MICRO LED

GAME, SET AND MATCH TO SPUTTER TECHNOLOGY?

Sputter is already the dominant technology for conventional LED technology, but will it now be "Game, Set and Match" to sputter for the manufacturing of TCOs, Contacts and DBRs for emerging Micro LED? Evatec Product Marketing Manager **Jakob Bollhalder** answers questions on how the technologies differ and what sputter can offer.

Q. Tell us how the drivers for LED and Micro LED technologies differ?

In mature LED production factors like costs of ownership plus technical drivers like LOP (light output) and forward voltage (Vf) have been dominant. For the emerging Micro LED however the focus is on other challenges right now at this relatively early stage:

- The much thinner structures make thickness uniformity across the wafer and repeatability from wafer to wafer and batch to batch critical.
- Structures typically two orders of magnitude smaller also necessitate even better control of particles to achieve the device yields that will be required.

Q. Do these drivers have implications for the types of thin film production platforms that will be needed for Micro LED?

The lowest particle levels and best process stabilites / repeatabilities demanded for Micro LED can only be achieved in automated load lock systems. Load lock technology keeping process chambers under vacuum continuously is the best way to maintain process stability and reduce particles in continuous production, while elimination of manual handling at the front-end further reduces particles, eliminates operator handling errors and enables prefect tracking of each and every wafer through the production process.

Q. What are the challenges for the different thin film processes in Micro LED?

Just like in conventional LED production, understanding the whole process chain is key. We know from many years experience working in close partneship with customers that the best results for overall device performance and yield come from optimizing individual processes as part of a package, but here in a nutshell are the processes where we can add value for our customers.

ITO deposition

For ITO deposition we need tools with two capabilities. The first is a process setup enabling low damage deposition on GaN or other active materials for the initial contact layer by keeping plasma discharge voltages low. The second is high rate deposition for the bulk layer to keep process times to a minimum and throughputs to maximum.

Long Evatec experience working with partners in the LED industry has already prepared us well for this using with several proven solutions already available on our CLUSTERLINE® 200 cassette to cassette platform using either "single (SPM)" or "batch (BPM)" process module technology according to customer fab requirements. Production experience enables us to support customers in developing processes tailoring film properties such as grain size, contact resistance or film roughness, while deposition uniformities < ±1% ensure the highest process yields. Some typical results showing how we can use process conditions to manage grain size and control thickness uniformity are illustrated in figures 1 and 2 respectively.

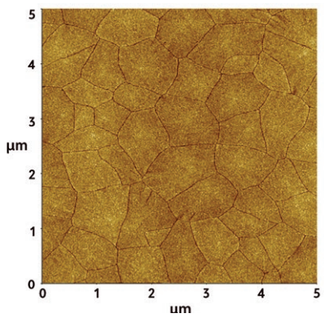


Figure 1a.
Film thickness: 30nm
Roughness: 0.164nm

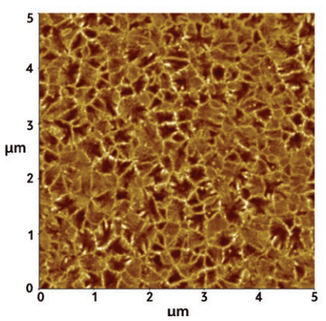
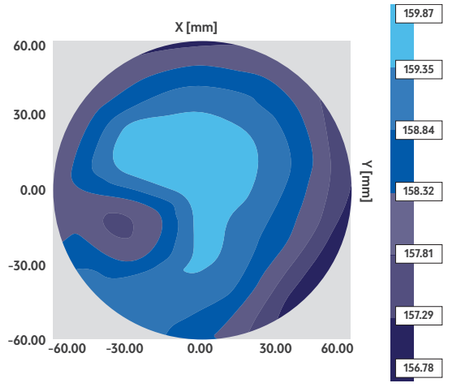


Figure 1b.
Film thickness: 80nm
Roughness: 2.205nm



Thickness / T1 (Å)			
Min	156.9249	AVG	158.4895
Max	159.7305	Unif	0.00886
			±0.89%

Figure 2: Low damage ITO with excellent thickness uniformity on 150mm wafers deposited on CLUSTERLINE® 200 BPM.

