A Novel UV2A Alignment Technique for Improving Skin Color Washout

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Abstract

This article introduces a new UV2A pixel design that improves skin color shift. Color shift at large viewing angle has always been a weakness of VA-LCD. In recent years, micro lens film compensation solutions have been developed in the industry to address this issue, but this has brought about a series of problems such as low CR, moiré mura, and high cost. The new pixel designed in this article, based on UV2A 8D, uses different tilt angles for Array and CF substrates. Through design, material, and process optimization, the visual effects and evaluation parameters have been achieved at the same level as VA displays with micro lens compensation polarizers (PSVA and UV2A): the skin color CR (80/20) has increased from 53.7% to 61%, the skin color △uv has decreased from 0.010 to 0.004, the CESI viewing angle has increased from 95 °to 125 °; the specification Δ UV<0.03, and the CR is 1000 higher than traditional VA products with micro lens compensation polarizers. This new UV2A alignment technology product provides consumers with better choices, allowing for a wider viewing angle while maintaining good contrast, and is also more competitive in terms of cost.

Author Keywords

UV2A；Skin Color；Color Washout；Gamma Shift.

1. Introduction

The UV2A mode is prevalently utilized in LCD technology due to its characteristics such as the absence of friction, high contrast, and excellent reliability. In the UV2A mode, a sub-pixel is partitioned into 4 domains with distinct tilt directions of liquid crystal molecules to offer symmetry and broad viewing angle characteristics. At large viewing angles, the side-looking gamma distortion of 4-domain pixels gives rise to significant color shifts,[1-5] which induces color washing phenomena, particularly in the perception of human skin color. Known as the 8-domain or 12-domain UV2A pixel, it mitigates side-view gamma distortion and color washout; however, the color shift from the axial to off-axis viewing direction remains perceptible. Therefore, the 8-domain scheme with microstructure film was developed and extensively applied in high-end TV display products. Nevertheless, due to the high cost of microstructure film and the considerable loss of Tr% and CR, the application of this scheme is severely limited. Thus, it is still of great significance to continuously enhance the color washout capability of the 8-domain configuration without increasing the cost, especially when the panel size becomes larger.

In this study, a novel UV2A alignment technique is proposed to enhance skin color rendition. By adopting different pretilt alignments for the UV2A Array and CF substrate, the azimuth angle of LC is reduced so as to improve the skin color shift. The new UV2A alignment technology can further render the side view of skin tone more natural and vivid.

2. Color washout capability of conventional 8D and 8D with micro-structure

In the traditional 8 Domain design, a sub-pixel is divided into two parts: Main and Sub. The voltage applied to the Main pixel is higher than that of the Sub pixel, resulting in two sets of V-T curves within this pixel. This design effectively reduces gamma distortion when viewed from different angles. The 8 Domain design with micro-prism structure POL was developed and implemented in the VA TV display to further augment the skin color washout of the side view. Figure 1 illustrates the 8 Domain design with an additional micro-prism structural film integrated into POL. By incorporating this film, more normal incident light can enter from side angles, thereby reducing brightness loss and minimizing Color shift and color washout caused by Gamma distortion under side viewing angles.

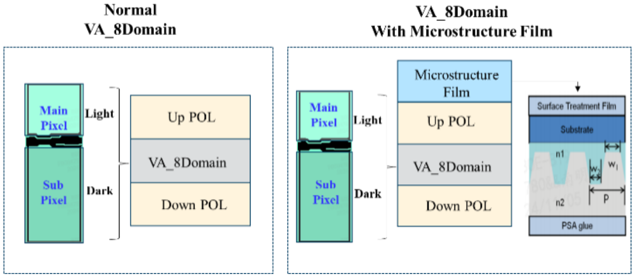

FIG. 1, Conventional 8D and 8D with microstructure

The Gamma test curve of the traditional 8 Domain design and the 8 Domain design with the micro-prism structural film at a side view angle of 60° is depicted in Figure 2. The 8 Domain design incorporating the micro-prism structural film exhibits exceptional performance in terms of Gamma distortion from a lateral perspective. Hence, to achieve an equivalent subjective picture quality effect as that achieved by the film design featuring a micro-prism structure, it is imperative to explore novel design schemes possessing comparable capabilities in mitigating Gamma distortion from a side view.

