



MicroLED Association

White paper: MicroLEDs 2023: state of the industry and future roadmap

December 2023
Non-member summary



MicroLEDs 2023: State of the industry and future roadmap

By the MicroLED Industry Association (MIA)

This document will provide an overall look at the status of the MicroLED industry and market, as well as projections for the future. This is a non-member summary of the full MicroLED Association Roadmap 2023 document, available for association member companies only. The full version also contains in-depth technical roadmaps covering areas such as LED technology & efficiency, microLED wafers, backplane technologies, production yields and scalability.

This report was written by the MicroLED Industry Association, a collaborative consortium that aims to support the adoption of microLED display technologies. The Association brings together companies, academia and organizations active in the MicroLED space and provides a forum for solving common technology issues, fostering cooperation and sharing relevant information, resources and tools.

MicroLED is a relatively nascent next-gen display technology, meant to replace incumbent technologies like LCD and OLED while offering improved performance – mainly in terms of efficiency, lifetime and brightness. Despite ongoing research and R&D (which has been going on for over a decade), it seems that mass production is still years away with several unsolved challenges to overcome [1]. It remains to be seen which processes and technologies will ultimately become prevalent in the industry.

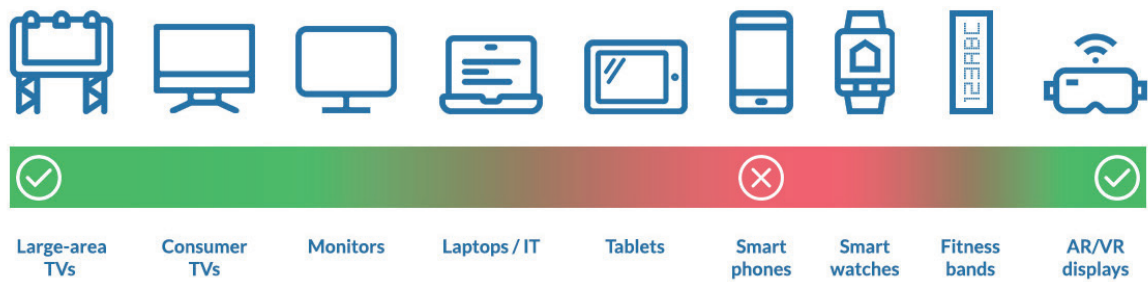
The number of displays currently being sold is very small, as high manufacturing costs and low production capacity limit the use of MicroLEDs in most markets. Nevertheless, this document will describe the existing market and attempt to give projections for the future. In the LCD and OLED industries, most of the displays are manufactured using more or less similar techniques. In the MicroLED industry, however, a larger number of manufacturing technologies exist, as well as different architectures [2]. It is plausible that as the MicroLED industry matures, different companies will still choose various different technologies and architectures, and it is also possible that displays meant for different applications will be different in terms of manufacturing and architecture. This could potentially harm the accuracy of our projections, but we hope this document can help decision makers to understand the various options and the future of the MicroLED industry in a way that will be valuable [3].

MicroLED Market and Industry Landscape, 2023

Despite Billions of dollars already invested in R&D in recent years, the state of the MicroLED market is still quite preliminary. Currently, a small number of displays are produced commercially, all targeting three markets:

1. Microdisplays, or near-eye displays
2. Displays meant for smartwatches or other wearable solutions
3. Ultra large area TV and signage displays

Albeit counterintuitive, it is easier and more cost effective for the MicroLED industry to manufacture displays that are either very small or very large. “in-between” sizes tend to be more challenging.

