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ISSN 1752-2935 (online)

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Vol. 16 • Issue 9 • November/December 2021 www.semiconductor-today.com

Silicon shortage constraining compound semi demand

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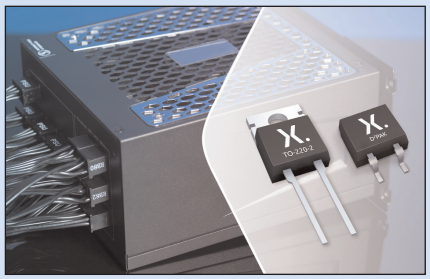
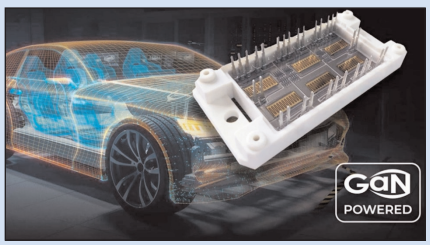
Vol. 16 • Issue 9 • Nov/Dec 2021



p22 Nexperia has entered the high-power SiC diode market with its new 650V, 10A SiC Schottky diodes.



p32 GaN Systems has announced a strategic partnership with USI — a subsidiary of Taiwan's ASE Technology — to co-develop GaN power modules for the EV market.

p56 The IOP Katharine Burr Blodgett Medal has been awarded to Brian Corbett, a researcher at Ireland's Tyndall National Institute and at IPIC, the Science Foundation Ireland (SFI) Research Centre for Photonics.

Cover: III-V Epi exhibited its MBE and MOCVD epitaxial manufacturing services at November's UK National Quantum Technologies Showcase 2021 in London. III-V Epi is also involved with the project SHARK-VECSELs (Supply cHAin for stRontium clocK Vertical External-Cavity Surface-Emitting Lasers) **p63**

editorial

Silicon shortages constrain compounds

Due to lower-than-expected third-quarter 2021 smartphone shipments and continued component shortages and logistical challenges (which may not improve until mid-2022), IDC has lowered its full-year smartphone shipment growth forecasts for 2021 from 7.4% to 5.3% and for 2022 from 3.4% to 3%, respectively (see page 10).

"The market declined by almost twice the projected rate as the supply chain and logistical challenges hit every major player in the market. Moreover, the shortage is more heavily concentrated on 4G components than 5G, which will impact vendors with a higher portfolio mix of 4G devices than vendors with a higher proportion of 5G models," says IDC.

"There have been significant shortages of components including 4G SoCs, low-end 5G SoCs, display panel driver ICs, etc," notes TrendForce (see page 11). "The persistent component gaps are constraining smartphone brands from raising device production for second-half 2021," the firm adds.

"This is expected to accelerate the jump to 5G, which is now forecast to be almost 60% of worldwide shipments by this time next year," says IDC.

Due to the continued growth of higher-RF-content 5G smartphones, RF component suppliers Qorvo and Skyworks both reported record quarterly revenue and earnings in Q3/2021 (pages 12–14, 16–17). "The RF content increase in mass-market phones is now greater on a percent basis than in flagship devices," says Qorvo. This was despite supply chain disruptions that worsened through the quarter, particularly in mid to late September.

"Our external supply chain is still recovering from disruptions in September," notes Qorvo's chief financial officer Mark Murphy. "Beyond that, select materials, products and production capacity remain tight," he adds. "These are industry-wide issues affecting all suppliers, and our customers are challenged in producing matched sets for products. In smartphones, even where channel inventory for certain parts is healthy, customers lack silicon chips to produce phones. This in turn creates changes in demand that add to constraints on our own production as we work to adjust mix."

For the December quarter, Qorvo now says that revenue will fall a more-than-expected 12% sequentially, due to (i) suppliers not having supply for Qorvo, or (ii) Qorvo's customers not having the chipsets and not being able to build their product and use its product, or (iii) Qorvo's own internal constraint.

Due to the softening demand in the smartphone supply chain, epiwafer & substrate maker IQE forecasts Q4/2021 revenue down sequentially, and full-year revenue down 8%, even on a constant-currency basis (see page 44). However, it expects these effects to be temporary.

In optical component manufacturing, Lumentum's September-quarter revenue saw a greater-than-expected $30m impact of semiconductor shortages in its Telecom and Datacom product lines. For the December quarter, Lumentum expects revenue to rebound due to a recovery in semiconductor supply. However, this will still be outstripped by the more rapid rise in demand, with over $40m of orders going unfulfilled (page 67).

Qorvo's Murphy expects supply effects to moderate this quarter, followed by improved supply–demand alignment in early 2022. In the March quarter, revenue for the firm's Mobile Product group should be up slightly sequentially, as a typical seasonal decline is offset by improved supply and demand.

"Despite near-term supply challenges, we are seeing a favourable demand environment that we expect will continue throughout fiscal 2022," concludes Lumentum's president & CEO Alan Lowe.

Mark Telford, Editor

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Original design Paul Johnson
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***Semiconductor Today* (ISSN 1752-2935) is published free of subscription charge** in a digital format 10 times per year by Juno Publishing and Media Solutions Ltd, Suite no. 133, 20 Winchcombe Street, Cheltenham GL52 2LY, UK. See: www.semiconductor-today.com/subscribe.htm

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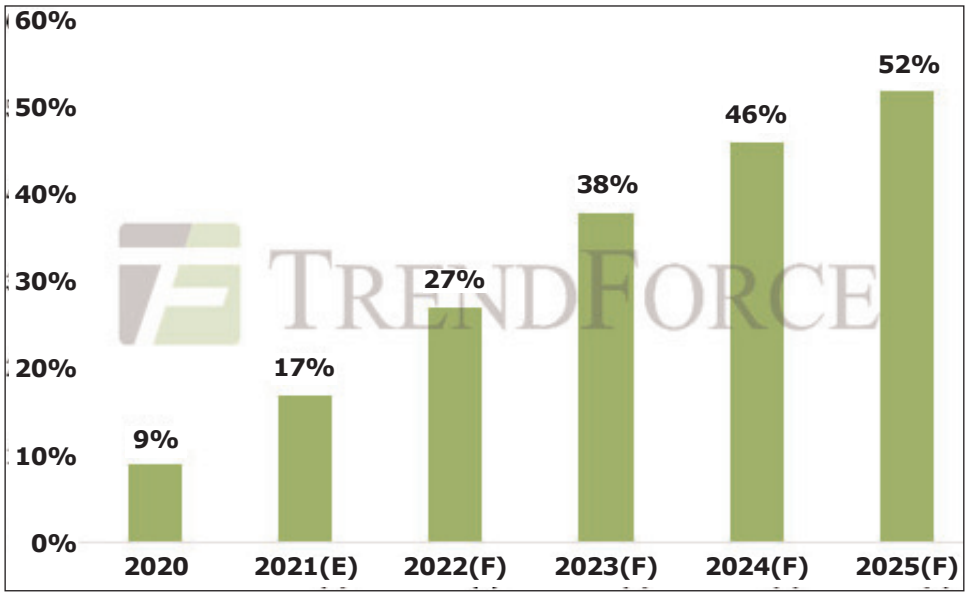
Gallium nitride to surpass 50% penetration in fast-charge market in 2025

Existing 62% penetration in fast-growing 100+Watt category driving adoption

Apple recently unveiled its 140W MagSafe charger for the new MacBook Pro, marking the first time that Apple has adopted gallium nitride (GaN) technology. As such, 100+ Watt fast charge products have thus entered a period of growth, in turn accelerating the adoption of 'third-generation' (wide-bandgap) semiconductor devices in consumer applications, according to market research firm TrendForce. While GaN power transistor prices have dropped to nearly $1 now, and GaN fast charge technologies continue to mature, TrendForce expects GaN solutions to reach a 52% penetration rate in the fast charge market in 2025.

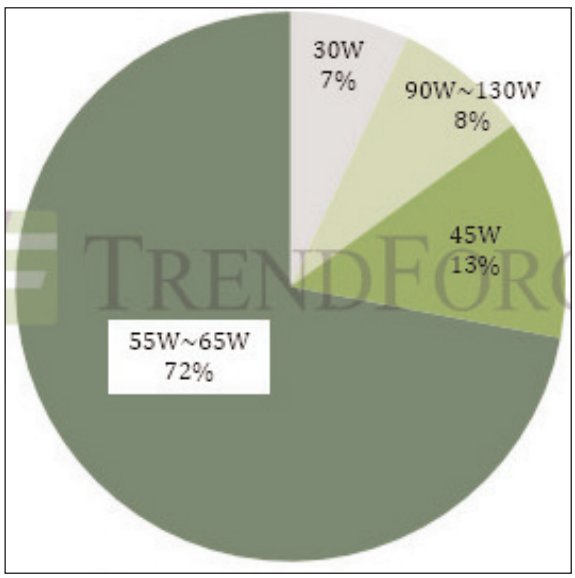
TrendForce also says that in 2020, GaN fast chargers with 55W–65W of peak power accounted for 72% of all GaN fast charger sales (with 65W being the mainstream), whereas those with peak power of 100W or more accounted for only 8%. Even so, the outlook for these high-power fast chargers appears relatively promising, as more and more companies release their own high-power fast chargers in response to consumers' increasing energy consumption demand. Fast chargers with a peak power of 140W are the most powerful solution currently available.

Within the 100+Watt product category, GaN fast chargers have reached a penetration rate of 62%. These chargers are primarily supplied by Navitas and Innoscience. With a market share of more than 70%, Navitas' GaN chips are used in products from Baseus, Lenovo and Sharge, among others. On the other hand, PFC+LLC combo controllers have become the mainstream solution for 100+Watt fast chargers, as these controllers allow for higher efficiency and smaller physical dimensions. The combination of silicon carbide (SiC) diodes and GaN switches results in increased PFC (power factor correction) frequency. As such, major manufacturers have quickly adopted the GaN+SiC wide-bandgap semiconductor combo for their fast chargers.



Forecasted penetration rate of GaN solutions in the fast-charger market.

For example, Baseus released the world's first 120W GaN (supplied by Navitas) + SiC (supplied by APS) fast charger in 2020 and saw excellent reception from the market. SiC power device suppliers, including Global Power Technology, Maplesemi and onsemi, have also been ramping up their shipments to power delivery (PD) fast-charger manufacturers. Notably, the fast charge interface has gradually become a standard feature in cars. In light of the rise of the high-power in-car charging market, the power consumption and maximum battery capacity of electronic products will propel the widespread application of third-generation semiconductors, including GaN and SiC, going forward, concludes TrendForce.



Market share (by sales volume, 2020) of various wattages of GaN fast chargers.

www.trendforce.com

Shipment of notebooks with mini-LED backlighting to reach 5 million in 2022

Forecast for 2021 cut to 1.65 million after Apple's delayed launch of high-end MacBook Pro

Apple recently unveiled its newest lineup of 14.2-inch and 16.2-inch MacBook Pros, which represent its latest effort to extend its application of display backlights with mini-LED technology from the 12.9-inch iPad Pro to the MacBook Pro range. In light of Apple's foray into the high-end notebook computer market with the latest generation of MacBook Pro, annual shipment of notebook computers equipped with mini-LED backlight for 2022 will likely rise by 213% year-on-year to 5 million units, reckons TrendForce.

The market research firm notes that, due to OLED supplier Samsung's aggressive efforts to capture share in the notebook market this year, annual shipment of notebooks with organic light-emitting diode (OLED) panels for 2021 will likely reach 2.5–2.7 million units, which represents a penetration rate of about 1.1%. OLED displays compete directly with mini-LED displays in the high-end notebook market, so the adoption of mini-LED displays by non-Apple notebook manufacturers has consistently been limited. Also, Apple waited until fourth-quarter 2021 to release the new MacBook Pro models. Taking these factors into account, TrendForce is therefore reducing its forecast of annual shipment of notebooks with mini-LED backlighting for 2021 from 2.4 million to 1.65 million units.

TrendForce indicates that Apple's product planning regarding the newest MacBook Pro lineup marks a departure from its previous strategy of having only a 13.3-inch model for the entry-level segment and a 16.2-inch model for the high-end segment, since the newest 14.2-inch MacBook is positioned as a product for the mid-range segment. Regarding pricing, the 14.2-inch model at base configuration costs $500 more than the 13.3-inch model and $500 less than the 16.2-inch model, assuming all aforementioned models are equipped with a 512GB SSD. Regarding technical specs, not only do the new models feature an improvement in CPU/GPU, but their backlight has also been upgraded to mini-LED technology. With these advances in both computing power and display performance, Apple will likely be able to erase any doubts from consumers regarding the merit of the price hike, reckons TrendForce.

Both of the new MacBook Pro models are equipped with a mini-LED backlight, with 8000–11,000 mini-LED chips divided across 2000–2600 local dimming zones, resulting in a 1,000,000:1 contrast ratio. Mainstream mini-LED backlight-equipped notebooks from other manufacturers, on the other hand, generally feature about 240–512 local dimming zones, showing Apple's relative superiority in display technology. Furthermore, despite being a step up in terms of display size from the 13.3-inch model, the 14.4-inch model maintains a similar thin and light profile even though it contains a direct-lit mini-LED backlight, which requires additional clearance for light mixing and additional PCB substrate thickness.

Along with Apple's continued adoption of mini-LED backlight technology, a plethora of new participants are expected to enter the mini-LED supply chain in 2022, in turn making this technology much more cost-effective and benefitting companies that are not part of Apple's supply chain as well. Companies that are set to benefit next year include mini-LED chip suppliers (e.g. Ennostar and Osram), testing and sorting service providers (e.g. FitTech, Saultech, and YTEC), SMT suppliers (e.g. TSMT and Yenrich), backplane PCB suppliers (e.g. Zhen Ding Tech, Tripod Technology, and Apex), driver IC suppliers (e.g. Parade, TI, Novatek, and Macroblock), light source module suppliers (e.g. Radiant/ROE and GIS) and OEMs (e.g. Quanta and Foxconn), concludes TrendForce.

www.trendforce.com

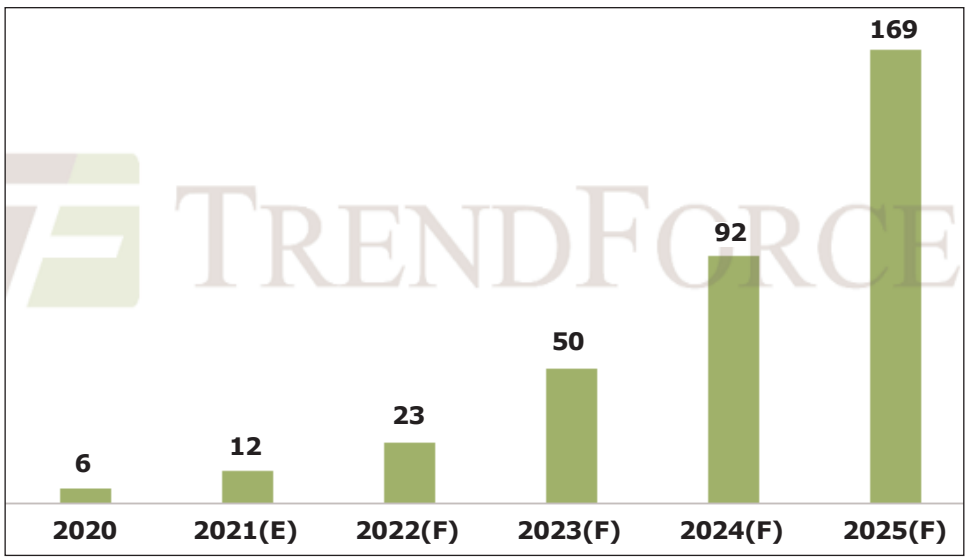
Apple MacBook Pro Technical Specifications

Release Year		2020	2021	2021
Series		MacBook Pro	MacBook Pro	MacBook Pro
Display	Screen Size	13.3"	14.2"	16.2"
	Refresh Rates	120	120	120
	Resolution	2560 x 1600	3024 x 1964	3456 x 2234
Backlight	Typical Brightness (nits)	500	~1000	~1000
	Peak Brightnes (nits)	-	1600	1600
	BLU Type	Edge LED-backlit	Mini-LED backlit	Mini-LED backlit
	LED Qtys	-	8000~9000	10000~11000
	Dimming Zone	-	~2000	~2600

Annual 6-inch SiC wafer demand for EVs to reach 1.69 million units in 2025

Arrival of 800V EV charging architecture to drive replacement of silicon IGBT modules

The demand for longer driving ranges and shorter charging times for electric vehicles (EVs) has intensified the rush of automakers towards high-voltage EV platforms, with various major automakers releasing models featuring 800V charging architectures, such as the Porsche Taycan, Audi Q6 e-tron, and Hyundai Ioniq 5. Due to the rising penetration rate of EVs and the trend towards high-voltage 800V EV architectures, demand from the global automotive market for 6-inch silicon carbide (SiC) wafers will grow to 1.69 million units in 2025, forecasts market research firm TrendForce.



The arrival of the 800V EV charging architecture will bring about a total replacement of silicon insulated-gate bipolar transistor (IGBT) modules with SiC power devices, which will become a standard component in mainstream EV VFDs (variable-frequency drives), TrendForce says. As such, major automotive component suppliers generally favor SiC components. In particular, tier-1 supplier Delphi has already begun mass-producing 800V SiC inverters, while others such as BorgWarner, ZF and Vitesco are also making rapid progress with their respective solutions.

At the moment, EVs have become a core application of SiC power devices. For example, SiC usage in on-board chargers (OBC) and DC-to-DC converters has been relatively mature, whereas the mass production of SiC-based VFDs has yet to reach a large scale. Power semiconductor suppliers including STMicroelectronics, Infineon, Wolfspeed and Rohm have started collaborating with tier-1 suppliers and automakers in order to accelerate SiC deployment in automotive applications.

TrendForce notes that the upstream supply of SiC substrate materials will become the primary bottleneck of SiC power device production, since SiC substrates involve complex manufacturing processes, high technical barriers to entry, and slow epitaxial growth. The vast majority of n-type SiC substrates used for power semiconductor devices are 6-inches in diameter. Although major IDMs such as Wolfspeed have been making good progress in 8-inch SiC wafer development, more time is required for not only raising yield rate but also transitioning power semiconductor fabs from 6-inch production lines to 8-inch production lines. Hence, 6-inch SiC substrates will likely remain the mainstream for at least five more years, expects TrendForce. On the other hand, with the EV market undergoing explosive growth and SiC power devices seeing increased adoption in automotive applications, SiC costs will in turn directly determine the pace of 800V charging architecture deployment in EVs.

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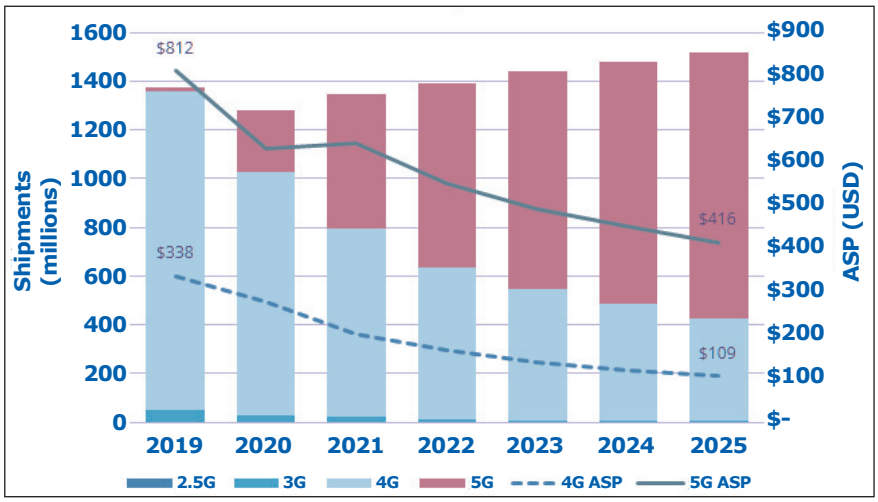
Smartphone shipments to grow 5.3% in 2021, despite lower-than-expected Q3 amid supply chain constraints

Growth forecasts lowered for 2021 from 7.4% to 5.3% and for 2022 from 3.4% to 3%

Shipments of smartphones will grow 5.3% year-on-year in 2021 to 1.35 billion units, according to the International Data Corporation (IDC) Worldwide Quarterly Mobile Phone Tracker. However, due to the lower-than-expected third quarter and the continued component shortages and logistical challenges, which may not improve until mid-2022, IDC has lowered its growth forecasts for 2021 from 7.4% to 5.3% and for 2022 from 3.4% to 3%, respectively. Looking at 2023 and beyond, IDC continues to expect a modest but healthy 3.5% five-year compound annual growth rate (CAGR) fueled by pent-up demand, declining average selling prices (ASPs), and continued transition from feature phones to smartphones.



Global smartphone shipments and ASP forecast Q3/2021.

"Although we expected a slowdown in the third quarter, the market declined by almost twice the projected rate as the supply chain and logistical challenges hit every major player in the market. Moreover, the shortage is more heavily concentrated on 4G components than 5G, which will impact vendors with a higher portfolio mix of 4G devices than vendors with a higher proportion of 5G models. These challenges surrounding 4G components have shifted our short-term forecast for Android more than iOS, which is now primarily 5G," says Nabila Popal, research director with IDC's Mobility and Consumer Device Trackers. "On the positive side, this is expected to accelerate the jump to 5G, which is now forecast to be almost 60% of worldwide shipments by this time next year, slowing the decline in smartphone ASPs over the forecast period."

Heading into the holiday quarter, all regions are forecast to see a single-digit decline, with the most significant decreases expected in Asia/Pacific (excluding Japan and China) (APeJC) and China, where shipments will be down 9.1% and 8.4% year-on-year, respectively. However, due to the robust growth in first-half 2021, all regions except China will finish 2021 on a positive note. Within China, a slowdown in consumer demand will lead to shipments finishing flat to slightly lower in 2021 (–0.2% year-on-year) and 2022 (–0.6% year-on-year). Demand in all other regions remains strong, with almost no channel inventory as supply continues to be less than demand. IDC expects this unmet demand will be pushed forward into the coming quarters and years, contributing to healthy long-term growth.

5G devices are expected to deliver year-on-year growth of 117% in 2021, driven by a supply-side push from both vendors and channels. The shift to 5G translates to greater revenues for most vendors compared with more affordable 4G devices, which saw a year-on-year decline of 22.5% in shipments. 5G-powered smartphones are expected to have a $643 ASP in 2021, which is 1.7% higher than 2020, due to the massive success of iPhone 12 and 13 devices that are all 5G. By the end of the forecast period, IDC expects the 5G ASP to drop to $416. The ASP for 4G devices is expected to reach $204 in 2021, down 26.5% on 2020, and fall to $109 by the end of the forecast period. China is forecasted to be the largest market for 5G smartphones in 2021 with 46.9% of shipments, followed by the USA at 16.1% and APeJC at 12.8%. However, China's share is expected to drop to 30.5% by 2025 as other regions ramp up their 5G networks and connectivity.

"As with our previous forecast, 2021 will represent peak average selling prices as Android will end the year at $265 while iOS climbs to a staggering $950," says Anthony Scarsella, research director with IDC's Worldwide Mobile Device Trackers. "The continued demand for premium models in developed markets has 2021 ASPs growing 11.4% to $382, up from $343 one year ago. In addition, the record-breaking $950 ASP for iOS in 2021 has Apple controlling nearly 43% of all smartphone revenues despite only a 17.1% market share. However, moving forward, prices in the overall market will slowly fall as 5G devices will decline 14.5% in 2022 while 4G devices drop more than 18% next year as the market continues to shift towards 5G."

www.idc.com

Smartphone production grows just 5.7% in Q3/2021 due to supply chain-related component shortages

Recovery to pre-pandemic levels remains unlikely

The smartphone market is showing an improvement in demand during second-half 2021 due to the peak season for e-commerce promotional activities and the easing of COVID-19 outbreaks in regions such as Southeast Asia, according to the latest report from TrendForce.

However, there have been significant shortages of components including 4G SoCs, low-end 5G SoCs, display panel driver ICs, etc. The persistent component gaps are constraining smartphone brands from raising device production for second-half 2021.

In Q3/2021, smartphone production was about 325 million units, up 5.7% quarter-on-quarter. Even so, not only does the quarter-on-quarter increase in smartphone production for Q3 fall short of that for the same quarter last year, but the quarterly production volume also shows weaker performance compared with Q3/2020 or Q3/2019, prior to the emergence of the pandemic.

For full-year 2021 production, TrendForce has lowered its projection for year-on-year growth from 7.3% (to 1.345 billion units) to 6.5% (1.335 billion units), mainly reflecting the impact of the component gaps on device production.

Going forward, an important point is whether the pandemic will further weaken smartphone demand. Other significant variables that will influence future smartphone demand include geopolitical tensions, distribution of production capacity in the foundry market, and global inflationary pressure, reckons TrendForce.

Company	3Q21		4Q21E	
	Ranking	Market Share	Ranking	Market Share
Samsung	1	21.2%	2	19.4%
Apple	2	15.9%	1	23.2%
OPPO	3	15.7%	3	13.9%
Xiaomi	4	13.7%	4	12.7%
Vivo	5	10.5%	5	9.8%

Market share of top 5 smartphone brands by production, Q3–Q4/21.

While Q3 smartphone production reached 325 million, new models helped Apple reclaim second

Samsung grew its smartphone production by 17.9% quarter-on-quarter to 69 million units in Q3/2021, attributed mainly to stabilization of capacity utilization rates at its device assembly plants in Vietnam. The firm continued to top the global ranking of smartphone brands with the largest market share in terms of unit production.

Apple launched four new models in the iPhone 13 series in Q3. Thanks to their contribution, total iPhone production for Q3 grew 22.6% quarter-on-quarter to 51.5 million units. Apple hence climbed to second place in the global ranking. In terms of product development, the firm is sticking with its plan to release its third-generation iPhone SE in Q1/2022 and four models under a new series in second-half 2022. The third-generation iPhone SE is expected to be a major instrument in helping Apple to establish a presence in the market segment for mid-range 5G smartphones. Its production volume for 2022 is forecasted to reach 25-30 million units.

OPPO marginally raised its smartphone production by 3% quarter-on-quarter to 51 million units in Q3, capturing third place in the ranking. Xiaomi held fourth place as its smartphone production fell by 10% to 44.5 million units. Vivo's smartphone production was relatively constant compared with the prior quarter, at about 34 million units, ranking fifth. The production figures of these three Chinese brands include devices under their respective sub-brands (i.e. OPPO's Realme and OnePlus; Xiaomi's Redmi, POCO, and Black Shark; and Vivo's iQoo). Looking at the three brands' production performances in Q3, TrendForce notes that there is a high degree of overlap in terms of target market as well as a high degree of similarity in their offerings. Hence, their production performances directly hinge on their ability to acquire enough of the components that are now in short supply.

Honor to expand into overseas markets as part of comeback plan

After spending first-half 2021 stocking up on components and undergoing business restructuring, Honor is now on a more solid footing and should achieve annual smartphone production of 43.5 million units, taking eighth place in the global ranking of smartphone brands for full-year 2021.

Also, Honor as an independent brand has obtained access to Google Mobile Services. Therefore, it plans to expand to other markets outside China next year and leverage the sales expertise that it has acquired from Huawei in order gain a bigger share of the overseas markets.

Regarding Honor's sales strategy as a whole, the main focus is still on the domestic market. As for the overseas markets, Honor will continue Huawei's strategy and avoid India, where competition revolves around low pricing. Instead, Honor will attempt to establish itself in regions such as Russia, the wider Europe, and South America.

In general, Honor's rise will likely affect the market shares of the other aforementioned brands. However, how much market share Honor will gain depends on its ability to have sufficient inventory of components that are now in short supply, concludes TrendForce.

www.trendforce.com

Qorvo reports record quarterly revenue and EPS

...but supply constraints to induce a more-than-expected 12% sequential decline in December quarter

For fiscal second-quarter 2022 (ended 2 October 2021), Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has reported record revenue of $1255.2m ($5m above the midpoint of the $1235–1265m guidance). This was up 11.5% on $1110.4m last quarter and up 18% on $1060.3m a year ago (which was a 14-week quarter, versus this fiscal year's more typical 13-week quarter).

"Strength during the quarter was broad-based across customers, and supported by new product launches," says president & CEO Bob Bruggeworth.

Mobile Products sales were $996m, up 19.1% on $836m last quarter and up 32% on $754m a year ago (and well above the $985m guidance) due to continued growth of higher-content 5G smartphones. "In mobile products, the multi-year migration of 5G continues to drive RF content and integration trends," says Bruggeworth. The RF content increase in mass-market phones is now greater on a percent basis than in flagship devices, he adds. "Qorvo enjoys broad exposure to mass-market designs at customers like Owner, OPPO, Pixel, Samsung, Vivo, and Xiaomi."

Infrastructure & Defense Products (IDP) revenue was $260m, down 5.1% on $274m last quarter slightly below the expected $265m due to reduced supply from outsourced assembly & test (OSAT) operations in Malaysia and elsewhere. As expected, IDP was down 15% on $306m a year ago due primarily to last year's strong infrastructure build-out and 14-week quarter.

Strategic highlights during September quarter

In Mobile, during the quarter Qorvo began shipping mid-high-band (MHB) and ultra-high-band (UHB) power amplifier duplexers (PADs), antenna tuners and multiple connectivity solutions to support the ramp of Google's recently announced Pixel 6 smartphone.

Qorvo also received initial production orders for MHB and UHB PADs, Wi-Fi front-end modules (FEMs) and multiple high-performance discrete solutions enabling advanced functionality in an upcoming Korea-based 5G mass-market smartphone platform.

In mobile Wi-Fi, Qorvo secured Wi-Fi 6 FEM design wins with multiple top-tier smartphone OEMs, and began sampling Wi-Fi 7 FEMs, enabling higher data rates and improved performance.

In ultra-wide-band (UWB), Qorvo says that it is advancing technologies for a diverse ecosystem of proximity aware connected devices. The firm secured a UWB design win to enable real-time device tracking and other location-aware applications in home mesh networks. It was also selected to supply UWB solutions for enterprise access points. Also, Qorvo has expanded its engagement with a leading provider of consumer Internet of Things (IoT) products spanning a broad range of connected home devices, and secured UWB design wins with multiple OEMs supporting enterprise access points and home mesh networks.

In automotive manufacturing, Qorvo was selected to supply UWB and Zigbee solutions with ConcurrentConnect technology to an automaker in Korea, streamlining automation in manufacturing.

In other connectivity markets, Qorvo began sampling 5.2GHz/5.6GHz Wi-Fi 6 iFEMs with an integrated bulk acoustic wave (BAW) filter, enabling higher capacity and improved efficiency in a reduced form factor.

In broadband, Qorvo began sampling a triple-output DOCSIS 3.1 amplifier module supporting network upgrades for major cable operators in the USA and in Europe.

In infrastructure, design-win activity was strong across OEMs, including small cells and base stations. Wins included all of the RF transmit- and receive-path content (including BAW filters) for 5G small cells at a major base-station OEM. "We see infrastructure markets picking up in 2022, with Qorvo's SAM [serviceable addressable market] growing year-over-year," says Bruggeworth. "The SAM for Qorvo outside of China will post significant growth next year and support a strong double-digit CAGR through 2025," he adds.

In aerospace & defense, Qorvo expanded its defense product portfolio with what it claims is an industry-leading 125W S-band power amplifier module and a 1.8kW L-band radar pallet for commercial and defense radar applications.

Finally, in RF-based biotechnology testing, Qorvo received its first commercial orders and commenced shipments of its Omnia Antigen Test Platform (including cartridges). During the quarter, the US National Institutes of Health (NIH) RADx variant taskforce conducted an external study that demonstrated its performance in effectively detecting COVID variants, including the Delta variant. "Although this is a new market for us, we believe we bring a novel technology that offers unique and real value as the world moves to more testing protocols, including for flu AB, and other seasonal pathogens," says Bruggeworth.

Operational performance

On a non-GAAP basis, gross margin was 52.4%, down slightly from 52.5% last quarter, but up on 51.7% a year ago and above the midpoint of the 52–52.5% guidance despite supply chain disruptions that worsened through the quarter. "We have premium products and these do allow us to price better and compete where we most want to compete," notes chief financial officer

Qorvo acquires UnitedSiC, to add to IDP business

Qorvo has acquired silicon carbide (SiC) power semiconductor manufacturer United Silicon Carbide (UnitedSiC) of Princeton, NJ, USA.

The acquisition expands Qorvo's reach into the fast-growing markets for electric vehicles (EVs), industrial power, circuit protection, renewables and data-center power. United Silicon Carbide will become part of Qorvo's Infrastructure & Defense Products (IDP) business and will be led by Dr Chris Dries, who was formerly UnitedSiC's president & CEO and is now general manager of Qorvo's Power Device Solutions.

"The addition of UnitedSiC to our IDP business significantly expands our market opportunities in high-power applications," says Philip Chesley, president of Qorvo IDP. "This acquisition enables Qorvo to deliver high-value, best-in-class intelligent power solutions covering power conversion, motion control and circuit protection applications," he adds.

"Our team is thrilled to expand our SiC portfolio as part of Qorvo and continue to build the business with speed and scale, working to accelerate SiC adoption with the industry's highest-performance devices," states Dries. "Our SiC technology, together with Qorvo's complementary programmable power management products and world-class supply chain capabilities, enable us to deliver superior levels of power efficiency in advanced applications."

United Silicon Carbide's product portfolio now spans more than 80 SiC FETs, JFETs and Schottky diode devices. Based on a unique cascode configuration, the recently announced Generation 4 SiC FETs are specified at what is claimed to be an industry-leading 750V at 5.9mΩ $R_{DS(on)}$, enabling new levels of SiC efficiency and performance critical for EV chargers, DC–DC converters and traction drives, as well as telecom/server power supplies, variable-speed motor drives and solar photovoltaic (PV) inverters.

Mark Murphy. "Also, we've maintained a utilization of our factory network. We continue to drive productivity programs aggressively."

Despite being less than expected, operating expenses were $222.1m (17.7% of sales), up from $215.6m last quarter and $218.6m a year ago, driven by technology and product development expenses associated with key growth programs and recent acquisitions.

Operating income has risen further, from $329.4m a year ago and $367m last quarter to $435.4m (34.7% of revenue — a fourth consecutive quarter of operating margin over 33%).

Likewise, net income has risen further, from $282.3m ($2.43 per diluted share) a year ago and $322.6m ($2.83 per diluted share) last quarter to $384.5m (a record $3.42 per diluted share, $0.18 above the $3.24 guidance).

Cash flow from operations was $244.8m. Capital expenditure (CapEx) was $47.3m (lower than the expected $75m, due to the timing of spending, and earlier-than-expected reimbursement for a portion of government-funded work on advanced packaging). Free cash flow was hence $197.5m.

During the quarter, Qorvo repurchased $223m of shares (making $523m over the last two quarters, representing 110% of free cash flow). "We've continued to repurchase shares as our outlook is positive, our free cash flow and ability to sustain investment in technology and growth is strong, and our leverage remains low," says Murphy.

Cash and debt hence remained largely unchanged from the prior quarter at $1.2bn and $1.7bn respectively.

"We are sustaining investments in highly differentiated technologies and best-in-class products to extend our leadership and drive growth," says Bruggeworth.

After the quarter closed, Qorvo acquired silicon carbide (SiC) power device maker United Silicon Carbide of Princeton, NJ, USA (a pioneer in silicon carbide JFETs) for over $200m. "The combination will further differentiate Qorvo's power portfolio, enabling more highly integrated power device solutions and expand our addressable market [by almost a billion dollars] to include higher-voltage applications that demand maximum power efficiency, such as electric vehicles, charging stations, and renewable energy systems," says Bruggeworth. "Our ability to deliver more power, more efficiently and using less current helped put us at the center of the digital transformation. We're eager to expand these competencies as global markets move to electrification and renewable energy," he adds.

Financial outlook

"After achieving a record September quarter, we expect December-quarter revenue to decrease sequentially amidst ongoing supply challenges and other factors impacting global smartphone demand," says Murphy. "Revenue outlook reflects broad-based challenges and supply, impacting Mobile and IDP, and near-term weakness in demand, principally in Asia. The supply environment worsened through the quarter, particularly in mid to late September. And then these publicized weakness in demand emerged over the past 3 weeks or so," he adds. "The lack of deployments going on in China… is the IDP story. The rest of the business is doing very, very well. If you look at that base-station business outside of China, it's actually growing way up over 30%," says outgoing IDP Group president James Klein.

"Starting with supply, we have several areas of constraint. Our external supply chain is still recovering from disruptions in September, including shutdowns in Southeast Asia. Beyond that, select materials, products and production capacity remain tight," notes Murphy.

"These are industry-wide issues affecting all suppliers, and our customers are challenged in producing matched sets for products. For example, in smartphones, even where channel inventory for certain parts is healthy, customers lack silicon chips to produced phones. This in turn creates changes in demand that add to constraints on our own production as we work to adjust mix… In a normal environment, Qorvo can move swiftly to respond and capture demand. These supply-driven gaps are making recent demand softness in select areas, such as our Asia smartphone customers, harder to quantify."

For fiscal third-quarter 2022 (to end-December 2021), Qorvo therefore expects revenue to fall a more-than-expected 12% sequentially to $1.09–1.12bn (albeit still up slightly year-on-year). Of the $150m decline, about $135m is in Mobile Products. The remaining $15m is in IDP (all due to supply constraints, i.e. suppliers not having supply for Qorvo, or Qorvo's customers not having the chipsets and not being able to build their product and use Qorvo's product, or Qorvo's own internal constraint).

IDP is still expected to grow sequentially, to $275m, returning to year-on-year growth. Mobile Product revenue is forecasted to be about $830m (down 17% sequentially and flat year-on-year). Of the $135m decline in Mobile Products, up to $100m is supply-related, so $35m is due to net demand being down (mainly in parts of Asia).

Gross margin should be 52–52.5%. "Our December quarter gross margin guide of 52.25% at the midpoint, is up versus the view we provided last quarter, despite a more challenging supply/demand environment than expected," says Murphy. "We see our technology and product mix and operating and capital efficiency yielding a gross margin above 52% for the fiscal year," he adds.

Operating expenses should rise slightly to about $224m in the December quarter, reflecting higher investments in core technologies and expanding capabilities in new businesses, including the addition of the UnitedSiC team. Diluted earnings per share should fall to $2.75.

"Capital expenditures are projected to exceed $70m in the December quarter as we work to intersect demand and support long-term supply agreements with multiple customers," says Murphy. "Currently, we are supply constrained and project to remain so through our fiscal year-end. We continue to expand BAW and GaAs capacity, as well as biosensor production capacity to support our growth projections for fiscal 2023," he adds. "The current supply challenges and near-term demand weakness are acute, but more temporary than durable. We expect supply effects to moderate starting this quarter and improved supply demand alignment early next calendar year."

"In the March quarter, we expect the challenges [for IDP] to moderate," says Murphy. IDP's growth is expected to accelerate in the March quarter, to over $300m. "We expect Mobile to be up slightly sequentially as a typical seasonal decline is offset by improved supply and demand." Total revenue is still guided to be up year-on-year. Gross margin should be about 52%.

For fiscal full-year 2022, Qorvo expects revenue growth of "over 15%" (towards the lower end of the prior guidance range of 15–20%). Gross margin should be over 52%, and operating margin about 33%. "We expect the business to strengthen through the second half of our fiscal year and contribute to a record full-year performance, including earnings growth over 20%," says Murphy.

"Looking beyond this fiscal year, we expect double-digit growth to continue as Qorvo's premium technology product portfolio and operating capability support 5G, Wi-Fi, IoT, defense, power, and other growth markets," concludes Murphy. "Qorvo is exceptionally well positioned to deliver earnings and free cash flow growth, serving a large and growing need for more efficient power and greater connectivity."

Qorvo appoints Philip Chesley as IDP president

Qorvo has appointed Philip Chesley as president of its Infrastructure & Defense Products (IDP) segment, reporting to president & CEO Bob Bruggeworth. He succeeds James Klein, who retiring from the firm.

"Philip has a proven track record growing world-class organizations at leading technology companies," comments Bruggeworth. "His deep expertise in RF, power, data communications, automotive, industrial and aerospace/defense markets will serve Qorvo well as he leads our talented IDP team to drive growth."

Chesley was most recently VP & general manager of the Industrial and Communications business unit at Renesas. He was previously senior VP & general manager of the Automotive, Aerospace and Analog Product Group at Intersil (acquired by Renesas in 2017). He joined Intersil in 2004 and served in several executive leadership roles. Prior to that, he was a founder and director at Primarion, a pioneer in software-programmable digital multiphase power architectures, which was purchased by Infineon. Chesley earned an MBA from Duke University's Fuqua School of Management and a Bachelor of Science degree from Brigham Young University.

"We are grateful to James Klein for his years of commercial and technology leadership of IDP," comments Bruggeworth. "James and his teams have established Qorvo as a leader in high-value markets while more than doubling the size of the business and diversifying Qorvo's business mix."

www.qorvo.com

Extra $4.4m takes Guerrilla's private placement to $11.5m

Guerrilla RF Inc (GRF) of Greensboro, NC, USA has raised an additional $4.4m in subsequent closings of its private placement offering.

In October, Guerrilla RF completed a reverse merger (with Laffin Acquisition Corp) and the initial closing of its private placement offering in which it raised over $7m in gross proceeds. The additional closings bring total gross proceeds to over $11.5m. The firm plans to pursue the listing of its common stock on the OTC Markets QB tier.

Founded in 2013, Guerrilla RF is a supplier of monolithic microwave integrated circuits (MMICs) targeting wireless infrastructure applications, including 5G and automotive. The firm has a well-established revenue stream, with 2020 sales totaling $8.09m. Despite the disruption caused by COVID-19, Guerrilla RF's sales have grown by 990% over the past three years.

"This additional capital will allow us to further accelerate our growth and expand our product offerings," says founder & CEO Ryan Pratt.

Guerrilla RF is currently expanding its R&D operations to a new 50,000ft^2 facility in Greensboro. The new site will provide room to expand operations and substantially increase headcount over the next two years.

Guerrilla RF has a portfolio of over 95 high-performance RF and microwave semiconductor devices. The existing product line includes ultra-low-noise amplifiers, gain blocks, driver amplifiers, mixers, RF switches, and linear PAs (power amplifiers) — the building blocks for mission-critical, performance-driven wireless applications, including 5G wireless infrastructure, cellular repeaters/boosters, and automotive telematics.

The private placement offering was orchestrated by GP Nurmenkari Inc (as consulted by Intuitive Venture Partners), which served as the exclusive placement agent. The Benchmark Company LLC served as sub-agent. Montrose Capital Partners was the sponsor for the transaction. Mark Tompkins and Jeffrey Shealy were lead investors in the offering.

http://guerrilla-rf.com

pSemi files 1000th patent application

Murata company pSemi Corp of San Diego, CA, USA — a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-insulator (SOI) — has grown its patent portfolio to over 1000 issued and pending patents worldwide. From 2017 to 2021, the firm increased its patent holdings by 100%, reflecting its continued RFIC and power management innovation.

"For more than 30 years, pSemi has fostered a culture of innovation in which our talented inventors have pioneered novel technologies, industry-transformative architectures and unique design techniques," says Takaki Murata, interim CEO. "This culture, reinforced by our continued R&D investment, has resulted in one of the industry's strongest patent portfolios."

pSemi's semiconductor patent portfolio enhances and complements Murata's portfolio of over 23,000 patents. Since Murata bought it in 2014, pSemi's portfolio has steadily grown, especially in recent years.

In 2020 alone, pSemi filed nearly 150 patent applications. Also, the quality of pSemi's patent portfolio has been recognized as one of the industry's most valuable in the IEEE Spectrum Patent Power Scorecard.

Since pSemi filed its first patent in 1993, the company has recognized over 200 inventors. In addition to financial incentives, pSemi sponsors an Innovators Club that presents annual awards including 'Patent of the Year' and 'Inventor of the Year'.

www.psemi.com

Altum RF announces sales rep agreement with HITECH

Altum RF of Eindhoven, The Netherlands (which designs RF to millimeter-wave solutions for commercial and industrial applications) has announced a new sales representative agreement with HITECH RF & Microwave Solutions, covering customers in the Netherlands, Belgium and Luxembourg.

Founded in 1981, HITECH has its headquarters in Zeist, Netherlands and specializes in servicing the RF and microwave market in Europe with solutions in components, design software, and test & measurement.

"We are proud of our steady progress to expand our sales coverage across the globe," says Niels Kramer, Altum RF's managing director Europe & VP marketing. "HITECH provides a key combination of technical expertise with excellent customer support, enhancing our ability to assist customers throughout the design process," he comments.

"Altum RF's innovative MMIC products enable us to better serve our customers with design solutions for a variety of applications," says HITECH's CEO Olaf Biezeman. "Moreover, with Altum RF's focus on developing new components, we have the opportunity to expand our customers' product selection options."

Altum RF is an international company, with strategic partnerships and office locations that span the globe to support its growing product portfolio.

www.altumrf.com

Skyworks reports record quarterly and full-year revenue and earnings

In-house capacity and technology investments minimizing impact of industry supply chain issues

For full-year fiscal 2021 (ended 1 October), Skyworks Solutions Inc of Irvine, CA, USA (which manufactures analog and mixed-signal semiconductors) has reported record revenue of $5109m, up 52% on fiscal 2020's $3356m. By business sector, Broad Markets revenue grew by 45% to over $1400m. Mobile revenue grew 55% to $3700m.

Fiscal fourth-quarter 2021 revenue was a record $1311m (towards the high end of the $1.27–1.33bn guidance range), up 17% on last quarter's record $1116.4m and 37% on $956.8m a year ago.

The quarter includes two months of revenue from the acquisition (on 26 July) of the Infrastructure & Automotive (I&A) business of silicon, software and solutions provider Silicon Labs Inc of Austin, TX, USA, which has a $100m per quarter run-rate (to be reported within Skyworks' Broad Markets segment). "We completed a strategic and compelling acquisition, immediately diversifying our product portfolio and expanding our market reach," notes chairman, CEO & president Liam Griffin.

"Revenues in our Mobile and Broad Markets portfolios both grew at double-digit rates sequentially and year-over-year as we capitalized on broad-based momentum fueled by demand for our unique connectivity solutions," says Griffin.

Broad Markets comprised 29% of total revenue, up 13% sequentially and 31% year-on-year.

Mobile comprised 71% of total revenue, up 19% sequentially and 40% year-on-year, after supporting the ramp of new phone platforms at the firm's largest customer (driving up that customer's share of Skyworks' total revenue from 56% in fiscal Q4/2020 to 59% in fiscal Q4/2021, and 59% also for full-year 2021). "Not only in the smartphone lineup, but almost in every other product that they have and that they sell, you will find Skyworks inside," notes senior VP & chief financial officer Kris Sennesael.

"Our strong performance throughout the initial stage of a multi-year wireless transition has been powered by deep customer relationships and decades of investments in innovative connectivity solutions," says Griffin. "The complexity inherent in 5G and demand for highly integrated solutions were major catalysts in driving our performance," he adds.

"The acceleration of 5G powered a broad set of use-cases in Q4, with design wins encompassing the newest, most innovative smartphones and IoT devices, as well as gains in wireless infrastructure," says Griffin. Specifically:

- In Mobile, Skyworks extended the reach of its Sky5 portfolio, powering the latest launches at leading tier-1 smartphone OEMs, supporting more than 20 platforms. In addition, it shipped Sky5 solutions across Samsung Galaxy's tablet portfolio.
- In IoT, Skyworks continues to gain new customers and expand content, delivering 5G CPE connectivity solutions to Nokia. It also partnered with Swisscom to launch their Wi-Fi 6 GPON residential gateways, and ramped Wi-Fi 6 and 6E platforms at NETGEAR and Cisco. Skyworks launched connectivity in home security devices with Amazon Ring and Comcast. It also captured design wins at Garmin supporting mobile fitness applications.
- In automotive, Skyworks supported autonomous driving systems with a market-leading Robotaxi platform. It also enabled the advanced charge control unit systems for a tier-1 European automotive OEM.
- Skyworks also provided power isolation solutions to a strategic manufacturer of EV, residential solar and energy storage systems.

"Leveraging strategic technologies from high-performance filters to custom gallium arsenide and advanced packaging, our world-class manufacturing capabilities enable us to effectively navigate a complex supply environment, capturing expanding opportunities across our end markets," says Griffin.

On a non-GAAP basis, quarterly gross margin has grown further, from 50.4% a year ago and 50.6% last quarter to 51% in fiscal Q4/2021 (aided by the I&A business, which is running at about 60% gross margin). This has boosted full-year gross margin from 50.2% in fiscal 2020 to 50.9% for fiscal 2021.

While operating expenses have risen further, from $147m a year ago and $161m last quarter to $180m in fiscal Q4, this is a cut from 15.4% then 14.5% to 13.8% of revenue (and at the bottom of the expected $180–183m range), "demonstrating leverage in our operating model while continuing our strategic investments in support of future growth," says Sennesael.

Top-line momentum and execution on margins drove quarterly net income up from $312.2m ($1.85 per diluted share) a year ago and $358.6m ($2.15 per diluted share) last quarter to $438.8m ($2.62 per diluted share, exceeding the $2.53 guidance by $0.09). This boosted full-year net income from $1041m ($6.13 per diluted share) in fiscal 2020 to $1753m ($10.50 per diluted share) for fiscal 2021.

"Skyworks set new records for revenue and earnings for the fourth quarter and the fiscal year, delivering significant year-over-year growth in response to robust demand across our expanded product portfolio," says Griffin.

Quarterly operating cash flow has risen from $272.9m last quarter to $398m (taking full-year operating cash flow to $1772m, up 47% year-on-year from $1204m). Capital expenditure (CapEx) has more than doubled from $115m last quarter to $263m.

During the quarter, Skyworks paid $93m in dividends and repaid $250m of its term loan. In full-year fiscal 2021, Skyworks returned $536m of cash back to the shareholders. This comprised $340m in dividends (up from $307m the prior year), plus $196m in share buybacks (down from $648m). The latter were all during fiscal Q1/2021.

"Starting into fiscal 2021, we temporarily suspended our share repurchase program in connection with the acquisition of the Infrastructure & Automotive business from Silicon Labs [for $2.75bn]," notes Sennesael.

As a result of the all-cash transaction, cash, cash equivalents & marketable securities hence fell during the quarter from $2978m to $1027m while long-term debt rose from $1487m to $2235m.

