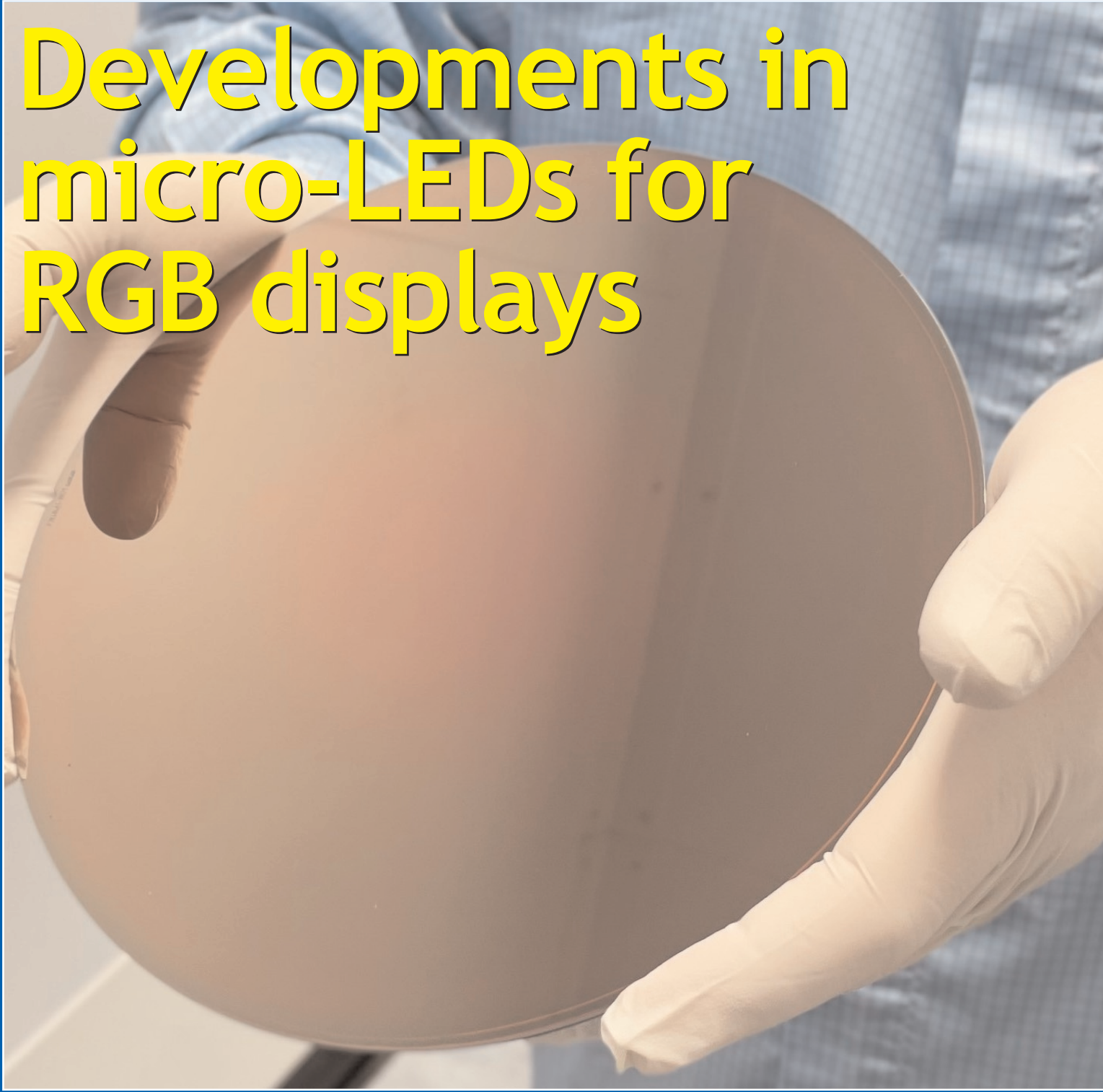


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Developments in micro-LEDs for RGB displays

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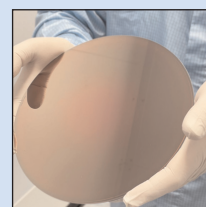
p20 onsemi has released the latest generation of 1200V EliteSiC silicon carbide M3S devices.



p66 Hamamatsu has broken ground for a new laser manufacturing building at its Miyakoda Factory, for completion in July 2024.



p89 Infineon has launched the EU-funded research project ALL2GaN (Affordable smart GaN IC solutions for greener applications).



Cover image: IQE has launched a new portfolio of 200mm (8") red, green and blue (RGB) epiwafers for micro-LED display qualification.

The firm's technology roadmap is also being scaled from 200mm to 300mm.
p41

Compound semiconductor trade with China unrestricted, for now

The escalating trade restrictions between the USA and China – in which the most advanced semiconductor manufacturing equipment (such as extreme ultraviolet lithography systems from ASML) is banned from importation into China — is restricting manufacturing in China at the leading-edge technology nodes (from 24nm down to 3nm).

China is hence focusing on using less advanced nodes (>24nm) while the country's SMIC, for example, develops its own 7nm technology. For both mature silicon chip manufacturing and compound semiconductor manufacturing, China can — so far — progress without trade restrictions.

Worldwide, silicon-focused power semiconductor manufacturers are increasingly entering silicon carbide (SiC) production, to meet demand from the rapidly developing electric vehicle (EV) market. This applies particularly to China, where multiple EV brands are targeting not only the domestic market but also markets in Europe etc.