At this early stage of Micro LED technology development there remain several manufacturing approaches including "mass transfer" (Figure 3) and "monolithic" (Figure 4) but Evatec ITO know-how is able to support both with deposition of high transmission films across the complete visible spectrum as illiustrated in Figure 5.

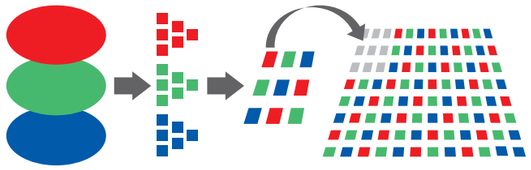


Figure 3: Mass transfer

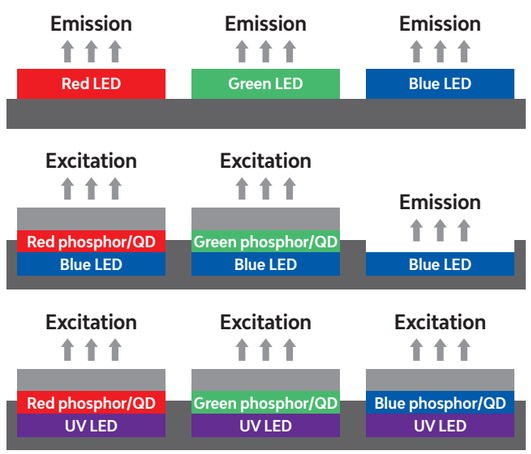


Figure 4. Monolithic

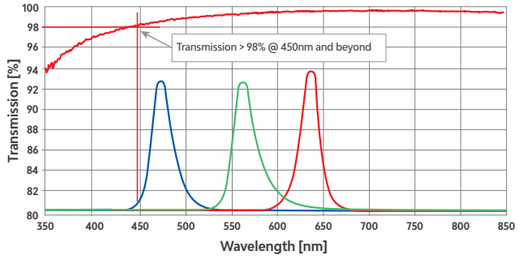


Figure 5: ITO films in the thickness range 20 - 110nm on sapphire show excellent transmission across the complete visible spectrum.

Typical layouts for production tools based on batch or single process module technology are shown below in figures 6 and 7.

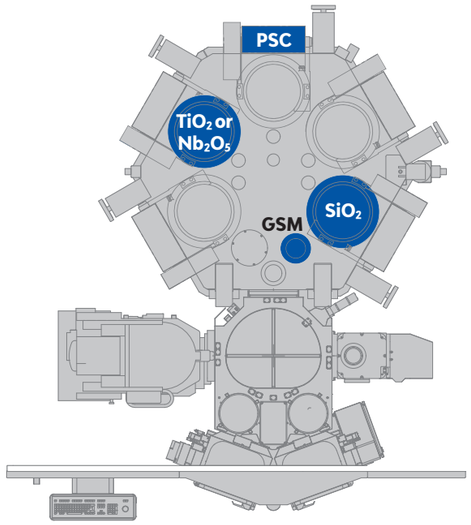


Figure 6: CLUSTERLINE® 200 BPM.

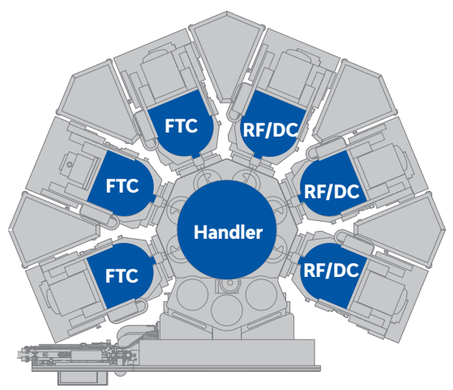


Figure 7: CLUSTERLINE® 200 equipped with proprietary FTC technology.

Contacts

Metals deposition by sputter is another area where we have long experience easily achieving the required uniformities of less than ± 1% over 6 or 8 inch substrates that will be required by Micro LED. Again our CLUSTERLINE® 200 platforms provide a flexible manufacturing solution for metals ideal for the Micro LED manufacturer.

