LED OR LASER – EVATEC HAS THE SOLUTION!

As the VCSEL (Vertical Cavity Self Emitting Laser) market booms due to their emerging use in 3D sensing applications for mobile phones, Evatec's Head of BU Optoelectronics **Dr. Stefan Seifried** explains how Evatec can help VCSEL manufacturers ramp up production leveraging its know how from LED.

The VCSEL market will explode

VCSEL technology may not be new, the first components were commercialised by Honeywell over 20 years ago in 1996, but the introduction of VCSEL technology in mobile applications in 2017 looks set to drive a 10 fold increase in demand over the next 5 or 6 years.

Relative to technologies like LED, VCSEL offers coherent, symmetrical, low divergence optical beam technology (typically 15 degrees) giving it a high degree of usable optical emission as a semiconductor optical source. Just like LEDs however It offers a high efficiency around 20% but its planar structure with vertical emission means it can be tested during wafer processing before sawing and building higher level assemblies. (see table 1 & 2) Some analysts such as Yole expect that the upcoming demand for consumer devices including front side for face recognition and rear side for 3D simulation applications for clothing / furniture plus applications like LiDAR could lead to growth of market volumes to US$ 3500 Million by 2023.

Attribute	Symbol	Units	SM VCSEL	MM VCSEL	EE Laser	LED
Electrical power	Pelec	mW	5	20	60	60
Optical power	Popt	mW	1	5	10	1
Efficiency at Popt=1mW	h	%	20	10	10	2*
Wavelength	l	nm	760 - 860	670 - 870	630 - 1300	400 - 1300
Spectral width	Δλ	nm	0.01	0.5	2	50
Spectral tuning (Temperature)	Δλ / ΔT	nm/°C	0.06	0.06	0.3	0.3
Spectral tuning (Current)	Δλ / ΔI	mm/mA	0.25	0.09		
Beam angle (full width at half of maximum value)	∠	°	<15	~ 15	15 par. 35 prpe	120

Table 1: Comparison of performance (Courtesy of Finisar)

The "ilities" of VCSEL						
Manufacturability	**Integrability**	**Reliability**	**Testability**	**Arrayability**	**Packageability**	**Low power consumption**
All-vertical construction enables the use of traditional semiconductor manufacturing equipment	Compatible with semiconductor manufacturing and wafer integration of the emitters with detectors and circuitry	Without the failure modes of traditional laser structures such as dark line defects and catastrophic optical damage; very long wearout life	Complete testing and burn-in in wafer form	VCSELs can be easily fabricated into one or two dimensional arrays	VCSELs allow use of traditional low cost LED packaging; chip on board technology for VCSEL-based sensors	Not strictly an "ilitiy" – extends battery life and reduces thermal design constraints in larger equipment systems

Table 2: (Courtesy of Finisar)

Using the experience from LED

Evatec has over 10 years experience in supporting the worlds leading LED manufacturers with sputter and evaporation processes. On one hand we could help them increase device performance by improving light output and other LED device properties, but on the other hand we also helped them implement processes driving down costs. ITO production on our CLUSTERLINE® RAD (CLN RAD) as well as "lift off" processes on BAK evaporator family are now LED industry standard. Sharing their device requirements, the real device performance data achieved and their new ideas, they worked together with Evatec optimizing processes to create a successful LED business, irrespective if it was a more cost-driven LED commodity-product for the lighting industry or a high power LED device for an automotive application.

Just like in LED, the explosion in demand for VCSEL will now set manufacturers the same challenges in driving up device performance, improving manufacturing yields, and lowering production costs.

"The VCSEL market - growing by a factor 10 over the next 6 years"

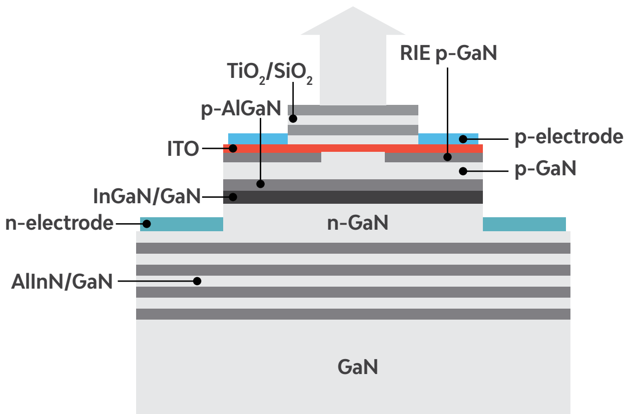
Applying VCSEL to 3D sensing applications

