New Approach to Process Simplification for Flexible TFT-LCD

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ABSTRACT

A new approach is proposed to fabricate flexible TFT-LCD with minimal process steps. Single substrate and without conventional cell process is obtained by introducing AOC and developed PDLC coating on the top of array without PI alignment process. The 4.99" 294ppi AOC prototype LCD on a single substrate was fabricated.

1. INTRODUCTION

Flexible displays are crucial for the next generation display technology. This is due to its characteristics of shatterproof, light weight and thin. Flexible active-matrix organic light emitting diodes (AM-OLED) displays do not need backlight and exhibit single substrate, therefore, there is much potential for flexibility. On the contrary, flexibility for LCD may be limited due to it possesses dual substrate layers. When the LCD panel is bending, the upper color filter and lower array backplane substrates were distorted, it may cause light leakage and color mixing. In order to overcome these issues, complex design of black matrix (BM) and photo spacer (PS) have been studied.[1~3]

In this study, we have introduced a single substrate LCD with TFTs array integrated on the color filter (AOC) substrate, the TFTs was fabricated at temperature lower than 230°C and coating polymer dispersed liquid crystal (PDLC) on the top of array and without alignment layer. We have successfully demonstrated 4.99" 294ppi prototype LCD.

2. Experiment and Result

2.1 Polymer Dispersed Liquid Crystal

The PDLC is a two-phase system containing liquid crystal (LC) droplets that embedded in the polymer encapsulation layer. Under off-state is optically isotropic due to extremely small particle size effect of LC nanocapsules embedded in the nanoencapsulated layer and when applied voltage it forms multi-domain structures to be determined by the configuration of in-plane electrodes.[4] As shown in Figure 1.

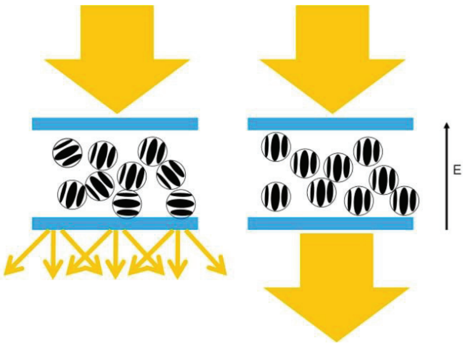

Fig. 1 Schematic diagram of PDLC operation.

2.2 AOC structure and process flow

In order to improve the alignment accuracy, the color filter (CF) and array used the same alignment marks, therefore the first PEP is metal mark. After the CF process including BM/R/G/B, the AOC structure had added an organic (OC-0) layer and passivation (PV-0) layer. The OC-0 layer was used to flatten unevenness surface of CF layer and the PV-0 layer was using a SiNx film to protect the organic layer to prevent the water permeation. As show in the Table I, conventional AOC configuration has dual substrates, metal mark on the upper substrate and the cell process was including alignment layer formation, photo spacer formation, photo-alignment or rubbing process, sealant formation, LC injection and seal process.

In this study, we have developed AOC structure using PDLC as shown in Figure 2. It has advantages of PEP reduction, photo-alignment or rubbing free, wide view angle and fast response time, except high operating voltage.

