MICROLED DISPLAYS

Market & Technology report - February 2017

Hype and reality: hopes for smartwatches and beyond must overcome technical and manufacturing challenges.

KEY FEATURES OF THE REPORT

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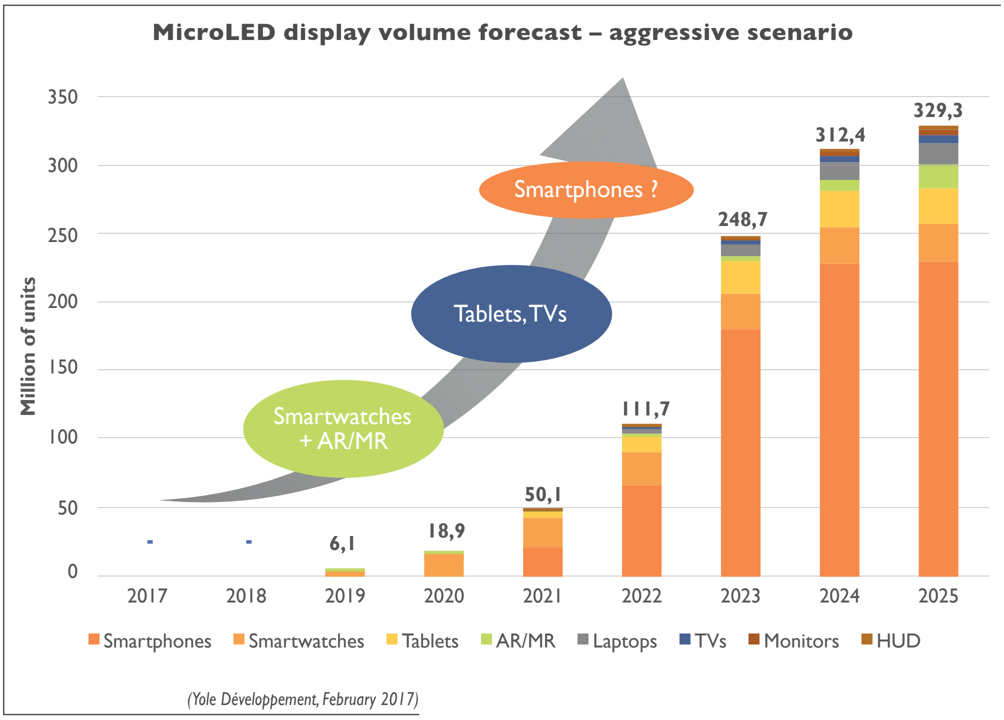
- Detailed analysis of microLED technology including epitaxy, die, display structure, color conversion, backplane, microLED transfer, defect management, light extraction and beam shaping
- Identification of key players and their intellectual property
- SWOT analysis, roadmap and forecast for microLED display applications, including TV, smartphones, wearables, augmented, mixed and virtual reality, laptops, tablets, monitors, light emitting diode (LED) video displays
- Disruption scenarios for incumbent liquid crystal display (LCD), organic light emitting diode (OLED) and liquid crystal on silicon (LCOS) technologies, with implications for the supply chain, impact on wafer and metal-organic chemical vapor deposition (MOCVD) reactor demand

MICROLED DISPLAYS COULD DISRUPT LCD AND OLED

Micro-light emitting diodes (microLED) are an emissive display technology. Just like organic light emitting diodes (OLED), they offer high contrast, high speed, and wide viewing angle. However, they could also deliver wider color gamut, dramatic – orders of magnitude – higher brightness, significantly reduced power consumption and improved lifetime, ruggedness and environmental stability. In addition, microLEDs allow the integration of sensors and circuits, enabling thin displays with embedded sensing capabilities such as fingerprint identification and gesture control.

The first microLED commercial product was unveiled by Sony in 2016 in the form of a small-pitch LED video display where traditional packaged LEDs are replaced by microLEDs. The first consumer killer-app could come in the form of smartwatches, propelled by Apple, which invested in the technology by buying Luxvue in 2014. MicroLEDs could also eventually dominate augmented and mixed reality displays thanks to their unique ability to deliver both the brightness and low power consumption required for the application.

Initial success in smartwatches could accelerate technology and supply chain maturation, making microLED competitive against OLED in high end TVs, tablets and laptops. Although less disruptive for those applications, microLED would still bring the best of OLED and liquid crystal displays (LCD) together. Smartphones will be a tough nut to crack and require further technology improvement in the manufacturing and handling of very small microLEDs (< 5 µm). In our most optimistic scenario, the market for microLED displays could reach up to 330 million units by 2025.



