

Four-Edge Deeply Curved AMOLED Display

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Abstract

The 4-edge curved display is one kind of flagship form of flexible display. In this paper, we study the effect of materials and back plate film (BPF) patterning on wrinkle effect of 4-edge curved display. By optimizing materials and pattern design of module stacking, the bending degree is improved obviously. In addition, a wrinkle prediction model is established, and the actual wrinkle degree can be predicted by CAE.

Author Keywords

4-edge curved; wrinkle; AMOLED; patterning; redundancy

1. Introduction

In recent years, active matrix organic light-emitting diode (AMOLED) has rapidly evolved from 2D, 2.5D to 3D display, and 3D display products have been widely used in mobile phone products^[1]. 3D mobile phone products are mainly long side bending, mobile phone display panel of the 4-edge curved products are fixed arc-bending, because of its 3D display effect is obvious, can reduce the front display border. When the display thickness and laminated structure is fixed, the higher the curvature of the four 4-edge of the cover plate is, the more serious the wrinkle is after 3D lamination^[2-4].

As shown in Figure 1, the interface position between the long side and short side of the 4-edge curved cover glass (CG) is a non-zero Gaussian surface, which is called the corner position in this paper. On the long and short sides, although CG is curved, but the Panel and CG laminated only need to be simple bending to achieve shaping. On the corner position, due to the area difference between CG and the panel, wrinkles will appear after the panel is laminated with CG. As shown in Figure 2, the smaller the bending radius R1 of CG on the long side and the short side is, the higher the height h is, and the greater the Angle θ is, the greater the bending degree of the corner position is, the bigger the area difference between CG and the panel is, and the panel at the corner position after fully laminating will appear obvious wrinkle. In this paper, "redundancy" is used to represent the bending degree of the corner position without wrinkles after the panel is laminated with CG. The bigger the redundancy is, the bigger the curvature of CG four edges is.

In this paper, by optimizing module material and patterning module structure, the wrinkle of 4-edge curved panel is eliminated and the redundancy of 4-edge curved display module is increased. In addition, a wrinkle prediction model is established to accurately predict the actual wrinkle condition through mechanical simulation in the product design stage.



Figure 1. Wrinkles at the corners position on CG

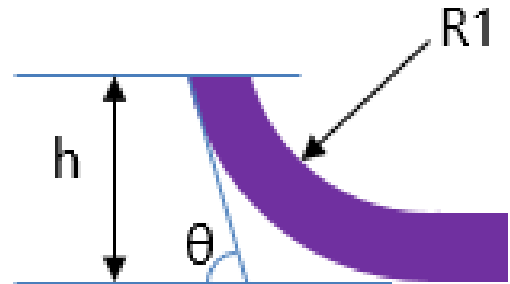


Figure 2. Schematic diagram of the 4-edge curved CG and its geometric parameters

2. Experiment

2.1. Product specification

In order to study the 4-edge curved technology of AMOLED display, the 6.57-inch mobile phone size display was selected for relevant experimental verification. The main mechanism parameters of CG are shown in Table 1.

Table 1. CG specification sheet

CG parameter	Long sides	Short sides
R1	3.0mm	3.4mm
h	2.3mm	1.49mm
θ	60°	40°

2.2. Product structure description

The product structure is shown in Figure 3, from top to bottom are cover glass(CG), optical transparent adhesive (OCA), optical polarizer (POL), Panel, back plate film (BPF), and composite foam (SCF). The main function of the optical POL above the panel is to reduce the reflectivity of the panel, the OCA realizes the bonding between the panel and the cover glass, and the BPF below the panel plays a certain supporting role for the flexible panel. When CG is fully laminated with the panel, the panel has been laminated with OCA, POL and BPF, and the composite SCF laminated under the BPF does not participate in the laminate of the panel and CG.



Figure 3. Module structure diagram

2.3. Module laminated structure design

The AMOLED display was used for this paper, and the traditional polyimide material is used as the substrate to obtain the flexible display after a laser lift off (LLO). In this paper, the modulus and thickness of the module material are optimized, and the patterned grooving design of the BPF and the panel is carried out. This paper studies three types of BPF patterning design schemes, as shown in Figure 4. Figure 4 (a) shows grooving in the BPF corner area, and the grooving range extends to a straight line position of BPF; Figure 4 (b) shows grooving near the connection of BPF corner and BPF straight line; Figure 4 (c) shows grooving in the BPF and panel corner area, and the grooving range extends to the straight line position of panel. The width, depth and density of the grooves are different from those in Figure 4 (a).