Griffin notes that capital assets and technology investments that Skyworks made 6–12 months ahead have minimized the impact of industry supply chain issues and shortages. "Having those assets in-house is strategic, it's critical, it's what customers want to see, all the way from gallium arsenide to packaging, assembly & test, TC-SAW [thermally compensated surface acoustic wave], bulk acoustic wave, standard SAW [filters]. We can mix and match to put the right solution together," says Griffin. "It was the ability to invest early, drive that cash flow, drive that performance to continue to do that and then bring those products to market in ways that are very flexible and having the ability to go from IoT to 5G to Bluetooth to Wi-Fi," he adds. "Whatever the connectivity protocol may be, we will have the technology execution vehicles within our company to execute for our customers."

"Looking ahead, Skyworks' cash generation ability is funding capacity expansion and next-generation technology development, positioning us for continued leadership and sustainable growth as the transition to 5G and other advanced connectivity solutions continues," reckons Griffin.

This is just the beginning of a long 5G cycle, the beginning of Wi-Fi upgrade, the beginning of proliferation of 5G outside of mobile into growth markets. It is a tight supply-constrained environment and we are facing some input cost increases. We continue to drive further operational efficiencies. Skyworks will continue to strategically invest in next-generation technologies and capital expansion, positioning us for market leadership and sustainable growth as the transition to 5G and other advanced connectivity technologies accelerates

CapEx has been running at 10–12% of revenue. "We made the necessary investments in our manufacturing footprint, not only just expanding the capacity but also adding new technology and improving the performance of our technology and our products," says Sennesael. "Demand is higher than the supply, but Skyworks has, compared to peers and competitors and other industry players, executed really well because we did not hesitate and put the CapEx in place," he adds.

"Based on continued content gains, product ramps and design wins across both mobile and broad markets, we expect further double-digit sequential revenue and earnings growth in the December quarter," says Sennesael. For fiscal first-quarter 2022 (to end-December 2021), Skyworks hence expects another quarter of double-digit sequential revenue growth, by 14% to $1475–1525m. Gross margin is projected to be 51–51.5%. Operating expenses should rise to $184–187m. At the $1.5bn mid-point of the revenue range, diluted earnings per share should be $3.10, up 18% sequentially.

"This is just the beginning of a long 5G cycle, the beginning of Wi-Fi upgrade, the beginning of proliferation of 5G outside of mobile into growth markets," says Sennesael. "It is a tight supply-constrained environment and we are facing some input cost increases right now. We continue to drive further operational efficiencies," he adds.

"Skyworks will continue to strategically invest in next-generation technologies and capital expansion, positioning us for market leadership and sustainable growth as the transition to 5G and other advanced connectivity technologies accelerates," says Griffin.

www.skyworksinc.com

Dividend payment

Skyworks' board of directors has declared a cash dividend of $0.56 per share of common stock, payable on 14 December, to stockholders of record at the close of business on 23 November.

"Given the strength of our business and the progress we have made on integrating the acquisition, and given the low leverage ratio of less than 1 turn, going forward we will, from time to time, consider share repurchases as part of our capital allocation strategy, depending on market conditions and in addition to our dividend program and further term-loan repayments," says Sennesael.

AmpliTech acquiring Spectrum Semiconductor Materials

Spectrum to package AmpliTech's new MMIC chip designs for high-volume applications

AmpliTech Group Inc of Bohemia, NY, USA — which designs and makes signal-processing radio frequency (RF) components for satellite communications, telecoms (5G & IoT), space, defense and quantum computing markets — has agreed to acquire the assets and operations of Spectrum Semiconductor Materials Inc of San Jose, CA, a global distributor of components (packages and lids) for integrated circuit (IC) assembly in prototyping, testing and production. The transaction is expected to close within fiscal-year 2021, subject to satisfying certain closing conditions.

The acquisition is expected to deliver significant strategic and top- and bottom-line benefits while also building on AmpliTech's technical and management expertise and distribution reach. Spectrum's unaudited 2021 revenue is on track for double-digit year-on-year growth to $10–11m, with pre-tax net income of about 25% of revenue. Spectrum achieves strong net margins by stocking a wide variety of specialty products and employing digital inventory practices that optimize operating efficiency. AmpliTech's revenue for the past four quarters was $3.5m, and order backlog recently reached a record $3.4m following $1.2m in new orders. Spectrum currently has record backlog of $8m in orders expected to ship through end-June 2022.

The purchase price is $8m in cash plus $1.5m to be held in escrow through December 2022 (to fund any adjustments) plus the grant of 188,442 restricted shares of AmpliTech common stock. The parties have agreed to a purchase price adjustment of 25% of Spectrum's cumulative net revenue above or below $20m in sales for calendar years 2021 and 2022 combined. On 30 September, AmpliTech had about $28m in cash, cash equivalents and marketable securities, and no long-term debt.

Of strategic importance, Spectrum provides a distribution platform in the USA, Europe and Asia for AmpliTech's new line of monolithic microwave integrated circuit (MMIC) chip designs, and Spectrum has been building its RF-focused semiconductor revenue base. AmpliTech's MMIC chip designs integrate its low-noise signal amplification (LNA), signal filter and signal attenuator technologies into the much smaller and more flexible chip form factor. Foundry production of initial MMIC chipsets is targeted for commercial availability by the end of first-quarter 2022.

It is reckoned that each company brings proven sales personnel and relationships that complement each other in addressing the combined firm's expanded market opportunity. Furthermore, as AmpliTech develops its new MMIC line, Spectrum can package the designs for high-volume applications expected to drive sales growth. The acquisition is expected to bring AmpliTech a substantial business development presence in Silicon Valley and international markets, building on its existing East Coast and Texas teams to create a broad global footprint.

Spectrum provides a distribution platform in the USA, Europe and Asia for AmpliTech's new line of MMIC chip designs, and Spectrum has been building its RF-focused semiconductor revenue base. AmpliTech's MMIC chip designs integrate its low-noise signal amplification, signal filter and signal attenuator technologies into the much smaller and more flexible chip form factor

"Spectrum Semiconductors is a perfect fit for advancing AmpliTech's strategic goals and delivering shareholder value. With Spectrum, we will add a well-managed, growing business with a long-term track record for high quality and excellent customer service and the ideal distribution platform for the launch of our MMIC chip solutions," says AmpliTech's CEO Fawad Maqbool. "This transaction will allow us to more than triple our current annual revenue run rate, while also being immediately accretive to our bottom line," he adds.

"Of equal importance, Spectrum brings us a highly satisfied, long-term and global customer base with excellent penetration in our core end markets of aerospace, defense, automotive and computing, along with a deep Silicon Valley presence, to support the launch of MMIC chip solutions [that] we plan to bring to market by the end of first-quarter 2022," Maqbool continues. "We expect AmpliTech and Spectrum will play a key role in improving the speed and efficiency of communications systems around the world in high-growth applications such as 5G cellular, MEO and LEO satellites, quantum computing and autonomous vehicles. Importantly, AmpliTech is well funded to complete this transaction and to then execute on the growth opportunities of the combined business," he concludes.

Joining forces with AmpliTech "provides us with a broader base of opportunity and exciting growth potential as we collaborate to bring AmpliTech's premier MMIC chip solutions to market, comments Spectrum's CEO Robert Larson.

www.spectrum-semi.com
www.amplitechinc.com

Soitec acquires NOVASiC to aid industrialization of SmartSiC for automotive and industrial markets

NOVASiC's wafering, polishing and reclaiming complements Soitec's SmartCut-based technology

Engineered substrate manufacturer Soitec of Bernin, near Grenoble, France has acquired NOVASiC of Savoie Technolac, France, which specializes in polishing and reclaiming wafers on silicon carbide (SiC). Soitec says that the acquisition allows it to drive the development of semiconductors for power supply systems in electro-mobility and industrial applications. The transaction is expected to be completed by the end of 2021.

In a strategic move to address the need of the automotive and industrial markets for performance and energy efficiency, Soitec is expanding its product portfolio beyond silicon-on-insulator (SOI) with silicon carbide, which it says unlocks greater performance, optimized design and lower environmental impact for power electronics (particularly in electric vehicles and other power-efficient applications).

Soitec reckons that SmartSiC substrates, resulting from the application of its patented proprietary technology SmartCut to SiC, will enable new levels of performance and energy efficiency compared with traditional bulk SiC, through higher donor wafer re-usability, improved yields and lower die sizes. In addition to reducing silicon carbide's environmental impact in its production process, SmartSiC is targeted at being a catalyst to accelerate the adoption of electric vehicles (EVs). SmartSiC is currently at the prototyping level for devices with several key partners.

Established in 1995 near Grenoble, NOVASiC provides wafering, reclaiming and polishing services for high-performance semiconductors and industrial crystals to laboratories and industrial customers, with a particular focus on silicon carbide. The firm has developed polishing processes that are said to allow enhanced device performance with a scratch-free, low-roughness, ultra-clean epiready surface, and no damaged layers.

With the acquisition, NOVASiC's CEO Didier Marsan will become senior technical advisor for Soitec.

"Soitec's SmartSiC substrates will be the backbone of energy-efficient electro-mobility," claims Soitec's chief operating officer Bernard Aspar. "The acquisition of NOVASiC and the integration of its expertise in wafering, polishing and reclaiming brings the latest technology building block for Soitec to deliver an optimal final product and prepare the industrialization phase of our SmartSiC product line. The expertise of NOVASiC will help us further accelerate the go-to-market and adoption of our smart silicon carbide applications in the promising and demanding automotive and industrial markets," he adds.

"We look forward to providing our expertise to support the roadmap of Soitec's new, very promising product line, and to contributing to the adoption of Soitec's smart silicon carbide solutions," says Marsan.

www.novasic.com

Soitec & Mersen partner on poly-SiC substrates for EVs

Soitec and Mersen of Courbevoie, France, which focuses on electrical specialties and advanced materials, have entered into a strategic technical partnership to develop a new family of polycrystalline silicon carbide (poly-SiC) substrates for the electric vehicle (EV) market.

Due to their respective experience in substrates and materials, the joint development by Soitec and Mersen of very low-electrical-resistivity poly-SiC substrates should optimize SiC power electronics components based on Soitec's SmartSiC technology. The collaboration between the Mersen teams in Gennevilliers and Soitec teams in Bernin and Grenoble will strengthen this development project. The teams will also be able to benefit from the expertise of the Soitec Substrate Innovation Center within CEA-Leti to validate the progress made in the industrialization process.

"By further pooling our materials and semiconductor expertise, we are able to produce substrates with very advanced performance," reckons Soitec's chief technology officer Christophe Maleville. "The results are compatible with our SmartSiC technology, and also exceed the specifications of our customers, which are the SiC power electronic circuit foundries. With its very low electrical resistivity, the poly-SiC substrate becomes a key element of our technology, and can vastly improve energy efficiency, thus making electric vehicles more efficient," he adds.

"This partnership demonstrates Mersen's polycrystalline SiC expertise and our ability to develop a custom-design product compatible with Soitec's technology," says Mersen's CEO Luc Themelin. "Thanks to this strengthened partnership, we will be able to offer the electronics industry a high-performance, cost-effective substrate for the production of power semiconductors, especially for the electric vehicle market."

www.mersen.com
www.soitec.com

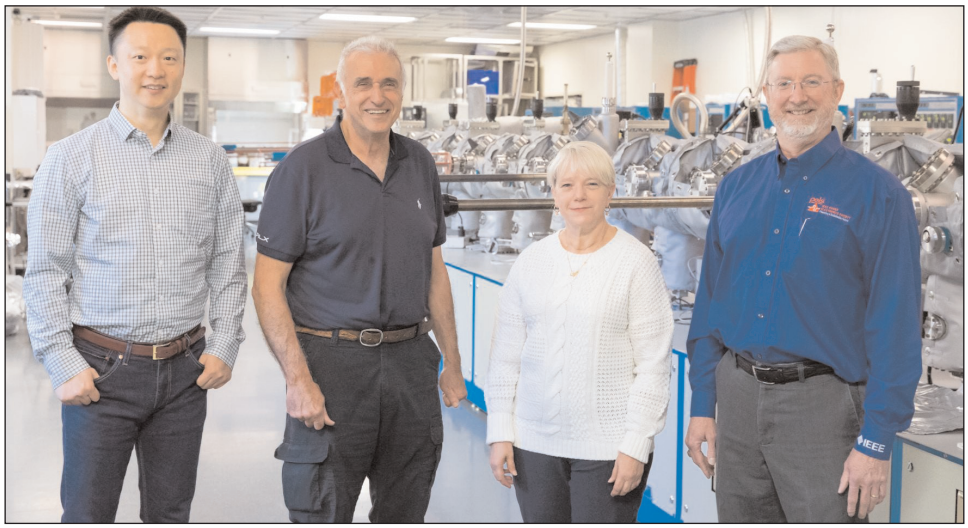
National SiC facility at University of Arkansas gains $5m more in grants from US Army

$4.5m from Army Research Office for equipment, plus $0.9m from Army Research Laboratory for student and staff compensation, tuition and materials for collaborative research

Following an $18m grant received in early October from the US National Science Foundation (NSF) to fund construction and operation of the national silicon carbide (SiC) research and fabrication facility, the University of Arkansas has now received further grants exceeding $5m ($4.5m from the US Army Research Office and $900,000 from the Army Research Laboratory) for the facility. Alan Mantooth, Distinguished Professor of electrical engineering, is principal investigator for both grants.

The Army Research Office grant will be used for equipment, and the Army Research Laboratory grant for student and staff compensation, tuition and materials for supporting collaborative research activities with the Army Research Lab.

Combining cutting-edge equipment and infrastructure with a core of research experts focused on silicon carbide semiconductor devices, sensors and integrated circuits, the fabrication facility will develop new electronics to address areas of national defense. Researchers are tasked with fabricating more energy-efficient and heat-resistant ICs for compact and robust electronic devices for branches of the US military.



Zhong Chen (associate professor of electrical engineering); Greg Salamo (Distinguished Professor of physics); Shannon Davis (business and operations manager in the Department of Electrical Engineering); and Alan Mantooth, Distinguished Professor of electrical engineering,

The facility will also train the next generation of semiconductor researchers and engineers for working in both the silicon and silicon carbide semiconductor industries. Students at all degree levels will be given research opportunities and be exposed to a high-need area of science and technology. The research also aims to engage under-represented students in this burgeoning area of electronics.

With now decades of experience working with silicon carbide, Mantooth will lead a team that will acquire, install and integrate equipment for the purpose of building a low-volume prototyping facility to produce silicon carbide ICs.

In addition to Mantooth, researchers on the project include Greg Salamo (Distinguished Professor of physics); Zhong Chen (associate professor of electrical engineering); and Shannon Davis (business and operations manager in the Department of Electrical Engineering).

https://research.uark.edu

BorgWarner receives $4.97m US DOE award for high-power-density inverter

Project to develop smaller, more power-dense and cost-effective solution

BorgWarner Inc of Auburn Hills, MI, USA is the recipient of a $4.97m US Department of Energy (DOE) award for the development of a Scalable Ultra Power-dense Extended Range (SUPER) inverter. The R&D project is one of 24 university- and industry-led projects that collectively were awarded $60m in an effort to reduce CO_2 emissions from the transportation sector.

BorgWarner is leading the 39-month project (begun in October) and working with Infineon Technologies Americas Corp, PolyCharge America, the US National Renewable Energy Laboratory (NREL) and Virginia Tech as partners to bring the SUPER inverter to fruition. Wolfspeed Inc will be a key supplier.

"With an intense focus on electrification, and as a leading systems integrator and high-voltage inverter supplier, we are proud to be selected by the DOE to develop a next-generation inverter that will accelerate innovation in electric drive systems and propel the performance and capabilities of electric vehicles," says Dr Stefan Demmerle, president & general manager, BorgWarner PowerDrive Systems. "We have a long-standing relationship with the DOE and have teamed up with an impressive group of industry partners and technology leaders."

The goal of the project is to develop a smaller, more efficient and more cost-effective inverter, with the intent of enabling 800V electrified vehicles to meet or exceed the DOE solicitation target of 100kW per liter of power density. Additionally, project plans call for a design that allows high power density with power scaling between 100kW and 300kW and that can be used either as a standalone device or integrated into a drive unit that includes a motor and gearbox.

During the first year of the project, the team will create the concept for the entire silicon carbide (SiC)-based inverter system. In the second year, it will make all critical components that make up the inverter, including the power module and capacitor, and finalize the inverter's design. The final year will be used for validation of the components and the SUPER inverter. Once complete, the team expects to take the technology from development to production relatively quickly.

"For this project, we will be leveraging our experience with our unique and high-performing 800V Viper silicon carbide-based inverter, advancing the concept with a building-block approach and increasing component integration to achieve higher performance targets and ultimately expand its commercial potential," says Demmerle. "We expect the number of high-voltage EVs to sharply increase in the coming years, and this scalable, high-power-density inverter will help expedite adoption."

www.borgwarner.com

BorgWarner to provide new 800V SiC inverter for German OEM's electric vehicles

BorgWarner is providing a new, high-voltage silicon carbide (SiC) inverter to a large German automaker for implementation in its next-generation electric vehicles, representing "the next stage of a long-standing cooperation". The 800V SiC inverter with proprietary power switches provides a more compact and efficient power module, resulting in higher electric vehicle range and enhanced driving performance.

"Our SiC inverter, with its new state-of-the-art power module, can be a game changer for automakers since the new technology offers enhanced power density, proven performance, and long-term reliability," reckons Dr Stefan Demmerle, president & general manager, BorgWarner PowerDrive Systems.

The SiC inverter uses a scalable power switch for 800V systems, allowing it to be optimized for a variety of customer applications at different power levels. The SiC design builds on BorgWarner's proven cooling technology that enables a reduced semiconductor area for cost-effectiveness. Additionally, the system offers greater durability and enhanced packaging due to its compact, patented power switch that is cooled on both sides and uses no wire bonds. The silicon IGBTs in the modular power switch have been replaced by SiC transistors. Because SiC has higher switching efficiency and fewer conduction losses, the new SiC inverter has reduced power losses of 40-70% compared with silicon-based based inverters, depending on the drive cycle.

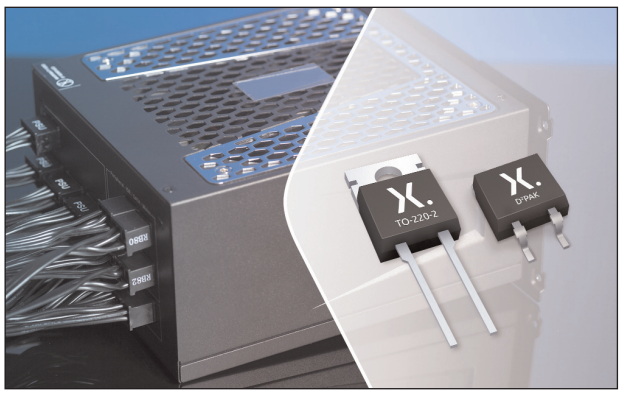
Due to its higher power density and higher efficiency, the inverter allows OEMs to design 800V high-power propulsion systems that are characterized by enhanced driving performance, longer battery electric ranges, and faster charging times. These enhancements can ultimately further efforts to broaden consumer acceptance of electric mobility, reckons BorgWarner.

Nexperia expands wide-bandgap range by entering high-power silicon carbide diode market

Industrial-grade 650V, 10A SiC Schottky diode sampled; 1200V/6–20A and automotive-grade parts planned

Nexperia BV of Nijmegen, Netherlands — which manufactures diodes, bipolar transistors, ESD protection devices, MOSFETs, gallium nitride (GaN) field-effect transistors (FETs) and analog & logic ICs — has announced its entry into the high-power silicon carbide (SiC) diode market with the introduction of 650V, 10A SiC Schottky diodes. This is a strategic move for Nexperia, which already supplies power gallium nitride (GaN) FETs, to expand its range of high-voltage wide-bandgap semiconductor devices.

Nexperia's first SiC Schottky diode is an industrial-grade device with 650V repetitive peak reverse voltage (V_{RRM}) and 10A continuous forward current (I_F), designed to combine ultra-high performance and high efficiency with low energy loss in power conversion applications. Providing the added benefit of a high-voltage compliant real 2-pin (R2P) package with higher creepage distance, it is available in a choice of surface-mount (DPAK R2P and D2PAK R2P) or through-hole



(TO-220-2, TO-247-2) devices. Engineering samples are available on request, with a full product release planned for second-quarter 2022. Nexperia plans to continuously increase its portfolio of SiC diodes, leading to a total of 72 products operating at voltage levels of 650V and 1200V and with currents in the range 6–20A.

"Wide-bandgap semiconductors like gallium nitride and silicon carbide are now well placed to meet the stringent needs of high-volume applications, bringing the promise of higher efficiency, greater power density, lower system cost and reduced operating costs for original equipment manufacturers," says Mark Roelofzen, general manager of the firm's Bipolar Discretes Group. "Nexperia's diverse portfolio of SiC diodes will bring greater choice and availability to this market," he adds.

The new SiC Schottky diodes initially target industrial and consumer applications including: switch-mode power supplies (SMPS); AC–DC and DC–DC converters; battery charging infrastructure; uninterruptible power supplies (UPS); and photovoltaic inverters.

Nexperia also plans to release automotive-grade devices for use in-vehicle electrification applications such as on-board chargers (OBC), inverters, and high-voltage DC–DC converters.

The new PSC1065H (-J/-K/-L) is the first in a portfolio of SiC Schottky diodes that Nexperia is developing to address the automotive and industrial markets.

www.nexperia.com

Chinese epi firm Tianyu chooses II–VI as primary silicon carbide substrate supplier

150mm wafers targeted at power electronics, to be followed by 200mm

Engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA – which manufactures silicon carbide (SiC) substrates – has been selected by China's Dongguan Tianyu Semiconductor Technology Co Ltd (which specializes in the R&D, design and manufacturing of SiC epitaxial wafers) as its primary strategic partner for the supply of 150mm SiC substrates for power electronics applications.

II-VI says that Tianyu (one of China's largest SiC epiwafer manufacturers) has recognized it as a long-established global supplier of 150mm SiC with the ability to achieve scale along with an aggressive 200mm substrate roadmap. "Tianyu will immediately benefit from our 150mm SiC global production capacity in the US and in China," says Sohail Khan, executive VP of II-VI's New Ventures & Wide-Bandgap Electronics Technologies business unit.

"II-VI is a world-class supplier of high-quality 150mm silicon carbide substrates," comments Tianyu's general manager Li Xiguang. "Together, Tianyu and II-VI will provide the high-quality and reliable supply chain and future 200mm capability that will be critical to support the rapidly growing demand for SiC power electronics in the mega-markets of electric vehicles, renewable energy, smart grids, micro-grids, and power supplies for data networks."

www.sicty.com

ST and A*STAR's IME team on silicon carbide R&D for automotive and industrial power electronics

Integrated devices and package modules to be developed and optimized

The Institute of Microelectronics (IME) at Singapore's Agency for Science, Technology and Research (A*STAR) and STMicroelectronics (ST) of Geneva, Switzerland have started an R&D collaboration on silicon carbide for power electronics applications in automotive and industrial markets. A*STAR reckons the collaboration sets a foundation for a comprehensive SiC ecosystem in Singapore and creates opportunities for other companies to engage with IME and ST in SiC research.

Since SiC solutions can outperform conventional silicon devices in power electronics for electric vehicles (EVs) and industrial applications in meeting the need for power modules with smaller form factors or higher power outputs (as well as higher-temperature operation), IME and ST aim to develop and optimize SiC integrated devices and package modules to offer significantly better performance in next-generation power electronics.

"Such efforts will continue to anchor high-value R&D activities in Singapore and bolster its reputation as an attractive regional hub for research, innovation and enterprise," reckons professor Dim-Lee Kwong, IME's executive director.

"This new collaboration with IME encourages the growth of a silicon carbide ecosystem in Singapore, as we ramp up our manufacturing activities there in addition to Catania (Italy)," says Edoardo Merli, Power Transistor Macro-Division general manager and VP of STMicroelectronics' Automotive and Discrete Group. "The multi-year collaborative effort helps us scale up our global R&D effort across our existing programs managed out of Catania and Norrköping (Sweden), covering the entire SiC value chain," he adds. "IME's strong knowledge and expertise in wide-bandgap materials, and notably SiC, supports us in accelerating the development of new technologies and products addressing the challenges of sustainable mobility and better energy efficiency in a wide spectrum of applications."

www.st.com
www.a-star.edu.sg/ime/Research/

UAES makes ROHM preferred supplier of SiC power devices

Japan-based power semiconductor maker ROHM Co Ltd has been certified as a preferred supplier of silicon carbide (SiC) power solutions by China's largest tier-1 automotive manufacturer United Automotive Electronic Systems Co Ltd (UAES, a joint venture established in 1995 by China's Zhonglian Automotive Electronics Co Ltd and Germany's Robert Bosch GmbH).

ROHM and UAES have been collaborating and engaging in detailed technical exchanges on the development of automotive applications utilizing SiC power devices since 2015.

In 2020 ROHM established a joint SiC technology laboratory at UAES' headquarters in Shanghai. Goals include strengthening cooperation on the development of power solutions centered on SiC, and mass production of automotive products equipped with ROHM SiC power devices such as onboard chargers for electric vehicles (EVs).

More recently, ROHM's SiC power device performance – along with power solutions that include peripheral components – were highly evaluated, resulting in ROHM being selected as the first preferred supplier in this field, it is reckoned. ROHM SiC power devices are also being used in inverter modules currently being developed by UAES to extend the cruising range of electric vehicles and reduce battery size. In the future, the two companies aim to continue to accelerate the development of SiC power solutions to achieve technical innovation for electric vehicles.

"The high rating that ROHM devices and peripheral solution proposals have received has led to ROHM being selected as a preferred supplier," says UAES' deputy general manager Guo Xiaolu. "For us at UAES, vehicle applications utilizing SiC are an important business that is about to go into full swing, and we have now entered a concrete stage of mass production of SiC-equipped inverters and other products. We would like to thank ROHM for the previous efforts and look forward to building a long-term collaborative relationship using this certification as a new start," he adds.

"As the automotive market moves quickly towards electrification, we see an important opportunity to help UAES develop advanced applications that meet customer needs," says Dr Kazuhide Ino, managing executive officer, chief scientific officer and director of Accounting & Finance Headquarters, ROHM Co Ltd. "ROHM offers a broad range of products in addition to SiC, including IPMs [intelligent power modules], IPDs [integrated passive devices], gate drivers and LED drivers that are ideal for onboard inverters and chargers," he adds. "We look forward to deepening our relationship with UAES and promoting the development of a wide range of products utilizing ROHM's cutting-edge technologies that will contribute to the further evolution of electric vehicles."

www.rohm.com
www.uaes.com

Wolfspeed quarterly revenue up 35.6% year-on-year

Growth sustained despite impact of COVID on RF device output at Malaysian contract manufacturer

For its fiscal first-quarter 2022 (ended 26 September 2021), Wolfspeed Inc (formerly Cree Inc) of Durham, NC, USA has reported a fifth consecutive quarter of revenue growth (for continuing operations) to $156.6m, exceeding the $144–154m guidance range. This is up 7.4% on $145.8m last quarter and 35.6% on $115.5m a year ago, bolstered by the rapidly expanding market for silicon carbide products.

"We are driving the transition to silicon carbide-based solutions during a period of momentous change, which is demonstrated by our expanding list of customers and formal name change," says CEO Gregg Lowe.

After divesting its Lighting Products business in May 2019 and its LED Products business in March, on 4 October Cree changed its name to that of its Wolfspeed business unit, focused on manufacturing silicon carbide materials as well as both silicon carbide (SiC) and gallium nitride (GaN) power-switching & RF semiconductor devices.

Power device revenue was up 57% year-on-year in fiscal Q1. "Momentum continued to build as our customers have a demonstrated need for our products," states chief financial officer Neill Reynolds.

"For RF, we continue to see good activity on the 5G front, but performance was slightly muted due to output challenges," says Reynolds. "We did see some supply constraints and some lower productivity during the quarter as our Malaysian contract manufacturer continued to ramp activities back up following the recent COVID-19 outbreak [which led to a seven-day closure reducing last quarter's revenue by $3–5m]. At this time, we do not expect any additional impact and to avoid shutdown as the factory continues to ramp towards the normal production schedule," he adds.

"For materials, we saw better order flow during the quarter, which we expect will continue for the remainder of the fiscal year," says Reynolds.

Driven by the solid performance in materials and improving SiC MOSFET cost and yields, non-GAAP gross margin has risen from 32.3% last quarter to 33.5% (at the top end of the 31.5–33.5% guidance range) . However, this is still down from 35% a year ago. "We view the gross margin impact as short-term in nature due to the sub-optimal device production footprint we have in North Carolina, and we expect it to modestly improve going forward as we work through factory transitions and improve yields," says Reynolds.

In May 2019, Cree began a multi-year factory optimization plan. "In Durham, we have a major expansion underway right now to continue the growth of our [silicon carbide] materials capacity," says Lowe. "The space, conversion and re-setup is actively being converted from an old lighting and office space into industrial space for significant growth of our crystal growth and epi capability [part of a plan to increase materials capacity by 30x]. Our expansion enabled us to increase the number of growers, and take advantage of our continued crystal growth technology improvements, which increased production yield." Also, in September 2019 Cree announced that the plan was being anchored by a new automated 200mm SiC device fabrication facility at Marcy in Mohawk Valley, New York State (expanding from the firm's existing 150mm-wafer SiC device fab in Durham).

Due largely to R&D, including investment in the 200mm pilot line supporting the ramp-up of the new Mohawk Valley Fab, operating expenses rose further, from $82m last quarter to $86m.

Start-up costs, primarily related to the ramp at the Mohawk Valley Fab, were about $8.6m in fiscal Q1/2022. They are expected to rise throughout the remainder of the fiscal year (coming mostly in the second half, through qualifying and ramping up the Mohawk Valley Fab), amounting to a total of about $80m for full-year fiscal 2022.

Net loss has been cut from $26.9m ($0.23 per diluted share) last quarter to $23.8m ($0.21 per diluted share), better than the guidance range of $25–29m ($0.21–0.25 per diluted share).

Cash outflow from operations was –$62.5m. Capital expenditure (CapEx) was $208.5m (up from $168.1m last quarter and $113.5m a year ago). Patent spending was $1m. Free cash outflow was hence –$272m (up from –$114m a year ago).

Cash, cash equivalents and short-term investments has hence fallen from $1154.6m, but still Wolfspeed has $857.8m of cash and liquidity on hand to support growth. "We will be opportunistic from a capital market standpoint to ensure we can have the flexibility to invest as we see fit, to continue to underpin our position in the market, and fuel future growth," says Reynolds. "We remain confident that the business is well positioned to realize its full potential as a pure-play global semiconductor powerhouse," adds Lowe.

"Our power business continues to see strong demand from the automotive markets, and we are also encouraged by the increasing demand across a number of industrial and energy customers," says Lowe. "The strength of our device opportunity pipeline, which now is about $18bn, underscores the significant demand we're seeing not only for automotive power, but also in RF, industrial and energy solutions," he adds. "At our 2019 Investor Day, we showed a $9bn

device opportunity pipeline. So, we doubled the pipeline in the last two years and now have more than 8200 potential projects. And the team continues to identify additional opportunities at a rapid pace. Meanwhile, the sales team is converting these opportunities at an impressive rate, with approximately $560m of design-ins awarded during the last quarter [and $2.9bn in fiscal 2021]. A significant portion of these [about half] were for automotive inverters, while we also continued to secure other interesting applications, including a low charger for electric vehicles, an elevator, energy storage products, and an induction cook top."

For fiscal second-quarter 2022 (to end-December 2021), Wolfspeed expects revenue to grow to $165–175m, driven by strength across all product lines, but particularly power devices. Gross margin should rise to 33.7–35.7%. Operating expense are targeted to rise slightly to $88m (after which they should continue to rise modestly each quarter as Wolfspeed invests in R&D and sales & marketing resources, says Reynolds). Net loss is targeted to be cut to $19–23m ($0.16–0.20 per diluted share).

"We are continuing to experience a significantly steeper demand curve from our customers for SiC products than we had initially expected," notes Reynolds. "This has led to supply constraints, for some customer orders will not be fulfilled in fiscal year 2022, and channel inventory levels will remain low, until we ramp our production in our Mohawk Valley Fab," he adds. "We're confident that we will be able to meet the high demand. But in the meantime we are continuing to accelerate CapEx capacity investments and our team is working hard to improve output in our Durham facilities. We are anticipating net capital expenditures of about $475m for the year, with Q1 representing the peak investment period. We'll start to see a modest step-down beginning in Q2 and continuing throughout the second half of the year as we receive more reimbursements [from the state of New York] for the Mohawk Valley construction [the firm has so far received only about $60m of the pending $500m reimbursements]. We continue to pull capacity expenditures where we can at the fiscal year 2022 to better support the steepening demand curves. We remain on track to operationalize the world's largest silicon carbide fab in the first half of calendar year 2022," he adds.

"Our massive device pipeline and continued success securing design-ins continues to give us confidence in our ability to achieve our target revenue for fiscal 2024 of $1.5bn, with current demand trends offering some potential upside based on the steepening demand for silicon carbide through 2024 and beyond," says Lowe. "Our strategy is further supported by developments in the broader market. Global electric vehicle sales are expected to be over 6 million this year according to consulting firm Wood Mackenzie. Electric vehicle sales in first-half 2021 nearly tripled worldwide compared to the first half of last year. The share of electric vehicle sales and the global passenger car sales doubled compared to the same period last year… And, as more OEMs and tier-1s leverage silicon carbide-based solutions for powertrain, on-board chargers and off-board fast chargers, which increases the vehicle's range and reduce charge times, we expect the adoption rates to continue to increase," adds Lowe. "We remain well-positioned to capitalize on these opportunities as we are in the midst of an increase in manufacturing capacity, including bringing online the world's largest SiC fab in a matter of months. In fact, we believe our capacity expansion efforts were a critical factor that led General Motors to choosing us to provide power device solutions for its future electric vehicle programs [as announced on 4 October]. Our silicon carbide devices will enable GM to install more efficient EV propulsion systems in several different models. That will extend the range of its rapidly expanding EV portfolio," continues Lowe. "The combination of Wolfspeed global leadership in silicon carbide and GM's commitment to an all-electric future — including a plan to launch 30 electric vehicles globally by the end of 2025 — establishes a powerful partnership."

Costs at Mohawk Valley are expected to be more than 50% lower than Durham, not fully including the benefit from the diameter change from 150mm for 200mm. We expect cycle times in Mohawk Valley to be more than 50% better, and yields in Mohawk Valley to be 20–30 points higher

"The key to our gross margin transition from the low 30% to 50% plus relies heavily on our fab cost footprint transition from North Carolina to Mohawk Valley," notes Reynolds. "As we transition to that new footprint and qualify the factory in 2022 and drive revenue growth into 2023 and beyond, we will see the benefits of increasing production from our advanced 200mm fab," he adds. "Wafer processing costs at Mohawk Valley are expected to be more than 50% lower than Durham, not fully including the benefit from the diameter change from 150mm for 200mm. In addition, we expect cycle times in Mohawk Valley to be more than 50% better than in Durham, and yields in Mohawk Valley to be 20–30 points higher than where we are in Durham today. We're already seeing good evidence from our Mohawk Valley pilot lines to support these projections, and anticipate a heavy margin improvement as we move to our new fab."

www.wolfspeed.com

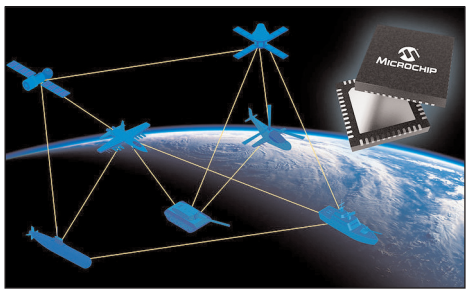
Microchip expands GaN RF power portfolio

New MMICs and discrete devices deliver performance required in 5G, satcoms and defense applications

Microchip Technology Inc of Chandler, AZ, USA has significantly expanded its gallium nitride (GaN) radio frequency (RF) power device portfolio with new monolithic microwave integrated circuits (MMICs) and discrete transistors that cover frequencies up to 20GHz. The devices combine high power-added efficiency (PAE) and high linearity to deliver new levels of performance in applications ranging from 5G to electronic warfare, satellite communications, commercial and defense radar systems and test equipment.

Like all Microchip GaN RF power products, the devices are fabricated using GaN-on-silicon carbide technology that provides the best combination of high power density and yield, as well as high-voltage operation and longevity of more than 1 million hours at a 255ºC junction temperature.

They include GaN MMICs covering 2–18GHz, 12–20GHz and 12–20GHz



with 3dB compression point (P3dB) RF output power up to 20W and efficiency up to 25%, as well as bare die and packaged GaN MMIC amplifiers for the S- and X-bands with up to 60% PAE, and discrete high-electron-mobility transistor (HEMT) devices spanning DC to 14GHz with P3dB RF output power up to 100W and maximum efficiency of 70%.

"Microchip continues to invest in our family of GaN RF products to support every application at all frequencies from microwave through millimeter wavelengths, and our product portfolio includes more than 50 devices, from low power levels to 2.2kW," says Leon Gross, VP of Microchip's discrete products business unit. "Together, the products announced today span 2–20GHz and are designed to meet the linearity and efficiency challenges posed by the higher-order modulation techniques employed in 5G and other wireless networks, as well as the unique needs of satellite communications and defense applications."

Microchip provides board design support to help with design-ins, as do the firm's distribution partners. It also provides compact models for the new GaN products that let customers more easily model performance and expedite the design of the power amplifiers in their systems.

The new power devices include the ICP0349PP7-1-300I and ICP1543-1-110I, as well as other Microchip RF products, and are available in volume production.

www.microchip.com

SEI launches high-power GaN devices for X-band radar

Devices span output powers of 24–270W with efficiencies of 37–38%

Japan's Sumitomo Electric Industries Ltd and its group company Sumitomo Electric Device Innovations USA Inc of San Jose, CA, USA, a provider of radio frequency (RF), wireless and optical communications solutions, has introduced its line of high-power gallium nitride (GaN) products for X-band radar applications.

Next-generation X-band radars face significant size, weight, power and cost (SWAP-C) challenges, notes Sumitomo Electric Industries. Among the challenges are the RF power amplifier designs used in these radar systems.

Since GaN provides very high power and bandwidth that improves performance and is a proven and reliable technology for radar applications, Sumitomo Electric has hence developed a line of high-power GaN X-band devices that enable RF solid-state power amplifiers to meet the SWAP-C challenges of these new radars while also improving reliability versus tube amplifiers.

The new product line comprises five new X-band GaN devices (with efficiencies of 37–38%):

- the 8.5–9.5GHz SGC8595-300B-R (with output power of 270W below 9.17GHz and 235W above 9.17GHz, and gain of 8.3dB below 9.17GHz and 7.7dB above 9.17GHz) in a hermetic metal/ceramic flange mount package;
- the 9.0–10.0GHz SGC0910-300B-R (with output power of 270W below 9.6GHz and 235W above 9.6GHz, and gain of 8.3dB below 9.6GHz and 7.7dB above 9.6GHz) in a hermetic metal/ceramic flange mount package;
- the 9.8–10.5GHz SGC1011-300B-R (with output power of 250W below 10.3GHz and 235W above 10.3GHz, and gain of 8.0dB below 10.3GHz and 7.4dB above 10.3GHz) in a hermetic metal/ceramic flange mount package;
- the 9.2–9.5GHz SGM6906VU (with output power of 43.7W, and gain of 21.4dB) in a hermetically sealed SMT package;
- the 8.5–10.1GHz SGM6901VU (with output power of 24W below 10.1GHz and 21.4W above 10.1GHz, and gain of 23.3dB) in a hermetically sealed SMT package.

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Navitas doubles sales volume year-on-year in Q3

Cash reserves of $260m to speed product development and expansion

For third-quarter 2021, gallium nitride (GaN) power integrated circuit firm Navitas Semiconductor of El Segundo, CA, USA and Dublin, Ireland has reported revenue of $5.6m, up 61% on $3.5m a year ago, reflecting the expansion of its product and end-customer base. Total sales volume rose by 103%, from 3 million to 6.1 million GaN ICs shipped. In total, over 30 million have now been shipped, with zero reported field failures.

Founded in 2013, Navitas introduced what it claimed to be the first commercial GaN power integrated circuits. Its proprietary GaNFast power ICs monolithically integrate GaN power field-effect transistors (FETs) and GaN drive plus control and protection circuits in a single SMT package. GaNFast power ICs have been integrated in over 135 mobile chargers, including fast chargers from Xiaomi, Dell, Lenovo, LG, Amazon, OPPO, Anker, Belkin and dozens of other major OEMs. An additional 150 GaN chargers are in development across all mobile customers worldwide.

On a non-GAAP basis, gross margin has grown from 37.6% a year ago to 46.2% in Q3/2021. However, net loss was $6.6m ($0.39 per share), up from $3.8m ($0.26 per share).

After using cash to fund operations, meet working capital requirements, for capital expenditures and strategic investments, total cash and cash-equivalents fell by $27.8m during the quarter to $11.1m. Total debt outstanding rose by $1.7m to $7.7m.

"We expect to continue to incur net operating losses and negative cash flows from operations and we expect our R&D expenses, general and administrative expenses and capital expenditures will continue to increase," says the firm. "We expect our expenses and capital requirements to increase in connection with our ongoing initiatives to expand our operations, product offerings and end-customer base."

After the quarter, on 19 October, Navitas completed its de-SPAC business combination with Live Oak Acquisition Corp II — a publicly traded special-purpose acquisition company (SPAC). Navitas' common shares and warrants begin trading on 20 October on the Nasdaq Global Market (under the ticker symbols 'NVTS' and 'NVTSW'), when CEO & co-founder Gene Sheridan rang the opening bell at the Nasdaq MarketSite. Gross proceeds raised in the business combination transaction were $325m. With about 117.7 million shares outstanding, Navitas has $260m in cash and cash equivalents to support growth.

Navitas expects that the additional capital will accelerate product development and expansion from its industry-leading position in GaN mobile fast chargers into consumer, enterprise, solar and electric vehicle (EV) markets, as well as providing funds for non-organic growth. "We expect our historical focus on near-term working capital and liquidity to shift to more strategic and forward-looking capital optimization plans," says Navitas. "The influx of capital from the business combination is sufficient to finance our operations, working capital requirements and capital expenditures for the foreseeable future." The firm's personnel strength has grown by about 50%, to about 150 staff worldwide. Also, new offices and teams in China and Europe are addressing expansion markets.

For fourth-quarter 2021, revenue is expected to grow about 60% year-on-year to $7.4m (±5%). Gross margin should be about 44%.

"Worldwide GaN penetration in the $2bn fast-charger market is estimated at only 2–3% so far, so we expect a fast revenue ramp ahead in mobile plus the higher-power expansion markets of data center, solar and EV," says co-founder & CEO Gene Sheridan. "Couple that with next-gen technology introductions, growing team strength and more than 130 patents issued or pending, and we have an extraordinary opportunity in front us is to become the next-generation power semiconductor leader."

www.navitassemi.com

Navitas concludes $30m forward-purchase transaction

Navitas has concluded a prepaid, forward-purchase transaction, resulting in the removal of restrictions affecting $30m of cash on the company's balance sheet and 3,000,000 outstanding shares of Navitas common stock.

On 6 October, Navitas (then known as Live Oak Acquisition Corp II (LOKB)) entered into a prepaid forward-purchase agreement with an affiliate of privately held, SEC-registered alternative investment advisory firm Atalaya Capital Management LP. Per the agreement, Atalaya had the right to purchase up to 3,000,000 LOKB shares from shareholders who had redeemed shares, or indicated an interest in redeeming shares, prior to the closing of LOKB's business combination transaction with Navitas. The agreement provided for Atalaya to sell the shares it purchased to Navitas within two years, at the redemption price in effect prior to closing. Atalaya also had the right to sell the shares to others during the two-year term, concluding the forward purchase obligations with Navitas in an amount corresponding to the number of shares sold.

On 18 November, Atalaya notified Navitas that it had sold all 3,000,000 shares covered by the agreement in open-market transactions. As a result, a total of about $30m has been remitted to Navitas, free of any restrictions.

Navitas launches third-generation GaN power IC with GaNSense technology

Real-time autonomous sensing and protection circuits improve reliability and robustness while boosting energy savings and fast-charging

Gallium nitride (GaN) power integrated circuit firm Navitas Semiconductor of El Segundo, CA, USA and Dublin, Ireland has launched its third-generation GaNFast power ICs with GaNSense technology. GaNSense integrates critical, real-time autonomous sensing and protection circuits, further improving reliability and robustness while increasing the energy savings and fast-charging benefits of Navitas' GaN IC technology.

GaNSense technology integrates real-time, accurate and fast sensing of system parameters including current and temperature. This enables a patent-pending loss-less current-sensing capability, which improves energy savings by up to an additional 10% compared with prior generations, as well as further reducing external component count and shrinking system footprints. In addition, if the GaN IC identifies a potentially dangerous system condition, it is designed to transition rapidly to a cycle-by-cycle sleep-state, protecting both the device and the surrounding system. GaNSense also integrates an autonomous standby-power feature that automatically reduces standby power consumption when the GaN IC is in idle-mode, helping to further reduce power consumption, which is especially important to the growing list of customers aggressively pursuing their own environmental initiatives.

With what is claimed to be the industry's tightest current-measurement accuracy and GaNFast response time, GaNSense technology means reducing dangerous over-current spikes by 50% and reducing time in the 'danger zone' by 50% compared with previous best-in-class solutions. GaNFast monolithic integration delivers dependable, glitch-free operation

with no 'ringing', for improved system reliability, says Navitas.

"From detection to protection in only 30ns, GaNSense technology is 600% faster than discrete GaN implementations," reckons chief operating officer/chief technology officer & co-founder Dan Kinzer. "This next generation from Navitas provides a highly accurate and effective defense against potential system failure modes. Couple that with immunity to transient voltages up to 800V and tight gate waveform control and voltage regulation, only possible with our proprietary process design kit, and you have a new standard in reliability, robustness and performance for power semiconductors," he claims.

The new family of GaN power ICs with GaNSense technology spans 10 products, which all have the core, critical GaNFast integration of GaN power, GaN drive, control and protection. All are rated at 650V/800V with 2kV ESD protection, and $R_{DS(ON)}$ of 120–450mΩ in 5mm x 6mm and 6mm x 8mm PQFN packaging… with the GaNSense protection circuits and loss-less current-sensing. This family of third-generation GaN ICs is optimized for modern power conversion topologies including high-frequency quasi-resonant (HFQR) flyback, active-clamp flyback (ACF) and PFC (power factor correction) boost, which are popular for delivering the fastest, most efficient and smallest chargers and adapters in the mobile and consumer markets.

Target markets include fast-chargers for smartphones and laptops, with an estimated GaN potential of $2bn/year, and another $2bn/year consumer market including all-in-one PCs, TVs and home networking and automation. GaNSense technology is already used in Lenovo's YOGA 65W laptop charger.

To date, over 30 million GaNFast power ICs have shipped, achieving over 116 billion device hours in the field — with zero reported GaN field failures. Each GaNFast power IC shipped has a 4–10x reduced carbon footprint and saves 4kg of CO_2 compared with legacy silicon chips, it is reckoned.

GaNFast power ICs with GaNSense technology were showcased at the following events in November:

- WiPDA 2021 (virtual) by COO/CTO & co-founder Dan Kinzer;
- CPSSC 2021 (Shanghai) by Dr Xiucheng Huang, senior director, Applications;
- PSMA Power Technology Roadmap (virtual) by Dan Kinzer.

GaNFast power ICs with GaNSense technology are in mass production with immediate availability. Full technical details of the new GaNSense technology, including datasheets, qualification data, application notes and samples are available to customer partners under non-disclosure agreement (NDA).

www.navitassemi.com

Navitas and Anker sign strategic partnership for next-generation mobile fast chargers

New 30W and 65W fast chargers first in a new series

Gallium nitride (GaN) power integrated circuit firm Navitas Semiconductor of El Segundo, CA, USA and Dublin, Ireland and consumer electronics firm Anker Innovations of Changsha, Hunan, China have signed a new strategic partnership.

Anker and Navitas have an established relationship, starting in 2017 when Anker was one of the first companies to create fast-charger prototypes and then qualify the new GaN technology. The 2019 Anker PowerCore Fusion PD combination charger and portable power bank used Navitas' GaNFast power ICs to reach higher levels of efficiency and power density.

"Having engineering teams from Anker and Navitas sitting side by side on a daily basis will greatly improve the efficiency of the product development process, translating into faster and better chargers for our customers," believes Anker Innovations' CEO Steven Yang.

The new agreement dedicates engineering teams from both Navitas and Anker to be co-located at Anker offices to develop and launch GaNFast chargers to accelerate time-to-market. The initial focus will be on next-generation mobile chargers but will expand into the high-growth energy-storage markets. The deal also provides a longer planning horizon for co-operative marketing across all media platforms and in-person events, such as January's Consumer Electronics Show (CES) in Las Vegas.

"As both a long-term customer and investor in Navitas, Anker has demonstrated a passion for innovation and vision for the future of charging," says Navitas' co-founder & CEO Gene Sheridan. "Mobile charging is a $2bn target market for GaN power ICs, and working with Anker on energy storage is aligned with our renewable/solar energy expansion strategy."

The first two fast chargers released under the new partnership are the 30W USB-C and 65W 2C+A chargers in Anker's collaboration with the 'League of Legends' multiplayer online battle arena video game, played on phones, tablets and laptops. With fast action and intensive, detailed graphics, the game has a high draw on battery power, and fast charging — with portability — is crucial.

At only 28mm x 29mm x 32mm, the 30W USB-C 'Jinx' is a similar size to the original 5W so-called 'sugar-cube' phone charger and 70% smaller than the standard silicon-based 30W.

The 65W 2C1A 'Yasuo' charger has 2x USB-C and 1x USB-A port to simultaneously charge three devices (such as a phone, headphones and a laptop) with enough power for high-performance gaming laptops.

www.navitassemi.com

Navitas' co-founder & COO/CTO gives keynote at IEEE WiPDA

Navitas' co-founder & chief operating officer/chief technology officer Dan Kinzer hosted a keynote session at the IEEE WiPDA (Wide Bandgap Power Devices & Applications) virtual workshop (7–11 November).

Sponsored by the IEEE Power Electronic Society (PELS), the IEEE Electron Devices Society, and the Power Sources Manufacturers Association (PSMA), the eighth annual IEEE WiPDA workshop provides a forum for device scientists, circuit designers and application engineers from the Power Electronics & Electron Devices Societies to share technology updates, research findings, experience and potential applications. During the Navitas keynote, Kinzer updated the audience on how innovations in GaN power ICs are driving improvements in efficiency, reliability and autonomy.

"The organizing committee is privileged to invite exceptional keynote speakers of industry leaders from large semiconductor manufacturers, dynamic and fast-emerging start-ups, academia and national research laboratories," comments WiPDA 2021's general chair Dr Sameh G. Khalil. "We wanted this key component of WiPDA 2021 to highlight the vision and the direction that industry leaders are projecting, share their high-level roadmaps and their plans for the future," he adds.