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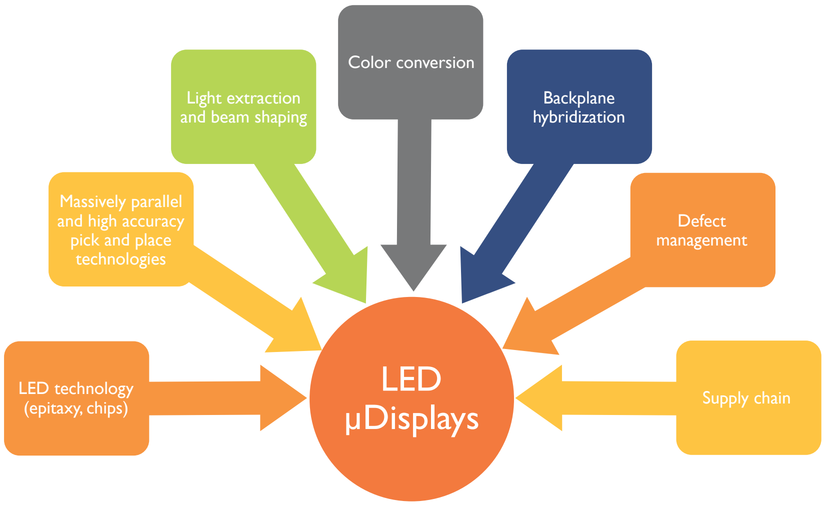
THERE ARE MANY ENGINEERING AND MANUFACTURING ROADBLOCKS BEFORE MICROLED REACHES PRIME TIME

The science is here, but microLED is an inherently complex display technology with cost drivers different from those of incumbent technologies. The concept is simple: each pixel is constituted of individual microLED emitters. However, at very small dimensions, microLED operation tends to be dominated by nefarious sidewall effects which impact performance. The reported efficiency of microLEDs below 10 µm side length is often 10-20% of larger LED chips or below. At those levels, microLED displays can't deliver on the key promise of low energy consumption. Solving this issue is a key priority for companies involved microLEDs. Some such as VueReal or Mikro-Mesa have reported significant improvement.

Multiple challenges need to be tackled to realize the microLED display opportunity



(Yole Développement, February 2017)

Efficiently manipulating high volumes of microLEDs and positioning them on the backplane is another major area. Assembling a single 4K display would take more than a month using traditional pick and place equipment! Companies such as Apple, X-Celeprint, Playnitride and others have developed massively parallel pick and place technologies that can process tens of thousands to millions of microLEDs simultaneously. However, the handling of the smaller size (<10 µm) chips and positioning accuracy needs further work. Alternatively, companies such as VueReal or Rohinni are developing "semi-continuous" processes akin to traditional printing.

In modern displays, dead or defective pixels are not acceptable. Achieving 100% combined yields in epitaxy, chip manufacturing and transfer is nothing short of utopia. MicroLED display manufacturers must therefore develop effective defect management strategies combining pixel redundancies and/or individual pixel repair depending on the characteristics of the display.

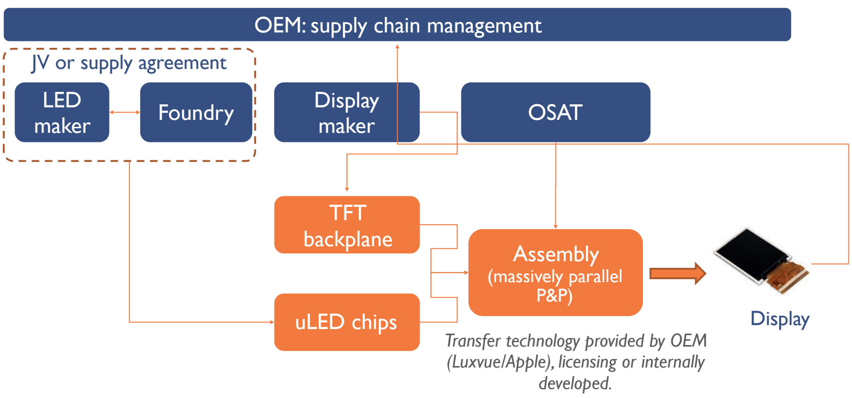
Other challenging technology nodes include color conversion, light extraction and beam shaping, all subjects of intense research, licensing and mergers and acquisition activities.

