High Picture Quality Technology Development of ADS Pro 8K Panel

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ABSTRACT

This paper develops an overall solution for extreme high picture quality based on ADS Pro technology, which includes high CR negative LC material, oblique angle optical compensation film, low reflectance film, CF and BLU spectral matching schema, new OD technology, etc. Based on this total solution, we acquire native CR close to 3000:1, the L0 light leakage in the oblique angle reducing by 80%, reflectance lower than 1.5%, the DCI higher than 99.5%, and the TR increasing by more than 20%. In the actual viewing scene, the subjective image quality is better than that of VA and WOLED products.

1 Introduction

With the development of technology, people's demand for display quality is getting higher and higher. In order to comprehensively improve the TV picture quality, based on the wide viewing angle ADS Pro display mode, we developed total solution, which adopts high CR negative LC, low reflection material, oblique viewing angle optical compensation film, high color gamut color resin, and combined with mini LED HDR backlight to achieve the ultimate high image quality.

2 High Contrast Ratio

The contrast ratio (CR) is one of the most important parameters affecting the image quality of the display [1-4]. The larger the CR is, the clearer the display image shows; the smaller the CR, the more blurred of the display shows. CR is usually means to native contrast ratio, while ambient light contrast ration (ACR) is more appropriate to evaluate the actual CR observed by human eye because TV is usually used in the environment with light. So in this work, we increase both native CR and ACR.

In order to improve native CR, we developed high CR negative LC with lower scattering effect. Reducing the refractive index Δn can reduce the light sensitivity of LC. Therefore, the scattering of the LC is reduced. In terms of materials, Δn is mainly determined by electron cloud density and conjugate effect. The method of reduce Δn is to select monomers with small conjugation effect. Each monomer has its own Δn. It can't be reduced indefinitely. The elastic constant K is mainly related to the intermolecular force. The intermolecular force is large and the elastic constant K is large. The larger of the elastic constant K, the better the order of LC molecules at L0. Therefore, the brightness of L0 is low. One way to increase the elastic constant K is to add rigid monomers, but the Δn of rigid monomers is larger. To keep the lower Δn, another way to increase the elastic constant K is to increase the ratio of length to width of LC molecules. We have developed a series of N-LC mixture and then selected LC molecules with large ratio of length to width to obtain larger K, as showed in Table 1.

Table 1. The character of new LC mixture

LC Type	N-LC-A	N-LC-B	N-LC-C
Δn	0.0916	0.0838	0.0835
$[(ne+no)*\Delta n]^2$	0.0779	0.0646	0.0642
Kave.	15	19	22
CR	~1700:1	~2500:1	~3000:1

Based on the high CR negative LC, the native CR of ADS PRO panels can reach to nearly ~3000:1 as shown in Fig.1. Since VA flagship usually use extra view angle expanding film, the CR would be largely reduced by about 30% to ~3000:1. From the figure we can see that, although the CR of the VA mode is higher than that of the ADS Pro mode in the front viewing angle, it decreases more quick with the increase of the viewing angle. When the view angle below 10°, the CR of VA flagship is higher than that of ADS Pro, while when the view angle larger than 10°, the CR of ADS Pro is higher than that of VA flagship. This means that in most oblique perspective angle, CR of ADS Pro has advantages.

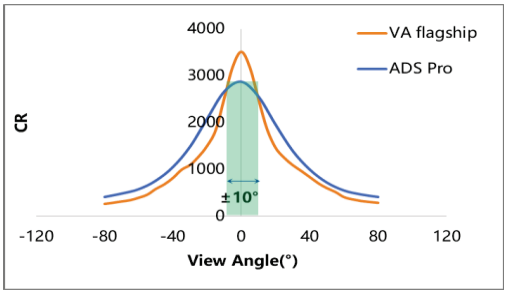

Fig. 1 Native CR of VA flagship and ADS Pro

ACR is the contrast ratio that includes the influence of ambient brightness. It is affected by the native CR and also effected by the brightness and reflection rate of the panel [3]. As shown in Figure 2, we test ACR of ADS PRO, VA and WOLED with same reflective rate ~1.5%, in different environment luminance. It is shown that ACR of WOLED decrease to below that of ADS PRO when ambient luminance above 70 lux. This is because the brightness of WOLED is below 200nit while that of ADS PRO is above 350nit. For most application scenarios of bedroom, living room and office / meeting room, although the native CR of ADS PRO is much lower than that of WOLED, the ACR of ADS PRO is even larger than that of WOLED.