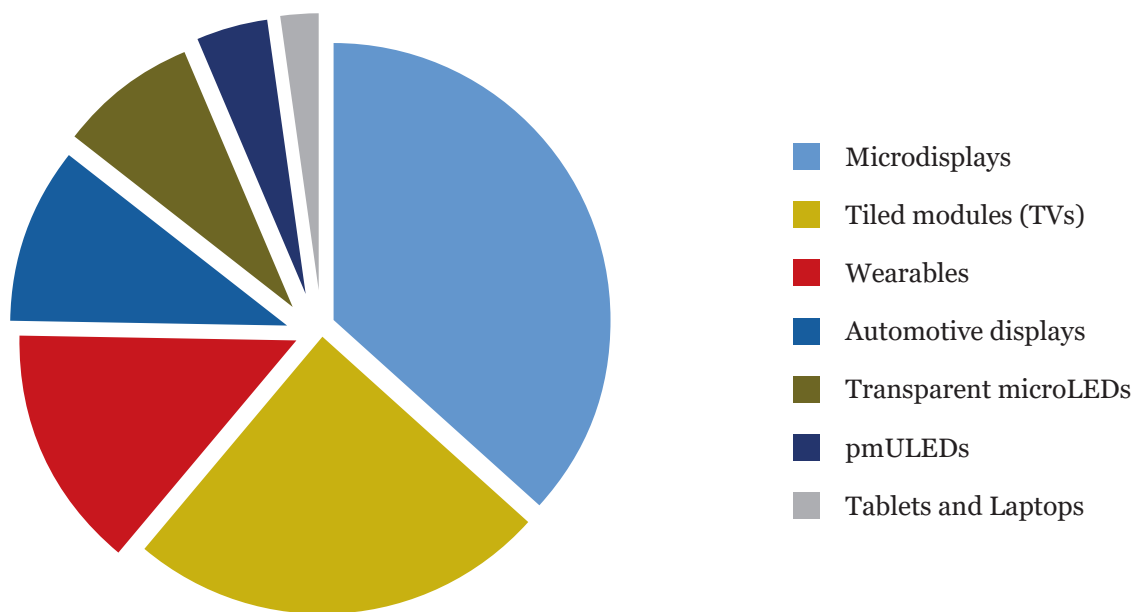


In the case of MicroLEDs, commercial production does not mean large quantities. Looking at the whole of 2023, it can be estimated that the number of produced MicroLED TVs or MicroLED signage displays does not even reach 1,000. In the field of microdisplays, the numbers are also very small so far. Some companies in the smartwatch space have already declared commercial production capabilities, but in fact these displays are not commercially produced at all and there is no actual smartwatch product on the market that uses MicroLED displays.

The industry, however, does not seem to lose hope because of these low numbers. The display industry is a large one, estimated at tens of billions of dollars per year, which produces billions of panels annually. Historically, every new technology has taken a long time to mature, and it is no surprise that MicroLED technology is no exception.

Following is a table that summarizes the current status of the industry. The full document (available for MicroLED Industry Association members only) also includes additional data and the names of the active companies in each segment.

	Microdisplays	Tiled modules (TVs)	Wearables	Automotive displays	Transparent microLEDs	pmULEDs	Tablets and Laptops	Consumer TVs	Smartphones
Number of active microLED developers	18	12	7	5	4	2	1	0	0



The chart shows that, in line with technology maturity level and relevant markets, the areas closest to mass production are:

- * Microdisplays, mostly for the AR market
- * Large area tiled displays
- * Smartwatch and other wearables
- * Automotive displays

Many companies also highlight transparent displays. It is an interesting segment with a major advantage for MicroLEDs over OLEDs (level of transparency). The main problem in this market segment remains the fact that there's no actual market demand or use case for a large number of displays.

Microdisplays

This segment of the display industry is probably the most mature and logical for MicroLED displays:

- * Microdisplays applications (mostly for AR/VR HMDs, HUDs) benefit very much from high performance displays (especially high efficiency and high brightness)
- * Manufacturers agree to pay a premium price for best-in-class performance
- * Manufacturing MicroLED displays in these sizes is easier than larger displays [\[4\]](#)

Many companies are developing such displays, but only one company commercially produces MicroLED microdisplays. Note that these are monochrome displays of a very small size (0.13 inch). While this is a humble start, there is great market interest in MicroLED solutions and we expect more manufacturers to start offering such displays, with selection and performance improving quickly. The production of microdisplays is easier than other types of displays, and the AR market is especially trendy, which explains why many companies try to cater to its needs.



Entering this market will be challenging, though, as OLED displays offer lower prices and very good performance (this fact is true for almost all market segments and is a major concern for microLED develops, one that will be addressed later in this roadmap). At the current status, microLEDs microdisplays may even underperform some OLED displays. However, the eventual superior brightness (and efficiency) that MicroLEDs offer will be a major advantage if microLED developers can increase actual production-ready performance.

Smartwatches and wearables

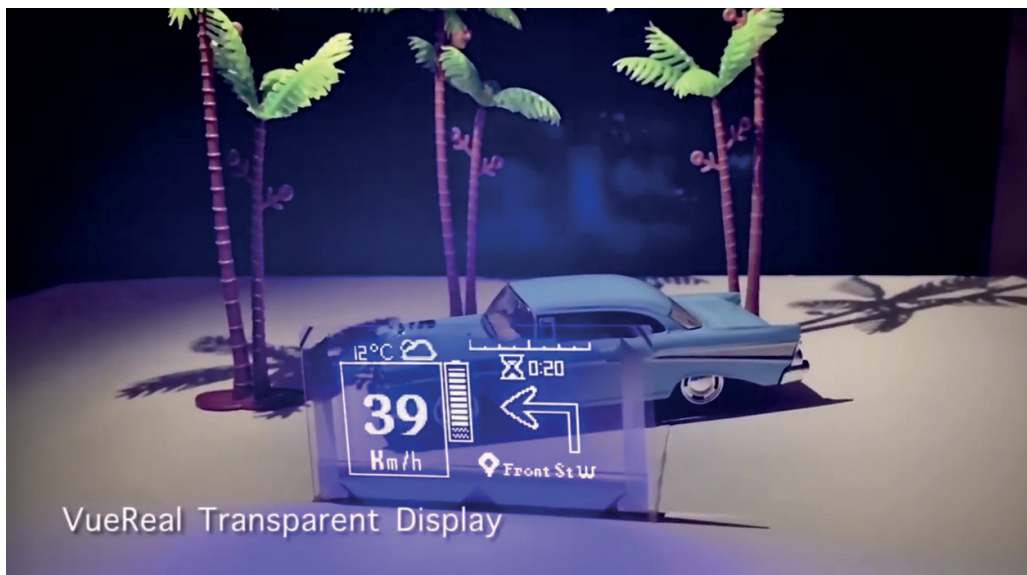
“Rumors” involving Apple’s plans to use MicroLED displays in its smartwatches have been circling for years. Producing MicroLED displays for the wearables market while avoiding high production costs is a difficult task. There are currently several companies (including leading display manufacturers) that are developing such displays, and the field seems to be progressing rapidly. MicroLEDs have advantages when it comes to power consumption, especially in such small displays that don’t require extremely high resolutions – meaning a small number of pixels and thus a small number of LEDs. In short, it seems quite plausible to manufacture MicroLED displays for the wearables market.



