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Electro-Optical PI-PSCOF Devices Fabricated by Anisotropic Phase Separation of FLC and Polymer.

D. W. Kim[1*], H. Choi[1], Y. U. Son[1], P.G. Kang[1], S. T. Shin[1], J. W. Jung[2], J. H. Kim[2]

[*1] Dept. of Applied Physics, Korea University, Seoul, Korea
[2] Division of Electrical and Computer Engineering, Hanyang University, Seoul, Korea

kdw@korea.ac.kr

We have studied the Pixel Isolated Phase Separated Composite Organic Film (PI-PSCOF). The PI-PSCOF can be made by the anisotropic phase separation between Ferroelectric Liquid Crystals and Pre-polymer materials by irradiating the UV with optimizing its intensity and time. In the technology, the FLC molecules are isolated in pixels where FLCs are surrounded by the inter-pixel vertical polymer walls and the horizontal polymer films on the upper substrate. The good merits of this technology are fast response time, and good mechanical and thermal stability against external high pressure and temperature. We will compare the results obtained from FLC, PSCOF, and PI-PSCOF modes by using the electro-optic measurement and x-ray scattering, and mechanical method. We believe that the PI-PSCOF technology can be a best candidate for future Flexible Display Applications.

1. Introduction

Since Meyer has found FLC (Ferroelectric Liquid Crystal) from rod-shape liquid crystal with chiral molecular structure in 1975[1], many manufacturing companies have applied to practical application in display such as SSFLC (Surface Stabilized Ferroelectric Liquid Crystal) and AFLC (Anti Ferroelectric Liquid Crystal) which have characteristics of fast response time and wide viewing angle. But, development of SSFLCD and AFLCD had been stopped because there were many serious problems to be solved for LCD application, such as due to difficulty of low contrast ratio caused by zig-zag defects [2-3], mechanical durability, and so on. Alternatives FLC modes which are Twisted FLC, Deformed Helix FLC (DHF), V-Switching AFLC, and Polymer Separated Composite Organic Films (PSCOF) [4] have been studied by many universities and institutes.

Nowadays, many researchers are concentrated to do researches for next generation LC devices, flexible display as an example. The flexible display should be solved core-problems for future applications, mechanical and thermal shock. In the addition, it is required a other conditions such as fast switching, lighter weight, the lower manufacturing cost, the simply processing [6-7], etc.

In this paper, we have studied to solve mechanical and thermal problems using polymer wall in the cell and layer on the one substrate as a supporting flexible structure [8-9]. We used ferroelectric liquid crystal for fast switching that its technology have many advantages, three color switching on one pixel, simple process, moving picture application, so on. We compared the results among original FLC mode, PSCOF mode, and PI-PSCOF mode in electro-optic characteristics, spontaneous polarization value, stability of the mechanical and thermal shock, and x-ray measurement [10].

2. Experimental Details

The technique used to construct the PI-PSCOF cell is shown in Fig. 1 whose technique is similar as that used for making Polymer-Dispersed Liquid Crystal (PDLC) devices. A pair of substrates coated with transparent electrodes of indium-tin-oxide (ITO) is prepared to make cell. One of the substrates is coated by a commercial polyimide (RN1286), and then is rubbed to enforce for LC alignment. The other substrate is remained without coating the polyimide. The cell gap between the substrates was controlled by 1.8μm spacer. For binary mixture, we used commercially available photo-curable pre-polymer NOA-65 from Norland and Liquid Crystals Felix- 015/100 and 016/100 from Clariant. The phase transition sequences of FLC (Felix-015/100, Felix-016/100) that we used are as followed; I-(86)-N-(83)-Sm A-(72)-Sm C* for Felix-015/100 and I-(94)-N-(85)-Sm A-(72)-Sm C* for Felix - 016/100. The ratios of photo-curable pre-polymer NOA-65 and FLC in cell are 30:70, 40:60, and 50:50. Two components are mixed for a few days to make homogeneous binary mixture, and then the mixture is filled into the cell by capillary at cell temperature above the clearing point of the LC. Phase separation is carried out at temperature above 100 ℃ by exposing UV light to the cell normally on the no-coated polyimide substrate. The photomask is placed on one of glass substrates no-coated the alignment layer. The first exposure is performed with the mask for 60 minutes in 1.2 mw/cm^2 UV intensity to make polymer wall. And then, the second exposure is performed without the mask for 20 minutes in 0.7 mw/cm^2 UV intensity to make polymer layer. During the first process, the FLC molecules which remain in polymer network after the first UV, λ = 365 nm, exposure are expelled from the polymerized volume. The FLC molecules are isolated in the pixel surrounded by polymer walls which act as supporting structures for mechanical shock. After making the PI-PSCOF cell, we tried to make very thin glass cell (bellow 100um thick cell) by etching used hydrofluoric acid solution to minimize x-ray absorption to the glass.

