Novel Liquid Crystal Display Mode “UV²AⅡ” with Photo Alignment Technology for a Large-Screen 8K Display

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ABSTRACT

We have developed a new liquid crystal display mode UV²AⅡ which is suitable for a large screen 8K display and commercialized as the 80” 8K TV. UV²AⅡ has brought large superiority that are 1.3 times higher transmittance, 35% faster response, and wider viewing angle property to compare with UV²A.

1 INTRODUCTION

Recently, high definition video distribution services and imaging of broadcasts are progressing, and rich content has also caught up with high definition display hardware so that it can be displayed with full specifications. At present, it has been advanced to 4K in the video distribution service of contents via the Internet and Japan Broadcasting Corporation launched a new 4K･8K satellite broadcasting in December 2018. Also, due to exponentially increasing data volume due to techniques such as IoT, big data, and AI, the demand for high definition displays capable of displaying more data and information has been increased.

More and more, development for higher resolution from FHD (1920 × 1080 pixels) to 4K (3840 × 2160 pixels), even 8K (7680 × 4320 pixels) has been accelerated.

We are the first in the world to introduce the UV²A panel production, of photo alignment technology that precisely controls the orientation of liquid crystal molecules, has long been used for mass production of large size liquid crystal display carried out with glass substrate sizes of the G10 and the G8 [1].

UV²A technology had developed when FHD was mainstream, at that time it was an excellent display mode with high performance and high productivity. However, as the resolution of television models is getting higher, especially in 8K development, further improvements on transmittance have been strongly required from the viewpoint of green product.

For 8K development, we started to analyze in detail about UV²A's problems and sought for an ideal liquid crystal display mode that we call UV²AⅡ. We have set the new display mode UV²AⅡ should meet the following two items.

1) Maximization of liquid crystal mode efficiency: For high-definition pixels, it is necessary to reduce loss due to dark lines by ideal alignment division patterns.

2) Leverage the knowledge of UV²A production experience and infrastructure: We will make maximum use of knowledge, production infrastructure accumulated in UV²A production for about 10 years, to both aims of productivity and yield meet in superior levels to other display modes.

2 EXPERIMENT

The occurrence of pre-tilt of liquid crystal molecules in VA is defined opposite to the oblique incidence direction parallel to the incident plane of linearly polarized UV and in the photo orientation, its orientation mechanism principle has been used [2] [3] [4] [5].

However, it was difficult for UV²A of this four domain VA TN to achieve both improvement of display characteristics required for 8K display and improvement of mode efficiency of orientation domain and the boundary domains.

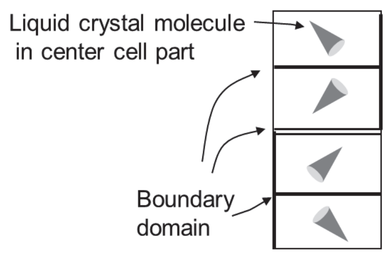


Figure 1. Schematic illustrations of LC orientation for each pixel of UV²AⅡ.

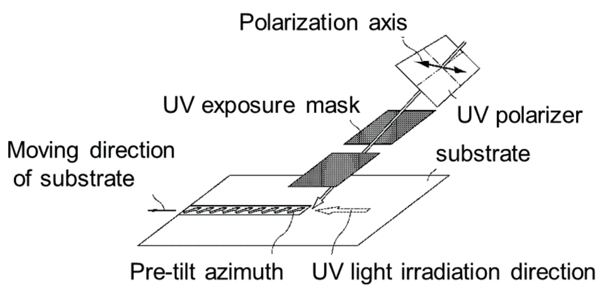


Figure 2. Schematic illustrations of the new UV exposure system for UV²AⅡ.

To maximize the liquid crystal mode efficiency in high definition pixels, we have adopted UV^{2}AⅡ orientation. Figure 1 shows a schematic view of illustrations of LC orientation for each pixel of UV^{2}AⅡ.

