Optimal Barrier Coating Processes to maximize the Alignment of Layers on Plastic Substrates

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Abstract

A 5.0-inch plastic TFT-LCD with the resolution of 400 X 3 X 300 lines (120ppi) was developed. The device is a transmissive type with the transparent PES plastic substrates. The PES films with one side barrier coating were used for the device. In order to produce the high resolution display device, the alignments between all the layers for the TFT and CF are essential. The fundamental shrinkage effect and the thermal expansion behavior of the plastic substrates with and without the barrier coatings were studied. The proper annealing processes followed by immediate second bar-rier coating processes provide the optimal alignment between all the layers of the TFT and CF..

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: i.e., ultra-slim, light-weighed, and unbreakable, etc. 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, color filter and backlight unit. To make a high resolution display devices, the precise alignments between the layers are essential. Therefore, the fundamental shrinkage effect and the thermal expansion behavior of the plastic substrates with and without the barrier coatings were studied.

2. Results

Normally, the plastic substrate was annealed before any TFT processes followed by cleaning process. Then either CVD or Sputter processes was done for the barrier coating of the plastic substrates, on both sides not only to minimize oxygen and water vapor penetration but also to balance the stresses on each side after the TFT processes. Since the plastic substrate was cleaned before the barrier coating processes on both side, there are huge chances to absorb the moisture, organic solvents and so forth.

The plastic substrate absorbs the moisture without the proper barrier coatings on both sides and the edges. In the Figure 1, the thermal behavior of the plastic substrates with one side barrier coating was shown using TMA analysis. When the substrate was annealed, the expansion of the plastic with the heat was anticipated; however, the shrinkage was occurred shown in the Figure 1 in the beginning and then when it cooled down after reached to 150 ℃, it expanded as expected. It means that the plastic substrate absorbed the moisture during the cleaning process and the annealing effect was faded away.

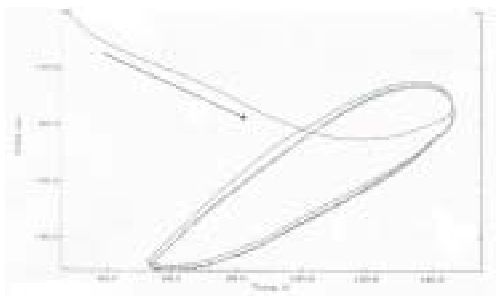


Figure 1. TMA of one side barrier coated plastic.

The thermal behavior of plastic substrate with barrier coating on both sides without proper removal of the moisture was quite complicated (shown in Figure 2). At the low temperature region of the beginning of thermal processes (①), the plastic was expanded since the evaporation was not active and moisture can be expelled only to the edges without the barriers. At the higher temperature (②), the evaporation became active and the shrinkage can compete against shrinkage. After the first heating cycle, the shrinkage was occurred and there was a big dimensional change was observed (③). With the further heating cycle, continuing dimensional changes were observed (④). Without the proper treatment, the barrier coating itself provided more severe problems on the alignment of the layers on TFT processes.

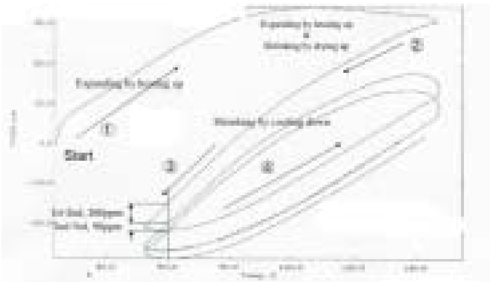


Figure 2. TMA of both sides barrier coated plastic without proper annealing.

Based on the results, extra annealing process was taken between the cleaning and the second barrier coating processes. With this process, the moisture was removed adequately and the barrier coating was efficiently worked as expected shown in Figure 3.