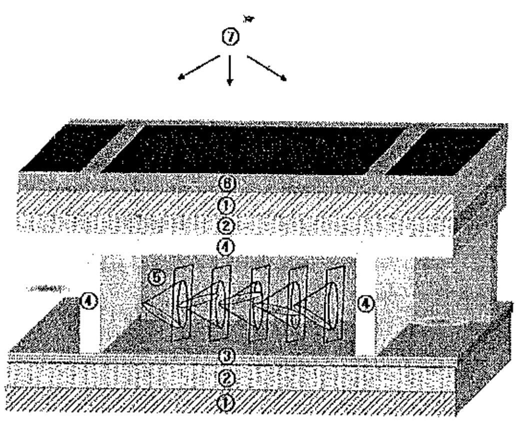
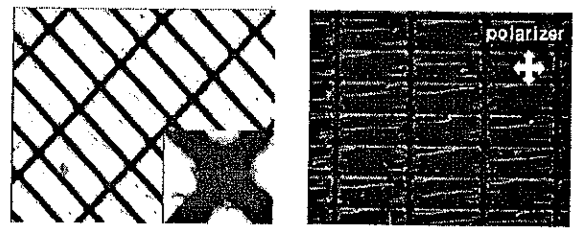


Fig. 1. Schematic structure of the PI-PSCOF cell. ① glass substrates, ② electrodes, ③ alignment layer, ④ polymer region, ⑤ FLC region, ⑥ photomask, and ⑦ UV source.

3. Results and Discussions

The PI-PSCOF cell is observed under crossed polarizers using a polarizing microscope (BX50, Olympus). One side of the polarizers is parallel to the rubbing direction of the cell because direction of the FLC molecules was stabilized in the rubbing direction. The Figure 2 shows microscopic textures of PI-PSCOF cell at room temperature. The pixels in PI-PSCOF cell are rich in FLC with uniform alignment and the internal pixels are rich in polymer with few embedded FLC molecules.



(a) (b)

Fig. 2 Alignment texture of PI-PSCOF (a) Normally White, (b) Normally Black under polarizing microscope. (x40, x500)

We assume that little prepolymer still remains in FLC region. We note that FLC molecules in binary mixture can be controlled by mixing ratio, UV intensity and exposure time, environment temperature, and sample thickness. The picture of PI-PSCOF obtained by scanning electron microscope is shown in Fig. 3. It can be seen well defined vertical polymer wall in inter-pixels and horizontal polymer film on upper substrate. Therefore the FLC molecules are surrounded by polymer layer and isolated into pixels. The polymer walls act as supporting structures from external pressures.

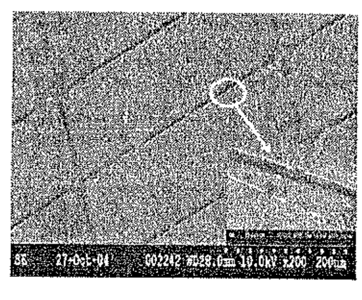


Fig.3. Scanning Electron Microscope (SEM) picture of PI-PSCOF cell.

We now describe the alignment stability of PI-PSCOF on an external mechanical shock. Mechanical stability has been considered one of the main problems to commercialize FLCDs. In Fig. 4, we compare the alignment textures for Pure FLC cell, PSCOF cell, and PI-PSCOF cell whose cells are pressed by any standard pressures. In Pure FLC cell [(a) and (b)], the texture shows crucial change due to reorientation of FLC molecules by mechanical shock. Specially, the textures of normal FLC cell are not reversible after removing external

