Liquid Crystal Switching Using Comb-on-Plane Electrodes

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Abstract

A new comb-on-plane switching (COPS) electrode design is presently proposed that not only allows for lower switching voltage, but also offers advantages including naturally scalable storage capacitance, low color dispersion and wide viewing angle with TN-like high transmittance.

Introduction

Twisted-nematic (TN) liquid crystals (LCs) are commonly employed in active matrix (AM) liquid crystal displays (LCDs) because they offer low drive voltage, true white and dark states, excellent contrast, low color dispersion, as well as ease of implementing gray scale and color displays. The principal drawback of the common TN LCDs is their narrow viewing angle. A number of techniques, such as the use of retardation films, have been proposed to increase the viewing angles of the common TN LCDs. However, such displays are difficult to optimize and the material cost as well as the added steps in manufacturing are undesirable.

Recognizing that the narrow viewing angles are associated with the homeotropic state in the common TN LCDs, Oh-e *et al.* [1] and Ohta *et al.* [2] eliminated such a state by using in-plane switching (IPS) of the LC molecules to produce wide viewing angles without the use of compensation films. However, while IPS has been rather effective in increasing the viewing angle, there may be difficulty in adopting the conventional IPS to higher definition displays since it requires high switching voltage, suffers from low transmittance [3] and offers limited storage capacitance.

Several improvements have been suggested to overcome the drawbacks of the original IPS scheme. Lee *et al.* [4] proposed the use of top and bottom grid electrodes to introduce a “4-domain” switching structure.

Shin *et al.* [5] proposed the use of common electrodes on the opposite sides of an LC cell to enhance the transmission. Kim *et al.* [6] proposed the use of non-straight electrodes so that there was a “2-domain”-like structure upon switching.

COPS Switching Electrodes

A new comb-on-plane switching (COPS) electrode design (Fig. 1), consisting of a comb electrode on top of an insulated plane electrode, is presently proposed. Indium tin oxide and low temperature oxide were used to form the electrodes and the inter-electrode insulation, respectively.

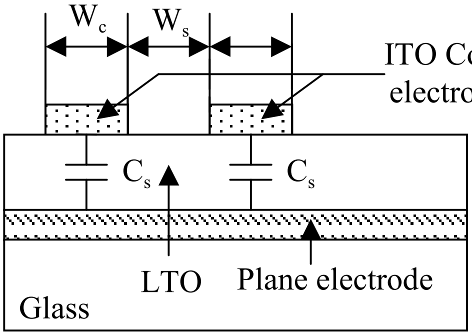

Figure 1: Schematic cross-section of the COPS electrode design. W_c and W_s denote the width of and the separation between the comb electrodes. C_s is the storage capacitance.

While some of the LC molecules are switched in the plane of the display (Fig. 2), the electrode arrangements and the principle of its operation are different from those of the conventional IPS.

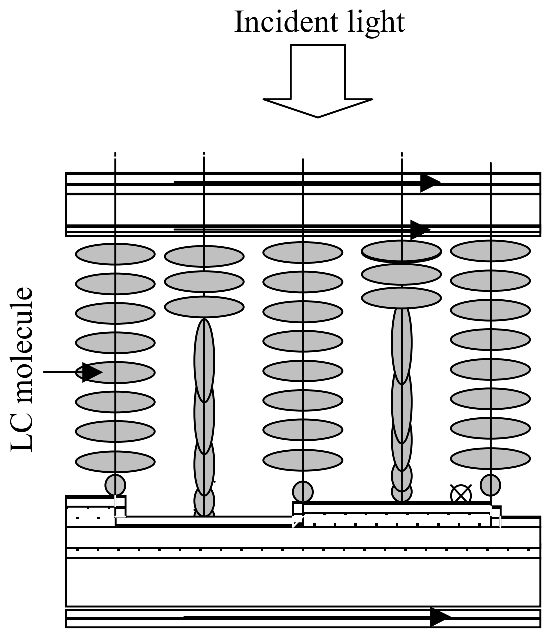

Figure 2: Schematic diagram of the COPS cell in the selected ($V_c \neq 0$) state.

For large y away from the COPS electrodes, the following approximations for the horizontal (E_x) and the vertical (E_y) components of the electric field ($\vec{E}$) apply:

$$E_x \approx -2\frac{V_c}{W}\left(\sin\frac{x}{W}\pi\right)e^{-\frac{y}{W}\pi},$$

$$E_y \approx -2\frac{V_c}{W}\left(\cos\frac{x}{W}\pi\right)e^{-\frac{y}{W}\pi},$$

where V_c is the voltage applied to the comb electrodes and $W \equiv W_s + W_c$. Clearly, $\vec{E}$ decays exponentially with y (Fig. 3) and the characteristic decay length can be controlled by selecting a suitable W. For an LC cell gap larger than a few multiples of W, only the alignment of the LC molecules close to, but not those far away from, the COPS electrodes are directly affected by $\vec{E}$. The creation of this fast decaying "surface" electric field, the magnitude of which scales inversely with W, is a unique and important feature of the COPS design.

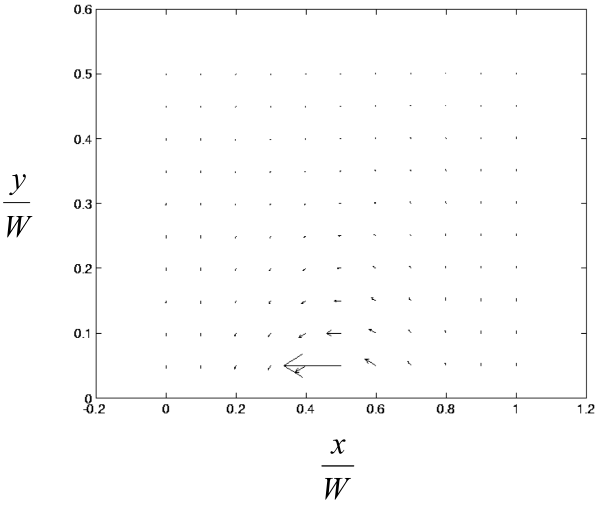

Figure 3: Approximate electric field ($\vec{E}$) distribution above the comb electrode.