For example, on 7 June, China's Sanan Optoelectronics — which makes not only LEDs but also silicon carbide (SiC) and gallium nitride (GaN) products — and Europe-based STMicroelectronics said they are to create a new 200mm SiC device manufacturing joint venture in Chongqing, targeting production start-up in Q4/2025 and full buildout in 2028 at a cost of \$3.2bn. Addressing EV as well as industrial power and energy applications, the JV will make SiC devices for ST, using its proprietary SiC process technology, and serve as a dedicated foundry to ST to support demand from China. In parallel, supplementing its existing SiC foundry, Sanan will build and operate a new 200mm SiC substrate-making facility — using the firm's own SiC substrate process — to fulfill the JV's needs. See next issue for details.

Meanwhile, in May, fellow European semiconductor device maker Infineon signed agreements for Chinese SiC suppliers SICC and TanKeBlue to supply SiC wafers and boules, as it expands capacities at its SiC device fabs in Malaysia and Austria — see page 24.

The boom in SiC contributed to US-based GaN power IC firm Navitas buying power device maker GeneSiC last August. In May, Navitas raised \$92m in a public offering, and has invested an initial \$20m in an epi-growth facility (using 6–8" wafer G10-SiC reactors from Germany's Aixtron) — see page 29.

Nevertheless, while SiC devices operating at 1200V are increasingly needed as EVs migrate from 400V to faster-charging 800V battery systems, at the lower EV voltages the incumbent silicon power devices are being displaced by lateral GaN devices operating at 650V (and prospectively by vertical GaN operating at 1200V from the likes of Odyssey Semiconductor, which cites Yole's forecast that the 1200V power device market will surpass the 50V segment in the second half of this decade) — see page 32.

The growing commercial prospects at stake are indicated by US-based GaN power device firm Efficient Power Conversion Corp (EPC) in late May suing China's Innoscience at the US International Trade Commission (ITC) for patent infringement, and seeking a bar on importation of its products into the USA — see page 36. Innoscience refutes this as "illegal competition tactics". It remains to be seen if this is an isolated legal dispute or if it becomes part of a broader trade war affecting compound semiconductors.

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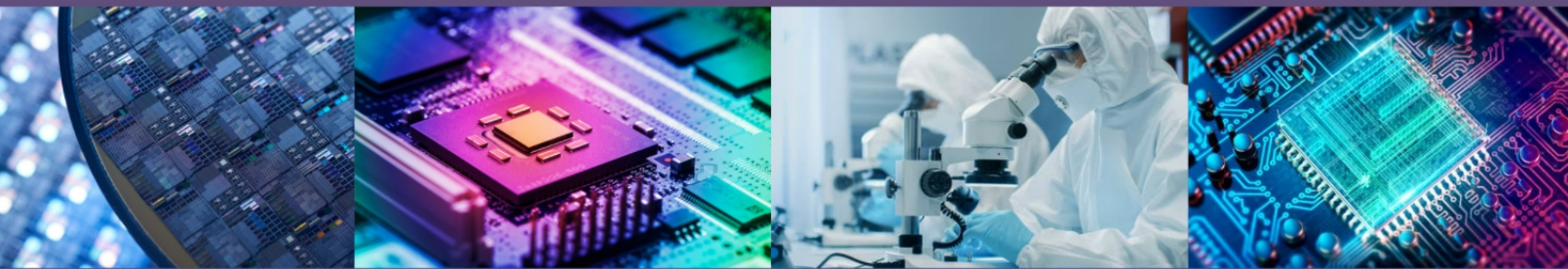
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Smartphone shipments down 12.7% year-on-year in Q1 Rebound to start in second-half 2023

Global smartphone shipments totaled 268.5 million units in first-quarter 2023, down 11.1% on 302 million last quarter and 12.7% on 308 million a year ago, according to the latest Omdia smartphone preliminary shipment report.

Two of the largest OEMs, Samsung and Xiaomi, reported 18.3% and 22% declines in shipments year-on-year, while Apple remains flat with its Q1/2022 shipment levels.

Despite the large year-on-year fall that Samsung has seen, it still had the most shipments in Q1/2023, at 60 million. It has seen a small 3.2% rise in shipments from last quarter, but this is a smaller rise than it has seen in previous years with its annual Galaxy S-series. Its lead on Apple has dwindled compared to Q1/2022, from 18 million more than Apple in 2022 to just 3 million more in Q1/2023 — so it has also seen its market share fall from 24% to 22%.

After the usual fourth-quarter bump Apple recorded in 2022, its shipments have fallen back to usual

levels again, remaining flat with the 57 million shipments recorded in Q1/2022. This is a 23.5% drop from last quarter but a 0.1% increase on a year ago. Despite this, Apple's market share has increased year-on-year as a result of all other OEMs seeing declines in shipments, increasing marginally from 18% in Q1/2022 to 21% in Q1/2023. It seems that Apple is weathering the economic storm better than other OEMs and is recovering from the blip in its eight-quarter/two-year streak of continued growth year-on-year that ended in Q4/2022.

"Due to production disruptions at Foxconn's Zhengzhou plant in December of last year, Apple was unable to supply the necessary quantities for the most important sales season, Christmas, and the end of the year. As a result, some of Apple's production was carried over to the first quarter of this year," says senior research manager Jusy Hong. "To clear inventory in major markets such as China, early

this year, the company conducted a promotion to lower the selling price of the new iPhone. This resulted in year-on-year growth rate of shipments in Q1 to perform relatively better compared to other OEMs. Apple's price promotion of the new iPhone in the first quarter is very unusual. This seems to be a strategy to lower inventory to prepare for the sluggish smartphone market expected in the first half of this year," he adds. "Among the newly released iPhone 14 series, the Pro Max sales volume was the highest, followed by the Pro model. This seems to be the adds effect of the Dynamic Island display applied to both models and the steady replacement demand from the high-income class, which is relatively less affected by the economic recession."

