Hybrid DBRs – One process change brings two benefits for Micro LED production

Evatec Senior Product Marketing Manager ***Dr. Chongqi Yu*** talks about Evatec's latest process developments in Micro LED technology delivering both, 1 the lower cost of ownership and 2, the more compact structures that will help drive growth of mass market applications exploiting the benefits of Micro LED technology.

Micro LED – The benefits are clear

The performance advantages of emerging Micro LED including excellent brightness, contrast, and viewing angle are already well documented (Figure 1), but that doesn't mean we don't need to support our partners around the globe with process innovations that enable the introduction of the technology across mass market applications including Augmented Reality in 2025 and beyond.

Micro LED technology and production trends reported by both leading players in the industry and confirmed by analysts like Yole Group are calling for both smaller and smaller device sizes and the lowering of manufacturing costs. Production on larger wafer sizes is just one aspect driving down manufacturing costs but the introduction of so called "Hybrid DBR" process technology is an exciting next step with double benefits, on one hand enabling thinner structure / total device thickness and on the other reducing the normal process times for DBR deposition.

"Hybrid DBR processes – Increasing wafer throughput by 50% and reducing the total thickness by half"

MicroLED vs. OLED and LCD

	LCDs	OLEDs	MicroLEDs
Energy consumption	Medium	Medium	Medium to Low
Pixel density	Up to 1000 PPI	Up to 4,000 PPI (RGB for micordisplays)	> to 20,00 PPI monochrome demonstrated >4,500 PPI RGB demonstrated
Brightness	High (3000 nits peak on commercial TV)	Lowest [1]	Highest (up to 10^6cd/m^2 for microdisplays)
Contrast	Low to medium	High (true black)	Very high (true black + high brightness)
Color gamut	Wide with QDs	Wide with filters, resonant cavities	Wide (better with QD color conversions)
Lifetime	Good	Medium	Best
Environmental stability	Good	Medium with appropriate encapsulation	Best
Operating temperature	-40ºC to 100ºC	-30ºC to 85ºC	-100ºC to 120ºC
Switching speed	Low - ms	High - µs	Very high - ns
Viewing angles	Low to medium	Medium to high	High
Flexibility	Low	High	Medium
Maturity	High	Medium	Low
Cost	Low	Medium	High (2022)

Figure 1: Comparison of competing display technologies in consumer applications (Courtesy of Yole Group)

DBRs – Choosing the right thin film production platform architecture as a starting point

Process yield is also one of the significant drivers in driving down manufacturing costs, and that means using fully automated cassette-to-cassette processing for the lowest particle levels. But that's not the end of the story, the growing demand for sputter technology, with its higher film densities and process stability offers the potential for the best process repeatabilities.

Evatec's CLUSTERLINE® 200 BPM is already established as an industry standard sputter solution in the LED business for deposition of low damage TCOs and now its time to use the latest hybrid DBR process solutions for driving down manufacturing costs and thinning down the total layer thickness for high performance reflector layers too. A typical tool layout for Hybrid DBR processes is shown in Figure 2.

Hybrid DBRs – More throughput and thinner total thickness without compromize in optical performance

Hybrid DBR process technology delivers the required optical performance by combining a dielectric stack with a metal layer on either front or backside according to the Micro LED manufacturers preferred architecture. Less layers means shorter process times, higher throughputs and smaller scale device architectures. The typical RGB optical performance for Hybrid DBRs combining traditional dielectric stack with a silver layer is show in Figure 3.

In Figure 4 we see a comparison of overall stack thickness, process time and throughput for hybrid vs traditional sputtered DBRs on Evatec's CLUSTERLINE® 200 BPM configured for 8 inch processing. Throughput can typical be enhanced by 50% or more across all colours on 6 or 8 inch processing, and the total layer thickness of the mirror can be reduced by 50%. The results reported in Figure 4 are for hybrid DBRs utilizing silver, but for those customers preferring aluminium we can offer process solutions too – all you need to do is ask!

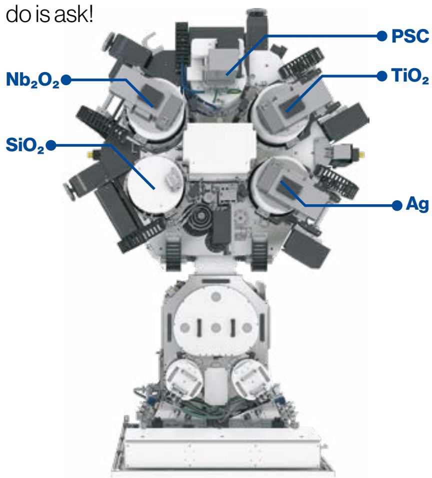


Figure 2: CLUSTERLINE® 200 BPM equipped with up to 5 process modules for depositon or etch or optical thin films with advanced process control technologies including broad band optical monitoring and plasma emission monitoring.