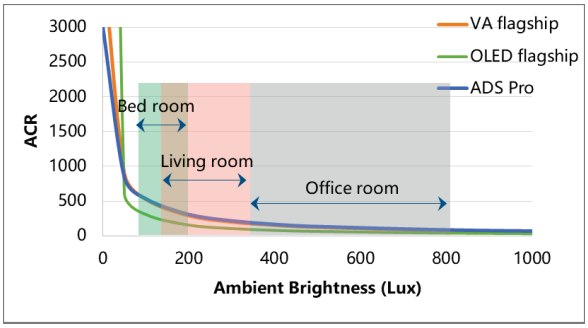

Fig. 2 ACR of VA, WOLED and ADS Pro

3 Color Expression in Large View Angle

ADS mode has excellent viewing angle characteristics in horizontal and vertical viewing angles. In the oblique viewing angle direction, since the included angle of the front and rear POL polarization directions is no longer vertical, there exists light leakage. Therefore, A+C optical compensation film (super true wide, STW POL) is used in this paper to compensate the light leakage at oblique viewing angle. The film structure and the principle are shown in Fig. 3. Through the suppression of light leakage, the image quality can be improved in three aspects.

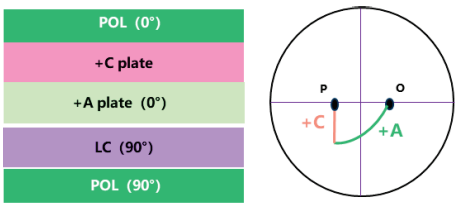

Fig. 3 Film structure (left) and Poincare (right) of STW POL

3.1 Color Washout/Shift of Pure and Mixed Color

Firstly, STW POL can greatly reduce the color shift and color washout of both monochrome and mixed color (such as skin pictures) pictures in oblique viewing angle.

As shown in Fig. 4, we tested the dC value of R191 / G191 / B191 gray pictures of ADS Pro, WOLED and VA products. As can be seen from the figure, for the ADS Pro panel, with the increasing of viewing angle, the purity of the R/G/B colors decreases, and the downward trend of the R/G/B colors is almost the same. For the WOLED panel, with the increasing of viewing angle, the R color purity decreases, while G and B increase at first and then decrease, and thus the trend of RGB colors is inconsistent. For VA panel, with the increase of viewing angle, all colors purity decreases, while dC of B color decreased much quick.

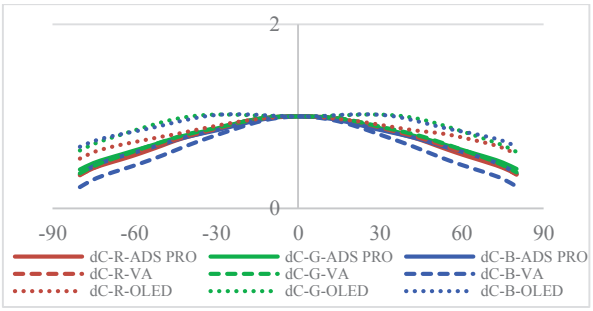

Fig. 4 dC of ADS Pro / WOLED / VA at R191/G191/B191 Pattern

In addition, we tested the dC value of mixed color patterns for ADS Pro, WOLED and VA. The mixed color patterns are four skin colors, as shown in Fig. 5. As can be seen from the figure, with the increase of viewing angle, dC of ADS Pro is relatively stable, and the dC of WOLED changes the most, followed by VA. The reason why is that R/G/B color in ADS Pro has a same downward trend as mentioned before.

