INDUSTRY TRENDS: OPTOELECTRONICS

We are only scratching the surface of potential of optoelectronics

Over the past 20 years, the strong growth in optoelectronics has been fueled by different technologies at different times. Laser diodes for high-speed optical networks were a major growth driver before the "dot.com" implosion in 2001. PV[1], image sensors and LED[2] devices then became star performers through the 2000s, followed by OLED[3] and Quantum Dots in the 2010s.

More recently, there has been a lot of hype on Micro LED, VCSEL[4] or 3D sensing / imaging technologies, and silicon photonics remains a good example of a booming trend in this domain.

Optoelectronic technologies are mostly driven by integration into industrial, automotive and consumer products (e.g.: smartphones, VR/AR[5] headsets...) as enabling intelligent next-generation systems. Typical examples include VCSEL technology at the heart of Apple's iPhone X FaceID function, matrix LED systems enabling intelligent glare-free lighting functions in recent car models, EELs[6] representing key enabling technologies for LiDAR and so to autonomous driving while OLEDs[7] and QDs[8] are now at the heart of the display industry.

We are, therefore, only scratching the potential of optoelectronic technologies and related market opportunities. Already a multi-billion-dollar industry at the component level, the optoelectronic business will continue to grow strongly in the next decade as long as already established technologies (e.g. LED, PV) continue to increase their penetration rate, and disruptive technologies / systems (e.g.: 3D sensors / imagers) are developed.

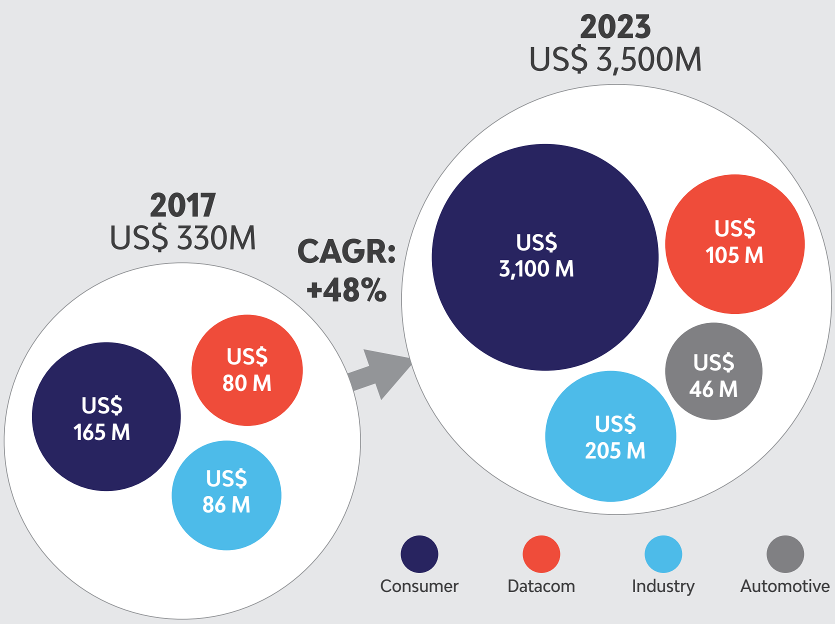
Although VCSELs have existed for 20+ years, mainly for short-distance data communications (e.g. datacenters), they were relatively unknown until Apple used three of them in the iPhone X to enable its 3D sensing and facial recognition functions.

This move from the smartphone giant subsequently generated huge interest in the technology from other smartphone manufacturers as well as all other players across the supply chain. Less than one year after the release of Apple's flagship, its competitors are following the trend and starting to integrate 3D sensing technologies. Xiaomi and Oppo were the quickest on the draw but other leading players like Huawei, Vivo and Samsung are also expected to integrate VCSELs into their next flagship models. For this reason, the explosive increase in demand for VCSELs, which started in 2017, will persist for the next five years, potentially multiplying the business opportunity more than tenfold: from US$330 million in 2017 to nearly US$3,500 million in 2023[9].

At the industry supply level, VCSEL integration into smartphones increased tension throughout the supply chain - partly because Apple's iPhone used a large portion of its suppliers' existing capacity, and also because new business opportunities were emerging practically overnight for players at all points of the supply chain. As a result, leading VCSEL