Xiaomi still occupies the third spot, but impacted by tougher market conditions than other Chinese OEMs. It is still facing a big inventory problem in Latin America and the

Quarterly Result: 1Q23

Rank	OEM	1Q23		4Q22		1Q22		QoQ	YoY
		Shipment	M/S	Shipment	M/S	Shipment	M/S		
1	Samsung	60	22%	58	19%	74	24%	3.2%	-18.3%
2	Apple	57	21%	74	24%	56	18%	-23.5%	0.1%
3	Xiaomi	31	11%	33	11%	39	13%	-8.1%	-22.0%
4	Oppo Group	27	10%	24	8%	27	9%	11.7%	-2.2%
5	vivo	21	8%	24	8%	24	8%	-9.3%	-11.2%
6	Transsion	13	5%	17	6%	15	5%	-24.9%	-15.4%
7	Honor	11	4%	14	5%	15	5%	-20.6%	-26.3%
8	Motorola	11	4%	11	4%	12	4%	-6.3%	-12.5%
9	Realme	8	3%	11	4%	15	5%	-27.4%	-43.8%
10	Huawei	6	2%	8	2%	6	2%	-14.7%	14.3%
	Others	24	9%	28	9%	24	8%	-13.6%	-1.8%
	Total	269	100%	302	100%	308	100%	-11.1%	-12.7%

Source: Omdia Global Smartphone Shipment Preliminary Result 1Q23

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Note: Oppo Group includes Oppo and OnePlus. Transsion includes Tecno, itel and Infinix

European market, with weak demand in India being another reason causing shipments in Q1/2023 to fall. It recorded 31 million shipments in Q1/2023, a 22% drop year-on-year and an 8.1% drop quarter-on-quarter. The two other biggest Chinese OEMs, Oppo and vivo, also saw declines, but much smaller than Xiaomi, at 2.2% and a 11.2% respectively.

Oppo recorded 27 million shipments and vivo 21 million shipments in Q1/2023. As a result, Xiaomi's lead over Oppo Group has diminished from 12 million in Q1/2022 to just 4 million in Q1/2023. Xiaomi's market share has also fallen from 13% to 11%, while Oppo has risen from 9% to 10%.

While Transsion and Honor seem to have resisted the negative winds of the market conditions last quarter, both have now succumbed to large year-on-year declines. Transsion still has the sixth highest shipment figures in the latest quarter, recording 13 million units, but this is a 15.4% drop year-on-year and a 24.9% drop on last quarter. It has been dealing with a high inventory problem since second-half 2022. The issue of inflation has also seriously weakened the purchasing power of the ultra-low segment market, such as Africa, Pakistan, Bangladeshi, which is the major market of Transsion Holdings. As a

result, Transsion is actively exploring other markets and achieving good growth in regions including the Philippines, Indonesia, and Latin American countries.

Likewise, Honor's shipments have dipped to their lowest levels since the amazing growth it saw in second-half 2021 — down 26.3% to 11 million. As a result of this dip in demand, Honor has also seen a problem of high inventory at the end of 2022.

But it is Realme that has taken one of the largest falls, down 43.8% from 15 million shipments in Q1/2022 to 8 million in Q1/2023. Compared to last quarter, it fell by 27.4% from 11 million — taking it down the rankings to the ninth largest OEM by shipments.

Motorola, which has experienced a smaller drop, has hence risen to eighth largest, with 11 million units in Q1/2023, a 12.5% drop from 12 million in Q1/2022.

"The correlation that Chinese OEMs are experiencing worse market conditions than others is no coincidence," says Zaker Li, principal analyst at Omdia. "This larger decline is happening within the context of a shrinking domestic market and India. Realme, in particular, may be hit harder by this due to its product range being primarily in the low-end price tier — and therefore demand being

more elastic than OEMs occupying the higher-end of the smartphone market."

This shrinking domestic market has also hit the recovery plans of Huawei, which has seen two consecutive quarters of shrinking shipments, following a year of growth from Q4/2021 to Q3/2022. Regardless, Huawei is still in a better position now versus a year ago, recording 6.5 million shipments in Q1/2023, up 14.3% from 5.6 million in Q1/2022.

"OEMs' shipments have fallen again, as forecasted by Omdia, with the few predicted to increase quarter-on-quarter seeing disappointing figures, particularly Samsung following the launch of the S23 series," Hong summarizes. "The key global economic problem facing the smartphone industry remains inflation, and the resulting squeeze on wage packets and the economy. The problem of high inventory levels is slowly lifting, although the low consumer demand is extending this problem longer than predicted. Our forecast shows that it is likely that the smartphone market will reach the bottom of this dip in the market in Q2/2023, before beginning to recover from the second half of this year."

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UK unveils National Semiconductor Strategy, with £1bn government funding

Strategy focuses on compound semiconductors, R&D and design

The UK government has unveiled its long-awaited National Semiconductor Strategy, which aims to boost the UK's semiconductor industry's strengths and skills (focusing on design, intellectual property, R&D and compound semiconductors) while safeguarding supply chains from disruption and protecting the technology sector against national security risks.

Working in tandem with industry, the government investment aims to drive research, innovation and commercialization through the sector — helping to deliver products from lab to market.

With semiconductors underpinning future technologies, such as artificial intelligence (AI), quantum and 6G, the strategy focuses on particular areas deemed to be of strategic advantage to the UK in the semiconductors sector — design, compound semiconductors, and the R&D ecosystem — supported by UK universities from Cambridge to Cardiff and Manchester to Edinburgh.

Used in evolving technologies such as autonomous driving and future telecoms, the creation of compound semiconductors in particular requires expertise in advanced materials, a focus of UK science.

Growing the UK industry

To support the growth of the sector in the UK, the government will invest up to £200m over 2023–2025 to improve industry access to infrastructure, power more R&D and facilitate greater international cooperation.

