MicroLED Association

White paper:

MicroLED Tiled Displays - Current Status and Future Roadmaps

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MicroLED tiled displays – current status and future roadmaps

By the MicroLED Industry Association

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One of the most unique [1] advantages of MicroLED technology is that it enables several displays with varying pixel sizes to be placed together in a completely seamless way. This is a fascinating ability – in case the technology would indeed allow to make such displays at a low cost – as it would facilitate the creation of extremely large displays as well as uniquely shaped modular displays. Interestingly, it may also open the door to changing the way displays have been made for over 20 years, thus completely changing the industry.

Current Status

For quite a few years, companies like LG, Samsung, Sony and others have been offering microLED tiled displays. Prices were very high in the first few years, hundreds of thousands per display, so the companies targeted the ultra-premium commercial market.

Since these are modular displays, there is, theoretically, no limit to the size of the display – although most installations (quite an undertaking it its own right) aim to create a display with standard resolution (like 4K or 8K) to easily comply with existing content.

In 2019, for example, Sony installed a 19.2 x 5.4 m tiled microLED display, with a resolution of 15360x4320 (16K). The company created its own content specifically for the display, which was installed at Shiseido's research center in Yokohama, Japan.

In 2020, Leyard Opto-Electronics installed what is likely to be the world's largest-area microLED display at CHN Energy Investment's command and control center. The display is 216 sqm in size and has almost 250 million pixels (that's 7 times 8K). The display uses microLEDs produced by Epistar.

Large displays seem attractive, but the market for such displays is very small, and since 2020 or so the companies have been busy trying to lower production costs and shrinking pixels to make displays that are suitable for residential use. Samsung, for instance, switched from PCB backplanes to LTPS, and reduced the size of the MicroLED chips.

Following is a short review of various MicroLED TVs by several manufacturers, that can readily be purchased today. As of early 2023, prices remain quite high and a MicroLED TV that drops below the $100,000 USD line is still anticipated.

LG

LG launched its MicroLED TVs in 2020, under the MAGNIT brand. In the first generation, the displays reached peak brightness of 1,200 nits, and at a pixel pitch of 0.9 mm, a 4k formation would be 163 Inches. In 2022, LG launched the second generation, that had smaller pixels (0.7 mm) and higher brightness (2,000 nits peak). Since the pixels are smaller, a 4k TV would be 136 inches.

Like all manufacturers of MicroLED TVs, LG does not make the prices of its TV public.

Samsung

Back in 2017, Samsung launched its huge displays under the brand The Wall. Several generations were launched through the years, aiming to lower prices, reduce pixel size and improve performance. The first displays targeted the commercial market (with 1,000-inch displays on offer) but recently Samsung has been more focused on the ultra-premium residential market.

In January 2023, Samsung presented its 2023 microLED TV lineup, which marked the first time that such displays have been directly marketed for buyers, and they can also be independently installed.

Samsung calls these displays Samsung MicroLED CX TV, and they will be offered in a variety of sizes, starting from 50

inches and reaching 140 inches. Prices have not yet been made public, but they are expected to be much higher than LCD or OLED displays.

Technical specifications have also not yet been released, except that the CX TVs will offer a 240Hz variable refresh rate, 2-nanosecond response time and 20-bit black detail. The main advantage of these TVs over current OLED TVs is supposed to be the brightness - it will be interesting to learn of the peak brightness of the CX TVs, as LG's latest OLEDs achieve over 2,000 nits in brightness, and so do Samsung's own and latest QD-OLED panels. MicroLED TVs will have to offer a dramatic improvement in performance at such high price levels.

Sony

Sony was the first company to have presented a MicroLED display, back in 2012. In 2016, Sony launched its first product called CLEDIS or Canvas LED.

Sony mostly targets the commercial market, but also the residential one. It has several product lines, all based on modules made of extremely small LEDs (the size of about 10 µm) with high performance. Sony developed a special version of the display processor X1 for the MicroLED displays, to obtain a clean and smooth image.

Sony's displays are customized, but the company also presented several standard sizes like 146 and 219 inches. According to reports, the price for a 219-inch display is about $800,000 USD. Sony also offers especially large displays, including a 790 inch one (16K resolution).

Additional manufacturers

Several other companies are developing or even offering tiled MicroLED displays. For example, China-based Konka launched a line of TVs in 2019, branded APHAEA. Two models were launched: 118 inch 4K and 236 inch 8K. Konka has supplied no updates on these TVs since 2019.

The abovementioned Leyard also launched a line of MicroLED TVs that are customized, targeting the commercial market. Taiwan-based research institute ITRI has presented such devices, based on PCB backplane, and research is still ongoing on this technology.

PlayNitride presented advanced displays, made of tiles of about 5 inch in size, with a resolution of PPI59. These displays can reach a brightness of 3,000 nits and the company hopes to commercialize the technology soon.

Advantages of Tiled TVs

Tiled TVs' most prominent advantage is the fact that the relationship between price and display size is mostly linear.

