Development of Enhanced Dual-Cell LCD with Mega Contrast

Lei GUO, Yanping LIAO, Xibin SHAO ,Yue DU , Lin ZHANG, Hao LIU, Ruichen ZHANG, Jiaqing LIU, Liangliang JIANG, Ke DAI, Seungmin LEE, Zhangtao WANG, Hongming ZHAN

guoleihf@boe.com.cn
BOE Technology Group Co., Ltd. Beijing, China
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ABSTRACT

This paper described the new key technology of Dual-Cell LCD with mega contrast. V-type pixel of sub cell, which contains enhanced mosaic slit ITO, is designed for eliminating moiré, transmittance fluctuation and horizon mura. Thanks to the development of functional films, Large size Dual-cell LCD such as 110 inch was realized without any special pixel design on sub cell. Although algorithm optimization was needed according to the difference of resolution between main cell and sub cell, the skill of stacking two cells directly greatly enriched the product group and lifetime of Dual-Cell LCD, as low cost as well.

1 INTRODUCTION

High-quality display is always the most important pursuit for display devices. Real natural display is the everlasting appeal for human being's eyes. Liquid Crystal Display (LCD), micro-LED (U-LED) and AM-OLED are regarded as the mainstream technology in current and in future. The advantages of LCD are larger size, high PPI and best gray scale show. Although, the disadvantages of LCD are also obvious such as lower contrast. This paper described the new enhanced technology of Dual-Cell LCD （BD cell for short） with mega contrast. BD Cell can be regarded as an updated technic on Local Dimming. It adds a black and white LCD screen (called as sub cell) between the backlight and the display screen (called as main cell), and uses the pixels of sub cell for regional light control, so as to realize HDR. If the resolution of subcell is FHD, the local dimming zones are already near to two million and mega contrast could be achieved, while its picture quality is as almost same as OLED. V-shaped pixels were necessary to be designed for the improvement of the moiré issue and for the minimization of transmittance fluctuations, which is easy to happen when two LCD panels stack together. At the same time, the pixel of large-size TV products with FHD resolution needs mosaic design, otherwise horizontal mura issue will occur under wide view angle. We will discuss the mechanism and improvement of horizontal grain separately in another article. New type pixel design means investment on new mask fee, which limited the rapid expansion of BD Cell's product portfolio. In order to reduce the development cost of BD Cell and expand its product group, the problem of moiré issue of BD Cell products with normal designed pixel must be solved. Based on the development of multi-functional materials and high-precision laminating technology, we have realized directly-stacked BD cell products such as such as 86 4K 120Hz, 98 4K 60Hz and 110 8K 120Hz BD cells. While OLED is very difficult to realize such large-size at present, and these BD Cells have no need to invest new mask, which greatly reduces the threshold of BD Cell and enriches the product group.

2 DEVICE MANUFACTURE

Dual cell is composed of two LCD panels, main cell and sub cell, which are fitted by OCA, as shown in the figure 1.

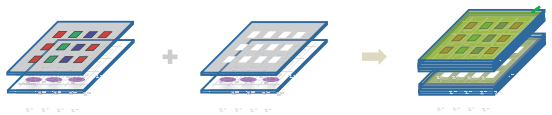

Fig. 1 Dual Cell Structure

Through FFC, the PCBs of the two LCD panels are connected to the programmable logic device, which is customized FPGA Board to drive the main cell and sub cell simultaneously to ensure the picture quality. The size of two panels must be close to each other. At present there are two kinds of common laminating process, one is frame fitting, meaning circling glue around the cell, and then putting the two screen stick together, this scheme has the advantage of low cost and downside of air layer between two screens. As is known that the refractive index of glass is different from that of air, refraction and reflection are easy to occur at the interfaces between glass and air cause of the light transmission in the discontinuous medium of refractive index, which will cause light efficiency loss, and also affect the polarization of light leading to lower contrast. At the same time, due to the presence of air gap, the phenomenon of Newton's ring issue occurs easily especially when the panel size is large because the gap of air layer will be very uneven due to gravity effect, leading to bad display quality. Based on the above considerations, we finally choose the OCA laminating process, and adopt the high quality optical OCA material, through experimental comparison, the OCA process can improve 10% transmittance than frame fitting, also perform better on eliminating Newton's rings. Based on OCA fitting

process, the corresponding panel size range is suitable from 12.3 inch to 110 inch, which have been successful completed. In addition, this process can deeply dig out the fitting accuracy of existing equipment, which lays a foundation for the subsequent development directly-stacked Dual-cell technology.