"As well as enabling efficiency improvements that reduce the carbon emissions of target applications, small die-size, fewer manufacturing process steps and integrated functionality mean that GaNFast power ICs have up to 10x lower CO_2 footprint than silicon chips and save 4kg of CO_2 per IC shipped when compared to legacy silicon systems," says Kinzer.

Kinzer's 40-year career led to him being inducted into the International Symposium on Power Semiconductor Devices and ICs (ISPSD) inaugural Hall of Fame in 2018. His experience includes developing advanced power device and IC platforms, wide-bandgap GaN and SiC device design, IC and power device fabrication processes, advanced IC design, semiconductor package development and assembly processes, plus the design of electronic systems. Kinzer holds over 130 US patents, and a BSE degree in Engineering Physics from Princeton University.

www.wipda.org

Gallium Semi chooses Nijmegen for European R&D center

Center to support GaN product development, customer application support and manufacturing operations

Singapore-based Gallium Semiconductor has launched its European research and development center in Nijmegen, Netherlands.

Gallium Semi says that its strategic choice of Nijmegen is based on the recognition of it being a European innovation hub for RF power technology with a very talented pool of engineers. The new R&D center is targeted at GaN semiconductor product development, device design, customer application engineering and production support.

"Nijmegen is the vibrant heart of Europe's RF power technology and our presence here will allow us to expand our team with world-class talent," says Michael Guyonnet, Gallium Semi's vice president of Networks.

The firm says that it will use the Nijmegen R&D center as an opportunity to work closely with global customers to design, test and commercialize RF GaN semiconductor solutions for 5G mobile communications, aerospace & defense, and industrial, scientific & medical applications. "With so much expertise in RF engineering and manufacturing operations, we are able to leverage the most advanced technology to drive our product development," says CEO Kin Tan.

www.galliumsemi.com

Navitas and Compuware partner to upgrade data-center power supplies

Power supply firm targets EU's 80 Plus 'Titanium' efficiency for 2023

Gallium nitride (GaN) power integrated circuit firm Navitas Semiconductor of El Segundo, CA, USA and Dublin, Ireland and Compuware Technology Inc (which provides high-end, green-energy power supplies) have announced a partnership to define new benchmarks for data-center power supplies. With 44% of data-center costs being related to power (electricity, power conversion and cooling), an upgrade to GaN-based data centers could save over 15TWhr or up to $1.9bn/year, which represents a 6x return on investment in a year, it is reckoned.

Founded in 2014, Navitas introduced what it claimed to be the first commercial GaN power ICs. Since GaN is reckoned to run up to 20x faster than silicon chips, the firm's proprietary GaNFast power ICs are said to deliver up to 3x faster charging or 3x more power in half the size and weight, and with up to 40% energy savings, for applications in the mobile, consumer, enterprise (data center, 5G), renewables (solar, energy storage) and electric vehicle (EV)/eMobility markets.

"GaN is a breakthrough new technology that is enabling dramatic reductions in size, energy savings and power density for data-center power supplies," says Robin Cheng, VP of Compuware's R&D team. "Navitas is an excellent partner with industry-leading GaN IC technology that integrates GaN power, GaN drive, plus control and protection to widen our horizon of GaN and cooperate to create new, breakthrough standards for high-performance computing, as the world's demand for data increases," he adds.

Typical data centers using silicon to process power achieve only 75% end-to-end efficiency from 'AC-to-processor'. A GaN-based data center is expected to reach 84% (representing a 36% increase in energy savings).

Since 2014, Compuware has introduced more 'Titanium-certified' power supplies than any other company, it is claimed. More than a third of the highest-efficiency-grade models certified are from Compuware, and the firm ships over 2 million server power supplies each year, with Supermicro as a lead customer. With an estimated $25 of GaN content per power supply, this represents a $50m per year opportunity.

The new benchmarks are not only enabled by GaN technology but also demanded by legislation such as the European Union's 'Directive 2009/125/EC, 2019 Annex', which states that new data-center power supplies must meet the extreme 80 Plus 'Titanium' level of efficiency from 1 January 2023.

"Navitas and Compuware are aligned on extreme efficiency gains and critical environmental impact," says Navitas' CEO & co-founder Gene Sheridan. "Together, I am confident we will set the efficiency, energy consumption and CO_2 benchmarks for the industry with the future of GaN-based data centers."

Manufacturing a GaN power IC has up to a 10x lower CO_2 footprint than for a silicon chip and — also considering the use-case efficiency, material size and weight benefits — then GaN can collectively save 4kg of CO_2 for every GaN IC shipped. Overall, GaN is expected to address a 2.6Gton/year reduction in CO_2 emissions by 2050. With over 13 million servers shipped per year, each with over $75 of GaN content, data centers represent an opportunity of about $1bn+ per year for GaN.

www.navitassemi.com

GaN Systems raises $150m in growth capital funding

Led by Fidelity, joined by new investor Vitesco plus BMW i Ventures

GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) has announced a US$150m growth capital funding round to accelerate innovation and adoption of GaN technology across its automotive, consumer, industrial and enterprise markets.

The fundraising round was led by Fidelity Investments (celebrating 75 years since its founding, with US$4.2 trillion in assets under administration), joined by new strategic investor Vitesco Technologies (an international developer and manufacturer of powertrain technologies for sustainable mobility) plus existing investors including BMW i Ventures.

GaN Systems says it will use the new funding to fuel the rapid market penetration of GaN as global power electronics companies shift from legacy silicon devices to small, low-cost, efficient power systems.

Vitesco has announced a broad strategic partnership with GaN Systems to enable GaN solutions across the electric vehicle (EV) platform. This follows GaN Systems' announcement in September of a capacity agreement with BMW.

"By combining our automotive know-how with our partner's GaN expertise, we will be able to reap the benefits of comprehensive wide-bandgap technology in the car," says Thomas Stierle, member of the executive board and head of Vitesco Technologies' Electrification Technology business unit.

"The demand for higher-performing, more efficient power electronics is growing exponentially, and traditional silicon solutions cannot keep up," says GaN Systems' CEO Jim Witham. "Gallium nitride takes the baton from legacy silicon to enable smaller platforms to run cooler and use fewer materials," he adds, claiming that GaN Systems is the only GaN power transistor company currently shipping to automotive, consumer, industrial and data-center customers. "Our relationships with industry leaders and our $8bn pipeline tell us that the GaN inflection is here, and the time is now to accelerate investment in the business."

With more than 200 billion device field hours, global companies (including industry leaders like Dell, Samsung, HARMAN, Siemens, Signify and Philips) rely on GaN Systems' transistors to reduce levels of CO_2 emissions and increase the utility and energy efficiency of their power systems. GaN Systems says that, with just a small change in the electronics design, its transistors enable design engineers to significantly decrease the size, weight and power lost by 4x while reducing overall system costs.

USI partnering to co-develop power modules for EVs

USI acquiring minority stake as part of growth capital round

GaN Systems has announced a strategic partnership with Universal Scientific Industrial Co Ltd (USI) — a subsidiary of Taiwan-based ASE Technology Co Ltd — to co-develop GaN power modules for the electric vehicle (EV) market. As part of the strategic partnership, USI is acquiring a minority stake in GaN Systems as part of its recent $150m growth capital round.

As the electric vehicle shifts from using legacy silicon power transistors to the increased performance of GaN, power modules are also transitioning to meet the demands of low heat loss and superior voltage control in the power conversion process, notes GaN Systems. GaN power modules enable higher efficiency, increased EV range, and increased EV performance, the firm notes.

"We have worked with GaN Systems for years and are impressed with the company's leadership in high-reliability, automotive-qualified GaN — an essential building block for EVs," comments JP Shi, USI's senior VP of strategic investment. "We look forward to building optimized and highly efficient modules that will be the cornerstone of best-in-class DC–DC converters, on-board chargers, and traction inverters."

The heart of the EV traction drivetrain is the semiconductor power module. USI has more than 20 years of experience in power electronics manufacturing of various package types and high-reliability modules, including power modules, IPMs (intelligent power modules), DC/DC converters, and RF power transistors. It has been recognized by OEMs and tier-1 suppliers in the automotive sector by introducing the automotive functional safety standard ISO26262 and being certified with Chapters II and VII for manufacturing.

"With today's announcement, USI joins our ecosystem of partners working to bring leading GaN technology to EVs," says Stephen Coates, general manager & VP of operations at GaN Systems. "Through this partnership, we bring together USI's leadership in complex, high-power integrated modules with our high-reliability GaN semiconductor technology to build truly disruptive, game-changing modules for next-generation EVs," he adds. "Building on our deep industry relationships with leaders like BMW, Toyota, and Vitesco, GaN Systems and USI will work together to accelerate GaN adoption across the EV platform."

www.gansystems.com

HG makes strategic investment in GaN Systems

Hong Kong-based HG Semiconductor subsidiary FastSemi Holding Ltd has invested in GaN Systems, and agreed to invest by subscribing for series F-2 convertible preference shares in GaN Systems as a strategic investor.

GaN Systems' current growth capital funding round (to raise $150m) is aimed at accelerating innovation and adoption of GaN technology across its automotive, consumer, industrial and enterprise markets. HG's strategic investment is also joined by existing investor BMW i Ventures, along with Fidelity, Vitesco Technologies and others. Following this investment, HG will be able to nominate an independent board observer from Canada to be on the board of GaN Systems.

HG's activities include the design, development, manufacturing, subcontracting services and sale of LED beads, LED lighting products, fast-charging products and a new generation of GaN-based products. Leveraging its industrial expertise in LED manufacturing, HG has been accelerating its R&D and expanding its business to various kinds of semiconductors including GaN-based products, through the integration of design, manufacturing and sale of chips. In particular, the firm strategically holds a 21.86% stake in Israel-based VisIC Technologies Ltd (a fabless supplier of GaN-based power conversion devices), using their respective strengths to develop GaN-based chips and products.

To further deepen its presence in the GaN sector, HG says it aims to capitalize on the extensive experience, resources and expertise of GaN Systems.

"The group expects this strategic investment will lay a solid foundation for its future development and prospects in its GaN semiconductor business. Upon completion of the investment, we expect both the group and GaN Systems may have the opportunity to pool our respective advantages to each other, creating synergistic effects," says HG's chairman & executive director Zhao Yi Wen. "In particular, GaN Systems can provide dedicated technical support (from Ottawa, California and Taiwan) to the group for process definition and qualification of GaN device manufacturing to achieve best-in-class yield targets and targeted qualifications. Such technical support may include elements of the developed process that are proprietary to GaN Systems only, and alignment on intellectual property strategy for resulting process know how," he adds. "The group will also be able to obtain technical support for reference design in Internet data center (IDC) power systems, electric vehicle (EV) and solar inverter applications from GaN Systems on most-favored-nation terms. GaN Systems also proposes to qualify the subsidiary of the group as a foundry partner to GaN Systems and enter into a licence agreement whereby the group may use certain GaN technology of GaN Systems for manufacturing its semiconductors components."

Share placement to fund R&D on GaN electronic devices

HG Semiconductor has completed a placing of 14,346,000 shares (about 2.55% of its issued share capital) to not less than six placees at a price of HK$6.20 per share.

After deducting professional fees and other related expenses, net proceeds were about HK$86.2m. About HK$64.3m will be used to strengthen R&D in LEDs, mini-LEDs, fast charging products, and GaN devices and related semiconductor products. Some will also be used to set up of R&D centers, recruit R&D staff and procure equipment and materials in order to develop and acquire patents and technology. The remaining HK$21.9m will be used for general working capital and boosting the firm's financial position.

HG says that, using its industrial semiconductor manufacturing expertise, it has been expanding to various kinds of semiconductors including GaN-related products. HG is hence setting up a new factory in the Xuzhou Economic and Technological Development Zone, comprising 7000m^2 of cleanroom space and 850m^2 of office area. A production line for GaN-based electronic products will be installed, and upgraded to full automation in the future.

The firm has added core members to its Technology & Manufacturing team. Xuzhou Factory general manager Dr Chen Zhen has over 20 years of experience in R&D, production and management in GaN-based optoelectronics, including full-band solid-state light-emitting devices as well as proprietary technology for 8" silicon-based GaN epi growth. Chen has applied for over 30 domestic and foreign patents.

Xuzhou Factory operation deputy general manager Lu Juilin has over 30 years of experience in semiconductor industry and foundry technology and management, including managing 8–12" fabs and 55nm to 0.5μm processes. He also has experience in building new factories and as factory manager for SMIC and Hua Hong Semiconductor (HHS).

Senior consultant Dr Chang Ru Gin is SMIC's founder and former CEO. Xuzhou Factory research deputy general manager Dr Thomas Hu has over 20 years of experience in GaN device design and fabrication, including GaN HEMTs. Hu is experienced in process control, fab operation and management and is in charge of new process recipe development, process optimization, new product development, product quality control and yield improvement for GaN HEMT devices and products.

www.hg-semiconductor.com

Transphorm turns profit as product revenue grows 30%

$50m in equity financing since June to aid uplisting to NASDAQ

For fiscal second-quarter 2022 (to end-September 2021), Transphorm of Goleta, near Santa Barbara, CA, USA — which designs and makes JEDEC- and AEC-Q101-qualified gallium nitride field-effect transistors (FETs) for high-voltage power conversion applications — has reported revenue of $11.3m, up from $3.2m last quarter and $1.9m a year ago.

Growth was driven by licensing revenue related to ongoing development work with a manufacturing partner plus record product sales from ramping shipments of GaN devices for power conversion applications. Product revenue rose sequentially for a seventh quarter and grew 30% year-on-year to a quarterly record.

"We continued to ramp device shipments in support of expanded design-ins going into production," says president & co-founder Primit Parikh. "Product revenue in the first half of fiscal 2022 has exceeded the revenue contribution from products for the full fiscal year of 2021, driven by growing traction with our GaN devices in fast chargers and adaptors as well as high-power gaming, server and crypto-mining applications. Additionally, we continued to lay the foundation for significant future growth highlighted by the recently achieved automotive qualification of our SuperGaN Gen IV FET device. With strong customer momentum and strong blue-chip strategic partnerships, we expect continued product revenue growth in the coming quarters."

Highlights during the quarter included continued momentum on adaptor and fast-charger market penetration, including partnerships with leading controller and integrated driver makers. Also, Transphorm achieved automotive qualification of its SuperGaN Gen IV multi-kilowatt-class power FET. The firm was also awarded a $1.4m GaN development contract by the US Defense Advanced Research Projects Agency (DARPA).

On a non-GAAP basis, operating expenses were $4.45m, up from $3.5m a year ago but cut slightly from $4.59m last quarter.

Net income was $3.6m ($0.09 per share), compared with net losses of $5.3m ($0.13 per diluted share) last quarter and $5.3m ($0.15 per diluted share) a year ago. Cash and equivalents remained $2.5m at the end of the September quarter.

During the quarter, Transphorm completed the transaction for its AFSW wafer fab in Aizu Wakamatsu, Japan to be acquired by GaNovation, its joint venture formed recently with its new Palo Alto-based strategic financial partner JCP Capital. The AFSW fab was previously a JV with Fujitsu Semiconductor Ltd (FSL).

After the end of the quarter, in October, strategic partner Yaskawa Electric Corp of Kitakyushu, Japan (a manufacturer of low- and medium-voltage variable-frequency drives, servo motors, machine controllers and industrial robots) converted 100% of its $15.6m Transphorm convertible notes into common stock at $5 per share.

In subsequent private placement transactions completed in early November, the firm closed $33m of equity financing at $5 per share, comprising follow-on investments of $5m by KKR and $10m by Sino-American Silicon Products (SAS) as well as participation by institutional investors. This followed the closing of a $5m initial private placement by SAS in August.

"We have significantly strengthened our balance sheet and cash position while also realizing a $50m increase in shareholder equity since June," notes chief financial officer Cameron McAulay. "The company is now positioned to meet the qualification requirements for uplisting Transphorm's common stock to the NASDAQ.."

www.transphormusa.com

SAS makes $15m investment in strategic partnership

GWC to be manufacturing partner for GaN epi; SAS to distribute

Transphorm has partnered with Taiwan-based SAS (Sino-American Silicon Products), the parent firm of GlobalWafers Co Ltd (GWC, one of the world's three largest silicon wafer manufacturers) to expand its supply chain for GaN epiwafers.

Also, SAS has made a $15m equity investment into Transphorm (including an initial $5m in August) through a private placement of common stock at $5 per share. This joins equity financing of $23m made through a private placement of Transphorm shares to KKR Phorm Investors L.P. and several US institutional investors.

The deal includes GWC becoming manufacturing partner and supplier captive for Transphorm GaN epiwafers, augmenting Transphorm's internal capacity. Also, SAS will distribute select Transphorm epiwafer products as well as power products.

"Our strategic partnership will enable Transphorm to scale at a faster pace," says SAS/GWC's chairwoman & CEO Doris Hsu.

"This partnership will allow for our rapid expansion in the GaN market, with a multi-year growth plan to scale GaN epiwafer manufacturing for Transphorm, while protecting our intellectual property," says Transphorm's co-founder & president Primit Parikh. "It will provide Transphorm's customers — from compact high-speed fast charger to efficient higher-power electric vehicles — the security of supply, multiple locations (including our core US manufacturing), and rapid expansion capability," he adds.

www.sas-globalwafers.com

Transphorm's SuperGaN Gen IV multi-kW-class power FET gains AEC-Q101 qualification

Flagship SuperGaN Gen IV 35mΩ device represents the firm's third automotive-qualified product line

Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and manufactures gallium nitride (GaN) field-effect transistors (FETs) for high-voltage power conversion applications — says that its flagship SuperGaN Gen IV 35mΩ device has completed the Automotive Electronics Council's AEC-Q101 stress tests for automotive-grade discrete semiconductors, representing the firm's third automotive-qualified product line.

As with its Gen III predecessor, the Gen IV TP65H035G4WSQA device is qualified to 175°C. This junction temperature is 25°C higher than what silicon MOSFETs qualify at and is a temperature rating yet to be achieved by any other GaN solution, some of which are only qualified to 125°C, says Transphorm.

"With each generation of its GaN platform, Transphorm has increased device performance, increased power density, increased manufacturability, all while bringing the device price down closer to that of silicon devices," comments Richard Eden, senior principal analyst at Omdia. "The automotive market is beginning to see increased interest in the benefits of GaN technology and Transphorm, having a strong AEC-Q101-qualified GaN portfolio, can fuel that adoption," he adds. "Omdia believes that the early adoption of GaN transistors within the multi-billion-dollar automotive market could pass $100m by 2025."

High-voltage GaN solutions positively address several electric vehicle (EV) issues. For example, GaN delivers higher power conversion efficiency from the EV battery to its drive train, enabling the use of either a smaller battery for the same range or the same size battery for extended range, reducing range anxiety.

Additionally, GaN FETs operate at higher frequencies, resulting in higher power density as well as smaller and lighter systems. These advantages benefit on-board chargers (OBCs), DC-to-DC converters, and main traction inverters while also contributing to larger battery range and faster charging. These three highlighted critical systems make battery electric vehicles (BEVs) not only drive but function properly, and GaN plays a part in all.

With each generation of its GaN platform, Transphorm has increased device performance, increased power density, increased manufacturability, all while bringing the device price down closer to that of silicon. The early adoption of GaN transistors within the multi-billion-dollar automotive market could pass $100m by 2025

The AEC-Q101-qualified TP65H035G4WSQA FET delivers a typical on-resistance of 35mΩ in an industry-standard, thermally superior TO-247 package — a package configuration that is not available in any version of e-mode (enhancement-mode) GaN, it is claimed. Via its patented SuperGaN technology, the device also offers:

- A flatter and higher efficiency curve with an improved figure of merit ($R_{ON}xQ_{OSS}$) that shows 27–38% reduction in power loss over silicon carbide (SiC) in a similar TO-247 package-based comparison.
- Reduced package inductance, resulting in softer switching, which helps to reduce electromagnetic interference (EMI).
- Increased noise immunity (threshold voltage at 4V), eliminating sporadic turn-on due to gate transients to which other GaN technologies with threshold voltages less than 2V are susceptible in higher-power systems.
- The industry's most robust gate at ±20V, it is claimed.

These advantages produce quieter switching and higher performance at higher current levels with minimal external circuitry compared with what other GaN devices such as e-mode require to maximize power density, reliability and system cost.

"We view GaN power semiconductors as a major differentiator in our automotive electric powertrain solutions," says Joachim Fetzer, chief technology & innovation officer at Marelli — a global independent suppliers to the automotive sector as well as a strategic Transphorm partner. "We partnered with and have invested in Transphorm as we see their commitment to quality, reliability and manufacturing is unmatched by any other GaN supplier today," he adds. "The automotive qualification of their SuperGaN Gen IV device is just one more proof point. It stands as a cost-effective, high-performing solution for our applications — allowing us to gain a competitive edge not just in performance and efficiency but in overall system advantages. With Transphorm, we aim to deliver more reliable electric power at a reasonable cost to our customers."

Transphorm's AEC-Q101 qualified TP65H035G4WSQA FET will be available in early December. The device is based on its JEDEC-qualified predecessor, the TP65H035G4WS, which is currently available from distributors Digi-Key and Mouser.

www.transphormusa.com

Diodes Inc and Transphorm introduce 130W ACF SuperGaN USB-C PD adapter evaluation kit

Kit pairs Diodes Inc's active clamp flyback controllers and Transphorm's normally-off SuperGaN Gen IV FETs with input PFC

Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and manufactures JEDEC- and AEC-Q101-qualified gallium nitride (GaN) field-effect transistors (FETs) for high-voltage power conversion applications — says that power semiconductor product supplier Diodes Inc of Plano, TX, USA has launched a complete 130W USB Type-C power delivery (PD) 3.0 adapter evaluation and development kit that uses its SuperGaN FETs.

The kit pairs Diodes' high-performing active clamp flyback (ACF) controllers and Transphorm's patented normally-off SuperGaN Gen IV devices with input power factor correction (PFC). The resulting solution delivers low standby power, higher efficiency, what is claimed to be unprecedented thermal performance, and optimal system bill-of-materials (BOM) cost compared with enhancement-mode GaN and silicon-based systems. It exceeds DOE VI and COC Tier 2 power efficiency requirements and allows for increased power density.

Diodes' ACF solutions are designed to leverage next-generation power conversion technologies in configurations offering greater performance than traditional flyback systems and significantly lower cost than half-bridge resonant LLC solutions in USB PD charging applications. The new 130W ACF SuperGaN kit is no exception, enabling easy and quick evaluation of advanced technologies while accelerating go-to-market timelines, it is reckoned. Capabilities include: high power peak efficiency (>93.5%); high power factor (>0.90 over line over 60% load); ultra-low total harmonic distortion (THD) (<18% over line over 60% load); low standby power (<43mW); and the lowest switch temperature (<75°C).

The kit uses three main Diodes controllers and two SuperGaN FETs from Transphorm:

- AP3306: A highly integrated ACF controller designed for ultra-low standby power and high power density requirements, with comprehensive protection mechanisms incorporated;
- APR340: A MOSFET driver intended for secondary-side synchronous rectification;
- AP43771V: A USB Type-C PD3.0 decoder, with on/off N-channel MOSFET control and robust protection features; and
- TP65H150G4LSG devices: SuperGaN 650V, 150mΩ FETs, with one each for the PFC control and ACF control stages, respectively.

"Diodes' AP3306 ACF controller allows high integration, low standby power, optimal system cost, and versatile protection for a wide range of power adapters from 45W to 140W, while our AP43771V USB-PD controller with PPS provision has an MCU with virtual multi-time programmable area for customization, supporting different quick charger power profiles," says Ernest Lin, Diodes' division manager, ACDC Power & Lighting (APL) Division. "Transphorm's SuperGaN technology enables us to deliver the highest-efficiency, lowest-device-temperature and ultimately high-power-density adapter system that is easy to drive without requiring any additional drivers or complex interfacing," he adds.

"The development kit from Diodes, an innovator and provider of multiple controllers in the USB-PD adapter market, is an invaluable opportunity to help customers quickly realize the benefits of GaN power conversion for high-performance notebooks," comments Tushar Dhayagude, VP, technical sales & field applications, Transphorm. "The adapter market is only beginning to realize the power and cost savings with advanced ACF topology, as we see more chargers greater than 100W hit the market," he adds. "Transphorm's SuperGaN FETs combine the highest efficiency with the simplicity of design and drivability along with the most robust and highest gate noise immunity in the market."

The simple-to-use 130W USB PD ACF kit allows manufacturers to quickly customize and implement 90W to 150W adapter designs with USB-C, PPS, and multi-protocol configurations. This kit is now available upon request from Diodes.

www.diodes.com
www.transphormusa.com

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GaN epi startup IVWorks raises $17.4m in Series C round

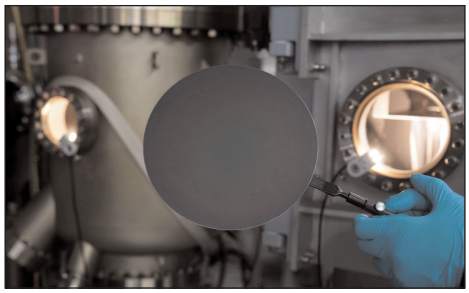
New funds to be used to expand production capacity and develop AI-based production platform

IVWorks Co Ltd of Daejeon, South Korea — which was founded in 2011 and manufactures 100–200mm gallium nitride (GaN) epitaxial wafers for RF & power electronics applications — has raised $17.4m in its Series C funding round.

This investment follows the $6.7m raised in December 2019's Series B round. Companies including YG Investment, Korea Investment & Securities, WONIK Investment Partners, Log Investment, Wooshin Venture Investment, Deslaube PEF and Hyundai Venture Investment have invested a total of $17.4m in new and existing shares.

Characterized by high efficiency and high output power, GaN epiwafers are core materials used in power and RF (radio frequency) devices for applications including fast chargers for IT products, electric vehicle (EV) power convertors, 5G base stations, and defense radars.

IVWorks says that it has used its



self-developed technology of a highly efficient and eco-friendly epitaxy system as well as an artificial intelligence (AI)-based production platform to produce 6–8-inch gallium nitride on silicon (GaN-Si) epiwafer products used in power devices and 4–6 inch gallium nitride on silicon carbide (GaN-SiC) epiwafer products used in RF devices.

The latest funds were secured through new investments and are planned for use in expanding production capacity and developing the AI-based production platform. In particular, recent market circumstances (e.g. the application of GaN fast chargers in the IT products of Apple, Samsung, Huawei etc, and increasing use of GaN power devices in EV onboard chargers and power convertors) have been reflected in this funding round. IVWorks says that the latest fundraising demonstrates its interest in maintaining differentiated technology competencies and focusing on scaled growth in response to market demand. Furthermore, to proceed with listing on the KOSDAQ (Korean Securities Dealers Automated Quotations) trading board of the Korea Exchange (KRX), IVWorks has entered into a contract with the Korea Investment & Securities listing underwriter and commenced a fully fledged initial public offering (IPO).

"Additional collaborations with global semiconductor companies and strategic investments are in progress," notes says IVWorks' CEO Young-Kyun Noh.

www.ivwkr.com

onsemi completes acquisition of GTAT

onsemi to scale and accelerate GTAT's development of silicon carbide

Power semiconductor IC supplier onsemi of Phoenix, AZ, USA has completed its acquisition (announced in late August) of silicon carbide (SiC) and sapphire materials manufacturer GT Advanced Technologies Inc of Hudson, NH, USA, which was founded in 1994. The acquisition enhances onsemi's ability to secure and grow supply of SiC.

onsemi says that its customers will benefit from GTAT's experience in crystalline growth as well as its technical capabilities and expertise in the development of wafering-ready SiC.

onsemi intends to scale and accelerate GTAT's development of SiC to assure customers' supply of critical components and further commercialize intelligent power technologies.

"As we move to a carbon-free economy, SiC technology is a key driver to enable zero emissions in high-efficiency electric vehicles, renewable energy and charging infrastructure," says onsemi's president & CEO Hassane El-Khoury. "By integrating GTAT, onsemi can now provide end-to-end power solutions from SiC crystal growth to fully integrated intelligent power modules," he adds.

"We are proud to welcome GTAT's incredibly talented employees to the onsemi family. Their experience and insights in the SiC space are second to none, and we look forward to working together to drive important new innovations that are critical to the growth of the sustainable ecosystem," El-Khoury continues.

onsemi says that the acquisition reinforces its commitment to make substantial investments in disruptive, high-growth technologies, consistent with its recently announced 2025 target financial model described during its Analyst Day presentation. Capital expenditures are expected to be about 12% of revenue in 2022 and 2023, as onsemi invests to drive differentiation and leadership, including in the SiC ecosystem. onsemi plans to invest in expanding GTAT's manufacturing facilities, supporting R&D efforts to advance 150mm and 200mm SiC crystal growth technology, while also investing in the broader SiC supply chain, including fab capacity and packaging.

www.gtat.com

www.onsemi.com

Aehr Test Systems joins PowerAmerica Institute

Wafer test and burn-in equipment to aid SiC and GaN adoption for power electronics and electric vehicles

Aehr Test Systems of Fremont, CA, USA has joined the PowerAmerica Institute, a public-private research initiative between industry, government, national labs and academia dedicated to accelerating the adoption of high-performing, wide-bandgap (WBG) silicon carbide (SiC) and gallium nitride (GaN) power electronics.

The collaboration is expected to result in bringing next-generation SiC and GaN power electronics to markets faster, reducing cost and risk factors associated with new-generation technologies. As an organization that brings together the semiconductor manufacturers and the companies that use power electronics in their products, PowerAmerica is well placed as an information hub, reckons Aehr.

With the backing of the US Department of Energy (DoE) and the engagement of top researchers, knowledge and processes can be provided to educate the US workforce and provide more innovative product designs.

"Wafer test and burn-in equipment play a key role in high-volume SiC and GaN production, as wafer-level stress testing contributes to highly reliable SiC and GaN power electronic products," says PowerAmerica's executive director Victor Veliadis.

"We look forward to joining some of the brightest minds in WBG research, device manufacturing, power electronics and systems, with the objective of reducing cost and the inherent risks in this new technology," comments Aehr Test Systems ' president & CEO Gayn Erickson.

"Wide-bandgap semiconductors permit devices to operate at much higher temperatures, voltages and frequencies, making the power electronic modules using these materials significantly more powerful and energy efficient than those made from conventional semiconductor materials," notes Erickson. "The benefits of bringing the more robust and cost-effective SiC and GaN technologies to market will drive longer range in electric vehicles, along with energy savings in consumer, data-center and industrial processes and help deliver renewable energy onto the electric grid."

www.aehr.com
www.poweramericainstitute.org

AXT's year-to-date InP revenue grows 46% year-on-year

GaAs demand for HBTs returning as industry capacity tightens

For third-quarter 2021, AXT Inc of Fremont, CA, USA – which makes gallium arsenide (GaAs), indium phosphide (InP) and germanium (Ge) substrates and raw materials – has reported a seventh consecutive quarter of growth to $34.6m (and a third consecutive quarter over $30m). This is up 2.7% on $33.7m last quarter and 35% on $25.5m a year ago, highlighting the increasing demand for InP and GaAs substrates.

Of total revenue, substrate sales were $26.2m, up 5.2% on $24.9m last quarter and 29% on $20.3m a year ago.

InP again set a new record, remaining the single largest product category. "Demand was strong across the board, as capacity in our industry is now tight," notes founder & CEO Dr Morris Young. "Sequential growth was driven by 4G and 5G telecommunication obligations as well as continued healthy demand for data-center connectivity," he adds.

GaAs revenue was the highest in more than four years. In semiconducting GaAs, AXT continues to see strong demand for high-end LED applications, including automotive lighting and displays. "We are also seeing rapid growth in high-powered lasers, particularly in China," notes Young. "On the wireless [semi-insulating] side, IoT [Internet of Things] continues to be strong."

Revenue from germanium substrates fell modestly again in Q3. "However, the satellite solar market remains healthy, and we are well on track for 2021 to be a growth year," says Young.

Revenue from AXT's two consolidated raw material joint venture companies — BoYu (which makes high-temperature pyrolytic boron nitride crucibles and pBN-based tools for organic light-emitting diodes) and JinMei (which supplies high-purity materials including gallium and germanium) — was $8.4m, down 4.5% on $8.8m last quarter but up 61.5% on $5.2m a year ago. "Demand continues to be strong. We are on track to achieve significant growth in this area of the business over the prior year," says Young.

"In 2020, both companies relocated to our campus in Kazuo [China], enabling them to expand capacity in response to market demand," says Young. "This, coupled with a recovery in pricing of raw materials such as raw gallium, has contributed to their growth this year."

Of total revenue in Q3/2021, the proportion from the Asia-Pacific region rose to 76% (from 73% last quarter) and North America rebounded slightly from 8% to 10%, while Europe fell back from 19% to 14%.

For the third consecutive quarter, no customers reached 10% of revenue. The top five customers generated about 25% of total revenue (down from 31% last quarter). "Our growth is not overly dependent on one large customer or application," comments chief financial officer Gary Fischer. "It is a unique and important aspect of our supply chain strategy," he adds.

"Our third quarter and year-to-date revenue results continue to underscore the gathering momentum of the technology mega-trends that our substrates help to enable — trends such as 5G telecommunications, data-center upgrades, health monitoring, the Internet of Things (IoT), and the proliferation of LED lighting and displays," says Young. "Year to date, we have increased revenue by 46% over the same period in 2020, including a 36% increase in GaAs and a 46% increase in InP substrates. With our new, expanded manufacturing facilities, we are able to accommodate increasing demand across these applications and others, while meeting the stringent technical requirements of tier-1 customers. As such, 2021 is unfolding to be a pivotal year for our business."

On a non-GAAP basis, gross margin was 33.8%, down from 34.8% a year ago and 36.4% last quarter, driven mainly by low-margin sales at JinMei, which has been selling materials at a pre-set price to several customers under long-term contracts. Due to the recent rise in the price of raw gallium that JinMei has to buy, the gross margin on those sales has eroded. The overall impact to the consolidated gross margin was about 220 basis points (without which gross margin would have been 36%). "At least one of those contracts expired in Q3 but we expect some continued pressure on gross margin in Q4 as a result of additional contracts that are coming to conclusion," notes Fischer.

The rise in raw material pricing also impacts cost of goods sold on the substrate side of the business. However, this has been offset by a $1.1m contribution to profitability provided by AXT's partially owned supply chain companies.

Also in Q3 AXT received two grants from local government totaling $1m for its facilities investments in the Kazuo region.

Operating expenses have risen further, from $6m a year ago and $7.4m last quarter to $7.7m. R&D is a primary driver, due to two major programs: the development of 6-inch InP and the development of 8-inch GaAs. In addition, sales, general & administrative (SG&A) expenses are on track to be up about $5m annually. AXT continues to make necessary investments to enable its initial public offering (IPO) in China. "We've hired a number of people to help us on the project. There's also been a lot of administrative and permit issues," notes Fischer. "There's a lot of required conformity that we need to follow in some of our employee compensation section in China," adds Young. "To be a public company in China requires that we pay housing allowances for employees… Our compensation to our employ-

ees was not minimum. So, that's an expanded expense."

Despite all this, plus a rise from $280,000 to $338,000 in the 25% tariff charged on importing wafers into the USA from China, net income remained level with last quarter at $5.4m ($0.13 per share, exceeding the $0.10–0.12 guidance range), up from $1.6m ($0.04 per share) a year ago.

Depreciation and amortization was $1.8m. Capital expenditure (CapEx) was $6.1m. During the quarter, cash, cash equivalents and investments hence fell from $58.5m to $56m.

Net inventory rose by $1.8m to $60.7m, consisting of 44% in raw materials, 50% in work in progress (WiP) and 6% in finished goods. "There are some customers that require us to build inventory, including customers that want the inventory consigned to their site, but it remains on our balance sheet. One in particular is growing, and so that is a contributor," explains Fischer. "We need to have inventory to keep growing the revenue and we're comfortable with our cash position," he adds.

"The demand environment remains strong in Q4, with some seasonality expected in certain applications like PON [passive optical networks] and GaAs for wireless devices and continued strength in several of the InP applications," says Fischer. Hence, for Q4/2021 (which is usually a down quarter for AXT), the firm expects revenue of $34–36m, with raw materials down slightly, InP and GaAs both up slightly, and germanium approximately flat. This is despite Q4 including the first 10 days of the national holiday in China as well as part of the Christmas holiday season. Taking into account that (unlike Q3) AXT should receive no China-based tax credits or grants in Q4, net earnings per share are expected to fall to $0.06–0.08.

For full-year 2021, AXT expects revenue growth of more than 40%, and an increase in annual profit of more than 300% on 2020. "This growth is the result of years of cultivating customer relationships, investment in operations and the convergence of technology trends that are likely to drive our growth for years to come," says Fischer.

The drag on gross margin from gallium pricing at Jinmei is expected to continue in Q4/2021 and "dribble" into Q1/2022. However, those long-term contracts will come to an end soon, and new contracts with new customers will be established. So, the targeted gross margin of 35% is "very achievable" for Q2/2022, believes Fischer. "JinMei is a very healthy business and there's increasing demand," he adds.

"Our increasing volume, improving product mix, and continued improvement in manufacturing efficiency will allow us to drive continued gross margin improvement as we progress through fiscal year 2022," believes Fischer. "This will be a primary focus for us over the coming quarters."

"We believe 2022 will be another year of strong [revenue] growth [of 15–20%], with existing applications continuing to mature, and new ones being layered on to the current demand," says Young. "This will take care of some of the added expense that we incurred."

With 6" capacity tightening up in our industry, we're beginning to see renewed customer interest in GaAs for HBT devices

In particular, InP is expected to grow by more than 30%. "We're talking to multiple customers in indium phosphide, and they have very exciting new applications," says Young.

"Gallium arsenide, we are also seeing renewed interest — the high-powered laser in gallium arsenide, especially in China, is giving us a very high expectation for growth next year. Customers are telling us that, for next year, they expect the volume ramp in high-power laser demand," he adds.

"With 6-inch capacity tightening up in our industry, we're beginning to see renewed customer interest in GaAs for heterojunction bipolar transistor (HBT) devices and our ability to expand capacity," says Young. "Industry experts are telling us they are seeing the HBT market demand actually growing almost 40–50% in the next two years. This has not been a strong application for us for more than 10 years, and our facilities give us the opportunity to be competitive," he adds.

"This is just the golden convergence of market and emerging technologies. For this reason, we're making important investment in our business, including larger substrates, capacity expansion, and our IPO in China. While these investments bring us to a higher level of operating expenses, they give us a significant competitive advantages in our ability to scale our business and meet the need of tier-1 customers in emerging high-volume applications."

STAR Market listing update

On 16 November, AXT announced a strategic plan to access China's capital markets and progress to an IPO by its China-based wafer manufacturing company Beijing Tongmei Xtal Technology Co Ltd on the Shanghai Stock Exchange's Sci-Tech innovAtion boaRd (STAR Market). The firm expects to submit the required documents to the STAR Market authorities in Q4/2021.

The process of going public on the STAR Market includes several periods of review and, therefore, is a lengthy process. Tongmei expects to accomplish this goal in mid-2022.

www.axt.com

Welsh Government awards £1.73m to expand project for Application Specific Semiconductor Etching Technology

Additional industry partners include CSconnected, UtterBerry, Wave Photonics and NPL

The Welsh Government has announced additional funding of £1.73m for ASSET (Application Specific Semiconductor Etching Technology), an industrially driven, collaborative project developing semiconductor process technologies that is partly funded by the European Regional Development Fund (ERDF), under the Welsh Government's SMART Expertise program.

Project partners across South Wales include SPTS Technologies (a KLA company), Cardiff-based epiwafer and substrate maker IQE plc, The Compound Semiconductor Centre (CSC, a joint venture founded in 2015 between Cardiff University and IQE), Biovici, BioMEMS, Swansea and Cardiff universities and Integrated Compound Semiconductors Ltd (a spin off from the University of Manchester that designs and manufactures RF, sensing and optical devices).

The ASSET industrial partners provide technologies for almost all the world's smartphones. By developing a host of new semiconductor process technologies using compound semiconductors and next-generation materials, ASSET aims to service new and emerging applications in automotive sensing, 6G, photonics and healthcare.

The expanded project involves additional industry partners from the South Wales Compound Semiconductor Cluster including: CSconnected, smart sensor and network producer UtterBerry, photonics company Wave Photonics, and the UK's national metrology institute National Physical Laboratory (NPL).

"The expanded ASSET project is a timely boost to the UK semiconductor industry, with exciting developments planned with several of our regional industry partners, and the opening of our £90m Centre for Integrative Semiconductor Materials (CISM) - a new state-of-the-art semiconductor facility at Swansea University - in 2022," says professor Owen Guy, head of chemistry at Swansea University and lead for the ASSET project.

"UtterBerry is proud to be working with professor Owen Guy and his team at Swansea University on the project, to revolutionize chip manufacturing and to become one of the most advanced centers in the UK," says Heba Bevan from UtterBerry. "We also look forward to the broader positive changes the team at UtterBerry will make to the area, including job creation, a more efficient transportation network, enhanced connectivity and automation in the clean energy sector."

"The ASSET expansion links with our new 'Driving the Electric Revolution (DER)' Industrial Centres (IC) initiative to create a new sovereign supply chain for the UK in next-generation power electronics components for transport electrification," note both CISM operations director Dr Matt Elwin and Dr Mike Jennings, associate professor in Electronic Engineering at Swansea. "This funding, plus the £4.82m from the DER Industrialisation Centres program, will help us deliver common goals for increased economic growth, developing clean and resilient supply chains in power electronics, machines and drives," he adds.

"The ASSET project gives the consortium the ability to work with the extensive fabrication supply chain in the region to further expand our capabilities and capitalize on new and exciting market opportunities," says Paul Rich, executive VP of product engineering & technology at SPTS.

"The South Wales semiconductor industry employs over 1400 highly skilled people in the region and is set to expand rapidly over the next five years with the growth of 5G, AI and other mega-trend markets," says the Compound Semiconductor Centre's founding director Wyn Meredith. "ASSET will support these markets by developing a range of advanced semiconductor processes and expertise to overcome technical and industry challenges," he adds.

www.csconnected.com

CSconnected appoints development manager

CSconnected has appointed Phillip Cornish as its new development manager to deliver the strategic development and business development activities that underpin the expansion of the compound semiconductor cluster across the South Wales region. In this new role, he will identify global market opportunities for the cluster's research, development and innovation activities as well as helping to develop start-ups and investment to enhance the regional cluster.

Cornish's compound semiconductor industry experience most recently is as director & co-founder of Stratium Ltd, a venture capital-backed university spin-off making quantum cascade lasers (QCLs) for precision gas analysis applications. His previous positions include management consultancy and business development for optical communications and laser solutions provider Oclaro Inc (now part of Lumentum Inc), all of which included responsibility for strategic management and business and product development.

"His expertise and drive will be invaluable for CSconnected," believes director Chris Meadows. "This appointment reflects our commitment to develop a global advantage in a sovereign, key enabling technology which will allow Wales and the UK to increase trade globally in critical sectors such as 5G communications, autonomous and electric vehicles, advanced medical devices and consumer electronics of the future."

www.csconnected.com

CSconnected sponsors Wales regional session at CBI

The role of the world's first compound semiconductor cluster CSconnected (formed in 2017) in driving jobs growth, exports and economic prosperity was centre stage at the 2021 Annual Conference of the Confederation of British Industry (CBI), chaired by Lord Bilimoria, on 22–24 November.

At the Wales regional session of 'Seize the Moment', CSconnected director Chris Meadows was joined by professor Max Munday of Cardiff Business School and Steve Whitby of MicroLink Devices UK Ltd to outline the strength of the industry cluster in South Wales. Supporting UK Government's 'levelling up' agenda, the event was held at Swansea University's Bay Campus.

CSconnected is based on winning a £43m UKRI Strength in Places bid and brings together more than a dozen organizations under a collective brand for advanced semiconductor-related activities in Wales.

Munday, director of the Welsh Economic Research Unit, told delegates that the emerging CS cluster and its high-tech companies bucked the general economic trend in Wales by creating high-quality, well-paid jobs. "We have a long productivity tail in the Welsh economy, and our GVA [gross value added] is consistently below the UK average, which is difficult to change," he added.

"The CSconnected cluster companies employ around 1400 full-time employees on salaries which are much higher than the average in Wales. The industry spends money in Wales to support another 2000 jobs, contributing around £170m of gross value added for Wales," Munday continues. "It creates a different picture than the usual inward investment pattern in South Wales. Some of the main cluster companies are headquartered here, are R&D intensive and export levels are very high – in many cases over 90% of manufacturing output goes to North America and the Far East. Cluster members have strong links with universities in Wales too," he adds.

"In economic development terms, it is a sector of interest, creating a richness that we don't see in some other areas of inward investment. Output in the CS cluster sector has been maintained through Brexit, and through Covid-19."

Meadows told the conference that the cluster aimed to push job creation from 1500 to 5000 over the next five years by developing start-ups and through attracting inward investment. "If we could attract a design team from just one of the mega companies, like Facebook, Apple or Google, it would bring an enormous supply chain with it. The growth potential of CSconnected is certainly there."

Whitby said MicroLink's recently opened research facility in Baglan Bay Innovation Centre stood to benefit by working within the cluster. "We will manufacture in the UK with different toolsets which the cluster may provide. We aim to use robotics processes, and increase efficiencies in the coatings on cells, packaging for different markets. The cluster offers us huge potential to do those things here in Wales."

At the earlier UK CBI session, Lord Bilimoria, chancellor at the University of Birmingham, thanked CSconnected for sponsoring the Wales regional session and urged industry to continue to tap into university expertise. He noted that the UK produced 14% of the most highly cited academic research papers worldwide, and remained one of the most entrepreneurial countries in the world.

Cardiff University's Institute for Compound Semiconductors was a founding member of CSconnected. The partnership paved the way for the creation of the Compound Semiconductor Centre (CSC), a for-profit partnership with wafer supplier IQE plc of Cardiff, Wales, UK. The Institute will move to the Translational Research Hub and its adjacent ERDF-funded cleanroom in 2022 on Cardiff Innovation Campus.

www.cbi.org.uk

IQE's 2021 constant-currency revenue to be down 8%

Semiconductor-shortage-induced softness in smartphone-related demand joins continued weakness in 5G infrastructure roll out

Epiwafer & substrate maker IQE plc of Cardiff, UK has announced a trading update for full-year 2021 as it faces ongoing foreign exchange headwinds.

Wireless update

In second-half 2021 demand for Wireless gallium arsenide (GaAs) epiwafers continued to grow, driven by 5G penetration of the smartphone handset market and WiFi 6. While growing year-on-year, GaAs volumes are below expectations in fourth-quarter 2021, in the context of softening demand in the broader smartphone supply chain.

Despite supply chain constraints in the broader semiconductor industry, the solid performance of GaAs throughout 2021 has resulted in high utilization at IQE's Taiwan facility, where the firm is investing in eight new and refurbished tools, including three new Aixtron G4 MOCVD reactors (now being commissioned).

Sales of Wireless gallium nitride (GaN) epiwafers have continued to be weak due to end-market dynamics, including much fewer massive MIMO base-station deployments in Asia and the slow rate of deployments in Western markets. GaN remains an essential material for 5G infrastructure, notes IQE, and demand is still expected to recover over the multi-year deployment cycle.

Photonics update

Demand for vertical-cavity surface-emitting lasers (VCSELs) used in 3D sensing has remained solid throughout second-half 2021 but is expected to tail off towards the end of the year, in line with supply chain seasonality and general softening in smartphone supply chains.

Sales of other Photonics products are also below expectations in Q4/2021 due to the re-phasing of defence and security orders associated with large programs into 2022 and the slower introduction of sales of new DFB laser products.

R&D update

IQE says that strong progress continues to be made on R&D programs, with key milestones reached for long-wavelength VCSELs, advanced healthcare sensing, porous silicon for front-end module switching, and the commercialization of GaN-on-Si for infrastructure markets.

Operational progress

Operational progress has also been strong, with the closure of IQE's Pennsylvania facility and associated consolidation of MBE capacity in North Carolina (on schedule for completion by 2024). The closure of IQE's Singapore facility is on track to be completed by mid-2022.

These closures are part of IQE's consolidation strategy and should improve production efficiency and margins in the medium to long term.

Outlook and guidance

A foreign exchange headwind has been incurred in 2021 on a reported basis, caused by the relative strength of Sterling versus the US Dollar (in which most of IQE's revenues are denominated).

Due to softening demand in Q4, IQE now expects full-year reported revenue of £152m. This is equivalent to about £164m at constant currency, down 8% year-on-year.

The reported adjusted EBITDA should be £18m (or £25m at constant currency, an EBITDA margin of 15%, down from 2020's 17%).

Capital expenditure (CapEx) should be £14–17m, below prior guidance of £20–30m due to the phasing of payments for certain tool purchases into 2022. Net debt is expected to be less than £10m.

"Whilst it is disappointing that 5G infrastructure deployments have remained weak all year, we still expect this macro trend to provide a multi-year growth cycle for IQE," says interim executive chairman Phil Smith. "In the immediate term, broader semiconductor market shortages have softened demand in some supply chains, but we believe these effects to be temporary."

www.iqep.com

IQE appoints Americo Lemos as CEO, replacing Nelson

After a search process led by interim executive chairman Phil Smith, IQE has appointed Americo Lemos as CEO, starting on 10 January.

With over two decades of managerial experience working with multi-national tech companies, it is reckoned that Lemos has the skills necessary to lead IQE into the next phase of its evolution.

Lemos joins from the executive team at New York-based GlobalFoundries. As GF's senior VP of business development for Asia Pacific and China country president, he was responsible for driving efficiency and growth in these critical markets. Prior to this, he held executive positions at firms including Qualcomm and Intel, having also worked at Flextronics, Texas Instruments and Skyworks.

"The depth and breadth of Americo's industry expertise make him the natural choice to take the business forward in its next stage of growth," comments Smith. "His appointment will enable us to build on our solid global industry foundations and market-leading positions, and take advantage of key structural drivers and opportunities arising with the proliferation of 5G and the Internet of Things."

Dr Drew Nelson, IQE's founder & CEO until September, will retain an advisory and ambassadorial role as a non-executive director on the board, with the title of president.

Riber's revenue grows 10% in Q3 to €6.6m

MBE systems order book up 45% year-on-year to €12.6m

For the nine months to end-September, Riber S.A. of Bezons, France — which manufactures molecular beam epitaxy (MBE) systems and evaporation sources and effusion cells — has reported revenue down 9% year-on-year from €17.5m to €15.8m. This included Services & Accessories revenue up 5% from €7.9m to €8.2m, but Evaporators flat at just €0.1m (due to the continuing lack of investment in OLED screen production equipment) and MBE Systems sales down by 22% from €9.5m to €7.5m (reflecting the seasonality of the delivery schedule, focused on second-half 2021).

