

# MICROLED DISPLAYS 2019

## Market & Technology Report - September 2019

*Significant progress over the last 18 months, but many challenges remain before ramping up for large volume consumer applications.*

### WHAT'S NEW

- Technology status and trends: epitaxy, microLED efficiency vs OLED, assembly processes and equipment, light management and color conversion
- Yield and defect management: status and roadmaps, analysis of the different strategies, cost analysis
- MicroLED display driving: analog vs. digital, TFT vs. microdriver ICs
- Applications: why are smartphones so hard? Is TV possible? Are smartwatches coming soon?
- Updated adoption roadmap and volume forecast for displays and epiwafers

### KEY FEATURES

- MicroLED technology status
- Competitive landscape and key player's profiles
- Intellectual property trends
- Supply chain
- MicroLED yield management and repair strategies analysis
- Cost analysis: TV, smartwatch and smartphones
- MicroLED display applications: strength, weakness opportunity and threat (SWOT) analysis, roadmap and forecast for TVs, smartphones, wearables, augmented reality, laptops, tablets and monitors
- MicroLED display panel forecast through 2027
- Wafer demand forecast

### MICROLED: PROGRESSING ON ALL FRONTS

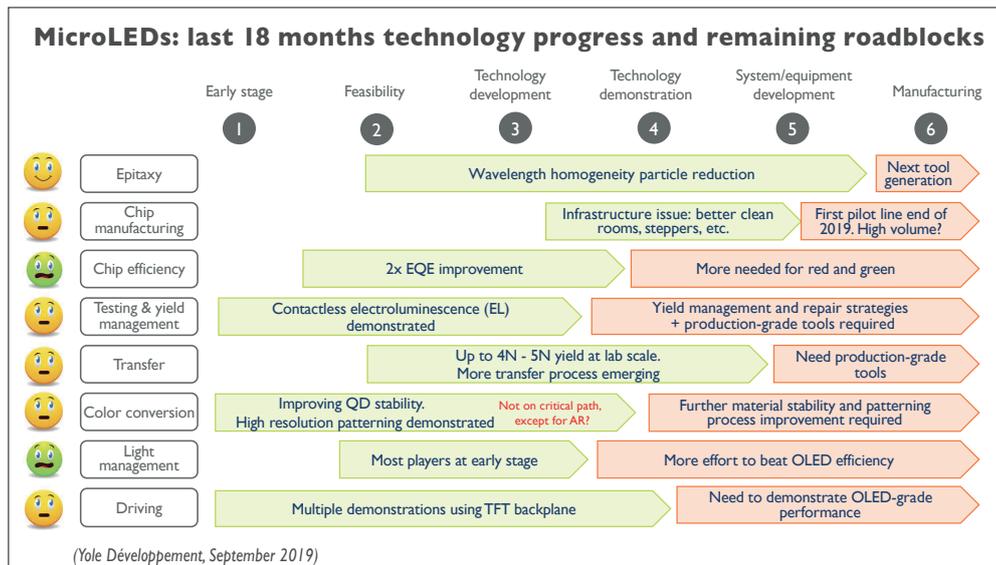
Microscopic light emitting diodes (microLEDs) are drawing an increasing amount of attention. Startups have raised more than \$800M to date, including at least \$100M in 2019. Apple has spent \$1.5-\$2B over the last five years. Panel makers such as Samsung, LG, AUO or Innolux have also significantly increased their efforts.

Patent filings are growing exponentially and technology is progressing on all fronts. The external quantum efficiency of blue and green microLED chips has more than doubled over the past 24 months. Some transfer and assembly processes are reaching performance close to what is required to enable some microLED consumer applications.

Progress is also visible in the proliferation of prototypes presented over the last 18 months by close to 20 companies. The demos cover a broad range of display types, sizes and technologies. Native RGB or color converted displays on Thin Film Transistor (TFT) backplanes are offered by many companies, with some examples including

Playnitride, CSOT, Samsung, LG, glō, AUO, eLux, and Kyocera. Lumiode has developed native RGB or color converted displays on monolithically integrated Low-Temperature Polysilicon (LTPS). Meanwhile such displays on CMOS backplanes are on offer from companies including Plessey, glō, Lumens, JB Display, Sharp and Ostendo. Finally, discrete microdriver ICs have been developed by X-Display. The multiple prototypes based on TFT backplanes give credence to the idea that microLED displays can leverage existing panel maker capacity, thereby simplifying and streamlining the supply chain.

Equipment makers have taken notice and are starting to develop microLED-specific tools for assembly, bonding, inspection, testing and repair. LED makers are also showing interest, with San'an planning to invest \$1.8B to set up a mini and micro-LED manufacturing base. Osram, Seoul Semiconductor, Nichia or Lumileds are also increasing their activity and Playnitride is completing its first microLED pilot line.



