

# Research on Novel Panel Design Technologies for Significantly Improving Moving Mura

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## ABSTRACT

*In this paper, we present multiple methods to mitigate moving mura in liquid crystal displays (LCDs). Through comprehensive optimizations spanning panel design, manufacturing processes, material selection and code optimizing, we aim to further address the persistent issue of subpar black-state performance in LCD panels.*

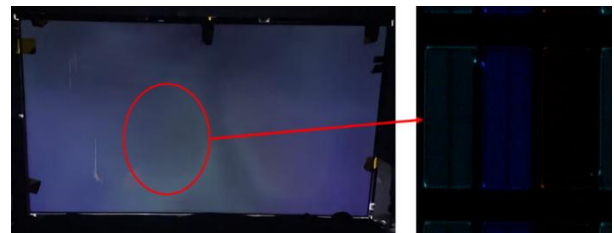
## 1 Introduction

In the 21st century, with the rapid advancement of information technology, Thin Film Transistor-Liquid Crystal Displays (TFT-LCDs) have emerged as a dominant technology in the flat-panel display industry. These displays are widely used in everyday devices such as smartphones, computers, televisions, and smartwatches[1-4]. TFT-LCDs have gained widespread adoption across various sectors due to their low radiation emission, energy efficiency, space-saving design, and aesthetic appeal.

As consumer expectations for display quality continue to rise, there is an increasing demand for enhanced performance metrics such as higher brightness, wider color gamuts, improved contrast ratios, and faster response times. Conventional LCD technologies are struggling to meet these evolving market requirements. The integration of Color Filter on Array (COA) and Pixel Overlapping Array (POA) technologies, combined with stripe-pattern color filter designs, offers a promising solution. This approach increases the aperture ratio, improves light transmittance, reduces parasitic capacitance, and is well-suited for high-refresh-rate, high-resolution, curved, and ultra-large displays, thereby elevating overall product quality.

However, COA-based LCD panels are susceptible to a phenomenon known as "moving mura," characterized by visible white streaks or patches in dark scenes when the panel is subjected to external pressure or tapping. Microscopic analysis reveals light leakage around data lines (near the edges of the black matrix (BM) and gaps between the common electrode (acom) and data lines) and scan lines (near BM edges and gaps between acom and gate lines), as depicted in Fig. 1. This issue is particularly prevalent in medium to large-sized panels. This paper introduces several innovative solutions to

address this challenge.



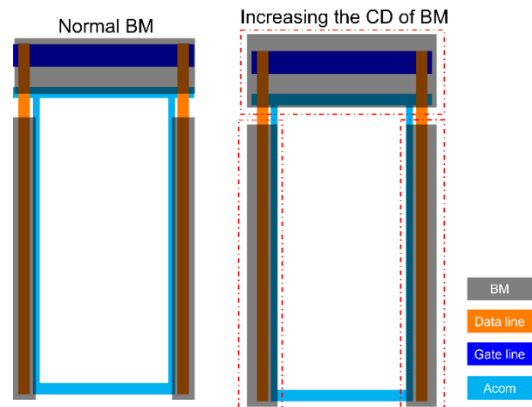
**Fig. 1 Light leakage on the data and gate sides after tapping (in dark state).**

## 2 Design Improvements

We improve moving mura by changing the width of BM and Acom, modifying the topography of the CF side, and applying new BOA technologies, etc.

### 2.1 Increase BM CD

When the panel is subjected to a large external impact force, the glass on the CF side and the TFT side is displaced and cannot be restored, causing light leakage between the gate line and the Acom gap. In this solution, the BM is designed to be widened (8μm). The wider BM is used to shield the gap between the gate line and Acom, reducing light leakage points to improve the whitening phenomenon (Fig. 2). It should be noted that CD refers to the dimension in a certain direction, namely "Critical Dimension".



**Fig. 2 The pixel design of increasing BM CD.**

## 2.2 Increase Acom CD

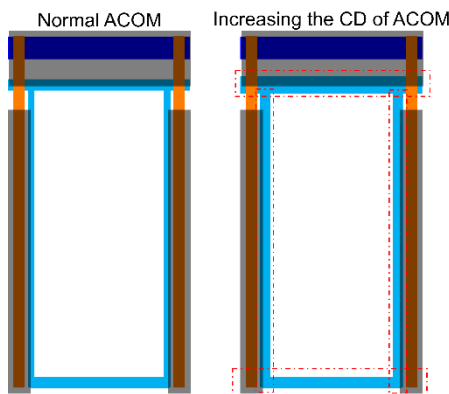


Fig. 3 The pixel design of increasing ACOM CD.

