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P11 Mechanical Stability of Pixel-Isolated Plastic LCDs.

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We demonstrated stability-enhanced liquid crystal (LC) displays using pixel-isolated LC mode in which LC molecules are isolated in pixel by horizontal polymer layer and vertical polymer wall. The device shows good electro-optic properties with external pressure and bending due to the polymer structures. The polymer wall acts as supporting structure from mechanical pressure and maintains the cell gap from bending. Moreover, the polymer layer acts as adhesive for tight attachment of two substrates.

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 layers, namely pixel-isolated LC (PILC) mode. 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 (EO) properties of those methods were degraded due to the polymer networks in the bulk resulting in increasing operating voltages. In this paper, the PILC structure is formed by the two steps of UV exposures, thus it shows the almost same EO properties as normal cell. Also our device shows stable EO properties with external pressure because the polymer wall acts as supporting structure from mechanical pressure and maintains the cell gap from bending. Moreover, the polymer layer acts as adhesive for tight attachment of two substrates.

2. Cell structure and condition

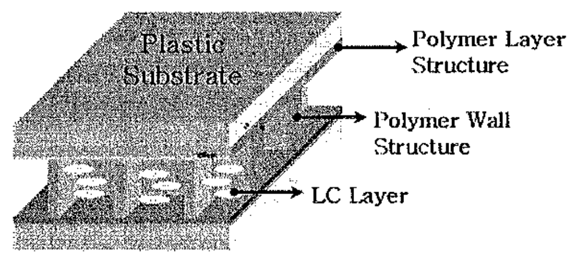


Fig. 1 Schematic diagrams of PILC structure

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, Merck) and photo-curable pre-polymer (NOA65, Norland Co.) with a ratio of 75:25 was filled into the plastic cavity at isotropic temperature. The cells are exposed to UV light of λ = 350nm to initiate polymerization. The source of UV light is a Xenon lamp operated at 200W of electrical power. At first UV exposure, the UV was illuminated onto the bare ITO-coated PES substrate through the photo-mask for 90 minutes. The 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]. The LC molecules were isolated in the pixel. Fig. 1 shows the schematic diagram of our PILC structure after UV exposure.

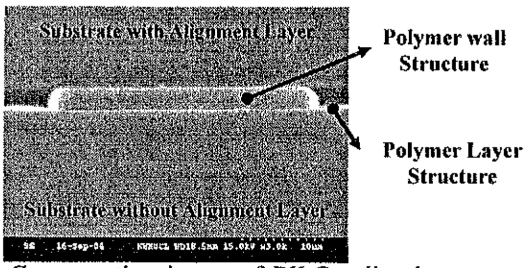
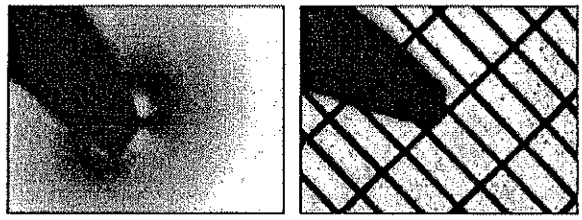


Fig. 2 Cross section image of PILC cell using scanning electron microscope.

Fig. 2 shows the cross section image of PILC cell using scanning electron microscope (SEM). The polymer walls fabricated by the first UV exposure which acted as supporting structures against external shock and maintained the cell gap from bending. 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 substrates. Due to this second step of UV exposure, our PILC mode can show the good electro-optic (EO) properties and the enhanced mechanical stability with good adhesion of the plastic substrates and the polymer walls.

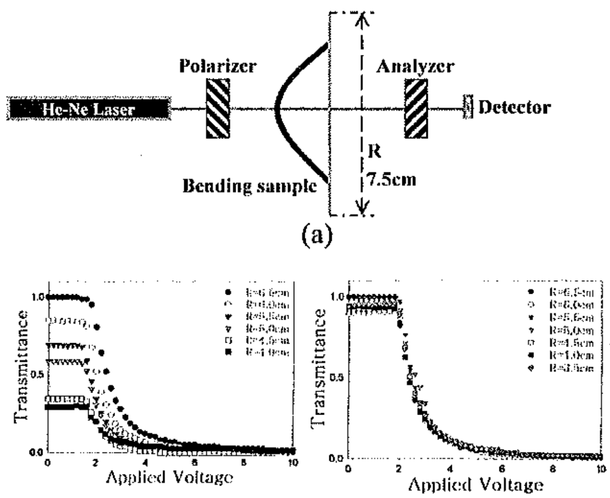
3. Result and Discussion

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 cell 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 cell showed no appreciable structural changes since the hydrodynamic properties of the LC are spatially restricted and the cell gap is sustained by the pixel-isolating polymer wall structure shown in dark regions of Fig. 3 (b).



