

P-108: A Flexible Display Using Dye-Doped PSCT

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Abstract: We investigated the effect of adding a dichroic dye to the polymer stabilized cholesteric texture (PSCT) normal mode light shutter display. We observed an improvement in the contrast ratio for a given applied voltage, which can be used to reduce the power consumption. We demonstrated displays fabricated on flexible plastic substrates.

Keywords: normal mode, polymer stabilized cholesteric texture (PSCT), liquid crystal display, flexible plastic substrate, rubbing-free, polarizer-free, low power, dichroic dye

Objective and Background

Recent efforts in liquid crystal display (LCD) research have been focused on reducing power consumption, making light-weight flexible displays, and reducing manufacturing complexity [1-8]. The normal mode polymer stabilized cholesteric texture (PSCT) display can be applied to meet these needs since it does not require polarizers or alignment layers [9-12]. This not only simplifies display fabrication, but it also allows the use of flexible plastic substrates. This study investigates the effect of adding a dichroic dye to the PSCT mixture to improve the contrast ratio, which will reduce the driving voltage and power consumption [13-14].

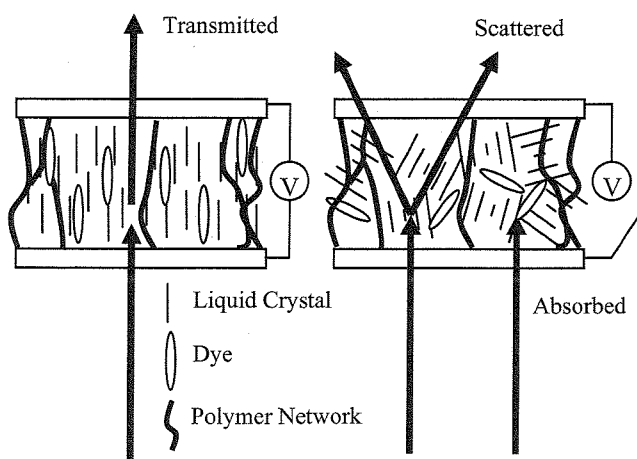


Figure 1. Cell geometry.

The PSCT normal mode light shutter consists of a few percent (<10%) of polymer network dispersed in a long pitch (>1 μm) cholesteric liquid crystal. The polymer network stabilizes a focal conic domain structure at zero applied field which scatters light. When a sufficiently

high field is applied to reorient the liquid crystal, the display becomes transparent with a large viewing angle.

In this paper, we investigated the performance of the PSCT normal mode light shutter with the addition of a dichroic dye. We experimentally fabricated mixtures with different concentrations of chiral dopant and dichroic dye and measured the electro-optic response. After analyzing the results, we made displays from flexible plastic ITO-coated substrates.

Formulation and Experiment

The PSCT mixture consisted of E44 liquid crystal (Merck), R811 chiral dopant, RM257 monomer (Merck) (Fig. 2(a)), and BME photoinitiator (Fig. 2(b)). Dye-doped mixtures also contained a yellow dye 1,5-bis-phenylsulfanyl-anthraquinone (laboratory synthesized) (Fig. 2(c)). The photoinitiator concentration was fixed at 10% of the monomer concentration. The mixture was vacuum filled into cells made from ITO coated substrates (glass or plastic) of thickness 10 μm with no alignment layer. The cells were cured in UV light of high intensity (14 mW/cm^2) for 20 minutes while a high voltage (70V_{AC} glass and 20V_{AC} plastic) was applied. The aligning effect of the liquid crystal on the monomer caused the polymer network to form perpendicular to the cell substrates.

