On the Improvement of Color Shift in TFT LCD VA Display

Guang-Yuan Liu, Xiao-Jie Wang, Bing Li, Le-Le Zhang, Yan-Peng Sun, Hong-Yan Chang, Bing Han, Shi-Shuai Huang, Paul Shi, Wade Chen

865940957@qq.com
Chuzhou HKC Optoelectronics Technology Co. Ltd.
No.101, Suchu Avenue, Economic and Technological Development Zone, Chuzhou City, Anhui Province, China
Keywords: M1 trunk; ITO slit; L0 pressure.

ABSTRACT

In this paper, we mainly study the generation mechanism of color shift in TFT VA LCD display, and how to improve color shift from three aspects of design, manufacturing process and code modulation, so as to enhance the display taste of liquid crystal displays.

1 Introduction

Liquid crystal display (LCD) has been widely used for TV, monitor, notebook, pad and mobile phone due to its good optical performance and low cost [1-3].

Liquid crystal display is to control the rotation of liquid crystal molecules through electrical signals to achieve, according to the different rotation of liquid crystal molecules, the liquid crystal display can be divided into different display modes, the common liquid crystal display mode has four types: TN (Twist), VA (Vertical Alignment), IPS (In-Plane Switching), FFS (Fringe Filed Switching) [4].

The VA display mode is to realize the display mode by controlling the rotation of liquid crystal molecules in the vertical direction. The pixel electrode and the common electrode are respectively on the TFT substrate and CF substrate, adopting vertical alignment and using negative liquid crystal. When no electric field is applied, the liquid crystal molecules stand perpendicular to the glass substrate. When the electric field is applied to the upper and lower substrates, the liquid crystal molecules gradually lie flat and perpendicular to the electric field line with the increase of the electric field intensity，as shown in Fig1. In VA mode, the actual Δnd in the dark state is very small, so there is less light leakage and high contrast, which is one of the biggest advantages of VA.

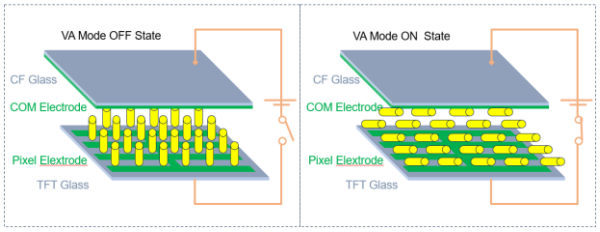

Fig. 1 VA Display Mode

VA display has become a common display mode for large-size TV TFT LCDS due to its advantages of high contrast, high penetration and no friction alignment. Although the vertical "standing" of the liquid crystal molecules of VA gives VA a very high contrast, when viewed from the side, the contrast decline of VA is very obvious, and it is easy to produce color shift. Color shift refers to the difference in the color of the unified color picture when viewed from the front Angle and the side Angle.

The characteristics of visual field angle are defined by contrast. The rotation characteristics of VA liquid crystal molecules in the vertical direction cause the brightness difference of VA display under different visual field angles, resulting in obvious color bias. The fundamental reason lies in the anisotropy of liquid crystal refractive index.

In this paper, the evaluation method of TV perspective is mainly based on SEC's verification method of TV product perspective. The specific measurement method is shown in Figure 2 (take 8bit 256 gray scale as an example)

$$CR\ (80/20) = \frac{IL_{204}^{30^\circ}/IL_{51}^{30^\circ}}{IL_{204}^{0^\circ}/IL_{51}^{0^\circ}}$$

$CR\ (80/20)$ is a measurement of the Angle of view，L_n is the number of nth gray scales (0~255)，$IL_{204}^{30^\circ}$ is the brightness of L_{255} gray scale at 30° viewing Angle，$IL_{51}^{30^\circ}$ is brightness of L_{51} gray scale at 30° viewing Angle，$IL_{204}^{0^\circ}$is the brightness of L_{255} gray scale at 0° viewing Angle，$IL_{51}^{0^\circ}$ is brightness of L_{51} gray scale at 0° viewing Angle, $CR\ (80/20)$ refers to the brightness ratio of 80% of the L255 gray scale and 20% of the L255 gray scale at 30° and 0° side angles The larger the value，the better the viewing Angle.

Generally, when users watch TV, it is mainly the left and right angle of view that has an impact on the viewing effect of customers, so the research and measurement in this paper are left and right Angle of view.

this paper takes the HKC TV product as an example to carry out research and illustration.

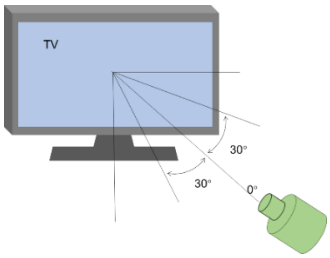

Fig. 2 Viewing Angle Test Method

2 Design improvements color shift

In terms of design, color shift is improved mainly from pixel ITO slit angle and M1 trunk.

2.1 Pixel ITO slit angle

According to the formula $T_r = \frac{\sin^2(2\theta)\sin^2\left(\frac{\Delta nd\pi}{\lambda}\right)}{2}$, The VA 4domian pixel ITO electrode is shown in Fig 3，ITO slit forms 45° with two horizontal and vertical trunk，When a certain driving voltage is applied, the liquid crystal molecules will be arranged in an orderly manner along the direction of the ITO slit, so changing the ITO slit angle will change the liquid crystal azimuth Angle θ , affect transmittance, and affect color shift. Therefore, we designed ITO slit Angle of 40° and 45° on ABC three products, and measured $CR\ (80/20)$ through actual measurement. It is found that the ITO slit angle of 40° is superior to the ITO slit angle of 45°，the measured results are shown in Table 1.

