Plastic LCDs Using Pixel Isolated LC mode

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Abstract

We developed a new device structure using anisotropic phase separation from liquid crystal (LC) and polymer composite materials using UV intensity variation and polymer wetting properties. In the device, the LC molecules are isolated in pixels where LCs are surrounded by the inter-pixel vertical polymer walls and the horizontal polymer films on the upper substrate. These devices show very good mechanical stability against external pressure. The electro-optic characteristics and the mechanical stability of the devices are discussed in view of the flexible display applications.

1. Introduction

Liquid crystals (LCs) have been extensively studied and used for display applications because of their efficient light-control capabilities with low power consumption. These advantages come from LC's hydrodynamic properties and high birefringence. In general, LC devices are prepared by sandwiching a LC between two glass substrates with transparent electrodes and alignment layers to obtain specific configuration of the optic axis. One of primary role of these substrates is supporting LC molecular orientation from external bending or pressure, which alter the arrangement of LC molecules and diminishes optical properties of the device.

In recent years, LC devices using plastic film substrates have drawn much attention for use in applications such as smart cards, PDA, and head mount displays because of their lighter weight, thinner packaging, flexibility, and reduced manufacturing cost through continuous roll processing [1-3]. Different electro-optical modes have been proposed for use in plastic LCDs including twisted nematic, cholesteric, polymer dispersed LC (PDLC), and bistable ferroelectric LC (FLC) modes. However, it is clear that plastic substrates can't give a solid mechanical support for the molecular alignment of LCs between them. In order to overcome the above problems, polymer wall and/or network as a supporting structure have been proposed and demonstrated [4-6]. These structures were fabricated using an anisotropic phase separation method from polymer and LC composite systems by applying patterned electric field or spatially modulated UV intensity. However, those methods require high electric field to initiate the anisotropic phase separation or there exist residual polymers in unexposed region which reduce optical properties and increase operating voltage of the device.

In this presentation, we propose a new device structure using anisotropic phase separation from LCs and polymer composite materials using UV intensity variation and polymer wetting properties. In the device, the LC molecules are isolated in pixels where LCs are surrounded by the inter-pixel vertical polymer

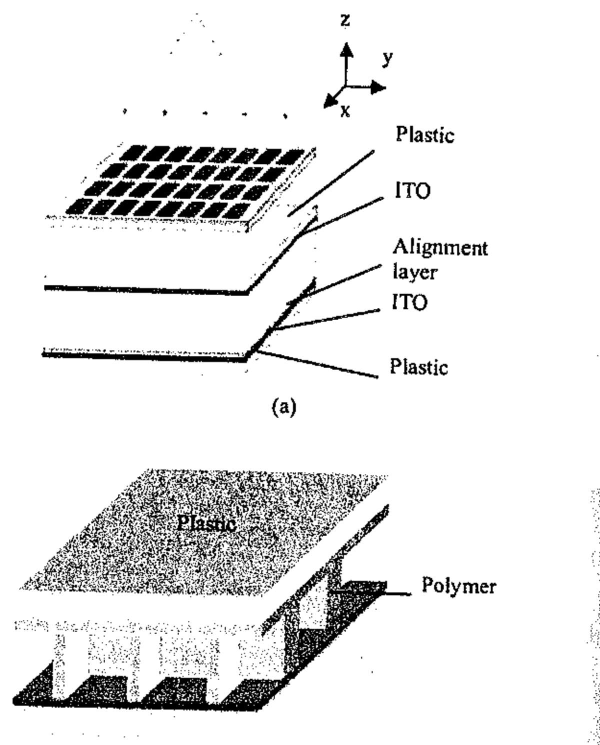

Fig. 1 Schematic diagrams of (a) experimental setup and (b) the resultant structure after UV exposure.

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walls and the horizontal polymer films on the upper substrate, namely pixel-isolated LC mode. These devices show very good mechanical stability against external pressure. The electro-optic characteristics and the mechanical stability of the devices are discussed in view of the flexible display applications.