In order to obtain UV^{2}AⅡ orientation by photo alignment treatment, we firstly had undertook basic studies of photo alignment treatment under various UV light irradiation conditions and developed the new exposure method. The new exposure system was realized by rotating the polarization axis of UV light using the conventional UV^{2}A exposure equipment as figure 2 shows. Also, in the pixel electrode without the fine slit, edge dark lines are generated due to the influence of the lateral electric field of the gate and the source signal wiring, causing the occurrence of the transmittance loss as shown in figure 3 (a). Therefore, in order to strengthen the alignment regulating force of the liquid crystal, fine slits were arranged on the array side or on the counter substrate so as to coincide with the liquid crystal orientation direction. It was found that arranging the fine slit in the pixel has an effect that the pixel edge dark line is pushed out of the pixel as a photograph of fine slit pixels of figure 3 (b) shows. Furthermore, it is clear that the width of the dark line between the boundary domains is also found to be considerably narrower than without fine slit. It is thought that the fringe electric field of the fine slit improves the regulating power of liquid crystal orientation, narrows the dark line width at the domain boundary, and suppresses the occurrence of dark lines due to the transverse electric field along the signal wiring.

(a) No fine slit pixels (b) Fine slit pixels

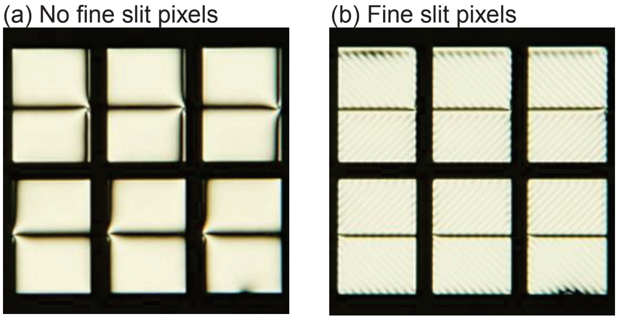


Figure 3. Photographs of white-state (on-state) for UV^{2}AⅡ panels of (a) No fine slit pixels and (b) Fine slit pixels.

3 RESULTS

The panel prototype of both UV^{2}A and UV^{2}AⅡ of the 45-inch 4K model were made at the factory, and the basic performance of transmittance, response, and viewing angle was compared and evaluated.

3.1 Transmittance

Figure 4 (a) and (b) show photographs of white state (on-state) pixel for the conventional UV^{2}A panel and UV^{2}AⅡ respectively. Compared to UV^{2}A, UV^{2}AⅡ reduced the occurrence of dark lines, and the width of the dark line decreased, it was confirmed that the transmittance improved. The transmittance improvement effect depends on the fine slit condition and the pixel pitch as shown in Figure 5. It is confirmed that the 1.3 times higher transmittance than UV^{2}A is obtained at a slit width of 3.1 μm and a pitch of 5.2 μm.

(a) UV^{2}A (b) UV^{2}AⅡ

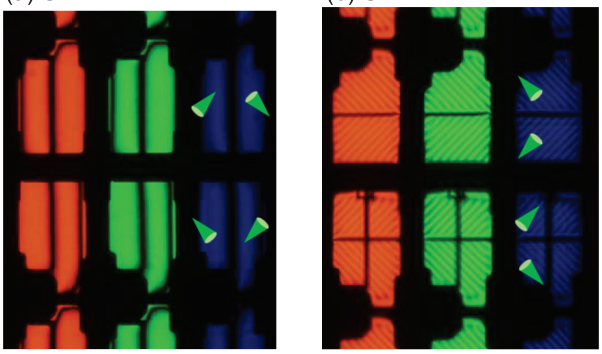


Figure 4. Photographs of white-state (on-state) for (a) UV^{2}A and (b) UV^{2}AⅡ panels.

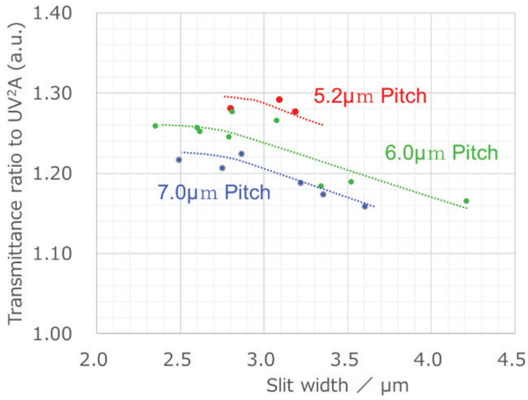


Figure 5. Evaluation results of transmittance ratio to UV^{2}A for each slit condition.

3.2 Response time

In the high definition UV^{2}A panel in which the area ratio of the dark line in the pixel becomes high, the problem of white tailing has become obvious.

