Mechanical Stability of Pixel-Isolated Liquid Crystal Mode in Flexible Display

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Abstract

We have characterized the mechanical stability of the Pixel-Isolated Liquid Crystal (PILC) mode for plastic LC display applications. In our device, the LC molecules are fully isolated in the pixels by the phase-separated polymer walls. The experimental results of microscopic observation and electro-optic characterization show that our flexible PILC device has good mechanical stability against external point pressure or bending distortion due to the polymer walls in our structure.

1. Introduction

For the past 10 years, flat panel display (FPD) devices have been developed and produced all around of the world. In the developing FPD, LCD technology is also greatly advanced. Nowadays preparing for new generation, flexible display devices are widely and extensively studied for the purpose of 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. Among various kinds of flexible displays, plastic LC devices have advantages in their efficient light-control capabilities with low power consumption[1-4]. But due to use the flexible substrates, there exist basic obstacles in fabricating plastic LCD. One is mechanical instability of LC molecules, and the other is adhesion of two substrates because flexible displays always experience bending and folding stress[5].

In order to overcome above problems, we have proposed pixel-isolating polymer wall structure by photo-polymerization induced phase separation from LCs and pre-polymer composite material[6]. Using UV intensity variation and polymer wetting properties[7], the LC molecules in our structure could be isolated in pixels where LCs are surrounded by the inter-pixel vertical polymer walls and the horizontal polymer film, namely pixel-isolated LC(PILC) mode. Schematic diagram of PILC structure is shown in Fig. 1. To enhance the mechanical stability of the plastic LC devices, other approaches of photo-polymerization method such as polymer network formation have been proposed. However, the electro-optic properties of those methods were degraded due to the polymer networks in the bulk resulting in increasing operating voltages. In our structure, the polymer wall structure is formed by the two steps of UV exposures, thus our structure shows the good EO properties. In this paper, we characterize such EO properties in the presence of external mechanical condition in our structure. By giving point pressure and bending pressure, the effect of the polymer wall structures on the cell gap uniformity in plastic substrates is discussed in view of the flexible display applications.

2. Experimental

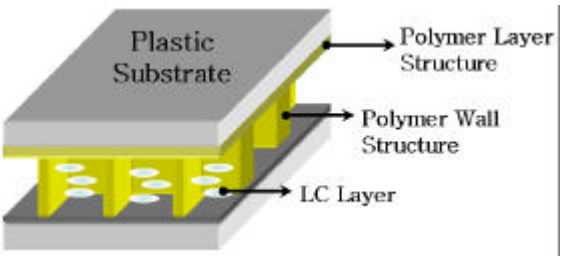
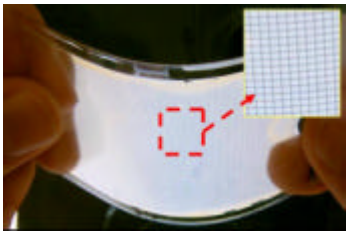


Fig. 1 Schematic diagrams of Pixel-isolated liquid crystal structure.

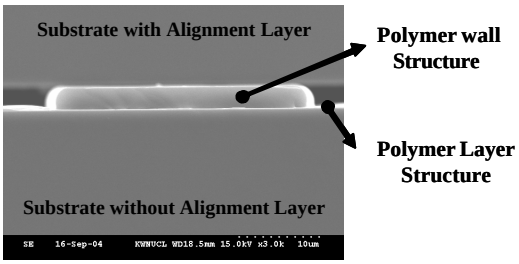
As plastic substrates, ITO-coated PES films were used in our experiment. One of the ITO-coated PES substrates was spin-coated with a homogeneous alignment layer and unidirectionally rubbed. A mixture of nematic LC (LC17) and photo-curable pre-polymer (NOA65, Norland Co.) with a ratio of 75:25 was filled into the plastic cavity at isotropic temperature. At first UV exposure, the UV was illuminated onto the bare ITO-coated PES substrate

through the photo-mask for 90 minutes. A second exposure was performed without the mask for 10 minutes to fully harden the pre-polymers. During these first and second photo-polymerization processes, the anisotropic phase separation occurs in the horizontal and vertical direction, respectively, forming vertical polymer walls and planar polymer layers[6,7].

