Research on Improving Skin Color Distortion Driven by Triple-Gate in LCD Display

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ABSTRACT

This paper primarily investigates the generation mechanism of skin color distortion for triple-gate driven products in liquid crystal displays (LCDs). It explores how to improve color non-uniformity in special skin color images from two aspects: manufacturing processes and code modulation, with the aim of enhancing the display quality of LCDs.

1 Introduction

Liquid crystal displays (LCDs), due to their excellent optical performance and low-cost investment, have been widely used in home display applications, work tablet displays, industrial instrument displays, and smart phones [1].

Generally, there are three pixel - driving structures for LCDs: 1G1D, dual-gate, and triple-gate. The conventional driving structure is 1G1D. Compared with the 1G1D structure, the triple-gate structure, the number of data lines is one third of the original, and the number of scan lines is tripled. When the frame frequency is set at 60 Hz and the resolution is Full High-Definition (FHD), the activation duration of 1G1D product is roughly 15.4 microseconds (μs). In contrast, the charging time of a triple-gate product is approximately 5.14 microseconds (μs)[2]. Therefore, the drawbacks of the triple-gate (Trigate) structure include a short charging time. With an increase in scan lines and a decrease in data lines, the load of resistance (R) and capacitance (C) in pixels is further increased, resulting in data signal delay. This in turn shortens the actual charging time of pixels, making it prone to insufficient charging, especially in skin color test images. As shown in Fig.1, this is a commonly used skin color image for panel quality testing by customers. On the left side of Figure 1 is the skin color test chart for triple-gate architecture product (50 inch), and on the right side is the skin color test chart for 1G1D architecture product (43 inch). It can be clearly observed that the skin color of 43inch 1G1D product is more saturated and uniform, and appears redder. In contrast, the skin color of 50inch triple-gate architecture product has distortion and is insufficiently red. As shown in Table 1, the chromaticity coordinates indicate that the U' chromaticity coordinate of 43inch 1G1D product is more to the right, thus making the color lean more toward red. As shown in Fig.2, the charging time of FHD trigate is short, and the pixel charging rate is low. The gate is turned on in advance, causing the high voltage of L255 in the G (green) sub- pixel to be mistakenly charged to the R (red) sub-pixel of the previous row, which makes the brightness of G brighter. This results in the skin color not being red enough.

Fig. 1 Trigate skin color distortion phenomenon under different pixel architecture

Table1：Chromaticity Coordinates under different pixel architecture

Item	U'	V'
50inch triple-gate	0.2771	0.5063
43inch 1G1D	0.3002	0.4992

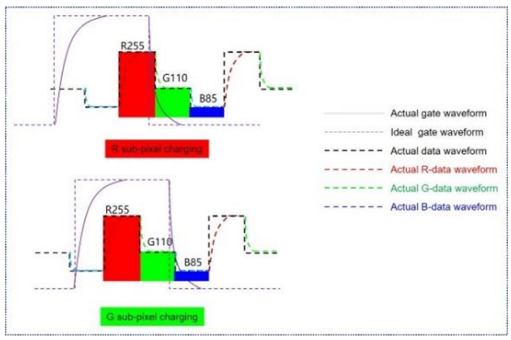

Fig.2 Mechanism diagram of skin color distortion in trigate driving structure

With the progressive development of display technology and the sustained impetus of market demand, the dimensional scale of display screens has been continuously expanding. At present, Full High-Definition (FHD) Triple-gate (Trigate) products available in the market have attained a size of 50 inches. Therefore, this paper takes the HKC 50-inch FHD Triple-gate product as a typical exemplar to conduct in-depth research and detailed illustration.

In summary, the color non-uniformity in special skin color images is primarily caused by data delay and insufficient charging. Therefore, we address the issue of skin color distortion through two aspects: manufacturing processes and code adjustment.

2 Process Technology Improvements: Insufficient Red in Skin Tone

In terms of process technology, improvements for insufficient red in skin tone mainly focus on the following aspects:

2.1 Increasing the thickness of AS remain

If the AS remain layer is too thin, insufficient hydrogen passivation will lead to an increase in defects and a decrease in mobility. In addition, its excessively thin characteristics make it vulnerable to process damage, resulting in an increase in interface state density. As shown in Fig. 3, increasing the thickness of the AS remain layer can significantly improve skin color uniformity and make the skin color lean toward red. In Table 2, the absolute value of the horizontal coordinate U' in the chromaticity coordinates increases as the film thickness increases, with the absolute value increasing by 3‰.