Taking a strategic approach to investment over the next decade, the government will invest up to £1bn in a range of measures targeted at securing what are perceived to be the UK's advantage and meeting three key objectives:

- growing the domestic sector;
- mitigating the risk of supply chain disruptions;

- protecting national security.

The new funding will be used to improve the talent pipeline and will make it easier for British firms to access things like prototyping, tools and business support.

These efforts will include investment in a new National Semiconductor Infrastructure Initiative to unlock the potential of British chip firms in these key areas. It will look at whether better access to prototyping facilities for chip firms is needed to tackle barriers to innovation and grow the industry. It will also explore opportunities to make specialist software tools more available for start-ups. The Department for Science, Innovation and Technology commissioned research that will look at the best way to establish the Infrastructure initiative. This will report its findings in the autumn.

Furthermore, the government will announce plans by the autumn on support for investment in the semiconductor manufacturing sector, particularly where they are critical to the UK tech ecosystem or national security.

Safeguarding supply chains

Taking a semiconductor chip from lab to market can involve thousands of production stages taking place across the world, with various locations that have particularly concentrated production capabilities.

The surge in demand for consumer electronics during the pandemic demonstrated how global industries can be impacted by semiconductor supply issues. This strategy highlights the importance of collaboration with international allies to develop secure supply chain resilience.

The UK government says it will take steps to help sectors mitigate the impact of supply shortages in the future. It also wants to protect critical sectors (essential services, healthcare, critical national infrastructure and defence) from disruptions that could cause risks to life,

or national security. To help ensure that the UK is better protected against future disruption the government commits to:

- new guidance to be published to help businesses better understand risks and steps they can take to be more resilient against supply chain shocks;
- continued collaboration through international initiatives — like the UK's technology partnerships with the US, Japan, and the Republic of Korea — to explore shared approaches and solutions to improve global supply chain resilience.

International cooperation for supply chain resilience

The UK's Integrated Review placed securing strategic advantage in science and technology at the heart of the UK's national security and foreign policy. In recognition of the fundamental importance of semiconductor technologies in these areas, as part of the National Semiconductor Strategy the UK will increase its cooperation with close partners, working together to manage national security threats and driving growth in the sector, while championing international cooperation to help develop a coordinated approach to supply chain resilience.

Announcement of the plan follows a UK and Japan commitment to establish collaboration in the semiconductor sector, spanning R&D cooperation, skills exchanges, and improving the resilience of the semiconductor supply chain. Meanwhile, UK Prime Minister Rishi Sunak is attending the G7 leaders' Summit in Hiroshima, Japan for discussions on strengthening tech collaboration with "like-minded economies" and strengthening supply chains for critical technology like semiconductors.

In Hiroshima, the UK and Japan committed to establishing a semiconductor partnership — led by the UK's Department for Science,

Innovation and Technology (DSIT) and Japan's Ministry of Economy, Trade and Industry (METI) — that aims to deliver new R&D cooperation, skills exchanges, and improving the resilience of the semiconductor supply chain for both countries.

UK Research and Innovation will work with the Japan Science and Technology Agency on a joint investment of up to £2m in early-stage semiconductor research next year that will support UK and Japanese researchers to work together on fundamental semiconductor technologies.

Protecting UK from security risks

Semiconductors can create vulnerabilities in the electronic devices they are used in, and these risks are becoming more significant as the use of Internet-connected devices increases. A compromise to the cyber-security of hardware is unacceptable. The acquisition of chip

firms can also present national security issues. The strategy announces actions to protect the UK against these security risks including:

- additional information on the government's approach to using the National Security and Investment Act, providing information to the industry on what areas of the sector the government has seen particular concerns potentially arising to ensure technology remains secure;
- the government continuing to support programs like Digital Security by Design, which aims to ensure that semiconductors can be more resilient and secure in the face of growing cyber-threats.

Semiconductor Advisory Panel

The UK government says that its strategy has been developed in close consultation with the semiconductor industry and academia, and it will build on this partnership by creating:

- a new UK Semiconductor Advisory Panel that brings together key figures from industry, government and academia to work together on shared solutions and implementation of the strategy. The Advisory Panel will speak on behalf of the sector and provide advice and feedback;
- a specialist incubator pilot that will focus on removing obstacles that hold semiconductor start-ups back from growth. The scheme will provide industry with better access to technical resources as well as coaching and networking;
- support for industry-led learning that will ensure people can gain the skills the semiconductor industry needs. Programs will provide opportunities for learning focused on the advanced skills needed for the sector, such as electrical and electronic engineering and computer science.

www.gov.uk

UK's CML Micro exhibiting extended RF-to-mmWave capability at IMS after acquiring Silicon Valley's MWT

UK-based CML Microsystems Plc, a designer and fabless manufacturer of mixed-signal, RF and microwave semiconductors for wireless communications applications, says that its presence in booth 655 at the IEEE International Microwave Symposium (IMS 2023) exhibition in San Diego, CA, USA (13–15 June) will reflect an expansion of its technology offering, as the firm is now developing more advanced RF, microwave and mmWave devices for transformative applications centred around its SpRF product range of gallium arsenide (GaAs)- and gallium nitride (GaN)-based devices.

"Our booth at this year's IMS will unveil a change of branding that represents much more than a simple refresh of our image," says Ion Furtuna, senior VP for sales & business development in the Americas. "Building on our years of experience in baseband and RF components for professional wireless and critical communications applications, we

have recently acquired [through buying Silicon Valley-based Microwave Technology Inc (MWT) in January] capabilities to extend our innovation into microwave and mmWave devices, including PAs [power amplifiers], LNAs [low-noise amplifiers] and gain blocks up to 100GHz," he adds. "Our eventual target is to reach new markets including security and defence."

