Development of 88-inch 120Hz 8K OLED TV for Mass Production

Koichi Miwa, Hyun-Haeng Lee, Seong-Eok Han, Yong-Joon Heo, Du-Hwan Oh and Shin-Kyun Park

LG Display Co., Ltd., 245 LG-ro, Wollong-myeon, Paju-si, Gyeonggi-do, Korea

Keywords: OLED TV, 8K, Oxide TFT, White on Color Filter, Mass Production

Abstract

88-inch 8K OLED TV has been launched to the market. The display features 7680 x 4320 pixel resolution and 120Hz refresh rate. White OLED on Oxide TFT backplane architecture is applied as were in our 4K/2K OLED TV products. Design and driving features of 88-inch 8K OLED TV will be presented in this paper.

1 Introduction

4K television comes up to the main stream in TV industry. High resolution is one of the keywords for large size displays, not just because the screen size gets larger and more pixels are needed. High resolution, combined with other display characteristics appropriately tuned, has a potential to raise a perception of depth on a two-dimensional image, and can enhance the reality of an image displayed on a screen.

NBC distributed a part of Olympic Games in Rio and Pyeonchang in 4K footage in 2016 and 2018. Since then, 4K TVs are steadily becoming the standard of TVs, and currently many 4K content available in some Sports Channels, Streaming Services, and Blue-ray titles.

In 2020, Tokyo Olympic and Paralympic are coming. NHK started 4K and 8K broadcasting via satellite in December 2018, and will broadcast the 2020 Olympics in 8K. Italy's RAI network is also planning to follow it. While TV transition to 4K is undergoing, Broadcasters are already pushing 8K as the next generation of 4K.

Under such circumstances, TV set companies already started shipping 8K TVs from late 2018. Among them, the world first 88inch 8K OLED TV is in mass production phase in July 2019. With high contrast of OLED display combined with 8K resolution, clear and detailed image expression becomes commercially available.

On the other hand, pixel count of 8K is 4 times as many as 4K, and 16 times as many as HD. Driving 8K OLED at 120Hz is quite a challenge. As OLED pixel circuit is busier than that of LCD's in general, load of data and scan line becomes heavier in OLED display. Challenge in 8K OLED display design is to correctly program data on a pixel with Gate-Integrated-on-Panel (GIP) in a limited period of time [1] and to secure sufficient emission area in a limited pixel area.

In this paper, 88 in. 8K OLED TV display panel design and approach to maximize aperture will be addressed, and some technologies introduced to achieve 120Hz drive of 8K will be explained, before specifications of 88 in. 8K OLED TV display is summarized.

2 Technologies

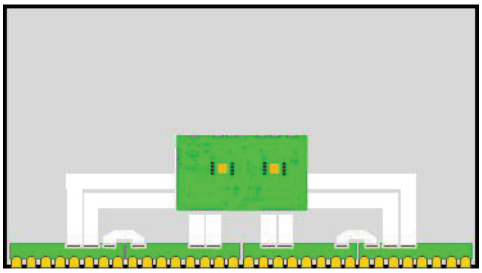
2.1 Panel and pixel design

Figure 1 shows the outline of an 88-inch 8K OLED display module. It receives image data through V-by-One from set module. The image data are timing-controlled and image-processed in two separate TCON chips in parallel. Each covers half of the display which is 3840 x 4320 pixels per frame, the same as 4K to the horizontal, but twice as many to the vertical. They are synchronized each other so that no image discrepancy occurs between left and right half of the display.

The image data is output to source driver IC's on the lower end of the backplane. Scan drivers are integrated on panel as GIP with IGZO TFTs.

The panel is bottom emission structure, in which OLED light goes down to glass substrate through TFT layers and encapsulated on top with metal this film. The key to mass production of OLED TV panel is the combination of Oxide TFT backplane and WRGB OLED [2].