While one company already declared the start of commercial production of displays for the wearables market, low-cost mass production is not here yet. Various estimations suggest that these displays will remain quite expensive for the next few years, and real large scale commercial production will not start before 2025 or even 2026.

Automotive displays

The automotive market is an interesting one for MicroLED manufacturers. It demands high performance and adopts new technologies relatively quickly. In addition, OLEDs are not ideal for this market due to requirements such as long lifetime and operation in a high temperature range. This gives the opportunity for MicroLED displays to enter this space and there are indeed many companies with prototypes of MicroLED displays for the automotive market.



Note that the unique ability of microLEDs to enable tiled displays could prove useful in automotive applications, as companies could produce standard modules and automotive display designers can create custom shaped displays. It remains to be seen whether this is a viable route, though.

Large-area displays

Large displays based on MicroLEDs have been around for years, by leading companies like LG and Samsung. These companies turned to markets like high-end signage or ultra-premium residential displays, offering MicroLED TVs at extremely high prices, sometimes reaching several hundreds of thousands of dollars per unit.












At this price level, the number of units sold annually is very small – so while this whole market is limited and far from mass production, companies find it possible to offer these screens as actual commercial products.

Although the TV market has seen the introduction of microLED TVs years ago, there doesn't seem to be an easy way to lower the price of these displays enough to compete with LCDs and OLEDs when it comes to classic TV market sizes, which are about 30-90 inches. It will take years for MicroLED production technologies to mature enough to allow competitive presence in the TV market. [5]

Note that all large-area microLED production today adopts a seamlessly tiled display architecture. Tiled displays offer advantages in scalability to very large size, compared to LCD and OLED production which is performed on large substrates. It is not clear whether tiled display architecture will ever be applicable to consumer TV applications. [6]

MicroLED Market Roadmap, 2023-2033

Market Segment	Short term 2023-2025	Medium term 2026-2029	Long term 2030-2033
 MicroLED Microdisplays	Simple monochrome displays enter the market	Full-color displays enter the market, prices still high, niche applications	Mass production and adoption of full color microLED microdisplays
 Passive-Matrix microLEDs	First pmOLED displays enter the market	Wider range of displays in production, prices still high	pmOLED compete with pmOLED, wider production and adoption
 Wearables	Pilot-level production of wearable amOLED for wearables	Full scale production, initial adoption in premium products	Full scale production, initial adoption in products
 Smartphones	—	—	Initial R&D efforts, pilot level production
 IT (tablets/ laptops/monitors)	—	Initial R&D efforts	Pilot level production, initial premium product adoption
 Consumer TVs	—	—	Initial R&D efforts, pilot level production
 Signage and ultra-large TVs (tiled)	Pilot-level production, ultra premium product adoption	Lower production cost, increased production capacity, still ultra-premium devices only	Lowering production cost, increased adoption, but volume remains low
 Automotive displays	R&D, prototypes	Initial pilot-level production, adoption in high-end models	Increased production capacity and adoption
 Transparent displays	R&D, prototypes	R&D, prototypes	Initial pilot-level production, looking for applications?