Among the CML Micro products on show at IMS are the recently introduced CMX90B701 and CMX90B702 low-current low-noise gain blocks for the 17–23GHz and 23–29.5GHz bands, respectively. Both devices have ultra-low current consumption of 10mA with a typical output power at 1dB gain compression point (P1dB) figure of +7.5dBm, a third-order intercept point (IP3) output of +17.5dBm and a noise figure of 4dB. The devices are housed in a low-cost 3mm x 3mm QFN package, and are fully matched to 50Ω.

"We plan to continue expanding our microwave device capability for the rapidly growing 5G mmWave, wireless infrastructure and Ka-band satcom markets, while consolidating our position as a trusted supplier of devices into our traditional RF and wireless communications markets that include maritime, smart meters, RFID, IoT and asset tracking," says managing director Mark McCabe.

"Our customers already choose to partner with CML Micro because of our reputation for quality and technical expertise, as well as our problem-solving and collaborative approach to innovation," he adds. "By pushing the boundaries of our technology towards higher frequencies and bandwidths, we look forward to developing exciting new partnerships as well as continuing to serve our traditional core markets."

www.ims-ieee.org

www.cmlmicroplc.com

www.mwtinc.com

Qorvo quarterly revenue down 45.7% year-on-year while channel inventory consumed

Under-utilization to delay return to 50% margin beyond next fiscal year

Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has reported revenue for the fiscal full-year (to 1 April) down by 23.2% from 2022's \$4646m to 2023's \$3569m. The two 10% customers were Apple (at 37%, up from 33% in fiscal 2022) and Samsung (at 12%, up slightly from 11%).

Fiscal fourth-quarter 2023 revenue was \$632.7m, down 14.9% on \$743.3m last quarter and 45.7% on \$1166.2m a year ago. However, this outperformed the midpoint of the \$600–640m guidance range, despite a weak demand environment and despite Qorvo reducing channel inventory of its components in the Android ecosystem by about 25% (following a more than 20% reduction in the December quarter).

Advanced Cellular Group (ACG) revenue was hence \$418m (down 14.9% on \$491m last quarter and 46.2% on \$777m a year ago). However, total Android revenue was up sequentially on the strength of a large customer flagship ramp with record Qorvo content. "March was a low point for China-based Android quarterly revenue," believes president & CEO Bob Bruggeworth.

High-Performance Analog (HPA) revenue was \$133m (down 14.2% on \$155m last quarter and 37% on \$211m a year ago). Relative strength in power devices and defense markets was offset by weakness in consumer-facing power management markets and inventory digestion at infrastructure OEMs.

Connectivity & Sensors Group (CSG) revenue was \$82m (down 15.5% on \$97m last quarter and 54% on \$179m a year ago). Relative stability in automotive was offset by continued inventory draw-downs and weak end-market demand for Wi-Fi-enabled products and cellular IoT.

"We held factory production at characteristically low volumes, which created under-utilization impacts that negatively affected margins," says chief financial officer Grant Brown. "Charges related to low factory utilization continued to weigh on margins on a year-over-year basis."

Impacted by about 1000 basis points due to lower factory utilization and 80-100 basis points due to inflation across direct costs, non-GAAP gross margin has hence fallen from 52% a year ago to 41.3%. Nevertheless, this was up slightly from 40.9% last quarter after a modest increase in factory utilization. Full-year gross margin has fallen from 52.4% for 2022 to 46.3% for 2023.

Operating expenses were \$227.4m, up from \$205.7m last quarter, given the timing of seasonal employee-related expenses such as payroll taxes, the timing of vacation accruals and other items driven principally by R&D as Qorvo supports its customers and invests in future growth opportunities.

Net income has fallen further, from \$339.6m (\$3.12 per diluted share) a year ago and \$76.5m (\$0.75 per diluted share) last quarter to \$25.7m (\$0.26 per diluted share, but above the forecasted \$0.10–0.15).

Operating cash flow has fallen to \$65.4m. Capital expenditure was steady at \$34.1m. Free cash flow hence fell to \$31.3m. During the quarter, Qorvo repurchased \$150m worth of shares. Overall, cash and equivalents therefore fell from \$919m to \$810m. Qorvo has about \$2bn of debt outstanding with no near-term maturities.

"We are seeing increasing strength in customer design activity across our businesses, and we expect improved financial performance supported by content gains in large customer programs," says Bruggeworth.

Strategic highlights of the quarter are listed as follows:

- In High-Performance Analog, Qorvo continues to see broad-based multi-year design win activity (spanning applications in aerospace, battery management, defense radar, electric vehicles and renewable energy systems) that it expects to contribute to long-term growth.

Qorvo was selected by an aerospace industry leader to supply cell-to-satellite solutions that combine aerospace, base-station and mobile technologies including multiple RF components and BAW-based multiplexers. These solutions enabled low Earth orbit (LEO)-based space-to-terrestrial connectivity, helping to provide cellular coverage in the hardest-to-reach geographies.

Qorvo achieved a milestone by delivering its first prototype RF multi-chip module (MCM-1) to BAE Systems under the SHIP contract with the US Department of Defense. Qorvo is leveraging its production capabilities in its Richardson, Texas facility to advance heterogeneous packaging integration, enabling significant savings in power, size, weight and cost.

In the power device business, Qorvo booked a multi-million-dollar follow-on silicon carbide inverter order for residential and industrial solar applications. This win complements the firm's ongoing business in automotive charging applications and data centers.

- In the Connectivity and Sensors Group, design activity was strong across applications including smart home, precision location, indoor navigation, automotive connectivity, automotive smart interiors and enhanced human-machine interfaces (wearables).