(a) Front side



(b) Backside

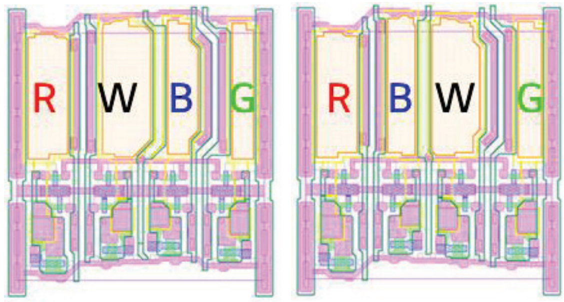
Figure 1. 88-inch 8K OLED display module outline

IGZO semiconductor thin film can be sputtered at room temperature, compatible with conventional mass production line for flat panel displays, and can achieve much higher mobility and much better stability compared with conventional amorphous silicon TFTs.

WRGB OLED is consisted of un-patterned White OLED on color filter with unfiltered fourth sub-pixel additional to RGB sub-pixels to compensate for the efficiency loss through the filter layers.

OLED emission efficiency is subjected to decay with cumulative current stress. To achieve sufficient product lifetime, emission area should be maximized to reduce the current density. In 88 in. 8K OLED display, 3T1C pixel circuit with single scan line is adopted to minimize the non-emissive area occupied by addressing metal lines and pixel circuit [3].

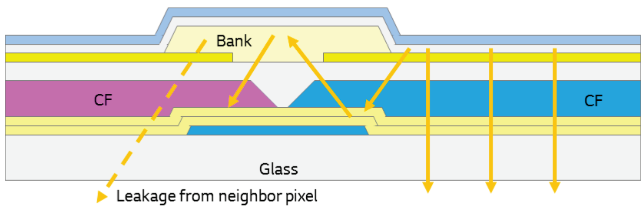
WRGB sub-pixel layout is optimized with putting aperture ratio higher priority. After studying several layouts, arrangement in the order of R-B-W-G exhibits the maximum aperture ratio with less winding in data lines. Figure 2 shows the comparison of aperture ratio between (a) R-W-B-G layout and (b) R-B-W-G layout.



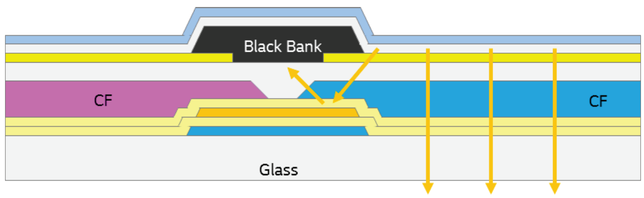
(a) R-W-B-G (b) R-B-W-G

Figure 2. Variation of pixel layout.

Bank layer material is also newly chosen for a better aperture ratio. Bank layer lies between anode layer and OLED organic layers to prevent electrical short between anode and cathode metal, and also defines the emission area. Bank layer material used to be a transparent resin in our previous models. Distance between sub-pixel apertures were determined to block the stray light from the neighboring sub-pixels through the transparent Bank layer (Figure 3a). Opaque Bank material is newly applied in 8K OLED. As the Black Bank bridges anode between two sub-pixels, it must be high-resistive [4]. Since stray light is absorbed in the Black Bank layer, the distance between the sub-pixels can be reduced and improve the aperture ratio (Figure 3b).



(a) Slit strucrture of Transparent Bank layer



(b) Black Bank layer

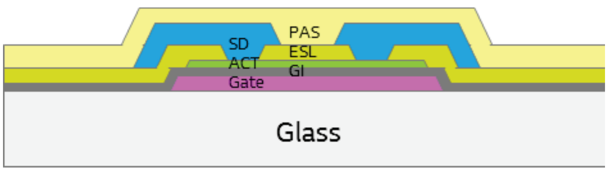
Figure 3. Bank layer between subpixels

With above mentioned improvements, 88 in. 8K OLED TV panel achieves aperture ratio over 30% even with 4 sub-pixel systems in 8K resolution.

