The OLED with an Extremely Low Proportion of Harmful Blue Light and Excellent Viewing Angle Performance

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Abstract

As the market share of OLED (organic light-emitting diodes) based display products increases, consumers are paying more and more attention to eye health. In this work, by selecting polarizer that can filter out harmful blue light, the level of harmful blue light proportion-A was reduced to 3.7%. While achieving ultimate low harmful blue light, there will be significant changes in the luminance decrease ratio of blue light, which leads to deterioration in the viewing angle. Based on this, we adjusted the viewing angle by optimizing the micro-cavity. The color shift 1 of 15/30/45/60/75° were 1.1/2.4/2.4/3.7/4.3 JNCD, respectively. Meanwhile, the subjective perspective of viewing angle meets the mass production standards.

Author Keywords

Harmful blue light; viewing angle; polarizer; eye health

1. Introduction

In recent years, due to its numerous advantages such as low power consumption, lightness and flexibility. More and more mobile phones, wearable devices, and laptops have adopted organic light emitting diodes (OLED) as the display solution. With the increasing market share of OLED products, more and more consumers have begun to pay attention to the issue of screen eye protection. As the direct channel for people to obtain information, the white light of the screen is composed of red, green, and blue colors. Among the three colors, because the blue light possess a short wavelength and high energy, it inevitably causes harm to the eyes, especially the blue light in the band of 415nm to 455 nm, which was defined as harmful blue light. This phenomenon is also defined as blue hazard. Studies have shown that harmful blue light causes chronic retinal damage and also triggers eye fatigue, dryness, and other discomforts, affecting sleep quality. Therefore, how to reduce the proportion of harmful blue light has become the focus of products.

There are many ways to quantify blue hazard. The world's major certification organization basically have blue hazard certification, of which Societe Generale de Surveillance S.A. (SGS) certification and TÜV Rheinland Group certification are most widely used. Different certification organization have different quantification methods of blue hazard. In this paper, we quantified the blue hazard by calculating the proportion of the harmful blue light band (415~455 nm) to the visible light band (380~780 nm), which is defined as HBLP-A (harmful blue light proportion-A).

To reduce the blue hazard, it is necessary to decrease the proportion of the harmful blue light band. At present, the following methods can effectively reduce the proportion of harmful blue light. Such as selecting blue dopant materials with longer wavelength, selecting module materials that can filter out harmful blue light, such as polarizers or cover glass. All the strategies mentioned above can achieve the ultimate lower HBLP-A. However, no matter which strategy is applied, it will inevitably have an impact on other optical performances, such as viewing angle, power consumption and color gamut. Especially when utilizing polarizer that can filter out specific wavelengths, it will cause a change on luminance decrease ratio of blue light, ultimately deteriorating the viewing angle and power consumption. Therefore, the focus of our research is how to achieve the reduction of HBLP-A while ensuring that other crucial optical properties don't deteriorate significantly.

In this article, firstly, we selected the blue dopant with longer wavelength, the harmful blue light components can be effectively decreased. Thus, the proportion of HBLP-A reduced to 5.1%. Meanwhile, the color shift 1 of 15/30/45/60/75° were 0.9/2.2/2.3/3.1/3.1 JNCD, respectively, the subjective visual effect of viewing angle met the production standards. Secondly, in order to further reduce the HBLP-A based on the above products, we selected the polarizers that can filter out the harmful blue light. Meanwhile, the luminance decrease ratio of blue light will be accelerated, the color deviation trajectory will shift towards the second quadrant, which resulting in the deterioration of color shift1 and subjective visual effects. Thus, we adopted the color coordinate of optimized Rx/Gx/By by optimizing the micro-cavity, the color deviation trajectory is comparable to the performance of the aforementioned products. The subjective visual effect of viewing angle can also meet the production standards.

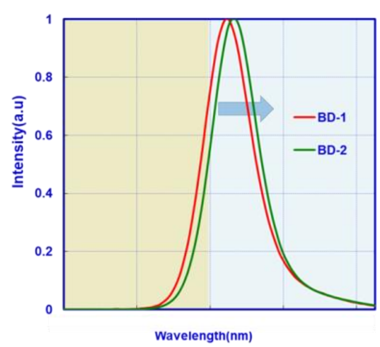

Figure 1. Electroluminescence spectra of blue devices based on blue dopant with different peaks

2. Results and discussions

Cells with different OLED device structure conditions were prepared based on the same product on the 6th generation AMOLED mass production line, and ensure that the array process, electronic code and module manufacturing process are completely consistent. The modules used for testing must conform to market standards, the edge test element group (TEG) was collected to test the relevant electrical properties. Power consumption was tested by the test platform built by CA410 color analyzer and W6 module lighting equipment, and the frequency of module measurement was 120Hz. The viewing angle, HBLP-A and DCI-P3 data was tested by CS2000. The full light emitting device structure is: Anode/hole injection layer (HIL)/hole transporting layer (HTL)/electron blocking layer (EBL)/emission layer (EML)/hole blocking layer (HBL)/electron transporting layer (ETL)/electron injection layer (EIL)/cathode/capping layer (CPL).

