

89-inch 5K Curved PixeLED Matrix MicroLED Display

Ying-Tsang (Falcon) Liu and Yun-Li Li

falcon@playnitride.com

PlayNitride Display Co., Ltd. Miaoli County, Taiwan

Keywords: MicroLED, Emissive Display, PixeLED Matrix, Seamless Tiling

ABSTRACT

MicroLED display is an emerging technology with high brightness, high contrast ratio, and wide color gamut. Based on proprietary PixeLED Matrix utilized by PixeLED display and SMAR-Tech repair technology, we could build borderless and tiling MicroLED displays with mature Surface-Mount Technology process.

1 Introduction

MicroLED display is believed to be the ultimate display which fulfills all display feature requirements. There are already many MicroLED demonstrations in different applications, such as large-size TV/signage, automotive transparent display, flexible display, wearable device, and AR/HUD display picture generation unit. MicroLED is already proved its high brightness, high contrast ratio, wide color gamut, good reliability, flexible, and high transparency.

A MicroLED is an LED chip removed substrate, and its size typically is thinner than 10 microns and narrower than 50 microns. MicroLED display is using such tiny LED chips as emitting source of each pixel. Within each pixel, MicroLED chips typically composed by red, green, and blue three-color chips, and it can also be composed by blue color or UV chips with color conversion material, such as quantum dot or phosphors, on top of each MicroLED chip to generate full color.

The most important advantages of MicroLED display are lower energy consumption and better reliability. Current LCD is a light absorbing device, which means most of light from backlight unit is wasted and transformed to heat. This will be a big energy crisis while we use more and more displays. OLED seems able to reduce some energy consumption as an emissive display, but it is limited by material lifetime and weak environmental reliability. MicroLED could be a good solution by higher efficient and inorganic LED chips.

Traditionally, LED is used for ultra-large size signage or TV wall. It uses printed circuit board assembly (PCBA) as driving backplane, which can be tiled seamlessly and driving high current for high brightness. This is a well-developed technology, but it is not easy to reduce the LED package for high pixel density. TFT backplane is a good solution for high pixel density, which is proved by OLED. However, the brightness has limitation by the high current

stress on TFT device.

Therefore, PlayNitride developed a new MicroLED on PCBA technology, named PixeLED Matrix. We successfully developed a 4x4 pixels MicroLED matrix unit, and bonding to PCBA by mature surface mount technology (SMT). By tiling these PCBAs, we successfully demonstrated an 89-inch, 5K, curved, MicroLED display.

2 Manufacture PixeLED Matrix Module

To realize such high performance PixeLED Matrix display, we have established a solution including wafer epitaxy, MicroLED chip process, massive process technology, including PixeLED display and SMAR-Tech repair technology, and new PixeLED Matrix display. In Fig. 1, we briefly showed the process flow of building a PixeLED Matrix display. Most of the technology is owned by PlayNitride, and it helped the technology realized faster.

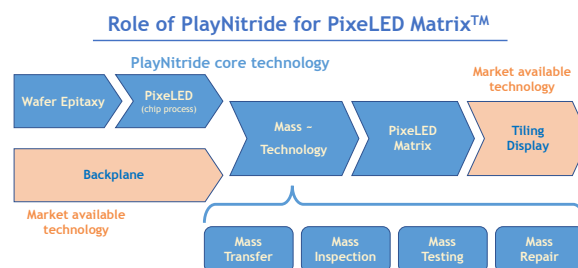


Fig. 1 Role of PlayNitride for PixeLED Matrix

2.1 Mass Transfer Process

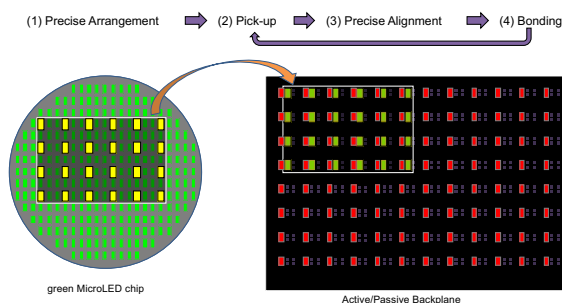


Fig. 2 Mass Transfer Process Flow

Most people focused on mass transfer since it needed a newly developed technology. There are many mass