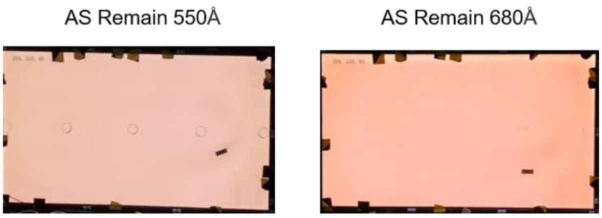

Fig. 3 Skin color phenomena under different AS Remain thicknesses

Table2：Chromaticity Coordinates under different AS Remain thicknesses

Item	U’	V’
As remain 550 Å	0.2771	0.5063
As remain 680 Å	0.2804	0.5026

2.2 Reducing the NTN distance

In TFT-LCD devices, the spacing between the remaining N-type doped tails (N tail) of the source and drain (i.e., the distance between two N tails) directly affects the device's on-current (Ion). The smaller the distance, the larger the on-current (Ion) of the device. As shown in the Fig. 4, after the NTN distance is reduced from 4.5 μm to 4.2 μm, the skin color distortion issue is significantly improved. In Table 3, the absolute value of the horizontal coordinate U' in the chromaticity coordinates decreases as NTN distance increases, with the absolute value increasing by 4‰.

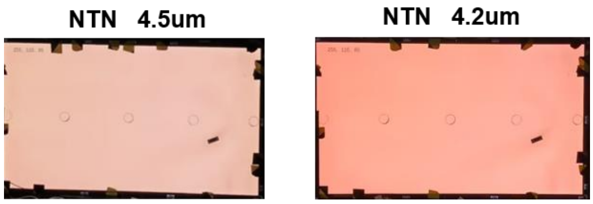

Fig. 4 Skin color phenomena under different NTN distance

Table3：Chromaticity Coordinates under different NTN distance

Item	U’	V’
NTN 4.5um	0.2771	0.5063
NTN 4.2um	0.2813	0.5016

2.3 Increasing the cell gap distance

The liquid crystal layer can be regarded as a capacitor, and its capacitance value C is inversely proportional to the cell gap d (according to the parallel-plate capacitor formula). Therefore, when the cell gap increases, the capacitance of the liquid crystal layer decreases, and the amount of charge required for pixel charging (Q = C \V) is reduced, greatly improving the charging efficiency. As shown in the Fig. 5, after the cell gap is increased from 3.2 μm to 3.4 μm, the skin color distortion issue is significantly improved. In Table 4, the absolute value of the horizontal coordinate U' in the chromaticity coordinates increases as NTN distance increases, with the absolute value increasing by 1‰.

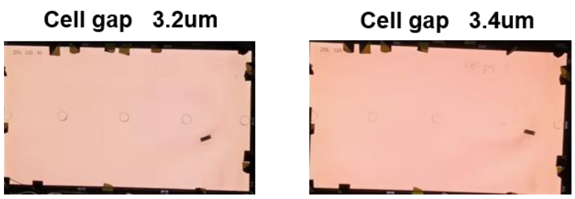

Fig. 5 Skin color phenomena under different cell gap distance

Table4：Chromaticity Coordinates under different cell gap distance

Item	U’	V’
Cell gap 3.2um	0.2771	0.5063
Cell gap 3.4um	0.2785	0.5029

3 Code Parameter Modulation Improvements: Insufficient Red in Skin Tone

The insufficient red in skin tone can be improved by adjusting the following code parameters:

3.1 Increase VGH voltage

Increasing VGH raises the gate-source voltage Vgs, which can increase the drain-source current Ids and enhance the charging capability of the Thin Film

Transistor (TFT). As shown in the Fig. 6, when VGH is increased from 36V to 39V, the skin color distortion issue is significantly improved. VGH is the gate high voltage. In Table 5, the absolute value of the horizontal coordinate U' in the chromaticity coordinates increases as VGH increases, with the absolute value increasing by 3‰.

