Development of Transparent MicroLED Display

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## **Abstract**

**MicroLED is considered as the next generation display technology, since MicroLED display has high brightness, wide color gamut, high aperture ratio, and good reliability. MicroLED display can be used for both current applications and innovative display technology. Based on our proprietary PixeLED® display technology and SMAR·TechTM repair solution, we have demonstrated high transparency borderless active-matrix MicroLED display.**

## Introduction

MicroLED display is believed to be the ultimate display which fulfills all display feature requirements. In CES 2020, Samsung has announced a series of MicroLED TV, from 75" to 150". 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 a 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.



Fig. 2. Mass transfer process

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. Fig. 1 shows different structures of transparent display technology. LCD had lowest transmittance due to ~40% polarizers transmittance and ~28% 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

## 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.

There are many mass transfer technologies under development. We used the stamping pick-and-place process to build samples. As shown in Fig. 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.

A screen shot of a computer

Description automatically generated

Fig. 4. Transparent MicroLED display demo in 2018



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

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·TechTM. 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·TechTM 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 Fig. 3. SMAR·TechTM could reduce the repair from 30,000 times to tens of times depending on display size.

## 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.

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 (Fig. 4).

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 (Fig. 5). 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. 5. Transparent MicroLED display demo in 2019

## 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·TechTM to achieve defect free panel, we are heading to mass production and will see products in the market in the near future.

## Acknowledgements

The TFT backplane of this MicroLED display is designed and manufactured by Tianma Microelectronics Group.

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