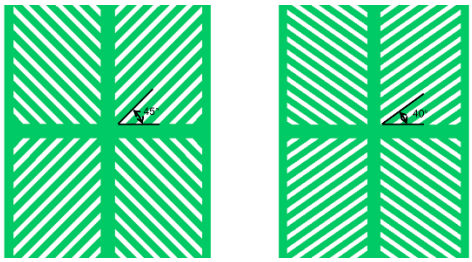

Fig. 3 ITO Slit Angle

Table1： Different ITO Slit Angle

Product TV	ITO slit angle	View angle $CR\ (80/20)$
Product A	45°	28.40%
	40°	29.93%
Product B	45°	28.54%
	40°	30.16%
Product C	45°	31.28%
	40°	34.13%

2.2 M1 trunk

When the ITO trunk of the sub pixel leaks light, the color coordinate points of the side view and the front view are the farthest apart, resulting in the most severe color shift. Using metal to shield the V-trunk significantly improves the color shift, while the transmittance remains almost unchanged. Specific data is as follows.

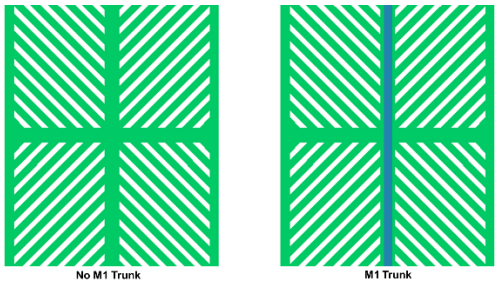

Fig. M1 Trunk Design

Table2： M1 Trunk

Product TV	M1 trunk	View angle $CR\ (80/20)$
Product TV C	M1 trunk	31.53%
	No M1 trunk	30.15%
Product TV D	M1 trunk	37.55%
	No M1 trunk	35.67%

3 Process improvements color shift

In the process, color shift is improved mainly by cell gap and liquid crystal materials.

3.1 Cell gap

According to the formula $T_r = \frac{\sin^2(2\theta)\sin^2\left(\frac{\Delta nd\pi}{\lambda}\right)}{2}$, d is cell gap，the cell gap will also affect the transmittance and affect the color shift, so we measured $CR\ (80/20)$ with different cell gap on the same product, and found that the Angle of view value of the small cell gap will be better than the Angle of view value of the larger cell gap ,the measured results are shown in Table 3.

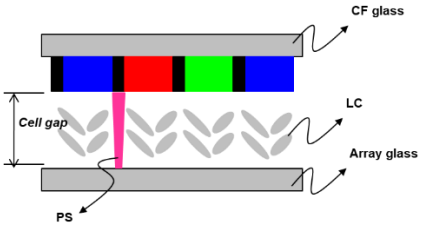

Fig. 4 Cell Gap

Table3： Different Cell Gap

Product TV	cell gap(um)	View angle $CR\ (80/20)$
Product TV E	3.1	32.49%
	3.2	31.60%
	3.3	30.24%
Product TV F	3.1	29.10%
	3.2	28.50%
	3.2	27.00%

3.2 liquid crystal materials

According to the formula $T_r = \frac{\sin^2(2\theta)\sin^2\left(\frac{\Delta n d\pi}{\lambda}\right)}{2}$, the Δn of the liquid crystal will also affect the penetration and affect the color shift, so we measured CR with different Δn liquid crystal materials on the same product, and found that the Angle of view value of the liquid crystal material with a small Δn will be better than the Angle of view value of the liquid crystal material with a large Δn. the measured results are shown in Table 4.

Table4：Different LC

Product TV	LC Δn	View angle CR（$80/20$）
Product TV G	$\Delta n \downarrow$	32.22%
	$\Delta n \uparrow$	29.61%
Product TV H	$\Delta n \downarrow$	35.70%
	$\Delta n \uparrow$	34.20%

4 Code modulation improvements color shift

After panel output, the optical taste of code should be adjusted to improve color shift by decreasing L0 pressure difference.

4.1 Decrease the L0 pressure difference

For different models I and J, we adjusted the L0 pressure difference for each, observed their display quality, and analyzed the optical measurement data. The results indicated that reducing the L0 pressure difference significantly improved color shift.

Table5：L0 Pressure Difference

Product TV	L0 pressure	View angle CR（$80/20$）
Product TV I	2.0 V	30.75%
	1.0 V	31.70%
Product TV J	2.0 V	30.01%
	1.0 V	30.60%

5 Conclusion

Experimental verification and data analysis confirm that the following five methods effectively improve color shift: When the pixel ITO angle is set at 40°, the viewing angle performance surpasses that at 45°. Adding M1 (Metal Layer 1) over the ITO trunk effectively blocks light leakage, enhancing viewing angle quality. A lower cell gap positively contributes to viewing angle improvement. Smaller Δn (birefringence) of the liquid crystal material yields better viewing angles. Reducing L0 delta-V achieves a darker dark state, effectively mitigating color shift.

these measures significantly mitigate color shift in small-sized 4-domain panels

References

[1] Yasusiro Ukai, TFT-LCDs as The Future Leading Role of FPD, SID 2013 Digest p.28-31.

[2] Liu C. T., Revolution of the TFT LCD technology, J. Journal of Display Technology, Vol. 3, N. 4, pp. 342-350, (2007).

[3] Pauluth D. T., Optimization Liquid Crystal for Television, J. Journal of Society for Information, Vol. 13, No. 8, pp. 693-702, (2005).

[4] Liao Y. P., Thin Film Transistor Liquid Crystal Display, Bei Jing: Publishing House of Electronics Industry, (2016).