Display Dynamics – March 2021: Micro LED display advantages, technical challenges, and manufacturers’ prospect
Table of Contents :

Key findings .................................................................................................................................. 2
Appendix .................................................................................................................................... 13

Table of Figures :

1. Figure 1: Properties comparison of LCD, OLED, and micro LED displays ........................................ 3
2. Figure 2: The SWOT analysis of micro LED displays ............................................................................ 4
3. Figure 3: Samsung 110-inch micro LED display and specification .......................................................... 5
4. Figure 4: Micro LED display forecast (thousands of units) .................................................................... 6
5. Figure 5: Micro LED display module manufacturing process ................................................................. 8
6. Figure 6: Micro LED manufacturing challenges and technical issues ..................................................... 9
Key findings

- Micro LED displays are projected to reach $7 billion in 2025 on a revenue basis.
- The high cost of micro LED displays is due to the complicated manufacturing process, the non-standardized process and equipment, the multiple participants of the supply chain, and the immature and unstable yield management and output.
- It is estimated that micro LED display capex will reach $8 billion from 2020 to 2025. Of this amount, $3.2 billion is for micro LED epitaxial wafer (epi wafer) process and $4.8 billion for micro LED mass transfer, modulization, and set assembly.

Micro LED is rising as an emerging display technology, although there are still many manufacturing and cost challenges. Many companies are viewing micro LED displays as the next-generation display to replace LCD and OLED. On the other hand, many have aimed to mass produce micro LED displays for applications where LCD and OLED are not a very good choice, such as super large-sized TVs/public signage or smartwatch displays.

The key to success in micro LED displays is achieving a high density of self-emissive LED chipsets with the micrometer-size pixel pitch and then placing the LED chips on an active matrix substrate or module to perform the display function with micro LED chip arrays offering high-quality colors and great luminance.

In other words, the micro LED display does not need a large substrate for photolithography or evaporation, unlike LCD or OLED, and it does not require a complicated process for converting colors and preventing luminance from decreasing. In theory, micro LED can be very simple, with a lower cost and a higher picture performance, which allows micro LED to be a perfect display technology.

Pros and cons of micro LED displays

Compared with LCD and OLED, which are prevailing display technologies, micro LED displays have many advantages. The following figure shows the score comparisons of the properties of LCD, OLED, and micro LED displays.
Micro LED beats LCD and OLED in terms of luminance efficiency, luminance level, contrast ratio, lifespan, water-oxygen resistance, response time, operating temperature, and power consumption. These are attributed to the characteristics of LED chipsets.

However, due to modularization, it is not better than LCD and OLED in terms of flexibility, cost competitiveness, and shock resistance.

For LCD, its cost is lower than OLED’s, and it has a better luminance efficiency, luminance level, and contrast ratio than OLED. OLED is not good in terms of water-oxygen resistance and lifespan, but OLED is great in flexibility, and as the production scale increases, there can be substantial reduction in the cost.

The comparisons show that micro LED displays have greater advantages over LCD and OLED, but there are still issues to be resolved, such as low cost competitiveness, shock resistance, and flexibility. This indicates that if micro LED display makers aim to replace LCD or OLED, they should target applications that do not need to be flexible and are also in the premium category. This explains many micro LED display developers are targeting super large-size high premium TV/digital signage displays, high premium luxurious automotive displays, or high-end IT displays.

The following figure shows the strength, weakness, opportunities, and threats (SWOT) of micro LED displays.
2. Figure 2: The SWOT analysis of micro LED displays

**Strengths**
- Smaller pixels
- Lower power consumption
- Many LED manufacturers

**Weaknesses**
- Cost increase
- Low demand
- Low uniformity
- Less differentiation

**Threats**
- Grow premium TV and mobile market
- Increase demand for LED epitaxy

**Opportunities**
- Difficulty of manufacturing backplane
- Unmatured mass transfer technology

Source: Omdia

Micro LED display prototype and commercialization

Until now, many companies have commercialized and demonstrated micro LED display prototypes or initial products:

- Plessey 0.7-inch 1920x1080 micro LED on silicon wafer
- JBD 0.4-inch 1280x720 micro LED with silicon wafer
- ADRC 0.22-inch micro LED with LTPS TFT backplane
- ITRI 2.5-inch 120x120 micro LED with passive matrix substrate
- ChinaStar 3.3-inch micro LED display with indium gallium zinc oxide (IGZO) TFT backplane
- PlayNitride 458 pixels per inch (ppi) micro LED with LTPS TFT backplane
- Tianma 720x480 transparent micro LED display on LTPS TFT substrate
- eLux 12.1-inch 720x240 full color micro LED display
- AUO 9.6-inch 1920x960 flexible micro LED display with 228 ppi and over 5.5 million of micro LED chipsets
- AUO 12.1-inch flexible micro LED display for automotive display applications
- Konka 230-inch 8K micro LED digital signage

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• Hisense 118-inch 4K micro LED digital signage
• TCL 132-inch 4K micro LED display TV with 0.76mm pixel pitch
• Samsung 146-inch The Wall 4K micro LED display for digital signage
• Sharp 24-inch curved micro LED display module
• Sony 395-inch 7680x2160 micro LED signage display
• Konka 2-inch micro LED display for smartwatch with quantum dot color conversion and LTPS TFT backplane

In 2020, Samsung Electronics started commercializing its 146-inch micro LED display “The Wall”.