Consequently, COPS allows for faster switching (Fig. 4) at a lower switching voltage and offers advantages including naturally scalable storage capacitance (C_s), much easier electrode fabrication and amenability to large scale production, as well as wide viewing angle (Fig. 5) with TN-like high transmittance (Fig. 6) and low color dispersion (Fig. 7).

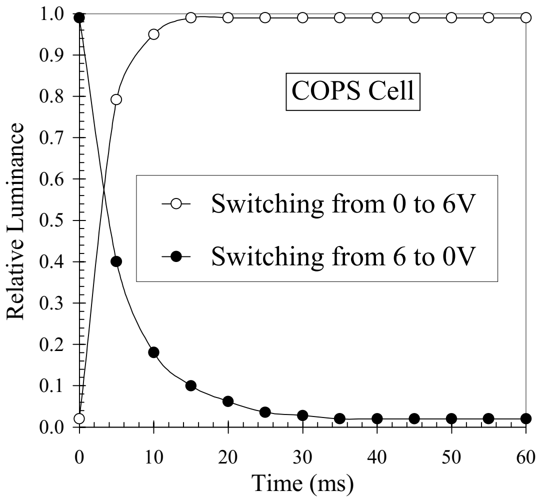

Figure 4: Switching characteristics of the COPS cell.

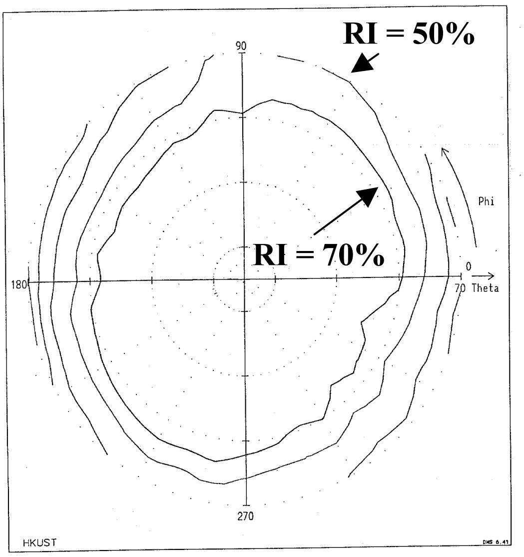

Figure 5: Angular distribution of the relative light intensity (RI) of the COPS cell in the bright state.

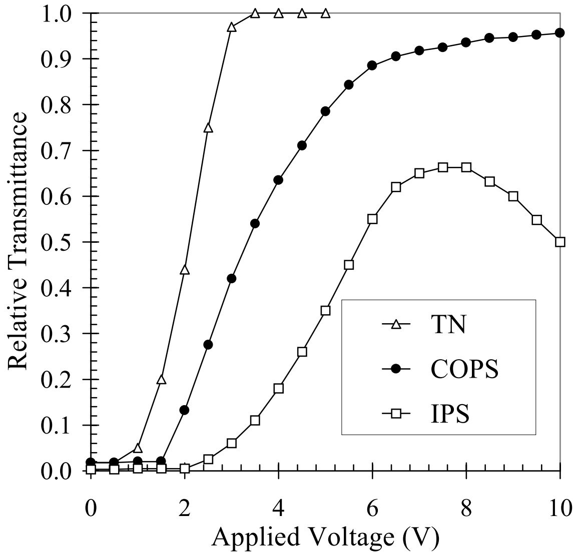

Figure 6: Comparison of the transmittance-voltage curves (TVC) of the COPS, the common TN and the conventional IPS LC cells.

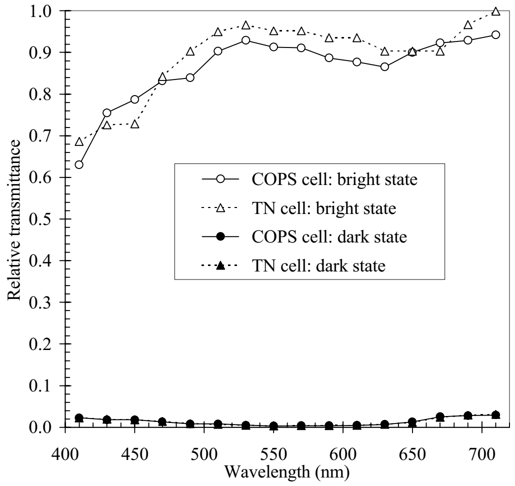

Figure 7: Measured relative dispersion spectra of the common TN and the COPS LC cells.

References

1. M. Oh-e *et al*, Proceedings of the 15th International Display Research Conference (Asia Display'95), pp. 577-580, 1995.
2. M. Ohta *et al*, Proceedings of the 15th International Display Research Conference (Asia Display'95), pp. 707-710, 1995.
3. S. H. Lee *et al*, Proceedings of the 18th International Display Research Conference (Asia Display'98), pp. 371, 1998.
4. S. H. Lee *et al*, SID Symposium Digest, pp. 702-705, 1998.
5. H. H. Shin *et al*, SID Symposium Digest, pp. 718-721, 1998.
6. K. H. Kim *et al*, SID Symposium Digest, pp. 1085-1088, 1998.