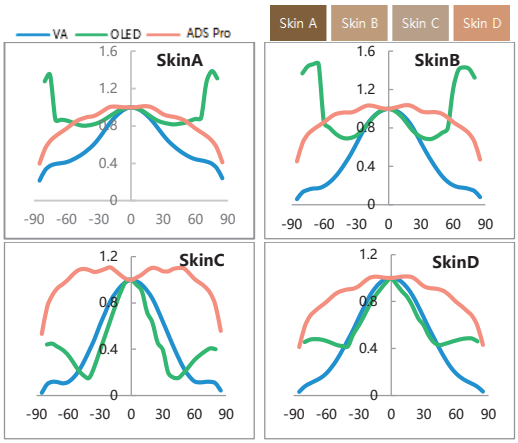

Fig. 5 dC of ADS Pro / OLED / VA at skin Pattern

It can be seen from the above test results that ADS Pro shows good color washout characteristics with the increase of viewing angle.

As shown in Fig. 6, we tested the *dH* value of R191 / G191 / B191 gray pictures of ADS Pro, WOLED and VA. It can be seen from the figure that within the viewing angle range of - 45° ~ 45°, the RGB color offset of ADS Pro is small with the increase of viewing angle. Taking dH±3° as the no color deviation reference, the no color

deviation viewing angle of ADS Pro is greater than ±60°.

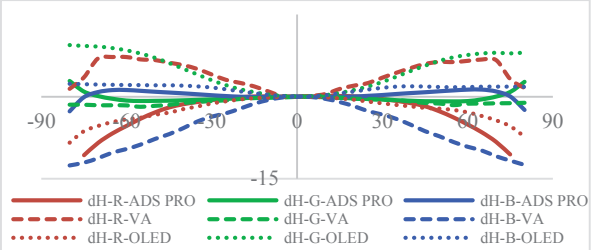

Fig. 6 dH of ADS Pro / WOLED / VA at R191/G191/B191 Pattern

We also tested the dH value of mixed color patterns for ADS Pro, WOLED and VA of four skin colors. As shown in Fig. 7, it can be seen from the figure, with the increase of viewing angle, the color of ADS Pro shift slightly. The reason is also that R/G/B color in ADS Pro has a same downward trend as mentioned before.

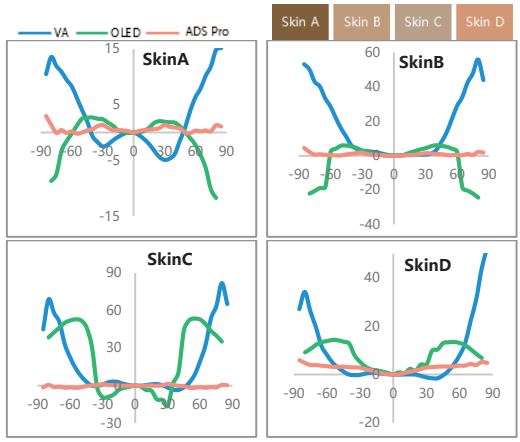

Fig. 7 dH of ADS Pro / OLED / VA at skin Pattern

3.2 Low Gray Image Quality

Secondly, STW POL could reduce the low gray color washout in the large view angle especially for large screen. The washout is resulted from the light leakage in oblique angle, so STW POL could solve it as mentioned before, as showed in Fig.8.

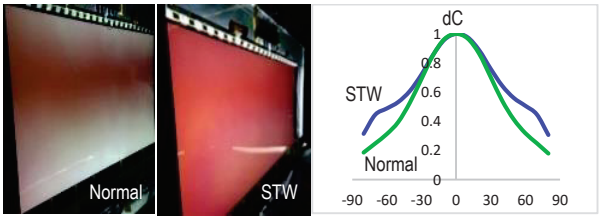

Fig. 8 Picture (left) and dC (right) of ADS Pro with STW and w/o STW at R gray L30

3.3 Large View Angle Halo

Thirdly, STW POL is helpful to reduce the halo issue with Mini BLU. Mini LED BLU has been used to realize high HDR image quality [5]. Large viewing angle halo is a common issue for LCD with mini BLU. POL with STW compensation film, as mentioned before, can reduce light leakage (L/L) in large view angle. As shown in Fig. 9, STW POL could greatly reduce the light leakage, and halo issue of ADS Pro TV with STW POL is much lighter than that of normal ADS TV.