Samsung Electronics is planning to introduce a new 110-inch micro LED display in 2021, targeting not only the public display arena but also the living room in a luxury mansion. It is still based on a printed circuit board (PCB) backplane, but Samsung Electronics is aiming to apply the LTPS TFT backplane in the near future.

There are several important milestones for this special product:

• The RGB 3-in-1 package of micro LED displays
• The very small micro LED size: 75µmx125µm
• The stamp transfer technology

The following figure shows the new 110-inch micro LED display of Samsung Electronics.

3. Figure 3: Samsung 110-inch micro LED display and specification

Samsung micro LED TV: The world first 110-inch micro LED TV

- Model: Samsung micro LED TV (Target to launch in March 2021)
- Screen size: 110-inch
- Resolution: 3840x2160
- Pixel pitch: 0.63mm/Subpixel pitch: 0.21mm
- Micro LED size: 75µm x 125µm
- Substrate: PCB backplane
- Module Specification: 10.0-inch 320x240
- Module assembly (WxH): 12x9 (Monolith Design)
- Transfer technology: Stamp
- Micro LED display color solution: RGB 3-in-1 package
- Brightness: (Unknown)
- Color gamut: (Unknown)
- Weight: (Unknown)
- Working temperature: (Unknown)

Source: Omdia, Samsung Electronics

Samsung’s 146-inch The Wall micro LED display for digital signage is priced at over $270,000 per unit. And the new 110-inch micro LED display is estimated at over $130,000 per unit. In other words, its price is still very high, making it falling into the super luxury segment.
Samsung Electronics is planning to introduce more micro LED displays for households from now on, including 75-, 88-, 94-, and 99-inch. All have a high density of micro LED chips with the micrometer-size pixel pitch and a new LTPS TFT backplane. Samsung Electronics’ micro LED TV supply chain includes San’an Optoelectronics, EPISTAR, PlayNitride, AUO, and BOE.

**Micro LED display forecast**

Micro LED displays will be commercialized in the public display and TV segment by 2021. As Omdia forecast in *Display Long-Term Demand Forecast Tracker – 3Q20 Analysis*, near-eye applications, such as smart glasses, head-mounted displays, and augmented reality (AR)/virtual reality (VR) devices, and smartwatches will start using micro LED displays in 2022.

Omdia expects that micro LED displays will be present in the automotive display and desktop monitor segment, starting from 2024. Micro LED display revenue is expected to reach $7 billion in 2025, up from $0.02 billion in 2020. It is still much smaller than LCD revenue ($92 billion) and OLED revenue ($48 billion). However, micro LED has a strong growth potential.

**4. Figure 4: Micro LED display forecast (thousands of units)**

![Figure 4: Micro LED display forecast (thousands of units)](source: Omdia)

**Micro LED display manufacturing challenges**

The most serious disadvantage of the micro LED display is its high cost caused by manufacturing challenges and small economic scale, which makes it hard to compete in the crowded display market.

Most crucially, the manufacturing processes of micro LED display modules are not standardized unlike LCD or OLED, and every maker is developing its own proprietary process and product technology. This makes the micro LED display manufacturing process complicated with great varieties.

Furthermore, the equipment and tools are all customized with high cost. Meanwhile, there are many companies involved in the manufacturing process, including micro LED epi wafer makers, PCB/LTPS...
backplane makers, mass-transfer makers, driver integrated circuit (IC) makers, cabinet assembly makers, modulization makers, and OEM/ODM makers. The more makers are involved, the higher the transition cost is.