A time of flight (TOF) sensor in a typical mobile phone first illuminates an object in front of the phone repeatedly at a very high rate, measuring the time taken for light to reflect or scatter back to a detector. If the TOF sensor detects an object, it triggers a True Depth camera to take a picture. If that reveals a face, the phone activates its dot projector, shining a single infrared VCSEL through an optical system to create 30,000 spots while its infrared camera captures an image. It sends both regular and spottily illuminated IR face images to an application-processing unit (APU) that can recognise the owner and therefore unlock the phone.*

Just like in LED technology, the VCSELs for NIR laser diodes used for mass production of 3D sensing and other applications use cost-optimised device designs. There are a wide range of VCSEL applications and designs on different substrate materials including silicon, aluminum oxide or GaN with specific power levels and ranges of wavelengths as shown below.

Typical VCSEL designs and operating wavelengths
AlGaInP/AlGaAs for Red wavelength (650-680nm) VCSELs
GaInAsP/AlGaAs for Near-IR wavelength (780-850nm) VCSELs
AlGaInAs for wavelength 850nm VCSELs
GaInAs for Long-wavelength (I .3-I.55µm) VCSELs
Sb for Long-wavelength (I.3- I.55µm) VCSELs
III-V Nitride for Visible wavelength VCSELs

Typical VCSEL structure



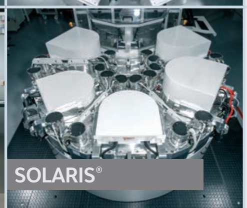
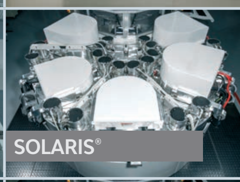
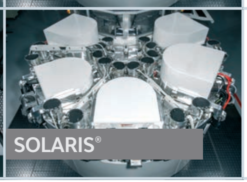
* Source: SPIE Newsroom, April 2018

Evatec production solutions are ready

Evatec's equipment and process portfolio

Whatever the VCSEL design, many of the thin film layers required are similar to those required for LED, and Evatec's equipment and process portfolio for VCSEL manufacturing covers all material types dependent on the device structure.

For metals	n/p contact electrodes with BAK lift-off evaporators.
For surface metals	e.g. TIW – Au sputtering in our dynamic CLUSTERLINE® RAD or static in our Semiconductor production proven CLUSTERLINE® 200 (CLN 200) depending on maximum temperature and step coverage requirements.
For TCOs	Typically ITO we can use either the damage-free ITO process on our CLUSTERLINE® RAD or the widely proven ITO process of our high-speed SOLARIS® system. For future high throughput / low damage requirements a combination of Facing Target Cathode (FTC) process for contact and fast sputter process for bulk layer is ready.
For the optical mirror layer stacks	We can deliver different options depending on the number of pairs forming the DBR stack. Above 20 pairs (e.g. NbO_2 / SiO_2) the CLUSTERLINE® RAD with high uniformity deposition of typically < 0.25% and in-situ process control features for optical thickness (GSM) and the plasma emission monitoring to control deposition rate and film stoichiometry would be beneficial, while for less complex optical interference coatings (OIC) our SOLARIS® would provide significant cost of ownership advantages thanks to higher throughput.
Other custom layers	The portfolio can be concluded with additional applications for anti-reflective and/or passivation layers using sputtering or PECVD or additional metals e.g. heat sinks.

Application	PVD Equipment			Process
Contact Metals Lift-off: n/p-contact **Surface Metal** TiW-Au sputter				**BAK: Evap lift-off** n-contact: Ti-Pd-Au-Ge P-contact: Ti-Pd-Ti-Au-Sn **CLN 200 / CLN RAD** Etch - TiW - Au seed
Dielectric DBR Top - DBR				**CLN RAD, MSP, SOLARIS®, Top DBR** TiO_2 / SiO_2 Ta_2O_5 / SiO_2 NbO_2 / SiO_2 a-Si / SiO_2
ITO damage-free ITO ITO				**CLN RAD / SOLARIS®** ITO, damage-free ITO
Dieletrics SiN PECVD pass SiO_2 PECVD/PVD Diamond, heat sink SiN AR				**CLN 200 / SOLARIS®** SiO_2 PECVD SiN AR, Diamond

Get off to a quick start

Our applications team is ready to help you with a production solution that's tailor made for you according to substrate size, process and throughput. Our processes are available for fully automated cassette-to-cassette operation and with proven particle performance. Minimizing human interactions enables high-yield mass production of either discrete VCSELs or as part of more highly integrated devices.