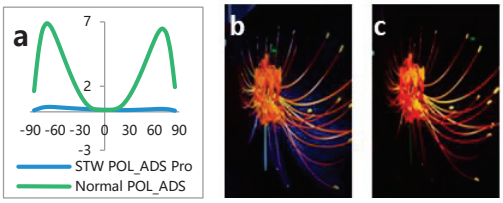

Fig. 9 L/L of normal ADS and ADS Pro in Oblique 45 ° angle (a); Halo of normal ADS (b) and ADS Pro (c) with same Mini BLU

4 True Black with Low Reflectance

True black is beneficial for ACR and for the dark image expression for TV. For the dark picture displayed on screen, the light in the environment will interfere with the picture display effect. When the light in the environment shines on the screen, it will have a strong reflection on the traditional LCD. The visual CR and color saturation will decrease.

Coating a layer of low reflective material on the surface of POL can make the reflectivity of the panel reach about 1.5%. The reflectivity of conventional LCD panel is about 5.0%. The mainstream WOLED products use AGLR surface treatment, and its reflectivity is about 2.1%. High end WOLED products use super LR surface treatment, and its reflectivity is about 1.4% by now. With the decrease of reflectivity, the picture is clearer and the image boundary become shaper. Fig. 10. Shows the photo in the table is black appearance of ADS PRO and WOLED flagship in shutdown status. As we can see, the visual black appearance of the two is almost the same. But it is worth noting that WOLED has side view color shift issue that may be resulted from the anti-reflection optical plate.

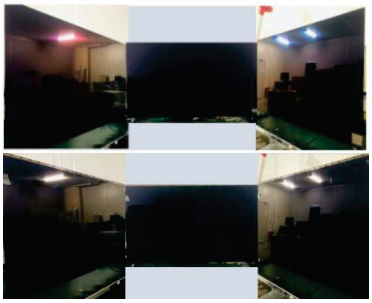

Fig. 10 Black state experience of WOLED (up) and ADS Pro (down)

5 High Color Gamut and High Transmittance

Color gamut is another important parameter of display picture quality. WOLED display devise has an ultra-high color gamut of DCI P3 99.5%. In ADS Pro, we jointly developed the best matching-based high color gamut color resin and LED backlights, including KSF and QD, with suppliers. Based on the new materials, we acquire DCI P3 >99.6% with both KSF and QD BLU, as well as optimized transmittance increased by about 20%.

6 Response Time Control with New Over Driving Method

In ADS display mode, response time $RT \propto (\gamma 1\ d\hat{}2)/K$. The response time of HCR negative LC becomes slower due to the increase of $\gamma 1$ value. Therefore, we developed small $\gamma 1$ LC single and designed lower cell gap. For HCR negative LC, the conventional one frame over driving (OD) cannot make LC molecule to reach the target state. We study the way of using two frames OD to make the LC reach the target state quickly. As showed in Fig.11, when there is no OD, the time required to reach the target state is T0. One frame OD: after the end of 1 frame OD, the brightness increases slowly and reaches the target state. The time is T1. Two frame OD: after one frame OD ends, the second frame continues OD and reaches the target state. The time is T2. It can be seen that two frame OD can effectively shorten the response time. We use 2 frame OD to realize GTG ~ 8ms of N-LC, which is equivalent to that of positive LC.

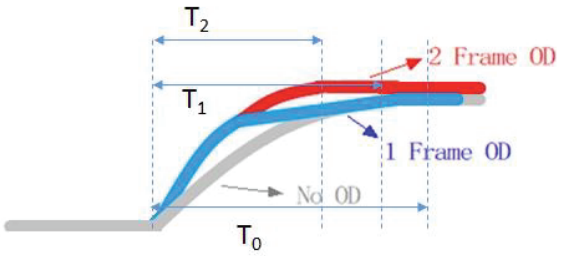

Fig. 11 No OD / 1frame OD / 2frame OD diagram

7 Conclusions

In this work, we developed new high CR negative LC material, STW POL, low surface reflection film, spectral matching optimization technology, and new OD method to increase image quality. Based on the total solution, the ACR, view angle color experience, color gamut and darkness expression has advantages compare to VA and WOLED.

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