In other words, the high cost of micro LED displays is due to the following four factors:

- Complicated manufacturing process
- Unstandardized process and equipment
- Multiple participants of the supply chain
- Immature and unstable yield management and output

The micro LED display module process can be sequenced in the following steps:

- Micro LED components
  - Ingot to epi wafer
  - Micro LED chip singulation
  - Flip chip micro LED on interposer
- Backplane and mass transfer
  - LTPS/PCB backplane
  - Mass transfer (from micro LED on interposer to the backplane)
  - Micro LED chips inspection and repair
- Modulization
  - IC bonding
  - Module assembly and cabinets
  - Inspection and repair
5. Figure 5: Micro LED display module manufacturing process

Micro LED display module manufacturing process

Source: Omdia, SAMSUNG—photo taken by Park Ken/Omdia at Consumer Electronics Show (CES) 2020, Las Vegas, NV, January 2020

There are four main challenges and technical issues in these processes:

- Micro LED chip and structure: The micro LED chip structure is more complicated than that of the traditional LED.
- Backplane: The TFT backplane design is more complicated than the normal TFT
- Mass process: There are many optional mass-transfer processes, such as electrostatic, electromagnetic, laser transfer, stamp transfer, monolithic transfer, fluidic ink jet transfer, pick and place, and stretchable mass transfer, and each one has its pros and cons.
- Inspection and repair: Each micro LED chip set needs to be inspected and repaired if necessary. Even with a 99.99% yield, a defective micro LED chip set needs to be repaired as there are millions of or even tens of millions of subpixels. The inspection and repair are very time-consuming.
Micro LED display investment

Although there are still technical and manufacturing challenges, many companies invest capex for micro LED display manufacturing. They invest capex for a variety of processes because micro LED display module manufacturing processes are complicated. The processes include metal organic chemical vapor phase deposition (MOCVD), epi wafer, mass-transfer process, micro LED chip design, complementary metal oxide semiconductor (CMOS) backplane, TFT backplane, driver IC, modulization, inspection and repair equipment, system integration, and so on.

Micro LED display equipment is very expensive due to the proprietary process. The estimated equipment prices are as follows:

- Micro LED chip MOCVD equipment: $2 million per unit
- Micro LED post-MOCVD process line equipment: $1 million per line
- Micro LED display module and device (from laser transfer to modulization): $500 million to $1 billion investment needed for 500,000 units of 100-inch micro LED display modules per year capacity

The followings are the list of micro LED display manufacturing investments by manufacturer.

**Table 1: Micro LED display investment companies and estimated capex from 2020 to 2025**

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Business</th>
<th>Country</th>
<th>Technical area</th>
<th>Activities</th>
<th>Capex ($m) estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADRC</td>
<td>Technical research</td>
<td>South Korea</td>
<td>Process</td>
<td>Concept of micro LED display on blue laser</td>
<td>$50</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Equipment Supplier</th>
<th>Supplier Type</th>
<th>Country</th>
<th>Technology/Service</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIXTRON</td>
<td>Equipment supplier</td>
<td>Germany</td>
<td>MOCVD</td>
<td>$150</td>
</tr>
<tr>
<td>ALLOS Semiconductors</td>
<td>Technical research</td>
<td>Germany</td>
<td>Epi wafer</td>
<td>$150</td>
</tr>
<tr>
<td>Aqlaser</td>
<td>Equipment supplier</td>
<td>Korea</td>
<td>Mass transfer</td>
<td>$50</td>
</tr>
<tr>
<td>eLux</td>
<td>Research &amp; development</td>
<td>Taiwan</td>
<td>Chip design, mass transfer</td>
<td>$100</td>
</tr>
<tr>
<td>EtaMax</td>
<td>Equipment supplier</td>
<td>South Korea</td>
<td>Inspection (non-destructive LED test process)</td>
<td>$30</td>
</tr>
<tr>
<td>EPISTAR</td>
<td>Component supplier</td>
<td>Taiwan</td>
<td>Epi wafer, epi chip</td>
<td>$200</td>
</tr>
<tr>
<td>ITRI</td>
<td>Technical research</td>
<td>Taiwan</td>
<td>Process Mass transfer for ultra-small to ultra-large display, focusing on micro-assembly</td>
<td>$60</td>
</tr>
<tr>
<td>Jasper Display</td>
<td>Component supplier</td>
<td>Taiwan</td>
<td>Complementary metal oxide semiconductor (CMOS) backplane</td>
<td>$40</td>
</tr>
<tr>
<td>Company</td>
<td>Type</td>
<td>Region</td>
<td>Process</td>
<td>Feature</td>
</tr>
<tr>
<td>-------------------------</td>
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<td>------------</td>
<td>------------------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>KIMM</td>
<td>Technical research</td>
<td>South Korea</td>
<td>Process</td>
<td>Roll-to-plate mass transfer process, applied to mass production</td>
</tr>
<tr>
<td>Lumens</td>
<td>Component supplier</td>
<td>South Korea</td>
<td>Micro LED module</td>
<td>Launching 0.57-, 5.35-, and 8.45-inch micro LED display modules</td>
</tr>
<tr>
<td>Macroblock</td>
<td>Component supplier</td>
<td>Taiwan</td>
<td>Driver IC</td>
<td>The world’s first LED display IC supplier, co-developing micro LED signage with ITRI</td>
</tr>
<tr>
<td>PlayNitride</td>
<td>Research &amp; development</td>
<td>Taiwan</td>
<td>Chip design, mass transfer</td>
<td>Customized micro LED chip production, mass transfer to custom backplane</td>
</tr>
<tr>
<td>San’an</td>
<td>Component supplier</td>
<td>China</td>
<td>micro LED module</td>
<td>Investing production capacity for micro LED epi wafer/epi chip</td>
</tr>
<tr>
<td>Seoul National University</td>
<td>Academic research</td>
<td>South Korea</td>
<td>Epi chip process</td>
<td>A discrete core-shell-like micro-light-emitting diode array grown on sapphire nano-membranes</td>
</tr>
<tr>
<td>Seoul Semiconductors</td>
<td>Research &amp; development</td>
<td>South Korea</td>
<td>Overall process</td>
<td>Most process including MOCVD, RGB LED fabrication, mass transfer, surface mounted technology, and</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Business</td>
<td>Target application</td>
<td>Product / Prototype</td>
<td>LED chip type</td>
</tr>
<tr>
<td>----------------------</td>
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<td>-----------------------------</td>
<td>---------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Toray Engineering</td>
<td>Equipment supplier</td>
<td>Japan</td>
<td>Inspection, repair</td>
<td>Inspection and repair equipment for micro LED wafer</td>
</tr>
<tr>
<td>X-Celeprint (XDC)</td>
<td>Research &amp; development</td>
<td>Ireland</td>
<td>Mass transfer</td>
<td>Micro-transfer-printing technology with elastomer stamp</td>
</tr>
</tbody>
</table>

