An Optimized Design for Improving LTPS LCD Blind-Hole's PV Value

Qingwen Hu, Xia Dan, Yuanyuan Zhong, Keshi Yang, Chao Deng, Xiai Xu, Zongzhui Liu, Jiamiao Kang, Xuexin Lan, Yanshan Huang, Guozhao Chen, Junyi Li

qingwen_hu@tianma.cn
Research and Development Center, Xiamen Tianma Microelectronics Co., Ltd., Xiamen, China

Keywords: Blind Hole, Full-screen-display, PV Value

ABSTRACT

The key factor that influenced the force on blind hole from the mechanism is analyzed. By optimizing the design of the PS support in the blind hole area, the PV value can be greatly improved and the thickness of the substrate can be reduced, which greatly improved user's experience.

1 INTRODUCTION

Beginning in 2017, the full-screen mobile phone becomes more and more popular because of the significant improvement in the user's experience. In just 2~3 years, the full-screen mobile phone has undergone three generations of upgrades, namely the first-generation 18:9 full-screen mobile phone, the second-generation "Notch" screen, and the third-generation Hole full-screen[1]. Blind Hole Display has high screen-to-body ratio (generally> 90%), small blind hole aperture, small hole area border, and good visual advantages. Once launched, it was sought after by consumers and quickly became popular.

There are fatal effects of the optical characteristic of the blind hole area for shooting performance of the camera under the hole.The transmittance is one of the most important factors that affect the imaging of the camera. Another equally important factor is the PV (peak-to-vally) value. The PV value is a widely used parameter in evaluating the quality of optical surface and camera-hole. By monitoring the PV value, the optical path difference (OPD) of the camera hole can be reflected. Figure 1 shows the mechanism of the PV value measuring of the blind hole of the panel. When a light beam with a wavelength of λ is perpendicular to the blind hole, the maximum OPD Δd formed by it can be given by equation (1)

$$\Delta d = n2d2 - n1d1 \qquad (1)$$

where n1, n2 are the refractive index of the material, and d1, d2 are the corresponding optical paths. Then the PV value can be obtained by equation (2)

$$PV = \frac{\Delta d}{\lambda} = \frac{n2d2 - n1d1}{\lambda} \qquad (2)$$

In this paper, we used Shineoptics's "G8U-PH" laser interferometer to test the PV of the blind hole.

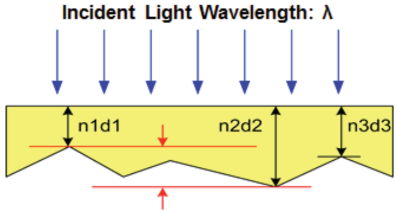

Fig.1 The mechanism of the PV value measuring

2 EXPERIMENT

2.1 Differences in PV Value

In order to increase the transmittance of the blind hole as much as possible, the designers do their best to remove the film in the blind hole area. The design of removing the film in the blind hole area will cause serious insufficient support in the blind hole area, causing deformation of the blind hole area, and deterioration of the PV value. Taking punch Φ3.5 as an example, the results of the PV value corresponding to different substrate thicknesses are shown in Figure 2, the thinner the substrate thickness, the worse the PV value, where "0.16T" means that the substrates of TFT and CF are both 0.16mm, and the total thickness of the panel is 0.32mm

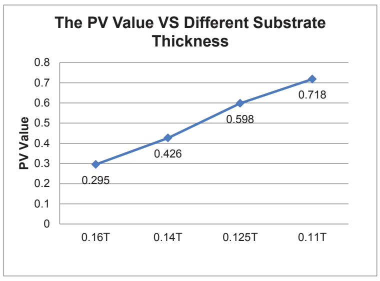

Fig. 2 The relationship between the cell PV value and substrate thickness

2.2 Reasons for Differences in PV Value

Why do different substrate thicknesses have different PV values under the same design? We tried to do some analysis on the mechanism. As shown in Figure 3, the panel is under the pressure of atmospheric pressure from the outside to the inside, and is balanced with the support of the liquid crystal and photo spacer (PS) from the inside to the outside. In the blind hole zone, the atmospheric pressure on the substrate is shown in equation (3)

$$F_{Hole}=F_{ATM}=P_{ATM}*S_{Hole}=P_{ATM}*\pi\Phi_{PS}^2/4\propto\Phi_{PS}^2 \quad (3)$$

Where F_{Hole} is the pressure on the blind hole, ATM means standard atmospheric pressure, Φ_{PS} is the minimum support diameter formed by the PS in the border zone of the blind hole, and the PS support in the innermost ring is similar to a circular ring. Once the Φ_{PS} support position is fixed, the F_{Hole} of the blind hole is determined，as the substrate becomes thinner, the rigidity of the substrate decreases. The greater the concave deformation of the substrate, the worse the PV value is easily to understand.

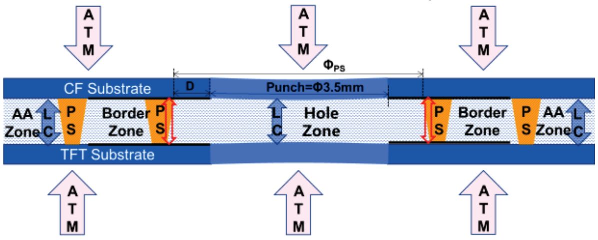

Fig. 3 The stress analysis of the blind hole

From equation (3), it can be concluded that in order to minimize the F_{Hole} value, we must maintain the minimum Φ_{PS} design. We have studied the conventional Punch 3.5mm blind holes. The actual distance between the innermost PS-ring and the border of the blind hole zone is about 0.15~0.2mm, in other words, the minimum Φ_{PS} formed by the innermost PS-ring is about Φ3.8~4.0mm. In order to improve the PV value, we have designed different PS DOE to improve the PV value.