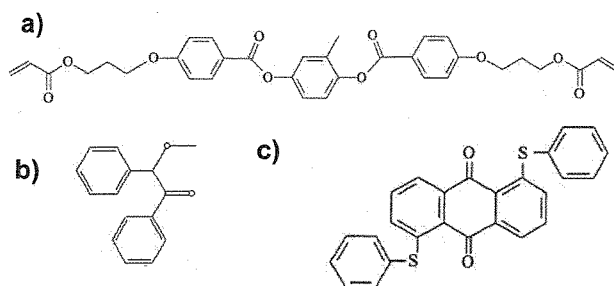


Figure 2. Materials used in the experiments. a) monomer RM257 b) photoinitiator BME c) dichroic dye 1,5-bis-phenylsulfanyl-anthraquinone

A few different mixtures with and without dye were characterized for contrast ratio and saturation voltage. Our experimental setup used a collimated white light source. The transmitted light was detected using a photodiode with a photopic filter and a collection angle of 2°. Contrast ratio is defined as the maximum transmission divided by the minimum transmission. Saturation voltage is defined as the voltage needed to reach 90% of maximum transmission. Our experiments measured the

transmission through the cell referenced to the transmission with no sample present as the voltage applied to the sample varied from 0 to 50V using a 1kHz square waveform.

Glass Substrate Results

The first series of mixtures held the monomer concentration fixed at 2 wt% and the dichroic dye concentration fixed at 3 wt% and studied the variation of the contrast ratio and saturation voltage with chiral dopant concentration. The results are shown in Fig. 3. As chiral dopant increased the scattering efficiency increased and therefore contrast ratio improved. There is a trade-off because improvements in contrast come at the price of higher driving voltage and power consumption.

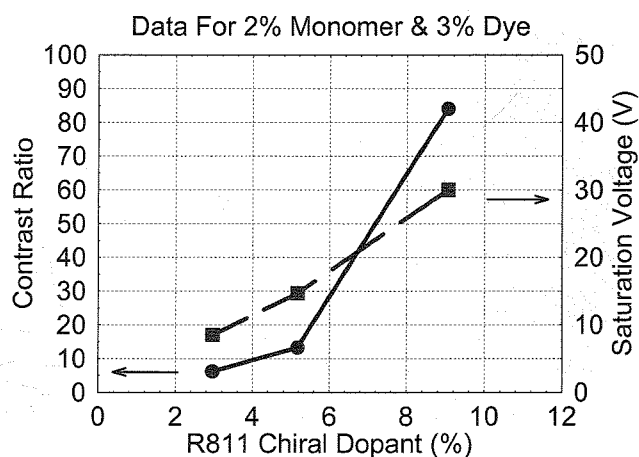


Figure 3. Contrast ratio and saturation voltage vs. chiral concentration with monomer fixed 2 wt% and dye fixed at 3 wt%

The second series of mixtures held the monomer concentration fixed at 2 wt% and the chiral dopant concentration fixed at 5.5 wt% while varying the dichroic dye concentration. The results are shown in Fig. 4. The contrast ratio of 6 wt% dye improved two-fold over the sample with no dye without a measurable change in the saturation voltage.

Flexible Substrate Results

To reduce the power consumption we choose a mixture with a low chiral concentration and high dye concentration. We filled flexible plastic substrate cells of thickness 10 μm with no alignment layer using a mixture with 2 wt% monomer, 4 wt% chiral dopant, 6 wt% dye. We used a patterned UV exposure on photoresist to remove the ITO forming the letters "LCI". Although the ITO was removed, meaning no field was applied there

during curing, the liquid crystal formed very large domains in the region and hence remained optically transparent. The measurement of a plastic substrate display is shown in Fig. 5. It can be seen that it has a low driving voltage as expected which will keep power consumption lower. The higher dye concentration only slightly improved the contrast ratio at this chiral concentration. The transparent state has a lower transmittance because the plastic substrates transmit less light than ITO on glass. This is shown in the data of transmission vs. wavelength for displays using different substrates as shown in Fig. 6 (referenced to no sample present). The absorption of the dye occurs mainly in the region from 400-500nm giving it a yellow appearance.

