Special Thema

Transmissive 7" VGA a-Si TFT Plastic LCD Using Low Temperature Process and Holding Spacer

이우재 책임연구원
(삼성전자㈜ LCD연구소 Mobile Device 개발팀)

Abstract

A 7.0-inch transmissive type plastic TFT-LCD was developed at the resolution of 640 × 3 × 480 lines (114 ppi). All of the processes of TFT, color filter and LC were carried out below 130 ℃ on PES plastic films. The process conditions of TFT, color filter and LC were optimized for large area TFT-LCD on plastic substrate. The backplane and the color filter was strongly adhered while the panel was bending by using holding spacers.

1. Introduction

The technology mega-trend of the mobile displays has been emphasizing at the viewpoint of convenience, personalization, and connectivity as well as display performance [1]. The development of plastic LCD has progressed for such mobile appliances as hand-held phones and personal digital assistants (PDAs) due to the distinguishable advantages of plastics with respect to glasses: ie. ultra-slim, light-weight and unbreakable, etc. Moreover, the needs of better features for plastic TFT-LCD were increasing to maximize the display performance such as higher resolution and fast response time for moving images. To meet the needs it became necessary to adapt active matrix LCDs on plastic substrates [2, 3]. In the present study a high resolution a-Si TFT based AMLCD device was developed on a Polyethersulfone (PES) substrate. Main components of the display were built on the plastic substrate: TFT and color filter. In order to maintain the cell gap while bending, the holding spacers were used.

2. Development of Plastic TFT-LCD

While the practical aperture ratio of transmissive LCD depends on alignment of each layer in TFT processes, it is important to control the misalignment carefully during the TFT process to fabricate a high-resolution TFT array. However, the alignment control of the TFT fabrication on plastic substrate is one of the most difficult things to resolve because of thermal expansion and shrinkage of plastic substrate during the thermal history at the TFT processes. The same issue occurs at the color filter fabrication processes on the plastics. We made three major efforts to minimize the dimensional change of plastic substrate during the TFT processes. Firstly, the plastic substrate was annealed to allow it shrink before entering the TFT process. And then the barrier layer of SiNx was applied to prevent water or moisture from penetrating. Secondly, all the TFT and LC processes took place below 130 ℃ to prevent the thermal distortion of plastic substrate. Finally, we reflected the dimensional change of the unavoidable misalignment in designing the mask.

We utilized PES films of 200 ㎛ for the plastic substrate. Although PES is not the best in coefficient of thermal expansion (54 ppm) point of view, it has high glass transition temperature (Tg) of 220 ℃, being highly transparent and commercially available. On the other hand, another LCD manufacturer reported that a slim glass was used to develop ultra-thin and light LCD instead of plastic [4]. A very thin glass plate can utilize the high temperatures of the normal TFT and LC processes, though it is not easy to achieve good mechanical strength and low manufacturing cost. Despite of using highly thermally stable PES films at the present time, we would like to use ordinary plastic films such as polyester (PET) and polycarbonate (PC), that are much less expensive than glass substrate, in the near future. In order to do so, it is necessary to develop even lower temperature processes of TFT and LC as well as plastic coating technology to release thermal stress of plastic film.

3. Results and Discussion

As mentioned above the film needs to be annealed prior to the TFT process. To minimize the dimensional changes, the barrier coatings on both sides were applied and the proper annealing was introduced between the barrier coatings. The plastic substrate used in this research had a side of barrier coating. It was annealed and followed by the second barrier coating on the opposite side. After this process, the films showed minimum dimensional changes during the fabrication processes. Fig. 1 showed the differences between the proper annealing and improper annealing (i.e., plastic substrate was annealed after second barrier coating was deposited).

After proper annealing processed done, the film was attached on a glass using the adhesives which can be delaminated by temperature or UV light control. And then, the film coated by SiNx deposited at 130 ℃ in PECVD to generate a gas and water-vapor barrier. Next, the gate electrodes were processed on the SiNx coated PES, and then SiNx, a-Si:H, and n+ Si:H were deposited by PECVD process at 130 ℃. After a-Si:H and n+ Si:H were patterned, source and drain electrodes were formed on them, followed by a dry etch of n+ Si:H. Next, organic passivation and pixel electrodes were consecutively formed to fabricate the TFT array on 7.0-inch PES successfully.