Distributed Bragg Reflectors (DBRs)

Another challenge for the Micro LED manufacturer is the choice of process for the DBRs. Just like for conventional LEDs, Micro LED structures also require highly reflective DBRs working over a well defined spectral range. These stacks are complex and formed through deposition of many alternating layers of high and low refractive index materials. Until now the approach the LED industry has been split with some manufacturers continuing to adopt conventional evaporation technology to achieve the optical performance required. The drivers in Micro LED including extremely low particle counts may well drive manufacturers to sputter providing performance specifications like layer thickness uniformities, repeatabilities and optical performance can be achieved. Processes can be tailored according to the optical performance required. Figures 8 and 9 show layer performance for examples of production qualified DBR processes optimized for monolithic or mass transfer approaches on a CLUSTERLINE® 200 BPM tool.

In figure 8, a 29 layer stack provides the wide transmission bandwidth required for a monolithic process while in figure 9 the layer stack design is optimized for one color.

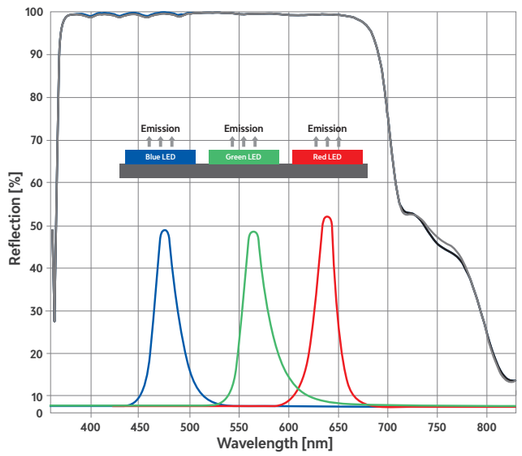


Figure 8: DBR design – 29 layer SiO_2/ TiO_2 (on Sapphire).

A view from Yole

Not just a new display technology: an opportunity to disrupt the supply chain. For many companies, interest in microLEDs lie beyond just the ability to offer the latest display technology. Intellectual property analyses indicate that Apple is planning to forgo thin film transistor (TFT) backplanes, opting instead for Si-CMOS microdrivers. The implications go far beyond a technological choice.

Apple's microLED supply chain would eliminate reliance on display makers, such as Samsung or LG. Apple can source microdrivers and microLED chips from foundry partners and assemble those components in-house or with other partners to create unique displays. Although it currently has more pressing battles to fight, the same logic applies to Huawei, with the possible added benefit of a 100% domestic display supply chain that does not rely on restricted US technology.

Availability of standard tools and processes enabled the commoditization of LCD and will soon do so for flexible red/green/blue (RGB) OLEDs. The lack of microLED process maturity and the proliferation of technology paths hinder the development of high-volume manufacturing tools as well as the supply chain.

For high volume consumer applications, economics drive die sizes to below 5µm with stringent yield requirements for which traditional LED fabs are not suited. A paradigm shift is required toward a semiconductor-like manufacturing mindset with high efficiency, automation, end-to-end defect prevention, and management strategies. This is creating an additional push toward the adoption of larger diameter substrates.

Going from 6" to 8" is especially desirable, as it gives access to battle-tested, retrofitted semiconductor equipment. This also increases the appeal of GaN-On-Si platforms, readily available in 8" and already looking toward 12".

OLED is the incumbent technology to beat. The cost of microLEDs must decrease by at least an order of magnitude to compete in the high-end segments. This is daunting, but there are challenging, yet credible, paths toward this goal. It is difficult, however, to produce a realistic scenario under which microLED becomes cheaper than OLED.

This raises the question: can microLED strongly differentiate from OLED?

Also, how much price elasticity should be expected? Each application has its own inflection point and, initially, its own supply chain enabled by a champion. Apple will lead on smartwatches and Samsung on TVs which, as manufacturing and technologies improve, will evolve smoothly from luxury, products costing more than $100,000 to high-end consumer devices. Apple has some unique challenges though. It is aiming at high volume consumer products that attract a high degree of scrutiny. From day one, everything must be perfect at every level of the supply chain, which must also be ready to produce high volumes from the day on which the switch is flipped. But there is no rush for Apple: as much as the technology itself, it is the supply chain disruption that could motivate the company.