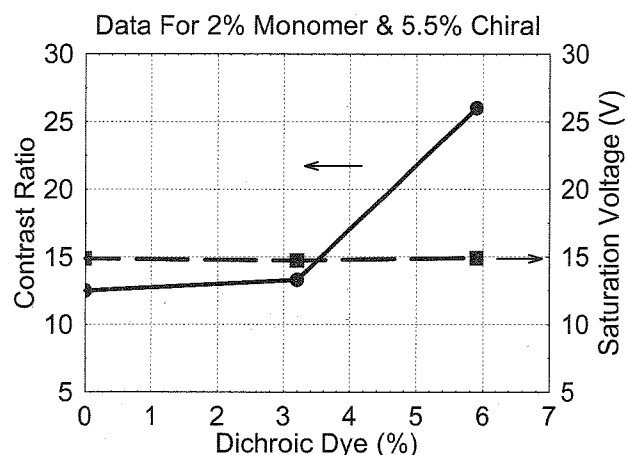


Figure 4. Contrast ratio and saturation voltage vs. dye concentration with monomer fixed at 2 wt% and chiral dopant fixed at 5.5 wt%

T-V Curve of Plastic Display

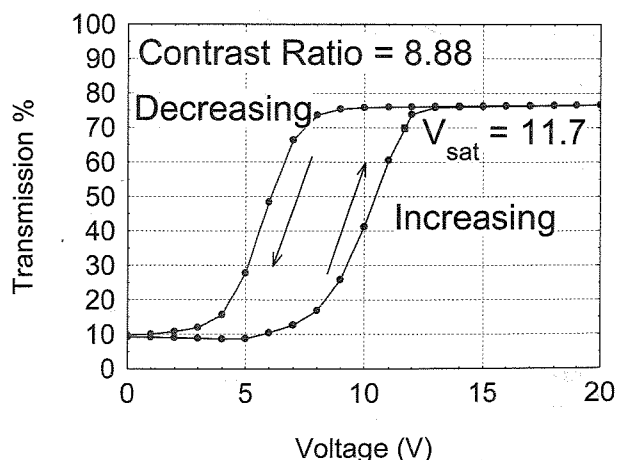


Figure 5. Measurement of a plastic display which had 2 wt% monomer, 4 wt% chiral dopant, and 6 wt% dye

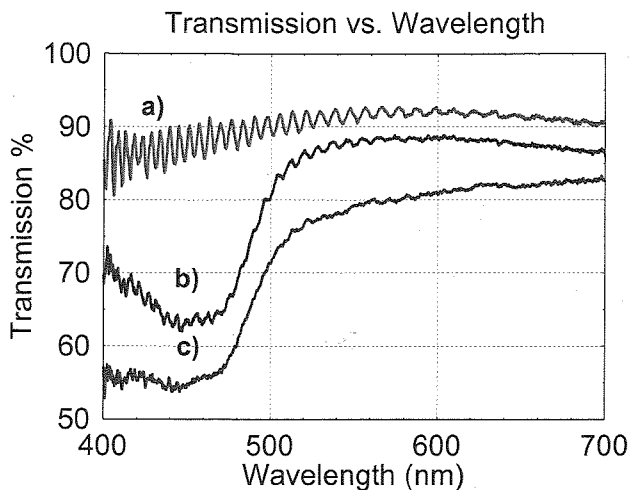


Figure 6. Spectra of a) glass PSCT at 30V, b) glass PSCT with dye at 30V, and c) plastic PSCT with dye at 20V

We took a photograph of a plastic display bent in hand (Fig. 7) and bent in a metal press to an 85mm radius of curvature (Fig. 8). The transparent state (Fig. 8(a)) is shown with a scenic background to show the clarity and color of the dye while the scattering/absorbing state (Fig. 8(b)) has a black background to accentuate the transparent patterned letters.