Qorvo was selected to supply ultra-wideband (UWB) solutions across multiple verticals, including

a next-generation smartwatch supporting secure car access, Wi-Fi access points enabling indoor navigation, and an additional 2024 flagship Android smartphone.

In automotive connectivity, Qorvo has collaborated with automotive OEMs and leading third parties to advance smart antennas and next-generation shark-fin architectures, and expanded design engagements with automotive tier-1s regarding 5G network access devices.

In sensors, Qorvo has secured a design win to supply force-sensing touch sensors leveraging the ultra-sensitivity of Qorvo's MEMS-based sensors to enable a new industrial design in a premium true wireless headset for a leading European OEM.

In Wi-Fi, Qorvo secured its first Wi-Fi 7 BAW filter design win and expanded sampling of its Wi-Fi solutions, enabling full coverage of 2.4GHz, 5GHz and 6GHz bands for smartphones and consumer and enterprise access points.

● In Advanced Cellular, design activity during the quarter continued to be favorable across all leading smartphone OEMs, increasing Qorvo's content in the highest-volume flagship phones.

Qorvo supported the ramp of a Korean-based smartphone OEM's flagship smartphone with broad-based content, including low-band (LB), mid-high-band (MHB) and ultra-high-band (UHB) power amplifier duplexers (PADs) as well as secondary transmit, tuning and Wi-Fi. "We are seeing expanding opportunities as they migrate their mass-market portfolio to integrated 5G solutions," says Bruggeworth.

Across the Android ecosystem, Qorvo was awarded broad-based design wins in support of upcoming flagship, mid-tier and mass-market 5G devices at the top five Android smartphone OEMs.

To support new designs, Qorvo shipped the first samples of its newest mid-high-band PAD to an Android OEM, addressing this customer's most challenging performance and size requirements for smartphones launching in 2024.

This new architecture is reckoned to be the industry's most highly integrated radio-frequency front-end (RFFE) placement, combining main-path and diversity receive content for the mid and high bands. This product leverages the reduced size and enhanced performance of Qorvo's newest BAW and SAW filters to integrate nearly twice the BAW filter content in a smaller footprint than existing main-path-only, mid-high-band pad architectures.

"Despite ongoing weakness in end-markets, our strong design-win activity on large customer programs supports our view for sequential revenue growth in June and robust sequential revenue growth in September," says Brown. "We anticipate continued progress reducing Android channel inventory in the coming quarters, with a return to historical norms by calendar year-end."

Qorvo hence expects total Android revenue to grow sequentially in June.

For fiscal first-quarter 2024 (to end-June 2023), Qorvo expects revenue of \$620–660m, gross margin of 41.5%, and diluted earnings per share of \$0.15.

Operating expenses should be up about \$10m sequentially due to investments in multi-year customer programs, investments in core systems and other productivity initiatives, and the return of incentive compensation based on expectations for improved financial performance.

For fiscal Q2/2024, Qorvo expects revenue to grow about 50% sequentially, driven by strong content gains and a large seasonal ramp. Gross margin should also rise by about 400 basis points as product mix begins to favor some newer products for Qorvo's largest customers that are less burdened by higher unit costs associated with under-utilization

"Inventory balance will increase in the June quarter as we support a seasonal ramp at our largest customer," says Brown. "Our expectations for this quarter are for channel inventories to decline again in the double digits. Later this calendar year, we expect Android channel inventories will normalize. Outside of the Android ecosystem, there are smaller pockets of channel inventory elsewhere in our business that may take longer to digest."

For fiscal Q2/2024 (to end-September 2023), Qorvo expects revenue to grow about 50% sequentially, driven by strong content gains and a large seasonal ramp. Gross margin should also rise by about 400 basis points as product mix begins to favor some newer products for Qorvo's largest customers that are less burdened by higher unit costs associated with under-utilization.

In fiscal Q3/2024 (to end-December 2023), revenue is expected to be roughly flat sequentially.

Gross margin should fall by 100–150 basis points as utilization begins to ramp down following that large seasonal ramp and product mix begins to modestly shift to some of that higher-cost inventory.

"In the March [2005] quarter, our fiscal Q4/2024, we expect Android to be a higher percent of our mix, but decline less than might be historic seasonality due to a clean channel and returning to shipping to end-demand," says Brown. However, gross margin will be down by 200–300 basis points quarter-on-quarter as mix reflects that higher-cost inventory.

For full-year fiscal 2024, Qorvo expects revenue to be up on fiscal 2023 and to benefit from strong dollar content growth at its largest customers. Gross margin should be about 44% (down from fiscal 2023's 46.3%). "Although there is no change to our view of returning to 50% in the gross margin line, it's unlikely in 2024... It's dominated by under-utilization," concludes Brown.

www.qorvo.com

Skyworks maintains strong cash flow generation

Slow Android smartphone market recovery leads to factory under-utilization charges hitting margins

For fiscal second-quarter 2023 (to end-March), Skyworks Solutions Inc of Irvine, CA, USA (which makes analog and mixed-signal semiconductors) has reported revenue of \$1153.1m, down 13.2% on \$1329m last quarter and 13.7% on \$1335.6m a year ago.

Skyworks' largest customer comprised about 64% of total revenue (down from 68% last quarter).

Mobile products comprised about 60% of total revenue (down from 65% last quarter). Mobile revenue from Skyworks' largest customer grew year-on-year, reflecting content gains across their product portfolio. However, this was offset by weakness in demand from the Android smartphone ecosystem as it continues to destock inventory.

Broad Markets products reached 40% of total revenue for the first time, with a strong contribution from automotive, infrastructure and industrial markets.

On a non-GAAP basis, gross margin was 50%, down from 51.5% last quarter (and at the bottom end of the 50–50.5% guidance range) due to the inventory destocking leading to factory under-utilization charges.

