

MICROLED DISPLAYS 2018

Market & Technology report - July 2018

MicroLED technology advances enable a credible cost reduction path toward high volume applications.

KEY FEATURES

- Detailed analysis of MicroLED technologies
- Key players
- Intellectual property
- Supply chain
- MicroLED die and assembly cost analysis for TVs and smartphones
- MicroLED display applications: Strength, weakness opportunity and threat (SWOT) analysis, roadmap and forecast for TVs, smartphones, wearables, augmented, mixed and virtual reality, laptops, tablets and monitors, plus detailed forecast through 2027
- Wafer, MOCVD reactor and transfer equipment demand forecast

WHAT'S NEW

- Technology update: recent progress and status on epitaxy, chip manufacturing, microLED efficiency, mechanical, laser-based and self-assembly transfer processes, light management and color conversion
- Yield and defect management: What are the reasonable targets for microLEDs?
- Can Thin Film Transistor (TFT) backplanes be used to drive microLED displays? Specific challenges in comparison to OLED displays
- Cost analysis: Can microLED TV or smartphone display manufacturing costs be compatible with these applications? Which cost reduction paths are realistic?
- Updated adoption roadmap and volume forecast

MICROLED TECHNOLOGY IS NOT READY YET - BUT IS PROGRESSING ON ALL FRONTS

MicroLED technology could match or exceed OLEDs for most key display attributes. However, it is also an inherently complex technology. Manufacturing a 4K resolution display implies assembling and connecting 25 million microLED chips the size of large bacteria without a single error, with placement accuracy of 1 μm or less.

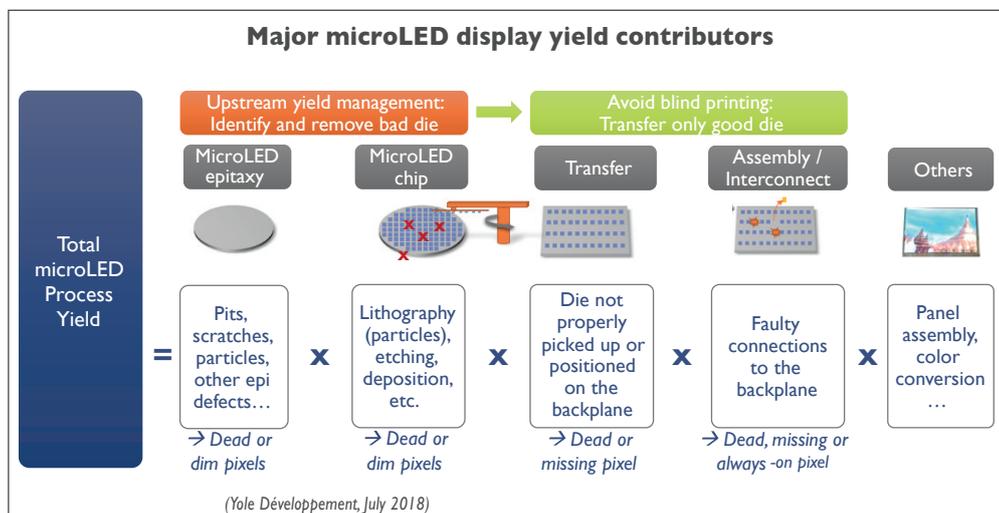
This challenge alone appears daunting, but many others were still seen as potential showstoppers as recently as early 2017. Eighteen months later, some assembly technologies are delivering close to 99.99% or 99.999% yields, and small die efficiency is approaching or exceeding that of OLEDs. MOCVD reactor suppliers also have credible roadmaps to deliver tools with the capabilities and cost ownership that the industry needs. Color conversion and other aspects are also progressing.

Increasing numbers of companies are demonstrating prototypes. Most are microdisplays on CMOS

backplanes but the number of “large” displays prototypes is increasing as well, whether they are using discrete microdrivers like X-Celeprint or thin-film transistor (TFT) backplanes like AUO and Playnitride.

Many are still focusing on realizing their first prototype, but the most advanced have realized that bringing up the technology from the level of functioning demo to consumer-grade products might require more effort than anticipated. Among others, driving microLEDs is more complex than OLEDs and using standard low temperature polysilicon (LTPS) or oxide TFT backplanes might not be as straightforward as expected.

The report presents a comprehensive analysis of all critical technology blocks with a focus on the most recent advancements, emerging options and remaining challenges.