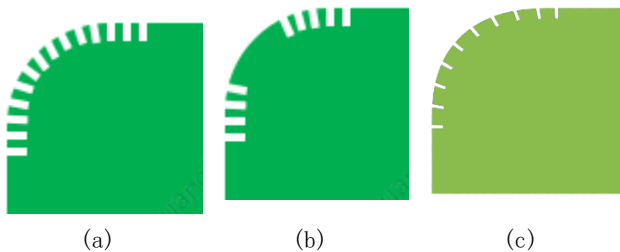


Figure 4. Grooves structure diagram: (a) BPF arc grooves; (b) BPF arc and straight line interface grooves; (c) Panel and BPF arc grooves

3. Result and discussion

3.1. Module material and stack optimization

The display structure and module materials were designed with different material modulus, different stack thicknesses, different patterned schemes and experimental verification, and the actual redundancy and reliability test results after full lamination were compared. Specific schemes are shown in Table 2, OCA1 modulus is greater than OCA2 modulus, BPF1 thickness is greater than BPF2, and POL1 thickness is greater than POL2.

There are four kinds of BPF patterning schemes, namely, pattern 1 (without pattern), pattern 2 (corresponding to FIG. 4a), pattern 3 (corresponding to FIG. 4b), and pattern 4 (corresponding to FIG. 4c). Panel1 has no special design, and the corner position structure of Panel2 is consistent with the BPF pattern 4. The redundancy results are shown in Figure 5. By comparison, it can be seen that the reduction of OCA modulus, the patterning design of BPF, the increase of the thickness of BPF&POL, and the patterning design of Panel promote the increase of redundancy. However, in the Panel patterning design scheme, although the redundancy is greatly improved, OCA bubbles appear after reliability test, as shown in Figure 6. Although low modulus OCA has a relatively obvious effect on the increase of redundancy, low modulus OCA rebounds under high temperature and high humidity environment, resulting in a certain loss of redundancy, as shown in Figure 7. BPF patterned trenching design has obvious positive effect on the increase of redundancy. In condition 4, the redundancy is highest, the specific

value is 0.22mm after reliability test, which is 29.4% higher than the conventional scheme.

Table 2. Description of verification conditions

Schemes	Specific materials in the product
1	Panel1&OCA1&POL1&BPF1&Pattern1
2	Panel1&OCA2&POL1&BPF1&Pattern1
3	Panel1&OCA2&POL2&BPF2&Pattern2
4	Panel1&OCA1&POL1&BPF1&Pattern3
5	Panel1&OCA2&POL1&BPF1&Pattern2
6	Panel2&OCA1&POL1&BPF1&Pattern4

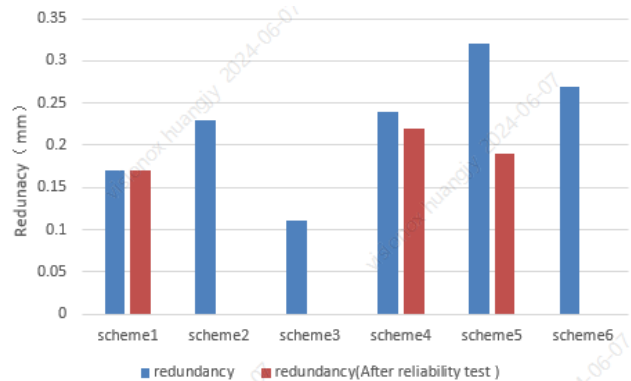


Figure 5. Redundancy results of each scheme

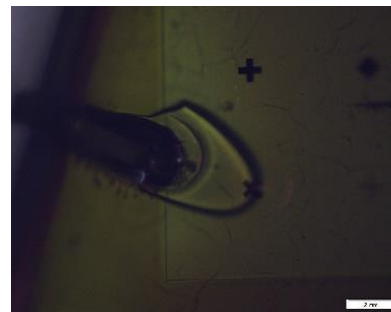


Figure 6. The bubble appeared after the reliability test of scheme 6

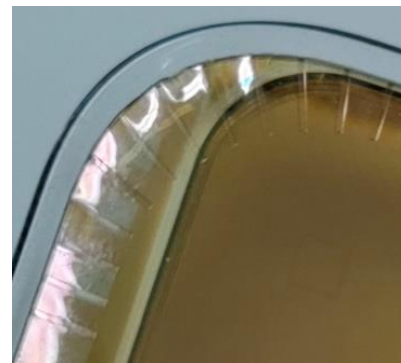


Figure 7. Scheme 5 winkles rebound after reliability test

4. Redundancy prediction model

Experimental verification costs a lot of resources and time. In order to improve efficiency, a redundancy prediction model was established and simulated by ANSYS software. After the simulation calculation was completed, the model displacement was measured to determine the actual wrinkle state of the display the color profile.

4.1. Model building

In this paper, 49 groups of experimental schemes with increasing redundancy are designed, and experimental and simulation analysis are carried out at the same time. After the experiment is completed, the wrinkle state of the display of each group of schemes is recorded. For the simulation results, the characteristic A, B and C of the panel were selected for measurement, and the gradient of the results was analyzed. As shown in Figure 8, the characteristic A and B have obvious gradient characteristics, in which the difference between the maximum value and the minimum value of the characteristic A is 12.4 times, and the difference between the maximum value and the minimum value of the characteristic B is 12.7 times, while the fluctuation between the maximum value and the minimum value of the characteristic C is less than 2%, and there is no gradient feature. Taking comprehensive consideration, the result of the characteristic B is selected as the evaluation index of the prediction model.