transfer technologies under development. Here we used the stamping pick-and-place process to build samples demonstrated since 2018. As shown in Fig. 2, the stamp picked up from a wafer with precise arranged MicroLED chips. Then, moved to backplane and precisely aligned the bonding position. Final step was bonding MicroLED chips onto the backplane. Continued and repeated these steps to transfer red, green, and blue MicroLED chips onto the backplane.

2.2 Selective Mass Addressable Repair Technology

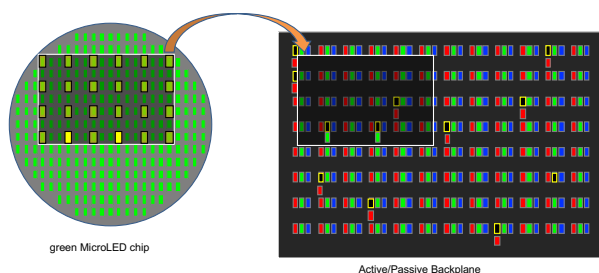


Fig. 3 SMAR-Tech

PixeLED display technology ensured MicroLED display can be realized. Then, we needed a repair technology to step into production on defect free panel. PlayNitride developed a new "Selective Mass Addressable Repair Technology", which is named as SMAR-Tech. With this technology, we can repair the defect dots by area which is much faster than single dot repair solution.

In the MicroLED display manufacturing process, defects might come from LED wafer or imperfect mass transfer. If we can achieve total 99.5% yield after transfer process, there are still more than 120,000 defect dots in one 4K panel. This is unlikely to repair one-by-one as traditional process. For our SMAR-Tech, it has similar process as mass transfer. We can only pick up the addressed MicroLED chips mapping to defect positions from LED wafer, then selectively mass transfer to the backplane as shown in Fig. 3. SMAR-Tech can reduce the repair process from 120,000 steps to tens of steps depending on display size.

2.3 PixeLED Matrix Module

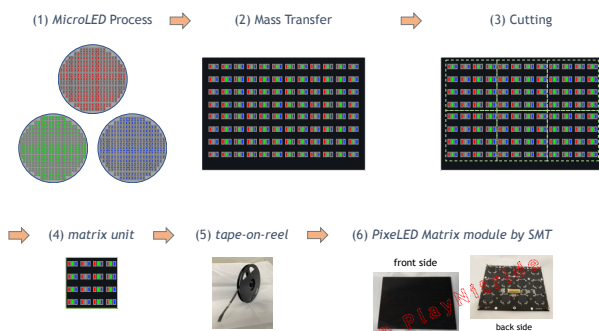


Fig. 4 PixeLED Matrix Process Flow

Fig. 4 showed how to make a PixeLED Matrix module. To transfer MicroLED chip direct to PCBA is difficult due to surface flatness requirement. Therefore, PlayNitride developed a solution, named PixeLED Matrix. It started with current mass transfer technology, transferring MicroLED chips from wafer to glass substrate. Then, we cut the glass substrate to 4x4 matrix unit, as step 3.

We can see the matrix unit after cutting on step 4. Each matrix unit has 4x4 resolution, and 48 MicroLED chips on it. The spacing is filled with black material, and this makes the display have ultra high contrast. This matrix unit size is around 1.7mm x 1.7mm for this design, and it can be packaged in tape-on-reel. Then, PixeLED Matrix can work with general SMT process.

By SMT process, we built the PixeLED Matrix module as single unit for tiling. We can see front side is mounted with matrix unit array, and back side has driving components and connector.