By geographic region, 45% came from Asia (up from 32% in the first nine months of 2020), 48% came from Europe (up from 44%) and just 7% came from North America (down from 24%).

However, most of the contraction in revenue occurred in first-quarter 2021 (down 41% year-on-year, from €5.4m to €3.2m).

In contrast, revenue for third-quarter 2021 was €6.6m, up 10% on €6m in Q2/2021 and 11% on €5.9m a year ago.

Riber notes that its commercial turnaround measures rolled out over the year have continued to deliver benefits. During Q3/2021, Riber recorded orders for one production system and two research systems (including the order announced on 4 October), while further strengthening its Services & Accessories business.

Riber's order book grew by 16.7% in Q3/2021 from €17.4m to €20.3m at the end of September, up 12% on €18.2m a year previously. This was due to MBE Systems orders growing by 45% year-on-year from €8.6m to €12.6m (comprising six systems to be delivered in 2021, including two production systems, as well as one research system to be delivered in 2022). Orders for Services & Accessories were down 19% to €7.7m, but this is from a higher-than-usual €9.6m a year ago.

Riber says that, in view of the industrial production schedule for fourth-quarter 2021, it can confirm its full-year 2021 forecast for revenue of over €30m and operating income of €1.2m.

www.riber.com

Veeco's Q3 revenue up 34% year-on-year to $150m

Full-year guidance raised for fourth time, to 28% growth to $580m

For third-quarter 2021, epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA, revenue was $150.2m, up 3% on $146.3m last quarter and 34% on $112.1m a year ago (and towards the top end of the $135-155m guidance range), driven by record sales in its Semiconductor segment — due to shipments of laser annealing and EUV mask blank systems — and strong Data Storage segment revenue.

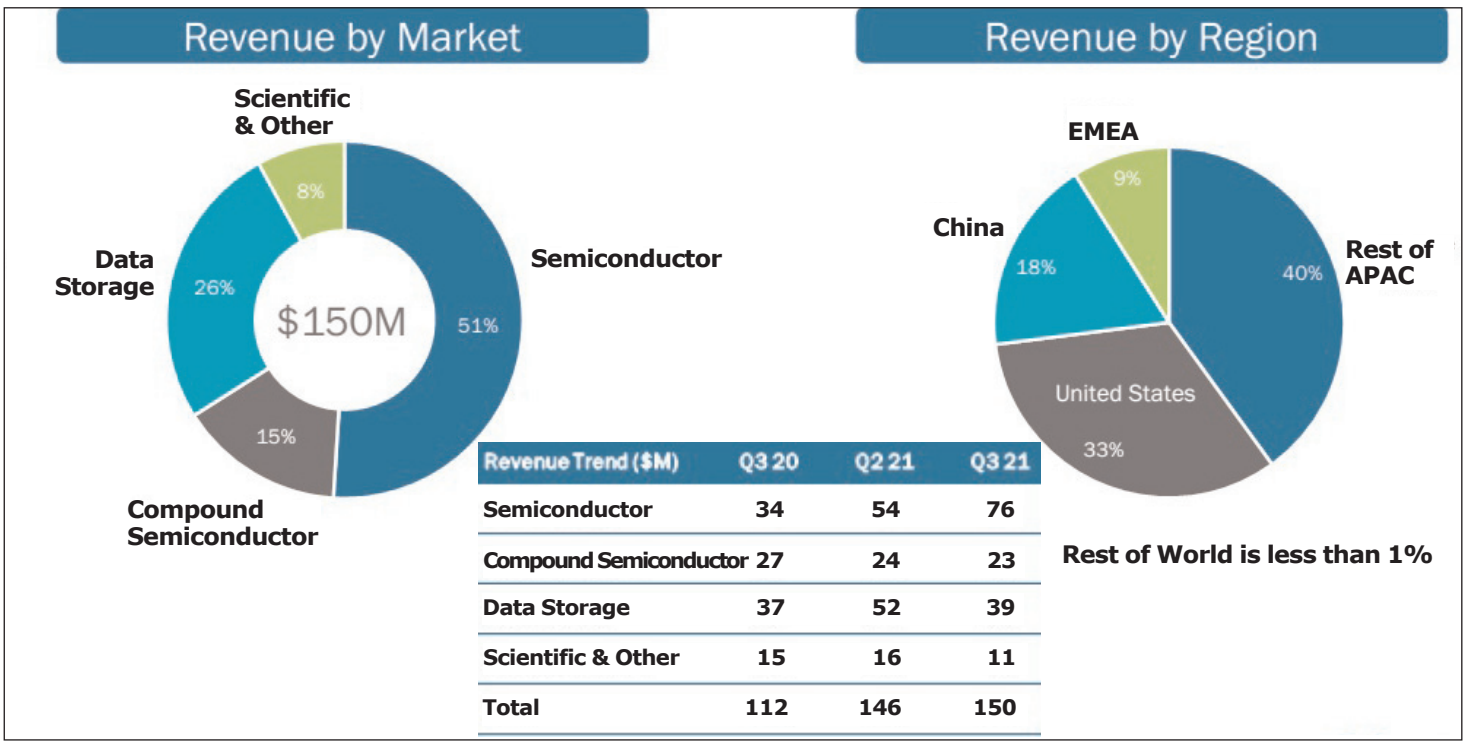
Semiconductor (Front-End and Back-End, as well as EUV Mask Blank systems and Advanced Packaging) contributed a record $76m (51% of revenue), up 42% on $53.7m (37% of total revenue) last quarter and up 127% on just $33.6m a year ago. "All three of our products serving the semiconductor markets [laser annealing for both advanced and trailing logic nodes, ion beam deposition systems for EUV mask blank production, and lithography for advanced packaging] are performing well and are expected to continue this momentum for the foreseeable future," comments CEO Bill Miller. "For a few quarters now, we have expressed increasing confidence in our advanced packaging opportunity. We had a strong equipment shipping quarter for our lithography systems and we had a repeat multi-system order from a leading OSAT [outsourced semiconductor assembly & test] to support production of GPUs and high-performance computing chips," he adds. "The investments we have made in evaluation systems, service, product development and manufacturing capacity have enabled success," says senior VP & chief financial officer John Kiernan.

Data Storage (ion beam deposition systems for cloud/data-center applications) contributed $39.3m (26% of revenue), down 25% on $52m (35% of total revenue) last quarter but up 6% on $36.9m a year ago, reflecting both capacity and technology additions by customers.

The Compound Semiconductor segment (Power Electronics, RF Filter & Device applications, and Photonics including specialty, mini- and micro-LEDs, VCSELs, laser diodes) contributed $23.3m (15% of revenue), down 12.4% on $26.6m a year ago but relatively flat on last quarter's $24.2m (17% of total revenue), driven by metal-organic chemical vapor deposition (MOCVD) systems as well as wet processing systems for power, RF and photonics applications.

The MOCVD business is operating at historically low revenues after exiting the commoditized LED sector, notes Miller. "We did a lot of work restructuring the business and pivoting towards new markets and new opportunities," he adds. "We go after the gallium nitride applications with our Propel single-wafer reactor. That can be used for both power electronics, RF devices as well as disruptive silicon-based micro-LED applications. We have a second product for arsenide-phosphide called the Lumina for applications in photonics such as indium phosphide lasers, VCSELs [vertical-cavity surface-emitting lasers] as well as red micro-LEDs. We are starting to gain traction in MOCVD."

The Scientific & Other segment (MBE/ALD/ion beam deposition



Revenue Trend ($M)	Q3 20	Q2 21	Q3 21
Semiconductor	34	54	76
Compound Semiconductor	27	24	23
Data Storage	37	52	39
Scientific & Other	15	16	11
Total	112	146	150

systems for university and government research) contributed $11.4m (8% of revenue), down from $16.4m last quarter (11% of total revenue) and $15m a year ago.

By region, the Asia–Pacific (excluding China) comprised 40% of revenue (up from 34% last quarter), mainly from sales of ion beam and laser annealing systems to semiconductor customers. China comprised 18% (up from 14%), primarily from semiconductor systems (boosted by the improving ability to obtain export licenses). The USA comprised 33% (down from 46% last quarter), driven by ion beam system shipped to data storage customers. Europe, Middle-East & Africa (EMEA) comprised 9% (back up from 6%).

On a non-GAAP basis, gross margin was 42.6%, down from 44.5% a year ago but up from 41.6% last quarter, and towards the top end of the 41–43% guidance range.

Operating expenses were $39.6m, up from $35.7m a year ago but flat on last quarter (and a reduction from 27% to 26.4% of revenue). This was also better than the expected $40–42m.

Net income has risen further, from $11m ($0.22 per diluted share) a year ago and $17.9m ($0.35 per diluted share) last quarter to $20.5m ($0.40 per diluted share), towards the high end of the $13–23m ($0.25–0.44 per diluted share) guidance range.

Cash flow generated from operations has tripled from $10m last quarter to $30m (the highest quarterly amount in the last seven years), "demonstrating the effectiveness of our transformation," says Miller. Capital expenditure (CapEx) has jumped from $7m last quarter to $22m. However, this is mostly due to an increase from $4m to $18m in spending on the construction project at Veeco's new manufacturing facility in San Jose, CA (to meet demand from Semiconductor customers). Cash and short-term investments hence rose during the quarter by $6m to $336m. Long-term debt rose slightly from $328m to $332m, representing a carrying value of $389m in convertible notes.

For fourth-quarter 2021, Veeco expects revenue of $140–160m. Gross margin should be 41–43%. Operating expenses are expected to rise to $41–43m, as Veeco continues to invest for growth (although full-year OpEx as a percentage of revenue should decline, compared with 2020). Net income is expected to be $14–23m ($0.27–0.45 per diluted share).

For full-year 2021, Veeco has now raised its guidance for a fourth time, to revenue growth of 28% (from 2020's $454.2m) to $580m with earnings per share (EPS) up more than 50% to $1.35. Originally, in late October 2020, the firm forecasted 10% revenue growth. But it raised this guidance in February to 17% growth to $520–540m (with EPS of $1–1.20), then in early May to 17-21% growth to $540–560m (with EPS of $1.10–1.30), and in early August to 25.5% growth to $570m (with EPS towards the high end of the $1.10–1.30 guidance range).

For Q1/2022, Veeco sees revenue in a similar range to its Q4/2021 guidance.

"We are excited about the traction in our semiconductor business, which has been a focus of our transformation," says Miller. "We expect to ship the first systems in the coming weeks from our new state-of-the-art San Jose semiconductor equipment manufacturing facility, and to be fully transitioned into that new facility by Q3/2022," he adds. "We will also be bringing on new capacity as we bring our San Jose new facility online. This would effectively double the amount of output from our facility compared to our current facility there as well in support of requirements coming from the semiconductor industry," says Kiernan.

"In the near term, we expect to see revenue growth in early-stage micro-LEDs next year from a number of opportunities including AR/VR as well as other photonics applications," says Miller. "Also, we did seed the 8-inch GaN-on-silicon power market with multiple customers and placed an evaluation tool for 8-inch power electronics at a large foundry. We also placed an eval tool for red micro-LEDs," he adds.

"Led by our traction in the semiconductor market, demonstrated by application wins, backlog position and visibility, we are confident we will grow revenue in 2022," concludes Miller. "Our investments in evaluation systems and service infrastructure are setting us up for success in 2022 and beyond."

www.veeco.com

Veeco repurchasing $111.5m of convertible senior notes

Veeco has entered into a privately negotiated note purchase agreement with Lynrock Lake LP under which Veeco will repurchase about $111.5m of its outstanding 2.70% convertible senior notes due 2023 from Lynrock Lake Master Fund LP for cash consideration of about $115.6m, and $1m of accrued and unpaid interest.

"We are excited to take this step to improve our capital structure," comments CEO Bill Miller. "With this repurchase, Veeco will have retired over 80% of our 2023 debt maturity obligation," he adds. This transaction de-levers our balance sheet, reduces potential dilution, and allows us to focus on continuing our growth strategy."

The repurchase is expected to close on 10 November, subject to customary closing conditions. Following the repurchase, about $20.2m of notes will be outstanding.

www.veeco.com

Aixtron's revenue almost doubles in Q3/2021

Order intake and revenue in first nine months of the year the highest since 2012

For third-quarter 2021, deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany has reported revenue of €130.8m. This is up 93% on €67.7m in Q2/2021 and more than doubling from €64.1m a year ago due to the high number of systems delivered.

Revenue for the first three quarters of the year was up by 54% from €161.1m in 2020 to €248.1m in 2021 (with 82% coming from equipment sales and 18% from after-sales service & spare parts).

Growth is being driven by applications including the manufacture of gallium nitride (GaN) power electronics and wireless and optical data transmission devices as well as of red LEDs.

On a regional basis, 67% of revenue in the first three quarters of 2021 came from Asia (down from 78% a year previously) and 23% came from Europe (up from just 13%), with the Americas level at 10%.

Quarterly gross margin improved further, from 40% a year ago and 41% in Q2/2021 to 43% in Q3/2021, due mainly to a higher share of products shipped with better margins.

Operating expenses in the first three quarters of the year rose from €52.9m for 2020 to €60.3m for 2021, due mainly to two particular effects. In first-half 2021, Aixtron incurred restructuring costs of about €3m for its South Korea-based organic light-emitting diode (OLED)-focused subsidiary APEVA (compared with the prior year, when a change of use for a production facility led to other operating income of €3m). Furthermore, the firm incurred higher variable compensation and R&D spending primarily for the development of its next-generation metal-organic chemical vapor deposition (MOCVD) tools.

EBIT quadruples year-on-year in first nine months

Nevertheless, as a result of the increase in gross margin, in the first nine months of the year the operating result (EBIT, earnings before interest and taxes) nearly quadrupled, from €10.3m (6% margin) for 2020 to €41.1m (17% margin) for 2021. Specifically, EBIT was €36.2m (28% margin) in Q3, up from €5.6m (8% margin) in Q2. Net income was €31.4m in Q3, up significantly from Q2's €7.7m.

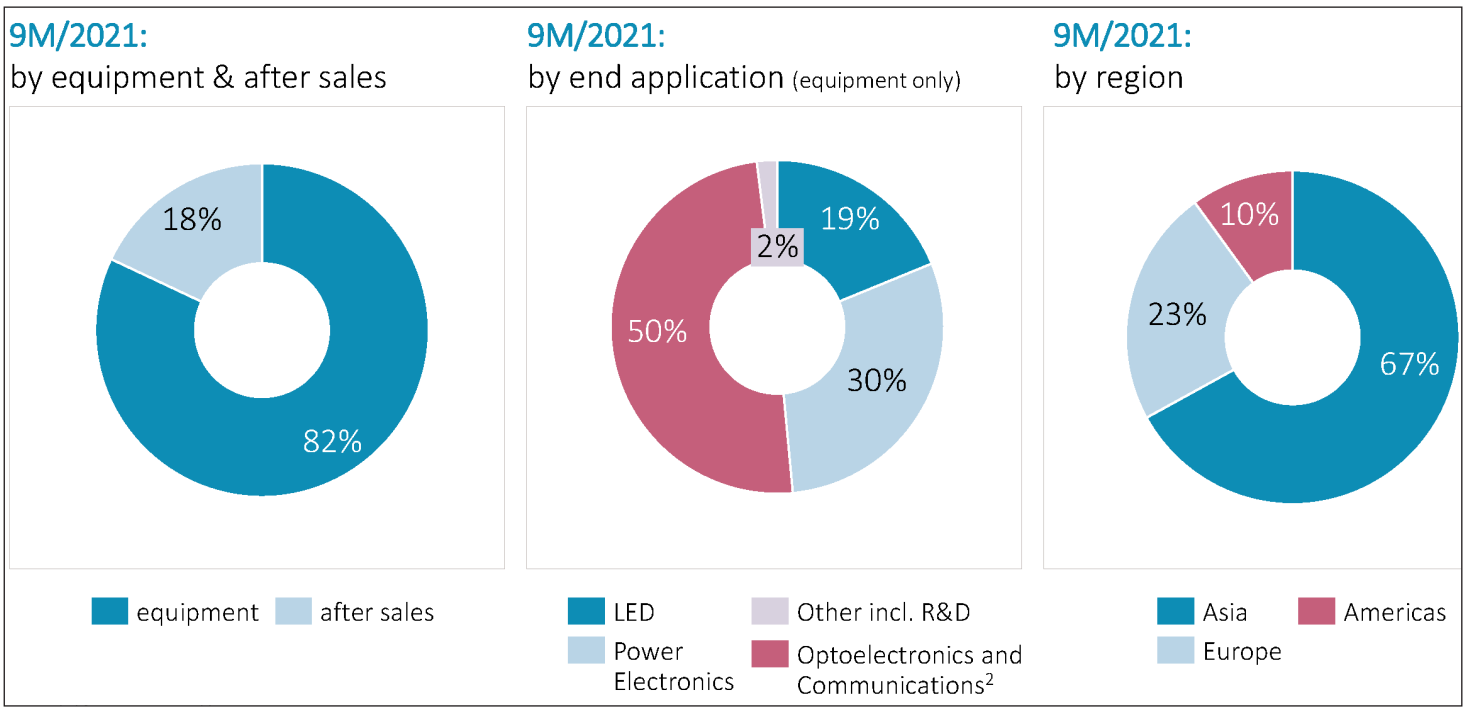
Inventory boosted for planned deliveries in Q4

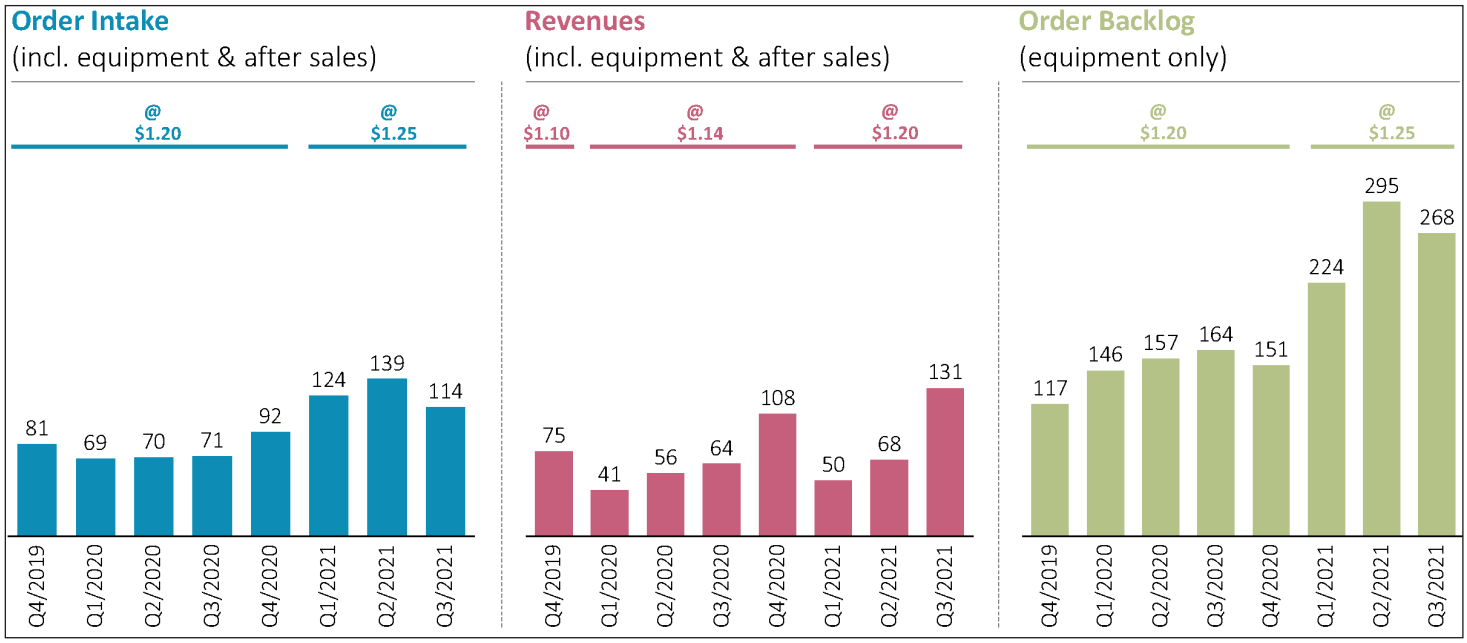
In line with the expected output for planned deliveries in fourth-quarter 2021, inventories have been boosted to €137.3m at the end of Q3/2021 (from just €79.1m at the end of 2020). During Q3/2021, working capital fell from +€13m to –€46.8m. Operating cash flow has hence fallen from +€20.8m in Q2 to -€12.2m in Q3.

Also, capital expenditure (CapEx) was raised from €2.8m in Q2 to €6.8m in Q3 (largely investments in next-generation MOCVD tools for Aixtron's laboratories).

Free cash flow in Q3 was hence –€19m (compared with +€18m last quarter and +€5m a year ago).

Despite this (and the €12m dividend payment in May), Aixtron's cash balance of €330.7m at the end of Q3/2021 was still up on €309.7m at the end of 2020, due mainly to advance payments





received from customers rising from €51m to €86m.

Order intake highest since 2012

Order momentum remained high in Q3/2021, at €114.2m (and up on €70.8m a year previously). Consequently, order intake in the first nine months reached its highest level since 2012, growing by 80% from €209.3m for 2020 to €377.6m for 2021. Demand is coming particularly for gallium nitride (GaN) and silicon carbide (SiC) power electronics applications, wireless and optical data communications as well as LED applications for fine-pitch displays and indoor farming.

Equipment order backlog fell slightly by 9% during Q3/2021, from €295m to €267.7m, due to the large volume of deliveries, but this is still up 63% on €164.1m a year previously.

"Megatrends such as digitalization and data communication, energy efficiency and e-mobility are driving demand for compound semiconductors," notes CEO & president Dr Felix Grawert. "Their outstanding properties are the basis for applications not only in optoelectronics but increasingly also in power electronics," he adds. "As a result, we expect revenues in the current fourth quarter of 2021 to increase even further compared to the already strong previous quarters."

Aixtron confirms 2021 guidance

After already raising its guidance for full-year 2021 order intake first (on 9 June) from €340–380m to €420–460m then again (in late July) to €440–480m, Aixtron has reiterated this guidance.

Based on the equipment order backlog (convertible into 2021 revenue) of €137–177m plus €15m of after-sales spares & services revenue, together with the €248m of revenue from Q1–Q3/2021, Aixtron has also confirmed its guidance for full-year revenue of €400–440m (previously raised on 9 June from prior guidance of €320–360m). The firm still expects gross margin of 40%, and EBIT margin of 20–22% of revenue (raised on 9 June from prior guidance of 18%).

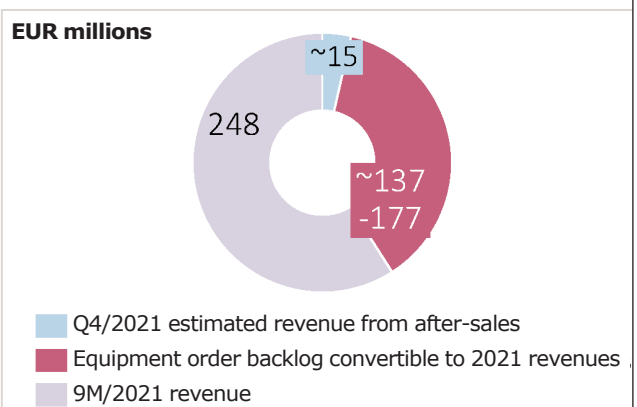
www.aixtron.com

2021 Guidance confirmed

based on 9-month results, current order situation and current environment:

Total Order Intake (EUR million)	440 - 480
Revenues (EUR million)	400 - 440
Gross Margin (%)	~ 40%
EBIT Margin (%)	20% - 22%

Revenue guidance FY 2021



Aixtron partners in EU doctoral program QUANTIMONY

Deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany is a partner in the new program QUANTIMONY ('Innovative Training Network in Quantum Semiconductor Technologies Exploiting Antimony').

Funded by the European Union's Horizon 2020 research and innovation program under the Marie Skodowska-Curie (grant agreement number 956548-QUANTIMONY-H2020-MSCA-ITN-2020), the project is an international network for doctoral education supporting the training of young academics as well as research into quantum technologies utilizing antimony (Sb).

QUANTIMONY provides 14 junior researchers with PhD positions, spanning all scientific and engineering aspects (from modeling to material growth and characterization to industrial use), as an entry into semiconductor science and technology.

QUANTIMONY is configured as a multi-site international network (spanning eight European countries, plus USA, Taiwan and Brazil). The consortium comprises 11 research teams as beneficiaries, supported by 12 partner organizations, namely: Agencia Estatal Consejo Superior de Investigaciones Científicas (CSIC), Universidad Politécnica de Madrid (UPM), Lancaster University, University of Warwick, Eindhoven University of Technology (TUE), Technical University Berlin (TUB), University of Würzburg, University of Rome 'Tor Vergata', Aixtron SE, IQE plc, Nextnano GmbH, Bruker AXS, Nanoplus GmbH, Lancaster Materials Analysis Ltd (LMA), TiberLab Srl, QuantCAD LLC, Fluxim AG, Lund University, European Synchrotron Radiation Facility (ESRF), National Synchrotron Radiation Research Center, Cardiff University, Universidad de Cádiz (UCA), Universidade Federal de São Carlos (UFSCar).

Focus on antimonide-based semiconductor components

The work focuses on research into semiconductor quantum components that contain the element antimony. With QUANTIMONY a contribution should be made to raise the full potential of the III–Sb compound semiconductors gallium antimonide (GaSb), indium antimonide (InSb) and aluminium antimonide (AlSb). Antimonic semiconductor components are to be used primarily in optoelectronic applications such as LEDs, lasers and detectors in the infrared spectral range as well as DRAM memories, single-photon sources and solar cells.

Via QUANTIMONY, it is intended for antimony compounds to find a path to volume production by using MOCVD technology, enabling usage in computers and memories, telecoms, automobiles, robotics and many other applications beyond those that are already served in aerospace and security.

"Quantum semiconductor technologies based on antimony are an important field of the future," says professor Michael Heuken, VP Advanced Technologies at Aixtron and head of the QUANTIMONY Exploitation and Industrial Engagement Committee. "The research work of these doctoral students within the framework of QUANTIMONY will make a decisive contribution to accelerating the necessary research and development work for this future technology," he adds. "The results will contribute to technological solutions for energy saving and solving the climate emergency."

www.quantimony.eu
www.aixtron.com

New MOCVD wafer carrier defect analysis feature added to kSA Emissometer

k-Space Associates Inc of Dexter, MI, USA — which produces thin-film metrology instrumentation and software — has added a new feature to the kSA Emissometer that will make it more effective for detecting defects in metal-organic chemical vapor deposition (MOCVD) wafer carriers.

The kSA Emissometer is a metrology tool designed to easily generate high-resolution diffuse and specular reflectance and total emissivity maps of MOCVD carriers. Variation in carrier emissivity correlates to temperature non-uniformity, which can lead to reduced device yield and growth run issues. This new feature makes the kSA Emissometer more essential for fabs to help with early defect detection, and for carrier manufacturers to detect quality issues before they ship the carrier to their end user, says k-Space.

At the end of a carrier scan, this new feature displays the number of defects it detected and summarizes the number of the pocket defects, web defect and halo-region defects. The software outlines the defect regions in the carrier image to easily identify their positions. The user can save the image files to examine or analyze later. This allows fabs to pull the defective wafer carriers before they cause an issue, and they can perform in-depth analysis later.

"We try to improve our products based on customer requests," says senior product engineer Greg DeMaggio. "This additional defect analysis was something our customer desired and we were able to implement it," he adds. "The new capability makes their defect identification process easier, will ultimately lead to improved quality, reduced production costs, and is a great addition to the analysis capabilities of the kSA Emissometer."

www.k-space.com

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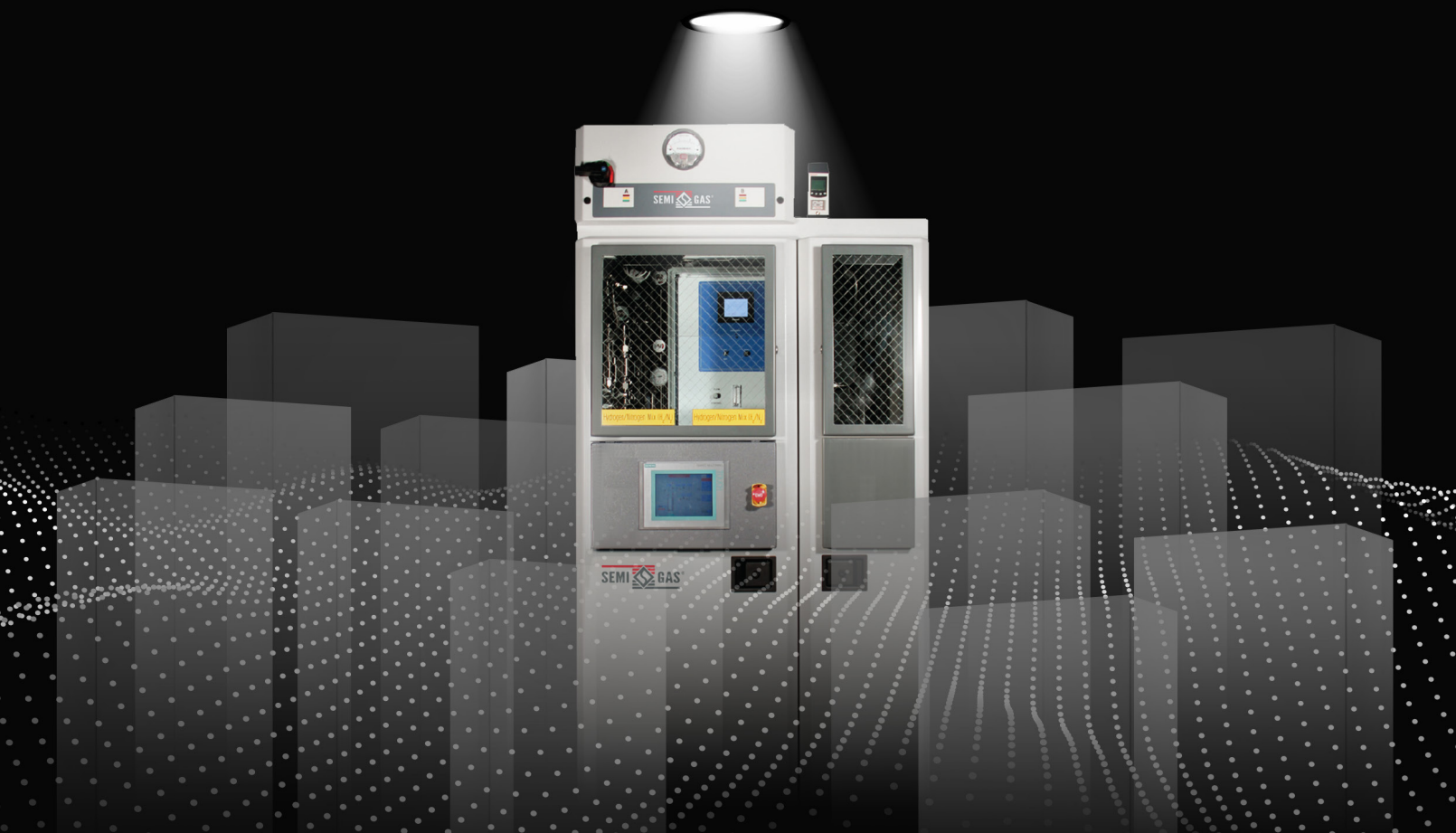

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Court orders search and seizure of products from suspected infringers of Seoul Viosys' patents in Europe

LED product manufacturer Seoul Viosys Co Ltd — an affiliate of Sensor Electronic Technology Inc (SETi) and a subsidiary of South Korea's Seoul Semiconductor — says that, in September, the Judicial Court of Paris, France ordered a search and seizure against a multi-national electric retailer and its suppliers for distributing UV LED sterilizers suspected of infringing Seoul Viosys' patents.

Seoul Viosys had filed a patent infringement complaint with the French court. Under the court's order, bailiffs seized products from the business offices of those companies located in Paris and Lille to secure evidence of suspected infringement.

As developers of second-generation technologies, Seoul Viosys and its affiliates say they have obtained permanent injunctions and orders of recall against products infringing their patented technologies.

For example, SSI (currently Mediana Electronics) was the subject of a search and seizure for supplying South Korea's largest companies with white LED chips, infringing Seoul Semiconductor's technology in order to generate hundreds of billions of Korean won in sales revenues, says the firm. SSI's employees were arrested for stealing Seoul's technology.

Recently, Seoul Viosys and its strategic partners also obtained a series of permanent injunctions or judgments for patent infringement in the USA and Europe against various UV LED makers (such as RayVio, Everlight, Bolb, Epileds and LED Engin) and they continue to pursue additional enforcements against some of those manufacturers.

Seoul Viosys has been collaborating for over 20 years with SETi, a pioneer in UV LED technology. Together, the firms co-developed Violeds technology, which can effectively disinfect water, air space and surfaces, including the elimination of 99.437% of the SARS-CoV-2 virus in less than 1 second. Seoul Viosys expects the probability of infection to be reduced to 3% in an indoor environment when using Violeds. Violeds technology also has applications in deodorization and 3D printing. Based on its technology, Seoul Viosys supplies LED solutions for refrigerators, air conditioners, washing machines and water purifiers to the top three global companies in Korea, the USA and China.

www.seoulviosys.com

SunLike natural spectrum LEDs chosen by LEDVANCE

Seoul Semiconductor Co Ltd says that its SunLike natural spectrum LEDs (for producing light that closely matches the spectrum of natural sunlight) have been applied to the 19 models of the Sun@Home product line of German lighting company LEDVANCE (which produces its products in 50 nations worldwide and exports them to about 140 nations).

Sun@Home is a premium lighting product line for homes and offices. With the SunLike natural spectrum LED technology, it can remotely and automatically adjust the color temperature and dimming as light changes from noon to evening.

LEDVANCE is promoting its new human-centric lighting for the health and well-being of users by applying SunLike technology to 19 products (launched in October) in 10 categories, including desk lamps, office lighting, panel lighting, room lighting, downlights, wall-mounted lamps, night lights, lightbulbs, candle-shaped lights, and track lighting.

"Children, students and office workers are staying longer at home amid the pandemic, increasing the importance of lighting for not only study and work but rest as well," says Seoul Semiconductor.

SunLike lighting semiconductor technology reproduces the spectrum curve of natural sunlight (matching the intensity of each wavelength, including red, orange, yellow, green, blue, navy and purple), replicating almost the same characteristics as natural light, and improving learning abilities such as memory, correct answer rate, speed of learning, and recognition speed (according to a clinical trial by Harvard University's Dr Rahman).

SunLike achieved Rf 95 (and higher) in a color fidelity test assessing the similarity to natural light at Underwriters Laboratories (an international organization for testing lighting equipment), becoming the world's first LED light source to obtain the Diamond Level.

Seoul Semiconductor has demonstrated the benefits of SunLike natural spectrum LEDs through research activities focusing on the effects of learning abilities, visual comfort and sleep quality. Following Seoul National University in Korea and Basel University in Europe, a research team found that exposure to short-wavelength enriched light with a daylight-like spectrum improves key components of learning such as working memory, cognitive processing speed, and testing accuracy. The clinical trial began in 2019, conducted by the Division of Sleep and Circadian Disorders at Brigham and Women's Hospital (a teaching affiliate of Harvard Medical School) and included college-aged adults. Results from the study showed effectiveness in improving procedural learning, says Seoul Semi.

www.SeoulSemicon.com

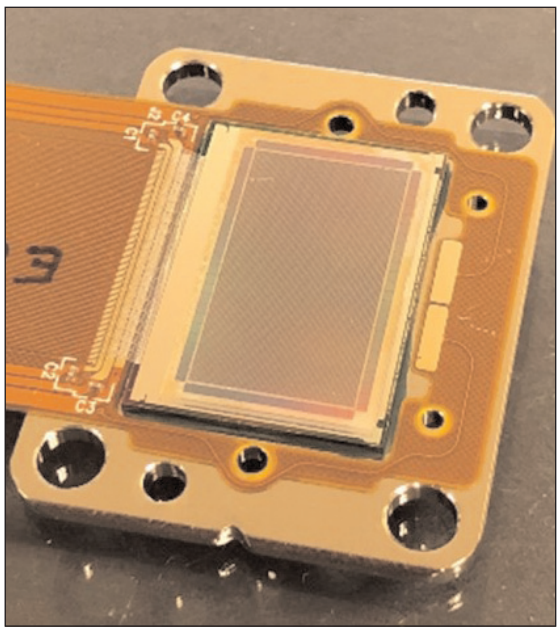
Sundiode achieves full-color micro-displays based on stacked 3-color micro-LEDs

Compact 15.4mm x 8.6mm display driven by active-matrix silicon CMOS backplane from Jasper Display

Sundiode Inc of Campbell, CA, USA, a Silicon Valley-based company developing micro-LED technologies for display applications including augmented reality (AR) and mixed reality (MR), has demonstrated a full-color micro-display, consisting of a stacked 3-color (RGB) micro-LED pixel array driven with an active-matrix silicon CMOS backplane.

Following the announcement in late April of a stacked-RGB micro-LED pixel technology patented by Sundiode and developed in collaboration with KOPTI (Korea Photonics Technology Institute), a micro-display using the stacked-RGB pixels was recently achieved using a full-color-capable Si CMOS backplane from Jasper Display Corp of Santa Clara, CA, USA. The compact 15.4mm x 8.6mm display has an array of stacked-RGB micro-LED pixels on a single chip bonded directly onto a Si CMOS backplane in its entirety, completely avoiding conventional pick-and-place processes required for transferring discrete R, G and B subpixels.

The development demonstrates full-color operation of a micro-display with significantly enhanced utilization of the small pixel area of a micro-display. In this display, the pixels are 100μm in size, resulting in a resolution of about 200PPI. The next phase of the development is currently underway to significantly increase the pixel density, in full color, to be suitable for the AR and MR applications.



A micro-display with a stacked-RGB pixel array, where each pixel is an RGB-emitting stacked microLED device.

The fully functional display shows the operation of a stacked-RGB pixel array together with a Si CMOS backplane and, as such, is reckoned to be a crucial milestone in the development towards ultra-high-resolution full-color micro-displays. With the development of epitaxial and fabrication technologies enabling the stacked-RGB pixel device, this demonstration is a step on the way to manufacturing micro-displays based on micro-LEDs that are suitable for AR, MR, and Metaverse.

Jasper Display Corp is a fabless IC design company providing CMOS backplane technology supporting micro-LED development. Jasper Display offers FHD and 4K-resolution backplanes, with what is claimed to be excellent current uniformity and flexible addressing. By working with Sundiode to showcase its 100μm stacked-RGB micro-LED in a single-panel full-color display, Jasper Display demonstrated that its CMOS backplane technology for micro-LEDs can be customized to support needs ranging from low-power AR all the way up to automotive headlights, all with custom resolutions.

Sundiode plans continued development efforts towards the ultra-high-resolution micro-displays using the stacked-RGB pixel technology.

www.sundiode.com

SemiLEDs' full-year revenue falls 23%

For its fiscal full-year 2021 (to end-August), LED chip and component maker SemiLEDs Corp of Hsinchu, Taiwan has reported revenue of $4.7m, down 23% on fiscal 2020's $6.1m. However, fiscal fourth-quarter 2021 revenue of $1.4m is level with both last quarter and a year ago.

Full-year gross margin fell from 26% in fiscal 2020 to 22% in fiscal 2021. Most recently, gross margin dropped from 46% last quarter to 11%, although this is still up on just 8% a year ago.

Full-year operating margin fell from –34% in fiscal 2020 to –83% for fiscal 2021. This includes quarterly operating margin worsening from –41% last quarter to –135% in Q4.

Net loss grew from $64,000 ($0.02 per diluted share) last quarter to $1.835m ($0.42 per diluted share), taking full-year net loss from $544,000 ($0.15 per diluted share) in fiscal 2020 to $2.85m ($0.68 per diluted share) for fiscal 2021.

During fiscal Q4, cash and cash equivalents rose from $1.7m to $4.83m.

SemiLEDs says that, given the continuing uncertain impact of COVID-19 on the economy and the firm, it is unable to forecast revenue for fiscal first-quarter 2021 (to end-November) at this time.

www.semileds.com

ams OSRAM unveils first batwing optic LEDs for horticulture applications

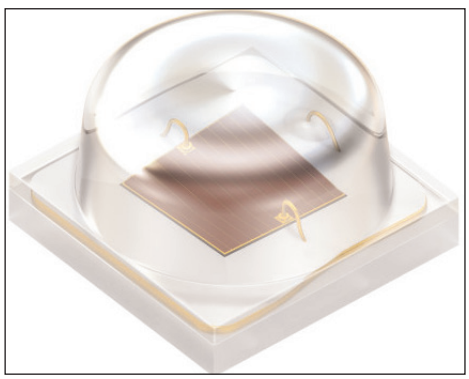
Oslon Square Batwing's new primary optics provide more homogenous light for greenhouses

ams OSRAM of Premstaetten, Austria has expanded its portfolio of horticulture LEDs with the Oslon Square Batwing. The Oslon Square family is now extended with four new devices — hyper red (660nm), deep blue (450nm), far red (730nm) and horti white — spanning all necessary wavelengths for horticulture applications.

Every plant needs a certain amount of light in different wavelengths for an optimal growth. Special luminaires in greenhouses and indoor farms combine red, blue and white LEDs, depending on the light recipe required for the plant. Current LED fixtures often have a lambertian primary lens and no secondary optic, or a simple glass cover, which lead to hotspots with high concentration of light directly under the luminaire. The result is areas with different intensities of illumination, causing inconsistent yields. Currently, these lighting gaps are commonly filled with additional fixtures. ams OSRAM says that it has solved this problem with the Oslon Square Batwing, which has a special shape of optics to enable customers to simplify their designs, likely reduce fixtures or be more efficient.

When it comes to horticulture lighting growers often face light uniformity issues with the pitch-to-distance ratio. Growers currently try to close the lighting gaps with a higher number of luminaires or accept that some plants receive more light than others. This is not a satisfying solution because the main aim for the grower is to get the highest possible yield at the lowest possible cost. To address this issue, ams OSRAM combined its established Oslon Square LED for horticulture lighting with a new primary optic.

Due to the special batwing optics, greenhouse owners can enlarge the distance between the single lamps without a decrease in light quality for the plants.



The hyper red version of ams OSRAM's new Oslon Square Batwing LEDs. With the four new products in the Oslon Square family, ams OSRAM can now better serve different customer wishes for horticulture lighting in greenhouses and indoor farms.

The new batwing optics enables a special radiation pattern of light that looks like wings. The wide beam angle of 140° and the rectangular shape of light distribution enables higher uniformity and optimum utilization of space in greenhouses. The wider angle also allows for a larger distance between the luminaires and hence possibly a reduction in the number of fixtures. Compared with lighting systems using LEDs with a secondary batwing optics, the primary batwing lens solution can offer an up to 5% higher system efficiency, it is reckoned.

All versions of the new Oslon Square Batwing family feature a compact footprint of only 3.0mm x 3.0mm and have high radiant flux maintenance and a lifetime of more than 102,000 hrs. In addition, the hyper red version achieves optical output of 1042mW at a drive current of 700mA, yielding a wall-plug efficiency (WPE) of 74%.

www.ams.com
www.osram.com/os/applications/horticulture-lighting

Lumileds launches first road-legal H4-LED headlight bulb for retrofitting halogen

Philips Ultinon Pro6000 LED range extended in Germany

LED maker Lumileds LLC of San Jose, CA, USA says that it is advancing automotive lighting and improving road safety with the launch of the first road-legal H4-LED in Germany, from its Philips Ultinon Pro6000 LED retrofit range. This is a range extension to the H7-LED that was approved in Germany in May.

The new Philips Ultinon Pro6000 H4-LED bulb delivers up to 230% brighter light (compared with the legal minimum for halogen bulbs), and its plug-and-play design allows DIYers and mechanics to install it on their own, the firm says.

Approval of the Philips Ultinon Pro6000 H4-LED type by the German federal authorities means that drivers across the country can now legally upgrade their headlight bulbs from halogen to Philips LED lighting.

These premium Philips LED bulbs improve safety by boosting visibility and delivering a beam pattern that illuminates the road ahead without dazzling other road users.

A comprehensive testing program in collaboration with TÜV Rheinland confirmed the new Philips LED bulb's high performance, enabling homologation by the German Federal Motor Transport Authority (KBA). The 'ABG' approval certificate was granted by the KBA based on national regulation §22a StVZO enabling use in selected vehicle models. Lumileds can therefore now offer its latest LED retrofit technology to German drivers.

"We will continue to provide ever-increasing coverage of the car marques and models available in Germany," says Swati Singh, EMEA product manager for LED at Lumileds.

Once fitted, the Philips Ultinon Pro6000 H4-LED provides up to 230% brighter light (compared with the minimum legal standard for halogen bulbs) courtesy of the Lumileds LUXEON Altilon LEDs — the same LEDs used by automotive original equipment manufacturers. Its cool-white beam with a color temperature of up to 5800K — the same color temperature used by OEMs — is said to aid driver comfort and reduce strain on the eyes.

The Philips Ultinon Pro6000 H4-LED also features greater durability, with up to 3000 hours' lifetime. Advanced AirBoost technology and a built-in fan for active cooling contribute to long-lasting reliability.

Due to plug-and-play installation, drivers can now convert their halogen headlamps to the brighter, approved light of Philips Ultinon Pro6000 H4-LED on a wide range of car models. Thanks to its new, one-piece design, the bulb fits easily into existing headlamp units. Integrated electronics ensure a compact footprint, making installation easy for DIYers or mechanics even where space is tight.

The Philips Ultinon Pro6000 LED range in Germany is available in the most common headlight bulb types, H4-LED and H7-LED.

www.lumileds.com

Lumileds introduces LUXEON 5050 HE LED

Higher efficacy in a high-power LED

LED maker Lumileds LLC of San Jose, CA, USA, the "innovator of the original 5050 LED", says that it has expanded its range of options to meet manufacturers' needs for differentiated solutions addressing cost, efficacy and power. Directly addresses the increasing demand for solar and off-grid solutions, renewable power options and improved sustainability metrics, the new LUXEON 5050 HE LED expands options along the efficacy–output continuum, giving luminaire manufacturers the ability to better target performance to their customers' requirements.

"Driving ever higher efficacy levels supports sustainability objectives and it reduces payback cycles," says product line manager Mei Yi. "The new LUXEON 5050 HE delivers 181 lumens per watt or more and allows for BOM [bill of materials] cost reduction while maintaining the robustness and longevity expected from an LUXEON LED."

The LUXEON 5050 HE delivers Lumileds' flux maintenance and color stability in high-sulphur environments, and its footprint compatibility makes it easy to design into existing and new platforms, says the firm. The new LED is suitable for outdoor, industrial and horticulture applications where robustness, longevity and efficacy are the driving attributes, it adds.

LUXEON 5050 HE is immediately available in 2700–6500K correlated color temperatures (CCTs) at 70CRI (color rendering index). It is characterized for both illumination and horticulture with lumen and efficacy ratings as well as photosynthetic photon flux, PPF (µmol/s) and PPF/W (µmol/J).

All LUXEON 5050 LEDs are available for immediate sampling. Production orders are available now through Lumileds' distribution network and lead times are up to 8 weeks.

www.lumileds.com

Tyndall's Corbett awarded Katharine Burr Blodgett Medal

Photonic device technology has driven development and growth of startups and innovation by multi-nationals

The 2021 Institute of Physics (IOP) Katharine Burr Blodgett Medal and Prize has been awarded to Brian Corbett, a researcher at Ireland's Tyndall National Institute at University College Cork (UCC) and at IPIC (the Irish Photonic Integration Centre), the Science Foundation Ireland (SFI) Research Centre for Photonics.

The gold medal has been awarded for Corbett's identification and creation of breakthrough photonic device technology solutions that have driven the development and growth of several startups, and major innovations by multi-national companies.

"Brian Corbett has raised visibility of Ireland's high-impact technology ability significantly on the world stage," commented the IOP.

Corbett invented the technology that enabled the establishment of Eblana Photonics (in 2001) to commercialize a scalable laser manufacturing technology that drives down the cost of high-performance, single-wavelength lasers for diverse mass-market applications. His work helped to launch Firecomms, which became the first Irish startup to be acquired by a Chinese corporation (ZJF). The acquisition included a €5m investment in Firecomms' engineering team in Cork, resulting in the growth of the team to about 30 today. He was also key to attracting X-Celeprint to establish their global headquarters in Tyndall in 2013, with X-Celeprint's CEO accrediting the decision to the capabilities and vision of Corbett and his team. The firm is developing and licensing patented Micro-Transfer-Print technology (a cost-effective and scalable manufacturing process for integrating microscale photonic devices onto silicon-based structures).

Brian Corbett of Ireland's Tyndall National Institute.

Based on his patented micro-LED technology, InfiniLED was founded in 2010 to commercialize this low-power 'ILED display' technology, which delivers energy-efficient and high-brightness displays. Corbett has supported InfiniLED from incubation, through funding rounds and ultimately to acquisition (by Facebook in 2016). Facebook's investment in Cork has grown to over 100 mainly physics-skilled scientists and engineers to develop Corbett's technology into augmented reality (AR) platforms.

The SFI says that not only is his work with startups and SMEs critical to the development of the Irish entrepreneurial and enterprise ecosystem, his partnerships with multi-national companies have ensured enduring relationships with companies such as Intel (as recognized by their 2013 Outstanding Researcher Award) and Seagate. It is reckoned that, through his leadership and vision, more companies will spin out and grow — one is currently targeted on superluminescent LEDs.

www.tyndall.ie

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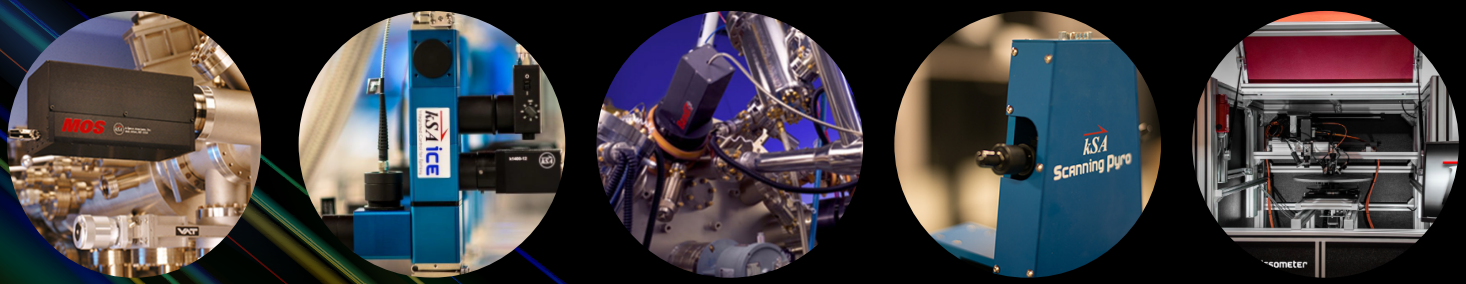

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Nakamura receives Goldstein Energy Lecture Award

Shuji Nakamura, a professor in the departments of Electrical and Computer Engineering (ECE) and Materials at University of California Santa Barbara (UCSB), is the recipient of the 3rd Annual Richard J. Goldstein Energy Lecture Award from the American Society of Mechanical Engineers (ASME).