2.1 Selecting blue dopant with different peak

As shown in Figure 1, when a blue dopant with a longer wavelength is selected, it can be clearly observed that the spectral intensity between 415 and 455 nm will significantly decreased, which is beneficial for reducing HBLP-A. Therefore,

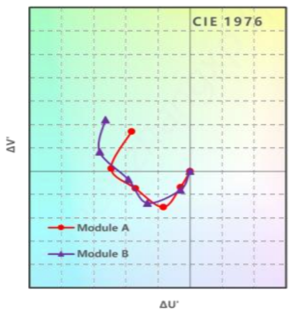

Figure 2. Color deviation trajectory based on different schemes

we have verified it on the product based on BD-2 material, focusing on viewing angle, color gamut, power consumption and HBLP-A. As we all know, in order to achieve lower power consumption and higher color purity, the blue-doped materials are generally oriented towards lower peaks and narrower spectra. Thus, when a long-wavelength material is chosen, the blue efficiency will be inevitably decreased. So, by adjusting the thickness and doping ratio of the blue light-emitting layer (B-EML) and the electron transport layer (ETL), we obtained the optimal device structure. This scheme was defined as module A. Module A has demonstrated outstanding optical and reliability performance and has been smoothly mass-produced on the production line. The color shift 1 of 15/30/45/60/75° were 0.9/2.2/2.3/3.1/3.1 JNCD. The color deviation trajectory and color shift1 were shown in Figure 2 and Figure 3. HBLP-A was only 5.1%.

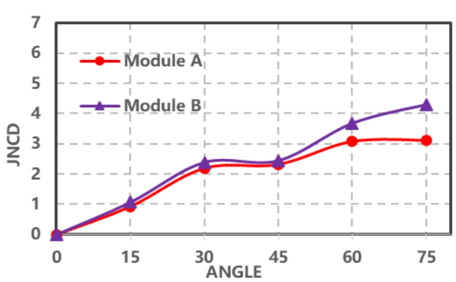

Figure 3. Performance of color shift1 from different angles based on different schemes

2.2 Verification and optimization of polarizer

Table 1. Schemes of CIE DOE

	R	G	B
CIE DOE	+20Å	G-Base	B-Base
	-20Å	G-Base	B-Base
	R-Base	+20Å	B-Base
	R-Base	+20Å	B-Base
	R-Base	G-Base	+20Å
	R-Base	G-Base	-20Å

In order to further reduce HBLP-A of the product, we replaced the polarizers based on module A, which can filter out the harmful blue light wavelength. Based on our previous research, filtering blue light would cause blue light brightness to decrease more rapidly, and the color deviation trajectory would shift towards the second quadrant. In the larger viewing angle, the subjective visual effect would be slightly yellowish. Thus the blue color coordinate (By) must increased, and the color deviation trajectory should be adjusted towards the third quadrant. Thus, we conducted color coordinate of 1931 design of experiment (CIE DOE) verification based on the product with low blue hazard polarizer to seek a balance between extremely low HBLP-A and meeting the viewing angle requirements of consumers. The CIE DOE scheme was shown in Table1, verification was conducted for Rx, Gx and By, respectively. Finally, a combination of Rx/Gx/By with a similar color deviation trajectory to module A was obtained. The product adopted this scheme was defined as module B. The color coordinates of Rx/Gx/By were shown in Table 2. The color shift1 of 15/30/45/60/75°were 1.1/2.4/2.4/3.7/4.3 JNCD, respectively. Compared with module A, the difference in the color deviation trajectory and visual effect of viewing angle of module B is insignificant. However, the HBLP-A of module B had significantly decreased, was only 3.7%.

Table 2. The color coordinates of Rx/Gx/By

	Rx	Gx	By
Module A	0.679	0.238	0.049
Module B	0.679	0.241	0.051

As we previously described, by utilizing polarizer that can filter out specific wavelength, and to ensure that the color deviation trajectory and subjective visual effect of viewing angle can meet requirements for mass production, the color coordinates of blue light (By) was increased. This results in a higher proportion of blue light in the white light compared to regular products, which in turn leas to an increase in power consumption. The detailed data was shown in Table 3 and Table 4.

Table 3. Color shift1 of Module A and Module B at different angles

Color shift1	15°	30°	45°	60°	75°
Module A	0.9	2.2	2.3	3.1	3.1
Module B	1.1	2.4	2.4	3.7	4.3

Table 4. The blue light brightness, current and power consumption at 380nit, and the HBLP-A and DCI-P3 data at 800 nit of Module A and Module B

	Brightness of blue light	Elvss current of blue light	Power consumption	HBLP-A	DCI-P3
Module A	100.0%	100.0%	100.0%	5.1%	⩾ 99.5%
Module B	110.0%	111.0%	106.2%	3.7%	⩾ 99.5%

3. Conclusions

In this paper, we have presented products based OLED that possess both extremely low proportion of harmful blue light and excellent viewing angle performance. By selecting blue dopant with longer wavelength, the HBLP-A was reduced to 5.1%, the color shift 1 of 15/30/45/60/75 °were 0.9/2.2/2.3/3.1/3.1 JNCD, respectively. Meanwhile, the subjective visual effect of viewing angle met the production standards. On the basis, by replacing the polarizer that can filter out harmful blue light, the HBLP-A was further reduced. However, due to the accelerated luminance decrease ratio of blue light, color deviation trajectory will shift towards the second quadrant. In order to solve the problem mentioned above, we optimized the color coordinates of Rx/Gx/By. Finally, we successfully adjusted the color deviation trajectory to a level comparable to that of products based on conventional polarizer, which can also met the production specifications. The HBLP-A was only 3.7%. On the other hand, the drawback is that the application of polarizer with low HBLP-A, which lead to 6.2% increase in power consumption. We believe that based on the work presented in this paper, by superimposing multiple CPL or phosphor-assisted TADF-sensitized fluorescence (pTSF), we will be able to achieve products with both low power consumption and low HBLP-A in the future.

4. Acknowledgements

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