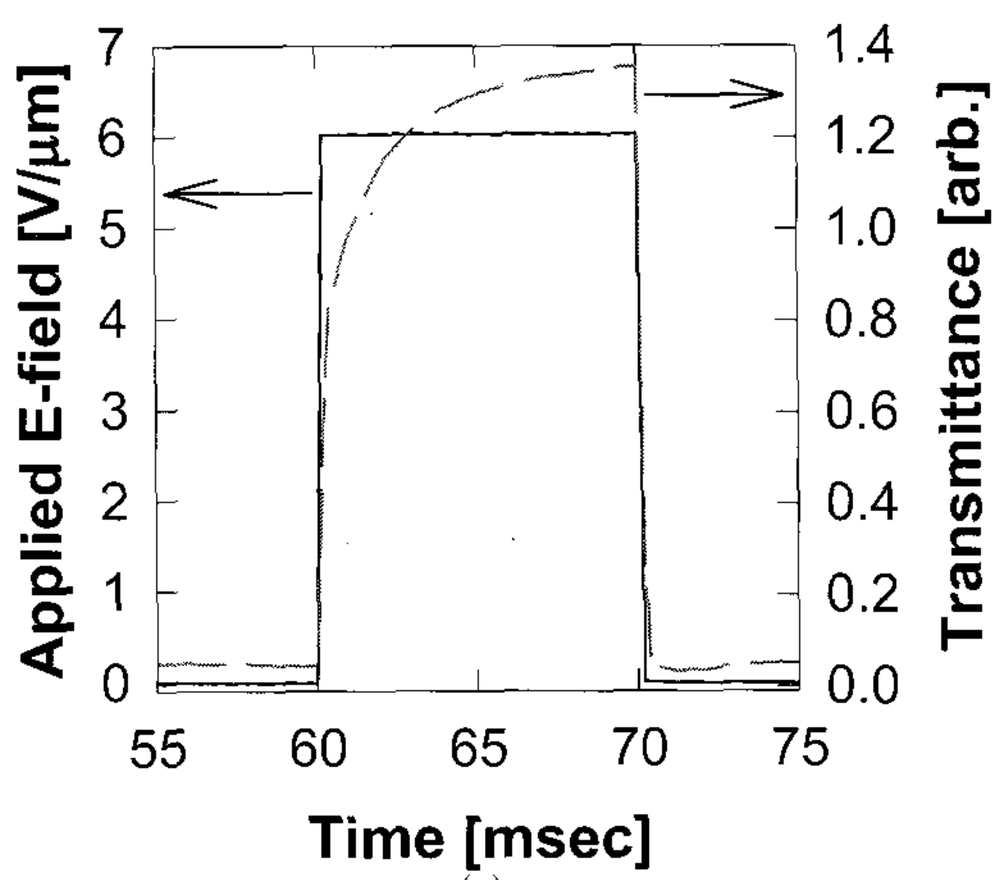


Fig. 3. The EO transmittances of the single and the dual in-plane electrode cases.

The analog gray scale capability of each cell is shown as a function of the applied electric field **E** in Fig. 3. The EO transmittance increases with increasing electric field above 1.8 V/μm, giving the analog gray scale capability. Starting at about **E** = 2.3 V/μm, a nearly linear relationship between the EO transmittance and **E** is obtained for which cases.



