Pixel isolated liquid crystal mode for flexible displays

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We developed a new device structure using anisotropic phase sepraration from liquid crystals (LCs) and polymer composite materials for flexible display applications. 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 and the mechanical stability of the devices are discussed in view of the flexible display applications.

I. 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 TN/STN, cholesteric, polymer dispersed LC (PDLC), and bistable FLC modes.

However, it is clear that plastic substrates can't give a solid mechanical support for the molecular alignment of LCs between them. Specially, ferroelectric LCs show very weak mechanical stability because of the presence of fragile smectic layers even between glass substrates.

In order to overcome the above problem, polymer wall and/or network as a supporting structure have been proposed and demonstrated. 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[4,5]. However, those methods require high electric field or there exist residual polymers in unexposed region which reduce optical properties of the device.

In this paper, we report pixel isolated LC (PILC) mode where the LC is isolated in the pixel surrounded by polymer. The PILC mode not only shows good mechanical stability, but also operates in low voltage.

II. Experimental

The materials used in this study are commercial nematic LC (NLC) E48 (Merck), ferroelectric LC (FLC) Felix 15-100 (Hoechst), and photocurable prepolymer NOA72 (Norland). For the alignment layers, we used polyimide RN1286 (Nissan) or

Nylon 6. The alignment layers are spin coated on one substrate followed by rubbing to achieve homogeneous LC alignment. We note that the results of phase separation are greatly affected by alignment layers. These results will be published elsewhere. The cell gap was maintained using glass spacers of 4 μm. A solution of the prepolymer and the LC, in the ratio 70 wt%:30 wt% for FLC and 50 wt%:50 wt% for NLC, is introduced into the cell at a temperature corresponding to the isotropic state of the LCs. The cells are exposed to UV light of λ = 350 nm to initiate polymerization. The source of UV light is a Xenon (Oriel model 6269) lamp operated at 200 W of electrical power. Fig. 1 shows the fabrication process for a pixel isolated LC. The photomask is placed on one of glass substrates without the alignment layer. The cell with the LC+prepolymer mixture is irradiated with UV light for ~ 10 minutes. A second exposure is performed without the mask for five minutes to fully harden the polymer. During this process, the LC molecules which remain in polymer network after first UV exposure are expelled from the polymerized volume.

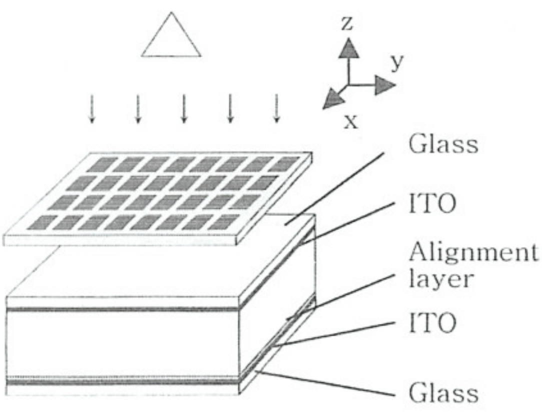


Fig. 1. Experimental set-up

III. Results and Discussion

In the simplest case, when a cell filled with a mixture of LC and prepolymer is exposed to normally incident UV light, an intensity gradient in the (z-) direction perpendicular to the cell is produced due to UV's absorption by the mixture. The intensity gradient causes anisotropic phase separation along the z-direction. Moreover, the surface interaction between LC and alignment layer plays essential role for the anisotropic phase separation[12]. The LC materials fully wet the RN1286 or N6 alignment layer and dewet on ITO substrate. The LC molecules near the alignment layer respond to its anchoring potential and align parallel to the rubbing direction. Oriented LC molecules determine the microscopic structure of the polymer-LC interface which becomes compatible with their alignment. Therefore the presence of alignment layer promotes the surface induced anisotropic phase separation in the direction of sample thickness. In our previous study, we successfully fabricated phase separated composite organic film (PSCOF) structure which has adjacent unifom polymer and LC layers using this one dimensional ansiotrpic phase separation method[6].

The use of a suitable mask during UV exposure produces additional intensity gradients in the (xy-) plane of the cell. Monomers in high intensity region near the UV source, undergo polymerization first and the monomers in low intensity region diffuse to the high intensity region, to maintain their relative concentration, and join the polymerization reaction. The LC molecules are immiscible in and are

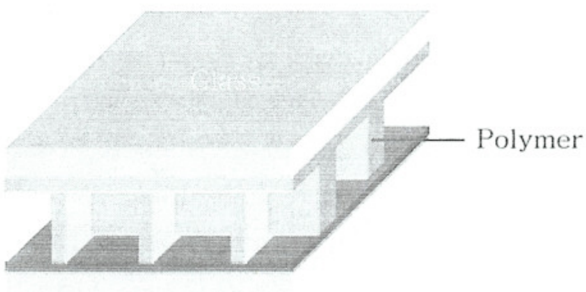
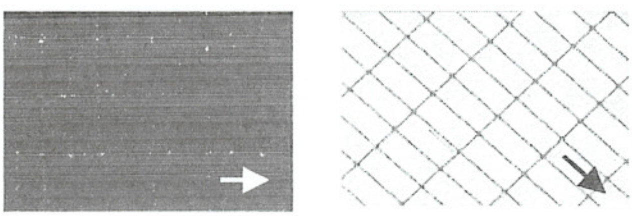


Fig. 2. PILC structure

expelled from the polymer. Therefore, the phase separation is anisotropic in 3-dimmension.

Fig. 2 shows the resultant element after UV exposure. Due to three dimensional anisotropic phase separation, the LCs are isolated in the pixels surrounded by polymer wall, namely pixel isolated LC (PILC) mode. Any LC modes such as nematic, ferroelectric, and cholesteric modes can be applicable.