Established in 2019, the award recognizes "pioneering contributions to the frontiers of energy, leading to breakthroughs in existing technology, leading to new applications or new areas of engineering endeavor, or leading to policy initiatives."

Nakamura was selected for "transformational innovation in energy-conserving electronic and photonic materials, particularly pioneering work in light emitters based on wide-bandgap semiconductors and the invention of efficient blue light-emitting diodes that have rendered substantive bright and energy-saving white light sources."

"It is my great honor to receive the Richard J. Goldstein Energy Lecture Award," Nakamura said. "LEDs have been used in applications in a variety of lighting and displays in order to reduce energy consumption. Laser lighting would be the next generation of lighting by utilizing blue lasers. I hope that the invention of LEDs and laser lighting will contribute to minimizing global warming in the future."

Nakamura received a bronze medal and a certificate, and gave a lecture on the topic of the invention of the blue LED and the future of lighting at the virtual ASME International Mechanical Engineering Congress & Exposition (1–4 November).

Nakamura's work has earned him numerous previous honors and accolades, including the 2006 Millennium Technology Prize, the 2014 Nobel Prize in Physics, a 2015 Global Energy Prize and the 2021 Queen Elizabeth Prize for Engineering. Nakamura, who joined the UCSB faculty in 2000, is a fellow of the National Academy of Engineering, of the National Academy of Inventors and of the Royal Academy of Engineering.

www.materials.ucsb.edu/people/faculty/shuji-nakamura

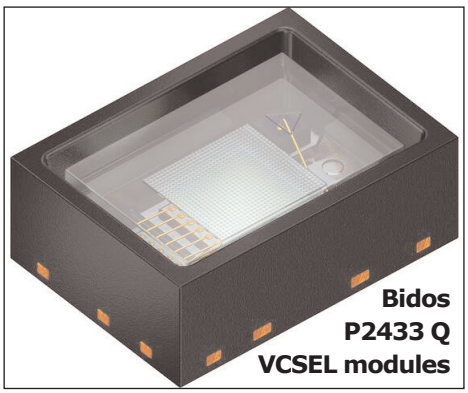
ams OSRAM expands VCSEL portfolio for ToF 3D sensing

Flood illuminator package integrates VCSEL emitter and photodiode

ams OSRAM of Premstaetten, Austria has expanded its 3D sensing portfolio with four new vertical-cavity surface-emitting laser (VCSEL) modules in the Bidos P2433 Q family of flood illuminators.

The number of applications that utilize 3D sensing technology continues to increase: From the detection of the surroundings for robots to avoid collisions to the unlocking of smartphones via facial recognition. But 3D sensing also plays a key role for augmented-reality and virtual-reality (AR/VR) glasses. ams OSRAM says that, due to components like its Bidos P2433 Q family of flood illuminators, various gestures can be reliably captured, raising the interaction between user and AR/VR glasses to a new level. The compact package also allows specific design flexibility.

For augmented- and virtual-reality devices, as well as other 3D world-facing applications, the focus is on maximum user experience combined with compact and light-weight design. In the 3D sensing market, VCSELs have a huge impact due to their good beam quality, cost efficiency and simple design. "With the expansion of our Bidos family we offer one of the smallest VCSEL packages available on the market for 3D applications at given power levels and field-of-illumination," claims product manager Simon Gubser. "By integrating the matching emitter and photodiode in one compact module, we reduce the installation effort for our customers significantly," he adds.



Bidos P2433 Q VCSEL modules

The Bidos P2433 Q is available in four different versions including two different fields-of-illumination and two output power levels. With a size of 3.3mm x 2.4mm, the VCSEL-based modules are suitable for 3D sensing applications using time-of-flight (ToF) measurement, which require homogeneous illumination of the scene. Due to their wavelength of 940nm, all modules are also free from the red glow effect, which is perceived by the human eye as a disturbing flickering.

In addition to the two 3W modules (with fields of illumination of 63°x50° and 74°x61° respectively), the two higher-power 6.5W modules (with fields of illumination of 66°x53° and 78°x65° respectively) use dual-junction VCSELs with efficiency of up to 45%. In addition, a photodiode monitoring system is integrated into the module as a special protection mechanism for eye safety. If the photodiode registers a change in the incidence of light — for example, if the optics are damaged — the current supply to the VCSEL is interrupted.

Besides 3D gesture recognition, the four new modules can also be used in industrial robotics for obstacle avoidance and virtual fencing, or in 3D face authentication systems in smart door locks or point-of-sale payment terminals.

www.ams.com/-/bidosp2433q

FBH exhibits at Space Tech Expo Europe

In conjunction with the Space Tech Expo Europe in Bremen, Germany (16-18 November), the Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH) of Berlin, Germany presented the following technologies.

Laser systems for quantum-optical precision experiments

With long-term experience in the development and fabrication of robust, compact diode laser modules for space applications, FBH says that its modules have already proven their capability several times in experiments under zero gravity conditions. Among others, FBH is currently manufacturing 55 ultra-narrow-linewidth laser modules developed for the BECCAL (Bose-Einstein Condensate – Cold Atom Laboratory) apparatus. From 2024 they will be used in the research facility operated by the German Aerospace Center DLR and the US National Aeronautics and Space Administration (NASA) for quantum optical experiments with ultra-cold atoms on board the International Space Station (ISS). The facility will be used to investigate fundamental physics questions involving quantum objects with high precision near absolute-zero temperature (–273.15ºC).

The core elements of these and previous diode laser modules are laser diodes developed by FBH, which are assembled together with optics and other passive elements. FBH says that, due to its unique micro-integration technology, the modules are extremely robust and suited to use in space. They feature small dimensions of only 125mm x 75mm x 23mm, a low mass (750g) and output power of >500mW with simultaneously narrow intrinsic linewidth <1kHz.

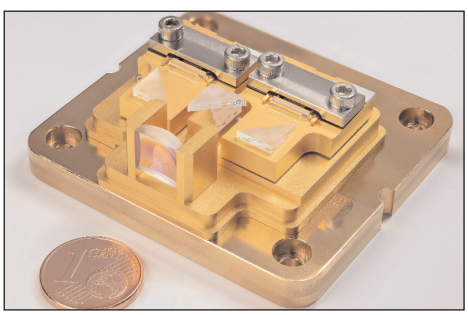
In collaboration with Humboldt-Universität zu Berlin, such modules are also being built into compact quantum sensors and optical clocks for use in space and for industry-compatible system solutions in quantum technology. The collaborative Joint Lab presents a novel, fully autonomous frequency-stabilized laser source with integrated distributed feedback (DFB) laser diode based on the D2 transition in rubidium, operating at 780nm.

Laser modules for satellites: from communications to climate protection

FBH is also developing a range of laser modules for satellite applications. Its laser diode benches (LDBs) have been used for many years as pump lasers in Tesat-Spacecom's laser communication terminals (LCT). They are used, among other things, to transmit high volumes of earth observation data particularly quickly between satellites and Earth. The LDBs have been developed and qualified according to the standards of the European Space Agency (ESA) for space applications. Their wavelength is stabilized to the pump transition band of a Nd:YAG laser such that the pump laser beam ensures stable LCT performance. On top of that, the pump laser has demonstrated what is claimed to be excellent reliability over the entire 15-year lifetime of the mission.

FBH will also exhibit a distributed Bragg reflector (DBR) laser array module that offers both low noise and high reliability due to an integrated Bragg reflector, stabilizing the wavelength at the chip level. The suitability of such modules has been demonstrated for continuous operation of more than 15 years, qualifying them as flight hardware for the next LCT space missions.

Another pump laser is to be used in the future on the MERLIN climate satellite, which is to measure the methane concentration in the atmosphere. For this purpose, FBH has developed, qualified and delivered laser modules, each equipped with two high-power laser half-bars. These modules deliver 130W pulsed emission at 808nm wavelength and pump a Nd:YAG laser. Performance and reliability over the mission lifetime have been demonstrated through extensive qualifications of the technology and independently confirmed by ESA's Technology Center ESTEC. So, even with a long operational lifetime of more than 4 billion pulses, the performance degrades only insignificantly.



Energy-efficient components for satcoms and sensors

Due to their high radiation hardness and capability for switching at high frequencies, gallium nitride (GaN) switching transistors are particularly suitable for power conditioning in satellites. FBH's newly developed 10A/400V aluminium nitride power core with GaN power transistors in a half-bridge configuration minimizes the parasitic inductances and capacitances of the switching cell. Power switch, gate driver and DC link capacitors are hetero-integrated in an extremely compact manner, and heat is efficiently dissipated through the aluminium nitride substrate. In this way, the switching times of the power cell can be halved compared with a traditional design using discrete devices. High switching frequencies combined with high converter efficiency are the prerequisite for power converters with particularly high power density (a decisive advantage, since weight is key in space).

Energy consumption and dissipated power are further critical issues when operating power amplifiers in space. FBH is hence also developing concepts for envelope tracking — a well-proven technique for increasing the efficiency of solid-state power amplifiers.

www.fbh-berlin.com

BluGlass' optical facet and metallization laser diode design iterations now in post-epi production

Testing of improvements to begin in coming weeks

BluGlass Ltd of Silverwater, Australia — which has developed proprietary low-temperature, low-hydrogen remote-plasma chemical vapor deposition (RPCVD) technology for manufacturing devices such as laser diodes, next-generation LEDs and micro-LEDs — has provided an update for fiscal first-quarter 2022 (to end-September 2021), including progress in its development of laser diodes.

Laser diode progress

BluGlass says that it continues to develop and test multiple iterations of its commercial laser diode prototypes, including single-mode and multi-mode products in 405nm, 420nm and 450nm wavelengths.

Alongside addressing flaws in the optical facet, BluGlass has also been improving metallization of the laser diode prototypes. Metallization is critical to laser diode development as it controls the input of electrical current into the laser as well as the removal of heat from the device. BluGlass is using analytical techniques to focus on failure modes to determine which components and processes within the manufacturing supply chain are causing issues.

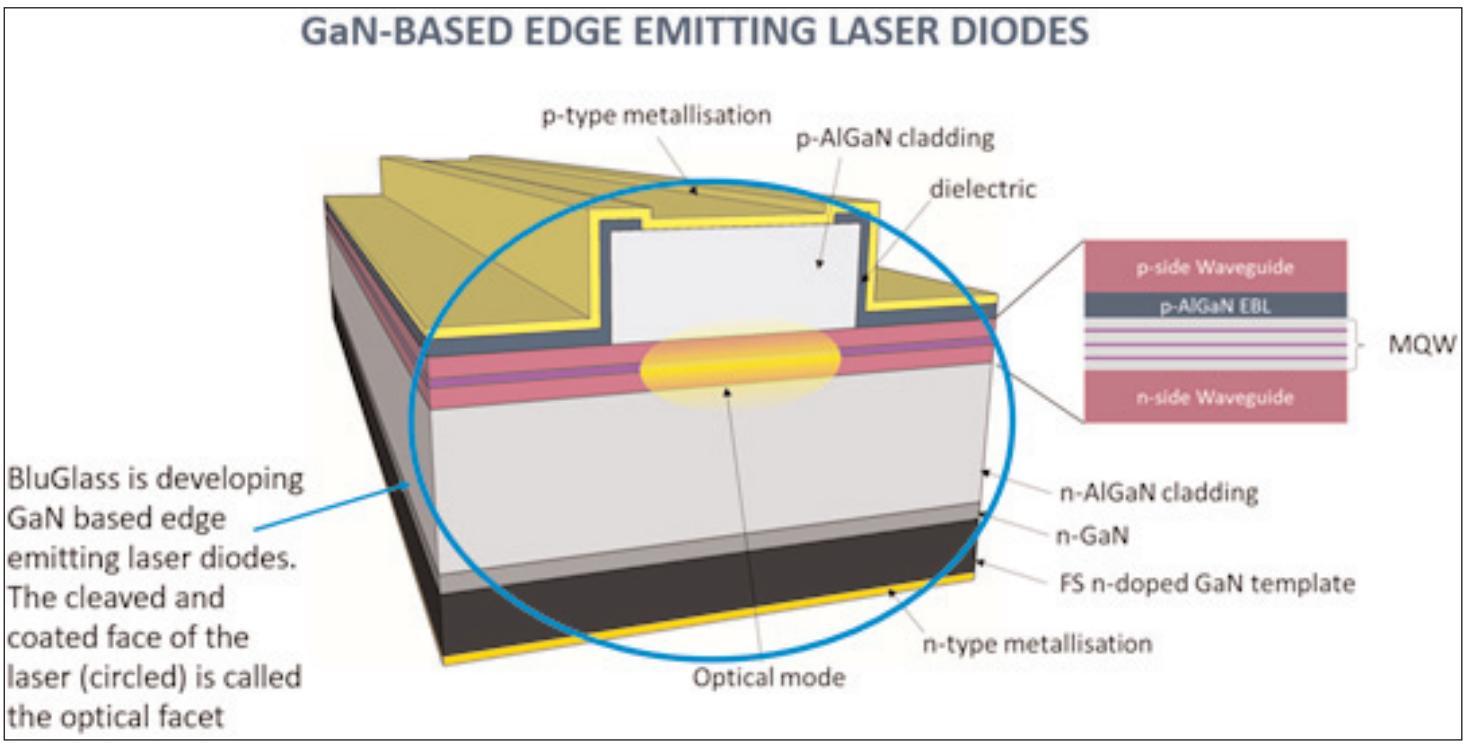
Both the optical facet and metallization are in the post-epitaxy production steps, which are currently outsourced to third-party manufacturing suppliers.

BluGlass says that it is focused on improving the reliability of its laser diodes and has several iterations progressing through the manufacturing supply chain. Since June, the firm has conducted extensive failure analysis and burn-in testing of multiple development iterations. BluGlass has progressed four legacy iterations to completion that were in the manufacturing pipeline before June. These development efforts have resulted in improved manufacturing processes being implemented at all steps of the supply chain, with a strong focus on improvements to the firm's front-end and back-end fabrication steps, and facet coating designs.

Following this extensive analysis and new process implementations, BluGlass has implemented two new design iterations. Testing of its first iterations of new laser diodes, which feature new metallization and optical facet improvements, will commence in the coming weeks.

BluGlass is focusing on eliminating variation between manufacturing suppliers, ensuring process and product repeatability — key steps for supply chain readiness ahead of commercial manufacturing.

"Laser diodes are complex technology and, while frustrating, reliability challenges are common within the industry," notes president Jim Haden. "I have personally experienced and solved many of these development pitfalls for other companies over the past few decades. There are four elements that are key to producing optimal laser diodes: high-gain, low-loss epitaxy; low-resistance metallization; low-loss, passivating facets; and mechanically sound thermal management for packaging," he adds. "Early prototype testing reassures us that our epitaxy is performing in line with expectations. Alongside our third-party fabrication specialists,



the team is focused on optimizing the other three key elements and ultimately solving the primary cause of our reliability challenges."

Haden was due to provide an update on laser diode development at the firm's Annual General Meeting in November.

World-first tunnel-junction laser diodes

In August, BluGlass demonstrated working tunnel-junction laser diodes in a world-first proof-of-concept using its RPCVD technology.

The RPCVD tunnel-junction prototypes have demonstrated good lasing behaviour, confirming the potential of these enhanced designs to address the 50% performance loss presently suffered by gallium nitride (GaN) laser diodes due to excess heat. BluGlass says that its laser diode designs replace the magnesium-containing layers that cause optical and performance loss with an RPCVD tunnel-junction and second n-type cladding layer (a dual nwave laser diode).

"Our RPCVD tunnel-junction laser diodes are designed to significantly improve GaN laser diode performance. This will enable higher-power, brighter and more efficient lasers for commercial applications, including advanced 3D printing applications for automotive, defence and aerospace manufacturing as well as industrial welding for electronics, battery and automotive manufacturing," says executive chair James Walker. "This successful proof-of-concept is an important technical and commercial validation. It demonstrates the capability of our RPCVD epitaxy to create brighter and better performing blue GaN laser diodes to support future applications and new wavelengths, providing a significant long-term growth opportunity for the business."

Leadership changes

In September, BluGlass appointed US-based expert laser diode executive Jim Haden as president to lead the firm to profitability. Haden has more than 30 years of laser industry expertise gained in senior leadership roles at several of BluGlass' prospective customers and competitors, including Kyocera SLD, nLight and Coherent. He has proven experience solving technical challenges, delivering products to market, and driving transformational revenue growth for advanced technology businesses, says BluGlass.

To aid the transition, executive chair James Walker remains in the role, supporting BluGlass' financial and governance functions as the firm nears commercialization and profitability.

"Jim's wealth of GaN laser expertise and commercialization experience will be instrumental in our transition to a global provider of next-generation laser diode products," believes Walker. "While laser diode reliability issues are new to BluGlass, Jim has encountered and solved similar technical and operational challenges many times before. He has a deep understanding of this domain, with hands-on experience improving laser diode performance and building market share in underserved segments," he adds.

"Jim's appointment further enhances our board and senior management bench strength, complementing the industry expertise of Jean-Michel [Peleprat] and preparing BluGlass for its next growth phase. The calibre of the talent we are now attracting reflects our truly disruptive technology and significant market opportunity," Walker reckons.

Outlook

BluGlass says that it remains focused on solving its reliability issues ahead of launching its direct-to-market laser diode products and securing the first customer orders.

"We have had a productive start to fiscal year 2022 and are now well-equipped to deliver on our growth strategy," reckons Walker. "Under Jim's leadership, we are well positioned to resolve our reliability challenges and optimize the performance of our first direct-to-market laser diodes. Our initial products will include the in-demand and under-served 405nm, 420nm and 450nm wavelengths, where we have collaborative customers with confirmed interest. While the majority of our focus is on the initial product range, we are also progressing the development of our novel RPCVD enhanced tunnel-junction laser diodes, which will offer more efficient and brighter, higher-performing blue GaN laser diodes and open the door to new applications and markets," he adds.

"We are preparing our supply chain for scale while also increasing our in-house production capability and expertise. This end-to-end capability enables us to meet unmet industry demand for small custom batches as well as volume production," concludes Walker.

www.bluglass.com.au

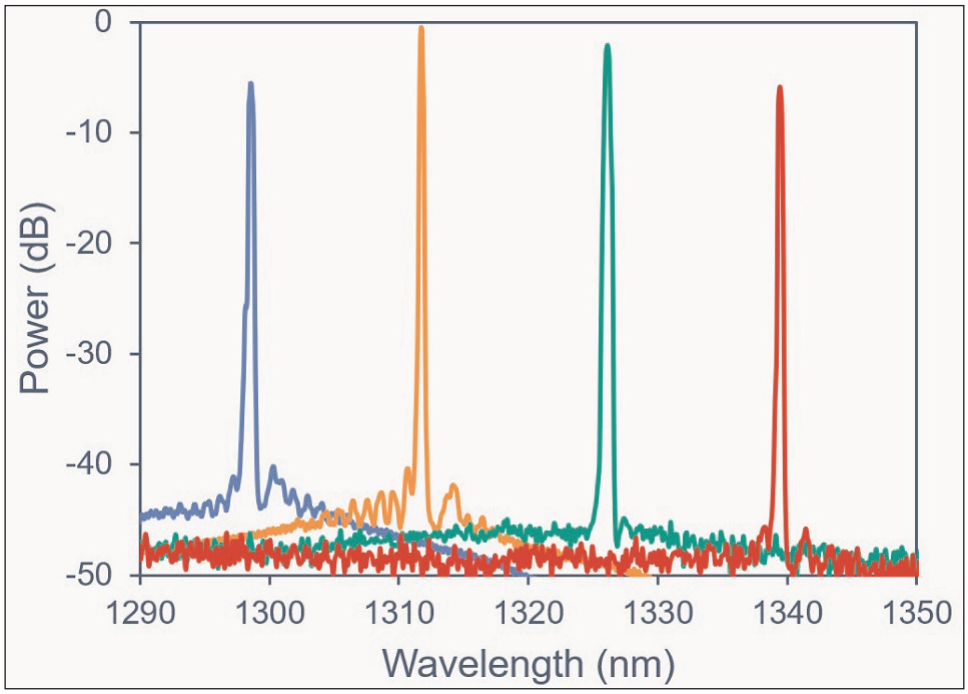
Vector Photonics completes LOCAL project

Innovate UK funding helps develop multi-wavelength data-center laser

Photonic-crystal surface-emitting laser (PCSEL) firm Vector Photonics Ltd of Glasgow, Scotland, UK has completed the project 'Lasers for Communications Applications' (LOCAL), which was supported by the Sustainable Innovation Fund of UK Government agency Innovate UK (which provides funding and support for business innovation as part of UK Research and Innovation) in collaboration with project partner University of Glasgow.

The 11-month project developed 1310nm all-semiconductor surface-emitting lasers for next-generation communications and data-center applications — a huge growth market, driven by the proliferation of mobile devices, the Internet of Things (IoT) and 5G.

"The LOCAL project was a huge success, with the resulting 1310nm all-semiconductor surface-emitting lasers delivering to plan, despite the Covid pandemic," says David Childs, director of product development. "Not only did the devices exhibit excellent optical performance, with a side-mode suppression ratio (SMSR) of 40dB, but they also supported



four wavelengths between 1298nm and 1340nm, on the same wafer — a breakthrough in the industry. This led to Vector Photonics' senior development engineer Dr Calum Hill giving a post-deadline presentation at the International Semiconductor Laser Conference (ISLC 2021) in Potsdam, Germany (10–14 October).

"Innovate UK funding reduces early-stage development risk," notes Childs. "The £175,000 we received for the LOCAL project funded the successful development of the 1310nm laser prototypes," he adds. "This established a business case to proceed with commercialization of this revolutionary new semiconductor laser technology."

Vector Photonics appoints development engineer, responsible for active testing of PCSEL devices

University of Glasgow graduate automating on-wafer testing

Vector Photonics has appointed Ibrahim Javed as development engineer, responsible for the active testing of its all-semiconductor PCSEL devices.

Javed is a recent graduate of the University of Glasgow, with an MEng in Electronic and Software Engineering. He also has commercial experience, gained while developing the ResDiary Now app for tvOS.

His role at Vector Photonics includes set-up of the burn-in and quality systems that validate the life-time performance of the PCSELs for next-generation datacoms, additive manufacturing and 3D printing applications.

"Ibrahim is a great asset to the Vector Photonics team, where he is already enhancing our test and quality assurance processes," comments senior design engineer Dr Calum Hill.

"Vector Photonics' PCSELs allow on-wafer testing, where the laser is checked, and its properties verified, whilst still in wafer format. It is a critical advantage over most current semiconductor laser technologies, as faulty lasers are detected early in the production process, reducing wastage," he adds.

"Ibrahim's electronic and software capability has enabled him to automate the testing of many different device types," continues Hill. "Not only does this generate real-time test reports for production, enabling improved device performance and yield, but it also ensures that test results are consistent between different setups and that rigorous, quality assurance standards are met."

www.vectorphotonics.co.uk

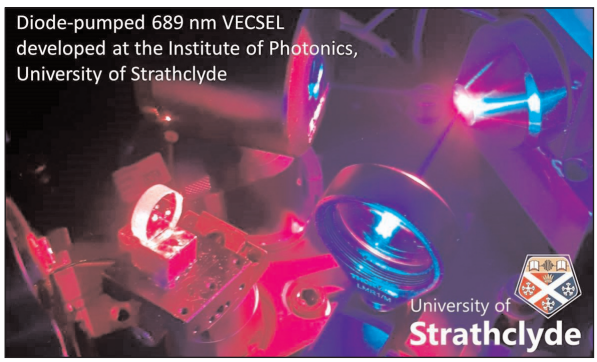
III-V Epi participating in Innovate UK-funded SHARK-VECSEL atomic-clock project

Epi foundry to contribute expertise in phosphide-based heterostructures and custom-designed VECSELs

III-V Epi Ltd of Glasgow, Scotland, UK says that it will consolidate its position as an essential part of the commercial quantum technologies supply chain following its involvement with the project SHARK-VECSELs (Supply cHAin for stRontium clocK Vertical External-Cavity Surface-Emitting Lasers).

Funded by UK Government agency Innovate UK (which provides funding and support for business innovation as part of UK Research and Innovation), the £50,000 project is focused on next-generation quantum timing applications in strontium-atom-based optical clocks.

"The SHARK-VECSELs project will set III-V Epi up to supply commercial quantum solutions," says chief technology officer professor Richard Hogg. "Pre-prototype VECSELs have already been successfully produced through a collaboration between the University of Strathclyde, the National Quantum Technology Hub for Sensing and Timing, and the Midlands Ultracold Atom Research Centre. This knowledge will be shared with III-V Epi, before adding our own expertise in phosphide-based semiconductor heterostructures and custom-designed VECSELs. We will go on to fabricate the quantum SHARK-VECSELs, which the University of Strathclyde will test," he adds.



"Quantum technologies play a mission-critical role in defence, security and other sensitive markets, however they typically require only low-volume production quantities, which large-scale industry suppliers find prohibitive," Hogg continues. "III-V Epi was set up specifically to address this low-volume, fast-turnaround market, including the supply of commercial quantum solutions."

www.iii-vepi.com

III-V Epi at UK National Quantum Technologies Showcase

MBE and MOCVD epi foundry among more than 80 UK exhibitors

III-V Epi exhibited its rapid-turn-around molecular beam epitaxy (MBE) and metal-organic chemical vapor deposition (MOCVD) epitaxial manufacturing services at the UK National Quantum Technologies Showcase 2021 at the Business Design Centre in London (5 November).

Supported by UK Government agency Innovate UK (which provides funding and support for business innovation as part of UK Research and Innovation) and its KTN (Knowledge Transfer Network), the showcase included more than 80 UK exhibitors with high-TRL (technology-readiness level) quantum solutions.

"The MBE and MOCVD epitaxial manufacturing and overgrowth services III-V Epi provides are ideal for quantum-based businesses, which often require low to medium volumes and a fast turnaround," reckons director Calum McGregor. "Quantum businesses have contributed to huge breakthroughs in automotive, healthcare, infrastructure, telecommunications, cybersecurity and defence industries, where we already have experience, including the supply of epitaxy for quantum dots, single-photon avalanche diodes (SPADs) and laser sources," he adds.

III-V Epi says that, driven by strong collaboration between academia and industry, the UK is home to around half the quantum-based businesses in Europe. The UK National Quantum Technologies Showcase allows these businesses to demonstrate current technology, including real-life projects, such as miniature satellites for ultra-secure communications; gas sensors for industrial leaks; and receivers for sensing data breaches.

Among the exhibitors will be the National Quantum Computing Centre, which works with business, government and the research community to expedite quantum computing development, and the UK National Quantum Technologies Programme (UKNQTP), which has a £1bn budget, over 10 years, for quantum research.

www.ktn-uk.org

Lumentum launches multi-junction addressable VCSEL arrays for long-range LiDAR

More compact, reliable, robust and fully solid-state LiDAR solution with no moving parts

Lumentum Holdings Inc of San Jose, CA, USA (which designs and makes photonics products for optical networks and lasers for industrial and consumer markets) has expanded its multi-junction vertical-cavity surface-emitting laser (VCSEL)-based range to include high-performance 1D and 2D addressable arrays for advanced automotive, consumer and industrial light detection and ranging (LiDAR) and 3D sensing applications.

Due to their proven reliability and ability to be manufactured at scale, VCSEL arrays have become the preferred laser illumination source for short-range 3D sensing applications such as biometric security and world-facing LiDAR in consumer mobile devices. Lumentum says that its multi-junction VCSEL arrays provide a solution to delivering the significantly higher peak optical power densities and efficiencies required for longer-range applications by decreasing the electrical current needed and simplifying electrical driver and package design. The addition of array addressability to Lumentum's VCSEL arrays enables a more compact, reliable, robust and fully solid-state LiDAR solution with no moving parts.

"On-chip array addressability can eliminate the need for mechanical beam scanning, which opens a new world of possibilities for autonomous vehicles and emerging 3D sensing systems and will help accelerate LiDAR adoption across a wide range of customer applications," says Matt Everett, product line director of 3D Sensing.

Lumentum's high-power multi-junction addressable VCSEL arrays emit at 905nm and 940nm and are built upon the manufacturing foundation developed over the past several years of high-volume VCSEL array shipments serving the consumer electronics market. The higher peak power, addressability, thermal stability and narrow wavelength range of these sources is said to open up new potential for all-solid-state short-, medium- and long-range LiDAR systems.

Lumentum's high-performance multi-junction addressable VCSEL array products are expected to be available from fourth-quarter 2022.

www.lumentum.com

Ganvix and ITRI form JV to commercialize GaN VCSELs

Yale spin-off's technology development & time to market to be sped up

Early-stage startup company Ganvix Inc of Wilmington, DE, USA, which specializes in the development of gallium nitride (GaN) vertical-cavity surface-emitting lasers (VCSELs), has signed a joint venture agreement with Taiwan's Industrial Technology Research Institute (ITRI).

Founded by Yale University's Dr Jung Han, Dr Rami Elafandy and Dr Jin-Ho Kim, Ganvix received funding from IP Group Inc, an intellectual property commercialization company that focuses on evolving ideas from its partner universities and national labs. The firm utilizes nanoporous technology to deliver compact, lightweight blue/green/ultraviolet (UV) VCSEL lasers that produce what is claimed to be superior wavelength control, smaller spot size and array architectures, allowing innovation across a wide range of applications.

As part of the agreement, ITRI will apply its decades of experience in commercializing and manufacturing electro-optic devices to accelerate Ganvix's technology development and time to market. The resulting products will be targeted at addressing the nascent opportunity for high-performance, low-cost GaN VCSELs in billion-dollar global markets, including consumer electronics, communications, medical and life sciences, and industrial applications.

VCSELs based on gallium arsenide (GaAs) that operate in the infrared spectrum are currently one of the fastest-growing technologies in electro-optics. However, GaAs cannot emit light in the ultraviolet or visible (blue and green) wavelengths. For these applications, GaN is required, but there has been no commercially viable solution to form the laser cavity mirrors required until now. Ganvix claims that it has solved this problem by using nanoporous technology to engineer the optical properties of GaN. The underlying nanoporous technology was developed by professor Jung Han over a period of more than a decade, is protected by more than 30 patents, and has been exclusively licensed by Ganvix.

"By forming this partnership, we take advantage of ITRI's technical expertise and long track record of helping bring innovative technologies to market," says Ganvix's CEO John Fijol.

"We see immense opportunity in commercializing GaN-based VCSELs and are enthusiastic about introducing them to the global markets," comments ITRI's general director Dr Wu. "The nanoporous technology is uniquely suitable for manufacturing at scale."

www.itri.org.tw/eng

Lumentum acquiring NeoPhotonics for $918m

Up to $50m in term loans to be provided to fund anticipated growth

Lumentum Holdings Inc of San Jose, CA (which designs and makes photonic products for optical networks and lasers in industrial and consumer markets) has entered into a definitive agreement to acquire San Jose-based NeoPhotonics Corp – a vertically integrated designer and manufacturer of silicon photonics and hybrid photonic integrated circuit (PIC)-based lasers, modules and subsystems for high-speed communications — for $16 per share in cash (a total equity value of about $918m), a premium of about 39% to NeoPhotonics' closing stock price on 3 November. Lumentum intends to finance the transaction through cash from the combined company's balance sheet.

Related to the transaction, Lumentum will provide up to $50m in term loans to NeoPhotonics to fund anticipated growth, which may require increased working capital and manufacturing capacity.

The transaction has been unanimously approved by the boards of directors of both companies, and is expected to close in second-half 2022 (subject to approval by NeoPhotonics' stockholders, receipt of regulatory approvals, and other customary closing conditions).

Lumentum reckons that the complementary combination of the two firms accelerates its exposure to and penetration of some of the fastest-growing areas of the more than $10bn market for optical components used in cloud and telecom network infrastructure. "The integrated company will be better positioned to serve the needs of a global customer base that is increasingly utilizing photonics to accelerate the shift to digital and virtual approaches to work and life, the proliferation of IoT, 5G and next-generation mobile networks, and the transition to advanced cloud computing architectures," says Lumentum. "The combination creates a stronger partner for customers, with the ability and intent to invest strongly in innovation and manufacturing capacity," it adds.

"With NeoPhotonics, we're making another important investment in better serving our customers and expanding our photonics capabilities at a time when photonics are at the forefront of favorable long-term market trends," says president & CEO Alan Lowe. "At the center of our strategy is a relentless focus on developing a differentiated portfolio with the most innovative products and technology in our industry... Adding NeoPhotonics' differentiated products and technology and innovative R&D team is consistent with this strategy and, together, we will better meet the growing need for next-generation optical networking solutions," he adds.

"The increasing global demand for our ultra-pure light tunable lasers and photonics technologies for speed-over-distance applications is more apparent than ever, and Lumentum is the ideal partner to serve our customers on a larger scale," says NeoPhotonics' president, CEO & chairman Tim Jenks. "Lumentum recognizes the importance of NeoPhotonics' differentiated photonic technology and products, which are well positioned for accelerated growth in the coming years," he believes. "The combination's complementary product portfolio, increased scale, breadth of customer application knowledge, and R&D capabilities will accelerate innovation, better serve customers, and deliver significant and immediate value to our stockholders."

Lumentum reckons that there are significant efficiency gains to be made through the acquisition, derived from increased scale, reducing redundancies and leveraging the best capabilities in the combination. The combined firm is expected to generate more than $50m in annual run-rate synergies within 24 months of the finalizing the acquisition. The transaction is expected to be immediately accretive to combined non-GAAP earnings per share upon closing. The combined company is expected to have a solid balance sheet and strong operating cash flows, creating substantial financial flexibility to pursue continued growth initiatives.

www.neophotonics.com
www.lumentum.com

Lumentum's quarterly revenue hit more than expected by semiconductor shortage

Increasing semiconductor supply to allow Telecom & Datacom recovery in December quarter

For its fiscal first-quarter 2022 (ended 2 October 2021), Lumentum Holdings Inc of San Jose, CA, USA (which designs and makes photonics products for optical networks and lasers for industrial and consumer markets) has reported revenue of $448.4m (exceeding the $430–445m guidance range), up 14.4% on $392.1m last quarter but down slightly (by 0.9%) on $452.4m a year ago.

"Driven by strong demand, first-quarter financial results were above our guidance ranges across all metrics," says president & CEO Alan Lowe. "Our Industrial & Consumer product lines and our Commercial Lasers segment revenues were ahead of expectations, which more than offset the [greater than expected] impact of semiconductor shortages in our Telecom and Datacom product lines," he adds. Demand that went unfulfilled impacted revenue by more than $30m, mostly in reconfigurable optical add/drop multiplexers (ROADMs) and ROADM line-cards (which have the heaviest concentration of semiconductors on them) but also in transmission products. "As we went through the quarter, it actually got tougher."

Optical Communications segment revenue was $406m (90.5% of total revenue), down 5.3% on $428.5m (94.7% of total revenue) a year ago. However, this is up 14.3% on $355.2m last quarter, since record first-quarter Industrial & Consumer revenue was up strongly, more than doubling from $98.8m last quarter to $190m — due to seasonality in the consumer market, such as vertical-cavity surface-emitting lasers (VCSELs) for 3D sensing applications — but also up 14% from $167.2m a year ago, aided by continued design-in activities and ramps in automotive light detection & ranging (LiDAR), driver monitoring and other new applications. In contrast, Telecom & Datacom revenue fell further, from $261.3m a year ago and $256.4m last quarter to $216m. However, strong cloud data-center end-market demand drove record externally modulated laser (EML) datacom chip revenue (which has roughly doubled over the last five quarters). Also, terrestrial pump laser revenue grew again to new multi-year highs. "Elevated pump shipments frequently have been a leading indicator of future telecom demand," remarks Lowe.

$ in millions	Q1 FY22	Q4 FY21	Q1 FY21
Revenue	**$448.4**	**$392.1**	**$452.4**
Optical Communications	406.0	355.2	428.5
Telecom & Datacom	216.0	256.4	261.3
Industrial & Consumer[1]	190.0	98.8	167.2
Commercial Lasers	42.4	36.9	23.9
Gross Margin (Non-GAAP)	**55.0%**	**47.7%**	**52.0%**
Optical Communications	55.6%	47.7%	52.5%
Commercial Lasers	49.1%	48.5%	43.5%

Commercial Lasers segment revenue was $42.4m (9.5% of total revenue), up 14.9% on $36.9m last quarter and 77.4% on $23.9m (just 5.3% of total revenue) a year ago due to the ongoing (and faster-than-expected) recovery from the impact of COVID-19 on fiber laser demand.

On a non-GAAP basis, gross margin was 55%, up from 47.7% last quarter and 52% a year ago, due to a better mix of products and improvements in Optical Communications and Lasers segment gross margins. "Demand mix is shifting to products aligned with next-generation customer solutions, many of which are just ramping," says the firm.

Optical Communications segment gross margin was 55.6%, up on 47.7% last quarter and 52.5% a year ago, due primarily to a richer product mix.

Commercial Lasers gross margin was 49.1%, up on 48.5% last quarter and 43.5% a year ago due to higher volumes (which are helping to reduce manufacturing overhead expenses).

Operating expenses were $87.8m (19.6% of revenue), up from $82.7m (18.3% of revenue) a year ago but cut from $90.6m (23.1% of revenue) last quarter. Specifically, selling, general & administrative (SG&A) expense was $38.8m and R&D expense was $49m.

Operating income was $158.9m (operating margin of 35.4%, above the expected 30.5–32.5%), up from $96.6m (24.6% margin) last quarter and a then-record $152.5m (33.7% margin) a year ago.

Net income was $135.1m ($1.79 per diluted share, exceeding the $1.47–1.61 guidance), up from $81.9m ($1.06 per diluted share) last quarter and the then-record $131.2m ($1.68 per diluted share) a year ago.

During fiscal Q1, Lumentum purchased 1.1 million of its shares for $91.7m (so, to date, the firm has repurchased a total of 4.2 million of shares for $333m under its $700m share buyback program).

Total cash, cash equivalents and short-term investments hence fell

by $61.4m during the quarter, from $1946m to $1884.6m.

For fiscal second-quarter 2022 (to end-December 2021), Lumentum expects revenue of $435–455m. This includes Telecom and Datacom revenue up quarter-on-quarter due to the increasing semiconductor supply. However, demand is increasing even faster than supply. Due to semiconductor and material shortages, more than $40m of demand is expected to go unsatisfied. Industrial & Consumer revenue (e.g. VCSELs for 3D sensing) will be down sequentially due to seasonality. "We expect this year's demand trend to be more like that of fiscal 2020 than that of fiscal 2021, since COVID-19 delayed key customer programs last year, says Lowe. "Commercial Lasers is recovering ahead of our original expectations, with strong kilowatt fiber laser sales." Lasers revenue should be up again sequentially, with strength across all major product lines.

$ in millions except for EPS, % of revenue	Q1 FY22 *Actual*	Q2 FY22 *Guidance*
Revenue	**$448.4**	**$435 - $455**
Operating Margin	**35.4%**	**30.0% – 32.0%**
Diluted EPS	**$1.79**	**$1.47 - $1.64**
Diluted Shares – M	**75.4**	**75.4**

Mid-point revenue projection assumes:
- Telecom & Datacom up Q/Q
- Industrial & Consumer down Q/Q
- Commercial Lasers up Q/Q
- >$40M revenue impact of semiconductor and other material shortages

Other mid-point assumptions:
- Interest and Other Income being a net expense of ~$1M in total
- 14.5% non-GAAP effective tax rate resulting in an approximate $20M non-GAAP tax expense

"Demand continues to be strong, particularly in Telecom and Datacom as well as Commercial Lasers," summarizes Lowe. "While we are increasing our supply of semiconductors, we expect the gap between demand and supply for our products in the second quarter will be larger than it was in the first quarter, and we have incorporated this in our guidance," he notes. Operating margin is expected to fall to 30–32%. Diluted earnings per share should fall to $1.47–1.64.

"We're continuing to add capacity," says Lowe. "Through the first half of the calendar year, the EML business will benefit from the additions we talked about over a year ago, and those are coming online now," he adds.

"Despite near-term supply challenges, we are seeing a favorable demand environment that we expect will continue throughout fiscal 2022," says Lowe. "Our markets are driven by powerful long-term trends, and customers have communicated that they are seeing accelerating end-market demand for their next-generation solutions," he adds. "We have been successful in developing differentiated new products and designing them into market-leading customers for their next-generation solutions, many of which are just starting to ramp."

www.lumentum.com

Update on acquisition of NeoPhotonics

On 4 November, Lumentum also announced that it had entered into a definitive agreement to acquire San Jose-based NeoPhotonics Corp — a vertically integrated designer and manufacturer of silicon photonics and hybrid photonic integrated circuit (PIC)-based lasers, modules and subsystems for high-speed communications — for $16 per share in cash (a total equity value of about $918m), a premium of about 39% to NeoPhotonics' closing stock price on 3 November. Lumentum intends to finance the transaction through cash from the combined company's balance sheet. As part of the transaction, Lumentum will provide up to $50m in term loans to NeoPhotonics to fund anticipated growth, which may require increased working capital and manufacturing capacity. The deal has been unanimously approved by the boards of directors of both companies.

The transaction is expected to be immediately accretive to non-GAAP earnings per share upon closing. Given the complementary nature of the businesses, Lumentum expects to generate more than $50m of annual run-rate synergies within 24 months. Cost of goods sold (COGS) synergies are expected to be more than 60% of this total, driven by manufacturing infrastructure and supply chain efficiencies. Operating expense synergies will be driven by organizational efficiencies related to aligning and integrating business processes post-closing and serving a similar customer base.

The transaction to currently expect to close in calendar second-half 2022 (subject to the approval by NeoPhotonics' stockholders, regulatory approvals, and other customary closing conditions).

POET agrees first phase of laser supply deal for Optical Interposer platform

Design requirements and operating specs to be followed by production phase for 400G optical engines

POET Technologies Inc of Toronto, Ontario, Canada has agreed the first phase of a supply agreement with a global supplier of lasers and other components used in high-speed optical networking equipment. The companies will collaborate on the design and production of flip-chippable continuous wave (CW) high-power lasers for use in the POET's 400G optical engines.

In this first phase, POET will work with the supplier on a customized version of its existing flip-chippable production CW laser. The customization to the physical design would enable the existing laser to be compatible with POET's Optical Interposer platform, which enables passive, wafer-scale hybrid integration of lasers to produce high-performance optical engines. CW lasers, combined with a silicon photonics-based modulator, will be incorporated into transmit optical engines operating at 400G speeds and beyond.

POET has issued a purchase order to the supplier for the first phase of the project, covering the design requirements and operating specs of the laser. In a subsequent phase, the supplier will build and supply known good lasers for use by POET in the production of 400G optical engines.

"The supplier's lasers are among the most reliable high-performance lasers on the global market. Our collaboration is another example of POET engaging with well-established, highly regarded companies in our industry," comments president & general manager Vivek Rajgarhia. "For most prospective customers, including the tier-1 network equipment suppliers and the hyperscale data-center operators, the incorporation of the supplier's lasers in our 400G designs will significantly increase their confidence about the operating performance and reliability of our products," he reckons. "The fact that the supplier is already producing flip-chip lasers provides POET a shorter time-to-market. If this project goes as we anticipate, we expect to have initial production chips available by mid-2022, which aligns with our roadmap for 400G optical engine beta-sample availability. This is a key move by POET to secure its laser supply in the face of a continued supply-constrained environment."

www.poet-technologies.com

POET raises US$14m from 2016 warrants

POET has raised about US$14.1m on the exercise of the CDN$0.52 warrants that were issued as part of its public offering in 2016. The warrants expired on 2 November.

Since the original date of issuance on 2 November 2016, a combined 33,867,000 warrants were exercised of the total 34,800,000 warrants issued, generating gross proceeds of US$14.1m. Of these, 13,115,750 have been exercised since 30 June, netting the firm about US$5.4m in additional capital.

POET appoints board sub-committee to plan Nasdaq listing

The board of directors of POET — a designer and developer of the POET Optical Interposer and photonic integrated circuits (PICs) for the data-center and telecom markets — has appointed a sub-committee consisting of three independent members to determine the timing and other matters related to its planned listing on the NASDAQ Capital Market.

The sub-committee will consider and recommend to the full board the selection of a lead underwriter to support the US listing, and the timing and ratio for a consolidation of the firm's outstanding shares within the ratios previously approved by its shareholders. Additionally, the sub-committee will evaluate the potential for up-listing to the TSX from the TSX Venture Exchange, and the timing and sequencing of each of these individual steps.

The sub-committee will work with the firm's senior management and company counsel on all aspects of the process and is expected to report its findings to the board by its next scheduled meeting in early 2022.

"Our board has taken another step in a process that we initiated earlier this year," says chairman & CEO Suresh Venkatesan. "We recently secured the approval from shareholders to consolidate our outstanding shares, changed transfer agents to ensure DTC eligibility for more seamless trading of our stock, and made application to the Nasdaq, with a few remaining items to be completed for the application," he adds. "The exact timing of the listings, their sequence and any related public offering of shares will be taken up by the sub-committee with the objective of presenting the optimal timing for a listing in order to maximize value to our shareholders."

POET's Q3 sample deliveries slowed by industry supply chain challenges

Firm now producing samples in expected volumes and shipping to customers

For third-quarter 2021, POET Technologies Inc of Toronto, Ontario, Canada — a designer and developer of the POET Optical Interposer and photonic integrated circuits (PICs) for the data-center and telecom markets — has reported a net loss of $3.5m ($0.01 per share), level with a year ago but cut from $4.4m ($0.02 per share) last quarter. This included R&D costs of $1.2m, down from $1.8m last quarter, driven by the current contraction in the global semiconductor chip supply chain. The current supply environment has resulted in slower deliveries of orders made by POET.

Debt-related finance costs fell further, from $244,000 a year ago and $95,000 in Q2 to $20,000 in Q3.

Other income (including interest) was $208,000 (up from $14,000 a year ago and $20,000 in Q2). This included $187,000 of COVID-19-related PPP loan that was forgiven.

During the quarter, POET recognized a gain of $0.4m on its investment in the Super Photonics Xiamen (SPX) joint venture with Sanan Integrated Circuit Co Ltd of Xiamen City, Fujian province (a subsidiary of Sanan Optoelectronics Co Ltd, China's first 6-inch pure-play compound semiconductor wafer foundry).

On a non-IFRS basis, cash outflow from operating activities was –$2.8m, down slightly on –$2.9m a year ago but up from –$2.6m last quarter.

POET says that it continues to execute on its stated strategic plan and achieved the following milestones during and subsequent to Q3/2021:

- Shipped its first 100G Transmit (Tx) Optical Engine sample to a leading European optical systems company;
- Participated in the two optoelectronics conferences/exhibitions in China (CIOE 2021 and ICCSZ) that generated numerous customer engagements in both its announced Optical Engine products and its Optical Interposer platform. Notably, transceiver module supplier Shenzhen Fibertop Technology Co Ltd committed to incorporating POET Optical Engines in its line of optical modules as soon as production Optical Engines are available;
- Secured a commitment from a leading network systems company for a unique multi-engine design for 100G CWDM4 and 100G LR4 Optical Engines based on the Optical Interposer. The combined value of the NRE (non-recurring engineering) and the purchase order for initial units exceeds US$1.2m;
- Agreed the first phase of a supply agreement with a leading global supplier of lasers and other components used in high-speed optical networking equipment. The firms will collaborate on the design and production of flip-chippable continuous-wave high-power lasers for use in POET's 400G Optical Engines;
- Converted all but $8000 of convertible debentures issued during 2019;
- Improved the cash position as a result of 97% of previously outstanding 2 November warrants being exercised prior to their expiration;
- Ended the quarter with cash and cash equivalents of $20.3m (up from $6.9m at the end of 2020);
- Reported an unaudited cash position subsequent to quarter-end of $23.7m (as of 3 November).

"The supply chain challenges facing the industry have definitely impacted our schedules for delivery of initial samples to customers. Nevertheless, we are now producing samples in the volumes we had expected and are shipping those samples to customers," says chairman & CEO Dr Suresh Venkatesan. "While it has been a long time in coming, we delivered the first complete Optical Engine to an initial customer," he adds. "We had a great showing at CIOE in China, with both Super Photonics Xiamen (SPX) and our Shenzhen team following up on the interest in our industry-standard Optical Engine designs," Venkatesan continues.

"In addition to our standard products, we are seeing substantial interest in novel architectures and in our 400G/800G and co-packaged optics designs. To move these projects forward, we are collaborating with one of the world's leading laser suppliers, as part of a determined effort to meet and surpass the expectations of the industry for advanced products as we enter the new year," Venkatesan concludes.

www.poet-technologies.com

II-VI reports record quarterly bookings of $939m and backlog of $1.4bn

Compound Semiconductors revenue grows 12.5% year-on-year

For its fiscal first-quarter 2022 (to end-September 2021), engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA has reported revenue of $795.1m, up 9% on $728.1m a year ago, driven by growth in virtually all of the firm's end markets.

Revenue for Photonics Solutions was $536m, up 7.7% on $497.7m a year ago.

Revenue for Compound Semiconductors was $259.1m, up 12.5% on $230.4m a year ago.

Specifically, the firm's Industrial business grew by more than 50% year-on-year. High-speed 200/400/800G datacom and telecom revenues have significantly accelerated, growing by nearly 70% sequentially. "This growth was underpinned by our industry-leading laser diode technologies that enabled the highest-output-power 400G coherent pluggable transceivers available in the marketplace," says CEO Dr Vincent D. Mattera Jr.

On a non-GAAP basis, gross margin was up from 39.4% a year ago to 39.8%. Net earnings grew from $100.4m ($0.84 per diluted share) to $117.7m ($0.87 per diluted share). Return on sales was up from 13.8% to 14.8%. During the quarter, cash and cash equivalents fell slightly from $1.59bn to $1.56bn, although this is still up on $0.684bn a year ago.