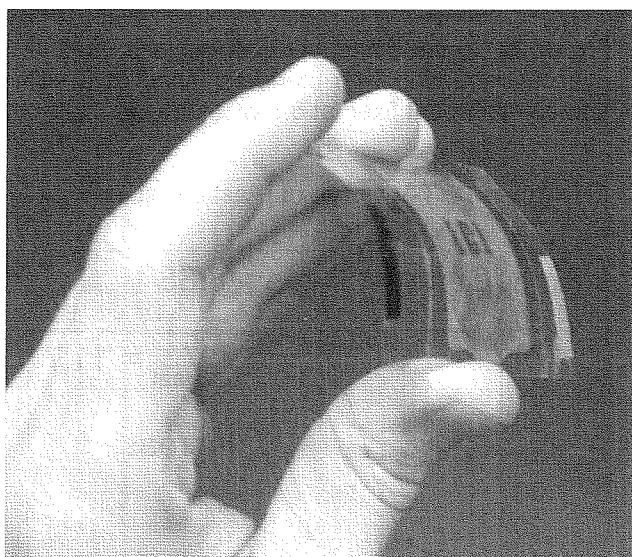


Figure 7. Photograph of a plastic display while bent in hand.

Conclusions

We showed that adding a dichroic dye to the normal mode PSCT display improves the contrast ratio without overly degrading the bright state transmission. We demonstrated

the performance in a flexible display by making cells on ITO coated plastic substrates with patterned letters. These displays were bent to a radius of 85mm and were still operable at this curvature.

Acknowledgements

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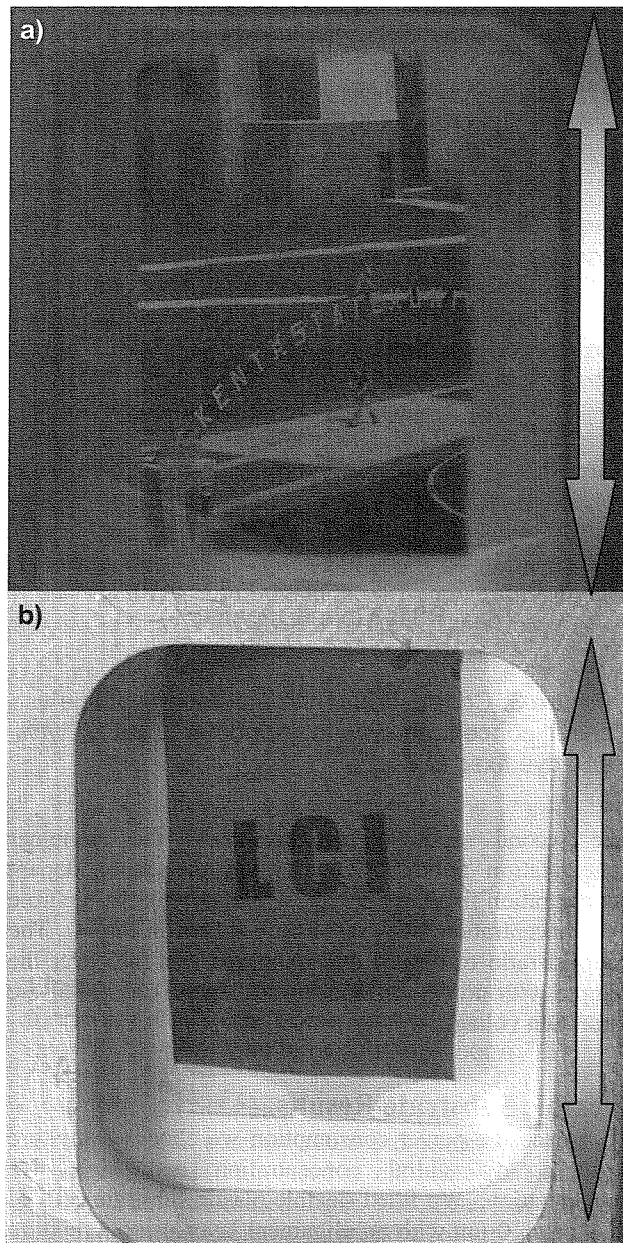


Figure 8. Photograph of a plastic display while bent vertically at an 85 mm radius of curvature a) in the transparent state (20V) with scenic background and b) dark state (0V) with black background

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