3. PIXEL DESIGN

3.1 V-Type Pixel Design

Dual-Cell LCD achieves high contrast ratio by laminating two cells. Generally, sub cell resolution is lower than main cell in order to reduce transmittance loss. However, with traditional square type pixel, unequal spatial frequency and alignment offset between two cells bring about not only moiré issue, but also transmittance fluctuation and horizontal mura (H-mura). Owing to alignment shift, metal lines of sub cell shift and pass through certain single row of main cell for the most part. Due to larger pixel size of sub cell, adjacent rows of main cell are unoccupied. There is a big risk appearing H-mura and discrepancy of transmittance between Dual-Cell panels.

Main cell pixel remains normal square shape. Here we provide a novel design of sub cell pixel. Figure 2 indicates new V-type pixel of sub cell which contains metal polylines, designed for eliminating moiré, transmittance fluctuation and H-mura. Constructing V-type pixel, gate line of sub cell is distributed across aperture area of main cell uniformly. It is illustrated in Figure 2 that transmittance fluctuation which cause by panel shift have been markedly mitigated to less than 3% by the new type of pixel, instead of reaching to 17% by normal square pixel of sub cell.

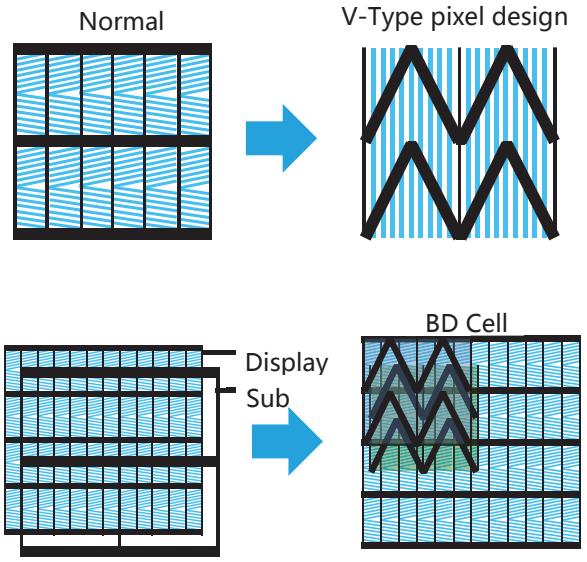

Fig. 2 New V-type pixel of sub cell compares with traditional square pixel

Moiré is the principal issue while two cells with diverse pixel size combine. Each pixel image of main or sub cell have its unique spatial frequency. When a wavy pattern overlies another wavy pattern with discrepant spatial frequency. Fortunately, it could be solved by V-type pixel of sub cell. There is moiré emulation method which base on graphical computing and contrast sensitivity of human vision having been developed. According to the image results demonstrated in figure 3, , combining with main cell, moiré streaks occur on V-type pixel sub cell is much slighter than which on square pixel sub cell.

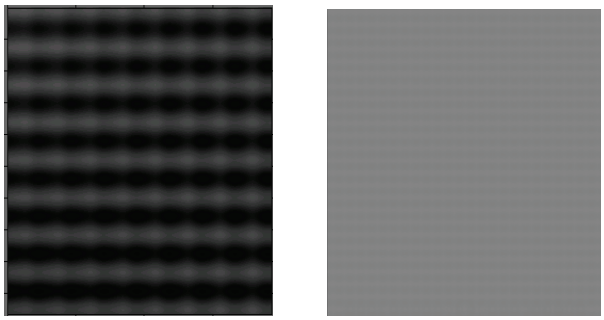

Fig. 3 Moiré emulation results between traditional pixel and V-type pixel

3.2 Mosaic Pixel Slit Design

As discussed above, in Dual-Cell LCD, the ppi of main cell is higher than sub cell. Take UHD main cell & FHD sub cell as example, the single pixel of sub cell is generally 4 times larger than normal pixel. In normal two-domain design, the size of single domain is too big so that the naked eye could observe the difference at side view. The actual situation is yellow and blue intersecting stripes caused by color shift, seen in figure 4.

Fig.4 Yellow and blue intersecting stipe in side view under simulation

In side view, LC retardation of different domain is not the same value because of the rubbing angle and electrode slit direction. As a result, transmittance and color changes periodically. Take example of 75 inch FHD sub cell, seen in figure 5, the same color means the domain distributed in the same direction so that the LC

retardation is the same value. The repeat period of this sub cell is about 1.7mm, which is larger enough to be observed easily. So pixel design must be optimized further.

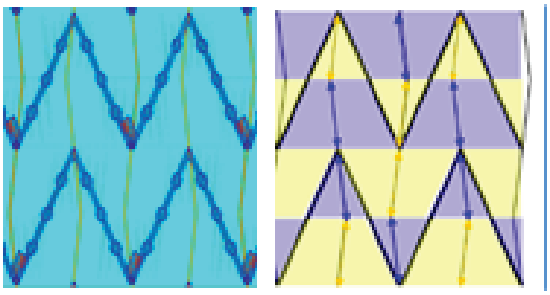

Fig.5 75 2K sub cell pixel

Modification of domain distribution is necessary to remote or decrease the H-line mura. The key point of electrode modification is decreasing the repeat period, or taking smaller single domain size, in aim to average the brightness of a unit pixel. We proposed several new designs with more refined domain which we called mosaic pixel design. Their brightness differences are also calculated and it is proved the brightness difference could be effectively reduced.

