A high accuracy plastic color filter development by using time-recovery and stress-free methods

W. Y. Cheng, K. L. Lo, Y. A. Sha, P. J. Su, C. H. Hsieh, K. H. Chang, C. C. Hsiao, J.W. Shiu, S. Y. Fuh, Y. C. Liao, J. C. Yang, D. W. Lee, K. C. Lee, and Y. P. Chang

Display Technology Center, Industrial Technology Research Institute,

Chutung, Hsinchu, Taiwan 310, R.O.C.

weiyuan.cheng@itri.org.tw

Abstract: *We have successfully developed the new processes for fabricating a high accuracy plastic color filter by using time-recovery and stress-free methods. So far, the deformation of plastic film is still an unavoidable problem during a plastic color filter development, which usually worsens the accuracy of superposition between different color layers. To minimize the influence of plastic deformation on color filter development, we proposed the new methods to resolve the problem so as to obtain a high accuracy color filter. In this study, the time-recovery and stress-free methods were adopted to fabricate a 4.1-inch QVGA plastic color filter, and a prototype of the corresponding hybrid LCD has also been shown.*

Keywords: *plastic color filter, time-recovery, stress-free, hybrid LCD.*

Introduction

In recent years, hybrid and flexible displays have been attracted much attention because of its light weight and thinness properties[1-2]. Due to the above advantages, the displays are very suitable for mobile display application, such as personal digital assistants (PDAs), watches, cellular phone and electronic books.

A color filter (CF) using plastic substrate is an essential component for hybrid and flexible LCDs. Fabricating a CF by pigment dispersion method has several advantages in color quality and mature process, so it has been adopted by most manufacturers[3]. However, the deformation of plastic substrate caused by thermal processes and moisture swelling is much larger than glass substrate while CF development, because of the large CTE of plastic compared with that of glass. And it usually worsens the alignment accuracy of different color layers on plastic and makes the handling more difficult.

To minimize the influence of plastic deformation during developing a CF, we proposed the new methods to compensate the poor dimensional stability of plastic so as to obtain a high accuracy CF. In this study, first, a carrier holder coated with PTFE was used to avoid the stress formed in the plastic substrate, i.e., stress-free method. Second, a newly design of alignment mark on the photomask was also used to observing the dimensional variation of the plastic substrate after pre-bake step so as to find a best condition to fabricate the high accuracy CF, i.e., time-recovery method. Finally, a prototype of the corresponding hybrid LCD has also been shown.

Results and discussions

In this study, PC film with 127 μm thickness was used for the plastic CF development. The thermal stability of PC film and manufacturing process should be concerned to reduce the stress occurred in the PC film during CF development. Table 1 lists some properties of glass and PC, and Fig. 1 shows the flowchart of the manufacturing process for CF development. As shown in Fig. 1, the PC film is encountered 7 times thermal processes (80^0C and 180^0C) during CF development. And as listed in table 1, the CTE of PC (73 ppm/^{0}C) film is about 20 times larger than that of glass (3.7 ppm/^{0}C). This means the PC film will first expand and then shrinks in size. That implies thermal stress will occur and that would also worsen the accuracy of superposition between different color layers if the glass substrate is used as the holder to carry the PC film for the CF development.

Table 1. Properties of glass and PC

	Total Transmittance (%)	Haze (%)	Retardation (%)	CTE (ppm/ ^{0}C)	Heat shrinkage (%)
Glass	93	93	1	3.7	0
PC	90	90	1	73	0.01

To reduce the stress formed in the PC film, we proposed a newly-developed handling method (so-called stress-free method) by coating PTFE and equipped with other tools on glass substrate (not shown here) as the holder for the PC film.

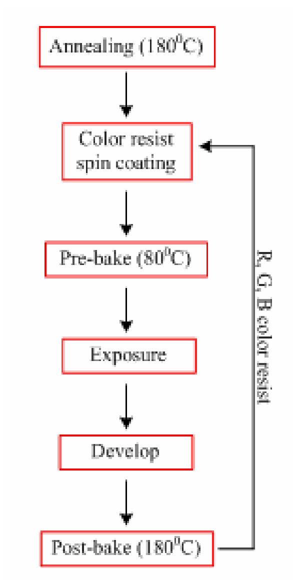

Figure 1. Flowchart of manufacturing process for color filter development.