Response time is significantly improved compared to UV^{2}A. 9 x 9 average values of gray-to-gray level response of UV^{2}A and UV^{2}AⅡ are 7.8 msec and 5.1 msec respectively, UV^{2}AⅡ is 35% faster than UV^{2}A, shown in Table 1 (a) and (b). Further, UV^{2}AⅡ is faster than UV^{2}A under the condition of 64 (yellow part) out of gray-to-gray level response 72 conditions. The ratio to satisfy one frame response (8.3 msec or less) among gray-to-gray level response is achieved over 99%, and the remaining 1% responds within 2 frames, shown in Table 1 (c).

In UV^{2}AⅡ, the response time is equalized at any transition between gradations, and there is no extremely slow transition. This shows that adjustment of images in modules and TV sets is relatively easy.

Table 1. Evaluation results of response time; (a) UV2A and (b) UV2AⅡ, (c) Comparison of response time distribution by frame period.

(a) UV^{2}A

End 9×9 ave. 7.8 msec

Start	0	32	64	96	128	160	192	224	255
0		26.0	15.9	14.7	12.2	8.6	6.2	4.6	3.7
32	4.6		11.9	22.0	16.4	10.5	7.8	5.4	3.3
64	4.5	7.3		17.8	12.6	8.7	6.7	4.6	2.7
96	4.5	7.3	8.7		8.8	7.1	5.6	3.8	2.7
128	4.6	7.3	7.0	7.6		6.4	4.6	3.6	3.2
160	4.7	7.1	6.7	6.7	6.6		4.4	3.3	8.4
192	4.8	7.0	6.5	6.2	6.4	5.9		3.9	13.0
224	5.0	6.7	6.4	5.9	6.3	5.7	5.4		42.4
255	5.3	6.6	6.6	6.0	6.3	6.0	5.6	4.3	

(b) UV^{2}AⅡ

End 9×9 ave. 5.1 msec

Start	0	32	64	96	128	160	192	224	255
0		5.6	5.2	4.9	5.0	5.0	5.1	5.8	10.9
32	4.1		6.6	6.3	5.8	5.7	5.3	4.6	8.1
64	4.1	5.7		6.5	5.8	5.7	5.2	4.3	7.0
96	4.1	5.5	6.6		5.2	5.3	5.1	4.2	5.7
128	4.1	5.0	5.7	5.8		4.5	4.3	3.5	4.8
160	4.2	4.8	5.4	5.4	5.7		3.5	2.9	4.0
192	4.3	4.6	5.3	5.4	5.5	5.4		2.6	3.3
224	4.5	4.7	5.2	5.3	5.4	5.3	5.2		2.6
255	4.9	4.5	4.8	5.4	5.5	5.3	5.1	6.4	

(c)

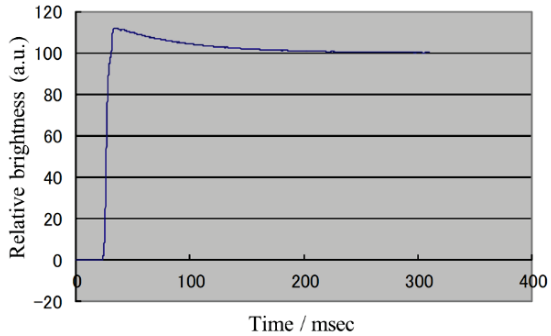
	UV^{2}A	UV^{2}AⅡ
1F 8.3 ms or less	76% (55 / 72)	99% (71 / 72)
2F 16.6 ms or less	18% (18 / 72)	1% (1 / 72)
3F 25.0 ms or less	3% (2 / 72)	-
4F 33.3 ms or less	1% (1 / 72)	-
4F 33.3 ms more	1% (1 / 72)	-

In the UV^{2}A panel, a phenomenon in which the black bar is brighter behind the surrounding white when scrolling the black bar on the full white display for example.

This display blur is due to the overshoot waveform of transient response as shown figure 6 (a). This overshoot waveform is derived from a transient phenomenon in the dark line of the domain boundary of liquid crystal alignment. No overshoot response waveform was observed in all response transitions of UV^{2}AⅡ whose example of the response waveform is shown in Figure 6 (b). This suggests that the optical change of UV^{2}AⅡ liquid crystal orientation domain and its boundary domain during transient is relatively stable and there is no unnecessary movement in the liquid crystal molecules, and it is an ideal orientation state.