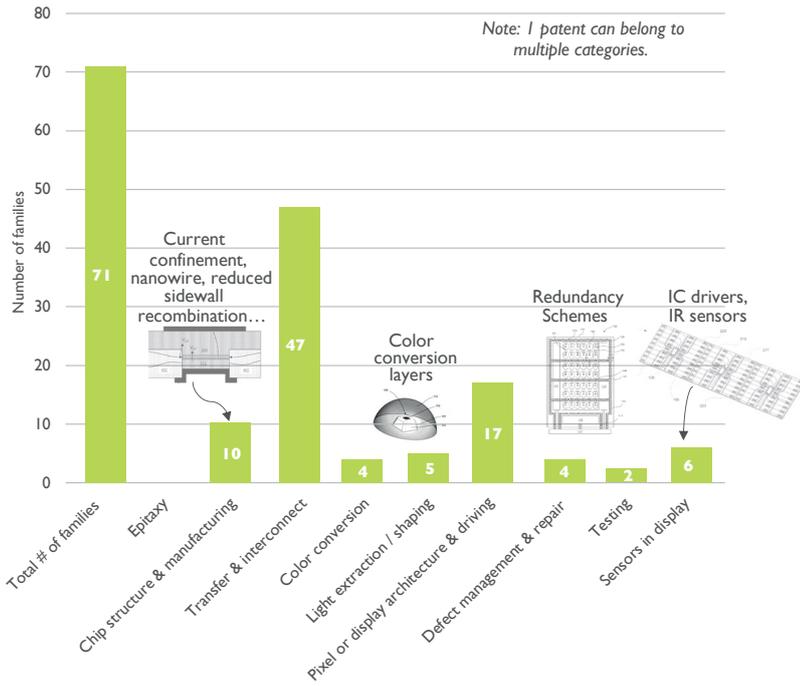
APPLE IS STILL THE BEST POSITIONED TO BRING HIGH VOLUME CONSUMER MICROLEDs TO MARKET

Sony’s demonstration of a full HD 55” microLED TV at CES 2012, more than six years ago, was the first exposure for microLED displays and generated a lot of excitement. Since Apple acquired Luxvue in 2014, many leading companies such as Facebook, Google, Samsung, LG or Intel have entered the game via sizable internal developments, acquisitions, like those of mLED and eLux, or investments in startups such as glō or Aledia.

Analyzing Apple’s microLED patent activity shows

that the company essentially halted its filing around 2015. This is a surprising finding in the light of the fact that the consumer electronics giant has maintained a large project team and consistently spent hundreds of millions of dollars annually on microLED development. A closer analysis however brought up the name of a possible strawman entity used by Apple to continue filing patents and shows that the company is still advancing key aspects of microLED technologies.

Apple microLED patent portfolio as of December 2017



This analysis has been performed by KnowMade, part of Yole Group of Companies.
(Yole Développement, July 2018)

Despite a later start compared to pioneers such as Sony or Sharp, Apple's portfolio is one of the most complete, comprehensively covering all critical technologies pertinent to microLEDs. The company is the most advanced and still one of the best positioned to bring high volume microLED products to the market. However, it also faces unique challenges:

- It can't afford to introduce a product featuring such a highly differentiating technology that is anything but flawless.
- It requires high volumes, which makes setting up the supply chain more challenging than for any other company.
- It has no prior experience in display manufacturing and due to its need for secrecy, has to develop pretty much everything internally, duplicating technologies and infrastructures that others have the option to outsource.

The report provides a detailed overview of key players and analysis the challenges associated with setting up an efficient microLED display supply chain, including front end and display assembly.

TECHNOLOGY ADVANCEMENTS PAVE THE WAY FOR VARIOUS COST REDUCTION PATHS TOWARD VOLUME MANUFACTURING, BUT NONE ARE STRAIGHTFORWARD

Dozens of technologies are being developed for microLED assembly and pixel structures. The cost and complexity range can be staggering. However, there are some fundamentals that anchor all those processes. Alignment dominates assembly cycle times, die size can't get infinitely small, epitaxy cost has already been through more than 20 years on the cost reduction curve. Cost analysis therefore allows companies to narrow the process parameters down to economically realistic windows and identify efficient cost reduction strategies.