In LCD and OLED technology, the production is done on one large substrate (be it plastic or glass). The substrate can then be divided into smaller parts, but the substrate size limits the final display size, which is why there are no extremely large LCD and OLED displays. Also, a larger display means an exponential rise in price. Again, this is of course a limiting factor.

When designing a TV out of tiles, the price of the resulting TV goes up linearly. In fact, with MicroLEDs, most of the price

will be determined by how many LEDs are required. In large TVs with relatively low density (as they are viewed from afar) – the number of LEDs is small in relation to the size.

Another advantage of tiling displays is a relatively high yield. As was explained in the former whitepaper [2], the larger the display – the lower the yield gets. Such a TV will also be easier to repair – specific modules can be replaced, in contrast to today's TVs that need to be completely replaced in case of damage (like fractures, burn-in issues etc.).

In addition, one of the most interesting advantages in the ability to create TVs of non-standard sizes. The selection of TV sizes is currently quite limited, but in the future, we might see much more varied sizes (and even non-rectangular shapes) to fit specific spaces.

Looking at the industry, it can be said that the ability to create small displays and combine them can allow for fascinating new manufacturing models, new business models and make stocks and logistics much simpler.

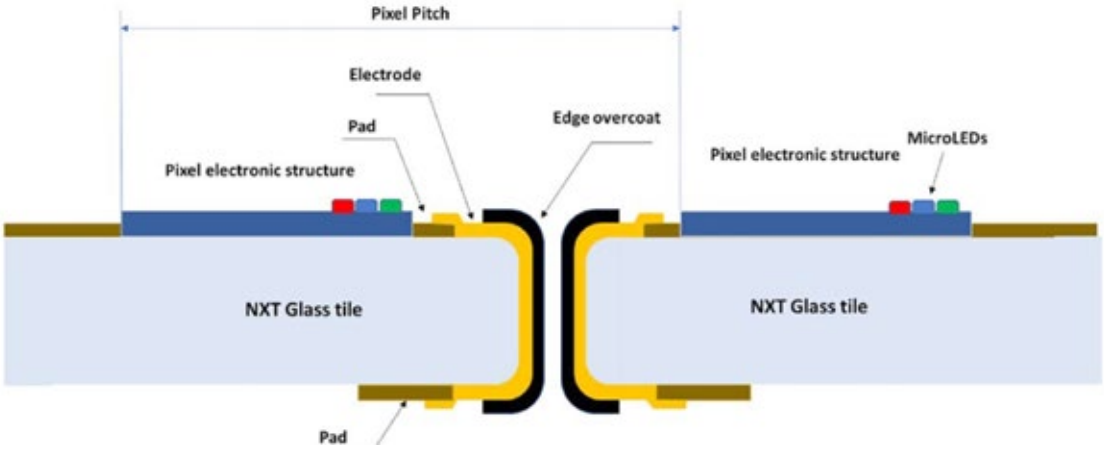
These advantaged have not yet come into play, mostly due to the currently high manufacturing costs of MicroLED display, that make prices for such TVs drastically high. Next, we will look at the technologies that are required in order to make these displays, and what the future may look like.

Required Technologies

The basic technologies needed for manufacturing MicroLED display modules are the "standard" technologies for manufacturing MicroLED displays. Meaning – manufacturing the MicroLEDs themselves, inspection to make sure all the transferred LEDs are valid, transfer processes, backplane production etc. In addition, there are some unique technologies that are required for these displays.

A unique requirement in a tiled display involves the interface, or connectors. A regular display is connected via one or more of the sides – but this is not possible in a seamless tiled display – in which the only option is to connect the modules via their bottom side.

There are two possible solutions. The first is to deposit very fine conductive lines on the sides of the microLED tile. This is referred to as **Edge Electrodes**, **side-wiring** and **wrap-around electrodes**. These electrodes need to be thin, conductive, and, of course, to have proper adhesion – as connections are mechanical and need to be connected and disconnected several times. There are several technologies that can be used to deposit these conductive wires on the display's side, including screen-printing, laser, photolithography, and more.



MicroLED tiles with wrap-around electrodes, cross-sectional schematic (source: Corning)

It is required to connect the tiles in a seamless manner, and since the distance between pixels can be small, we'd want these electrodes to be thin, conductive, and, of course, to have proper adhesion – as connections are mechanical and need to be connected and disconnected several times.

An alternative to side wiring is to drill vertical holes (called **Via Paths**) through substrate and fill them with conductive materials, to create the electrodes. The main challenge is that these paths are very small in diameter, but they are relatively long. Creating Via Paths is considered to be a more complicated and expensive technology compared to side wiring. But Via Paths offer some performance advantages, such as support for higher densities (smaller pixels) and even smaller tile distance (but that is likely negligible).

Customized displays of different sizes and resolutions can drive up demand for technologies in the field of image processing which will enable better image quality and use of different resolutions or even display shapes. These technologies, however, are outside the scope of this document.

Tiled Displays Industry

In the LCD and OLED industry, the entire production process in done on one large substrate, which means fabs are large, expensive and require a complicated supply chain and skilled workers. This led to a very concentrated Industry with very few manufacturers and only four countries in which displays are mass produced. Beyond panel productions, there is also the production of the final product: be it TVs (adding the operating system, signal processing, connections, package etc.), monitors, or any other display. But most of the value and display technology happens at a single fab.