IF SUCCESSFUL, MICROLED DISPLAYS COULD HAVE PROFOUND IMPACT ON BOTH THE LED AND DISPLAY SUPPLY CHAINS

Many startups and large companies are working on microLEDs, from LED makers such as Epistar, Nichia or Osram to display makers like AUO, BOE or CSOT and original equipment manufacturers (OEMs) such as Apple or Facebook/Oculus.

Enabling large scale microLED displays requires bringing together three major disparate technologies and supply chain elements: LED, thin-film transistor (TFT) backplane and chip transfer. The supply chain is complex and lengthy compared with that of traditional displays. Each process is critical and managing every aspect effectively will be challenging. No single player can solve all the issues and it seems unlikely that any will fully vertically integrate. Small companies could bring together the different technologies to serve the augmented reality (AR) market, but for high volume consumer applications such as mobiles or TVs, only a strong push from a leading OEM can enable a supply chain. Apple is the most likely candidate with enough leverage and financial strength to bring all partners together. Other candidates include Oculus, which has also invested in microLEDs for AR/mixed reality (MR) applications.

Example of a possible supply chain (see others in report)



(Yole Développement, February 2017)

Each participant will attempt to capture as much added value as it can. For LED makers, low defect requirements and high resolution features of microLED means large investments in new clean room and lithography equipment which might be better suited to CMOS foundries. Traditional display makers are used to manufacturing both back and front planes in an integrated fashion and delivering finished panels to OEMs. With microLEDs, they will struggle against becoming component suppliers, only providing a TFT backplane to whichever participant will produce the final display assembly: OEMs or outsourced semiconductor assembly and test (OSAT) players.

Some companies will benefit from microLED displays independently of how the supply chain is shaped. These beneficiaries include metal-organic chemical vapor deposition (MOCVD) reactor and other LED equipment manufacturers as well as wafer suppliers. For the latter, however, sapphire manufacturers will have to keep an eye on a possible come back of the old LED-on-silicon idea which could have definite advantages in microLED manufacturing.

COMPANIES CITED IN THE REPORT (non exhaustive list)

Aledia (FR), Allos Semiconductor (DE), Apple (US), AUO (TW), BOE (CN), CEA-LETI (FR), CIOMP (CN), Columbia University (US), Cooledge (CA), Cree (US), CSOT (CN), eMagin (US), Epistar (TW), Epson (JP), Facebook (US), Foxconn (TW), Fraunhofer Institute (DE), Glo (SE), GlobalFoundries (US), Goertek (CN), Hiphoton (TW), HKUST (HK), HTC (TW), Ignis (CA), InfiniLED (UK), Intel (US), ITRI (TW), Kansas State University (US), Kopin (US), Lumiode (US), Luxvue (US), Metavision (US), Microsoft (US), Mikro-Mesa (TW), mLED (UK), Nichia (JP), Nth Degree (US), Oculus (US), Osterhout Design Group (US), Osram (DE), Ostendo (US), Playnitride (TW), PSI Co (KR), Rohinni (US), Saitama University (JP), Samsung (KR), Sanan (CN), Semprius (US), Sharp (JP), Sony (JP), Strathclyde University (UK), Sun Yat-Sen University (TW), Texas Tech (US), TSMC (TW), Tyndall National Institute (IE), University of Illinois (US), VerLASE (US), VueReal (CA), Vuzix (US), X-Celeprint (IE).

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OBJECTIVES OF THE REPORT

Understand microLED display technologies:

- Benefits and drawbacks versus other display technologies
- Key technology elements and associated challenges and cost drivers
- Technology roadblocks

Which applications could microLED display address and when?

- Detailed analysis and roadmaps for major display applications
- How disruptive for incumbent technologies?

Competitive landscape and supply chain:

- Identify the key players and IP owners in technology development and manufacturing
- Scenarios for the microLED display supply chain
- Impact on the LED supply chain
- Impact on the display supply chain

Dr Eric Virey serves as a Senior Market and Technology Analyst at Yole Développement (Yole), the "More than Moore" market research and strategy consulting company. Eric is a daily contributor to the development of LED, OLED, and Display activities at Yole, with a large collection of market and technology reports as well as multiple custom consulting projects: business strategy, identification of investments or acquisition targets, due diligence (buy/sell side), market and technology analysis, cost modelling, technology scouting, etc. Thanks to its deep knowledge of the LED/OLED and displays related industries, Eric has spoken in more than 30 industry conferences worldwide over the last 5 years. He has been interviewed and quoted by leading media over the world.
Previously Eric has held various R&D, engineering, manufacturing and business development positions with Fortune 500 Company Saint-Gobain in France and the United States.
Dr Eric Virey holds a PhD in Optoelectronics from the National Polytechnic Institute of Grenoble.

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