Toward for Ultimate Displays with MicroLED by PixeLED Display Technology

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ABSTRACT

MicroLED display is an emerging technology with high brightness, wide color gamut, and high aperture ratio. Based on our PixeLED® display technology to build MicroLED display, and SMAR·Tech™ to build defect free panel, we are heading to mass production for MicroLED display.

1 Introduction

MicroLED display is believed to be the ultimate display which fulfills all display feature requirements. In CES 2019, Samsung has announced 75" MicroLED TV. In this event, MicroLED was proved to make large size TV, and also showed high display performance. This indicated MicroLED display is not only an ideal in concept, but also a technology able to be manufactured.

A MicroLED display is composed by tens of microns LED chips on an active matrix or passive matrix driving backplane, and these MicroLED chips typically use red, green, and blue three colors. It can also use blue color with color conversion material on top of each LED chip to generate full color.

The most important advantages of MicroLED display is 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.

Since MicroLED can be driven by high current without lifetime concern, MicroLED display is easily to achieve high brightness with relative lower power. This characteristic can enable more emerging display applications, such as transparent display, cinema display, AR/VR, or outdoor wearable devices.

MicroLED display especially can be the best solution for transparent application. Figure 1 shows different structures of transparent display technology. LCD had lowest transmittance due to ~40% polarizers transmittance and ~30% color filter transmittance. OLED could reach higher transmittance, but it should consider lifetime and brightness balance which constrained the optimized transmittance to ~50%. MicroLED chip is very small comparing to pixel size, but still easily achieves high brightness.

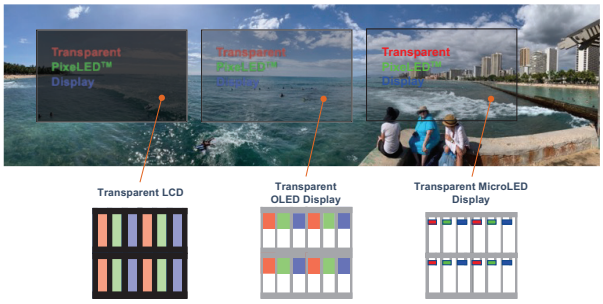

Fig. 1 Structures of transparent display technology

2 MicroLED Display Manufacture

To realize such high performance MicroLED display, we have established a solution including wafer epitaxy, chip process, and mass transfer technology, named as PixeLED® display.

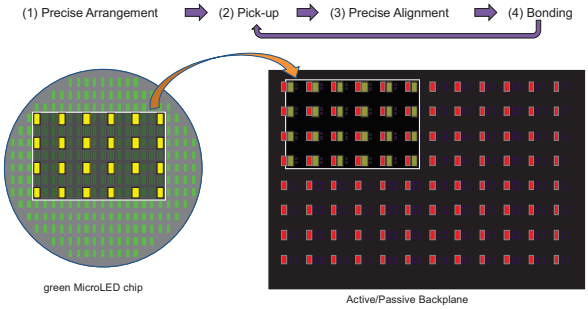

Fig. 2 Mass transfer process

There are many mass transfer technologies under development. We used the stamping pick-and-place process to build samples demonstrated in SID Display Week 2018 and 2019. As shown in Figure 2, the stamp picks up from a wafer with

precise arranged MicroLED chips. Then, move to backplane and precisely aligns the bonding position. Final step is bonding MicroLED chips onto the backplane. Continue and repeat these steps to transfer red, green, and blue MicroLED chips onto the backplane to build a MicroLED display.

PixeLED® display technology ensured MicroLED display can be realized. Then, we need a repair technology to step into production on defect free panel. We 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 30,000 defect dots in one FHD panel. SMAR·Tech™ has similar process as mass transfer. We can only pick up the addressed MicroLED chips mapping to defect positions from LED wafer, then selective mass transfer to the backplane as shown in Figure 3. SMAR·Tech™ could reduce the repair from 30,000 times to tens of times depending on display size.