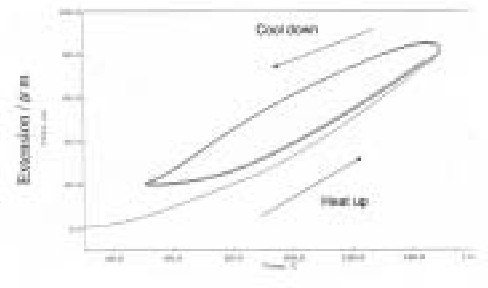
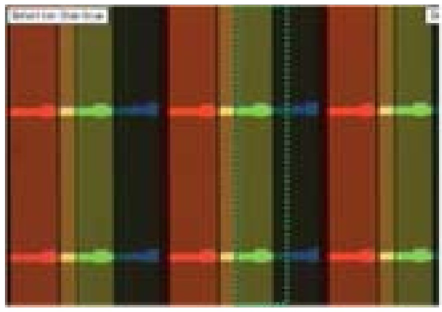


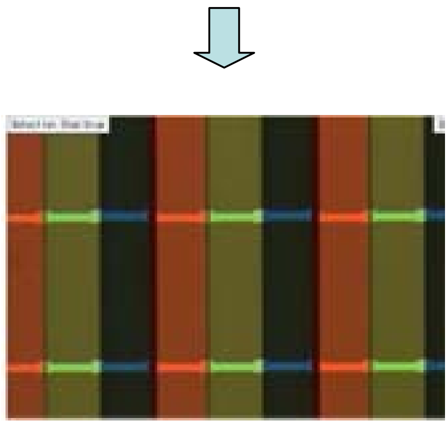
Figure 3. TMA of plastic with proper annealing and barrier coatings.

3. Impacts

An optimal barrier coating process was achieved with the proper annealing timing and the barrier layer deposition processes. Using these processes, the misalignment of the layers of TFT and CF was minimized. Without these, high resolution plastic LCD device is impossible. All the TFT, color filter, and LC processes were carried out at less than 150 ℃ on PES plastic. All the misalignment between the layers were controlled within 10 μm. (Figure 4)



(a)



(b)

Figure 4. C/F (a) before proper annealing and barrier process (b) after proper annealing and barrier process

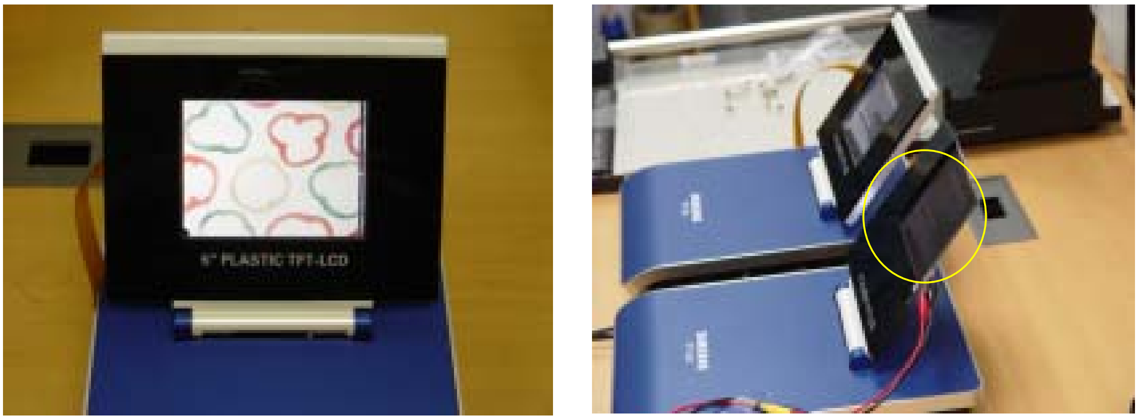
Using this improvement, a 5.0-inch transmissive type plastic TFT-LCD (Figure 5) was developed with 400 X 3 X 300 lines (100ppi).

4 References

[1] Semiconductor FPD World, pp30-40, August (2002).

[2] S. Aomori et al, "Reflective MIM-LCD Using a Plastic Substrate", SID'01 DIGEST, pp558.

[3] Y. Okada et al, "A 4-inch Reflective Color TFT-LCD Using a Plastic Substrate", SID'02 DIGEST, pp1204.



(a) CCFL backlight. **(b) Flexible inorganic EL backlight**

Figure 5. 5" Transimissive full colored plastic LCD module.