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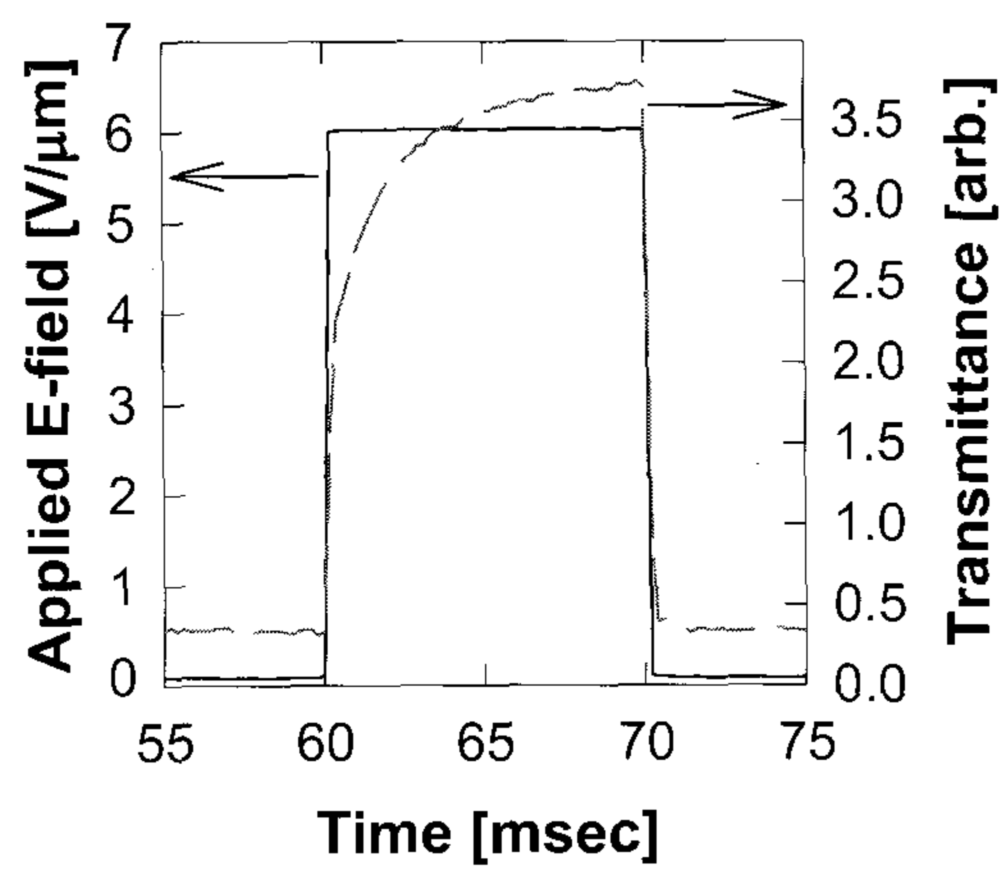
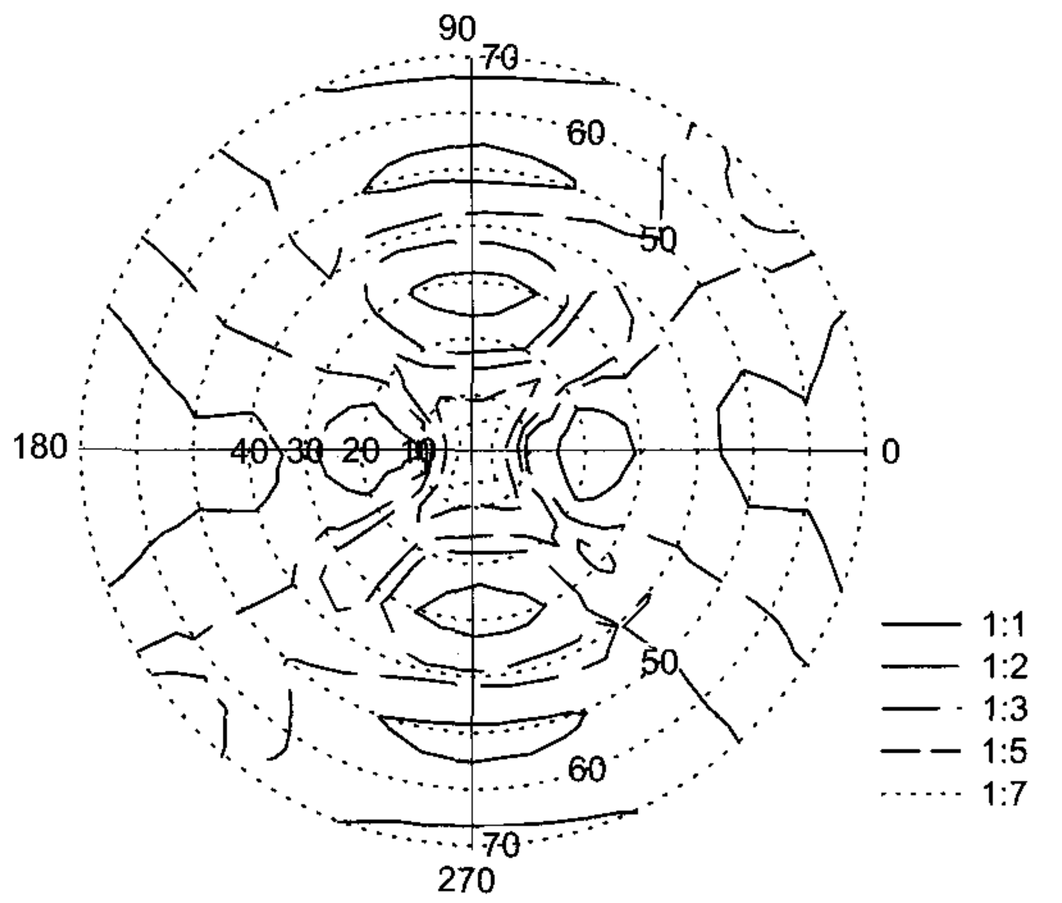


(b)

Fig. 4. The dynamic EO response of the VC-DHFLC cells to the electric field of a unipolar square waveform; (a) the single and (b) the dual in-plane electrode cases.