MicroLED industry technical roadmaps, 2023-2033

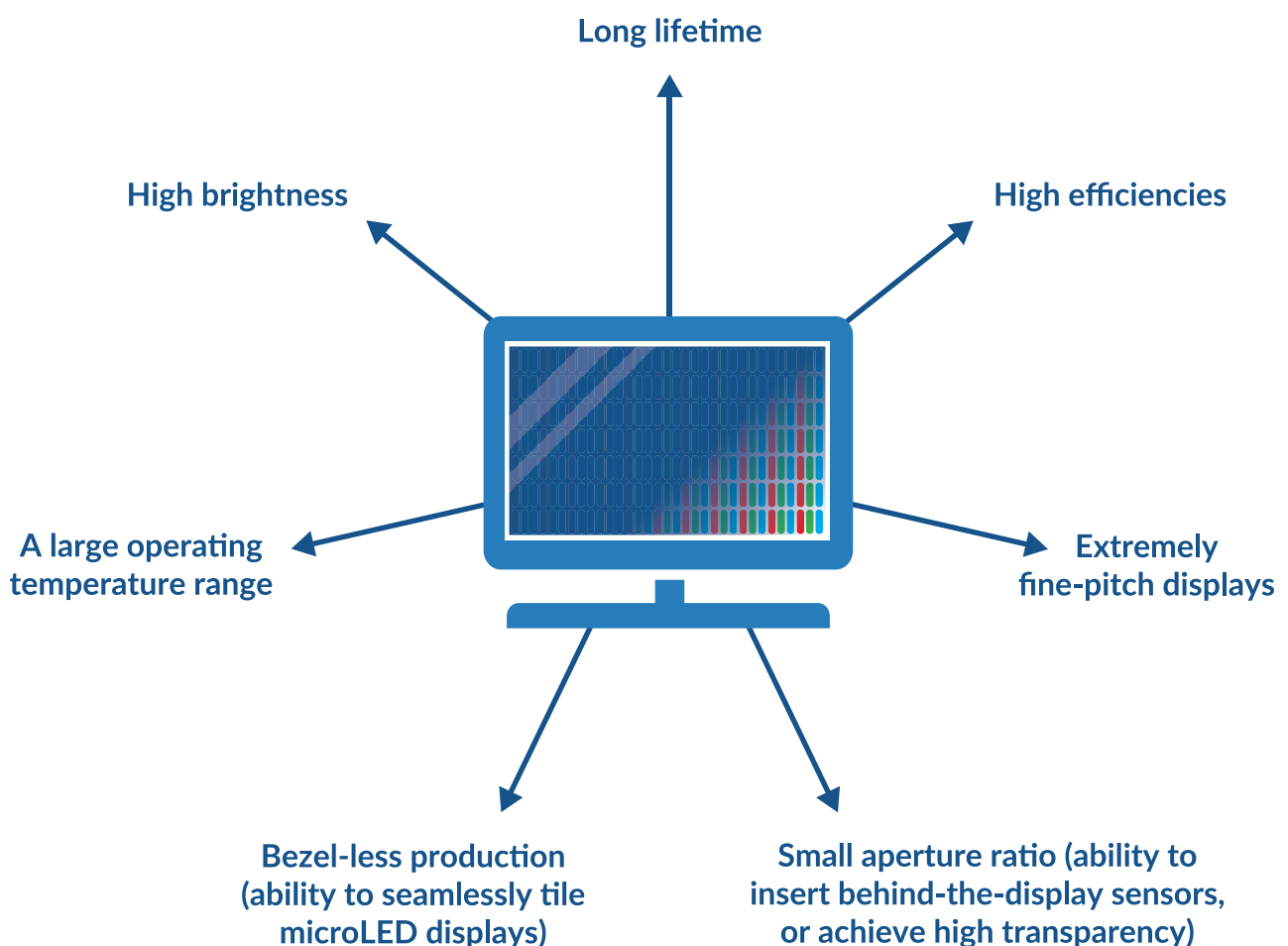
MicroLED Market Advantages

The MicroLED industry faces a very difficult challenge, in the form of a low-cost high-performance existing display industry. LCD and OLED displays today achieve very high performance, excellent image quality - and all that we low production costs at very high capacities. The ability to produce displays inline on large substrates has resulted in very low cost of production, without sacrificing the image quality or performance.

This is the status of the market that microLEDs currently face, and it is likely that as time progresses, the production cost of OLED displays will continue to decline, while performance will continue to increase (driven by the adoption of technologies such as high-efficiency blue emitters, maskless production, MLA, plasmon OLEDs and more).

In such an environment, it is vital for microLED developers to make sure the advantages of microLED displays are distinct and that these are **not compromised by the choice of production processes or display architectures**.

The following list summarizes the major advantages of microLED displays:



It is likely that as the first step, the market will adopt microLEDs in applications that especially benefit from these advantages, and that have the ability to use premium displays at premium prices.

Footnotes

[1] The number of challenges in the MicroLED market is substantial: improving LED production yields, choosing an efficient and suitable transfer technology, manufacturing extremely small LEDs that remain efficient, developing native red LEDs or using color conversion in a way that allows efficient manufacturing, and more.

[2] There are several architecture levels in MicroLED display production. At the single LED level, there is a choice between blue or UV LEDs while using color conversion, Nanowire LEDs, tunable LEDs and more. At the backplane level, there are TFT solutions like the ones used in LCD and OLEDs or solutions like MicroICs and Smartpixels. Is the display made of a single unit or is it a seamlessly tiled module, etc.

[3] Market projections are always hard to put together reliably, and they almost always miss the mark. However, it seems that the MicroLED industry is at such a preliminary stage that it not only has 'known unknowns' like when will production start and will adequate technologies be developed in time, but there are also 'unknown unknowns' which are likely to catch the industry by surprise. These could (hopefully) be new technologies that would address today's major challenges, which would allow for significant advancements to follow.

[4] Small displays (generally under 2 inch, often even smaller than 0.5 inch) can be manufactured without a transfer process, through what is known as a monolithic process. More information on this matter can be found in the Monolithic Processes White Paper by the MicroLED Industry Association.

[5] More information on this subject can be found in the MicroLED Yields – and Strategies to Overcome Them white paper, by the MicroLED Industry Association (<https://www.microledassociation.com/downloads/>).

[6] More information on this subject can be found in the MicroLED Tiled Displays – Current Status and Roadmap white paper, by the MicroLED Industry Association (<https://www.microledassociation.com/downloads/>).

Member Directory

#Lasers, #production equipment,
#Mass transfer, #inspection & repair



3D-Micromac

Laser equipment for μ LED forward transfer, lift-off and repair process steps - ready for high volume production

Germany-based 3D-Micromac AG is the industry leader in laser micromachining and roll-to-roll laser systems. The company develops and manufactures processes and laser systems delivering powerful, user-friendly and leading-edge processes with superior production efficiency.

3D-Micromac systems and services have been successfully implemented in various high-tech industries worldwide. This includes semiconductor, photovoltaic, glass and display industry, electronics, as well as medical device technology.

For microLED display manufacturing, 3D-Micromac offers industrial laser solutions for mass production:

- Laser-Induced Forward Transfer (LIFT) which enables the transfer of hundreds of millions of microLEDs without having to apply mechanical forces
- Laser Lift-Off (LLO) which guarantees a highly uniform, force-free lift-off of different layers on wafer and panel substrates
- REPAIR: Single die repair process at every step of the microLED production process

<https://3d-micromac.com/>

#materials & technologies



3M

Produces a wide range of products including electrical and electronic connecting and insulating materials, and optical films.