MicroLED technology may change that, as the manufacturing process can be decoupled (epiwafers, substrate and transfer) and divided across several companies.

Using modules to put displays together can also cause another separation in the display making process: having companies that supply the modules and other companies that assemble the final displays. This can make for interesting models, with standards to allow for combination of modules by different companies.

How does the Future Look for Tiled Displays?

As was demonstrated, there are many advantages to tiled displays. On the other hand, cost is a difficult challenge – not only is manufacturing a MicroLED display a complicated matter that will take years for costs to go down, but making a display out of modules raises these costs further.

In addition, producing small modules runs against the volume (size) production advantages that benefited the display industry and drove production costs down dramatically.

Despite all of that, there is potential to these displays. Even today, making extra-large LCD and OLED displays is not possible with current technologies (depending on the glass size of the fab, but most displays are limited to up to 100 inch), and so MicroLEDs have an advantage.

Prices of tiled MicroLED TVs are likely to go down in the next few years. They will remain relatively high for at least 5 years or so, but they will probably go down when solutions improve.

Beyond extra-large displays, it will be interesting to see if solution providers find new applications and uses for these displays, when prices are more accommodating.

Competing with OLEDs – microLED Chip Cost Analysis

The main goal of most MicroLED manufacturers will probably be entering the residential TVs market, a market valued at around 250 million displays per year and about 250-300 billion dollars in sales. For the first few years at least, MicroLEDs will likely want to compete in the premium segment, currently controlled by OLEDs and QLEDs.

The bigger the display size and the smaller the resolution, the more MicroLEDs have an advantage, as was already explained. So, in this review, we will look at the 77 Inch 4K TV market [3].

There are quite a few premium 77” TVs on the market. LG, for instance, offers the OLEDG3 at about $4,200 and Samsung offers its 77” QD-OLED for around $4,500 [4].

For the sake of this discussion, we will estimate that to compete in this market, assuming customers will be willing to pay a premium for a MicroLED TV, one should aim for a price tag of around $5,000 for such a TV at its launch price. That should be the final retail price, meaning the cost of production should be around $2,000.

Producing a tiled MicroLED display involves several factors, the main ones being:

- Backplanes production (this could be a major factor, as the tiled displays use many different backplanes, one for each module)
- LED chips fabrication
- Depreciation of equipment: transfer, inspection & repair, etc.
- TAKT Time related costs

A TV with a resolution of 4K has 3840 x 2160 = 8,294,400 pixels, meaning 24,883,200 LEDs (since each pixel is made of 3 LEDs, in RGB colors).

This short analysis will focus on the LEDs themselves, considered one of the most expensive parts (if not the most expensive) in microLED display production. More information about this analysis can be found at the recently published white paper 'MicroLED Smartwatch Displays in 2023, LED Cost Analysis', by the MicroLED Industry Association.

As discussed in the aforementioned whitepaper, it will be likely possible to reach a price of about $0.0000404 per 10 micron MicroLED die, a reasonable size for an application like TV. The price of producing the 24.8 million LEDs required for 4K resolution will be around $1,000. We assume 100% yields here, which is obviously unlikely, but gives an interesting view of the financial feasibility from the LED perspective. One must remember that other technologies in this field still incur high costs as well, so looking at the price of LEDs is only a part of the story.

It is noteworthy that the size of the LEDs is of great importance. We referenced small chips of 10x10um, which is the size Sony, for example, uses in its TVs. But other companies use larger chips, like Samsung for instance, which uses (according to reports) chips of around 35x85 um at the smallest. In these sizes, LED prices rise significantly, and making a TV will mean a cost of over $10,000 for the LEDs alone. It will most certainly require a technological leap – or using smaller LEDs – to lower costs and approach the price range that will allow to compete with LCDs and OLEDs.

Footnotes

[1] There are other technologies that can enable the creation of seamlessly tiled displays, but not of the same quality as MicroLEDs. Many companies propose the idea of attaching several LCD panels to make a large screen, but the seam is apparent and a real seamless display is not possible depending on the distance between pixels.

As the whitepaper explains, OLED technology can not allow for two modules to be connected without a gap – because of the need for encapsulation.

Over 10 years ago, Mitsubishi started selling displays called Diamond Vision OLED which were made of small modules of PMOLEDs, to make one large screen. To overcome the seam or bezel problem, pixel size was large – 3 mm – so these were displays meant for viewing from a distance (signage). In displays based on projectors, it is possible to use several projectors to make one large image, which can be successful using the right image processing

[2] On microLED yields, and strategies to overcome (MicroLED Industry Association, February 2023)

[3] Larger TVs also exist today, like 83", but it seems that the market share of such sizes is relatively negligible and that most buyers will purchase 40-77" TVs. We will note that at the 83" and upwards market share, it'll be easier for MicroLED TVs to compete, as long as they stay with the 4K resolution.

[4] Source: Amazon.com, and publications (2023 Q1).