Operating expenses were \$190m (16.5% of revenue), cut from \$193m last quarter, given the focus on managing discretionary expense.

Net income has fallen further, from \$432.3m (\$2.63 per diluted share) a year ago and \$415m (\$2.59 per diluted share) last quarter to \$323.1m (\$2.02 per diluted share).

"Despite a challenging macro backdrop, the fundamentals of our business remained strong in the second quarter with solid profitability and robust cash generation," says chairman, CEO & president Liam K. Griffin.

Operating cash flow was \$411.7m. Capital expenditure has been cut further, from \$126.7m a year ago and \$64m last quarter to just \$45.3m. Free cash flow was hence \$366m

(cash flow margin of 32% of revenue). Through fiscal first-half 2023, Skyworks has now generated record free cash flow of \$1.1bn (exceeding the whole of fiscal 2022), representing free cash flow margin of 43%.

During the quarter, Skyworks paid \$98.7m in dividends, repurchased \$9.1m of stock, and repaid \$200m of variable-rate term loans.

Overall, cash, cash equivalents and marketable securities hence rose from \$992.6m to \$1061.4m, providing sufficient liquidity to repay \$500m of bonds that will reach maturity during fiscal Q3/2023.

Also, following quarter-end, Skyworks' board of directors declared a cash dividend of \$0.62 per share of common stock (payable on 20 June, to stockholders of record at the close of business on 30 May).

"We are driving operational efficiency while leveraging our leading-edge technologies and world-class manufacturing capabilities to capture new opportunities across an expanding set of customers," says Griffin. "We expanded our design-win pipeline, reflecting our success in diversifying our customer base and product portfolio."

Across mobile and IoT applications, Skyworks:

- delivered Sky5 platforms for Samsung's newly released premium and mass-tier smartphones;
- launched tri-band WiFi 6E and WiFi 7 gateways for CommScope and ASUS; and
- secured 5G content in platforms with market leader in mobile computing.

Across infrastructure and industrial applications, Skyworks:

- enable small-cell infrastructure deployments with a Japanese telecoms company;
- provided enhanced Power-over-Ethernet functionality to Cisco for their enterprise networks;
- shipped programmable timing solutions to the top US satellite provider; and

● leveraged its expanding industrial product suite with the leading firm in smart meter technology.

In automotive applications, Skyworks:

- captured electric vehicle (EV) onboard charging (OBC) content with a top European automotive supplier; and
- ramped key digital radio products with a leading Korean automotive OEM.

Taking into account the ongoing challenging macroeconomic environment and a slower-than-expected recovery and inventory destocking (especially in the Android ecosystem), for fiscal third-quarter 2023 (to end-June) Skyworks expects revenue to fall to \$1.05–1.09bn, with Broad Markets revenue down slightly.

"Initially, we were anticipating a stronger second half of the fiscal year and calendar year... We do see some signs of recovery, although I would say later and slower than initially anticipated," notes senior VP & chief financial officer Kris Sennesael. "As a result of that, we are adjusting our factory utilizations across all our factories. We have been operating our business at a slightly elevated level of inventory [\$1257m, up from \$928m a year ago], in anticipation of a stronger recovery in the back half. Now that the recovery is going to be slower than expected, we are also going to adjust our internal inventory levels and right-size that."

While the firm is reducing its internal inventory levels, fiscal Q3 gross margin should be 47–48%, reflecting a 400–500 basis-point impact from factory under-utilization charges, partially offset by ongoing cost cuts and operational efficiencies that should cut operating expenses to \$183–187m. Diluted earnings per share is expected to fall to \$1.67.

"Given our consistent level of profitability and lower CapEx spending, we expect free cash flow margin to remain well above our target of 30% for the fiscal year," says Sennesael.

www.skyworksinccom

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MACOM completes acquisition of OMMIC

Facility to be foundation of new European Semiconductor Center

MACOM Technology Solutions Inc of Lowell, MA, USA (which designs and makes RF, microwave, analog and mixed-signal and optical semiconductor technologies) has completed its acquisition (announced in February) of the key manufacturing facilities, capabilities and technologies of OMMIC SAS of Limeil-Brévannes, near Paris, France, which has expertise in wafer fabrication, epitaxial growth and monolithic

microwave integrated circuit (MMICs) processing and design.

Going forward, the facility will become the foundation for MACOM's newly established European Semiconductor Center, which will enable MACOM to offer its customers higher-frequency gallium arsenide (GaAs) and gallium nitride (GaN) MMICs.

"We look forward to building upon the existing team's expertise in

material science, semiconductor wafer processing and millimeter-wave MMIC design," says MACOM's president & CEO Stephen G. Daly.

MACOM plans to showcase certain European Semiconductor Center product offerings in booth 1135 at the International Microwave Symposium (IMS 2023) in San Diego, CA, USA (13-15 June).

www.ommic.com

www.macom.com

AmpliTech's growth in LNA sales offset by drop in semiconductor distribution demand

For first-quarter 2023, AmpliTech Group Inc of Hauppauge, NY, USA — which designs and makes signal-processing radio frequency (RF) microwave components for satellite communications, telecoms (5G & IoT), space, defense and quantum computing markets — has reported revenue of \$4.1m, down on \$5.1m a year ago. Core low-noise amplifier (LNA) sales continued to grow, but semiconductor distribution sales fell due to softer international demand.

Gross margin was 44%, down only slightly from 45.6% a year ago despite inflationary pressures.

Compared with net income of \$3.63m a year ago, net loss was \$619,000, attributed largely to a combination of corporate expenses, continuing R&D efforts in new product development, and a temporary downturn in sales in the Spectrum Division.