Fig. 3 shows microscopic textures of pixel isolated NLC (PINLC) cell at room tempaerature after UV exposure under polarizing microscope. The pixels were rich in LC with unifrom alignment and the interpixels were rich in polymer with some embedded LC molecules.



(a) (b)

Fig. 3. Alignment textures of pixel isolated NLC cell: The rubbing direction indicated by arrow is rotated (a) 0° and (b) 45° with respect to one of crossed polarizers.

We note that LC molecules in polymer can be controlled by mixing ratio, UV intensity and exposure time, environkent temperature, and sample thickness.

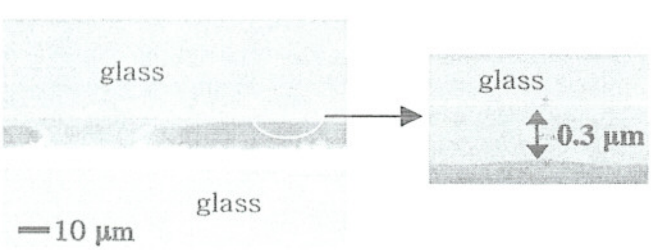


Fig.4. SEM image of PILC sample

The cross section image of PINLC using scanning electron microscope was shown in Fig. 4. It can be seen well defined polymer wall in interpixels and unifom polymer layer in upper glass. Therefore the LC molecules are surrounded by polymer and isolated into pixels. The polymer walls act as supporting structure.

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. Fig. 5 shows microscopic texture of normal [(a) and (b)] and pixel isolated FLC (PIFLC) [(c) and (d)] before and after a external pressure. In normal FLC, the texture shows crucial change due to broken smectic layers after mechanical shock. It can be seen from Fig. 5 (c) and (d) that no appreciable structural change in PIFLC was present.

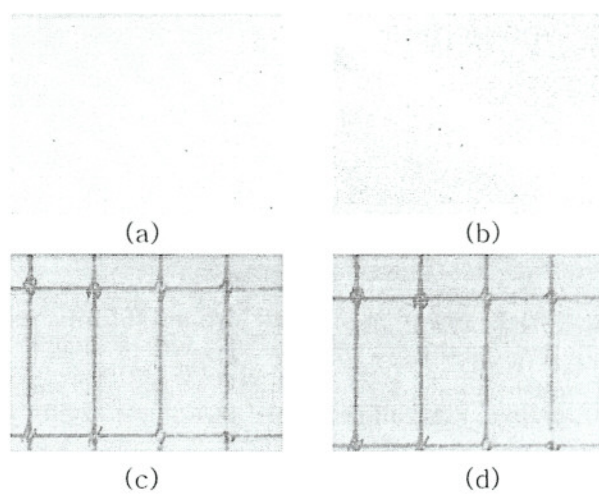


Fig. 5. Alignment textures before [(a) and (c)] and after [(b) and (d)] external pressure: (a) and (b) are normal SSFLC cell, and (c) and (d) are PIFLC cell.

Fig. 6 shows electro-optic behavior of normal, PSCOF and PINLC samples. In all samples, tranmittance and response time show almost same behavior.

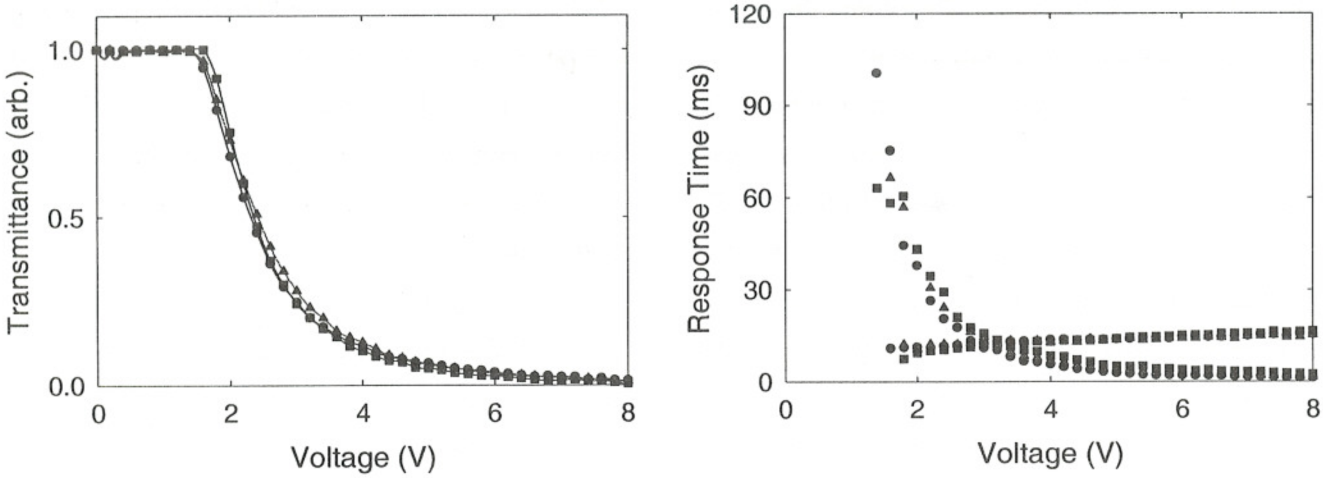


Fig. 6. Electro optical properties of normal (circle), PSCOF (triangle), and PINLC (square) as a function of applied voltages.

IV. Concluding Remarks

In conclusion, we successfully fabricated a new device structure using three dimensional anisotropic phase sepraration 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 nematic LC structure.

Acknowledgements

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