"Our customers are growing and demanding much more from us as the end markets we serve, and the mega-market trends driving them, continue to accelerate," continues Mattera. "We are looking ahead and aggressively investing to serve these transformative and sustainable market trends, consistent with our strategic plan," he adds.

"Our integration planning with Coherent [of Santa Clara, CA, which provides lasers and laser-based technology for scientific, commercial and industrial applications] is well underway [after approval by shareholders in late June]. All integration planning teams are fully engaged and excited about the prospect of combining our complementary talent, technology platforms, and scale across the value chain," says Mattera. "All remaining regulatory reviews are progressing on track, with China having formally commenced its review process in September." The firm continues to expect that the transaction will close during calendar first-quarter 2022. "Our synergies on the Finisar transaction [acquisition of the Sunnyvale, CA-based fiber-optic communications component and subsystem maker in September 2019] now exceed $180m, which are well ahead of schedule," concludes Mattera.

Fiscal year 2022 is starting with "very strong momentum and sustainable demand signals" that translated into another quarterly bookings record of $939m (up 43% year-on-year) and record backlog of $1.4bn.

For fiscal second-quarter 2022 (to end-December 2021), II-VI expects revenue of $790–840m and net earnings of $104–128m ($0.75–0.95 per diluted share).

www.ii-vi.com

II-VI's Julie Eng and Chris Cole elected Optica Fellows

Eng elected for work on transceivers and 3D sensing VCSELs

Engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA says that Dr Julie Sheridan Eng (senior VP & general manager, Optoelectronic Devices & Modules business unit) and Chris Cole (II-VI adviser) have been elected by the Optica board of directors to its 2022 Fellows Class.

Optica Fellows are members of Optica (formerly the Optical Society of America, OSA) who have served with distinction in the advancement of optics and photonics through their sustained contributions to education, research, engineering, business and society. Fellows are elected annually by the Optica board of directors in a highly competitive process.

Eng was elected for her contributions in technology development and productization of fiber-optic transceivers and 3D sensing VCSELs.

Cole was elected for pioneering contributions to architectures, specifications, standardization and product development of 10G, 40G, 100G, 200G and 400G optical interfaces.

"The election of Julie and Chris to the distinguished ranks of Optica Fellows speaks to their lifelong scientific curiosity and technical ingenuity, as well as their outstanding career contributions as innovators in photonics, most notably for datacom transceivers and laser arrays for 3D sensing, which are contributing to the growth of our business while enabling the convergence of communications, computing and sensing," comments II-VI's CEO Dr Vincent D. Mattera Jr.

www.ii-vi.com

II-VI Inc powers all its European sites with 100% renewable electricity

Major manufacturing sites in Asia to use more renewable electricity

Engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA says that it is powering all its facilities in Europe with 100% renewable electricity sources.

The renewable electricity is supplied to II-VI's manufacturing operations, R&D sites and sales offices throughout six European countries (Belgium, Germany, Italy, Sweden, Switzerland, and the UK), encompassing 615,000ft^2 (57,000m^2) of facility space across 12 sites. To power its footprint across Europe, II-VI is purchasing about 38 million kilowatt-hours (kWh) per year of renewable electricity, eliminating about 5800 metric tons of CO_2 emissions each year.

"II-VI has made it a top priority to reduce its carbon footprint across its global operations," says Dr Karl-heinz Gulden, senior VP, Laser Devices and Systems business unit.

Globally, II-VI has entered into renewable-electricity contracts for 24 sites, including 14 of them now covering 100% of their annual electricity usage from renewable sources. Over 20% of II-VI's global electricity needs are now being supplied by renewable sources across the USA and Europe. The percentage of renewable electricity powering II-VI's operations is expected to grow annually and, in the future, include the company's major manufacturing sites in Asia.

II-VI participates at ECOC 2021 Exhibition Virtual Catch Up

IC-TROSA wins Industry Award for product innovation

II-VI Inc of Saxonburg, PA, USA, which provides optical communications solutions for datacom and telecom networks, participated at the European Conference on Optical Communication (ECOC 2021) Exhibition Virtual Catch Up (online 1–3 November). The firm's virtual booth displayed product and technology capabilities from its portfolio of telecom and datacom components, modules and subassemblies as well as wavelength-management ROADM and optical amplifier modules.

During the live event, II-VI presented a video at the Product Focus Theatre to highlight the unique applications of what is claimed to be the first high-performance compact 400G QSFP-DD coherent pluggable module. At the heart of the transceiver is an integrated transmitter and optical subassembly (IC-TROSA), which was honored with an ECOC Industry Award for product innovation.

In addition, II-VI's chief marketing officer Sanjai Parthasarathi presented, during the ECOC Market Focus replay, 'Optical Communications for Satellite Networking: From Free Space Optics to Optics in Space'. II-VI advisor Chris Cole also participated to present 'A New Specification for Multi-Wavelength Optical Laser Sources for Advanced Integrated Optics'.

www.ecocexhibition.com

MACOM promotes VP of Asia sales to newly created position of MACOM China president

Hualiang Xiong to lead China operations, reporting to president & CEO

MACOM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog RF, microwave, millimeter-wave and photonic applications) says that Hualiang Xiong has been promoted to the newly created position of president of MACOM China, leading the firm's China operations and reporting directly to president & CEO Stephen G. Daly.

Xiong joined MACOM in January 2015 and, during his tenure as VP of Asia sales, has supported the firm's business growth strategy across the Asia Pacific region. In his new role, Xiong will be responsible for MACOM's activities in China, including business development, customer relationships and management of MACOM's engineering, operations, quality and applications support organizations and facilities. Xiong has over 20 years of experience in the semiconductor industry and has established a successful track record of growth and building effective organizations, says MACOM.

Hualiang Xiong.

"Under Hualiang's leadership, our China team will continue to achieve amazing results," believes Daly. "MACOM has a strong customer and employee base in China, and I look forward to working with the team to further expand our presence and capabilities in the China market," says Xiong.

www.macom.com

New SFP112 & SFP-DD112 specs from SFP-DD MSA

The Small Form Factor Pluggable Double Density (SFP-DD) Multi-Source Agreement (MSA) Group has announced its updated 5.0 hardware specifications and drawings for the SFP-DD, SFP-DD112 and SFP112 pluggable modules. This revision enables SFP112 operating at 112Gbps and SFP-DD112 operating at an aggregate rate of 224Gbps; aligning with next-generation higher-speed networking, storage and access equipment. The new revision also includes an SFP112 module specification to ensure that the industry roadmap from SFP28/SFP56 to SFP112 and SFP-DD to SFP-DD112 maintains overall compatibility.

SFP-DD MSA revision 5.0 hardware specification includes significant signal integrity enhancements to address 112Gbps differential signaling. Three new clauses have been added as follows:
Chapter 5 for SFP112 electrical and management interface requirements, Chapter 8 for SFP-DD 112G mechanical and board definition, and Chapter 9 for SFP112 mechanical and board definition. In addition, the new revision includes an ePPS/Clock signal definition for SFP-DD/SFP-DD112. Lastly, TS-1000 Normative Module and Connector performance requirements for SFP112 were added into Appendix A.

Maintaining SFP-DD and SFP for future applications

This critical addition to the MSA specification ensures that the industry will be able to continue to leverage the single-channel and two-channel form factors for current and future generations of equipment and market applications. Updating both SFP+ and SFP-DD form factors enables the SFP-DD host equipment ports to be able to reliably accept SFP112 modules, as has been a crucial use case with prior generations. Additionally, this effort can maintain SFP+ and SFP-DD power capability alignment with trends and technologies. The SFP-DD form factor addresses the technical challenges of achieving a double-density interface and ensuring mechanical interoperability for module components produced by different manufacturers while still enabling use of legacy SFP modules. This updated specification supersedes previous versions and has updated mechanical connector dimensions.

SFP-DD MSA promoters include Alibaba Group, Broadcom, Cisco, Dell Technologies, Hewlett Packard Enterprises, Huawei, II-VI Inc, Intel, Juniper Networks, Lumentum, Molex, Nvidia and TE Connectivity. Contributors include Accelink, Amphenol, AOI, Eoptolink, Foxconn Interconnect Technology, Fourte International, Genesis Connected Solutions, Hisense Broadband, Infinera, InnoLight, Maxim Integrated, Multilane, Nokia, Senko, Source Photonics, US Conec, Yamaichi Electronics, and ZTE.

www.sfp-dd.com

Skorpios presents co-packaged optics at ACP 2021

3.2Tb/s Tru-SiPh interface chip serves up to 51.2Tb/s switch bandwidth

At the Asia Communications and Photonics Conference (ACP 2021) in Shanghai, China (24–27 October), Skorpios Technologies Inc of Albuquerque, NM, USA (which provides integrated silicon photonics products based on a proprietary, wafer-scale heterogeneous integration process) presented details of its approach to co-packaged optics, which provides optical interfaces directly at the package level for high-speed digital interfaces by utilizing the firm's Tru-SiPh platform (integrating lasers, modulators and other components on a polarization-insensitive silicon photonics platform). This highly integrated photonic chip can provide 3.2Tb/s FR4 optical interfaces and is small enough that 16 can be placed around an IC to provide 51.2Tb/s as a chip-scale interface for the next generation of high-bandwidth switches.

Skorpios' silicon photonics platform integrates lasers, electro-absorption modulators (EAM), semiconductor optical amplifiers (SOAs) and photodiodes (PDs) in III-V compounds directly into silicon-based wafers.

Electronics and optics can then be integrated, burned in and tested at wafer scale. Laser materials are bonded directly to the silicon substrate, vastly improving heat management and minimizing the size of the laser. Since all laser stripe processing occurs after bonding, multiple devices can be implemented on each implanted epitaxial layer, and laser power into the waveguide is optimized. Similarly, EAMs are built from other implanted epitaxies, reducing size and control complexity of the modulator.

The thick silicon platform that Skorpios uses is said to offer several advantages: low waveguide loss, low coupling loss, polarization insensitivity, and high optical power handling. Multiplexing (Mux) and demultiplexing (DeMux) functions do not require tuning. The entire platform is covered in silicon dioxide after fabrication, so III-V devices and facets are environmentally protected, eliminating the need for hermetic packaging.

"With our design, we can integrate all devices on a single small chip, including 16 lasers (plus 16 redundant), 32 EAMs, 32 SOAs, 32 PDs, and 8 tuning-free wavelength Mux and DeMux, to provide eight standard 400Gb/s FR4 links," notes chief technology officer Glenn Li. "This product is an outstanding demonstration of highly integrated heterogeneous silicon photonics possible with our platform," he adds.

www.acpconf.com
www.skorpiosinc.com

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5N Plus completes acquisition of AZUR SPACE for €74.6m

Combined firm spans critical IV, III–VI and II–VI materials to finished epitaxy engineered substrates

Specialty semiconductor and performance materials producer 5N Plus Inc of Montreal, Québec, Canada has completed its acquisition (announced in March) of AZUR SPACE Solar Power GmbH of Heilbronn, Germany (which develops and manufactures multi-junction solar cells based on III-V compound semiconductor materials) for €74.6m (subject to post-closing adjustments), in exchange for 6.5 million shares of 5N Plus, to be issued from the treasury estimated at €13.1m (based on the volume-weighted average trading price for the seven trading days preceding the closing) along with a cash payment of €37.7m. Furthermore, 5N Plus will finance working capital of €23.8m. The cash portion and the working capital of the transaction is funded through the firm's liquidity and senior debt facility.

5N Plus provides purified metals such as bismuth, gallium, germanium, indium, selenium and tellurium, and also produces related II-VI semiconducting compounds such as cadmium telluride (CdTe), cadmium sulphide (CdS) and indium antimonide (InSb) as precursors for the growth of crystals for solar, LED and eco-friendly materials applications. Operating R&D, manufacturing and commercial centers in several locations in North America, Asia and Europe (including three in Germany and one in Belgium), the firm supplies to the thin-film PV renewable energy industry and is a supplier within the US satellite supply chain.

"AZUR's acquisition is the linchpin of our strategic transformation toward critical material technology," says 5N Plus' president & CEO Arjang Roshan. "Our combined pool of talent and AZUR's cutting-edge space technology are key enablers for our entry into the larger markets within the field of specialty semiconductor substrates."

Considering the strategic importance of AZUR and its advanced technologies, the relevant regulatory authorities conducted an exhaustive review to vet 5N Plus as an appropriate acquirer. The firm says that the acquisition is the cornerstone of its transition to advanced materials based on cutting-edge technology. In alignment with its growth strategy, the transaction will enable 5N Plus to expand its product portfolio within specialty semiconductors and position the firm to benefit from potential growth linked to several critical industries that rely on advanced compound semiconductors in the future.

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With nearly 60 years of experience in space solar cell manufacturing, AZUR is supported by nearly 120 patent families. 5N Plus reckons that its integration creates a global enterprise with comprehensive competencies across the specialty semiconductor value chain that rivals global competitors, fuels innovation and grants entry to larger markets with significant growth opportunities.

5N Plus says that, as well as a highly skilled and experienced workforce, the acquisition of AZUR brings incremental sales revenue in excess of €50m, a well-established portfolio of business providing €5–7m EBITDA per year, strong backlog, and solid financial support from several agencies (confirming AZUR's strategic importance).

The combination of 5N Plus and AZUR forms a "one-of-a-kind" ecosystem that will enable:

- a fully integrated suite of compound semiconductor products (a family of IV, III-VI and II-VI materials) from procurement of critical materials to finished epitaxy engineered substrates;
- entry and access to new markets with higher total addressable market (TAM) such as high-power electronics, electric mobility, wireless charging and advanced communications;
- closed-loop management of critical materials including much of its own in-process by-products and those of its customers — enhancing sustainability and competitiveness of the business model;
- unlocking tangible synergies, resulting in more value capture from the space and security markets, it is reckoned.

It is also reckoned that the integrated company will be more diversified, with improved product mix, and will:

- attain 5N Plus' strategic aim to expand its total addressable market;
- further reduce the reliance on a single customer;
- further reduce the exposure to metal price notations;
- confirm its merger & acquisition (M&A) focus on specialty semiconductors;
- establish 5N Plus' importance in the critical material space and its strategic position, as perceived by various agencies and governmental bodies

www.azurspace.com
www.5nplus.com

5N Plus' president & CEO steps down

Roshan to advise interim CEO while replacement sought

Specialty semiconductor and performance materials producer 5N Plus Inc of Montreal, Québec, Canada says that Arjang Roshan will be stepping down as president & CEO, effective 1 December. However, he will continue to act as a strategic advisor to the board of directors, the interim president & CEO and the company until a permanent president & CEO is appointed, which is currently expected to be on or before the firm's 2022 annual general meeting of shareholders.

5N Plus provides purified metals such as bismuth, gallium, germanium, indium, selenium and tellurium, and also produces related II-VI semiconducting compounds such as cadmium telluride (CdTe), cadmium sulphide (CdS) and indium antimonide (InSb) as precursors for the growth of crystals for solar, LED and eco-friendly materials applications. Sectors addressed include renewable energy, security, space, pharmaceutical, medical imaging, and industrial and additive manufacturing.

"Arjang was with us for six years, during which he implemented a strategy and business plan that allowed for the reorganization of the company's affairs, the stabilization of the company's EBITDA and solidification of our balance sheet, and the refocusing of our operations on value-added markets, as evidenced most recently by our acquisition of Azur Space," says Luc Bertrand, chairman of the board of directors.

"The recent Azur Space acquisition will uniquely position 5N Plus for space and other essential markets," believes Roshan. "The past 16 years of my career have been spent abroad and in the past 6 years I have been often away from my home and family in the USA. After consulting with the board of directors, we have agreed that a new president and chief executive officer should lead the company in its next chapter," he adds.

Gervais Jacques has been appointed interim president & CEO, effective 1 December. Jacques brings "decades of leadership experience managing global businesses," says Bertrand. "During the transition period, the board of directors, the interim president & chief executive officer and the company's senior management, with the support of Mr Roshan, will continue to work on the orderly integration of Azur Space," he adds.

5N Plus says that Jacques has extensive knowledge of the affairs of the company and its industry and is a seasoned business executive with over 30 years of experience in metals. Jacques is the former managing director (and previously chief commercial officer) of Rio Tinto Aluminum, where he led more than 6000 staff in five countries. Jacques also previously served as chairman of the International Aluminum Institute (the only Canadian ever appointed to this position) and as chairman of the Canadian Aluminum Association. He is currently chairman of the board of Nemaska Lithium and Airex Energy, and is a board member of Alliance Magnesium.

www.5nplus.com

Lightsource/bp order up to 5.4GW of First Solar modules

First Solar Inc of Tempe, AZ, USA says that San Francisco-based solar energy project developer and manager Lightsource bp and integrated energy company bp (America's largest energy investor since 2005, which has a 50% stake in the joint venture) have placed multi-year orders for up to 5.4GW combined of its cadmium telluride (CdTe) thin-film photovoltaic (PV) solar modules. As part of the deal, Lightsource bp and bp have placed firm orders for about 4.4GW$_{DC}$ of modules, with options for an additional 1GW$_{DC}$.

Lightsource bp has agreed to procure up to 4.3GW$_{DC}$ of modules for its US utility-scale projects, and bp will procure up to 1.1GW$_{DC}$ to power their projects being developed by Lightsource bp. bp acquired the projects as part of its net zero ambition and target to grow its net developed renewable generating capacity to 20GW by 2025 and 50GW by 2030. Planned deployments for both companies include projects in Arkansas, Kentucky, Ohio, Pennsylvania and Texas.

The framework agreements, the largest in First Solar's history, will provide modules scheduled to be delivered between 2023 and 2025 to support the companies' solar development pipelines in the USA. Under the agreement, First Solar has firm orders for 1.55GW$_{DC}$ of modules in 2023, 1.3GW$_{DC}$ in 2024, and 1.55GW$_{DC}$ in 2025.

"This landmark solar industry procurement deal is a testimony to Lightsource bp's exponential growth in the United States, and our confidence in First Solar's technology," says Kevin Smith, CEO Americas, Lightsource bp. "As we continue to grow and progress our 10GW development pipeline across America, in addition to our partner bp's 9GWs, executing significant long-term procurement agreements with bankable, world-class suppliers like First Solar enables us to deliver on our growth plans and industry-leading global target of 25GW of solar by 2025," he adds.

The 163MW Elm Branch solar power project in Texas was developed by Lightsource bp and is powered by First Solar Series 6 photovoltaic modules. (Photo: Lightsource bp)

"To help reach our net-zero ambition and develop 50GW of renewable power by the end of this decade, we continue to invest in clean, reliable energy in the US," says Felipe Arbelaez, bp's senior VP of zero carbon energy. "Today's announcement reflects the speed in which we're moving... These modules are a critical step in delivering our 9GW solar pipeline," he adds. bp aims to deliver 20GW of developed renewables by 2025.

As well as having access to modules produced at First Solar's fully vertically integrated manufacturing complex in Ohio, Lightsource bp and bp will benefit from the evolution of the firm's CdTe thin-film module technology platform over the span of the agreement.

"The US solar industry is at an important inflection point where it must continue the charge towards delivering 45% of our country's electricity by 2050 while addressing the risks and uncertainty posed by increasingly volatile solar panel production, pricing and supply," says First Solar's chief commercial officer Georges Antoun. "Our ability to help our customers manage these risks by providing long-term firm pricing and supply commitments, backed by First Solar's reputation, is a key differentiator," he reckons.

In addition to the multi-year module sales agreement, First Solar also signed a memorandum of understanding (MoU) to explore opportunities to source electricity from generation assets developed, owned and operated by Lightsource bp in Ohio, where First Solar operates the Western Hemisphere's largest solar manufacturing footprint. When it joined RE100 in 2020, First Solar committed to powering 100% of its global manufacturing operations with renewable energy by 2028, with an interim goal of transitioning its facilities in the US to carbon-free electricity by 2026.

In June, First Solar announced that it is investing $680m to expand America's domestic PV solar manufacturing capacity by 3.3GW annually by building its third US manufacturing facility (in Lake Township, Ohio). The new facility is expected to be commissioned in first-half 2023 and, when fully operational, will scale the firm's Northwest Ohio footprint to a total annual capacity of 6GW, which is believed to make it the largest fully vertically integrated solar manufacturing complex outside China.

In addition to its Ohio manufacturing facilities, First Solar also operates factories in Vietnam and Malaysia, and has previously announced plans to build a new 3.3GW factory in India that is expected to be commissioned in second-half 2023. With First Solar's expansion in the USA and India and optimization of its existing fleet, the firm anticipates that its nameplate manufacturing capacity will double to 16GW by 2024.

www.firstsolar.com

Midsummer receives €38m in Italian grants to set up solar roof production plant in Bari

50MW factory to expand Midsummer's annual capacity tenfold

Together with the Italian Ministry for Economic Development (MISE) and Invitalia (the Italian Ministry of Finance's state investment and economic development institution), the Puglia regional authorities have confirmed that Midsummer AB of Järfälla, near Stockholm, Sweden – a provider of turnkey production lines as well as flexible, lightweight copper indium gallium diselenide (CIGS) thin-film solar panels for building-integrated photovoltaics (BIPV) – will receive incentives of about €38m in the form of grants and soft loans to build a factory and commence manufacturing of light, discreet and environmentally friendly thin-film solar roofs in Bari, Puglia, Italy for the global market.

The production capacity at the Italian factory will be 50MW per year. Midsummer's production capacity will hence expand will tenfold, says CEO Sven Lindström. "The finished factory will make Midsummer the largest producer of thin-film solar cells in Europe," he reckons.

Midsummer has already purchased a plant in Bari in southern Italy. The subsidiary Midsummer Italia will own and operate the factory and, in the initial stage, will order a number of DUO solar cell production systems from its parent company, as well as recruiting staff in both Italy and Sweden. The factory is expected to commence production in summer 2022.

The entire project represents an investment of about €66m, of which Midsummer will receive about 35% in grants and 23% in 'soft loans' from the Italian state via its investment arm Invitalia, whose aim is to increase Italy's economic growth and focuses on strategic sectors for development and employment (including renewable energy).

Demand for Midsummer's solar roofs is very strong in the Nordic countries, with an increase in order intake for third-quarter 2021 of 500%. The solar roofs manufactured in Italy will be sold to customers in mainly southern Europe. Midsummer comments that Italy offers homeowners favorable subsidies (of over 100%) for the installation of solar cells, allowing owners of private property to install solar cells on their houses at no cost.

Midsummer's Italian factory and its grants and loans comprise the first Swedish project to be included in Italy's 'Recovery and Resilience plan', which covers a total of just over €190bn from the EU.

The decision was announced just after a visit to Italy by a large Swedish trade delegation, in which Midsummer took part. Other members of the delegation were Sweden's Crown Princess Victoria and Prince Daniel, Sweden's Minister for Foreign Trade and Nordic Affairs Anna Hallberg and Sweden's Ambassador to Italy Jan Björklund.

"Midsummer's expansion in Italy is a concrete example of cooperation between Sweden and Italy that is beneficial to both countries and well aligned with several of the trade delegation's focus areas — renewable energy and innovative technology," says Björklund, Sweden's Ambassador to Italy.

"We truly appreciate the support that has been given to us from the Swedish Embassy in Rome, the Ministry for Foreign Affairs and Business Sweden," comments Lindström.

www.midsummer.se

Indium arsenide quantum dot laser for E-band dry fiber

Researchers extend wavelength of InAs QD laser diodes to 1428nm, continuous wave, enabling use of dehydrated glass for transmission.

University of Tokyo in Japan has demonstrated laser diodes emitting in the 1360–1460nm E-band range [Jinkwan Kwoen et al, Optics Express, v29, p29378, 2021]. The devices used a multi-functional metamorphic buffer (MFMB) to enable indium arsenide (InAs) quantum dot (QD) structures to operate at these wavelengths.

Until relatively recently (<20 years), the development of such devices was hindered by optical fibers for the E-band strongly attenuating transmission, due to the presence of OH groups in the glass material. Water vapor has an absorption band around 1400nm.

But now that 'dry' ITU-T G.652.D optical fiber resulting from new dehydration techniques has become available the search is on for efficient emitters in the E-band. Indeed, the dry fibers now give better performance

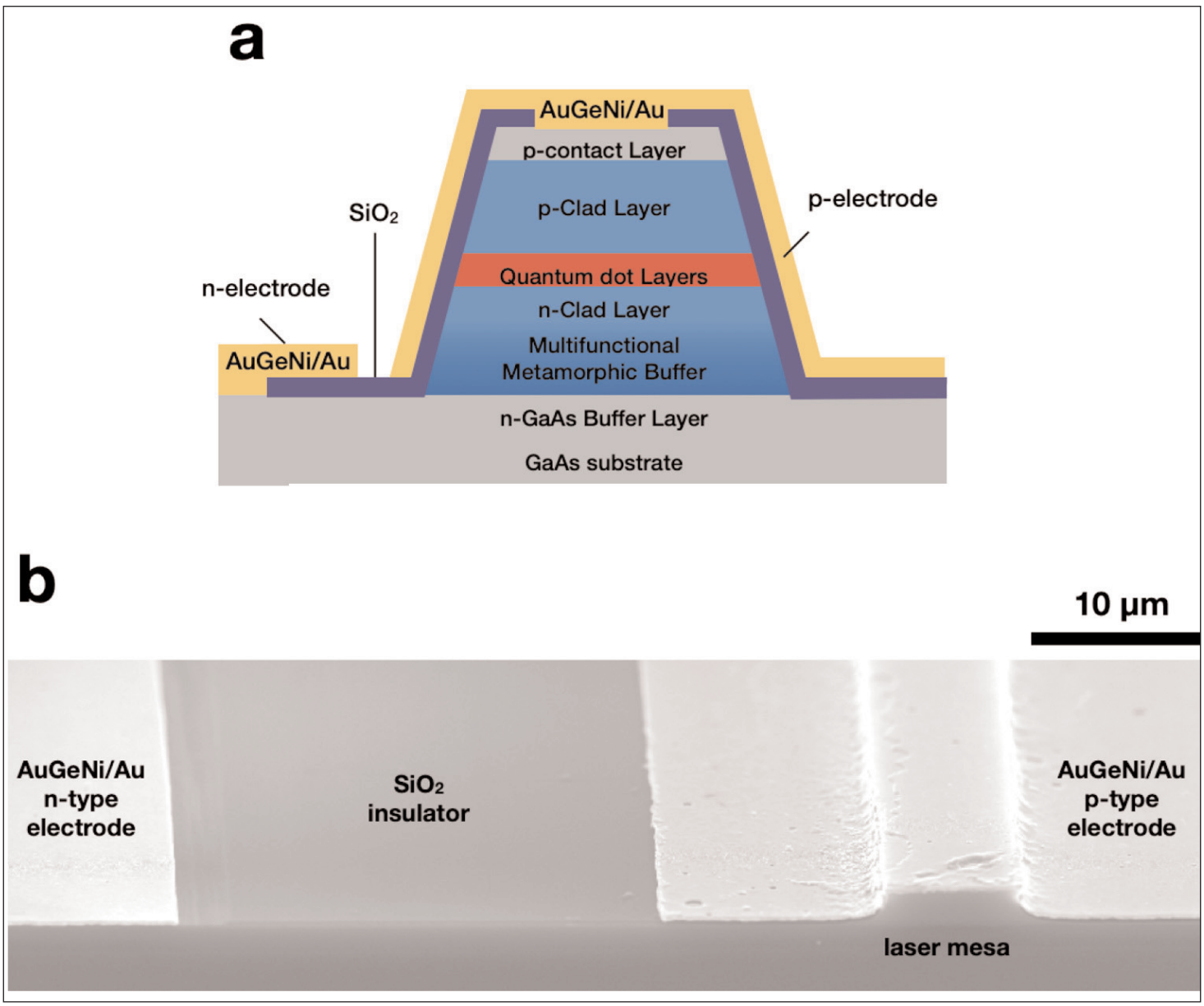

Figure 1. (a) Schematic and (b) scanning electron microscope images of InAs/InGaAs QD laser device on MFMB layer.

than fibers designed for O-band (1260–1360nm) transmission. The researchers also express hopes that the metamorphic technique can be applied to create optical emitters on a silicon photonics platform.

Solid-source molecular beam epitaxy (SS-MBE) on n-type (001) gallium arsenide (GaAs) substrate was used to create the InAs QD laser material. The structure included a metamorphic buffer grown on an initial 200nm GaAs buffer layer. The strained layer superlattice (SLS) consisted of three indium aluminium gallium arsenide (InAlGaAs) strained layer superlattices separated by 1.5nm AlAs to filter out threading dislocations and other defects. Each strained layer superlattice consisted of 5 pairs of 10nm/10nm $In_{0.23}Al_{0.35}Ga_{0.42}As/In_{0.33}Al_{0.35}Ga_{0.32}As$ sandwiched between two layers of 100nm $In_{0.15}Al_{0.35}Ga_{0.50}As$. The AlAs interlayers were designed to avoid indium desorption during 700°C thermal annealing steps.

The laser structure was 600nm n-$In_{0.23}Al_{0.35}Ga_{0.42}As$ cladding, 50nm InAs QDs, 1500nm p-$In_{0.23}Al_{0.35}Ga_{0.42}As$ and 400nm p-$In_{0.23}Ga_{0.77}As$ contact. The QD layer consisted of 8 layers of InAs QDs in an InGaAs matrix.

Photoluminescence spectra on the structure showed a peak at 1440nm (861meV) with 44meV (74nm) full-width at half-maximum (FWHM).

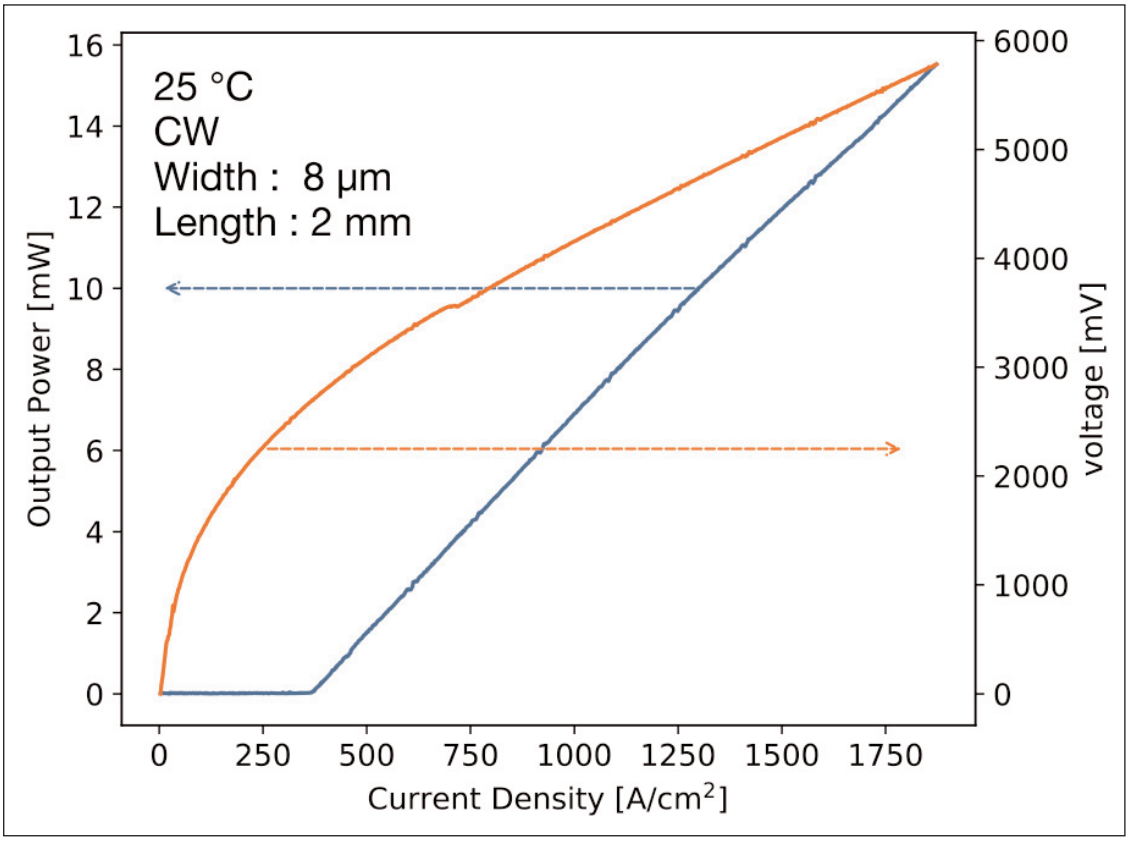

Figure 2. Output power-current-voltage (L–I–V) characteristics under CW operation at 25°C for the InAs/InGaAs QD laser on MFMB layer.

Until relatively recently (<20 years), the development of such devices was hindered by optical fibers for the E-band strongly attenuating transmission, due to the presence of OH groups in the glass material. Water vapor has an absorption band around 1400nm. But now that 'dry' ITU-T G.652.D optical fiber resulting from new dehydration techniques has become available the search is on for efficient emitters in the E-band

Ridge lasers with 6µm-wide and 8µm-wide mesas were fabricated (Figure 1). Sputtered silicon dioxide (SiO_2) provided electrical isolation, and presumably surface passivation. The annealed electrodes consisted of gold-germanium-nickel/gold (AuGeNi/Au). The final laser bars featured 1.5mm or 2.0mm cavity length. The cleaved facets were uncoated.

The metamorphic buffer allowed an increase in lattice constant from 0.56nm for GaAs to 0.575nm for $In_{0.23}Al_{0.35}Ga_{0.42}As$. This allowed the InAs QDs to emit longer-wavelength light than usual.

The laser diodes were operated under pulsed and continuous wave (CW) modes. At 20°C, the pulse lasing threshold was 72mA, representing current density of 380A/cm^2, for a 1.5mmx6µm laser diode. The threshold characteristic temperature T_0 was approximately constant at 44K up to 70°C. The slope efficiency was 92.3mW/A at 20°C, 70.4mW/A at 50°C, and 23.2mW/A at 80°C.

In CW operation, the threshold was 69.2mA (360A/cm^2) at 25°C on a 2mmx8µm laser diode. The researchers comment: "This is much smaller than the threshold current density of ~1kA/cm^2 reported from InGaAsP MQW lasers and GaInNAs MQW lasers."

Multimode lasing was observed with a ground-state peak at 1428nm. ■

https://doi.org/10.1364/OE.433030

Author: Mike Cooke

Direct-epi InP quantum dot micro-disk lasers on silicon

HKUST has claimed the first micro-disk lasers made using direct epitaxy of indium phosphide quantum dots on silicon that emit in the red spectral range.

Hong Kong University of Science and Technology (HKUST) in China claims the first red micro-disk lasers (MDLs) fabricated using material from direct epitaxy of indium phosphide (InP) quantum dots (QDs) on silicon (Si), with a view to the integration of silicon photonics with red (625–700nm) and near-infrared (NIR, 700–1400nm) lasers [Wei Luo et al, Optics Letters, v46, p4514, 2021].

Silicon photonics is seeing much interest from areas such as optical communication, bio-photonics, and sensing. The red/NIR areas of the spectrum accessible to InP QDs are attractive for displays, underwater communication, and molecular diagnostics.

A range of compact light sources integrated into silicon photonics structures is often needed for such applications. Efficient semiconductor light sources are presently made from the various III–V compounds, which often don't mix easily with silicon production processes. Direct epitaxy, creating monolithic devices, would be much preferred over the direct wafer bonding techniques that presently dominate commercial production.

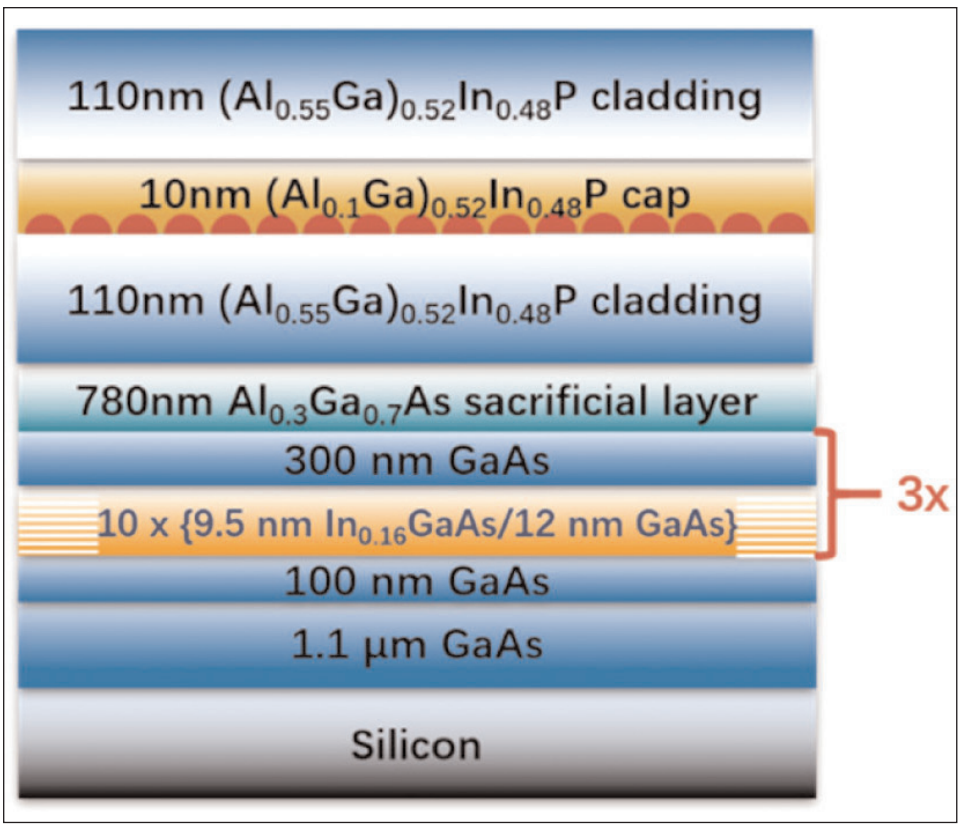

Figure 1. Schematic of InP QD laser structure grown on GaAs/Si template.

One barrier to direct epitaxy is the large numbers of defects that tend to be generated inside the III–V semiconductor structures. QDs are less prone to be affected by defects, presumably due to the carrier recombination processes being more confined in the localized states of the individual dots.

The InP QD structures were grown on gallium arsenide (GaAs)/Si templates using metal-organic chemical vapor deposition (MOCVD). A separate three-step MOCVD process was used to create the GaAs templates on (001) Si to which was added three sets of strained-layer superlattices (SLS) separated by 300nm GaAs spacers to further reduce defect density (Figure 1). The SLS consisted of 10 pairs of 9.5nm/12nm $In_{0.16}Ga_{0.84}As$/GaAs.

The laser structure itself consisted of an aluminium gallium arsenide (AlGaAs) sacrificial layer, AlGaInP lower and upper cladding, and inbetween InP QDs capped with AlGaInP. The QD density was $1.3x10^{10}/cm^2$, which compares with $1.2x10^{10}/cm^2$ density for QDs grown on bulk GaAs. Close inspection with transmission electron microscopy (TEM) showed the QD dimensions to be of order 40nm diameter and 4nm height. In addition, there was a low density of larger-sized QDs, which created a shoulder on the long-wavelength side of photoluminescence (PL) spectra. QDs on GaAs/Si emitted at somewhat longer wavelengths relative to InP QDs on GaAs. The team attributes the red-shift on GaAs/Si to "residual tensile strain caused by the introduction of SLSs and the thermal mismatch between the III–V material and silicon".

Fabricated micro-disk lasers measured 1.5µm in diameter. Dispersed silica beads were used as a hard mask for the inductively coupled plasma (ICP) etch process, resulting in columns down to the sacrificial layer.

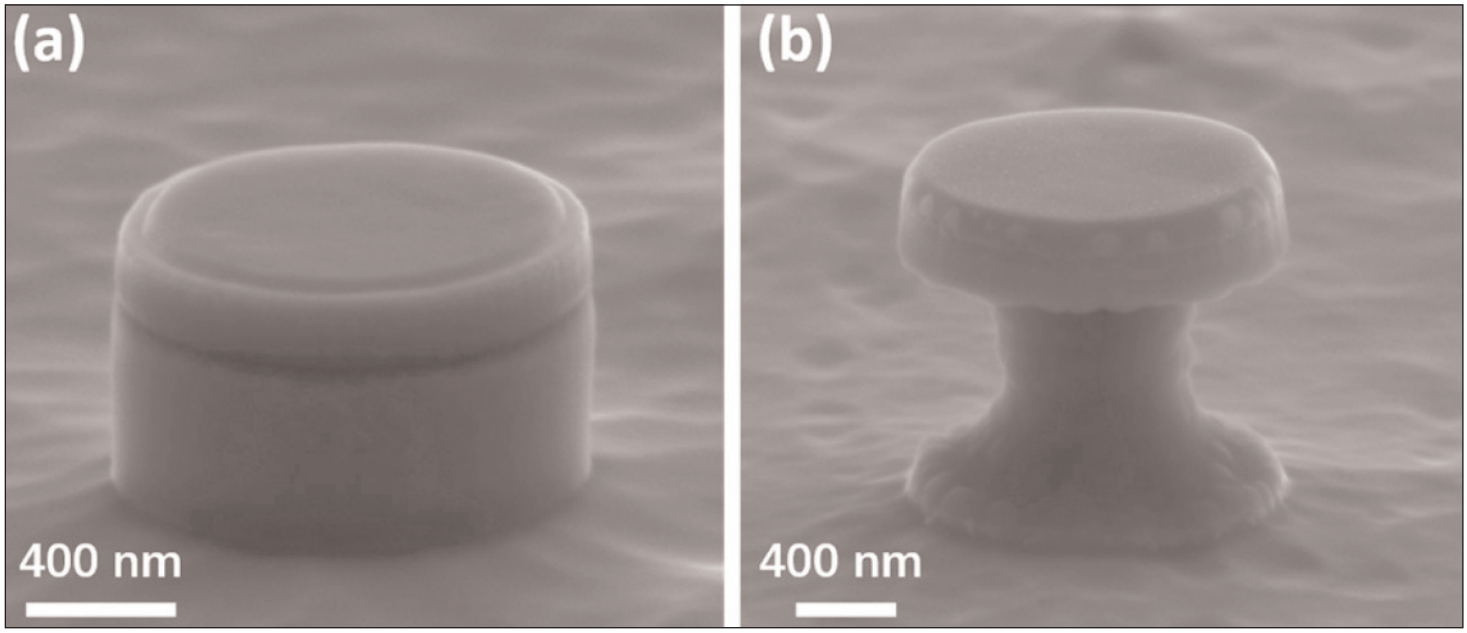

Figure 2. 70°-tilted scanning electron micrograph of micro-disk lasers on GaAs/Si template (a) before and (b) after pedestal formation.

The pedestals were formed using a selective AlGaAs wet etch.

Smooth sidewalls of the circular disk structure (Figure 2) were critical for achieving a 'whispering gallery'-type mode for the laser cavity. Even well below the lasing threshold, this mode peak was clearly visible in continuous wave spectra from a 514nm pump laser diode at 6.25nW (Figure 3).

The laser threshold pump power was around 1μW for micro-disk lasers both on GaAs/Si and GaAs (Figure 4).

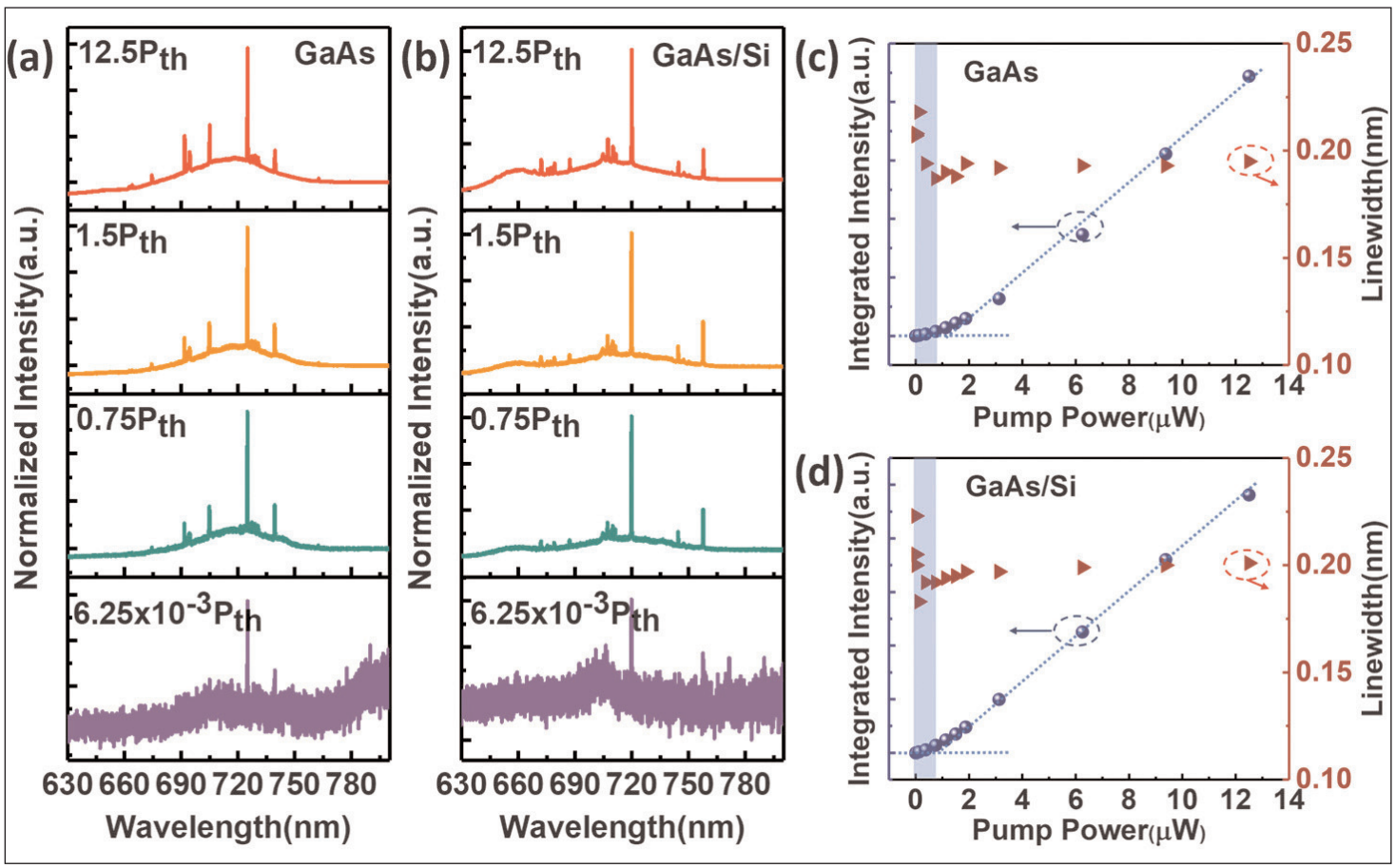

Figure 3. Representative room-temperature power-dependent PL spectra of InP QD MDLs on (a) GaAs substrate and (b) GaAs/Si template, respectively. (c) and (d) Corresponding collected PL intensity and mode linewidth of dominant peak in (a) and (b) as a function of pump power.

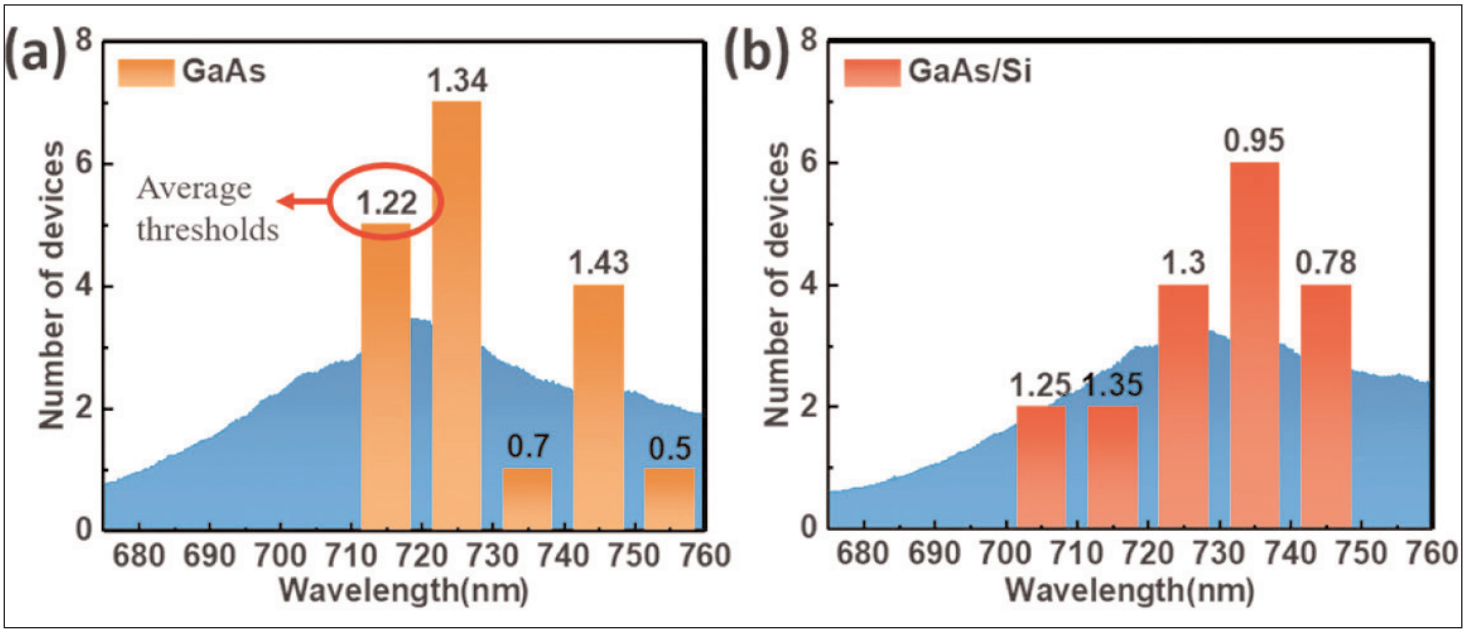

Figure 4. Statistical analysis of lasing behavior of InP QD MDLs on (a) GaAs and (b) GaAs/Si. The numbers on top of each column denote average MDL thresholds. Backgrounds: normalized PL spectra of unprocessed samples.

The researchers compare this with 30μW threshold reported in 2009 by University of Notre Dame in the USA and Ioffe Physical Technical Institute in Russia for InP QD micro-disk lasers directly bonded onto silicon. In addition, the laser output power increases linearly with the pump power up to 12.5x the threshold value. The lowest threshold achieved was 500nW (0.5μW).