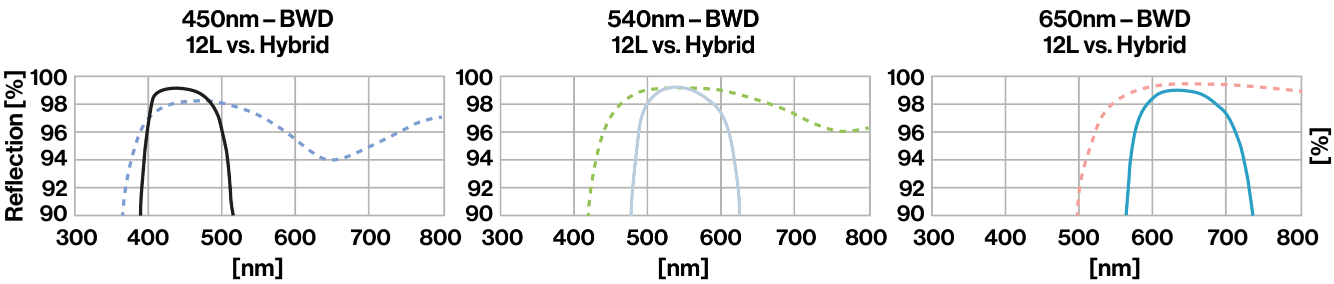


Figure 3: Optical performance of Hybrid stacks (- - -) for blue, green and red vs traditional DBRs (—)

	Blue – 450nm		Green – 540nm		Red – 650nm	
	12L	Hybrid 5L	12L	Hybrid 5L	12L	Hybrid 5L
End layer	SiO_2	Ag incl. Capping	SiO_2	Ag incl. Capping	SiO_2	Ag incl. Capping
Number of dielectric DBR layers	12	4	12	4	12	4
Total thickness (including Capping)	797.4 nm	529.8 nm	987.3 nm	586.96 nm	1177.2 nm	622.02 nm
Process time (tool time w/o handling) + Ag Capping	01:11:23	00:38:32	01:20:53	00:41:33	01:30:43	00:43:10
Resuts Sputtering on D263						
Max Reflectivity @nm	99.33% @ 437nm	98.90% @ 461nm	98.99% @539nm	99.30% @ 552nm	98.77 @ 637nm	99.54% @ 664nm
Reflectivity @nm – (Bwd)	99.23%	98.85%	98.96%	99.26%	98.65%	99.50%
Range of Reflectivity	>98% @ 405-483nm >99% @ 417-463nm	>98% @ 399-554nm	>98.8% @ 517-556nm	>99% @ 487-622nm	>98% @ 597-678nm	>99% @ 553-819nm
Stopband width	78nm @98% 46nm @99%	155nm @98%	39nm @99%	135nm @99%	81nm @98%	266nm @99%
Throughput 8"						
Substrates / h	9.1	13.7	8.2	13.1	7.5	12.6
Substrates / month (48 weeks/y, 85% uptime)	5198	7825	4684	7483	4284	7197
Throughput 6"						
Substrates / h	12.1	17.6	11	16.9	10	16.4
Substrates / month (48 weeks/y, 85% uptime)	6912	10053	6283	9653	5712	9368