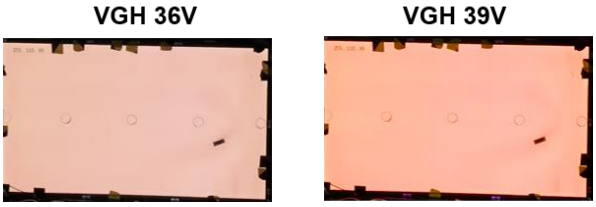

Fig. 6 Skin color phenomena under different VGH

Table5：Chromaticity Coordinates under different VGH voltage

Item	U’	V’
VGH 36V	0.2771	0.5063
VGH 39V	0.2805	0.5032

3.2 Extend charging time

As shown in the Fig. 7, after extending the actual charging time from 3.55μs to 3.65μs, the skin color distortion issue is significantly improved. In Table 6, the absolute value of the horizontal coordinate U' in the chromaticity coordinates increases as charging time increases, with the absolute value increasing by 2‰.

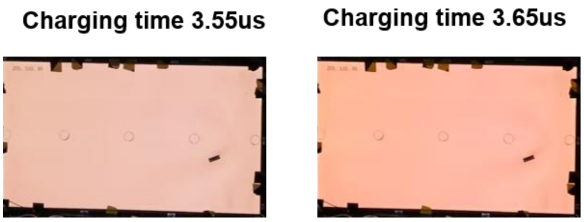

Fig. 7 Skin color phenomena under different actual charging time

Table6：Chromaticity Coordinates under different actual charging time

Item	U’	V’
3.55us	0.2771	0.5063
3.66us	0.2793	0.5019

3.3 Decrease Gamma One voltage

By increasing the driving voltage of medium gray levels, reducing the Gamma 1 voltage corrects the compression of skin color luminance by the original Gamma curve. As shown in the Fig. 8, after decrease Gamma 1 voltage from 13.5V to 12.5V, the skin color distortion issue is significantly improved. In Table 7, the absolute value of the horizontal coordinate U' in the chromaticity coordinates increases as VGH increases, with the absolute value increasing by 3‰.

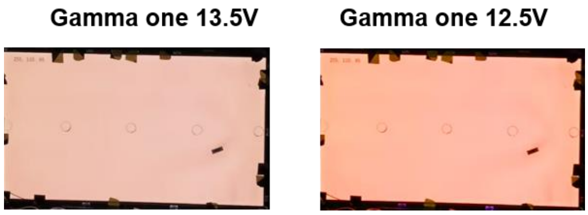

Fig. 8 Skin color phenomena under different Gamma one voltage

Table7：Chromaticity Coordinates under different Gamma one voltage

Item	U’	V’
Gamma one 13.5V	0.2771	0.5063
Gamma one 12.5V	0.2802	0.5045

3.4 Optimal Conditions

As shown in Fig. 9, by adjusting the AS remain, NTN distance, and cell gap in the manufacturing process to their optimal values, while optimizing the code, extending the charging time, increasing the VGH voltage, and decreasing the gamma voltage, the skin color distortion issue has been significantly improved. In Table 8, the absolute value of the abscissa U' in the chromaticity coordinates increases with the increase of charging time, and its absolute value increases by 5‰.

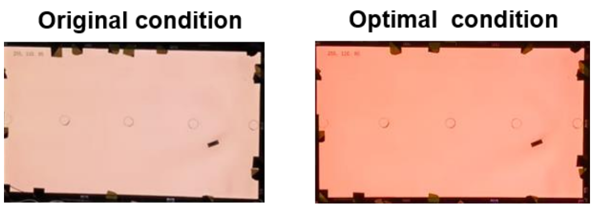

Fig. 9 Skin color phenomena between original conditions and optimal conditions

Table8：Chromaticity Coordinates between original conditions and optimal conditions

Item	U’	V’
Original conditions	0.2771	0.5063
Optimal conditions	0.2822	0.5023

4 Conclusions

Based on the generation mechanism of skin tone distortion, this study conducts a systematic investigation from two dimensions: optimization of manufacturing process parameters and calibration of digital driving algorithms.

1. Optimization of Manufacturing Process Parameters:

Thickness optimization of the AS remain layer enhances the uniformity of the electric field distribution; NTN spacing reduction technology reduces parasitic capacitance and significantly improves the charging efficiency of red sub-pixels; Increase in cell gap parameters optimizes the phase delay of red light.

2．Calibration of Digital Driving Algorithms:

VGH voltage enhancement strategy: The gate high-level voltage is increased from 36V to 39 V (ΔV = 3V) to ensure improved charging saturation of red sub-pixels; Extension of charging time eliminates the undercharging phenomenon in the red channel; Adjustment of Gamma One voltage parameter: The Gamma One voltage parameter is adjusted from 13.5V to 12.5V (ΔV = 1V).

5 Acknowledgements

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