The 3M Company, based in the US, operates in the fields of industry, worker safety, U.S. health care, and consumer goods. The company produces a wide range of products (over 60,000, in fact) including adhesives, abrasives, laminates, passive fire protection, protection films, dental and orthodontic products, electrical and electronic connecting and insulating materials, and optical films.

3M's Display Materials and solutions Division (DMSD) is offering several products for the industry – transparent adhesives (OCAs), micro/nanoreplication technologies, printable optical materials, and multilayered optical films.

<https://www.3m.com>

#microdisplays, #LED epiwafers



ALEDIA

Aledia is a start-up company established in 2021 in the Grenoble area (France) to develop GaN nanostructure-based LEDs for Display applications. It has 220 people (30% PhDs), has more than 250 patent families granted or in application, and has raised €270M in four financing rounds.

Aledia has two nanowire LED platforms, one based on blue GaN nanowires on 8-inch wafers, and the second that utilizes RGB LEDs. The company targets a wide range of markets, from AR microdisplays to TVs and videowalls.

Aledia has built a factory near Grenoble (France) for high volume epitaxial growth and low volume LED processing manufacturing; high-volume manufacturing capacity is being implemented in different countries including in Asia, closer to the market.

<https://www.aledia.com/>

#materials & technologies, #LED epiwafers



ALLOS Semiconductors

GaN on Silicon IP licensing and technology

ALLOS Semiconductors is an IP licensing and technology company that focuses on GaN-on-Si technology.

For the micro-LED market, ALLOS offers a turn-key technology transfer to establish a super-uniform CMOS-compatible large (200 mm) epiwafer process at customers within only 12 weeks.

<https://www.allos-semiconductors.com>

#LED epiwafers



ams-OSRAM

In an increasingly connected world, sensing is taking a crucial role by closing the gap between the physical and the digital. Using the full spectrum of light we allow humans and machines to capture and understand the world around us. Combining sensors, software and emitters, we bring the information that our environment holds to light by capturing, analyzing and visualizing it. We sense the world and make sense of it.

<https://ams-osram.com>

#MicroLED research



CEA Leti

One of the world's largest microelectronics and nanotechnology organizations

CEA-Leti is a non-profit research institute based in Grenoble, France. CEA-Leti is one of the world's largest microelectronics and nanotechnology organizations.

Leti is developing micro LED displays, with a focus on high-performance microdisplays. Leti has implemented this LED technology to manufacture high-brightness uLED arrays hybridized on silicon circuit with a 10-um pixel pitch and the institute manufactures blue and green arrays offering a brightness of 107 cd/m².

<http://www.cea.fr/english>

#Production equipment, #Microdisplays



ClassOne Technology

Single wafer electroplating and wet process platform for microLED production

US-based ClassOne Technology develops and sells high-performance electroplating and wet processing systems for the manufacture of advanced microelectronics, for both R&D and high-volume fab environments.

For the microLED industry, ClassOne offers its Solstice single wafer electroplating and wet process platform, which the company says is installed at several microLED developers. The company also offers its reactor technology for the industry.

In 2022, ClassOne announced that it shipped its Solstice S4 single-wafer plating system to Raxium, a microLED microdisplay developer acquired by Google. ClassOne also collaborates with the Fraunhofer ENAS to develop hybrid bonding for microLED applications.

<https://semi.asmpt.com/en/>

#Lasers, #production equipment,
#mass transfer



Coherent

Laser-based solutions for the microLED industry: from a single laser source up to LLO, LIFT and repair systems

Coherent makes the amazing possible using the power of light. Performance, quality, and a global expert network support our customers in scientific, medical, electronics, and manufacturing markets.

MicroLEDs represents an exciting opportunity, potentially lowering the costs for very large area displays as well as some small area display applications. High energy, ultraviolet lasers are the key to success to cut production costs, increase throughput, and improve quality. Coherent provides several solutions from a single laser source, optical systems up to an integrated system for the three vital processes in MicroLED fabrication: Laser Lift-Off (LLO), Laser-Induced Forward Transfer (LIFT), and Repair/Trimming. Coherent also covers more process steps of the entire MicroLED production chain from laser cutting by ultrashort pulse lasers to Laser Assisted Bonding (LAB) by diode lasers.

<http://www.coherent.com/>

#materials & technologies, #LED epiwafers



Comptek Solutions

Develops quantum technology that boosts the performance of devices such as microLEDs and lasers

Founded in 2017 as a spin-off from the university of Turku, Finland, Comptek Solutions develops quantum technology (branded as Kontrox) that boosts the performance of devices such as microLEDs and lasers and makes their manufacturing process easier by solving the problem of aggressive oxidation of compound semiconductor materials.

Kontrox results in a high-quality passivation layer with substantially reduced defect densities that help to greatly decrease the surface recombination phenomena which is a predominant mechanism for such small devices.

Comptek says that MicroLED efficiencies increase significantly with Kontrox, the company has demonstrated up to 250% EQE (external quantum efficiency) improvements.