2.3 Optimized Designs of the PS Support

The goal of our DOE design is to reduce the actual Φ_{PS} as much as possible, supplemented by increasing the support area of the innermost PS-ring, as shown in Table 1. The plan and cross-sectional schematic diagrams are shown in Figure 4. In addition to the internal shift design to reduce the actual Φ_{PS}, we also designed a M3 + Main-PS as the "over-support" type.

Table 1 DOE table of ΦPS Design

DOE	Punch	Main-PS	Sub-PS
Design 1	3.5mm	N/A	Oval-Shape, Distance to inner edge: 20um
Design 2	3.5mm	N/A	Dot-Shape, Distance to inner edge: 20um
Design 3	3.5mm	Dot-Shape, & M3 "over-support"	Dot-Shape, Distance to inner edge: 20um
REF	3.5mm	N/A	Dot-Shape, Distance to inner edge: 150~200um

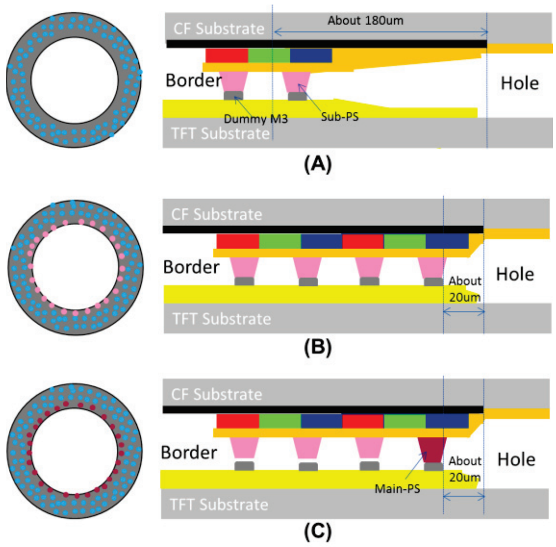

Fig. 4 Optimized design of PS support. (A)REF Design; (B)Minimum Φ_{PS} With Sub-PS; (C) Minimum Φ_{PS} With M3 + Main-PS as "over-support"

3 RESULTS

We tested three DOE Panels with different optimized designs in Table 1, and added the samples before improvement as a reference (marked as REF), and thinned them to 0.14T and 0.125T respectively. Each set of data collected no less than The quantity of 60pcs. Figures 5 and 6 are the test results of the PV value of the substrate thickness of 0.14T and 0.125T. No matter 0.14T or 0.125T, the optimized design can greatly improve the PV value compared to REF. Among them, Design 1 can improve up to 0.225 at 0.14T, and 0.18 at 0.125T. Design 2 is similar to Design 1, and the PV value is also similar. However，Design 3 is the design with the worst improvement in PV value among the three optimization designs due to the formation of "over-support" on the edge of the hole, which enlarged the deformation of the hole.

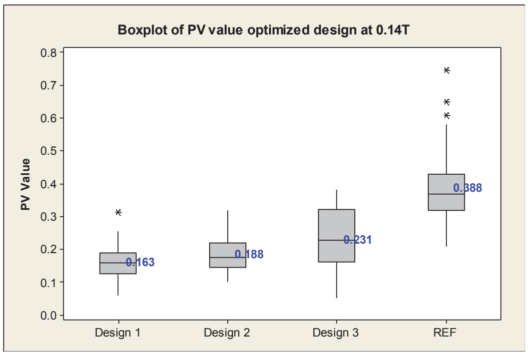

Fig. 5 Optimized design to improve PV value at 0.14T

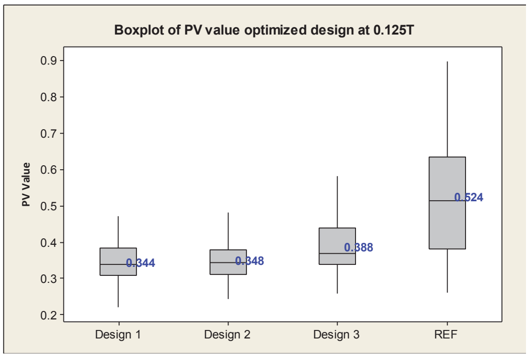

Fig. 6 Optimized design to improve PV value at 0.125T

4 CONCLUSIONS

By optimizing the design of the PS support in the blind hole area, the PV value of the blind hole can be greatly improved: the best Design 1 improved the PV value of 0.14T by 0.225, and 0.125T improved by 0.18. In this way, through the PV value optimization design scheme, the PV value is no longer the risk of thinner substrates. It can reduce the substrate thickness of the blind hole full-screen mobile phone and greatly improve the user experience.

REFERENCES

[1] H. Xie, D. Li, Z. Wang, X. Zhou, B. Shen, J. Li, “Research on Full-Screen Notch of LTPS LCD”, SID Symposium Digest, P-53, 1396-1398 (2018).

[2] X. Lan, Y. Huang, Y. Zhou, X. Wang, S. Lan, L. Bei, C. Deng, Z. Zhu, G. Lai, G. Chen, J. Li, L. Wang, “Novel LCD Devices with Circular Hole in Active Area for Camera Integration”, IDM’18, DESp1-1, 1445-1447 (2018).