Fig. 2 (a) shows the resultant 3 inch size plastic LCD cell. The sample shows uniform texture over the whole sample. By observing under microscope which is represented in inset in figure, we can see 500 *m*m x 500 *m*m size of active zone and polymer walls about 30 *m*m width. Fig. 2 (b) shows the cross section images of the polymer structure in our PILC cell using scanning electron microscope (SEM). The spatially distributed polymer walls fabricated by the first UV exposure act as supporting structures from external pressure and bending keeping the cell gap of the plastic cell. The residual pre-polymers are completely expelled from the bulk LC layer by second UV exposure forming thin polymer layer onto the bare ITO-coated PES substrate. Due to this second step of UV exposure, our PILC mode can show the good EO properties and the enhanced mechanical stability with good adhesion of the plastic substrates and the polymer walls.



(a)



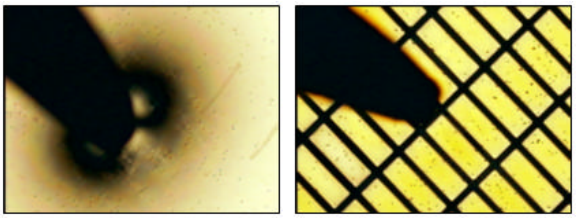
(b)

Fig. 2 Flexible PILC device using polymer walls and layers: 3 inch PILC using plastic substrates (a) and Cross section image using scanning electron microscope (b).

We tested the alignment stability of our PILC cell against an external mechanical shock and bending with 3 inch cell of plastic substrates

3. Result and Discussion

Fig. 3 shows polarizing microscopic textures of a normal plastic LC cell and a plastic PILC cell in the presence of an external point pressure with a sharp tip. Under the same amount of the point pressure, the alignment texture of the normal sample was severely distorted due to the cell gap variation and the LC-orientation variation. Fig. 3 (a) shows only point pressure can cause crucial damage to the optical properties of the normal plastic LC cell in a large area. However, that of the proposed PILC sample showed no appreciable structural changes since the hydrodynamic properties of the LC are spatially restricted and the cell gap are sustained by the pixel-isolating polymer wall structure shown in dark regions of Fig. 3 (b).



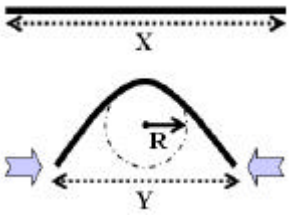
(a) Normal Sample (b) PILC Sample

Fig. 3 Alignment textures of (a) a normal sample and (b) a PILC sample fabricated with the plastic substrates. The polarizing microscopic textures are taken in the presence of an external point pressure with a sharp tip.

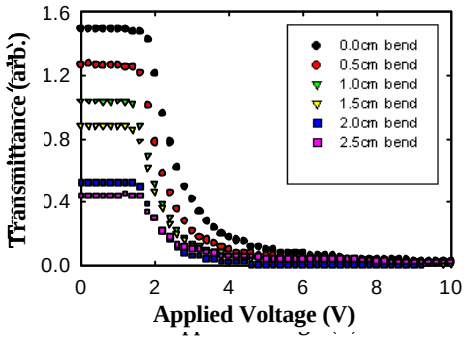
Polymer wall structures have other merits during bending of the device. The one feature is to prevent the flow of the LC molecules across the polymer walls if exfoliation of the polymer walls from the substrates does not occur. The other advantage of adhesive polymer walls structures is to deconcentrate the bending strain in the device plain [8].

Moreover for the case of PILC, LC molecules not only have stability against external shock by polymer wall structure but also exhibit uniform optical properties against bending stress which cannot be accomplished in normal cell. To compare the optical properties under bending stress between PILC and normal cell, we measured optical transmittance as voltage. First to represent the amount of bending stress, we estimate the radius of curvature for 3 inch size sample as bending increases. Fig. 4(a) shows the schematic diagram of measuring the diameter of curvature.