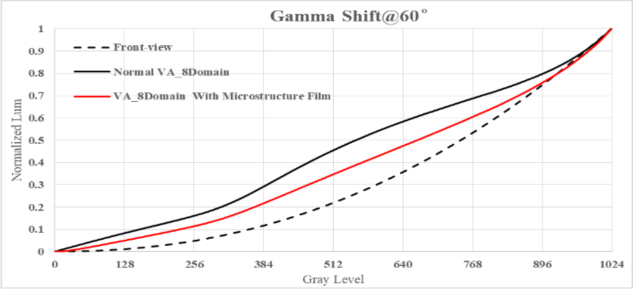

FIG. 2, Gamma distortion of Normal 8 Domain and 8 Domain with microstructure film at 60 °side view

3. The influence of the azimuth angle of LC molecules on the viewing angle

In the traditional UV2A pixel design, the azimuth angles of the LC molecules in the four domains of UV2A were designed as 45 °,

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135 °, 225 °, and 315 ° to obtain the maximum transmittance. as shown in Figure 1, we utilized Techwiz 3D simulation to model the trend of brightness changes at different azimuth angles of LC molecules under a 60 ° horizontal side view angle. The results indicate that due to the relationship between the effective Δnd of LC molecules and the viewing angle, the horizontal viewing angle brightness progressively increases as the azimuth angle of LC molecules increases from 30 ° to 60 °. Specifically, an azimuth angle of less than 45 °can achieve excellent performance in terms of horizontal side view and front view Gamma consistency.

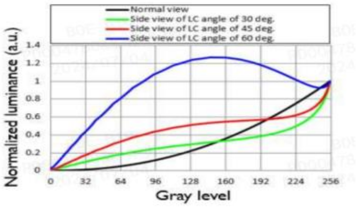


FIG. 3 The luminance of LC molecules at different azimuth angles in the horizontal view

4. The design of the azimuth angle of UV2A LC molecules

In the traditional UV2A alignment, Array substrate and CF substrate use different exposure directions. After exposure, as shown in Figure 4, the LC molecules of Array substrate symmetrically divide each pixel into left and right parts. The tilt direction of the LC molecules is parallel to the long side direction of the pixel, and the tilt angles of the LC molecules on the left and right sides differ by 180° . The LC molecules of CF substrate symmetrically divide the Main and Sub regions of each pixel into up and down parts, where the tilt direction of LC molecules is parallel to the short side direction of pixels, and the tilt angles of LC molecules on up and down sides differ by 180° . This way, after forming Array and CF substrates, each pixel is divided into eight regions, forming an 8-domain structure. At the same time, both Array and CF alignments adopt identical pretilt angles. as shown in Figure 4, When an electric field is applied, the LC molecules in the LC layer tilt toward the pre-tilted direction. In the conventional UV2A design, the LC molecules in the Array substrate LC layer are typically aligned parallel to the tails of the LC molecules in the CF substrate LC layer, forming a 45 ° azimuthal angle.

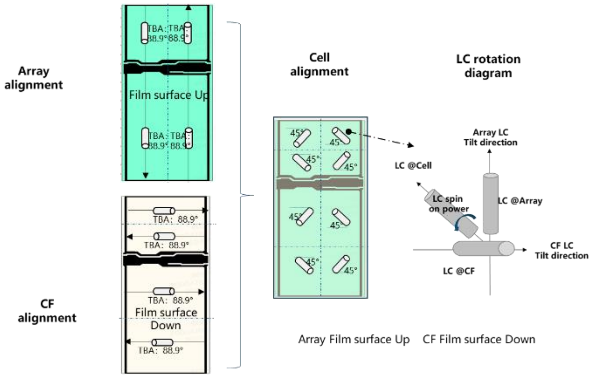


FIG. 4 Schematic diagram of UV2A alignment mechanism

In the UV2A alignment design, changing the orientation of the Array and CF substrates to obtain different azimuth angles results in inconsistent subpixel orientation angles. Therefore, alternative methods are needed to adjust the LC molecule orientation. Our research shows that when the CF substrate LC molecules have a smaller pretilt angle than those on the Array substrate, the LC orientation vector deflects more towards the CF side due to molecular continuity. This causes the LC orientation angle to be less than 45 °from the X axis. Using Techwiz 3D, we found that with a smaller pretilt angle on the CF substrate, the LC orientation angle in the Z direction shifts from 135 °to 150 °.