Fig. 4 shows the dynamic EO response of the VC-HDFLC cell to the applied electric field. Both the two cases show similar behavior under the unipolar square waveform. The rising and falling times are about 3.2 msec and 280 μsec for the single electrode case, respectively. The rising and falling times are about 2.9 msec and 280 μsec for the dual electrode case, respectively. The dual electrode case has faster response than the single case. This may be attributed to the higher electric field strength for the dual in-plane electrode structure. The switching time on the order of msec is fast enough to achieve good dynamic image quality.

The measured viewing properties of the VC-HDFLC cell, shown in Fig. 5, give the iso-contrast maps for (a) the single and (b) the dual in-plane electrode structures without a compensation film.



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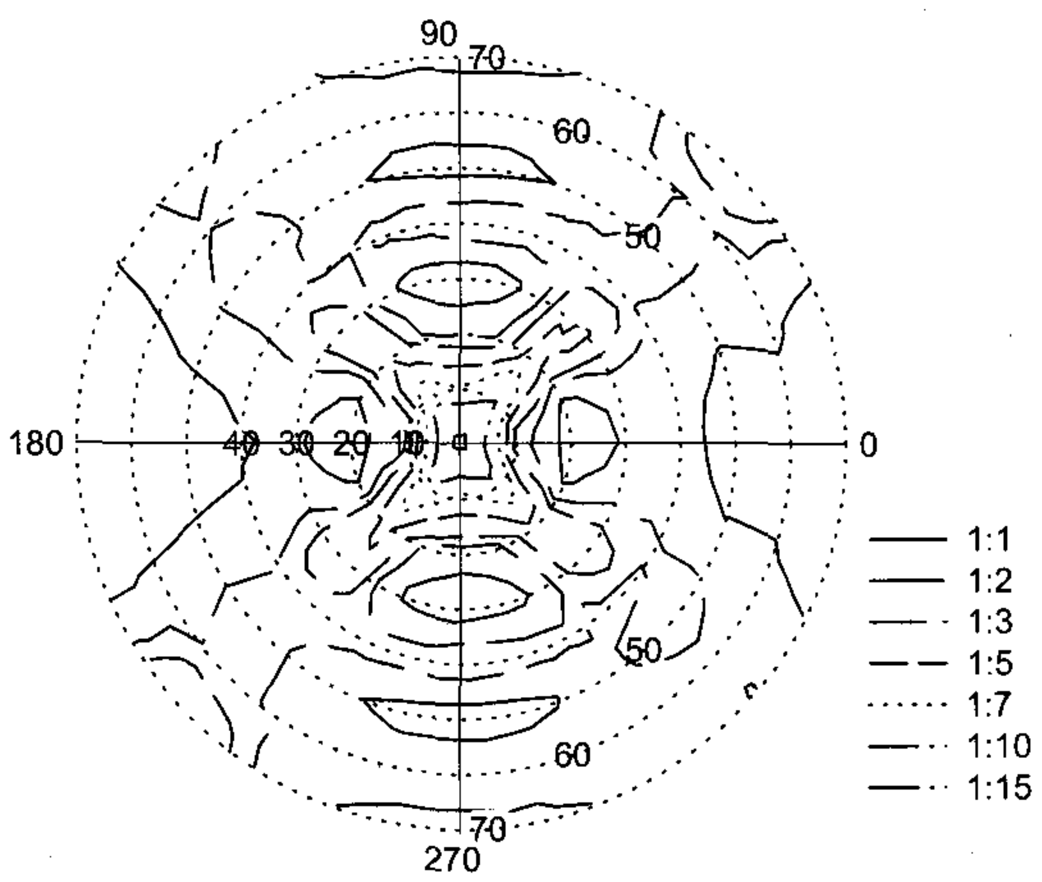

(b)

Fig. 5. The iso-contrast maps of our VC-HDFLC cells for (a) the single and (b) the dual in-plane electrode structures without a compensation film.

In Fig. 5, the x-axis is parallel to the in-plane electrodes, and thus the electric field direction is parallel to the y-axis. The dual electrode case shows higher contrast ratio than the single electrode case at the center region. This is because of the dual electrode case, where the more uniform and higher electric field is obtained in space through the VC-HDFLC cell.

As expected from the fact that our configuration has normally two domains in each pixel, the iso-constrast contours exhibit two-fold symmetry. In order to optimize the viewing properties, a proper design of electrode patterns such as four domains and the precise control of the birefringence compensation are needed.

5. Conclusion

In summary, our new electrode structure improved the brightness of the VC-DHFLC considerably Moreover, it was found that the electric field distribution in the dual in-plane electrode case was more uniform than that in the single in-plane electrode case. With a proper design of electrode patterns on the substrate, the polar nature of FLCs naturally allows for a multi-domain structure without any additional process.

References

[1] J.- H. Lee, C.-J. Yu, D.-H. You, and S.-D. Lee, "Wide-Viewing Display Configuration of Helix-Deformed Ferroelectric Liquid Crystals," Proc. of IDW'99, pp. 129-132, 1999.

[2] Data sheet from Chisso Petrochemical Corp.