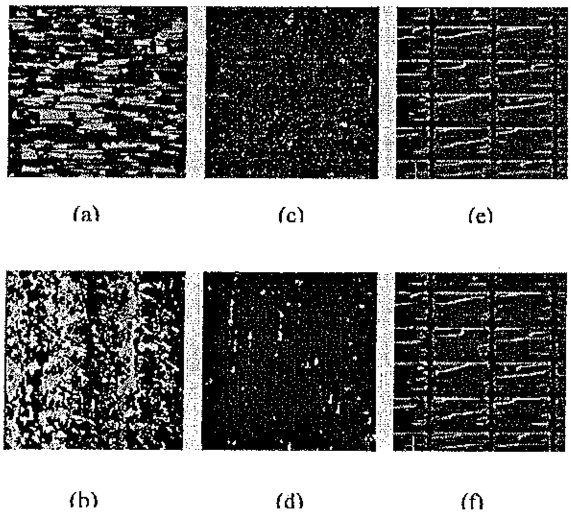


Fig. 4 Mechanical Stability of FLC Modes (a) Pure FLC cell (b) Pure FLC cell after external shcok (c) PSCOF cell made by mixture of Felix-016/100:NOA65=70:30 (d) PSCOF cell after external shock (e) PI-PSCOF cell made by mixture of Felix-016/100:NOA65=50:50 (f) PI-PSCOF cell after external shock.

pressure due to the broken smectic layers.

In PSCOF cell [(c) and (d)], smectic layer of FLC molecules is not broken by external shock even though there is partially small change. In the case of PI-PSCOF cell, there are no appreciable structural changes as shown in Fig. 4 (e) and (f).

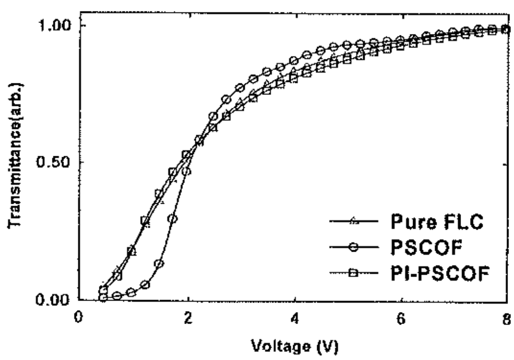


Fig. 5 V-T curves of Pure FLC cell, PSCOF cell, and PI-PSCOF cell.

	Pure FLC	PSCOF	PI-PSCOF
Threshold Voltage	0.75V	1.1V	0.8V
Saturation Voltage	5.5V	4.5V	5.0V
Contrast Ratio	132:1	200:1	137:1
Response Time	0.465ms	0.678ms	0.833ms

Table. 1. E/O properties of Pure FLC, PSCOF, and PI-PSCOF.

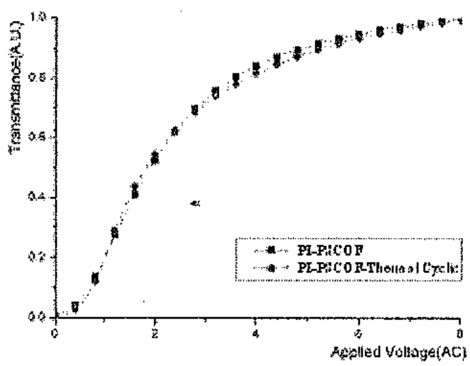
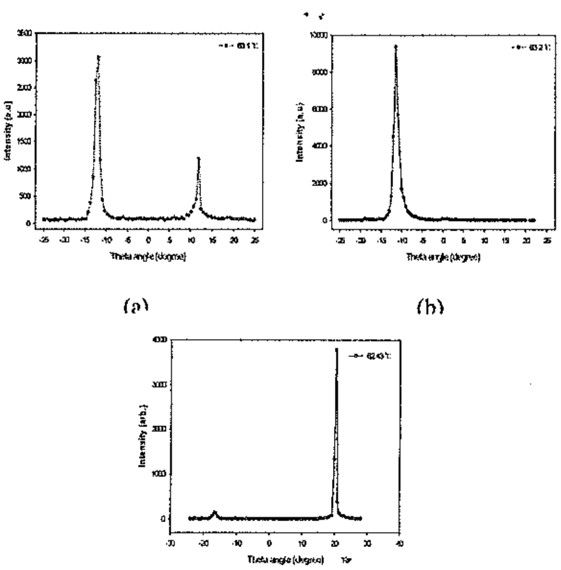


Fig. 6 V-T curves of PI-PSCOF before Thermal Cyclic and PI-PSCOF after Thermal Cyclic.

The cells are placed between crossed polarizers and are illuminated by He-Ne laser light of 633nm wavelength. Figure 5 and Table 1 show electro-optic characterization of the Pure FLC, PSCOF, and PIFLC cells. In three samples, transmittance, voltages, and response time are in almost same, in 20% change, and in below 1ms, respectively. The increase in the threshold voltage and response time for switching the FLC molecules near the polymer wall and layer influences the electro-optic properties. Transmittance at black stage of FLC cell is highest among three cells because of zig-zag defect. The contrast ratio of PI-PSCOF cell is lower than its of PSCOF cell because of light leak at PI-PSCOF cell. The reason is that we may not optimize the condition to make the polymer wall and layer. We have confirmed the thermal stability of PI-PSCOF through the Figure 6.