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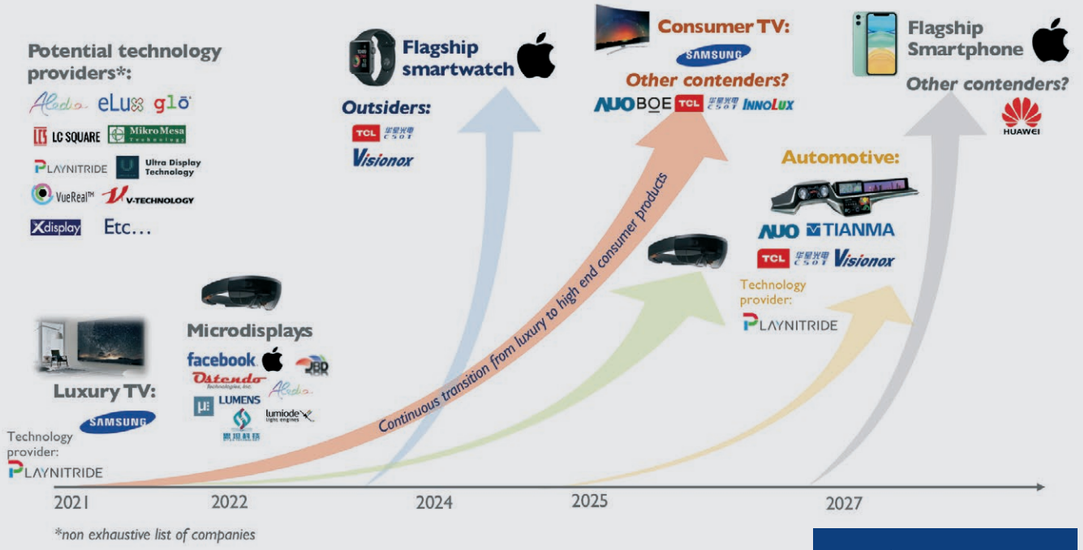
MicroLED adoption: enabling leaders and major inflection points for major applications

(Source: MicroLED Displays - Market, Industry and Technology Trends 2020 report. Yole Développement, 2020)



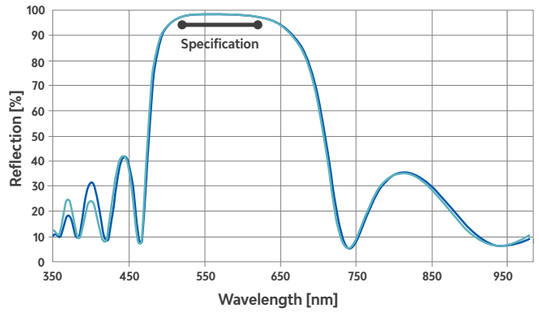


Figure 9: DBR – 10 Layer SiO_2/TiO_2 (on D263).

Q. The Micro LED market is in a ramp up phase at the moment. How can Evatec help customers be competitive during this time?

There are several ways we can help right now.

Flexible platforms like CLUSTERLINE® can be configured for multiple processes at the same time in this early phase. That means that our customers could even run all three processes (TCO, contact and DBRs) on a single tool right now for development, pre or low volume production to the lowest investment costs. As demand increases, further dedicated tools can then be added according to customer throughput requirements. Running all the processes on a single type of platform also makes sense from training, maintenance and production security perspectives.

Just as importantly however, Evatec process know-how across TCOs, contacts and DBRs can also help our customers fast track their own customized process development.

Q. How do you see demands from manufacturers developing in future?

We know that there will be a huge drive to reduce Micro LED manufacturing costs to enable market growth. Some industry experts have set ambituous targets of an overall 95% cost reduction over current levels by connecting the supply chain from wafer manufacture, chip process, transfer technology, display module, backplane driver and system tuning more effectively. Most of the processes already exist but need more integration in resource and technology. We at Evatec will also play our part to further improve CoO for essential processes like DBRs, TCOs and metal contacts by working closely with industry partners.

Q. Does process know-how for Micro LED also help in other emerging Optoelectronic emerging markets?

Yes, this is already helping us as we enable an even wider bandwidth of optoelectronic markets like UV LED and Mini LED.

GAME, SET AND MATCH?

Q. So is it really game set and match to sputter technology for Micro LED?

Sputter technology lends itself well to achieving the repeatabilities, uniformities and low particle levels essential for high yield Micro LED production. For TCOs and contacts the industry trend is clearly sputter. However, key technologies like optical monitoring ensuring the best optical performance combined with proprietary sputter technology and plasma emission monitoring for the maximizing uniformities and deposition rates respectively mean that that sputter can be an ideal choice for DBR in Micro LED too.