The researchers conclude: "Direct epitaxy of InP QDs on a high-Al-composition $(Al_{0.55}Ga)_{0.52}In_{0.48}P$ barrier leads to higher QD density, which also contributes to the low threshold of the micro-disk lasers." The team hopes to fabricate in future electrically pumped micro-disk lasers using similar techniques. ■

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Author: Mike Cooke

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Gallium oxide white LED prospects

A vertically integrated rare-earth-doped layer structure emits at a relatively low forward voltage of 8.8V.

Saga University in Japan has reported work towards white light-emitting diodes (WLEDs) based on rare-earth (RE)-doped gallium oxide (Ga_2O_3) [Yafei Huang et al, Appl. Phys. Lett., v119, p062107, 2021].

The researchers adopted a vertical integration strategy with Ga_2O_3 layers doped with thulium (Tm), europium (Eu) and erbium (Er) grown on top of each other. The team comments that "films grown by lateral integration are deposited side-by-side, while the co-doping of multiple rare-earth elements into the same host will unavoidably degrade the crystal quality and, thus, induce undesirable threshold voltage and luminous efficiency." The vertical strategy leads to more compact devices without compromising crystal quality.

The team adds: "On the other hand, compared with phosphor-assisted WLEDs, direct white light emissions are achieved from single-material-based LEDs in this work without using additional red, blue or green phosphors, which can greatly reduce the energy re-absorption effect between different phosphors." Such energy re-absorption would naturally impact power efficiency.

The researchers also see the phosphor-free approach based on single-material-based WLEDs with direct primary color mixing as more conducive to displays based on smaller-pixel micro-LEDs. Although rare-earth doping has been tried in gallium nitride and zinc oxide devices, there are problems such as needing high voltages (~100V) or poor color balance due to spectral gaps.

The Saga team sees β-Ga_2O_3 as "an ideal host for rare-earth ions benefiting from its ultrawide bandgap (4.9eV), which is advantageous to improve the thermal stability and luminous ability of rare-earth dopants at room temperature". According to the researchers, at present, "there are no reports available related to full-color (white) LEDs based on rare-earth-doped Ga_2O_3."

The doped Ga_2O_3 layers were deposited on p-type gallium arsenide, p-GaAs (111), using alternate-target pulsed laser deposition (PLD) at 500°C. The Ga_2O_3 targets were variously doped with rare-earth oxides: 1wt.% Tm_2O_3, 1wt.% Eu_2O_3 and 5wt.% Er_2O_3. The laser light came from a krypton fluoride (KrF) excimer laser emitting deep-ultraviolet light at 248nm wavelength. The PLD was carried out in an oxygen atmosphere at 0.1Pa pressure.

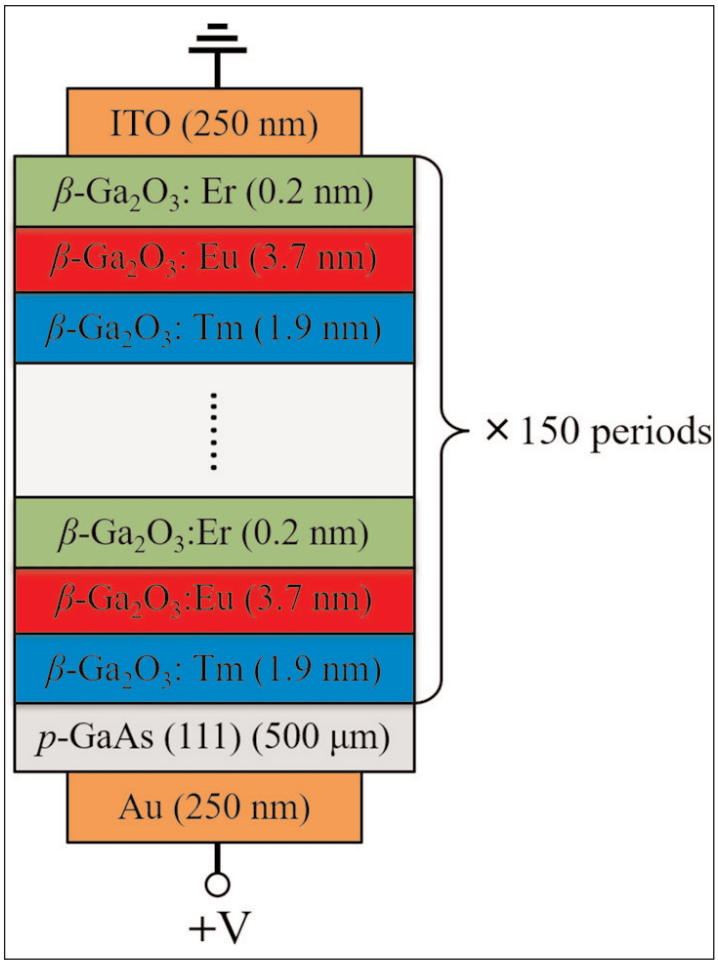


Figure 1. Schematic structure of LED-A based on Ga_2O_3:(Tm+Eu+Er)/GaAs heterojunction.

Compared with phosphor-assisted WLEDs, direct white light emissions are achieved from single-material-based LEDs in this work without using additional red, blue or green phosphors, which can greatly reduce the energy re-absorption effect between different phosphors

The samples consisted of 150-periods of the sequence of the three types of Ga_2O_3 doping (Figure 1). The growth process lasted 150 minutes. Material analysis suggested that the atomic concentrations for the doped layers were 0.3% Tm, 0.5% Eu and 2.3% Er.

The LEDs featured an indium tin oxide

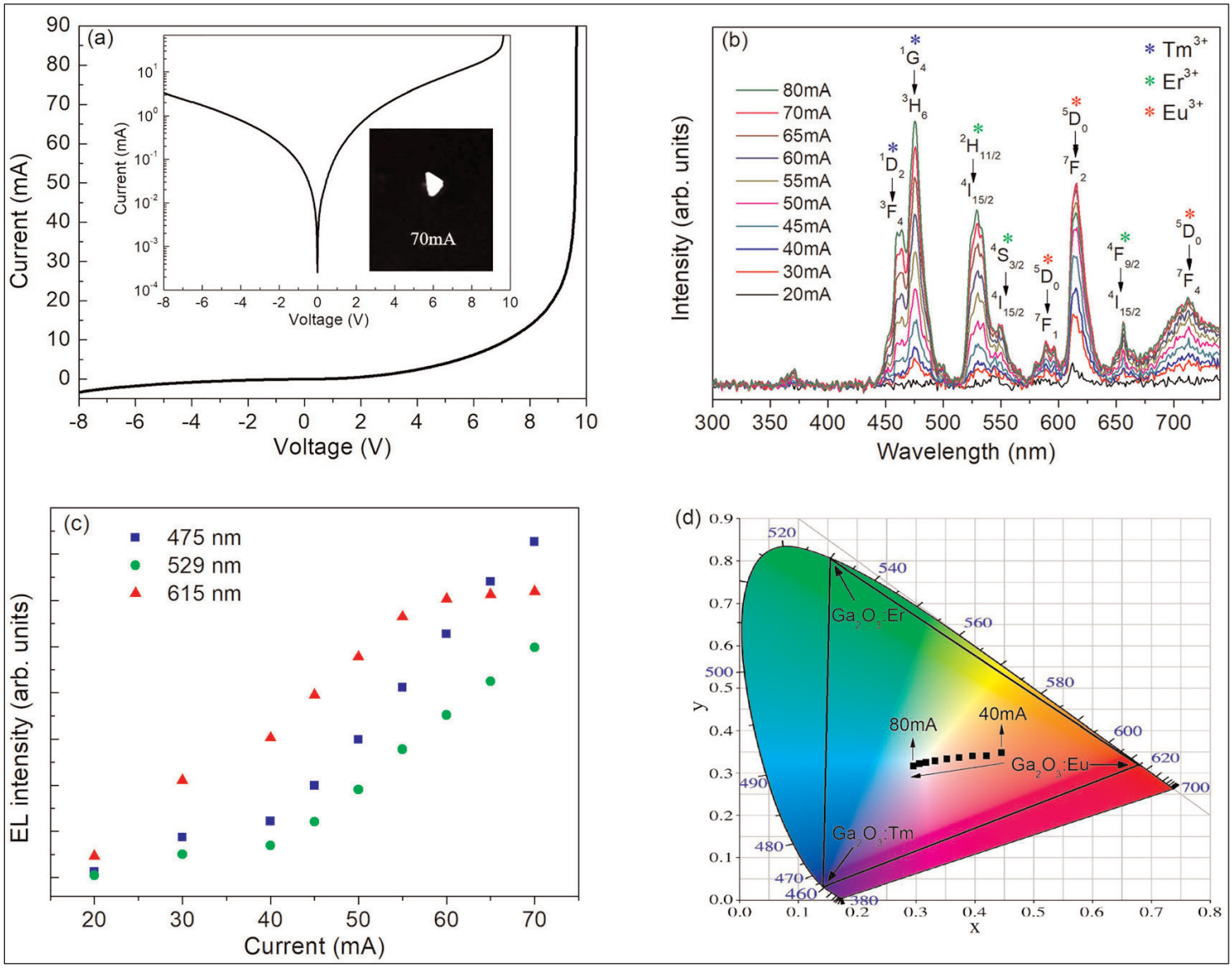


Figure 2. (a) Current—voltage characteristics curve of LED-A. Inset: semi-log characteristics and digital photograph of LED-A at 70mA. (b) EL spectra under different operating currents. (c) EL intensities of emissions at 475nm, 529nm and 615nm as function of injection current. (d) CIE chromaticity coordinates under different currents.

(ITO) transparent conductor n-electrode and gold (Au) p-electrode. The ITO was applied with direct-current sputtering; the gold with electron-beam evaporation.

Atomic force microscopy showed a sample surface "filled with uniformly distributed grain-like structures" with a root-mean-square roughness of 10nm.

When subjected to a forward voltage of more than 8.8V, the current begins to increase rapidly. The researchers also note that the electro-luminescence (EL) is only observed under forward bias, suggesting that "simultaneously injected electrons and holes are indispensable for the EL". The researchers associate the emitted light with 4f transitions from the Eu^{3+}, Er^{3+} and Tm^{3+} ions (see Figure 2).

Due to the existence of oxygen vacancy defects in the film, the simultaneous red, green and blue emissions are supposed to be triggered by the defect-assisted energy transfer from the gallium oxide (Ga_2O_3) host to rare-earth RE^{3+} (Eu^{3+}, Er^{3+} and Tm^{3+}) ions

The various peaks associated with the different ions were: 461nm and 475nm with Tm^{3+}; 529nm, 550nm and 656nm with Er^{3+}; 590nm, 615nm and 712nm with Eu^{3+}. Although the emissions somewhat overlap, the Tm ones are mainly in the blue range, Er green, and Eu red. The combination gives white light.

The researchers explain: "Due to the existence of oxygen vacancy defects in the film, the simultaneous red, green and blue emissions are supposed to be triggered by the defect-assisted energy transfer from the Ga_2O_3 host to RE^{3+} (Eu^{3+}, Er^{3+} and Tm^{3+}) ions."

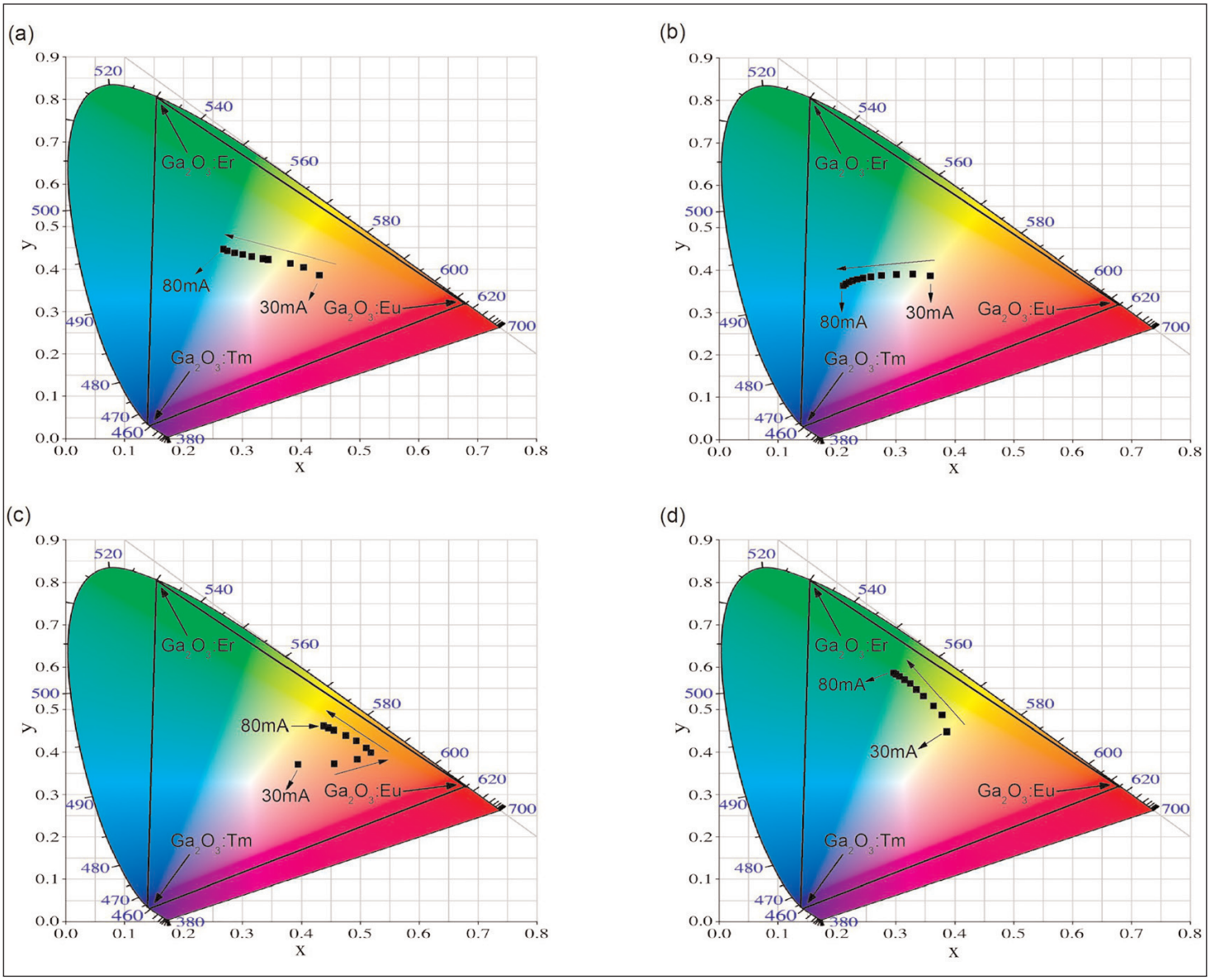


Figure 3. CIE chromaticity diagrams for (a) LED-a, (b) LED-b, (c) LED-c, and (d) LED-d under different operating currents.

Table 1. Thicknesses of doped Ga_2O_3 layers.

Sample	Ga_2O_3:Tm	Ga_2O_3:Eu	Ga_2O_3:Er
LED-A	1.9nm	3.7nm	0.2nm
LED-a	2.0nm	3.2nm	0.4nm
LED-b	2.6nm	1.9nm	0.4nm
LED-c	1.0nm	5.1nm	0.4nm
LED-d	1.3nm	2.6nm	1.4nm

On the basis of previous reports, the researchers expect the emission to be relatively independent of the temperature environment since the complete outer 5s and 5p orbitals shield the 4f shell from such influence.

The positions of the peaks were found to vary little with changing current injection. However, the strength of the emissions did vary, with the balance shifting from red to green and blue as the current increases.

The color content of the main device reported, LED-A,, shifted from pink to white with injections from 40mA to 80mA. The correlated color temperature (CCT) varied from 2370K to 7592K, respectively, a shift from a warm to cold tone.

The team reports: "For instance, the emitted light at 55mA locates at a warm-white point with CIE coordinates of (0.3739, 0.3410) and CCT of 3926K, which meets the requirements for indoor lighting applications." The researchers also see 65mA as providing "superior" CIE coordinates, (0.3329, 0.3335), but 5479K CCT, suitable for indoor/outdoor cold-white illumination.

The color balance was also varied in hardware, with the researchers producing four other device structures with different layer thicknesses of the various components (Table 1). These resulted in different color balance behavior (Figure 3). ■

https://doi.org/10.1063/5.0060066

Author: Mike Cooke

UV LED market to grow to $2.466bn in 2026, driven by impact of COVID-19

The total UV lighting market will roughly double or triple to $3.5bn by 2026, forecasts Yole Développement.

The UV lighting market is expected to rise at a compound annual growth rate (CAGR) of 17.8% from 2021 to $3.5bn in 2026, with the UV LED market in particular growing to $2.466bn, forecasts market analyst firm Yole Développement in its report 'UV LEDs and UV Lamps — Market and Technology Trends 2021'.

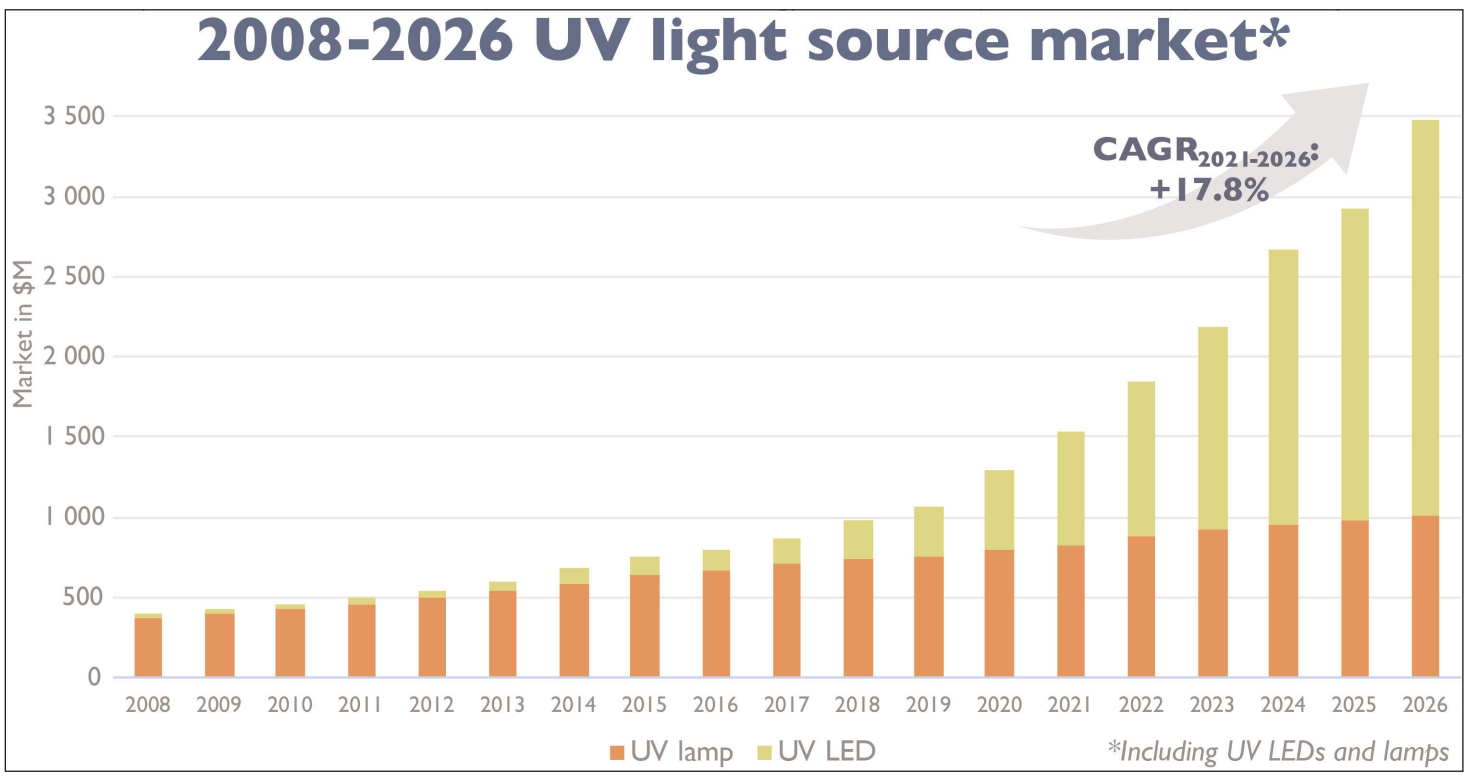
The UV lighting market overall was about $400m in 2008. By 2015 UV LEDs alone were worth $100m. In 2019, the total market reached $1bn as UV LEDs spread into UV curing and disinfection. The COVID-19 pandemic then drove demand, increasing total revenue by 30% in just one year. Yole hence expects the UV lighting market to be $1.5bn in 2021 before rising at a 17.8% CAGR, doubling or tripling to $3.5bn in 2026.

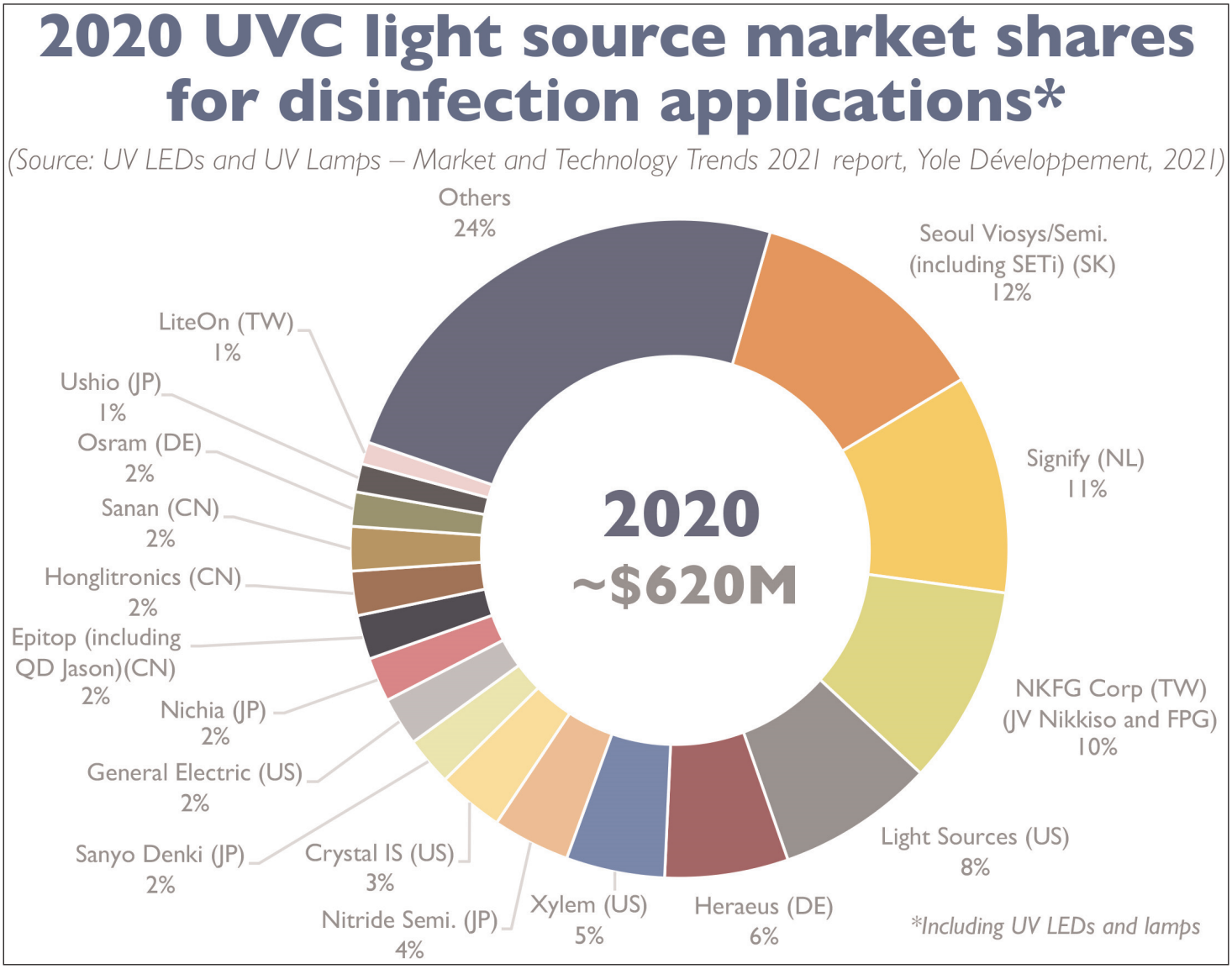
"The COVID-19 pandemic has created some perfect use-cases for UV lighting technologies to spread throughout a rapidly changing disinfection market," says Pars Mukish, business unit manager, Solid-State Lighting & Display, at Yole.

Indeed, SARS-COV-2, the virus that causes COVID-19, has one of the highest reproduction/transmissibility rates among all viruses that have emerged. To reduce the spread of the disease, light in the UVC wavelength band (which can deactivate bacteria and viruses through physical methods) has gained unprecedented attention. Overall, there will be a 'before' and an 'after' the COVID-19 pandemic for the UV lighting industry, says Yole.

"Indeed, the health crisis due to the SARS-CoV-2 virus has generated unprecedented demand for the design and manufacture of disinfection systems using optical UV rays," notes Joël Thomé, CEO of photonics innovation services provider PISEO (a partner of Yole), which has released the report 'UV-C LEDs in the Time of COVID-19 — Update November 2021'. "LED manufacturers have seized this opportunity, and we are currently seeing an explosion in UV-C LED products," he adds.

The COVID-19 pandemic has strongly impacted the





UV industry in general, notes the report 'UV LEDs and UV Lamps — Market and Technology Trends 2021'. On the one hand UV lamps are historic, established and mature technologies in the UV lighting market. Business before the COVID-19 pandemic was driven mostly by polymer curing with UVA wavelength light and water disinfection with UVC light. On the other hand, UV LED technologies are still emerging. Until recently, business was mostly driven by UVA LEDs. It was only a few years ago that UVC LEDs reached the performance and cost specifications of early adopters and started generating revenue.

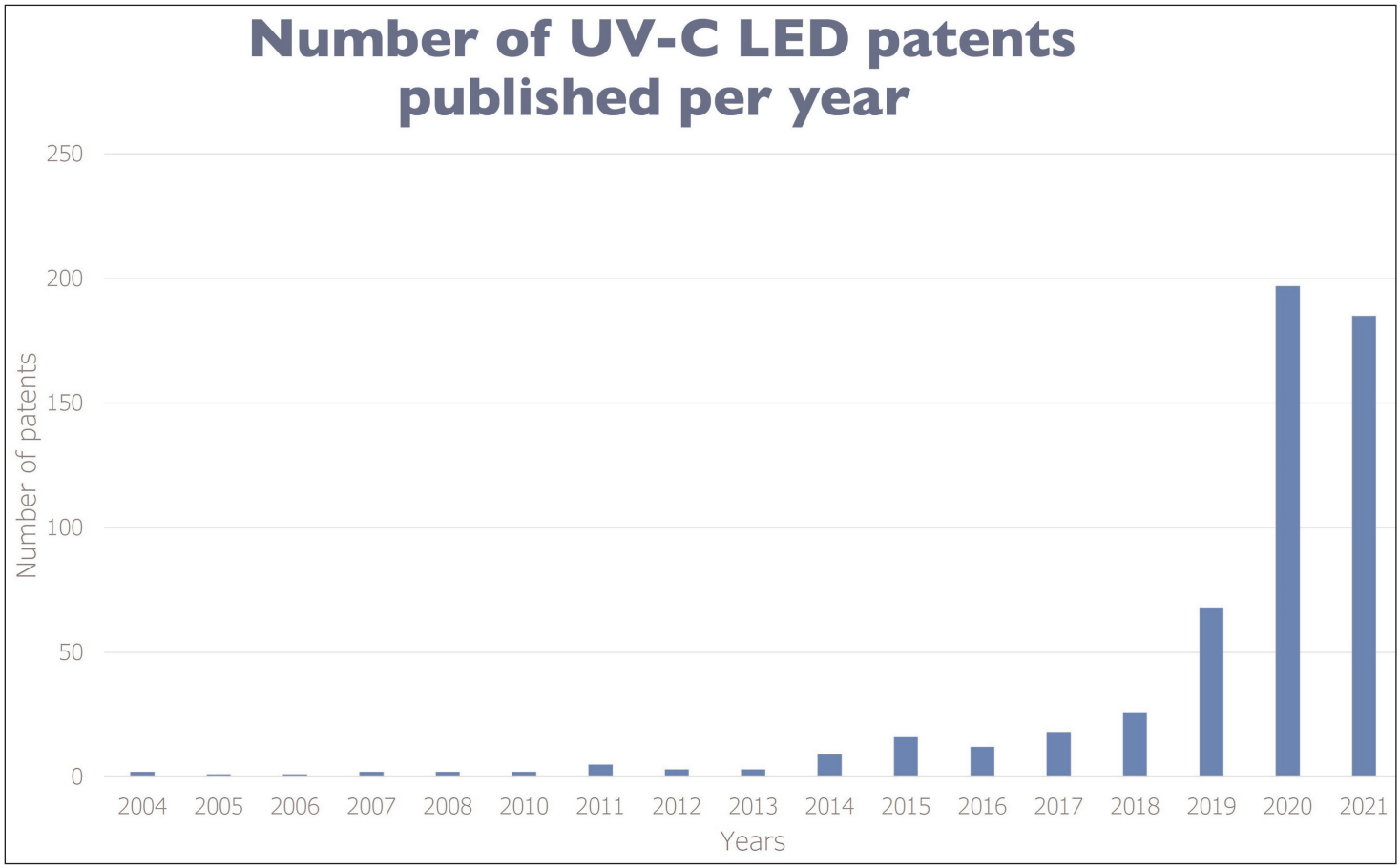
"Both technologies will benefit, but on different timelines," says Pierrick Boulay, senior technology & market analyst, Solid-state Lighting, at Yole. "In the very short term, UV lamps might dominate end-systems because they are already established and easy to integrate. However, this proliferation of applications is a catalyst for the UV LED industry that will further push the technology and its performance forward. In the middle-to-long term, several end-systems might further adopt UV LED technology".

Numerous industries and players supply UV lamps and UV LEDs. Signify, Light Sources, Heraeus and Xylem/Wedeco are the top four UVC lamp players, while Seoul Viosys and NKFG are currently leading the UVC LED industry. There are few overlaps between the two industries. Yole expects this to remain the case even though some UVC lamp players, such as Stanley and Osram, are diversifying their activities into the UVC LED field. In total, PISEO has identified 15 more UV-C LED manufacturers compared with 2020.

Overall, the UVC LED industry is likely to be the most transformed by recent trends. The industry has waited more than 10 years for this moment to happen. All the players are now ready to grab a piece of this booming market, says Yole.

UV-C LED-related patents

The number of UV-C LED-related patents filed in the last two years has exploded, illustrating the dynamism of research in this area, states PISEO. In its new UV-C LED report, PISEO offers a particular focus on the key patents of four LED makers, highlighting the main



challenges of the rollout of this technology: intrinsic efficacy and cost. Yole also offers a complementary analysis of the patent landscape. The need for disinfection and the opportunity to use small light sources enabled the creation of increasingly compact systems. This evolution, including new form factors, has clearly generated renewed interest on the part of LED makers.

Wavelength is also a key parameter for germicidal efficiency and optical risk assessment. "Although currently relatively scarce and expensive, several system manufacturers, such as Signify and Acuity Brands, are taking a close interest in sources emitting a 222nm wavelength due to the harmlessness of this optical radiation on the human body," notes Matthieu Verstraete, Innovation Leader and Electronics & Software Architect at PISEO. Several products have already been placed on the market, and there are more to come that integrate excimer sources made by the company Ushio. PISEO's specialists therefore review the state of medical research, the technology of sources emitting at 222nm, the germicidal effect of this wavelength, the regulatory environment, and the roadmaps produced. ■

www.i-micronews.com/products/uv-leds-and-uv-lamps-market-and-technology-trends-2021

Relaxed InGaN for green/red light emission

A simple MOCVD structure has been used to create a 85% relaxed indium gallium nitride pseudo-substrate.

University of California Santa Barbara (UCSB) in the USA has reported a simpler process for producing relaxed indium gallium nitride (InGaN) pseudo-substrates with a view to more efficient long-wavelength light-emitting devices in the green (500–565nm) and red (625–700nm) wavelength ranges [Philip Chan et al, Appl. Phys. Lett., v119, p131106, 2021]. Up to now, attempts to reduce strain in InGaN layers have been quite complex. The UCSB method used just MOCVD.

The work aimed to reduce the strain in InGaN layers and allow higher-temperature growth. Indium incorporation in GaN is reduced in strained material, an effect referred to as 'composition pulling'. Lower-temperature growth is normally used to compensate for reduced indium incorporation. For example, red InGaN light-emitting diodes (LEDs) are typically grown by metal-organic chemical vapor deposition (MOCVD) at temperatures ranging from 700°C to 765°C.

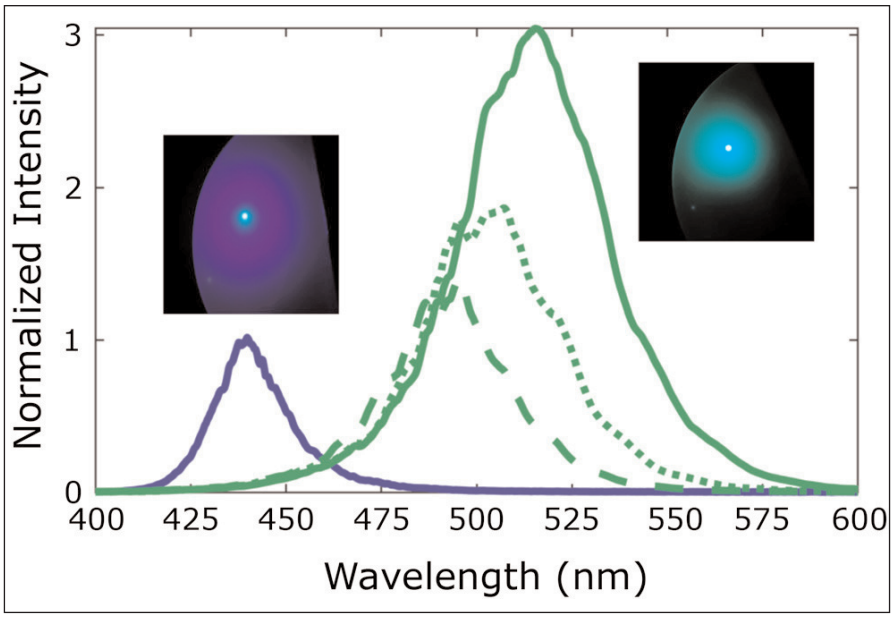


Figure 1. Room-temperature PL emission from MQW regrown on GaN template and relaxed InGaN buffer by thermal decomposition of an InGaN underlayer. Solid lines depict emissions from half-radius of substrate, dotted depicts center, and dashed depicts edge.

Unfortunately, low-temperature growth also generates higher defect densities, increases impurity incorporation, and degrades surface morphology. These effects are associated with decreased adatom mobility during MOCVD, along with reduce efficiency in LEDs and lasers.

The researchers see their work as potentially benefiting efforts towards displays based on micro-LEDs (μLEDs), which need red, green and blue emitters. Blue GaN-based LEDs are well established, but increasing indium incorporation for longer wavelengths has been problematic. However, InGaN-based LEDs are attractive for these applications due to less impact from surface recombination effects that particularly hit smaller devices, relative to the standard red-emitting material, aluminium indium gallium phosphide.

The UCSB epitaxial material was grown on (0001) sapphire through MOCVD. The relaxed InGaN pseudo-substrate was achieved by growing a 5.5μm GaN template layer, followed by a 2.5nm 750°C InGaN 'decomposition layer' (DL) and a 100nm GaN decomposition stop-layer (DSL).

The growth temperature of the first 30nm of the DSL was 750°C; then the temperature was ramped to 1000°C during the remaining 70nm. The high temperature was designed to both result in a high-quality crystal structure for subsequent growth, and to decompose the underlying InGaN DL, forming voids that would allow an overlying 200nm 920°C $In_{0.04}Ga_{0.96}N$ buffer/pseudo-substrate to relax.

A high-resolution x-ray diffraction (HRXRD) reciprocal-space map (RSM) suggested that the pseudo-substrate consisted of 85%-relaxed $In_{0.04}Ga_{0.96}N$. "The sample shows deep pitting and poor surface morphology from unoptimized growth temperature and InGaN buffer growth conditions," the team comments.

The pseudo-substrate was loaded, together with a simple GaN/sapphire template, into an MOCVD reactor to grow further InGaN layers, creating a 4-period multiple quantum well (MQW) structure of 2.5nm/2.5nm 865°C InGaN well/2.5nm GaN cap, along with 8.3nm 900°C InGaN barrier. The researchers comment that the sample on the pseudo-substrate had "a slightly yellow appearance from the increased indium incorporation". They add: "The decomposed InGaN layer

appears dark in the center, possibly from the metallic indium that remains after thermal decomposition during the high-temperature GaN DSL growth."

Photoluminescence (PL) from 325nm helium–cadmium laser excitation showed peaks at 440nm and 515nm for the MQWs grown on the GaN template and InGaN pseudo-substrate, respectively. Further, the intensity of the peak from the MQW structure on the pseudo-substrate was up to three times stronger than that on GaN. There was variation of intensity and wavelength according to where the MQW was excited for photoluminescence (Figure 1).

The researchers comment: "The wavelength shift could be attributed to the lessening of the compositional pulling effect in the sample with the relaxed buffer." In other words, the reduced strain allowed more indium to be incorporated into the MQWs, reducing the bandgap energy, increasing the wavelength of the emitted photons. The increased light intensity was attributed to better light extraction due to the rough surface reducing total internal reflection back into the epitaxial material.

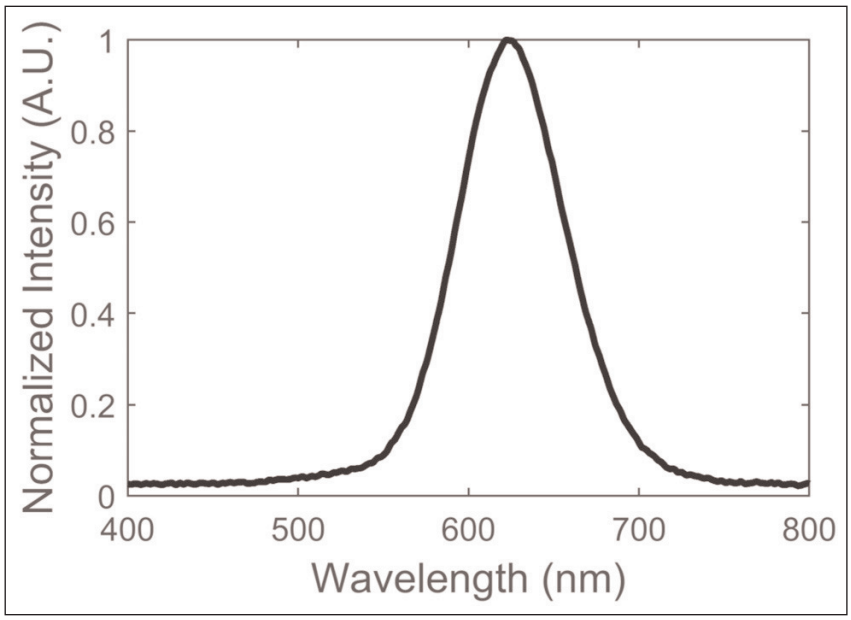


Figure 2. Room-temperature electroluminescence spectrum of red LED at 20A/cm^2 current density.

Material for a red LED was grown in a similar way except the DL, DSL and buffer layers were doped n-type with silicon. Also, the MQW was grown at 825°C with 6nm GaN barriers rather than the thicker GaN/InGaN combination. The 920°C p-contact layers consisted of 80nm p-$In_{0.04}Ga_{0.96}N$ and 12nm more heavily doped $In_{0.04}Ga_{0.96}N$. The MOCVD was carried out without interruption between the pseudo-substrate and MQW layers. The p-type layers were activated with 650°C annealing. The metal contacts consisted of indium dots used for electrical probing.

The electroluminescence from this device peaked at 622nm wavelength when the current injection was 20A/cm^2 (Figure 2). The full-width at half-maximum (FWHM) was 77nm. The researchers describe the performance of the LED as "quite poor", due to surface morphology of the buffer layer being rough and pitted. Also, the LED structure was basic, without optimizations such as electron-blocking layers or defect-reduction strategies (e.g. underlying superlattices).

The researchers managed to reduce the surface roughness of a 90%-relaxed $In_{0.025}Ga_{0.975}N$-buffer pseudo-substrate recipe to 1.3nm root-mean square. This was grown with the low-temperature portion of the GaN DSL reduced to 4nm. The high-temperature portion was thickened to 150nm, grown at 1150°C in hydrogen. Also, the buffer was more complex: 50 periods of 16nm 950°C InGaN with 2nm/2nm GaN interlayers grown at 950/1000°C. The lower-temperature growth used nitrogen ambient. The high-temperature step included 5% hydrogen carrier, which was designed to fill any v-pits that were formed. The team hopes to extend this better morphology to higher indium contents. ■

https://doi.org/10.1063/5.0064755

Author: Mike Cooke

Ruthenium gate for indium phosphide MOSFETs

Researchers claim record transconductance and subthreshold swing for a planar device with a high-k metal gate incorporating Ru.

University of California Santa Barbara (UCSB) in the USA has reported record high transconductance (g_m) and subthreshold swing (SS) for planar indium phosphide (InP)-channel metal–oxide–semiconductor (MOS) field-effect transistors (MOSFETs) [Hsin-Ying Tseng et al, Appl. Phys. Lett., v119, p123502, 2021].

The UCSB team used ruthenium (Ru) as the gate metal, applied using atomic layer deposition (ALD). A key aspect was the use of titanium nitride (TiN) as a nucleation/stiction layer on the high-k dielectric part of the high-k metal gate (HKMG) stack. Without the TiN layer, Ru tends to grow in a rough and non-uniform manner. In MOS capacitors, the use of TiN to nucleate Ru was found to reduce frequency dispersion in capacitance–voltage measurements, "suggesting a metal–semiconductor interface with low defect density".

The researchers suggest that the development of high-performance InP high-electron-mobility transistors could be used in "mm-wave receivers, and in the gate structure of tunnel FETs for ultralow-voltage VLSI logic".

The researchers deployed the gate stack on planar (Figure 1) and vertical (Figure 2) MOSFETs on semi-insulating iron-doped InP substrates. The epitaxial layers were applied using metal-organic chemical vapor deposition (MOCVD).

The epitaxy for the planar MOSFET began with 9nm zinc-doped p-InP, which compensated for donor impurities of the substrate surface. This was followed by 9nm unintentionally-doped (UID) InP.

The MOCVD was then interrupted to enable the formation of a dummy gate structure, consisting of hydrogen silsesquioxane (HSQ) resist, around which self-aligned source-drain layers would be regrown by MOCVD.

After the MOCVD regrowth, the device structures were electrically isolated using wet etching. The dummy gate was then removed and the surfaces treated to remove oxides. The gate stack was applied using 300°C ALD.

The high-k dielectric part of the HKMG consisted of ~1nm aluminium oxynitride (AlO_xN_y), ~2.5nm zirconium dioxide (ZrO_2). This was followed by ~2nm titanium nitride (TiN) and the ~30nm ruthenium (Ru) gate electrode.

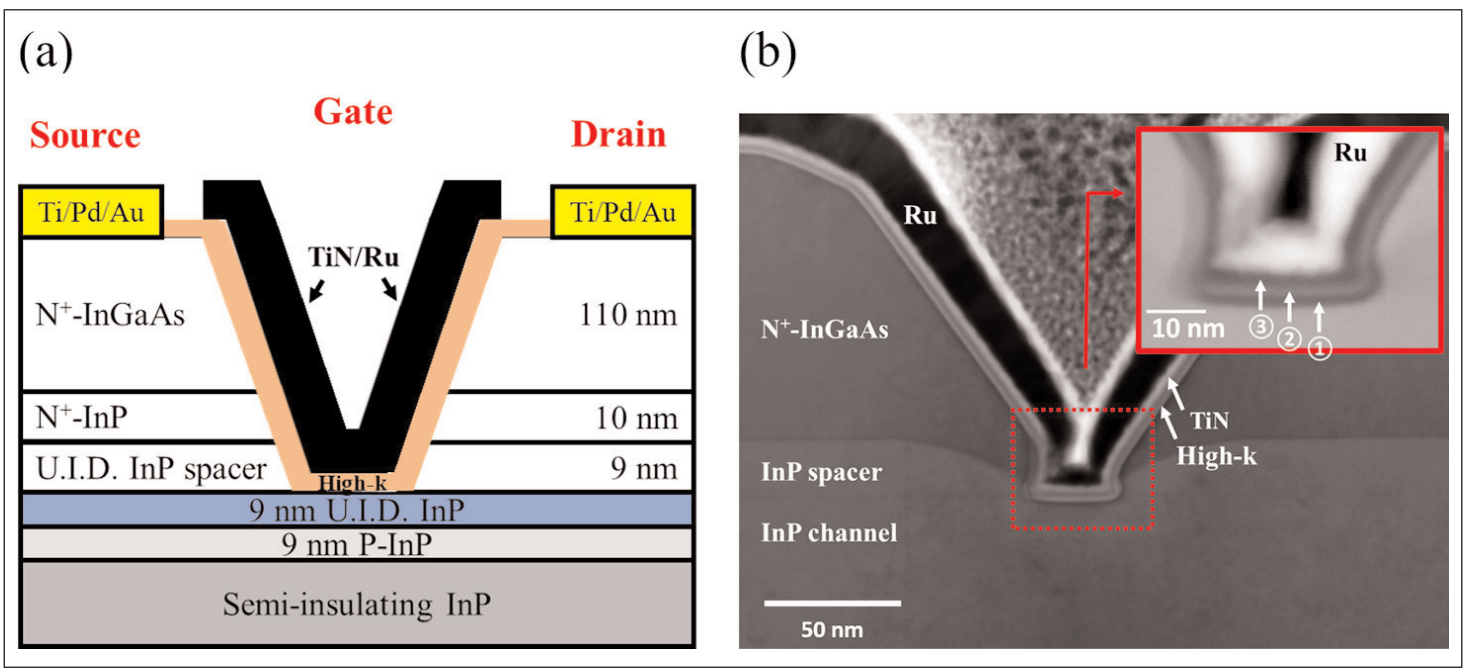


Figure 1. (a) Planar MOSFET schematic cross-section and (b) scanning transmission electron microscope (STEM) image of MOSFET with 30nm TiN/Ru gate. Inset: high-angle annular dark-field STEM image of InP channel. Layers 1, 2, and 3 represent ~1nm AlO_xN_y, ~2.5nm ZrO_2, and ~2nm TiN, respectively.

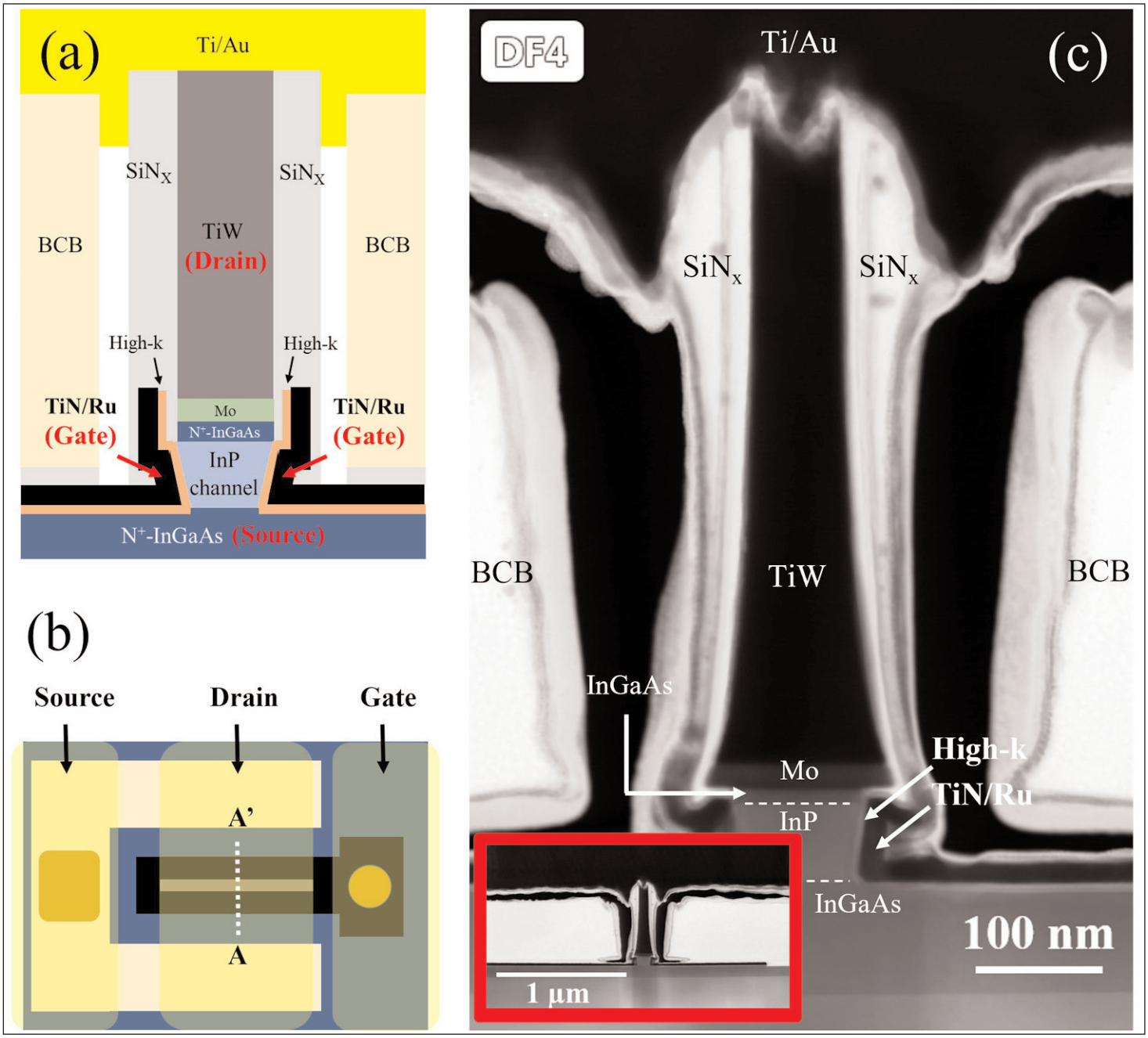


Figure 2. (a) Cross-sectional and (b) top-view vertical MOSFET structure, and (c) cross-sectional STEM image cutting along A and A', as indicated in (b). P-InP channel length is 50nm, Inset in (c) is large-field image.