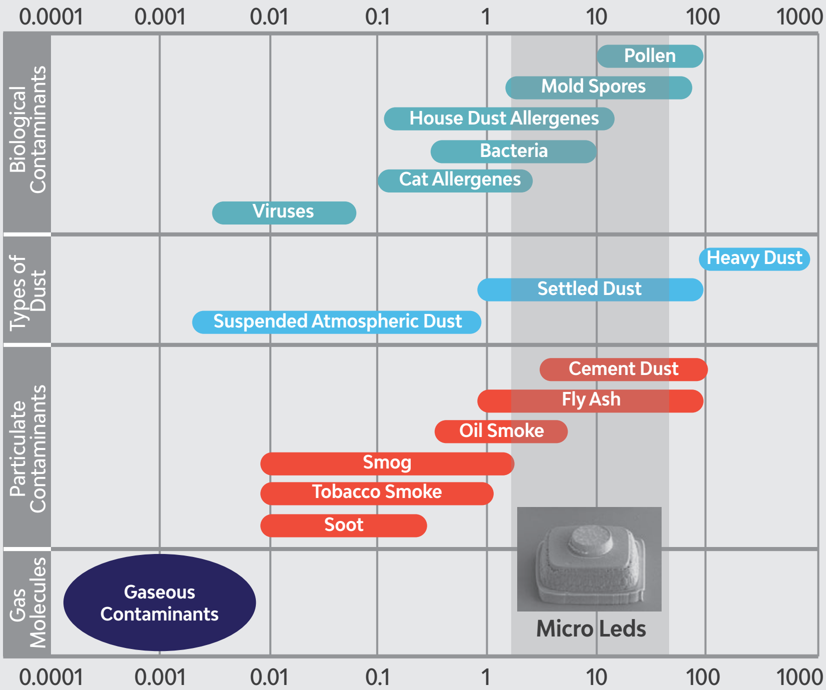
VCSEL market forecast by segment

Source: VCSELs – Technology, industry and market trends report, Yole Développement, 2018



MicroLED are Small!

Source: SID 2018 Symposium Speaker: Eric Virey from Yole Développement



Comparison of µLED dimensions vs. atmospheric particles

Background graph: Wikipedia, concept courtesy of Allos Semiconductor

manufacturers are moving from datacoms to the consumer market, and several new entrants are trying to get their piece of the cake. But VCSEL manufacturing for consumer applications is complex and there is a lengthy period of process optimisation between R&D and production. Recently, there were several M&As in this field (e.g. II-VI, ams, Osram) and Yole Développement anticipates more in the coming years as it seems to be only the beginning of the success story for the technology.

In a parallel development, micro LEDs for display applications also play a significant role in the optoelectronic industry today. MicroLED displays could potentially match or even exceed OLED performance in all critical attributes such as brightness, contrast, color gamut, refresh rate, viewing angle, ruggedness and durability, lifetime, efficiency etc.

Excitement about this technology grew in 2014 after Apple acquired Luxvue, the microLED display startup. Since then, many large consumer electronics and semiconductor companies such as Facebook-Oculus, Google, Sharp-Foxconn, Samsung, LG, Intel, etc., have entered the field. More than 120 companies or research organizations have already filed about 1500 patents in more than 500 patent families.

The technology is inherently complex. Just like OLED, micro LED is a self-emissive display: each subpixel is an independently controllable light source. However, unlike OLED, there are no technologies allowing the deposition of blanket LED layers over large area substrates (up to 5.5 m^2 in the case of OLED Generation 8.5 fab, and soon 9.9 m^2 on upcoming Generation 10.5!).

LED emitters are grown by traditional semiconductor technologies on 4 to 8" wafers and the art of making a micro LED display consists of patterning and singulating tiny LED emitters (less than 10 or even 5 µm for most consumer applications) and assembling them on a backplane which incorporates the circuitry to drive individual subpixels.

To put this in perspective, for a 4K display (3,840 x 2,160 resolution), this implies assembling and connecting 25 million microLED chips, each the size of a bacterium, with a placement accuracy of 1 µm or less.

This technology is nevertheless progressing on all fronts and the emergence of microLED consumer displays appears increasingly realistic. There are challenging but credible cost-reduction paths for both TVs and smartphones toward levels compatible with penetration in high-end market segments, in competition with OLED. Small panels for smartwatches and microdisplays for Augmented Reality and Head Up Displays could be the first commercial applications, with smartphones and TVs to follow.

1. *PV : Photovoltaic*
2. *LED : Light Emitting Diode*
3. *OLED: Organic LED*
4. *VCSEL: Vertical Cavity Surface Emitting Laser*
5. *AR/VR : Augmented Reality/Virtual Reality*
6. *EEL : Edge Emitting Lasers*
7. *OLED : Organic LED*
8. *QD : Quantum Dot*
9. *Source : VCSELs - Technology, Industry and Market Trends report, Yole Développement, 2018*

Since 2015, **Pars Mukish** has taken on responsibility for developing SSL and display activities as Business Unit Manager at Yole Développement where he is a member of the Photonics, Sensing & Display division. Previously, Pars worked for several years as Marketing Analyst and Techno-Economic Analyst at the CEA (French Research Center).

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