Also, this straightforward waveform of UV^{2}AⅡ in Figure 6 (b) can be said to be strong against scroll images and images with fast motion. Therefore, these are response performance suitable for displaying realistic images of 120 Hz driving with high definition display.

(a) UV^{2}A



(b) UV^{2}AⅡ

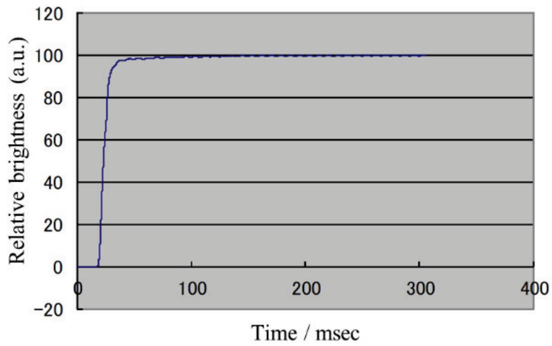


Figure 6. Response waveform of the transition from 0 to 255; (a) UV^{2}A and (b) UV^{2}AⅡ.

3.3 Viewing angle

In high definition panels such as 8K, the viewing distance is getting shorter because the user feels more realistic, and there is a strong demand for improvement of the viewing angle characteristics from the user.

The same mono-scope test image was projected on each of the UV^{2}A panel and the UV^{2}AⅡ panel, and the viewing angle dependency of the display quality was visually evaluated. Compared with the conventional UV^{2}A, white inversion improvement of the viewing angle in deep oblique over 45 degree (yellowish color change in white state) is confirmed as figure 7 are shown. It was proved that UV^{2}AⅡ can simultaneously improve the transmittance and the viewing angle.

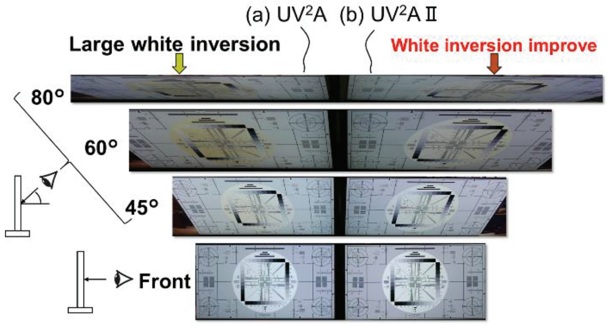


Figure 7. Evaluation results of viewing angle performance; (a) UV^{2}A and (b) UV^{2}AⅡ.

Figure 8. New 80-inch 8K LCD-TV product model.

4 CONCLUSIONS

We have pursued an ideal orientation to improve transmittance in high definition pixels. In order to realize this, we have developed the new exposure method to UV^{2}A Ⅱ liquid crystal orientation, whereas the conventional exposure method was employed that pre-tilt direction and the incidence plane of photo alignment were in parallel.

We have succeeded in dramatically improving image quality by realizing UV^{2}AⅡ liquid crystal display mode which can solve the problem of reduction of transmission efficiency due to dark line generated in UV^{2}A orientation in high definition large screen liquid crystal panel.

Other modes such as PSA [7], IPS [8], and FFS [9] are evolving, and are applied to large size high resolution LCD-TVs. We developed the original liquid crystal display mode UV^{2}AⅡ which is competitive with other modes. It has been confirmed that UV^{2}AⅡ mode has realized 1.3 times higher transmittance, 35% faster response, and wider viewing angle property to compare with the conventional UV^{2}A mode. The UV^{2}A Ⅱ technology combined with HDR (high dynamic range) technology enables to display more realistic vivid images due to the improvement of basic optical performance.

We released the world's first 8K tuner built-in TV in the world. As Figure 8 shows, our new 80-inch 8K LCD-TV product model (AQUOS® 8T-C80AX1) with UV^{2}A Ⅱ technology [10] and IGZO5-TFT technology [6], which achieves higher mobility is 15 cm2 /Vs, drives at high speed of 120 Hz. It reproduces the ultimate real and provides a completely new user experience.

We are confident that this innovating result of the new photo alignment process of UV^{2}AⅡ leads the large-screen 8K Display to become widely used. 8K high-definition technology is expected not only in the broadcasting / video field, but also in medical, security etc., which may change society. We will fulfill its role to realize “8K society” that is more convenient, safer and exciting.

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