The chemicals used to form the AlO_xN_y were trimethyl-Al alternated with nitrogen plasma. For the ZrO_2, water (H_2O) and tetrakis(ethylmethylamido) zirconium (TEMAZ) were used. The TiN came from cycles of tetrakis(dimethylamido)titanium (TDMAT) and nitrogen/hydrogen plasma. The Ru resulted from alternate (ethylbenzene)(1,3-cyclohexadiene)ruthenium (EBCHDRu from Hansol Chemical) and oxygen.

The structure was annealed in hydrogen for 30 minutes to "recover plasma damage at the high-k/InP interface". The devices were completed with titanium/palladium/gold source/drain electrodes on the heavily n-type indium gallium arsenide (n^+-InGaAs) contact layer, and ALD aluminium oxide passivation.

The vertical MOSFET used a semi-insulating indium phosphide substrate with MOCVD layers of 90nm n^+-InGaAs source, a 50nm p-InP channel, and a 5nm/10nm n^+-InP/n^+-InGaAs drain/contact.

Device fabrication began with electron-beam deposition/DC sputtering of the 20nm/500nm molybdenum/titanium–tungsten (Mo/TiW) drain metals, which was then patterned and plasma etched, creating a fin structure. The sidewalls of the fin were coated with 20nm plasma-enhanced chemical vapor deposition (PECVD) silicon nitride (SiN_x).

Wet etching cut into the InGaAs drain layer, which was also coated with 20nm Si_3N_4. Further wet etching into the InP layers (drain and channel) formed the vertical channel. Digital etching based on hydrochloric

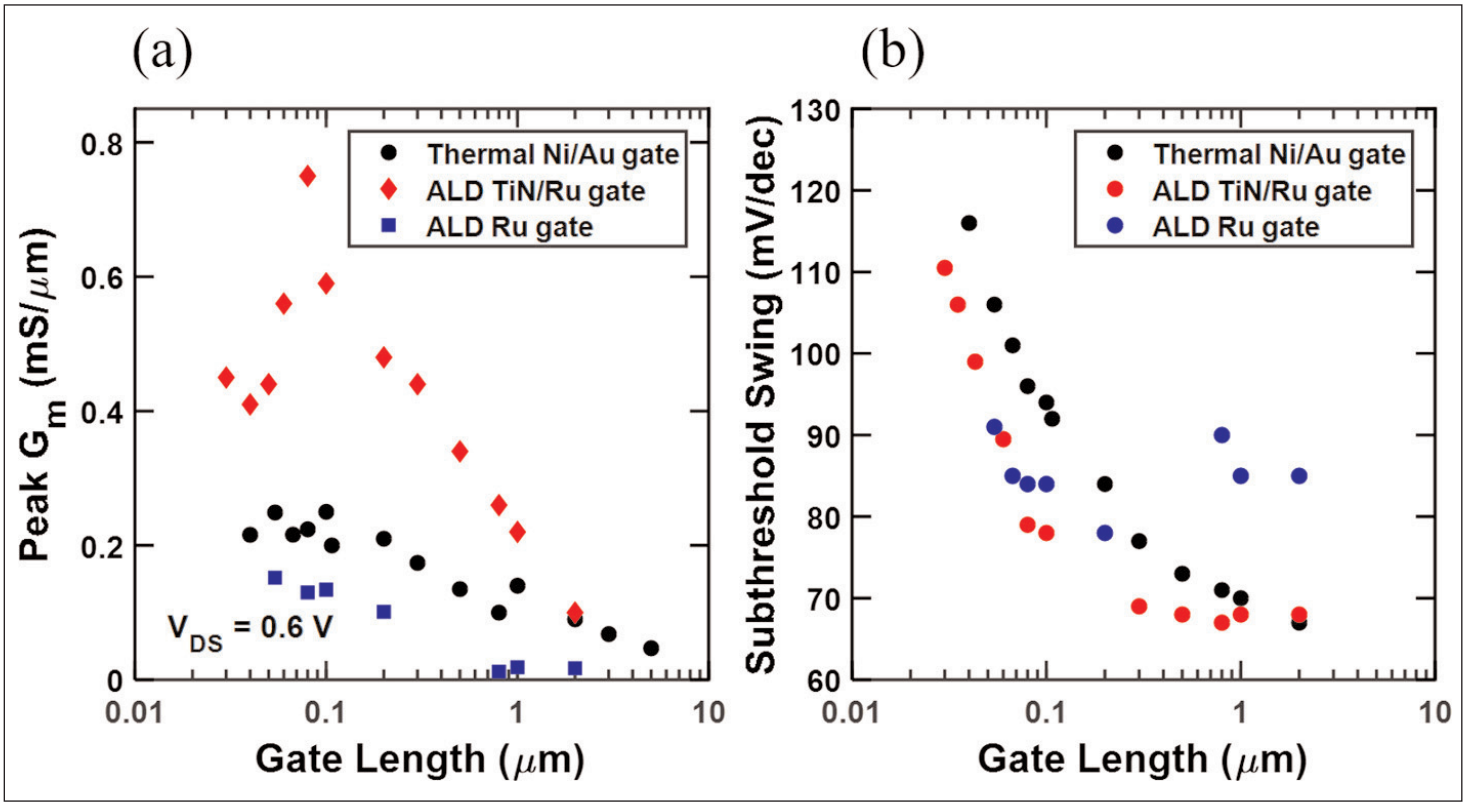


Figure 3. Comparisons of peak g_m versus L_g (a) and minimum SS versus L_g (b) for InP planar MOSFETs with thermally evaporated Ni/Au gates, ALD TiN/Ru gates, and ALD Ru gates.

acid removed native oxides before high-k deposition in an ALD process, as before.

The TiN layer was also made identically, but the Ru metal gate electrode had to be deposited at 250°C, rather than 300°C. Deposition at the higher temperature tended to suffer from precursor decomposition in the more tricky geometry. The lower temperature ran the risk of oxide formation, stunting growth. To stop this, the researchers added hydrogen as a co-reactant in the ALD recipe.

The complete HKMG was annealed as for the planar device. The source contact was Ti/Pd/Au. Ti/Au metal posts were applied to the source and gate contacts. Passivation consisted of 30nm PECVD SiN_x.

A key aspect was the use of titanium nitride (TiN) as a nucleation/stiction layer on the high-k dielectric part of the high-k metal gate (HKMG) stack. Without the TiN layer, ruthenium (Ru) tends to grow in a rough and non-uniform manner. In MOS capacitors, the use of TiN to nucleate Ru was found to reduce frequency dispersion in capacitance–voltage measurements, "suggesting a metal–semiconductor interface with low defect density"

The structure was planarized with spin-on dielectric (BCB) benzocyclobutene), which was baked and ashed back.

The device was finished with wet etching to remove the SiN_x and excess Ru around the drain electrode, creating a 60nm PECVD SiN_x sidewall spacer, and forming the backend wiring/contact pads with Ti/Au.

The Ru/TiN planar MOSFETs were found to have an optimum gate length (L_g) of 80nm in terms of peak g_m. Below 80nm, the device suffered from short-channel effects, due to the relatively thick ~18nm channel layers. At 80nm, the peak g_m was ~0.75mS/μm, for 0.6V drain bias, claimed as the highest yet reported for InP-channel MOSFETs (Figure 3).

When L_g exceeds 800nm, the Ru/TiN MOSFET also demonstrated "record" low subthreshold swing values of 68mV/decade at 0.1V drain bias. The previous record was 70mV/decade for an InP MOSFET with nickel/gold (Ni/Au) gate metal.

The vertical MOSFET suffered from short-channel effects due to the low aspect ratio of L_g and fin width (50nm:90nm). Also, the channel doping was not sufficient to cut off leakage currents in the off-state. "To overcome this issue, a higher P-channel doping or a higher aspect ratio between L_g and body thickness (t_{body}) is needed," the team comments. The peak g_m with 0.6V drain reached a respectable 0.42mS/μm. This is close to the value achieved in the 50nm L_g planar device. ■

https://doi.org/10.1063/5.0058825

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ALD equipment market growing at 12% CAGR to $680m in 2026

Atomic layer deposition is penetrating all More than Moore applications, says Yole Développement.

The atomic layer deposition (ALD) equipment market for More than Moore (MtM) device manufacturing totaled $345m in 2020 — dominated by CMOS image sensors (CIS), with 47% share — and is estimated to be rising at a compound annual growth rate (CAGR) of 12% to $680m in 2026, according to the report 'Atomic Layer Deposition Equipment for More than Moore' from Yole Développement.

The ALD equipment market for non-CIS More than Moore applications is really taking off now for commercial device manufacturing, says Yole, which gives two main reasons for this high growth.

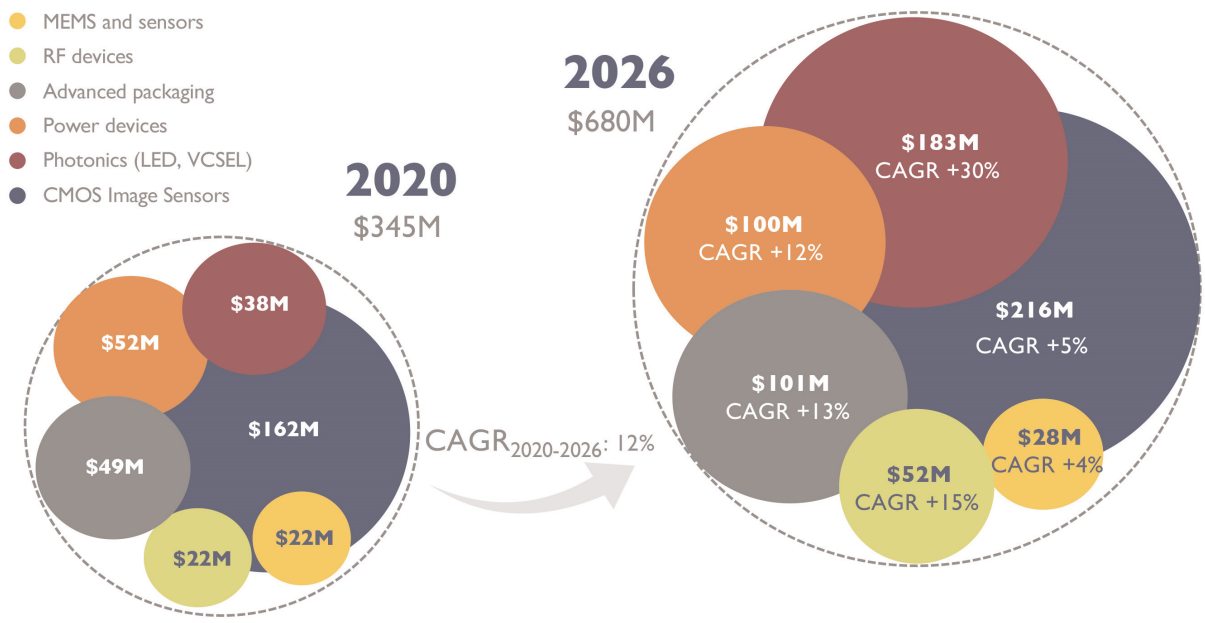
Firstly, manufacturing sites are gearing up for the production of More than Moore devices that are gaining importance across all the megatrends: for example, compound semiconductor-based power devices, in particular gallium nitride (GaN) and silicon carbide (SiC), as well as photonic devices, including mini-LEDs and micro-LEDs. Their manufacturing is rocketing for automotive and consumer applications.

Specifically, CAGRs over 2020-2026 are expected to be 30% for the production of photonics devices, and 12% and 15% respectively for power and radio frequency (RF) devices. CAGRs will be 4% for micro-electro-mechanical systems (MEMS) and sensors and just 5% for CIS. Growth is further strengthened by the high wafer production volume of CIS devices, silicon power electronics, and advanced packaging – mainly wafer-level encapsulation – used across all More than Moore applications.

Secondly, the global semiconductor market is favorable. Chip shortages across all markets and More than Moore devices have pushed manufacturers to announce fab capacity expansion worldwide. "The worldwide fab capacity expansion is accelerating the industrial adoption of ALD equipment," notes Taguhi

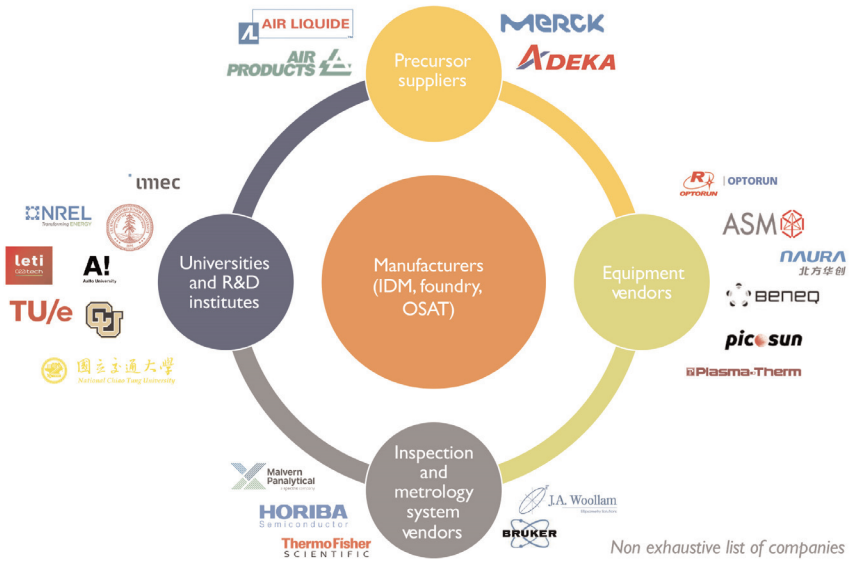
2020-2026 market size of atomic layer deposition equipment for More-than-Moore applications

(Source: Atomic Layer Deposition Equipment for More than Moore 2021 report, Yole Développement, 2021)



More-than-Moore atomic layer deposition supply chain and ecosystem analysis

(Source: Atomic Layer Deposition Equipment for More than Moore 2021 report, Yole Développement, 2021)



Yeghoyan Ph.D., technology & market analyst, Semiconductor Manufacturing.

"This is an excellent opportunity to deploy new materials and processes that improve device performance," adds Yeghoyan. "The ALD ecosystem and supply chain actors, traditionally tightly interrelated, now collaborate even more to accelerate ALD adoption. These include ALD process developers such as academic and R&D institutes, precursor suppliers (off-shelf and customized), equipment subpart providers, as well as inspection and metrology system providers."

Moreover, fab expansions concern not only the leading manufacturing players but also smaller production sites, giving emerging ALD equipment vendors a growth opportunity, says Yole.

The 2020 ALD equipment market was led by 300mm platforms. Yole identifies the following leading ALD players: ASM International with 30% market share, and Tokyo Electron Ltd (TEL) with 18% market share, as well as NAURA. All these players offer 300mm platforms with high average selling price (ASP) as well as high throughput.

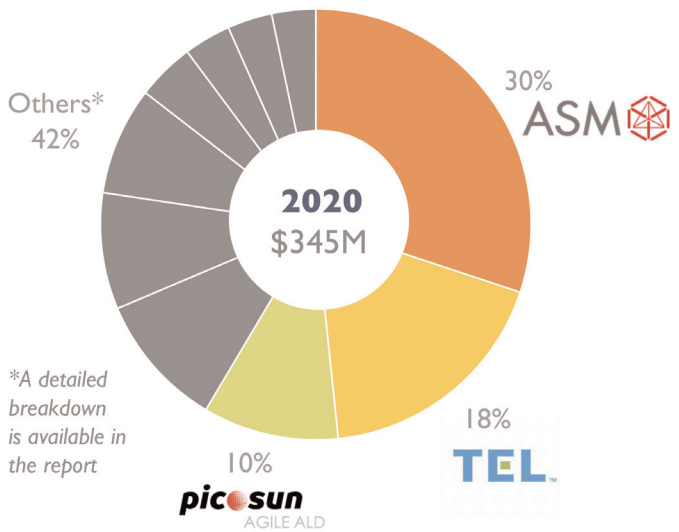
These players are followed by Picosun, specialized in 200mm platforms, which has 10% market share. However, the company is closely followed by Optorun, Beneq, Plasma-Therm, Oxford Instruments, and Veeco, among others.

Moreover, in response to the chip and equipment shortages, equipment vendors previously active only in ALD research are now developing their machines for volume production. All in all, the ongoing global semiconductor market upside gives an optimistic prospect for More than Moore ALD equipment vendors' revenues, believes Yole. However, the ALD market is competitive, and market shares can change significantly in the coming years. ■

www.i-micronews.com/products/atomic-layer-deposition-equipment-for-more-than-moore-2021

2020 Atomic layer deposition equipment vendor revenue market share for More-than-Moore

(Source: Atomic Layer Deposition Equipment for More than Moore 2021 report, Yole Développement, 2021)



Logic technology scaling options for 2nm and beyond

imec presents a roadmap marked by the increased synergy between advanced logic device and nano-interconnect research.

Naoto Horiguchi, director CMOS device technology, and Zsolt Tokei, imec fellow & program director nano-interconnects at imec, offer a broad spectrum of options to scale logic technology generations beyond 1nm.

Along the scaling path, they show how logic device development needs to go hand in hand with introducing innovations in the back-end-of-line and, to an increasing extent, in the middle-of-line.

How do you see the scaling of logic devices evolving in the coming years?

Naoto Horiguchi: "A majority of IDMs and foundries have recently announced the transition from mainstream FinFET to gate-all-around (GAA) nanosheet FET architectures for their 3nm or 2nm logic technology generations. The forksheet architecture, which is an imec invention, could prolong this nanosheet generation. After the forksheet, we are anticipating complementary FETs (CFETs) to enter the logic scaling roadmap."

"These transitions will allow us to gradually push track height scaling of standard cells below 4T, while still providing a power-performance advantage."

"Beyond CFETs, 2D monolayer crystalline materials like tungsten disulfide (WS_2) are promising replacements for silicon in CMOS channels, offering opportunities for further gate-length scaling."

How will these innovations impact the back-end-of-line? Which developments will be needed in the back-end- and middle-of-line to keep pace with scaling in the front-end-of-line?

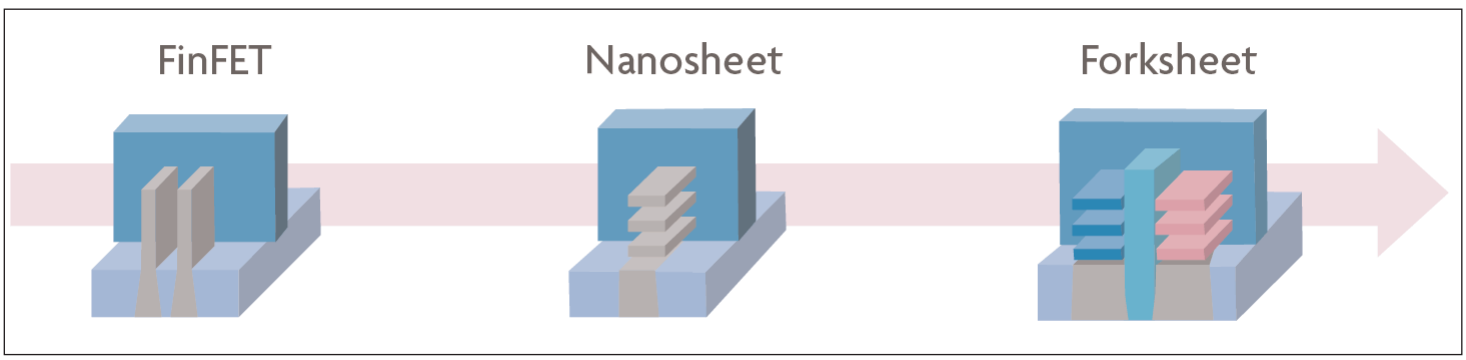
Zsolt Tokei: "Advanced scaling in the front-end-of-line (FEOL) needs to go hand in hand with innovations in the back-end-of-line (BEOL) — the network of interconnects that needs to connect seamlessly to the underlying device structure. With the forksheet architecture entering the roadmap and cell heights being pushed below 5T, metal pitches in the critical BEOL layers will become as small as 20nm and below. This is extremely challenging from capacitance, resistance (via and wire) as well as from cost, printability and reliability point of view – requiring innovations at design, module and material level. This has driven the development of new interconnect integration schemes such as hybrid via metallization (addressing via resistance increase) and semi-damascene process flows – as a replacement for today's mainstream Cu dual-damascene processes. Semi-damascene involves the direct etch of metal to achieve higher-aspect-ratio lines, and can include gapfill, partial or full air gaps to counter the capacitance increase."

Naoto Horiguchi: "To strengthen the synergy between advanced logic device scaling and interconnect development, the middle-of-line (MOL) activities begin to play an increasingly important role. The MOL, which ties together the BEOL and the FEOL, has for a long time been organized as a single-layer contact to source, drain and gate."

"But the transition to below-5T cell architectures drives the evolution towards multi-layer MOL structures, in which extra layers and vias are added – similar to how the BEOL has evolved in the past."

Which breakthrough did your team recently achieve?

Naoto Horiguchi: "While the area and performance benefit of the forksheet device architecture was already shown through TCAD simulations, we have for the first time presented electrical characterization of functional integrated forksheet FET devices —



Evolution from FinFET to nanosheet and to forksheet.

a breakthrough result that was highlighted at the 2021 VLSI Symposium. We have demonstrated the key modules of this architecture, including the dielectric wall and replacement metal gate patterning at 17nm n–p spacing. And, although the forksheet device is a tri-gated device architecture, no degradation of the electrostatics has been observed in our work."

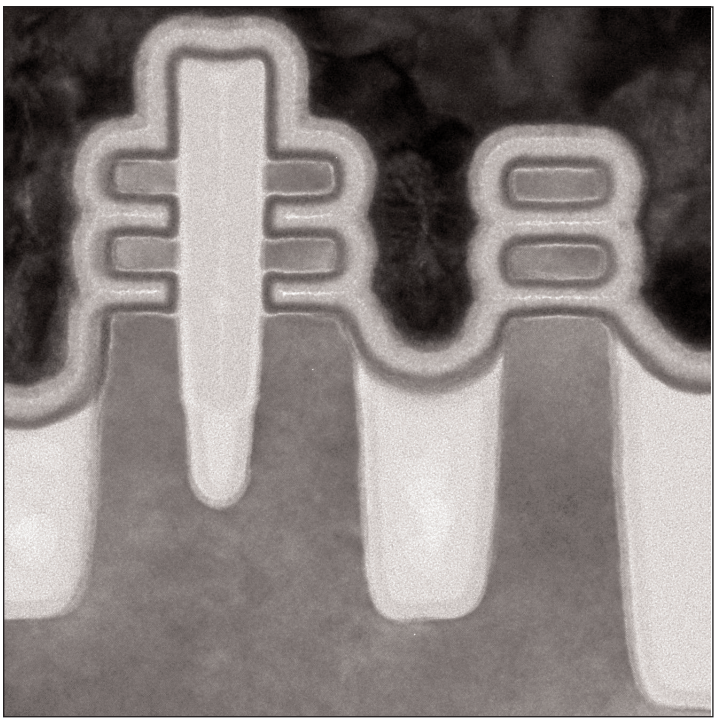
Which avenues is imec exploring to complement this achievement from a nano-interconnect perspective?

Zsolt Tokei: "Extended nanosheet architectures such as the forksheet require new BEOL integration schemes such as semi-damascene to enable sub-20nm metal pitches. At the same time, we are developing new multi-layer MOL routing schemes, such as the vertical–horizontal–vertical (VHV) scheme. In combination with scaling boosters (such as self-aligned contacts and buried power rail), these multi-layer MOL schemes will pave the way to a more efficient intra-cell routing at smaller cell heights."

Naoto Horiguchi: "Implementing the multi-layer process flow in the MOL, in combination with scaling boosters such as the buried power rail (BPR) will largely enhance the scalability of our forksheet-based cell designs, pushing track heights from 5T to 4T. As such, introducing semi-damascene in the MOL is another example of the benefits brought about by the cross-fertilization between FEOL, MOL and BEOL activities."

What are the next important milestones that you expect to achieve?

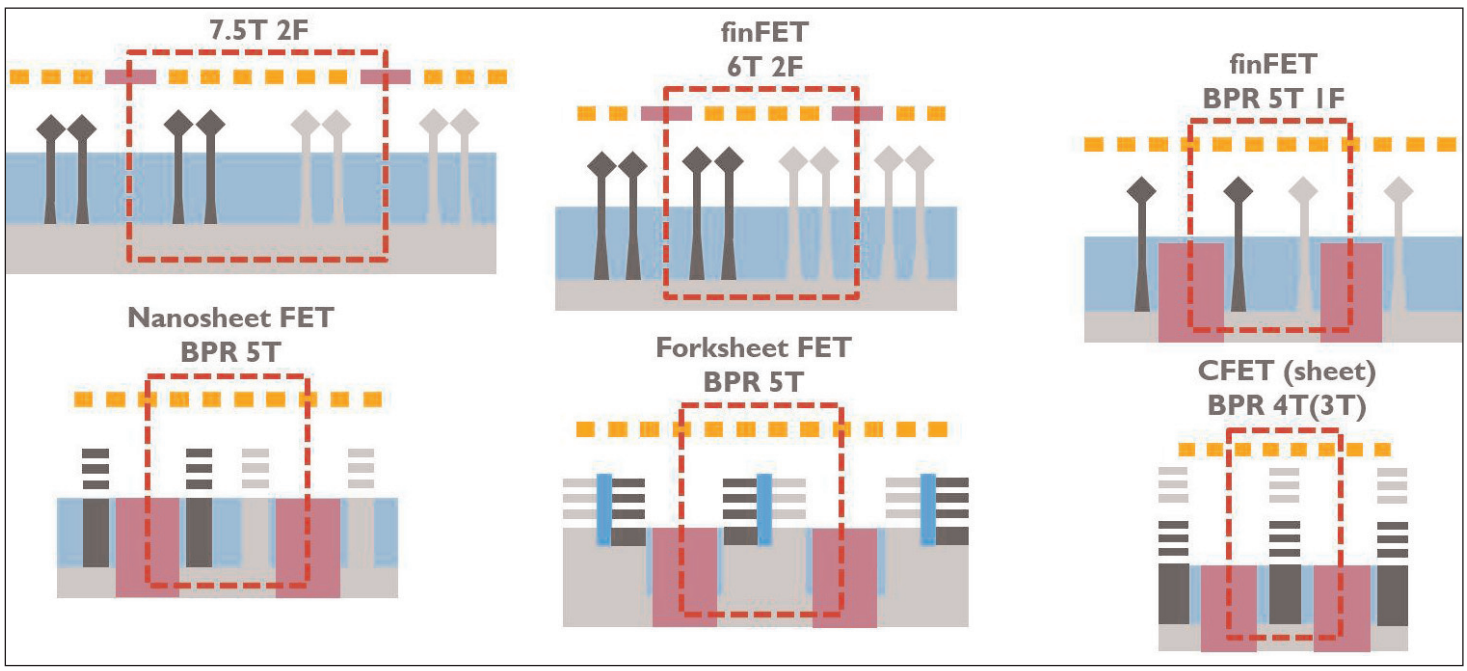
Naoto Horiguchi: "Our program focus will move from forksheet to CFET gradually after forksheet key modules and device demonstration. The CFET architecture is complex due to its many degrees of freedom.



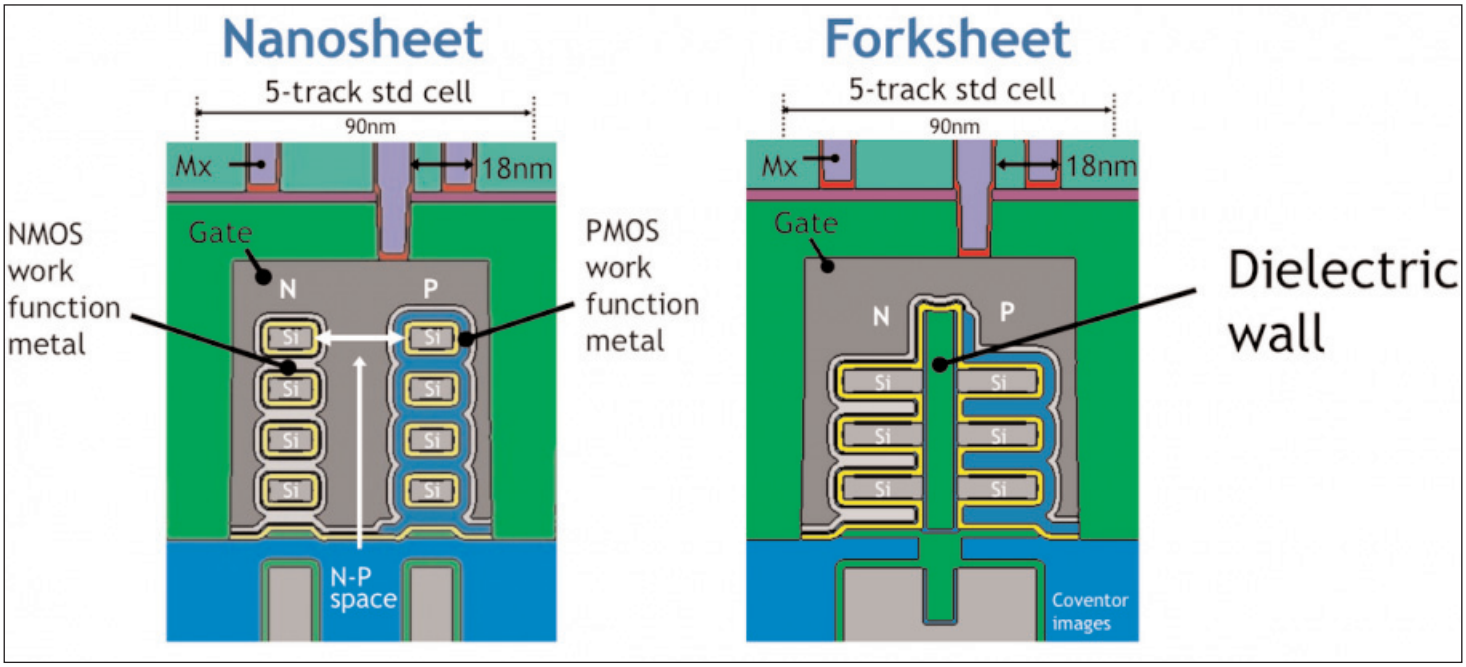
Transmission electron micrograph (TEM) image of forksheet and nanosheet structures.

Imec will quantify the power-performance-area (PPA) benefits and the complexity of CFET process flows and recommend best option(s) to our partners. While nanosheet, forksheet and CFET architectures will gradually reduce cell track heights to 4T and beyond, we are exploring alternative device architectures that might address the slowdown in scaling the contact poly-pitch (CPP), which measures from one transistor's gate contact to the gate contact on the adjacent device."

Zsolt Tokei: "Evolution towards the 1nm CFET family of logic devices drives the development of new BEOL



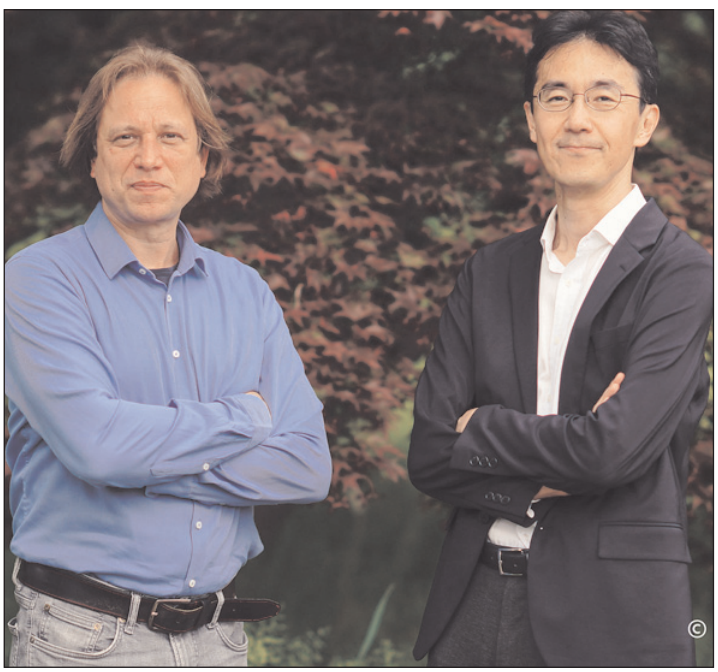
From FinFET to nanosheet to forksheet and to CFET.



Comparison of horizontal nanosheet (NHS) gate-all-around (GAA) structure versus forksheet (FS) structure. The latter maximizes the active width in low-track-height standard cells by minimizing the n–p space.

and MOL solutions. In the BEOL, we earlier proposed a new metallization construct referred to as 'hybrid height with zero via'. In this construct, each metal layer is now split into three separate sub-layers, which allows to tune the height and aspect ratio of the metal lines (and hence, exchange resistance for capacitance) depending on their application need."

"We are excited to report on a first SRAM assessment, confirming a significant improvement in read speed (by 30%) and write margin (by 50%). Currently, we are working towards real logic cell layouts."



Authors: Zsolt Tokei (imec fellow and program director nano-interconnects at imec) and Naoto Horiguchi (director CMOS device technology).

"On the longer term, we will need to complement these integration schemes with the introduction of new conductors. Of interest are ordered binary or ternary compounds with better figure of merit than, for example, ruthenium (Ru) or molybdenum (Mo). We have already been pioneering this field with first ab-initio simulations and initial experiments, and we are now intensifying our activities in close collaboration with imec's materials R&D group."

What is the key message you want the chip industry to remember?

Naoto Horiguchi: "In recent years, several people have claimed that traditional CMOS scaling has already come to an end. But with many innovations in the pipeline, we are convinced that we can continue CMOS scaling for at least the next ten years. Imec is a good place to work towards that goal. The close collaboration with our partners helps us to address the industry's biggest challenges and push logic device scaling beyond the 1nm technology generation — leveraging the tight collaboration with imec's nano-interconnect, INSITE and material development activities."

Zsolt Tokei: "Also from a BEOL perspective, we have many interesting and valid options allowing us to address the RC delay bottleneck and to pipeline interconnects for the coming ten years. We can offer our partners a comprehensive roadmap with a broad spectrum of options that are relevant for future logic device scaling, and of which elements can be re-used for memory development. We are continuously enriching this roadmap with new insights, improved integration schemes and new materials." Some of these were presented at July's 2021 IEEE International Interconnect Technology Conference (IITC). ■

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How AI and ML can save $38bn for semiconductor manufacturers

Atonarp's CEO Prakash Murthy explains how artificial intelligence and machine learning can be used for semiconductor manufacturing equipment and process co-optimization.

Today, increasing throughput is the number-one priority for semiconductor fabs, as they work to overcome the challenges of the global chip shortage.

Looking beyond throughput, there are significant opportunities for long-term cost savings from optimizing, simplifying or removing processing steps. We call this approach EPCO – Equipment and Process Co-Optimization. It is a combination of good engineering and applying data-driven machine learning (ML) to the manufacturing process and equipment.

A 2021 paper by McKinsey argued that semiconductor manufacturing optimization, using artificial intelligence (AI) and machine learning (ML), could save $38bn, through improved yields and increased throughput.

Real-time, accurate and actionable data is vital to achieving this potential. McKinsey highlighted that the single most important point to address is the real-time, run-to-run adjustment of tool parameters, using live in-situ tool sensor data. This enables AI/ML algorithms to optimize the nonlinear relationship between process operations.

The problem: increasing process complexity

Today's high-volume, advanced logic processes — including Fin-FET and gate-all-around (GAA) transistors, as well as high-aspect-ratio etch techniques used in 3D-NAND memories — require a new approach to the established standards based on Intel's CopySmartly! methodology.

As process nodes have shrunk, new variables have emerged that affect process yield, and can cause deviations even on the exact same equipment. In Figure 1, shared in a study of machine learning for high-volume manufacturing metrology challenges, chamber-based effects on process critical dimensions (CD) can be clearly seen.

Some of these critical variables that can affect process performance include localized virtual vacuum leaks, subtle reaction gas partial pressure variations, wafer surface saturation due to changes in pumping performance, surface reactivity due to changing wafer temperature, chamber clean end-point, and chamber seasoning profile.

Additional challenges — inter-layer adhesion, 300mm wafer mechanical stresses, new atomic-level deposition

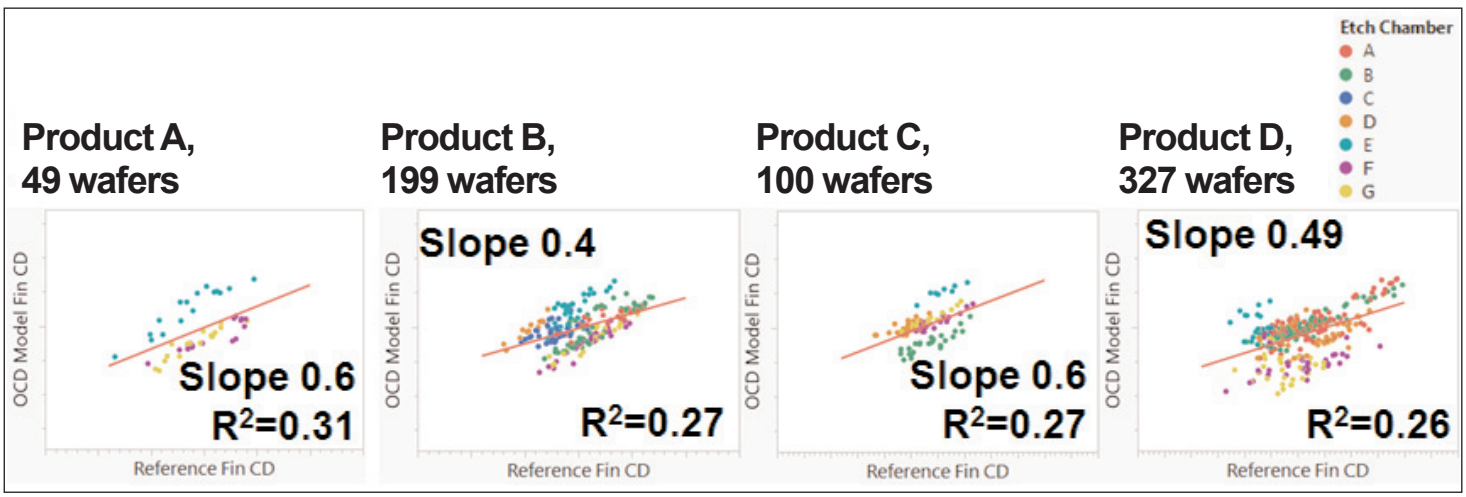

Figure 1. Wafers of four different products from eight process chambers were evaluated above. Each chamber is represented by a different colored dot. Based on the colored dot clustering, some chambers demonstrate significant variation in CD values between wafers, clearly showing a chamber-related effect on the unit process.

and etch chemistries, exotic low-resistance contact and fill metals, stringent cross-contamination protocols, and maximizing throughput — all require greater insight into how the process and equipment are interacting. Optimizing advanced processes such as these now demand higher-accuracy metrology tools and add a new layer of in-situ molecular complexity.

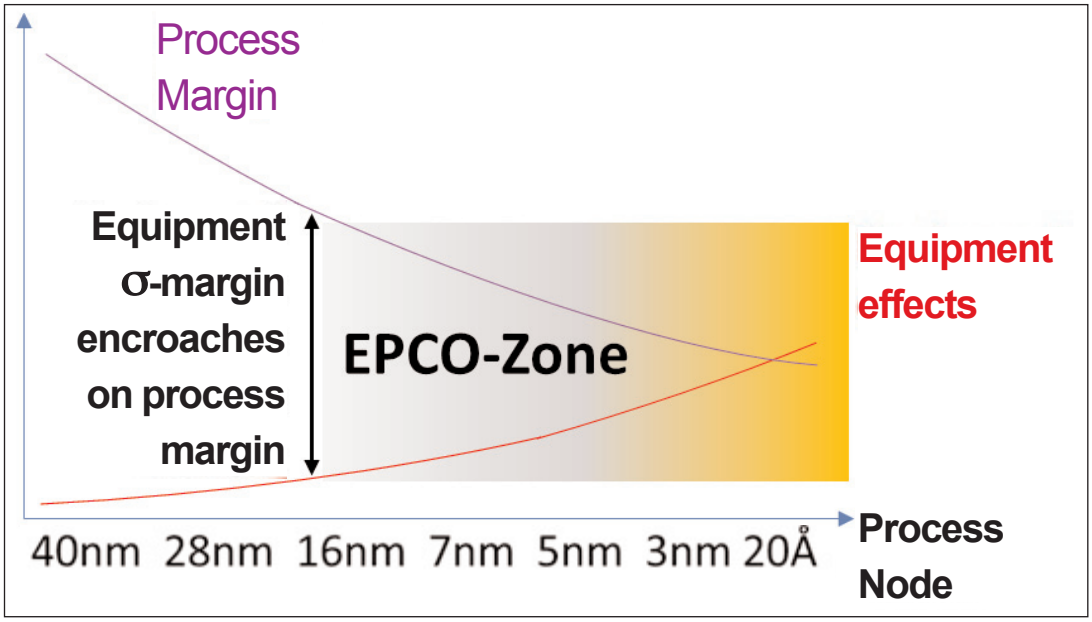

Figure 2. As process geometries shrink, the effects of equipment variation on process margins drive the need for equipment process co-optimization within the EPCO Zone.

The solution

We can improve semiconductor metrology in two ways: either by capturing better data with more sensitive metrology tools or by extracting more value from existing data with new ML algorithms. Of course, if we can do both, we may well see the biggest improvements.

Either way, for successful AI/ML deployment, it's vital to have truly actionable real-time data. This enables appropriate models to be created and tested with data correlation between real-world and ML model inputs and outputs.

For example, statistical process controls can look at the real effects of chamber-to-chamber, machine-to-machine and run-to-run performance variances, even on the exact same equipment with the same recipe. Chamber cleaning and seasoning have material effects on chamber performance and drift in process results (process margins) between cleans, and PM (performance management) cycles are common. The difference is that, at mature nodes like 40nm, the differences run-to-run are small compared with the process control limits. However, as process geometries shrink, so do process control margins and the chamber and equipment effects (sigma variation) become increasingly critical (see Figure 2).

Process control has become a lot more complicated as critical dimensions have shrunk, along with the margin for error. This means that individual chamber management is becoming fundamental to ensuring high line-yield, with tight statistical process control.

This is what EPCO is all about: leveraging ML to jointly optimize equipment, chambers and processes in unison.

In-situ, real-time data

There are three main types of data in the semiconductor process control environment:

1. in-situ data taken real-time on the process tool;
2. in-line data to measure results (usually immediately) after a processing step;
3. parametric or post-fab data (used for wafer line-yield and wafer ship acceptance criteria).

One of the fundamental changes needed to optimize fab management is the switch from in-line to in-situ metrology. Measurements taken after processing is completed are sequential in nature, costing throughput and cycle time, and lack the immediacy to affect meaningful real-time process change and optimization.

Measuring in-situ, real-time data at the molecular level gives true insight to how the process is set up and proceeding, offering rich, actionable and impactful data. Reactants, by-products and partial products can be identified and quantified, allowing for dynamic process control to ensure tight mean and standard deviation control for a given process module across run-to-run, chamber-to-chamber, tool-to-tool and even site-to-site.

Managing overall complex semiconductor process control and line-yield starts with having tight control on individual process steps and ensuring low variability and precise statistical process control (SPC). In-situ data from processing chambers can be used with machine learning to improve linearity and accuracy, and to achieve the control required.

Molecular sensor

Atonarp has spent a lot of time understanding the fab and equipment manufacturers' problems and challenges. The result of those efforts is the Aston, a robust molecular sensor.

Aston provides the accurate, actionable, real-time data that's critical for effective EPCO. This data enables

Figure 3. Atonarp ASTON metrology instrument.

suitable ML models to be built and tested. In fact, Aston was designed from the ground up to meet the needs of in-situ molecular analysis to enable EPCO.

Importantly, Aston is more robust than existing in-situ metrology solutions, meaning it can provide dependable, consistent data in the harsh environment of a fab — including corrosive gases and particles. For example, Aston's self-contained ionization source enables a scheduled maintenance period that is up to 100 times longer than regular residual gas analysis (RGA) solutions.

EPCO examples: plasma impedance and process end-point detection

Let's look at a couple of examples where real-time in-situ data is essential for an EPCO approach to achieve the best results in semiconductor manufacturing.

Every time you clean a process chamber you change its characteristics. Unnecessary time (and lost throughput) is spent in fabs over-cleaning and then re-seasoning process chambers. Optimized end-point-based cleaning and chemically specific chamber fingerprinting and characterization can reduce the time to get a chamber back to production and minimize process variations and process margin risk.

Secondly, end-point detection (EPD) is used in many semiconductor processes and is difficult to get right. A common use of EPD is in etch, where it is vital to avoid the etching process from stopping too soon (under-etch) or continuing too long (over-etch), as both scenarios can decrease yield. The etch process can be optimized by monitoring the quantity of etch by-products and looking for a clear flattening of the etch rate curve. This will provide optimum throughput and a consistent etch profile, reducing risk in subsequent processing steps and providing more consistent electrical performance.

Additionally, Aston works with 'lights out' or non-plasma processes such as atomic layer deposition (ALD) to give insight where legacy optical emission spectroscopy (OES) does not work.

Conclusion

For today's semiconductor manufacturing fabs, optimizing processes can achieve significant improvements in yield and other metrics, while helping to reduce costs. Equipment and Process Co-Optimization (EPCO) provides a way to do this effectively — but requires highly accurate real-time data, obtained in-situ.

Existing metrology solutions are unable to provide this data in a practical manner, and lack the necessary durability to deliver under harsh chamber conditions. We believe that advanced metrology solutions, such as our Aston platform, will help further digital transformation within fabs and unlock the many benefits of EPCO for semiconductor manufacturers. ■

www.atonarp.com/products/aston
www.mckinsey.com/industries/semiconductors/our-insights/scaling-ai-in-the-sector-that-enables-it-lessons-for-semiconductor-device-makers

Authors:
Prakash Murthy is the co-founder & CEO of Atonarp of Tokyo Japan, which provides molecular sensing and diagnostics solutions for life sciences, pharmaceutical and semiconductor markets.
Murthy has two decades of experience in engineering management and entrepreneurial ventures. He also co-founded Inspiration Technologies and C2Silicon Software and served as the CEO of Core Solutions Inc.

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Fax: +49 2407 9030 40
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Fax: +39 02 383 06 118
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7 Wafer processing materials

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www.kayakuam.com

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9 Materials & metals

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15 Assembly/packaging materials

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event calendar

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E-mail: info@ieee-iedm.org
www.ieee-iedm.org

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www.semiconjapan.org/en

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37th annual Applied Power Electronics Conference (APEC 2022)
George R. Brown Convention Center, Houston, Texas, USA
E-mail: apec@apec-conf.org
http://apec-conf.org/conference/sessions/technical

25–27 April 2022
18th International Conference on Concentrator Photovoltaic Systems (CPV-18) and 13th World Conference on Thermophotovoltaic Generation of Electricity (TPV-13)
University of Miyazaki, Japan
E-mail: info@cpv-18.org
www.cpv-18.org

26–28 April 2022
25th Annual Components for Military & Space Electronics Conference (CMSE 2022)
Four Points by Sheraton (LAX) Los Angeles, Los Angeles, CA, USA
Abstract submission deadline: 15 January 2022
E-mail: info@tjgreenllc.com
www.tjgreenllc.com/cmse

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9 May 2022
36th annual Reliability of Compound Semiconductors Workshop (ROCS 2022)
Monterey Marriott & Conference Center, Monterey, CA, USA
E-mail: rocs@jedec.org
www.jedec.org/events-meetings/rocs-workshop

9–12 May 2022
2022 CSMANTECH (International Conference on Compound Semiconductor Manufacturing Technology)
Monterey Marriott & Conference Center, Monterey, CA, USA
E-mail: chairman@csmantech.org
www.csmantech.org

10–12 May 2022
PCIM (Power Conversion and Intelligent Motion) Europe 2022
Nuremberg, Germany
E-mail: pcim@mesago.com
www.mesago.de/en/PCIM/main.htm

12–13 May 2022
Collaboration and innovation across the CS supply chain (CoInnovateCS)
Monterey Marriott & Conference Center, Monterey, CA, USA
E-mail: events@csconnected.com
www.coinnovatecs.com

15–20 May 2022
2022 Conference on Lasers & Electro-Optics (CLEO)
San Jose Convention Center, San Jose, CA, USA
E-mail: CLEO@compusystems.com
www.cleoconference.org

30 May – 3 June 2022
IEEE 72nd Electronic Components and Technology Conference (ECTC 2022)
The Sheraton San Diego Hotel and Marina, San Diego, CA, USA
E-mail: reg.ectc@gmail.com
www.ectc.net

13–17 June 2022
2022 IEEE VLSI Symposium on Technology & Circuits - Technology and Circuits for the Critical Infrastructure of the Future
Hilton Hawaiian Village, Honolulu, HI, USA
E-mail: vlsi@vlsisymposium.org
www.vlsisymposium.org

10–15 July 2022
(postponed from 14-19 June 2020, then 4-9 July 2021)
20th International Conference on Metal Organic Vapor Phase Epitaxy (ICMOVPE XX)
Stuttgart, Germany
E-mail: info@icmovpexx.eu
www.icmovpexx.eu

21–25 August 2022
SPIE Optics + Photonics 2022
San Diego Convention Center, San Diego, CA, USA
E-mail: customerservice@spie.org
www.spie.org/opstm

31 August – 2 September 2022
PCIM (Power Conversion, Intelligent Motion) Asia 2022
Shanghai New International Expo Centre, China
E-mail: pcimasia@china.messefrankfurt.com
www.pcimasia-expo.com

11–16 September 2022
19th International Conference on Silicon Carbide and Related Materials (ICSCRM 2022)
Davos, Switzerland
E-mail: info@icscrm2021.org
www.icscrm2021.org

19–21 September 2022
48th European Conference on Optical Communication (ECOC 2022)
Basel, Switzerland
E-mail: info@ecoc2020.org
www.ecoco2020.org

25–30 September 2022
25th European Microwave Week (EuMW 2022)
MiCo, Milan, Italy
E-mail: eumwreg@itnint.com
www.eumweek.com

16–21 October 2022
International Workshop on Bulk Nitride Semiconductors — XI (IWBNS-XI)
Lehigh Valley, PA, USA
E-mail: iwbns-xi@gmail.com
www.iwbns-xi.org

15–18 November 2022
SEMICON Europa 2022 (co-located with electronica)
Messe München, Munich, Germany
E-mail: semiconeuropa@semi.org
www.semiconeuropa.org

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