Fig. 2 shows the transfer characteristic and stability of an fabricated a-Si:H TFT on PES. The fabricated a-Si:H TFT has a field effect mobility of about 0.5 cm^2/Vs. The on-current is above 1.1 μA and off-current is below 10^{-13} A. Thus, the on/off-current ratio is 7 decades when the gate voltage varies from - 7 V to + 20 V. After all stress steps for 5,000 seconds, on-current decreased from 1.08 μA to 0.476 μA but I_{off} degradation cannot be found. Fitting of the ΔV_{TH} vs. stress time curve according to the $\Delta V_{TH} \propto |V_{gs}|^{\alpha} t^{\beta}$ equation gives the fitting parameters of $\alpha = -0.43$, $\beta = 0.30$. The performance of achieved TFT on 7 inch PES substrates is considered to be fairly good, especially for such a low deposition temperature as 130 ℃.

On the other hand, the main issue of color filter process is the dimensional change of plastic substrates during color filter process. The moisture absorption is an important factor in dimensional change of plastic substrates. In order to minimize it, we have to optimize the sequence of cure process and the barrier layer. In addition, we developed the low temperature curing system of the color photo resist at below 130 ℃. We can obtain the misalignment free between color pattern and black matrix pattern at below 10 um.

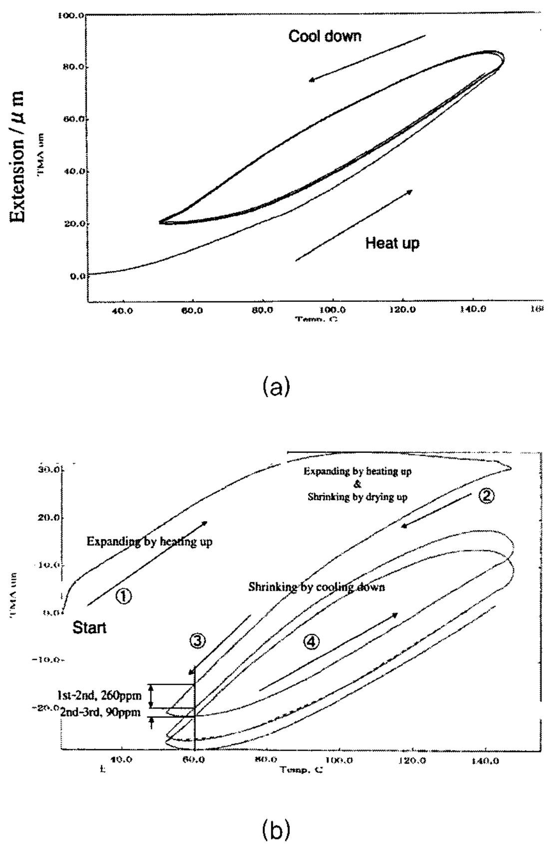


Fig. 1. TMA analysis of plastic substrate with second barrier coating (a) with proper annealing, (b) without proper annealing.

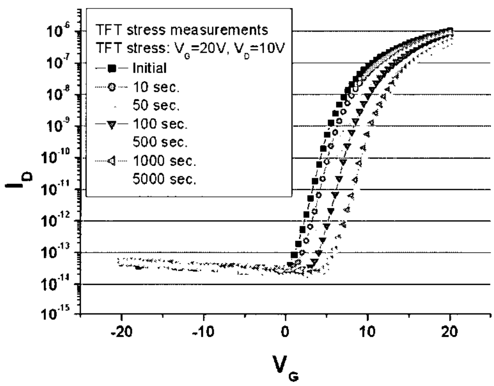


Fig. 2. The transfer characteristic and stability of a-Si:H TFT on PES.

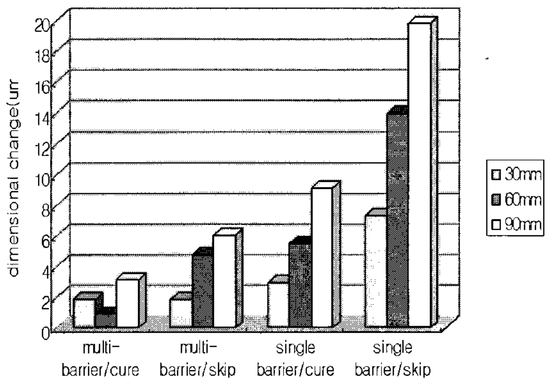


Fig. 3. Dimensional Change of CF pattern on plastic substrate by process condition.