<http://www.comptek-solutions.com>

#materials & technologies



DELO

DELO is a leading manufacturer of high-tech adhesives and other multifunctional materials as well as corresponding dispensing and curing equipment. Their products are mainly used in the automotive, consumer electronics and semiconductor industries. They can be found in almost every mobile phone and half the cars worldwide, for example in cameras, loudspeakers, electric motors, or sensors. Customers include Bosch, Daimler, Huawei, Osram, Siemens, and Sony. The company has 1,000 employees and achieved revenues of €204 million in fiscal 2023.

Additionally, adhesives facilitate miniaturization, increase performance, and improve device functionality and reliability, from tiniest SMD component like miniLED and microLED to large size edge sealing.

<https://www.delo-adhesives.com>

#mass transfer



eLux

Massively parallel fluidic assembly of microLED displays

eLux Inc. was established in 2016 in the USA as a spin-out from Sharp Labs of America. eLux expertise and intellectual property development focus on the massively parallel assembly processes that enable low cost manufacturing of microLED displays.

<https://www.eluxdisplay.com/>

#LED epiwafers



Epistar

One of the world's leading LED producer

Epistar Corp, based in Taiwan and established in 1996, is one of the world's leading LED producers. The company specializes in high-brightness LED devices for general lighting and consumer electronics.

Epistar is developing Micro LED chips and technologies. In 2021 Epistar merged with Lextar to form Ennostar.

http://www.epistar.com.tw/index_en.php

#Mass transfer



Ennostar

The holding company of Lextar, Epistar, Unikorn and Yenrich

Taiwan-based Ennostar was established in early 2021 as a joint venture between Epistar and Lextar. Ennostar is the holding company that owns both Epistar and Lextar, and together the two companies hold about 12.5% of the global LED chip market. Ennostar also holds Unikorn and Yenrich.

Ennostar official goal is to become a multinational investment platform for the compound semiconductor industries. Specifically the focus is on mini LEDs and microLEDs products and technologies.

<https://www.ennostar.com/>

#materials & technologies,
#microdisplays, #MicroLED Research



Fraunhofer FEP

Electron beam technologies, vacuum thin film deposition techniques and technologies for organic electronics, microdisplay technology and sensorics.

The Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP is one out of 76 institutes and research units of the Fraunhofer-Gesellschaft e. V., the largest European institution for applied research. The core competences of Fraunhofer FEP are electron beam technologies, vacuum thin film deposition techniques and technologies for organic electronics, microdisplay technology and sensorics. Main activities target development and adaption of the thin film deposition technologies to a wide range of industrial applications. Fraunhofer FEP runs multiple pilot scale vacuum coating systems.

Furthermore, Fraunhofer FEP has a unique position in designing microelectronic circuits and components with application- and customer-specific adaptations of silicon circuit foundries' CMOS processes that allow these finished wafers to be subsequently processed with OLED coatings, for example. This subsequent processing is used in particular for augmenting silicon CMOS wafer functionality with optical and photonic components, such as for high-resolution OLED microdisplays.

<https://www.fep.fraunhofer.de/en.html>

#materials & technologies,
#MicroLED Research



Fraunhofer IZM

One of the world's leading institutes for applied research and the development and system integration of robust and reliable electronics

For 30 years, more than 440 employees have been finding technological solutions in cooperation with partners from industry and academia. Emerging challenges are addressed in branches such as automotive and industrial electronics, medical engineering, ICT and semiconductor technology.

Our technologies connect the individual components, protect components and devices from vibration and moisture, and reliably dissipate heat. Fraunhofer IZM thus ensures that electronic devices continue to function reliably in even the harshest conditions. Modern packaging technologies make developing smaller and smaller products possible. We process ICs thinner than a sheet of paper. The institute, founded in 1993, disposes of a lab area of over 8,000 sqm. About 80 percent of our turnover in 2021 was earned through contract research.

<https://www.izm.fraunhofer.de/en.html>

#color conversion



General Electric

For more than 125 years, GE has invented the future of industry. Today, GE is best known for its work in the Power, Renewable Energy, Aviation and Healthcare industries.

GE's Licensing team provides access to GE's patent portfolio and technical and intellectual resources. Licensees receive world-leading technology paired with advice and guidance to accelerate their technology development and achieve market differentiation.

The GE LED Phosphors team has world class chemistry and physics expertise as well characterization capabilities that have resulted in commercial successes in both lighting and LCD display technologies. Multimillion-dollar yearly revenue, multiple awards, hundreds of patents, over 20 licensees of our patents, along with various publications and invited conference presentations show that this team is on the cutting edge of luminescent material development and can advance from concept to invention to commercialization.

<https://www.ge.com>

#inspection & repair



InZiv

Testing and inspection tools for the microLED industry.

InZiv provides testing and inspection tools for the microLED industry. InZiv's technology offers one comprehensive platform for both full wafer mapping and individual chip testing and characterization at the highest resolution. Automated PL and EL provide today's most critical measurements, including EQE and angular measurements, and Nano-PL and Nano-EL enable the user to zoom in on individual chips and sub-pixel features and defects with 100nm resolution.

InZiv integrates multiple inspection modalities in one system, and provides a comprehensive analysis of both the whole wafer and its sub-pixel features. This unique combination empowers microLED developers and manufacturers with the ability to better understand the relationship between light, color, current, and structure – directly addressing today's most critical challenges in microLED.