Fig. 2 shows the PC film after heat treatment by using this method. As Fig. 2 shows, the PC film flatly covered on glass substrate. This result evidences our proposed method which means that this method could reduce the stress formed in the PC film after a thermal treatment. The thermal deformation of plastic is an important issue for fabricating a plastic CF. Variation of the substrate dimension leads to the inaccuracy of alignment, and the thermal deformation is hard to define during CF development.

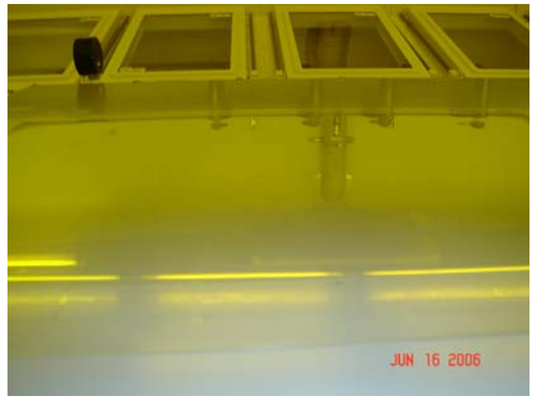

Figure 2. Photograph of PC/glass substrate by stress-free method after heat treatment.

Multi-times thermal processes, color resists and solvents complicate the thermal deformation of plastic. In this work, a new process for fabricating CF on plastic substrate has been developed to improve the alignment accuracy of superposition between different color layers. The main process was similar to that of the CF developed on glass substrate. But some handling techniques were adopted to overcome the deformation problems caused by thermal process. The tact time between the pre-bake step and exposing step was a key point to the accuracy of alignment [4]. The plastic substrate expanded then shrunk after pre-bake, and then expanded slowly because of moisture absorbency and polymer relaxation. If a tact time that substrates expanded to the same dimension before the exposing step could be found, each color layer could be exposed in its related position accurately. Unfortunately, the degree of substrate shrinkage and expanding rate were not the same after each pre-bake step. In order to make sure the dimension of the plastic substrate was the same before each exposing step, a simple method called time-recovery (alignment mark fitting) method was adopted to observe the deformation of plastic substrates. The tact time between the first pre-bake step and the first exposing step was controlled to make the plastic substrate expand to a specific dimension. After first exposing and developing step, two alignment marks were formed on the both edge of the substrate as shown in Fig. 3b.

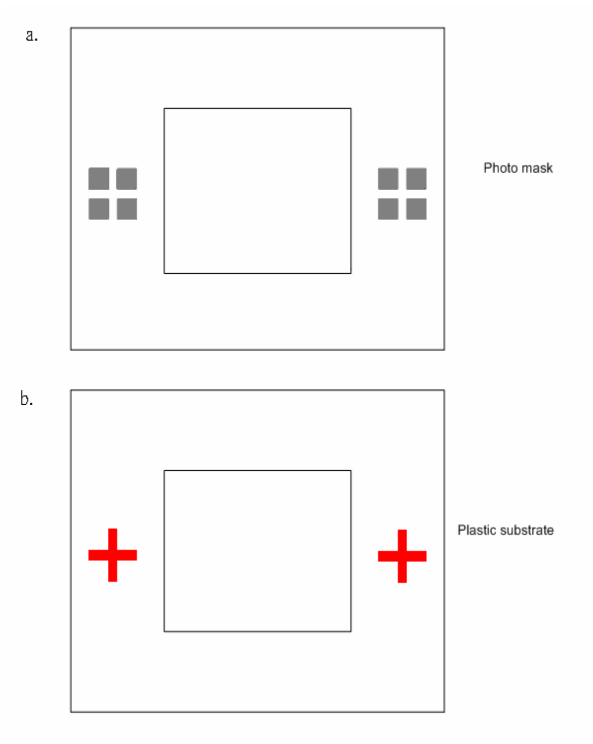

Figure 3 a. two alignment marks were designed on the photomask.
b. two corresponding marks were fabricated on the plastic substrate after photolithography.