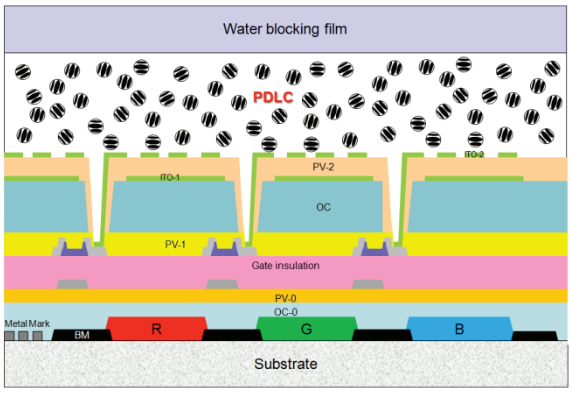

Fig. 2 Cross-section structure of AOC with PDLC

Table I Comparison of different structure and process flow

	STD	AOC	AOC+PDLC
Process (□ Lower sub. / ⁞ Upper sub.)	Lower sub.: Gate, CVD 3-layer, Source & Drain, PV-1, OC, ITO-1, PV-2, ITO-2; Upper sub.: BM, RGB, OC, PS	Lower sub.: Metal Mark, BM, RGB, OC-0, PV-0, Gate, CVD 3-layer, Source & Drain, PV-1, OC, ITO-1, PV-2, ITO-2, PS; Upper sub.: Metal Mark	Lower sub.: Metal Mark, BM, RGB, OC-0, PV-0, Gate, CVD 3-layer, Source & Drain, PV-1, OC, ITO-1, PV-2, ITO-2
PEP (Array+CF)	13 (8+5)	15 (14+1)	13 (13+0)

2.3 Low temperature CVD process

Low temperature (LT) CVD process is necessary for AOC structure to prevent the CF layer outgassing and color coordinate shift. Figure 3 shows the low temperature process resulted in little variation of the color coordinates. In addition, we had modified the low temperature SiN_x film stress to avoid the stacking film peeling as shown in Figure 4. In Table II, the preferred LT SiN_x film stress should be close to zero, LT-1 SiN_x having more negative film stress (-223.3MPa) caused the film peeling phenomenon. The transfer characteristics of low temperature a-Si TFTs were shown in Figure 5. Comparing to the normal high temperature (HT) a-Si TFTs, the on-current of LT-TFT was comparable to HT-TFT. The off-current of LT-TFT was smaller than HT-TFT. The low temperature a-Si TFTs exhibited well on/off current ratio and it is suitable for the AOC structure.

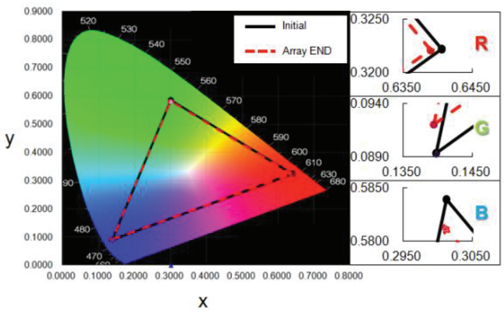

Fig. 3 Comparison of process for color coordinates

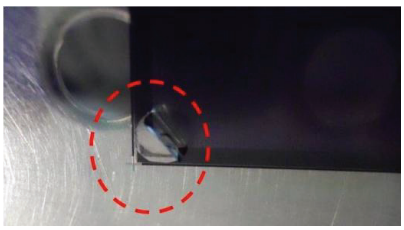

Fig. 4 Stacking film peeling image of recipe LT-1.

Table II Film stress test.

Recipe	SiN_x Film Stress (MPa)
LT-1	**-223.3**
LT-2	**-31.8**

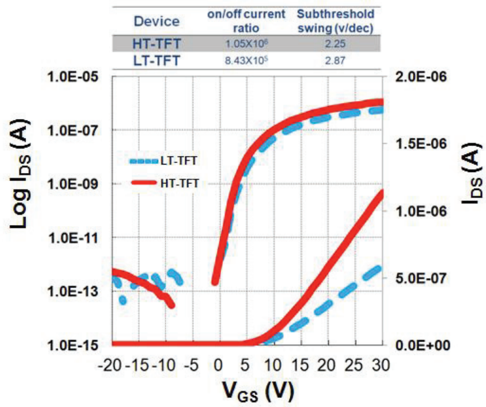

Fig. 5 Comparison of LT and HT a-Si TFT transfer characteristic.

3. SUMMARY

We have demonstrated the minimal process steps by using AOC with coating PDLC, the LCD cell can be fabricated on a single substrate as shown in Figure 6. The AOC with coating PDLC exhibits the simple and cost-effective approach for flexible LCD application.

Fig. 6 4.99” 294ppi AOC with PDLC panel light on image.

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