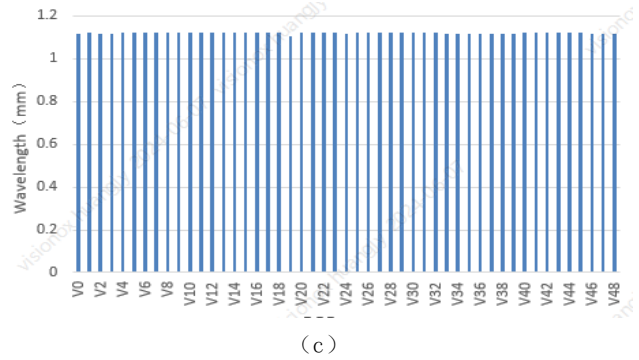


Figure 8. (a) Characteristic A results; (b) Characteristic B results; (c) Characteristic C results

4.2. Threshold of redundant prediction

By matching the results of each experimental scheme - "wrinkle" or "no wrinkle" with the simulation results, we found that when the characteristic B exceeds a certain value, the corresponding panel has wrinkles, when the characteristic B is less than a certain value, the corresponding panel has no wrinkles at all, and in a certain range, there are wrinkles or no wrinkles. This is due to experimental error. The evaluation criteria of wrinkle threshold are shown in Table 3.

Table 3. Wrinkle threshold evaluation criteria

Result	Characteristic B
No wrinkles	≤ 0.0023
Have wrinkles	≥ 0.0026
Uncertainty	$0.0023 < B < 0.0026$

4.3. Verification

In order to verify the accuracy of the wrinkle prediction model, four groups of 6.39-inch displays with different redundancy were selected for experiment and simulation calculation. The module stacking information is shown in Figure 9, and the verification results are shown in Table 4. The actual wrinkling condition of the four groups of displays and their simulated characteristic B are in line with the above prediction model.

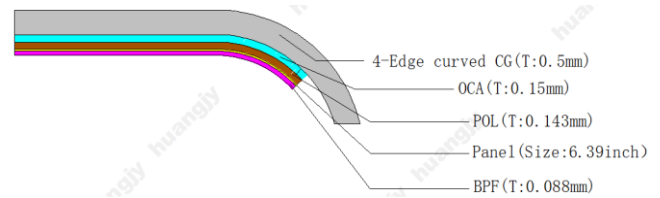


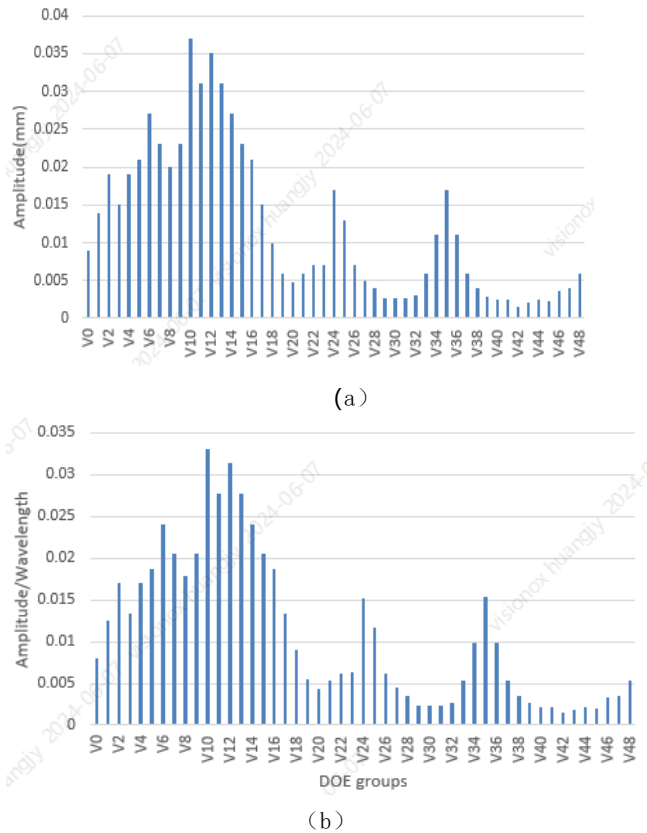
Figure 9. Module stack description

Table 4. Model accuracy verification results

Group	Wrinkle or NOT	Characteristic B
1	NO	0.0023
2	YES	0.0028
3	YES	0.0029
4	YES	0.0033

5. Conclusions

In this paper, by improving module materials and patterned design



of module stacking, the redundancy reaches 0.22mm, and the AMOLED panel with deep 4-edge curved display is realized. Through the comparison and verification of material thickness and modulus, it is found that thinning module stacking has a bad effect on wrinkle effect, and the reduction of OCA modulus has an obvious effect on the increase of redundancy, but in the reliability test process, the redundancy is reduced to a certain extent, and the BPF pattern grooving design has an obvious effect on the increase of redundancy, and the redundancy can be optimized by optimizing the groove shape. In addition, the prediction model of the wrinkle is established, and the standard for judging the actual wrinkle effect by simulation is given, which can be applied to various 3D curved surface products.

6. References

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