Application of Polymer Network Liquid Crystal to Mobile Display and its Electro-Optical Characteristics

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Abstract

The electro-optic properties of an active-matrix polymer network liquid crystal display (AM-PNLCD) with crossed polarizer films to improve its contrast ratio were evaluated. By using crossed polarizer films, it shows good contrast ratio as well as wide viewing angle and adequate response time at normal TFT-twisted nematic (TN) LCD driving voltage (2.8V).

1. Introduction

Due to their high light efficiency (no polarizer), easy processing (no rubbing process), wide viewing angle and flexibility, polymer/LC composites have been studied for a wide variety of applications such as electrically switchable windows, optical shutters, flexible displays, diffractive optics, and photorefractive systems.[1] [2] [3]

In general, polymer/LC composites can be switched from light scattering(OFF) state to transparent(ON) state by external electric field. The transparency of sample is due to matching of refractive indices of LC(n_o) droplets and polymer(n_p).[4] But their display application was somewhat restricted by its high driving voltage, slow response time and poor contrast ratio. In recent years, in order to overcome the weakness, various types of polymer/LC composites have been developed including polymer dispersed liquid crystal(PDLC), polymer network liquid crystal(PNLC), polymer stabilized ferroelectric liquid crystal and others.[5]

In this paper, we adapted the PNLC material system with crossed polarizer films and lowered the thickness of PNLC films to improve weak points of PDLC for display device application. We report on the electro-optic properties of an TFT-PNLCD and will discuss the effect of crossed polarizer films on the contrast ratio variation as well as an image mode control.

2. Experimental

The PNLC material used in this experiment is homogeneous mixture of 70 wt% LC and 30 wt% UV-curable prepolymer. Homogeneous mixture was injected into a conventional TNLCD empty panel using LC injection equipment and photo-polymerized to separate the LC/polymer phases. We used 1.8" QCIF(176X144) TFT-TNLCD mobile panels(cell gap=4.75㎛) which is normally-white when filled with normal TN LC material.

Several electro-optic properties were measured including its morphology, voltage-transmittance, viewing angle, contrast ratio and video image.

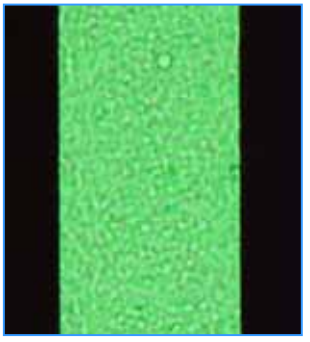
3. Results and Discussion

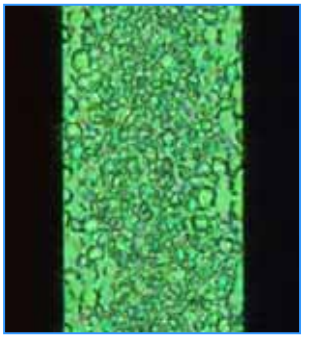
3.1 Film morphology

In polymer/LC composites, the size and shape of LC domain are most important factors affecting the electro-optic performance of the device.

Figure 1 shows optical micrographs of PNLC morphology after phase separation. Most of the LC domains (bright area without any contrast) seems to be far from a spherical shape. Considering high LC contents as much as 70%, the PNLC morphology would be preferred rather than PDLC so that the cell gap is filled by continuous LC phase in polymer network. In general, PNLC morphology is known to exhibit low driving voltage, fast response time, and low contrast ratio compared to PDLC.

(a)





(b) at V=off (0 V) light scattering state

(c) at V=on (2.8V) light transmission state

Figure1. Optical micrographs of PNLCD pixel (a) and PNLC morphology (b) (c) without crossed polarizers.

3.2 Voltage-transmittance property

The light transmission of PNLCD with crossed polarizers was measured as a function of the applied voltage, as shown in Figure2. We used conventional LED BLU system with additional diffuser sheet as a diffusive light source right behind the panel.

The curve shape is similar to conventional normally white mode LC displays.

Driving voltage of normally white mode LC display is generally chosen as V10, and threshold voltage is usually defined as V90, where V10 and V90 are the voltages necessary to obtain a transmission of 10%, 90%, respectively.

In our PNLC panel with crossed polarizers, driving voltage is 2.8~3.0V, so it is well operated at the conventional TFT-LCD driving condition.

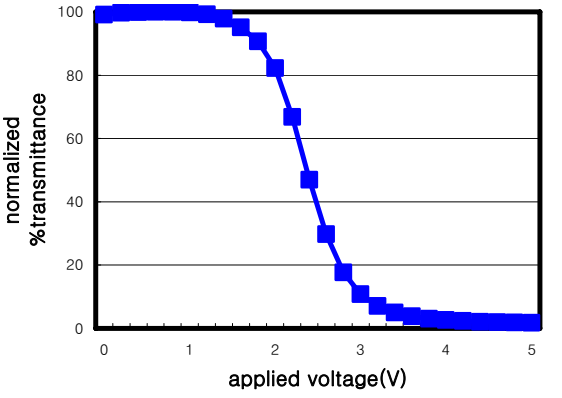


Figure2. Voltage-transmittance graph of PNLCD panel with crossed polarizers

3.3 Image inversion effect

Figure 3 shows the TFT-PNLCD for same input image(the inset) with and without crossed polarizer. Without polarizer, the colour is inverted and the image is hard to be recognized due to the poor contrast ratio. Equipped with crossed polarizers, however, the display is reproducing the input image and also the contrast ratio is greatly improved.

(a) without polarizer (b) with polarizer

Figure3. TFT-PNLCD module image without(a) and with(b) polarizer at 2.8V. (The inset is the original input image.)

3.4 Viewing angle property

Figure 4 shows the images of various viewing angles at a driving voltage of 2.8V. At any angle, the images look same without severe colour inversion and brightness degradation. This property comes from the inherent scattering characteristic of PNLC material.

Figure4. PNLCD panel images with crossed-polarizer taken at various viewing angle.

3.5 Contrast ratio property

Contrast ratio is very important property of display devices, but it cannot be easily compared in the literature. Indeed, several definitions of contrast ratio are used, although the most widespread is: contrast ratio = Tmax / Tmin. The measurement was carried out both with and without crossed polarizers at the front direction of panel.

Contrast ratio has greatly improved by using crossed polarizers more than 50 times.

Table1. Contrast ratio property of PNLCD panel

	without polarizers	with polarizers
Contrast ratio	1.07	54.7

4. Conclusions

In order to improve the contrast ratio, we applied crossed polarizer and examined the feasibility of its application for display device.

The driving voltage was reduced down to 2.8V, which is comparable to the conventional TFT-LCD device, by increasing the LC contents in the composite (PNLC system) and lowering the cell gap about 4.75㎛. By using crossed polarizer, the device performed successfully with good contrast ratio, wide viewing angle at a driving voltage of 2.8V.

The proposed device has great potential for both small size mobile displays and flexible large size moving image displays.

5. Acknowledgements

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6. References

[1] L. Bouteiller, P.L Barny, Liq. Cryst., 21,157 (1996)

[2] G. Spruce, R.D. Pringle, Elec. Comm. Eng. J., 4,91 (1992)

[3] J. W. Doane, J. L. West, SID Digest, 224 (1990)

[4] M. Mucha, Prog. Polym. Sci., 28, 837 (2003)

[5] H. Fujikake, H. Sato, T. Murashige, Displays, 25, 3 (2004)