7.0-inch sized a-Si:H TFT array on PES was able to be fabricated through the low temperature CVD process (< 130 ℃) for plastic LCD with 640 × 3 × 480. Finally, the TFT film and color filter were delaminated from a glass before plastic LC assembly processes.

All plastic LC processes also took place at low temperature to avoid severe distortion between the plastic TFT and color filter. First, the PI processes were done while plastic substrate was laminated on the glass carrier. The coated LC alignment layer was dried at 130 ℃. After the PI baking processes, the TFT and color filter were separated from the carriers, the assembly steps were followed. We used special holding spacers to maintain cell gap uniformly while bending (Fig. 4). Using UV sealant the color filter and TFT layers were assembled. The assembled cell was then filled with liquid crystal via a conventional vacuum filling process. This filling process will be changed to a one-drop filling process to be suitable for mass production in the future. We used the elastic UV sealant able to conserve flexibility of the cell. Upon finishing the LC process the cell gap uniformity reached to 4.7 ± 0.2 ㎛.

After all, we developed a 7.0-inch transmissive type plastic TFT-LCD with 640 × 3 × 480 lines (114 ppi) using LCD pilot line as shown in Figure 4. It has color reproducibility of 60 % and aperture ratio of 40 %. The resulting panel luminance is 100 cd/m^2 (transmittance of 4 %).

4. Conclusion

A 7.0-inch transmissive type plastic TFT-LCD was developed with 640 × 3 × 480 lines (114 ppi). All the TFT, color filter, and LC processes were carried out at less than 130 ℃ on PES plastic. The holding spacers were applied to maintain cell gap

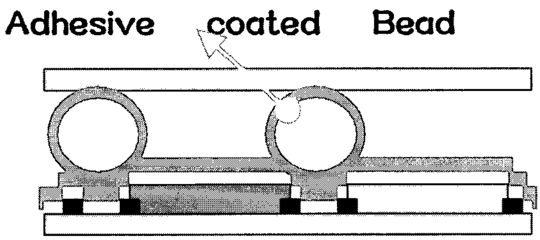
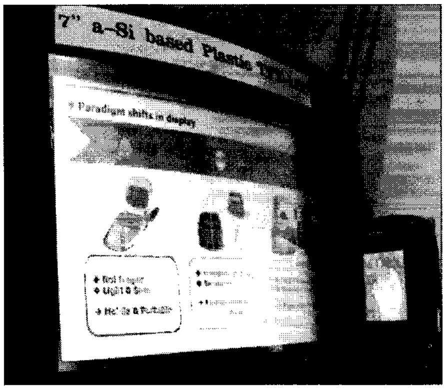


Fig. 4. Hold spacers to maintain cell gap uniformly when the panel was bended.



(a)

(b)

Fig. 5. Prototype of 7.0-inch transmissive plastic TFT-LCD.

uniformly while the panel was bended. Therefore, it could be very effective not only for a slim and free design of hand-held phones and personal digital assistants (PDAs), but also for a real flexible displays.

References

[1] Semiconductor FPD World, p. 30, August, 2002.
[2] S. Aomori et al, "Reflective MIM-LCD Using a Plastic Substrate", SID'01 DIGEST, p. 558.
[3] Y. Okada et al, "A 4-inch Reflective Color TFT-LCD Using a Plastic Substrate", SID'02 DIGEST, p. 1204.
[4] T. Hioki et al, "A Flexible 8.4-in. Color Low-temperature Poly-Si TFT-LCD", IDW'02, p. 319.

저|자|약|력

성 명 : 이우재

◈ 학 력
· 1991년 연세대 화학과 이학사
· 1995년 Iowa State Univ. 화학과 이학석사
· 2000년 Iowa State Univ. 화학과 이학박사

◈ 경 력
· 2000년 – 2001년 Bowling Green State University 연구원
· 2001년 – 2002년 Univ. of Wisconsin at Madison 연구원
· 2002년 – 현 재 삼성전자㈜ LCD연구소 Mobile Device 개발팀 책임연구원