<https://inziv.com/>

#mass transfer



Kulicke & Soffa

Advanced microLED placement solutions

Kulicke & Soffa (NASDAQ: KLIC) is a leading provider of semiconductor, LED and electronic assembly solutions serving the global automotive, consumer, communications, computing and industrial markets. Founded in 1951, K&S prides itself on establishing foundations for technological advancement – creating pioneering interconnect solutions that enable performance improvements, power efficiency, form-factor reductions and assembly excellence of current and next-generation semiconductor devices.

The Company further extends its mini and micro LED technology and solutions through strategic acquisition of Uniqarta in 2021.

<https://www.kns.com/>

#LED epiwafers



Lextar

LED developer and microLED chip maker

Established in 2008 in Taiwan as a subsidiary of AU Optronics, Lextar Electronics Corporation is a leading global LED developer. Lextar produces LED chips, LCD backlights, automotive LEDs, lumiaires and other lighting solutions.

In 2018 Lextar introduced its first micro-LED chips – both RGB ones and color conversion ones, both suitable for mass transfer processes.

Lextar is now a part of Ennostar, following a merger with Epistar.

<http://www.lextar.com/>

#microLED displays



LG Electronics

The LG Business Solutions Company is a trusted partner offering innovative products and solutions for diverse industries worldwide.

With a portfolio of unique offerings, such as industry-leading OLED signage, LED signage and commercial TVs, LG is a respected name among customers around the world.

For more on LG's Business Solutions, visit www.LG.com/b2b

<https://www.lg.com/global/business>

#color conversion



Mitsui Kinzoku

Produces functional engineered materials and electronic materials, nonferrous metal smelting.

Japan-based Mitsui Mining & Smelting (also known as Mitsui Kinzoku) produces functional engineered materials and electronic materials, nonferrous metal smelting, minerals resource development, precious metal recycling, raw material related businesses, manufacturing and sale of automotive parts/components, etc.

For the MicroLED Industry, Mitsui Kinzoku developed a sulfide phosphor for color conversion. The material is highly durable and does not contain any hazardous material. As of 2023, the company is sampling the material for microLED developers.

<https://www.mitsui-kinzoku.co.jp/mlab/en/>

#Materials & Technologies



Mojo Vision

Developing RGB Micro-LED displays

The Future of Micro-LED Technology is Here

Mojo Vision is focused on developing and commercializing world-class micro-LED technology for consumer, enterprise, and government applications. Developed as a critical component of Mojo Lens and first announced in 2019, the Mojo Vision Micro-LED Display is the smallest, densest dynamic display ever made, and the Micro-LED technology platform underlying it is powerful and flexible enough to serve a wide range of applications from next generation wearables all the way up to future televisions and video walls. We believe Micro-LED will disrupt the entire \$160B display industry and our unique technology puts us at the forefront of this disruption.

<https://www.mojo.vision/>

#display drivers



nsc innovation

Monolithically integrating GaN LEDs with silicon CMOS to enable microdisplay solutions

nsc is a groundbreaking integrated circuit design company based out of Singapore. Our chips are the first to effectively integrate silicon CMOS with GaN LEDs monolithically and at full wafer scale, while maintaining compatibility with traditional CMOS manufacturing. By doing so, nsc offers the functionality and manufacturability needed to enable widespread adoption of microdisplays. These highly efficient and cost-effective LED pixelated light engine (PLE™) chips can serve as the backbone for displays that will change the form factor of wearables, increase battery life, decrease cost, and make possible game-changing new product innovations. Our integrated chips are produced by co-opting existing manufacturing equipment and processes in order to deliver them at commercial scale.

<https://www.nscinnovation.com>

#Materials & Technologies



Pixelligent

Create and manufacture advanced tunable, high refractive index (RI) nanocrystal formulations and dispersions, Extended Reality (XR) devices, and sensor applications.

Pixelligent is a developer of industry-leading PixJet®, PixNIL®, PixCor™, and PixClear® Designer Compounds®. We create and manufacture advanced tunable, high refractive index (RI) nanocrystal formulations and dispersions that deliver the highest refractive index, most robust mechanical properties, and near-perfect transparency for next-generation displays, Extended Reality (XR) devices, and sensor applications.

Pixelligent has nearly 100 issued and pending patents, raised \$100M in funding, been awarded over \$15M in federal grant programs, and is ISO 9001 certified. Our 20,000 square-foot, state-of-the-art manufacturing and laboratory facility is located in Baltimore, Maryland and is supported by sales offices in the Republic of Korea and Taiwan and distributors throughout Asia.

<https://pixelligent.com>

#LED epiwafers



Q-Pixel Inc.

Q-Pixel

Overhauling Decades of microLED Display Technology by Replacing Century-old Monochromatic LED.

Q-Pixel is an innovator of polychromatic RGB microLED which is a revolutionary device to solve several key issues with decade-old microLED display technology. Problems, such as achieving ultra-high density pixels, high-yield mass transfer, etc., can be solved with a single full-color pixel.

<https://www.quantum-pixel.com>

#Color conversion



QNA Technology

Quantum dots for the display industry, based on unique surface engineering and QD inks

Poland-based QNA Technology, established in 2016, develops and produces quantum dots for the display industry. The company optimizes its QDs for two applications: electroluminescence display devices (QD-EL) and for microLED displays devices based on UV microLEDs.

QNA developed QD surface engineering to enable the delivery of its materials in various solvents, such as polar, non-polar, monomers, powders, and more. The company is also developing QD inks for ink-jet printing and for UV-curable inks.