### SIGNIFICANT ROADBLOCKS STILL IN PLACE FOR KEY APPLICATIONS

For many applications, economics is pushing die size requirements below 10µm. This compounds efficiency, transfer and manufacturability challenges and despite significant improvement, small die efficiency remains low. Display efficiency based on this technology still can't match OLED. Significant effort is therefore needed to further improve

the internal quantum efficiency, light extraction and beam shaping of green and red microLED chips.

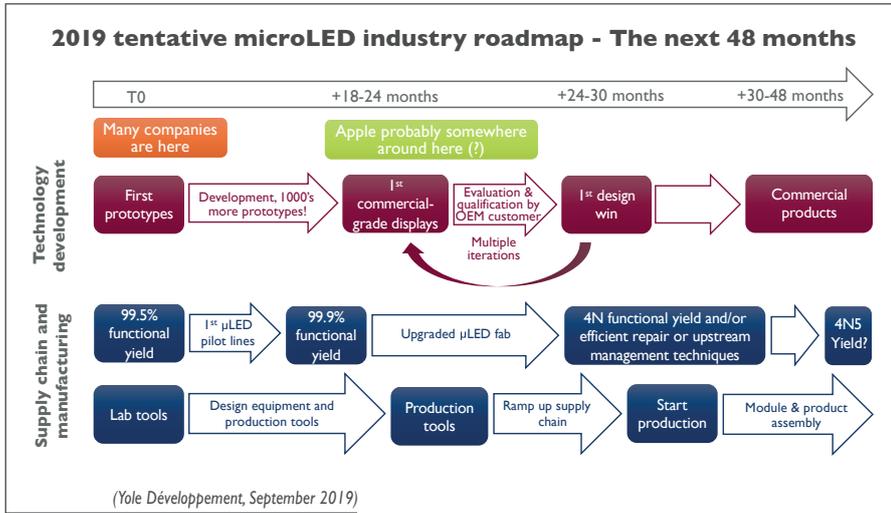
Epitaxy and chip fabrication are no longer seen as roadblocks, but solid yield management and repair strategies must be implemented. Transfer and assembly processes need to

evolve from table-top experiments to robust high-volume production tools. The proliferation of technology paths creates some confusion and delays. Equipment makers can be reluctant to commit. A piece of equipment developed for certain processes or architectures therefore

often won't work with others. Developing process-agnostic tools is challenging. Choosing a technology today is risky, but so is waiting too long to get in the game with an increasingly crowded intellectual property (IP) landscape

For microLED companies, the first few prototypes provide strong returns in terms of experience, but maturing toward consumer-grade displays could require thousands more. Startups are entering the 'valley of death'. Many might fail to raise enough money to successfully go through this more capital- and resource-intensive phase. Support and partnership with large display makers or original equipment manufacturers (OEMs), either as strategic investors or development partners is critical.

The situation is less challenging for microdisplays. Many prototypes can be built from a wafer run, and setting up the supply chain is easier as a lot of steps can be outsourced. Small foundry runs are expensive, however, and non-recurring engineering costs can be significant.



## A STRONG CASE FOR AR, SMARTWATCHES AND AUTOMOTIVE, BUT WILL PHONES AND TVS MATERIALIZE?

Smartwatches are a perfect 'beach-head'. Low volumes, small displays with high price elasticity make it possible to use larger dies and more redundancy. Apple could push high volume manufacturing and make smartwatches a stepping stone to overcoming supply chain obstacles and improve technology toward other applications. Other companies could enter the market sooner with lower volume, lower specification devices. glō is partnering with Kyocera to set up its supply chain and Playnitride expects to ship passive-matrix wearable displays with its partner RiTdisplay by the end of 2020.

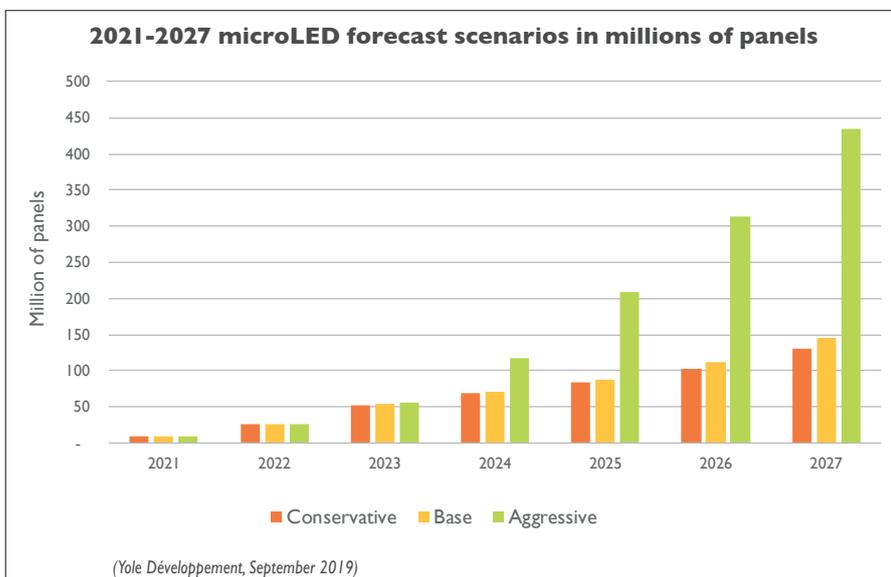
There is also a strong case for augmented reality (AR) and head-up display (HUD) microdisplays where microLEDs could be the only technology delivering