As shown in fig. 4 (a), X is the normal length without bending, and Y represents the length between two ends of sample with respect to bending stress. The resultant diameter as bending stress is represented in Fig. 4 (b), which shows inversely proportional to ?L. Now we measured transmittance - voltage properties for normal plastic cell and PILC cell.



(a)



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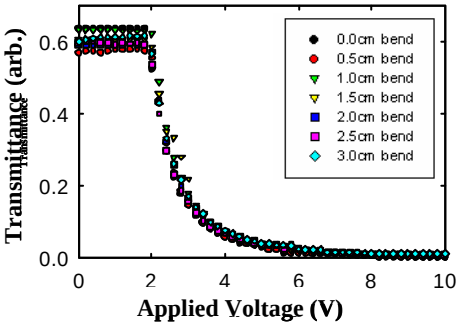
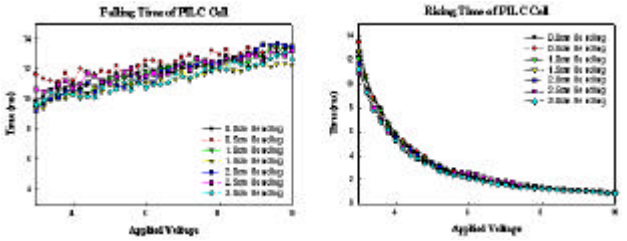


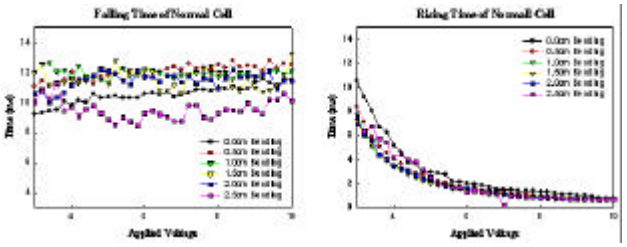
(c)

Fig. 5 (a)Schematic diagram of bending stress. The degree of bending here is ? L=X-Y in figure. Electro-optic properties of (b) a normal sample and (c) a PILC sample depending on bending amounts.

Fig. 5 shows the EO properties of a normal plastic LC cell and a plastic PILC cell in the presence of an external bending pressure with a pair of linear stages. At bending normal plastic LC cell, cell gap and LC molecules orientation are distorted over large area depending on the bending amounts because of the unstability of flexible substrates and unrestricted propagation of orientational distortion. Such effects resulted in the decrease of the transmittance as shown in Fig. 5 (b). However, our PILC cell shows almost same transmittance properties irrespective of the amount of the bending pressure in the whole operating voltages. Notice that the transmittance curves for normal plastic sample in fig. 5 (b) are degraded by 70 % contrary to the PILC sample. Fig. 4 (c) represents the LC alignment and the cell gap of our PILC cell are supported well by the polymer structures against external bending pressures.



(a) Response time of PILC cell



(b) Response time of normal cell

Fig. 6 The measured rising and falling times as applied voltages (a) for normal cell and (b) for PILC cell under external bending stress.

Fig. 6 shows the response times of both samples as bending amount increases. The average response time of both samples are almost same but the deviations are different. For normal plastic cell, the response times show broad distribution with bending stress variation. On the contrary for PILC plastic cell, they exhibits almost uniform distribution, where we can thought that PILC structure gives not only good mechanical property but also stable molecular dynamics of liquid crystal.

4. Concluding Remarks

In conclusion, we demonstrated the mechanically stable plastic LC device by pixel-isolating the LC molecules between the polymer walls and the uniform polymer layer. The mechanical stability tests of the proposed PILC structure shows good EO properties irrespective of the point pressure or the bending pressure. Therefore, it is expected that the PILC structure and the fabrication methods presented in this paper would be suitable to solve current main problems in plastic LC devices.

5. Acknowledgements

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