Figure 4: Comparison of throughput for standard vs hybrid DBR

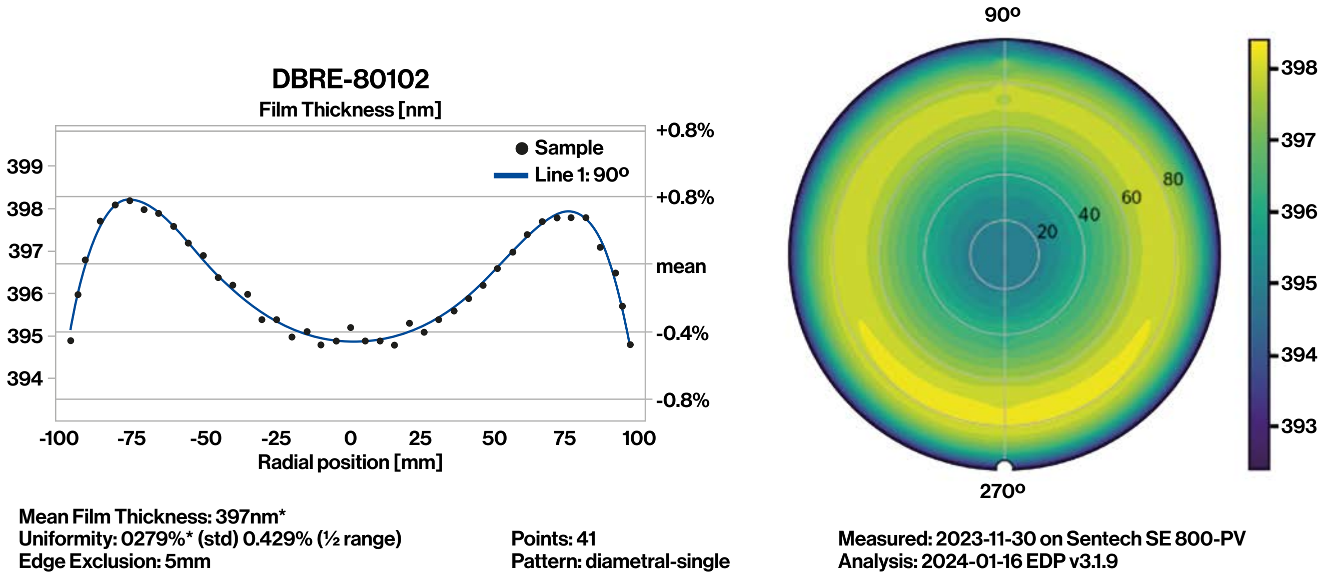


Figure 5: Deposition uniformity of SiO_2 on CLUSTERLINE® 200 BPM < ± 0.5% over 8 inch.

Base system performance is key

The benefits of reduced process times, high deposition rates and enhanced throughput can only be achieved if base system performance including deposition uniformities and run to run process repeatability meet the required Micro LED standards. CLUSTERLINE® 200 BPM uses advanced process control (APC) technologies including in-situ broadband optical monitoring (GSM) of the substrate itself plus plasma emission monitoring (PEM) combined with dynamic sputter architecture without shapers to deliver the levels of process control required.

Figure 5 illustrates typical film thickness uniformity for deposition of dielectrics of better than ± 0.5% on 8 inch.

Figure 6a shows typical wafer in wafer, wafer to wafer and run to run repeatabilities on 6 inch of less than ± 0.6%. Figure 6b shows optical performance repeatability.

Material	Layer thickness	Thickness uniformity $U(Max\ Min)\ [\pm\%] = \frac{(Max - Min)}{2 \cdot Avg} \cdot 100$		
		WiW	WtW	RTR
SiO_2*	300nm	<±0.5%	<±0.5%	<±0.5%
Nb_2O_5*	300nm	<±0.5%	<±0.5%	<±0.5%
TiO_2*	300nm	<±0.5%	<±0.5%	<±0.5%

*with rotating Chuck, PEM & GSM

Figure 6a: Deposition uniformity achievements for single layers on 6" substrates

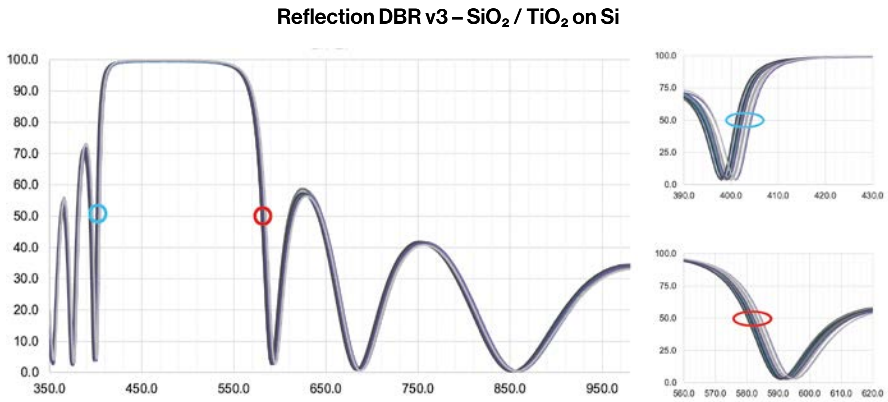


Figure 6b: Optical performance repeatability

How can we help you?

Every manufacturer has different device architectures and therefore requirements. Our LED process specialists are here to help not just with DBR solutions but also with metals and TCOs too.
Contact your local Evatec sales and service office to find out more.