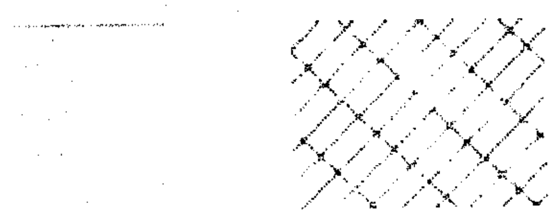
2. Experimental

Cells were made using two PES plastic substrates. The alignment layers are spin coated on one substrate followed by rubbing to achieve homogeneous LC alignment. The cell gap was maintained using glass spacers of 3 μm. The materials used are commercially available E7 nematic LC, isobronylmethacrylate monomer, and Irgacure 651 photoinitiator. A solution of LC and monomer was prepared in 9:1 ratio. We added photoinitiator of 0.5 % in weight ration in the solution. The solution was introduced into the cell by capillary action at an isotropic temperature of the LC. The cells are exposed to UV light of $\lambda = 365$ nm to initiate polymerization. The source of UV light is a Xenon lamp operated at 200 W of electrical power. The photomask is placed on one of plastic substrates without the alignment layer. Fig. 1(a) shows the fabrication set-up for a PILC. The cell with the mixture is irradiated with UV light for 20 minutes. A second exposure is performed without the mask for 10 minutes to fully harden the polymer. During this process, the LC molecules which remain in polymer network after the first UV exposure are expelled from the polymerized volume. Fig. 1(b) shows the resultant element after UV exposure. The LC molecules are isolated in the pixel surrounded by polymer layers which act as supporting structures from external shock.

3. Results and Discussion

The Fig. 2 shows microscopic textures of plastic LCDs with normal and PILC at room temperature after UV exposure under polarizing microscope. The pixels in PILC were rich in LC with uniform alignment and the interpixels were rich in polymer with few embedded LC molecules. Since the phase transition temperatures from isotropic to nematic state are almost same in both normal and PILC samples, we conclude that there are just few unpolymerized monomers in LC region. We note that LC molecules in polymer can be controlled by mixing ratio, UV intensity and exposure time, environment temperature, and sample thickness.

The cross section image of PINLC using scanning electron microscope was shown in Fig. 3. It can be seen well defined vertical polymer wall in interpixels and horizontal uniform polymer film on upper substrate. Therefore the LC molecules are surrounded by polymer and isolated into pixels. The polymer walls act as supporting structures from external pressure and bending.



(a) (b)

Fig. 2 Alignment textures of (a) normal and (b) PILC samples with plastic substrates under polarizing microscope.

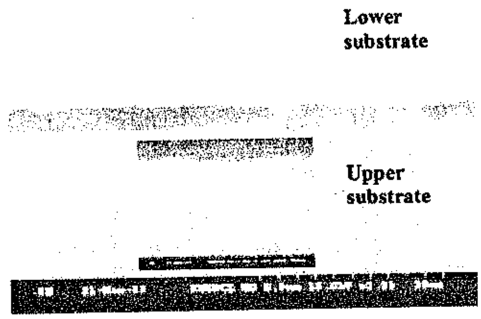


Fig. 3 Cross section image of PILC sample using scanning electron microscope. The inlet is the magnification of dotted circle.

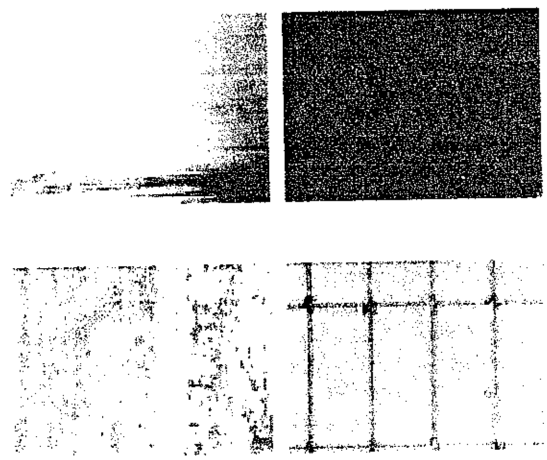


Fig. 4 Comparison of alignment textures for NLCs and FLCs with glass substrates by external pressure for normal and PILC samples: (a) and (c) are normal NLC and FLC, respectively. (b) and (d) are pixel isolated NLC and FLC, respectively. We took pictures with pressing the samples by sharp tip for NLC samples, and after removing press for FLC samples.

We now describe the alignment stability of PILC against an external mechanical shock. Such mechanical stability has been one of the main problems to commercialize plastic LCDs, specially using FLCs. In Fig. 4, we compare the alignment textures for nematic LCs (NLCs) [(a) and (b)] and FLCs [(c) and (d)] with glass substrates by external pressure for normal and

PILC samples. In normal samples [(a) and (c)], the texture shows crucial change due to reorientation of LC molecules by mechanical pressure. Specially, the textures of normal FLC is not reversible after removing external pressure due to the broken smectic layers different from NLCs. However, there are no appreciable structural changes in PILC as shown in Fig. 3 (b) and (d). It is clear that the PILC is very promising structure for flexible display applications.

Fig. 5 shows a demonstration of 3cm x 5cm plastic PILC sample applying to mobile phone display.