We also can partially mount matrix unit on PCB and working well, as shown in Fig. 5. This also can be a special feature for advertisement.



Fig. 5 Partially mount PixeLED Matrix module

3 PixeLED Matrix MicroLED Display

PixeLED Matrix is an achievable technology of MicroLED on PCBA. There are many advantages: (1) Utilized MicroLED chips and mass transfer for express production; (2) Compatible to SMT process; (3) Similar sorting/binning/repair capability as LED chips and packages; (4) With tiny MicroLED chip size, most of display area can fill-in black material to reach ultra-high contrast; (5) Could fit to curved surface; (6) Reduce bonding pads from 64 pads to 16 pads.

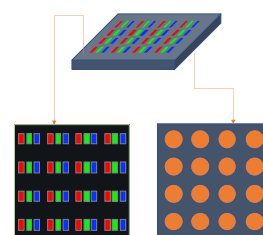


Fig. 6 PixeLED Matrix unit

For each PixeLED Matrix unit, it is a 4x4 resolution display. We could drive this small matrix by passive matrix driving. Compared to direct bonded to PCBA, which requires 4 pads for each pixel, PixeLED Matrix only needs 16 pads for 16 pixels as shown in Fig. 6.

3.1 P0.43 PixeLED Matrix Module

We first built a module with 0.43mm pitch 4x4 pixel matrix and bonded to a 240x180 PCBA as shown in Fig. 7. This module has 2,700 matrix units on it.



Fig. 7 P0.43 PixeLED Matrix module

3.2 37-inch FHD PixeLED Matrix Display

By tiling PixeLED Matrix modules, we successfully demonstrated a 37-inch FHD display. This display has 48 modules and 129,600 matrix units on it. The display has more than 2,000nits brightness and it can easily be recognized the outstanding performance than an LCD screen, as shown in Fig. 8.



Fig. 8 PixeLED Matrix display vs. LCD screen

3.3 89-inch 5K Curved PixeLED Matrix Display

We used 168 PCBA modules to build an 89-inch ultrawide curved MicroLED display. It has 5040 x 1440 resolution, which is around 32:9; and 0.43mm pitch, which is 59ppi; and curvature 2500mm radius. This display also showed ultra-high contrast ratio, with more than 2000nits and more than 95% black area coverage, as shown in Fig. 9.

4 Conclusion

MicroLED display is believed to be the ultimate display. By utilized LCD and OLED technology, MicroLED display could develop much faster than previous display technologies. In this paper we demonstrated our newly developed PixeLED Matrix display. This display showed an outstanding image performance and easily for tiling. It could be a good solution for large-size fine-pitch TV, curved wall signage, or any application required high brightness and high pixel density. Our demonstration showed another solution for MicroLED display, and this proved MicroLED is a solution for all display applications.

References

- [1] Liu Y and Li Y, "Borderless Tiling MicroLED PixeLED Matrix Display", SID Symposium Digest of Technical Papers, 52: 857-859 (2021)
- [2] Liu Y, Liao K, and Li Y, "Development of MicroLED Display by PixeLED Display Technology", SID Symposium Digest of Technical Papers, 51: 429-431 (2020)
- [3] Liu Y, Liao K, and Li Y, "Toward for Ultimate Displays with MicroLED by PixeLED Display Technology", IDW 2019 Symposium Digest
- [4] Liu Y, Liao K, Lai Y, and Li Y, "High Transparency Borderless Active-Matrix MicroLED Display", Vehicle Display Symposium 2019
- [5] Liu Y, Lai Y, and Li Y, "Heading to Ultimate Display with MicroLED", ICDT 2019 Symposium Digest
- [6] Liu Y, Liao K, Lin C, and Li Y, "PixeLED Display for Transparent Applications", SID Symposium Digest of Technical Papers, 49: 874-875 (2018)



Fig. 9 89-inch 5K Curved PixeLED Matrix MicroLED display