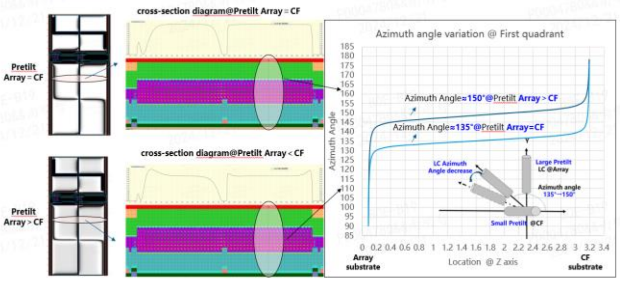


FIG. 5 The UV2A LC azimuth angle varies with the Array and CF substrate's different pretilt angle

As illustrated in Figure 6, Techwiz 3D was employed to simulate the impact of the relative relationship between Array and CF substrate Pretilt angles on Gamma distortion. The simulation results demonstrate that an increase in Array substrate Pretilt angles compared to CF substrate pretilt angles leads to a reduction in Gamma distortion at a side angle of 60° . Consequently, enhancing Array pretilt over CF pretilt can effectively ameliorate color washout.

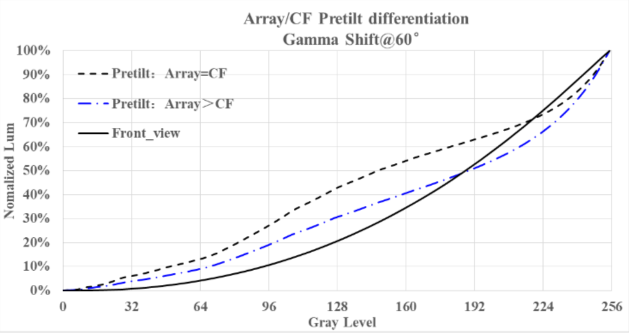


FIG. 6 The simulation results of Gamma distortion of Array and CF substrate with different pretilt angles

5. UV2A Color Washout improvement Solution

As depicted in Figure 7, Techwiz 3D was employed to simulate the Gamma distortion at a side angle of 60° with varying CF substrate Pretilt angles. The Array substrate Pretilt angles remained consistent and set at 88.9° throughout the experiment. The findings demonstrate that a decrease in CF Pretilt from 88.5° to 86.5° induces significant alterations in the Gamma Shift of the side view within the middle and high gray levels (> L64), while no discernible change is observed within the low gray levels (< L64). Moreover, as CF substrate Pretilt angles decreases, there is an increasing trend of Gamma shift beyond the 160-gray level, which adversely affects accurate representation of skin colors in high grays and may result in color shift. Consequently, we opt for a moderate CF substrate Pretilt angles angle of 87.8° to account for distortions occurring within medium and high grayscale ranges.

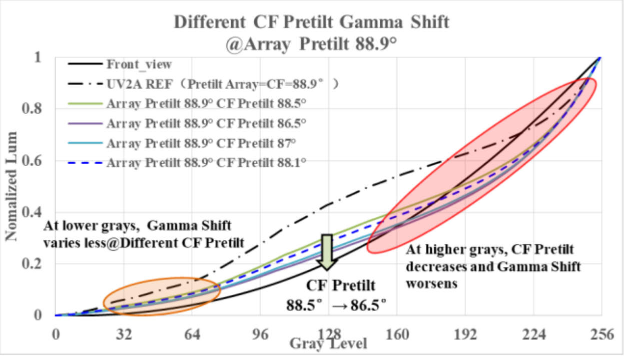


FIG. 7 Gamma distortion Techwiz 3D simulation results at 60° side Angle with different CF substrate Pretilt angle@Array substrate Pretilt angle 88.9°

Although we selected a relatively suitable CF substrate Pretilt angle of 87.8° to ensure that the high gray scale does not deteriorate too much, compared to Gamma Shift with the same Pretilt angle for Array and CF substrate, when CF substrate Pretilt angle is less than Array substrate Pretilt angle, the side view Gamma Shift still significantly deteriorates at high gray levels, therefore, continuous optimization is still required.