the right combination of brightness, efficiency and form factor. More work however is needed to deliver full-color displays and efficient coupling to waveguide optics. For automotive, microLEDs offer a unique and compelling combination of high brightness, contrast, ruggedness and environmental stability, while enabling freeform, conformable displays. Higher price elasticity means microLED could be technology-ready rapidly, but lengthy qualification cycles will delay adoption past 2023.

The TV market is more challenging. OLEDs are progressing and might leave little room for differentiation by the time microLEDs are ready. TV sizes up to 75" will be commoditized by then, but larger panels with modular builds present an opportunity. Companies like Samsung could test the water as early as 2020-2021 with low volume "luxury" models aimed at "mansion" home theatres or high-end retail. Smaller dies, below 5µm, are needed to address consumer markets, which will require at least two more years.

For smartphones, OLED will be a mature, high-performance, cost-effective solution by the time microLED is ready. MicroLED can't match OLED's cost. Differentiating performance and features still to be invented are required to compete. Die sizes below 5µm are needed to remain within an acceptable cost bracket, and high volumes require massive investments in the supply chain.

Apple still appears the best positioned to enable high volume microLED smartphones. This could happen 2-3 years after introduction in smartwatches but also raises an existential question for the industry. What happens if Apple pulls the plug on microLEDs?



## REPORT OBJECTIVES

Understand the status of microLED technologies:

- Recent progress
- What are the remaining pinch points?
- What are the best yield management and repair strategies? Current status and roadmaps

Which applications could microLED display address and when?

- Detailed analysis and roadmaps for major display applications
- Cost analysis

Competitive landscape and supply chain

- Identify the key players and IP owners in technology development and manufacturing. Who's taking the lead? Key partnerships
- Scenario for a microLED display supply chain
- Impact on the display supply chain



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- 6.5 The Buyer shall define within its company a contact point for the needs of the contract. This person will be the recipient of each new report. This person shall also be responsible for respect of the copyrights and will guaranty that the Products are not disseminated out of the company. In the context of Bundle and Annual Subscriptions, the contact person shall decide who within the Buyer, shall be entitled to receive the protected link that will allow the Buyer to access the Products.
- 6.6 Please note that whether in Bundles or Annual Subscription, all unselected reports will be cancelled and lost after the 12 month validity period of the contract.
- 6.7 As a matter of fact the investor of a company, external consultants, the joint venture done with a third party, and so on cannot access the report and should pay a full license price.

## 7. TERMINATION

- 7.1 If the Buyer cancels the order in whole or in part or postpones the date of mailing, the Buyer shall indemnify the Seller for the entire costs that have been incurred as at the date of notification by the Buyer of such delay or cancellation. This may also apply for any other direct or indirect consequential loss that may be borne by the Seller, following this decision.
- 7.2 In the event of breach by one Party under these conditions or the order, the non-breaching Party may send a notification to the other by recorded delivery letter upon which, after a period of thirty (30) days without solving the problem, the non-breaching Party shall be entitled to terminate all the pending orders, without being liable for any compensation.

## 8. MISCELLANEOUS

All the provisions of these Terms and Conditions are for the benefit of the Seller itself, but also for its licensors, employees and agents. Each of them is entitled to assert and enforce those provisions against the Buyer.

Any notices under these Terms and Conditions shall be given in writing. They shall be effective upon receipt by the other Party.

The Seller may, from time to time, update these Terms and Conditions and the Buyer, is deemed to have accepted the latest version of these terms and conditions, provided they have been communicated to him in due time.

## 9. GOVERNING LAW AND JURISDICTION

- 9.1 Any dispute arising out or linked to these Terms and Conditions or to any contract/orders entered into in application of these Terms and Conditions shall be settled by the French Commercial Courts of Lyon, which shall have exclusive jurisdiction upon such issues.
- 9.2 French law shall govern the relation between the Buyer and the Seller, in accordance with these Terms and Conditions.