(a) Normal cell (b) PILC cell

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



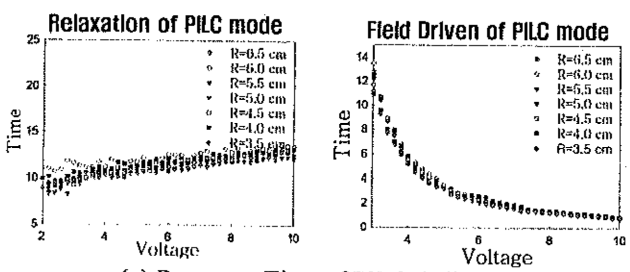
(a)

(b) (c)

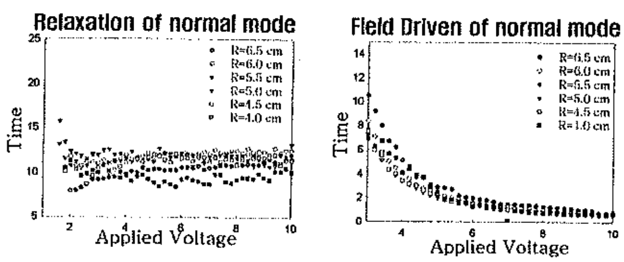
Fig. 4 (a) schematic diagram of EO properties measurement at bending states. EO properties of (b) a normal and (c) a PILC cell depending on degree of bending.

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 diameter of curvature for 3" cell as bending increase.

Fig. 4 (a) shows the schematic diagram of EO properties measurement at the bending state. Fig. 4 (b), (c) show the EO properties of a plastic normal LC cell and a plastic PILC cell in the presence of an external bending pressure with a pair of linear stages. At bending plastic normal 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. 4 (b). However, our plastic 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 plastic normal cell in fig. 4 (b) is degraded by 70 % contrary to the PILC cell. Fig. 4 (c) represents the LC alignment and the cell gap of our PILC cell is supported well by the polymer structures against external bending pressures.



(a) Response Time of PILC Cell



(b) Response Time of Normal Cell

Fig. 5 The measured relaxation and field driven times as applied voltages (a) for normal cell and (b) for PILC cell under external bending stress.

Fig. 5 shows the response times of both cells as bending amount increase. The average response times of both cells 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, PILC plastic cell exhibits almost uniform distribution, where we can think that PILC structure gives not only good mechanical property but also stable molecular dynamics of liquid crystal.

Fig. 6 3" plastic LCD cell using PILC mode

Fig. 6 shows 3" prototype plastic LCD with PILC mode in bending state.

4. Conclusion

We demonstrated the mechanically stable plastic LC device by pixel-isolating the LC molecules between the polymer walls and the uniform polymer layers. 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.

Acknowledgement

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References

[1] F. Matsumoto, T. Nagata, T. Miyabori, H. Tanaka, and S. Tsushima, *SID '93 DIGEST*, 965 (1993).

[2] J. L. West, M. Rouberol, J. J. Francl, J. W. Doane, and M. Pfeiffer, *ASIA DISPLAY '95*, 55 (1995).

[3] R. Buerkle, R. Klette, E. Lueder, R. Bunz, and T. Kallfass, *SID '97 DIGEST*, 109 (1997).

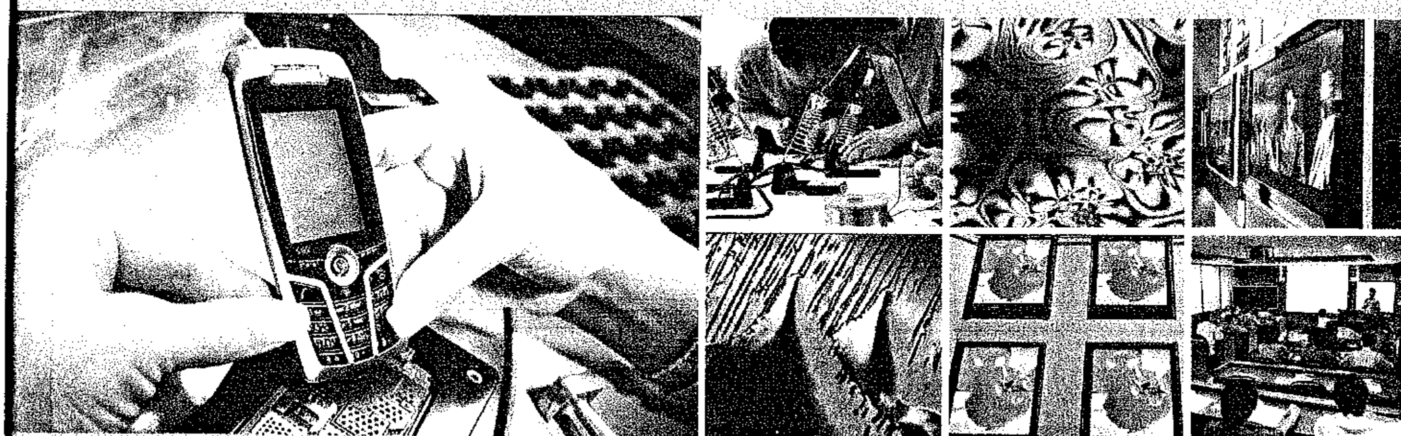
[4] J. L. West, G. R. Novotny, M. R. Fisch, and David Heinman, *J. Inform. Display*, **2**, 15 (2001)

[5] H. Sato, H. Fujikake, H. Kikuchiand, and T. Kurita, *Jpn. J. Appl. Phys.*, **42,** 476 (2003).

[6] J.-W. Jung, S.-K. Park, S.-B. Kwon and J.-H. Kim, *Jpn. J. Appl. Phys.*, **43,** 4269 (2004).

[7] T. Qian, J.-H. Kim, S. Kumar, and P. L. Taylor, *Phys. Rev. E*, **61**, 4007 (2000).

[8] Hiroto Sato, Hideo Fujikake, Hiroshi Kikuchi and Taiichiro Kurita, *Jpn. J. Appl. Phys.*, **42**, L476 (2003).



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