The design of 8 Domain pixels of Discharge type is well-known for its ability to optimize the Gamma distortion of different gray levels by adjusting the voltage of Main and Sub pixels. Additionally, reducing the Cell Gap can further enhance the Gamma Shift at higher gray levels. as depicted in FIG. 8, We conducted simulations using Techwiz 3D to analyze the Gamma Shift curve from various side views. By simultaneously decreasing both Discharge voltage and Cell Gap, we can effectively compensate for the deterioration observed in high gray Gamma Shift when employing the new UV2A alignment technique.

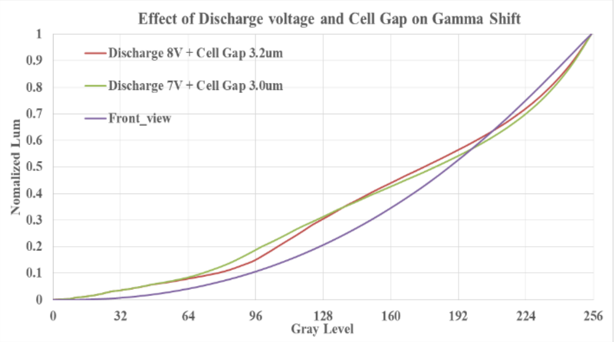
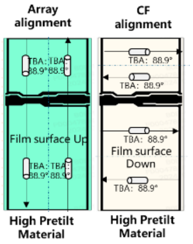
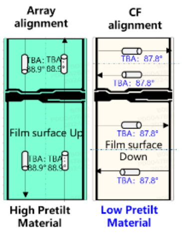


FIG. 8. Effect of Discharge voltage and Cell Gap on Gamma Shift

6. Improved results of color washout by the new UV2A alignment technique

As shown in Table 1, in the new UV2A alignment technology, the high Pretilt angles PI material is coated on the Array substrate and the low Pretilt PI angles material is coated on the CF substrate, thus providing the Array substrate with a high Pretilt of 88.9°and the CF substrate with a low Pretilt of 87.8°. At the same time, the Cell Gap is reduced from 3.2um to 3.0um, and the Discharge voltage is reduced from 8V to 7V.

Table 1, new UV2A alignment technology design scheme

Item		Traditional UV2A alignment	New UV2A alignment
PI Type@Array		High Pretilt Material	High Pretilt Material
PI Type@CF		High Pretilt Material	Low Pretilt Material
Pre tilt	CF	88.9°	87.8°
	Array	88.9°	88.9°
Orientation diagram			
Cell Gap		3.2um	3.0um
Discharge voltage		8V	6.5V

In Fig. 9, the measured Gamma Shift results of the new UV2A alignment technology are displayed in a side view using the aforementioned method. It is evident that compared to traditional UV2A alignment technology, the new UV2A alignment technology exhibits a wider optimization range for Gamma distortion at large viewing angles and can essentially achieve the same level as micro-prism structural film.