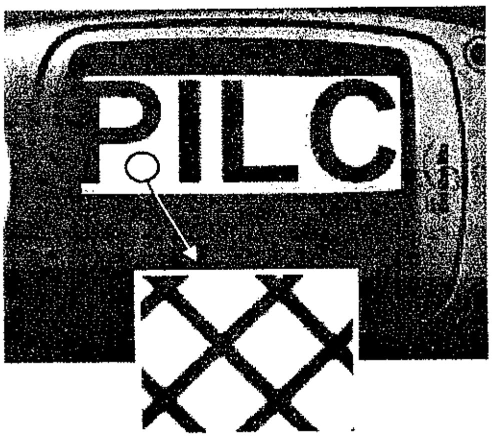


Fig. 5 3cm x 5cm cell with plastic substrates in mobile phone. The inlet is the alignment texture of circle under polarizing microscope with 40 times magnification.

Fig. 6 shows electro-optic behavior of normal and PILC samples. In both samples, transmittance and response time show almost same behavior except the slight increase of threshold voltage in PINLC. The slight increase of threshold voltage is due to the polymer layers and increasing anchoring force at the polymer wall.

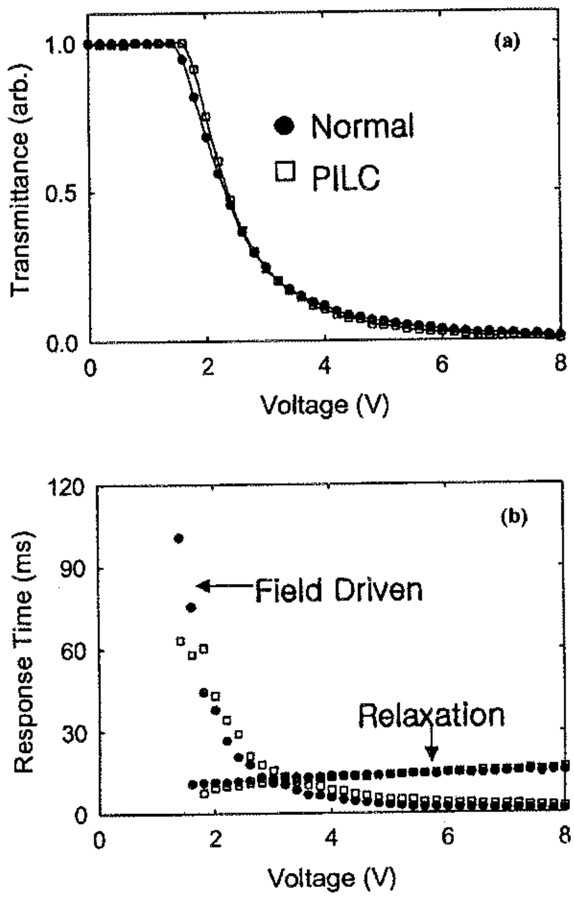


Fig. 6 Electro optical properties of normal (circle) and PINLC (square) samples as a function of applied voltages: (a) transmittance and (b) response time.

4. Concluding Remarks

In conclusion, we successfully fabricated a new device structure using three dimensional anisotropic phase separation method. In the device, the LC molecules are isolated in pixels where LCs are surrounded by polymer layers. These devices show very good mechanical stability against external pressure. The electro-optic characteristics are almost same as normal LC structure. We believe that the PILC mode open new generation of plastic LCDs in near future.

6. Acknowledgements

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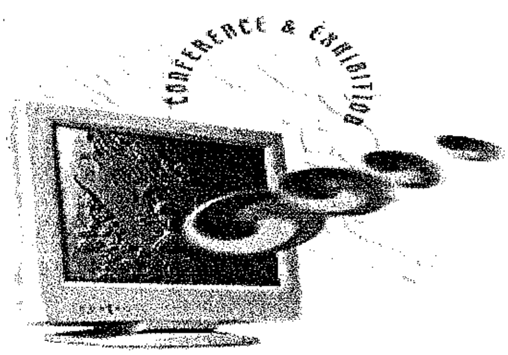

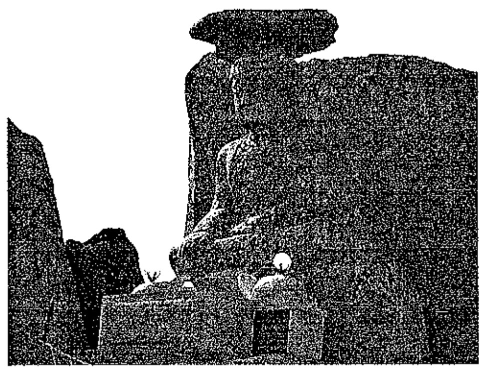

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