After second pre-bake, the substrate was put into exposure instrument subsequently, and these alignment marks were observed under the camera as shown in Fig. 4. When left side alignment mark of the plastic substrate was fitted with the mark on the photomask, the right side alignment mark would not be in the correct position (Fig. 4a). This was because the dimension of the substrate after second pre-bake became smaller. As time went on, the substrate expanded, and the deviation of left alignment mark decreased slowly (Fig. 4b). When the right side alignment mark was fitted with the mark on the photo mask (Fig. 4c), the substrate was supposed to have the same dimension as it was exposed in the first step and the second exposing step could be started to form the second color layer in the accurate position. The same process could be repeated in the next exposing step.

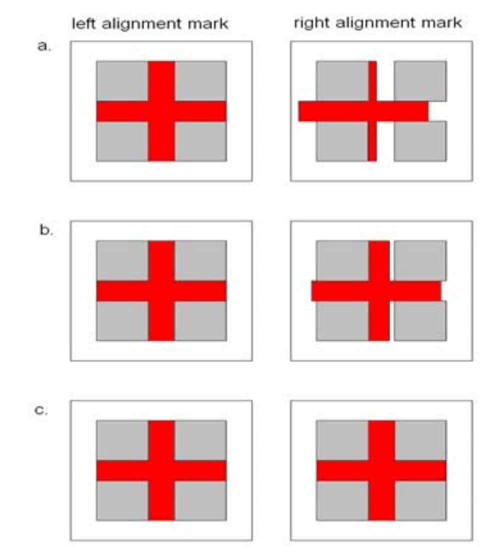

Figure 4. The alignment marks under camera.

Fig.5a and 5b show a prototype of the 4.1-inch hybrid LCD and its corresponding CF, respectively. As shown in Fig. 5b, a high accuracy CF is observed. This evidences that a high accuracy CF can be fabricated by using the time-recovery and stress-free methods.

a.

b.

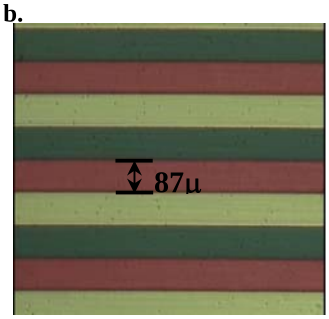

Figure 5 a. A prototype of the 4.1-inch QVGA hybrid LCD
b. Its corresponding color filter fabricated by using time-recovery and stress-free methods

Conclusions

We have successfully developed the new processes for fabricating a high accuracy plastic color filter by using time-recovery and stress-free methods. By using these two methods we proposed, the influence of thermal deformation of plastic can be minimized and a high accuracy of CF can be fabricated.

References

1. S. Utsunomiya, T. Saeki, S. Inoue and T. Shimoda, "*Low Temperature Poly-Si TFT-LCD Transferred onto Plastic Substrate Using Surface Free Technology by Laser Ablation/Annealing (SUFTLA®)*," *IDW'01*, 2001, p.339-342.

2 M. Okamoto, Y. Okada, A. Ban, W. Oka, Y. Matsuda and S. Shibahara, "Development of a Color Reflective TFT-LCD Using Plastic Substrates," *IDW'02*, 2002, p.315-346.

3. Y. Chikama, H. Nishiki, Y. Nakatani, N. Watanabe, H. Gotoh, H. Umeda and W. Oka, "Development of a Transmissive a-Si TFT-LCD with Transparent Plastic Substrates," *IDW'04*, 2004, p.375-378.

4. C. H. Chen, K. H. Liu, Y. A. Sha, L. P. Wang, J. M. Ding, K. H. Chang, S. S. Liu, C. C. Liao and J. W. Shiu, "Development of Color Filter Processes on Plastic Substrate," *IDW'02*, 2002, p.315-346.