By increasing the line width of Acom, when the glass on the CF side shifts due to external force, the BM will not shift into the gap between Acom and the data line, which can also improve this issue (Fig. 3).

## 2.3 PFA on BM

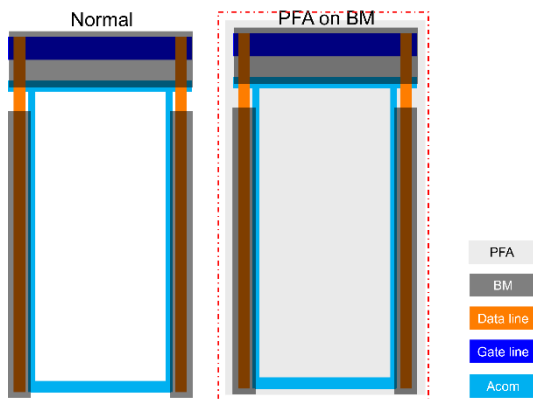


Fig. 4 Normal and PFA on BM.

If one does not want to lose the aperture ratio of pixel, a flat layer (Polymer Film on Array, PFA) can be designed on the BM side to enhance the liquid crystal anchoring force at the BM edge, optimize the alignment, and weaken the light leakage at the BM edge (Fig. 4).

## 2.4 BOA Technology

Most products are based on BOC (BM On CF) technology. The terrain and landform changes at the edge of the BM on the CF side are relatively large, which leads to the BM edge being affected by PI adhesion and liquid crystal alignment, resulting in severe brightness. After flapping the CF glass, it shifts, and the panel shows uneven brightness, forming mura. By designing the BM on the array side (BM On Array, BOA technology), after flapping the CF glass and causing it to shift, the edge of the BM is hidden within the metal lines and does not expose to the display opening area. There is also no light

leakage between the metal and the metal lines, so there will be no uneven brightness. Macroscopically, the difference in brightness and the whitening phenomenon are improved (Fig. 5).

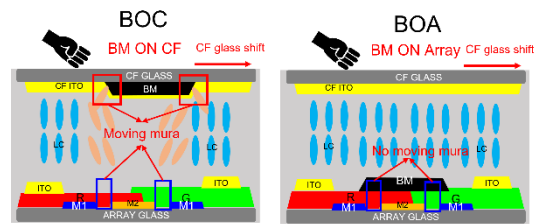


Fig. 5 The pixel design of increasing ACOM.

## 3 Process Improvements

In the manufacturing process, moving mura is improved by adjusting the proportion of liquid crystal.

### 3.1 Adjust the Ratio of BB/GM

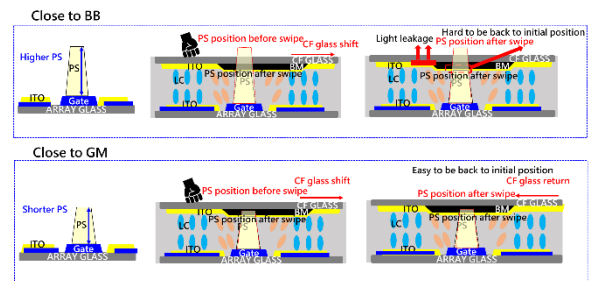


Fig. 6 Diagram showing the relationship between different proportions of BB/GM and PSH.

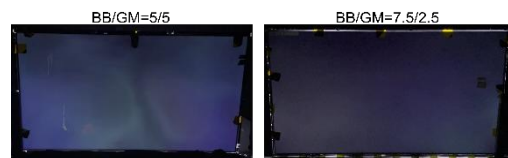


Fig. 7 BB/GM different proportions of dark state tapping resulted in whitening (right side tapping was better than left side).

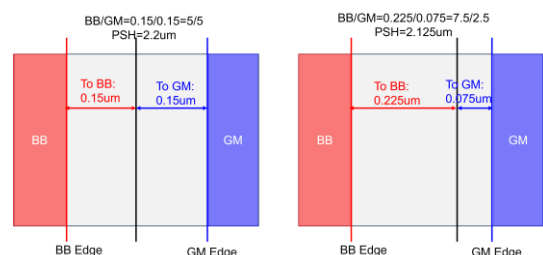


Fig. 8 Adjustment of the BB/GM ratio.