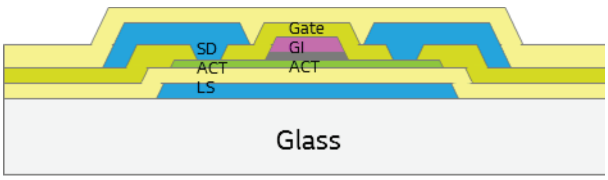
2.2 8K 120Hz driving

When 8K is driven at 120Hz, addressing time for 1 horizontal line (1HT) is less than 2usec. Scan signal delay is critical to correctly program data voltage in each pixel within the short period of time.

Cu wiring for scan line and self-aligned top-gate coplanar structure for IGZO TFT are applied in 88-inch 8K OLED TV panel to minimize the load of scan line and reduce the line delay [5]. Figure 4 shows the comparison between conventional bottom gate back-channel etch structure TFT and self-aligned top gate coplanar structure TFT, respectively. Because there is no overlap between the gate and source-drain metals in the self-aligned coplanar structure, switching TFT gate to source capacitance as a load of scan line can be greatly reduced.



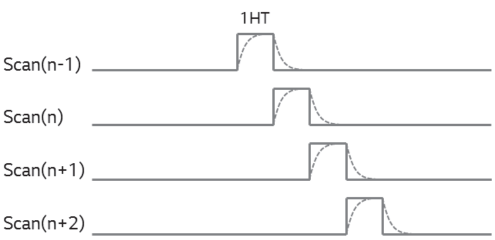
(a) BCE Bottom Gate



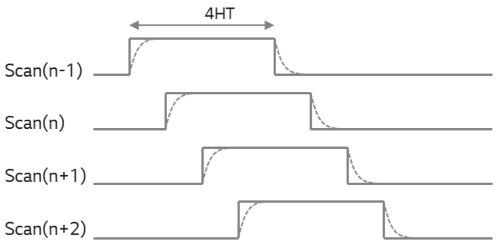
(b) Self-Aligned Top Gate

Figure 4. Oxide TFT strucrture

We also applied scan overlap drive and scan under-drive to improve rising and falling characteristics of scan signal. Scan overlap drive is to turn scan voltage high before target line addressing timing to reduce scan signal rising delay influence on data charging. As depicted in figure 5, 4HT drive is adopted in 88-inch 8K OLED in which scan signal is turned high at 3 horizontal line time ahead of the addressing timing.



(a) 1HT Scan Drive



(b) 4HT Scan Overlap Drive

Figure 5. Scan timing diagram

Scan under-drive is to add an extra low voltage lower than scan low voltage (VGL) to accelerate falling edge reaching down to scan off voltage, the threshold voltage (VTH) for the switching TFTs on pixels. It is a similar technique reported in reference [6]. Figure 6 shows scan signal transition in scan under-drive in solid line compared with that of conventional scan signal in dashed line. As the scan signal aims to the third voltage by ΔVGL below VGL when scan signal is turned off with scan under-drive applied, it reaches VTH faster than the conventional scan drive by the falling time delta shown in the figure. After scan signal is turned off, it recovers to VGL again and retains VGL until the next frame.

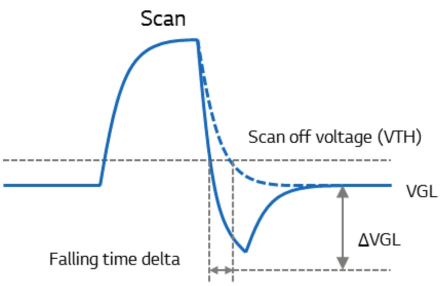


Figure 6. Scan under-drive

Scan signal delay is relatively smaller near panel edge and gets larger around the center of the display. Scan-to-Data signal offset is adjusted adaptively to the Scan signal delay. The concept of adaptive Data offset is depicted in figure 7. Scan-to-Data offset is set larger as the distance from the panel edge gets larger to secure effective overlap period between Scan and Data regardless of the Scan signal delay to improve data programming on each pixel.