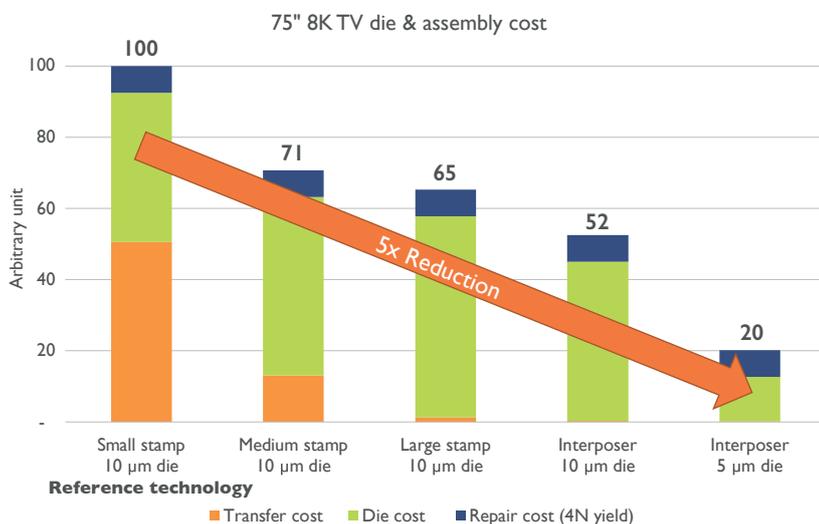
MicroLED companies must understand the cost targets for each application and work backward, making process choices and developing each step so it fits the cost envelope. Processes that can't deliver the right economics will disappear. If none can deliver the right economics, the opportunity will never materialize. MicroLED is entering the valley of death between technology development and industrialization and commercialization.

As the technology improves, there are credible cost reduction paths for microLED to compete in the high-end segment of various applications such as TV, augmented and virtual reality (AR/VR) and wearables. With the right approaches, assembly cost could become a minor contributor. For smartphones, however, approaching OLED cost implies pushing microLEDs toward what is likely to be the limits of the technology in term of die size. To succeed, microLEDs will have to count on some level of price elasticity. It must deliver performance and features that no other display technology can offer and that are perceived by the consumer as highly differentiating.

Microdisplays for AR and head-up displays (HUD) will be the first commercial applications, followed by smartwatches. TVs and smartphones could follow 3-5 years from now.

The report features a detailed analysis of the contribution of die and assembly costs, looking at factors such as die size, redundancy, yield and assembly strategy for both TV and smartphone applications.

MicroLED displays technology: cost reduction path for 75-inch 8K TV with 99.99% (4N) yield



A complete analysis and figures in value are detailed in the report.

(Yole Développement, July 2018)

OBJECTIVES OF THE REPORT

Understand microLED display technologies:

- Benefits and drawbacks compared to other display technologies
- Key technology bricks and associated challenges, cost drivers
- Technology roadblocks

Which applications could microLED display address and when?

- Detailed analysis and roadmaps for major display applications
- Cost analysis
- How disruptive will microLED be for incumbent technologies?

Competitive landscape and supply chain

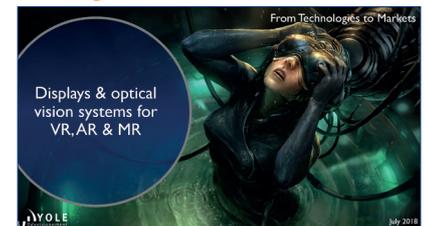
- Identify the key players and IP owners in technology development and manufacturing
- Scenario for a microLED display supply chain
- Impact on the LED supply chain
- Impact on the display supply chain

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TABLE OF CONTENTS (complete content on i-Micronews.com)

Executive summary	10	Light extraction and beam shaping	189
Introduction to microLED displays	51	Color conversion	204
MicroLED display manufacturing yields	63	Backplanes and pixel driving	214
MicroLED epitaxy (FE Level 0)	79	Economics of microLED – cost reduction paths	240
Chip manufacturing and singulation (FE Level I)	96	Television	247
MicroLED singulation	97	Smartphones	265
MicroLED efficiency	104	Applications and markets for microLED displays	277
MicroLED chip manufacturing	112	AR, MR and VR	284
Transfer and assembly technologies	124	Smartwatches	290
Overview	125	Smartphones	294
Pick and place processes	129	TVs	301
Continuous/semi-continuous assembly	141	Others: tablets, laptops, monitors	310
Self assembly	150	Wafer and equipment forecast	315
Summary	154	Competitive landscape	322
Transfer and assembly equipment	165	Supply chain	332
Bulk microLED arrays	171		
Pixel repair	183		

Find more details about this report here:





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