A view from Yole Group

As OLED keeps improving, Apple's withdrawal increases sense of urgency for MicroLED commercialization

Apple created the MicroLED industry when it acquired startup Luxvue in 2014. It then spent ten years and $3 billion developing the technology. If it hadn't been for that keen interest, the enthusiasm since shown in MicroLED by most OEMs and display makers would have been much more subdued.

Osram completed a $1.3 billion 200 mm MicroLED fab to meet Apple's needs, and an Apple watch was scheduled for release in 2026. But in February 2024, Apple canceled the project, sending shockwaves into the industry and seriously undermining its prospects. Two years ago, this could have been the death of MicroLED. However, Yole Group believes it has now gained sufficient momentum of its own to keep going.

Exiting 2023, the industry had spent $12 billion in MicroLED directly and another $2 billion in M&As. About 40% of that total is related to Apple. Yet, other players have spent $7 billion non-related to Apple's efforts. MicroLED remains critical for the long-term strategies of Taiwanese companies such as AUO. The ecosystem is strengthening further, and MicroLEDs had a strong showing at the recent Touch Taiwan and Display Week industry events.

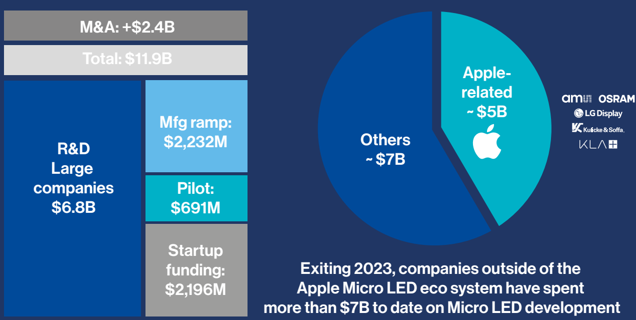
To succeed, MicroLED must reach a similar cost structure to OLED while delivering strong performance differentiation. With Apple gone, MicroLED will focus on applications with clear differentiation against OLED: AR, automotive, and various specialty applications such as transparent displays. Smartwatch forecasts are cut drastically but remain the low-hanging fruit for MicroLED in terms of consumer applications. AUO started shipping small volumes for luxury watches.

Despite Apple's project cancellation, there's still good momentum, but also a sense of urgency to accelerate commercialization. With Apple gone, the central question is how to incubate the industry. Can low-volume smartwatches, automotive, and various niche applications bootstrap the industry to achieve the economies of scale required to enable higher-volume consumer applications? This is reminiscent of OLED's situation until 2007, when Samsung bit the bullet and built the first AM-OLED fab, at a time when benefits compared to LCD were still very questionable. That's what the industry was hoping Apple would do for MicroLEDs.

The next 18 months will be critical. Will Samsung remain committed to MicroLED TVs? Can other champions emerge? For now, the industry's center of gravity has shifted toward Taiwan, but China could once again surprise us.

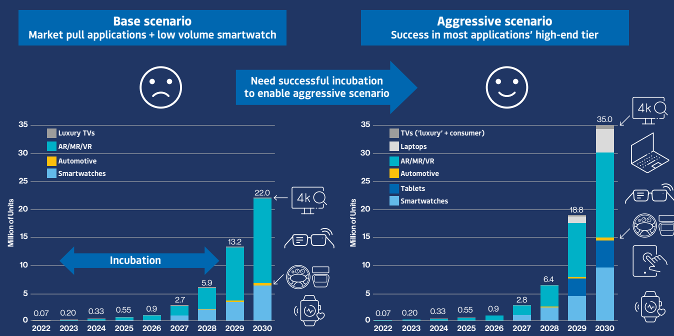
Micro LED development and industrialization effort

Source: Micro LED 2023 report, Yole Intelligence – June 2024 update



Consumer MicroLED volume forecast - intermediate 2024 analysis

Source: MicroLED 2023 report, Yole Intelligence – June 2024 update



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About the author

As Principal Analyst, Display at Yole Group, **Eric Virey, Ph.D.**, is a daily contributor to the development of LED, OLED, and display activities. He has authored an extensive collection of market and technology products as well as multiple custom consulting projects on subjects including business strategy, identification of investments or acquisition targets, due diligence in buying and selling, market and technology analyses, cost modeling, and technology scouting. Thanks to his deep knowledge of the LED/OLED and display industries, Eric has spoken at more than thirty industry conferences worldwide over the last five years. He has been interviewed and quoted by leading media all over the world. Eric Virey holds a Ph.D. in Optoelectronics from the National Polytechnic Institute of Grenoble.