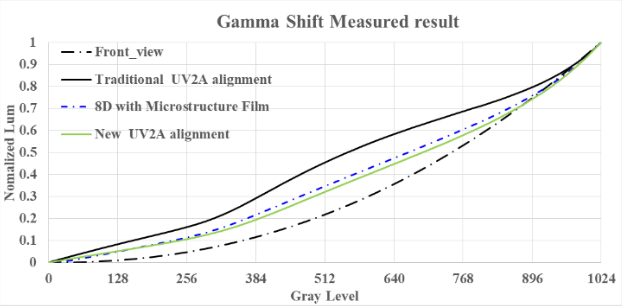


FIG. 9 the Gamma Shift test results of the new UV2A alignment technology, the traditional UV2A alignment technology and the micro-prism structure film

Simultaneously, we conducted tests on the optical and Color Washout quantitative indicators of the aforementioned three approaches. Color Washout is tested using two evaluation criteria, one is Skin Color and the other is CESI viewing angle specification. The Skin Color shift specification is divided into CR(80/20) and Δuv, CR(80/20) tests the brightness of 20% and 80% gray levels in the normal viewing angle and 30° side viewing angle, the formula is as follows, the larger the value, the smaller the Color Washout. The △uv test measures the chromaticity of the mixed color image RGB(179/140/102) in the normal viewing angle and 30° side viewing angle, and the △uv is obtained by calculating the chromaticity difference between the normal viewing angle and the side viewing angle. The smaller the △uv, the smaller the color shift in the side viewing angle.

$$\mathrm{CR}(80/20) = \frac{80\%\ Gray\ Lv.@30°/20\%\ Gray\ Lv.@30°}{80\%\ Gray\ Lv.@0°/20\%\ Gray\ Lv.@0°}$$

CESI measures the chromaticity of nine different mixed color images at a side viewing angle of 0° to 80°, then calculates the difference in chromaticity between the front and side views to obtain the △uv for each of the nine images at different viewing angles. The average △uv of the nine images is then used to determine the viewing angle that satisfies the condition of delta uv ≤0.03.

Table 2 demonstrates that in comparison to traditional UV2A alignment technology, the Skin Color CR (80/20) is enhanced from 53.7% to 61% with the new UV2A alignment technology. △uv decreases from 0.010 to 0.004, aligning with the performance of micro-prism structural film. CSEI color specification increases from 95° to 125°, only slightly lower by 5° than that of micro-prism structural film. CR decreases from 7500 to 6500 but still remains higher by a margin of 1000 compared to micro-prism structural film. Tr% experiences a decrease of 12.5%, consistent with Tr% values observed for micro-prism structural film. Additionally, the reflectivity is reduced by 0.5% when compared to that of micro-prism structural film, and it also offers a more cost-effective solution.

Table 2 The comparison of optics and color washout of the new UV2A alignment technology

Item		Traditional UV2A alignment	8D With Microstructure Film	New UV2A alignment
CR		7500	5500	6500
Tr%		5.9%	5.13%	5.16%
SCI%		1.3%	1.8%	1.3%
Skin Color	CR（80/20）	53.7%	60%	61%
	△uv	0.01	0.003	0.004
CESI	@△uv≤ 0.03	95°	130°	125°
	@30°	0.016	0.012	0.013

The comparison results of the traditional UV2A alignment, the new UV2A alignment, and the micro-prism structural film in the Skin Color screen are illustrated in Figure 9. It can be observed that compared to the traditional UV2A alignment, the novel UV2A alignment technology significantly mitigates Color Washout on skin color and minimizes color shift. Moreover, there is no discernible excessive saturation phenomenon on the forehead of black figures, leading to a substantial enhancement in overall color image quality comparable to that achieved by employing a micro-prism structure film.

FIG. 10 The comparison results of the traditional UV2A alignment, the new UV2A alignment and the micro-prism structural film in the skin Color screen

7. Conclusion

In this study, distinct PI materials were employed for Array and CF respectively to achieve a smaller Pretilt in CF compared to Array. By leveraging this novel UV2A alignment technology, the color washout capability can be on consistent with that of the microstructure 8Domain design. The Skin Color CR (80/20) has been enhanced from 53.7% to 61%, while optimizing the Skin Color △uv from 0.010 to 0.004, consistent with the micro-structure 8 Domain design. Furthermore, CESI Angle of view specification △uv < 0.03 has been extended from 95° to 125°, which only deviates by a mere difference of 5° when compared to the microstructure 8Domain design. Additionally, the new UV2A alignment technology does not increase the cost, so it is more advantageous than the 8 Domain product with microprism structure film.

8. References

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