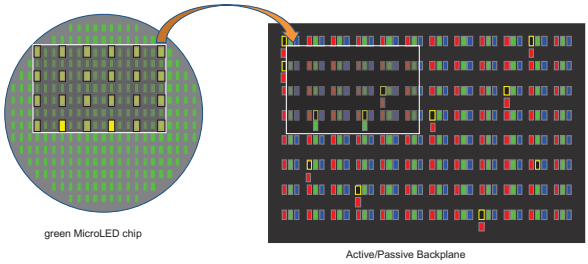

Fig. 3 SMAR·Tech™
(Selective Mass Addressable Repair Technology)

3 MicroLED Displays Enabled by PixeLED Display Technology

Because MicroLED is a current driving device, which is the same as OLED, we can utilize most of OLED design and components to speed up MicroLED display development.

From 2016, we started to demonstrate MicroLED technology to public, only after two years of development. Starting from a driving array (Figure 4), we continued demonstrate real display in 2017 with less than 1.0-inch passive matrix MicroLED display as Figure 4.

Fig. 4 MicroLED array in 2016 and
small size MicroLED display demo in 2017

In 2018, we made 5-inch transparent display with 50% transparency. This demo was shown in SID Display Week 2018 I-Zone and won the Best Prototype Honoree (Figure 5).

Fig. 5 MicroLED display demo in 2018

We continued the development to show in SID Display Week 2019, and much closer to real product. We demonstrated 7.56" high transparency and borderless MicroLED display with more than 60% transparency and higher than 1000nits peak brightness (Figure 6). The TFT backplane of this MicroLED display is designed and manufactured by Tianma Microelectronics Group. This demo was also recognized by visitors and got Best New Display Technology Award.

Fig. 6 Transparent MicroLED display demo in 2019

We also demonstrated a 2.17" extremely thin flexible MicroLED display with only 28μm thickness (Figure 7). This display only had MicroLED chips on polyimide backplane. There is no encapsulation layer by superb reliability of MicroLED. It also proved that MicroLED is viable for flexible display.

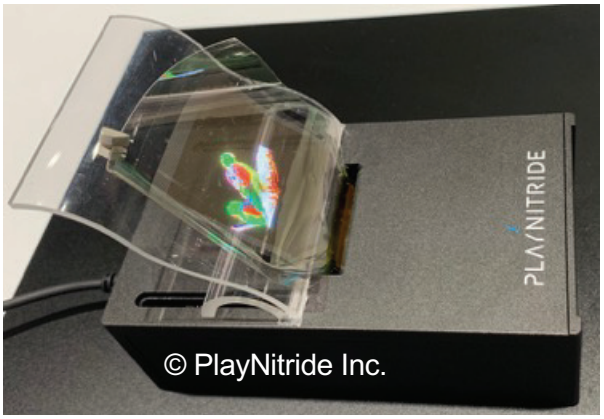

Fig. 7 Flexible MicroLED display demo in 2019

4 Conclusions

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 development progress which only takes three years from light up a MicroLED array to transparent and flexible displays. Based on our PixeLED® display technology to build MicroLED display and SMAR·Tech™ to achieve defect free panel, we are heading to mass production and will see products in the market in the near future.

REFERENCES

[1] Y. Liu, et al, "High Transparency Borderless Active-Matrix MicroLED Display", Vehicle Display Symposium 2019

[2] Y. Liu, et al, "Heading to Ultimate Display with MicroLED", ICDT 2019 Symposium Digest

[3] Y. Liu, et al, "Invited Paper: PixeLED Display for Transparent Applications", SID Symposium Digest of Technical Papers, 49: 874-875 (2018).

[4] M. Meitl, et al, “Invited paper: Emissive Displays with Transfer-Printed Microscale Inorganic LEDs”, SID Symposium Digest of Technical Papers, 257-263 (2017).

[5] E. Virey, "MicroLED Displays: Hype and Reality, Hopes and Challenges," Yole Developpement, 2017