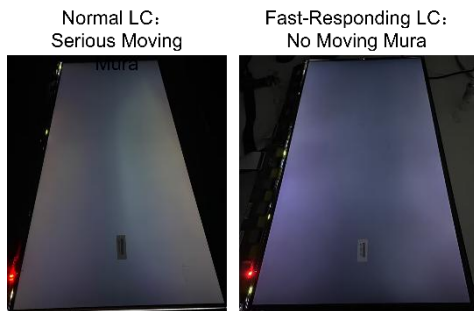
In terms of the manufacturing process, by adjusting the proportion of liquid crystal, the ratio of BB (Bubble) / GM (Gravity Mura) larger, the more it leans towards gravity. After being tapped, the liquid crystal recovers quickly, and the phenomenon can be observed to become less severe or even disappear macroscopically.

When the cell gap is the same, the two heights of PS are compressed to the same height within the cell. The higher the PS, the greater the pressure, resulting in a larger friction force between the PS and the CF side. When an external force slides the CF glass, the glass substrate will shift. The CF glass with a high PSH (leaning towards BB) is difficult to return to its initial position after shifting; while the CF glass with a low PSH (leaning towards GM) is more likely to return to its original position (Fig. 6 and Fig. 7), because there is no direct contact between PS and CF, resulting in less friction between LC with CF galss. In the manufacturing process, by reducing the height of PS (cell gap remains unchanged), the liquid crystal is brought closer to GM, as shown in Fig. 8. After reducing the PSH from 2.2  $\mu\text{m}$  to 2.125  $\mu\text{m}$ , the BB/GM ratio changes from 5/5 to 7.5/2.5 (for example).

#### 4 Materials improvements

We solved the problem by changing the type of liquid crystal and the polarizing film.

##### 4.1 Fast-Responding LC



**Fig. 9** The dark state tapping effect of normal liquid crystal and fast-response liquid crystal is whitening .

**Table 1 Comparison of LC Parameters**

Item	Nnormal LC1	Nnormal LC2	Fast-Responding LC
Y1 (m Pa.s)	95.6	92	87
K33 (pN)	14.5	15.1	16.8
Y1/K33	6.59	6.09	5.18
Moving Mura	Serious	Middle	No

In terms of materials, the use of fast-response liquid crystals can be considered for improvement. When the glass is struck, if the liquid crystal can quickly return to its original state after the strike, it can also effectively alleviate the whitening phenomenon (Fig. 9). Because the rotational viscosity (Y1) of the fast-response liquid crystal is relatively small, and the smaller the Y1/K33 ratio as shown in table 1, the faster the response speed (K33: elastic constant) .

##### 4.2 Ultra-Wide viewing angle polarizing film

Panels with higher viewing angle requirements are sometimes paired with wide-angle polarizing films. Their

internal structure adds a special layer, similar to a grating effect, which disperses the vertical light and increases the side-view light, thereby achieving an increase in viewing angle. In the white mode, it enhances the viewing angle through diffusion, and in the black mode, it cuts off the leakage light through refraction. By leveraging this characteristic of the wide-angle polarizing film, it can be applied to improve the dark-state photography and white enhancement (Fig. 10).



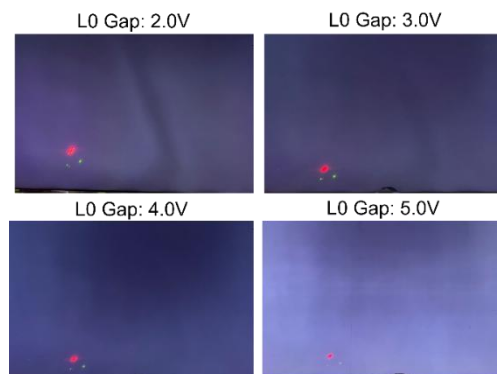
**Fig. 10** The dark state of the wide-angle and normal polarizing films causes a whitening effect (the center is the wide-angle polarizing film, the periphery is the normal polarizing film, and the middle position is much better than the periphery).

#### 5 Code modulation improvements

By adjusting the L0 gap and increasing the brightness of the L0 frame, the situation can be improved. L0 pressure difference refers to the pressure difference between positive and negative polarity voltage at 0 gray level(L0 Gap).

##### 5.1 Increase L0 Gap

The L0 Gap was gradually adjusted from 2.0V to 3.0V, 4.0V, and 5.0V. The moving mura phenomenon became increasingly mild. The principle behind this is to enhance the brightness of the L0 image, thereby reducing the contrast difference after the impact and achieving the improvement (Fig. 11).



**Fig. 11** Moving mura corresponding to different L0 gaps.

## **6 Conclusions**

This article addresses the actual problems of the product, integrating multiple dimensions including design, manufacturing process, materials, code optimizing, and provides various solutions to improve the "moving mura", thereby has significantly enhanced the competitiveness of the product.

## **7 Acknowledgements**

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