The mosaic design segments pixel in several domain which at the same size level of 75 inch 8K panel pixel. On this way, we simulated the mosaic design in 75 8K panel according to the simulated brightness and the gray scale translation. Two cases are effective in solving H-line mura without other risk. In conclusion, multi-domain could solve color shift, but it is necessary to pay attention to single domain size, especially in low ppi product, the H-line risk need to be carefully considered.

3.3 Multifunction Material

In order to reduce the development investment of BD Cell and rapidly expand the product group, breakthroughs should be made in the technology of directly-stacked BD cell. The so-called directly-stacked BD cell refers to the formation of BD cell by directly stacking existing mass-produced LCD panels together. The biggest challenge of this scheme is the problem of moiré. In order to eliminate the moiré, multifunctional material is developed, which is characterized by its special microstructure so that it has a high haze value without affecting the polarization state of polarized light, thus ensuring the picture quality and contrast of directly-stacked BD Cell. Limited by the requirement of technical confidentiality, there is not much information here. In a word, the main function of this material is to weaken the recognition of moiré pattern by human eyes. One material should be highlighted, called the IDF (Isotropic Diffusion Film), its obvious character is microstructure with hollow cylindrical, this structure has brought the two important advantages, one is the diffusion effect is bigger and more uniform compared with general diffusion film usually used in back light for LCD product, the other one is this structure will not affect the polarization of light. Conventional diffusion films rely on the diffuse reflection of particles, which will affect the polarization of polarized light, resulting in a decrease in contrast, while IDF can ensure that the contrast is not affected because of its special micro structure. Figure 6 shows a schematic diagram of multifunctional material. It can be seen that after the use of multifunctional material, the moiré has been well weakened, making it difficult to be recognized by human eyes.

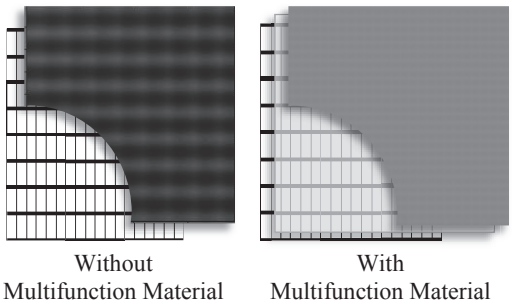

Fig.6 Moiré improvement result with different material

The second challenge of directly-stacked BD cell is the adhesion accuracy, because bad adhesion accuracy will lead to a large transmittance fluctuation between different products. Figure 7 shows the transmittance fluctuation of 65 4K BD cells under the conventional adhesion accuracy. It can be seen that the transmittance fluctuation is close to 20%. Thanks to the process route of OCA full fitting, we have greatly improved the precision of the fitting equipment, which has been increased by 6 times. Keep transmittance fluctuation within 10%, which ensures the quality of the directly-stacked BD cell. The 110 inch 8K 120Hz BD Cell, which was exhibited in Shanghai Display Innovation Convention & Expo in July 2020, is a directly-stacked technology.

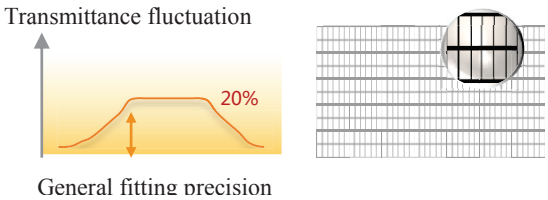

Fig. 7 Transmittance fluctuation of directly-stacked BD cell

4 CONCLUSIONS

This article focuses on the latest key technologies of the BD Cell with mega contrast. BD Cell is an advanced version of HDR technology. Two LCD screens are fitted together through OCA. The top screen is used for normal display, called main cell, while the bottom one is black

and white, mainly used for light control, called sub cell. In order to improve the moiré caused by the overlapping of two screens, v-type pixel design is needed, which is also the first time used in LCD. The design details of V-shaped pixel are optimized through software simulation to ensure the elimination of moiré. At the same time, due to the 2 domain pixel design, attention should be paid to the problem of large angle horizontal lines when the pixel size of sub cell is too large, so the pixel should be designed as a mosaic shape. In order to rapidly expand the BD Cell product group, directly-stacked BD cell technology has been applied. Multifunctional materials have been developed to improve the moiré, and meanwhile, the fitting accuracy has been increased by 6 times, so as to ensure that the transmittance fluctuation of directly-stacked BD cell is less than 10%.

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