In Fig. 7, result of x-ray scattering obtained from three cells, (a) obtained typically Pure FLC cell shows two peaks at rocking scan which indicates a chevron structure. Figure 7(b) show one peak, which indicates bookshelf structure, obtained by theta scan at 63.2 ℃ using PSCOF cell made by binary mixture of 70wt% with the FLC Felix-016/100 and 30wt% and with pre-polymer NOA65. The strong peak position is near -12° which means the layer structure of PSCOF cell is a tilt-bookshelf structure and layer structure is very uniform. Like a PSCOF cell result, PI-PSCOF cell is almost a tilt-bookshelf structure with a strong peak at 20°. The tilt angle of bookshelf structure is same as tilt angle of layer as shown in Fig. 7 (b) and Fig. 7 (c) because of compensating the layer buckling. We can expect that the PI-PSCOF technology is one of best solution to naturally remove the zig-zag defect and to overcome the mechanical and thermal shock.



(a) (b)

(c)

Fig. 7 (a) Rocking scan of FLC cell made by pure Felix-016/100 FLC at 63.1 ℃. (b) Rocking scan of PSCOF cell made by mixture of Felix-016/100:NOA65=70:30 at 63.2 ℃. (c) Rocking scan of PI-PSCOF cell made by mixture of Felix-016/100:NOA65 = 50:50 at 62.43 ℃.

4. Concluding Remark

We successfully make a new PI-PSCOF cell using phase separation method which may be one of best solution for flexible display applied for moving picture. In this device, the FLC molecules are isolated and surrounded in polymer wall and polymer layers, respectively. Response time of PI-PSCOF cell, 0.8 ms, is slower than response time obtained from other two cells because of interaction between polymer wall and layer, and molecules. The contrast ratio is higher than 100:1 even though the PI-PSCOF cell may not be optimized. The x-ray result of PI-PSCOF cell almost shows one peak which means a tilt-bookshelf structure. It is very stable from mechanical and thermal shock. We can conclude that this technology can be one of best candidate for flexible application. In future work, we will optimize the condition to get best electro-optical results and prove that the PI-PSCOF mode will become the new best FLC modes for flexible display application.

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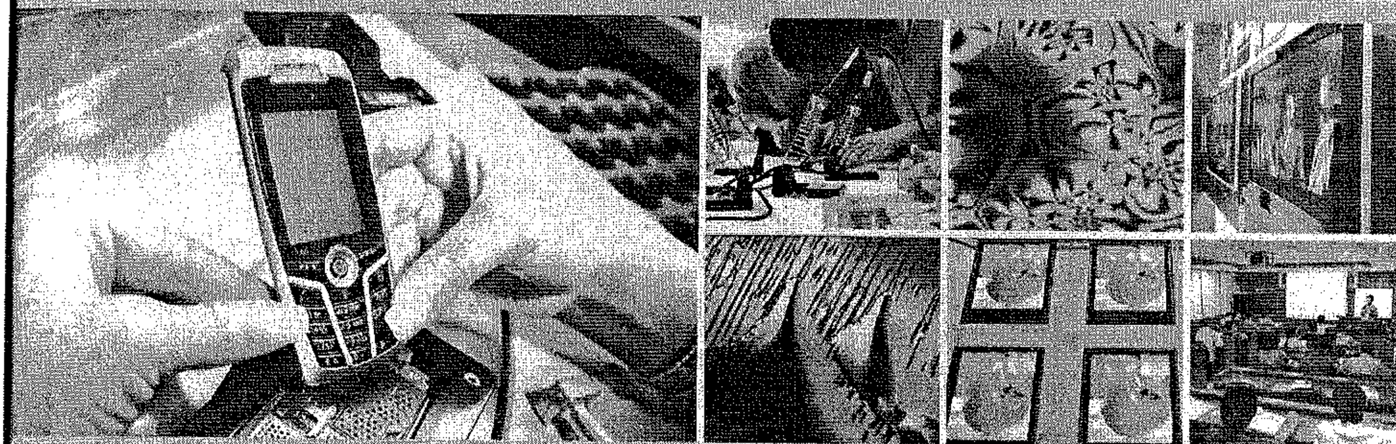

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