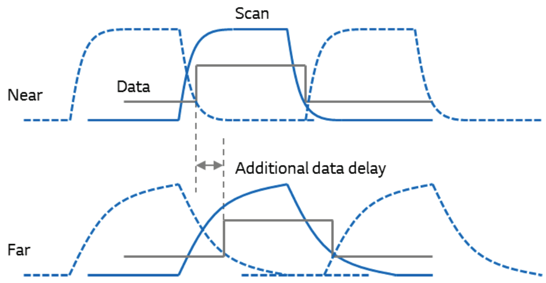


Figure 7. Adaptive Scan to Data offset

2.3 88-inch 8K OLED TV Specifications

Table 1 shows major specification of 88-inch 8K OLED TV display. The 8K OLED TV was honored with Innovation Awards in CES 2019. The 8K OLED TV is already in mass production since July 2019 (Figure 8).

Table 1. 88-inch 8K OLED TV Panel Specifications

Item	Specification	Unit
Panel Size	88	Inch
Resolution	7680 x 4320	RGBW
Brightness	500 (1,000)	(HDR) cd/m2
Contrast	> 100,000	-
Gamut	98.5	% DCI
Refresh rate	120	Hz

Figure 8. Picture of 88-inch 8K OLED TV

3 Conclusion

88-inch 8K OLED TV display is successfully developed for mass production. The display features 7680 x 4320 pixels driven at 120Hz. Self-aligned top gate IGZO TFT and Black Bank are applied to reduce address line load. 4HT Scan Overlap drive, Scan Under-drive and adaptive Scan-to-Data offset are also applied to improve data loading characteristics.

4 References

[1] Hong-Jae Shin, Shinji Takasugi, Woo-Seok Choi, Min-Kyu Chang, Jae-Yi Choi, Sang-Ki Jeon, Seong-Ho Yun, Hee-Whan Park, Jin-Mok Kim, Han-Seop Kim, Chang-Ho Oh, "ANovel OLED Display with High-Reliability Integrated Gate Driver Circuit using IGZO TFTs for Large-Sized UHD TVs", SID 2018 DIGEST, 358, 2018.

[2] Chang-Ho Oh, Hong-Jae Shin, Woo-Jin Nam, Byung-Chul Ahn, Soo-Youle Cha and Sang-Deog Yeo, "Technical Progress and Commercialization of OLED TV", SID 2013 DIGEST, 239, 2013.

[3] Ryosuke Tani, Joong-Sun Yoon, Soon-Il Yun, Woo-Jin Nam, Shinji Takasugi, Jin-Mok Kim, Joon-Kyu Park, Sun-Young Kwon, Pan-Youl Kim, Chang-Ho Oh and Byung-Chul Ahn, "Panel and Circuit Designs for the World's First 65-inch UHD OLED TV", SID 2015 DIGEST, 950, 2015.

[4] Youn-Sung Na, Chul-Ho Park, Dong-Woo Kang, Young-Seok Choi and Su-Ho Jeon, "Study of Optimized Design for High Resistance Black Matrix at In-cell Touch Structure", SID 2015 DIGEST, 1008, 2015.

[5] Chang-Ki Ha, Heung-Jo Lee, Jin-Woo Kwon, Seong-Yoon Seok, Chang-Il Ryoo, Kwi-Young Yun, Bong-Chul Kim, Woo-Sup Shin and Soo-Youle Cha, "High Reliable a-IGZO TFTs with Self-Alighned Coplanar Structure for Large-Sized Ultrahigh-Definition OLED TV", SID 2015 DIGEST, 1020, 2015.

[6] Yasuaki Iwase, Akira Tagawa, Yohei Takeuchi, Takuya Watanabe, Satoshi Horiuchi, Yoshihiro Asai, Kaoru Yamamoto, Tohru Daitoh and Takuya Matsuo, "A Novel Low Power Gate Driver Architecture for Large 8K 120Hz LCD Display Employing IGZO Technology", SID 2018 DIGEST, 698, 2018