Source: Omdia

### Table 2: Micro LED display device and application makers

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Business</th>
<th>Target application</th>
<th>Product / Prototype</th>
<th>LED chip type</th>
<th>Backplane</th>
<th>Capex ($m) estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td>Application</td>
<td>Smartwatch</td>
<td>-</td>
<td>Vertical chip</td>
<td>LTPS, CMOS</td>
<td>$100</td>
</tr>
<tr>
<td>AUO</td>
<td>Display</td>
<td>Automotive, Signage, TV</td>
<td>12.1-inch 1920x720 9.6-inch flexible</td>
<td>Flip chip</td>
<td>LTPS</td>
<td>$50</td>
</tr>
<tr>
<td>CSOT</td>
<td>Display</td>
<td>TV, automotive</td>
<td>3.3-inch 232x116</td>
<td></td>
<td>Indium gallium zinc oxide (IGZO)</td>
<td>$50</td>
</tr>
<tr>
<td>glō</td>
<td>Display</td>
<td>AR</td>
<td>0.7-inch 1080x640</td>
<td>3D chip</td>
<td>CMOS, LTPS</td>
<td>$30</td>
</tr>
<tr>
<td>Hisense</td>
<td>Application</td>
<td>Signage</td>
<td>144.5-inch 3840x2160</td>
<td>Flip chip</td>
<td>PCB</td>
<td>$80</td>
</tr>
<tr>
<td>Jade Bird</td>
<td>Display</td>
<td>AR</td>
<td>0.31-inch 1280x720</td>
<td></td>
<td>CMOS</td>
<td>$30</td>
</tr>
<tr>
<td>Konka</td>
<td>Application</td>
<td>Signage, TV, Smartwatch</td>
<td>236-inch 7680x4320</td>
<td>Flip chip</td>
<td>PCB, LTPS</td>
<td>$300</td>
</tr>
<tr>
<td>LG Electronics</td>
<td>Application</td>
<td>Signage</td>
<td>141.9-inch 3840x1620</td>
<td>Flip chip</td>
<td>PCB</td>
<td>$100</td>
</tr>
</tbody>
</table>
It is estimated that micro LED display capex will reach $8 billion from 2020 to 2025. Of this amount, $3.2 billion is for micro LED epi wafer process and $4.8 billion for micro LED mass transfer, modulization, and set assembly.

## Appendix

### Further reading

- [Display Long-Term Demand Forecast Tracker – 3Q20 Analysis](January 2021)
- [MicroLED Display Technology & Market Report – 2020](August 2020)
- [Display Dynamics – December 2020: Konka announced the first micro LED display smartwatch](January 2021)
- [Display Dynamics] AUO develops 9.4-inch flexible and 12.1-inch automotive micro LED displays (September 2020)
- [Display Dynamics] Large-sized micro LED displays are improving (August 2020)
- [First Micro LED mass production facility in China planned through joint venture between Leyard and Epistar](January 2020)
- [Display Dynamics] Micro LED and flexible OLED are the key displays for the automotive application in SID 2020 (August 2020)
**Display Technology & Trend - Micro/Mini LED, Curve, Gaming and New Notebook Display – 2020** (August 2020)

*[Display Dynamics] Samsung enhances micro LED display supply chain to lead the TV market* (February 2020)

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