<https://qnatechnology.com/en/>

#Color conversion



Qustomdot

Cadmium-free quantum dots technology for microLED displays

Belgium-based QustomDot brings unmatched colors through quantum dot (QD) color conversion to microLED applications. The team combines QD synthesis, surface engineering and ink/photoresist formulation into patterned color conversion layers for microLED displays. QustomDot's patented technology is cadmium free and can withstand high light intensities.

<https://www.qustomdot.com>

#Mass transfer



Rohinni

Precise miniLED and microLED placement technology

US-based Rohinni, established in 2013, focuses on miniLED and microLED technologies for lighting and displays.

Rohinni has developed precise placement technology that can achieve speeds greater than 100Hz for mini LEDs. Rohinni's technology has been adopted in the display, automotive and consumer electronics markets.

<https://www.rohinni.com>

#Materials & Technologies



Smartkem

Seeking to reshape the world of electronics with a revolutionary semiconductor platform that enables the next generation of low-cost displays and sensors.

SmartKem's patented TRUFLEX® inks are solution deposited at a low temperature, on low-cost substrates to make organic thin-film transistor (OTFT) circuits. The company's semiconductor platform can be used in a number of applications including mini- and micro-LED displays, AMOLED displays, AR and VR headsets, fingerprint sensors and integrated logic circuits. SmartKem develops its materials at its research and development facility in Manchester, UK, and its semiconductor manufacturing processes at the Centre for Process Innovation (CPI) at Sedgefield, UK. The company has an extensive IP portfolio including over 124 issued patents across 19 patent families.

<https://www.smartkem.com>

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Safran Vectronix

Safran Vectronix AG, part of a multinational aerospace and defense company

Safran Vectronix AG, based in Switzerland, is part of the Safran Group – a multinational aerospace and defense company equipment and components.

Safran Vectronix AG designs, develops and manufactures observation devices for defense and security forces. The company integrates microdisplays in its products.

<https://safran-vectronix.com>

#MicroLED research, #LED epiwafers



Solid State Lighting & Energy Electronics Center

Researchers to advance solid-state lighting and energy efficient power switching using wide-bandgap semiconductors.

The Solid State Lighting & Energy Electronics Center (SSLEEC) at UC Santa Barbara is a collaborative center, which partners key industry leaders and UCSB researchers to advance solid-state lighting and energy efficient power switching using wide-bandgap semiconductors.

SSLEEC is focused on new semiconductor based technologies for disinfection, advanced mobile displays, energy efficient lighting, and power electronics. The objective of the SSLEEC is to provide a forum for its members – key industry partners and the faculty and student researchers at the University of California, Santa Barbara – to work in collaboration and across scientific disciplines to address the most challenging problems in these important and timely areas of research.

<https://ssleec.ucsb.edu>

#microLED displays

STRATACACHE

STRATACACHE

Digital signage systems developer, microLED display producer

STRATACACHE is a digital signage, merchandising and customer engagement systems developer, targeting the retail, restaurants, banking and financing, gaming, events and education markets.

STRATACACHE is constructing the first US-based complete display production facility in Eugene, Oregon, the future MicroLED E4 fab.

<https://www.stratacache.com/en/>

#production equipment

TEL

Tokyo Electron (TEL)

Global semiconductors production equipment maker

Tokyo Electron Limited (TEL) is a Japanese electronics and semiconductor company headquartered Tokyo, established in 1963. TEL supplies equipment to fabricate ICs, photovoltaic cells and flat panel displays. TEL is considered to be the world's largest manufacturer of IC and FPD production equipment.

<https://www.tel.com>

#Mass transfer, #materials & technologies



Terecircuits corporation

Photo-polymer mass transfer system for microLED production

Terecircuits develops technologies and manufacturing processes for microassembly based on a new class of photo-chemical polymers.

The company focuses on the development of a microLED photo-chemical mass transfer process.

<http://terecircuits.com/>

#Services

Unikorn

Unikorn

Professional III-V compound semiconductor foundry

Unikorn, spun-off Epistar and now part of Ennostar, is a professional III-V compound semiconductor foundry located in Hsinchu Science Park, Taiwan. Unikorn focuses on epitaxy and wafer/chip processing.

<https://www.unikornsemi.com/?lang=en>

#microLED displays, #mass transfer,
#microdisplays



Vuereal

Micro-LED display technologies and display production

Canada-based VueReal is a startup company that develops Micro-LED display technologies. VueReal developed a cartridge-based microLED printing process that can produce high density displays at high production yields.

In addition to microLED technologies, VueReal also produces microLED displays, and offers custom display production done at its pilot production line in Waterloo, Canada.

<https://www.vuereal.com>

#MicroLED displays



Yenrich

miniLED and microLED direct view displays

Yenrich, spun-off from Epistar and now part of the Ennostar group, develops mini-LED and micro-LED packaging. The company is focused on direct-view displays, both miniLED based and microLED based.

<https://yenrichtech.com/en/>

#MicroLED Microdisplays



XPANCEO

XPANCEO is a deep tech company developing the next generation of computing via an invisible and weightless smart contact lens

The XPANCEO smart lens reinvents the whole concept of human-technology interaction and redefines the way we experience both real and digital worlds, including social media, content consumption, and gaming.

<https://www.xpanceo.com/>