As of end-March, cash, cash equivalents and marketable securities totaled \$10.6m (down from \$16m a year ago). Working capital was \$18m. AmpliTech says that this still gives it ample capital to finance all of its strategic growth initiatives.

With the AmpliTech MMIC Design Center (AGMDC) division completing design releases and ready to manufacture monolithic microwave integrated circuit (MMIC) products,

in Q2/2023 an intense marketing campaign has begun, with expected bookings to occur during Q2 and shipments of MMIC-related products expected to contribute to sales in Q3/2023.

AmpliTech says that, by utilizing its Customer Relationship Management (CRM) engine, implementing artificial intelligence (AI)-powered sales prospecting techniques and leveraging increased attendance at trade shows, it achieved a 70% surge in request for quotes (RFQs) for its low-noise amplifier and 5G systems. CRM currently has \$66m in the opportunity funnel, some of which the firm expects to turn into sales over Q3 and Q4/2023.

AmpliTech is participating as a gold sponsor at the IEEE International Microwave Symposium (IMS 2023) in San Diego, CA, USA (11-16 June).

"Our team has been working relentlessly to develop the lowest-noise, lowest-power-dissipating amplifiers on the market and these are included in our new 5G and wireless infrastructure products and MMIC designs for the satellite, wireless and 5G markets, including the advanced military and commercial markets," says CEO Fawad Maqbool.

"We have also recently expanded into the design of full-service,

true5G Open Radio Access Network (O-RAN) front ends. These offerings are cutting-edge, end-to-end solutions and also backwards-compatible and retrofittable with existing obsolete 3G, and 4G systems," he adds.

The 5G infrastructure market will rise at a compound annual growth rate (CAGR) of 37% to \$99bn by 2030, forecasts Precedence Research. "This tremendous growth outlook reaffirms our belief in the significant potential of our product line to serve this market," continues Maqbool.

"Despite weakening economic trends and the expected 11% decline in the semiconductor market for 2023, as reported by Gartner, we remain optimistic about semiconductors, which are integral to modern technology, and why we have invested heavily in our AGMDC semiconductor division in Texas. We anticipate that global demand will bounce back as market conditions improve," says Maqbool.

"The second-quarter launch of the MMIC line under the AmpliTech Inc division, coupled with our recent distribution deal with NGK, are important developments that are expected to drive future growth, in addition to our diversified portfolio, strategic investments, and the unwavering commitment of our team."

www.amplitechinc.com

UMC announces 40nm RFSOI platform to accelerate 5G mmWave applications

40RFSOI suits integration of beam-formers, core and passive devices, and front-end components on single IC

Semiconductor foundry United Microelectronics Corp of Hsinchu, Taiwan says that its 40nm radio-frequency silicon-on-insulator (RFSOI) technology platform is now ready for the production of millimeter-wave (mmWave) RF front-end products, enabling the proliferation of 5G wireless networks and applications including smartphones, fixed-wireless access (FWA) systems, and small-cell base stations.

While most existing 5G networks operate in sub-8GHz bands, mmWave technology employs a new frequency spectrum between 24GHz and 60GHz, making it possible to deliver fast transfer speeds, extremely low latency, and more reliable connectivity. UMC's new platform 40RFSOI is optimized for manufacturing RF switches, low-noise amplifiers (LNA) and

power amplifiers (PAs) capable of handling the wider bandwidth of mmWave frequencies. Balancing the need for more RF components in mmWave modules while keeping the size compact, 40RFSOI is suitable for customers designing integrated RF chips that combine beam-formers, core and passive devices, as well as front-end components on a single IC.

"The full potential of 5G hinges on the mainstream rollout of mmWave to deliver the speed and capacity required for virtual and augmented reality, smart cities, industrial automation, and applications in healthcare," says Raj Verma, UMC's associate VP of technology development. "With the introduction of our 40RFSOI platform, UMC expands our RF portfolio to enable our customers to deliver their

advanced 5G devices to market and capture opportunities in the growing mmWave market," he adds.

"Several customers are currently engaged with us to customize the 40RFSOI process for their RF front-end products, and volume production is expected to start in 2024."

UMC offers RF front-end module solutions serving applications spanning mobile, Wi-Fi, automotive, IoT, and satellite communications. Its family of RFSOI solutions ranges from 8-inch to 12-inch wafer manufacturing. Since 2014, UMC has had over 400 product tape-outs and more than 35 billion RFSOI chips shipped. Its 55nm RFSOI technology has been in production for years serving the 5G sub-8GHz market.

www.umc.com

PRFI's 150th MMIC design moves to production

PRFI Ltd of Cambridge, UK (which designs and develops RFICs, MMICs and microwave/millimeter-wave modules) says that its 150th custom MMIC design, a low-current mmWave gain block, has moved to production. The firm's list of clients includes Samsung, Sony, Analog Devices, BAE Systems and Qorvo.

The milestone MMIC provides a small-signal gain of 17dB across an operating range of 23–29.5GHz from a very low current consumption of just 10mA. It is housed in a

low-cost 3mm x 3mm QFN package and is fully matched to 50Ω, making its use very straightforward, says PRFI. The part was designed for CML Microcircuits' SpuRF product range, and is commercially available as the CMX90B702. A companion part has also been designed by PRFI, which has similar gain with the same very low 10mA current consumption and covers 17–23GHz.

"The 10mA current consumption is an industry-leading figure and the two parts we developed cover 17–29GHz, making them very use-

ful building blocks in a wide range of applications," says PRFI's CEO Liam Devlin. "We were pleased that we could use our innovative design techniques to create a solution able to reduce the current to such low levels while still covering a significant operating band with a good level of gain."

PRFI is exhibiting in booth 1820 at the International Microwave Symposium (IMS 2023) in San Diego, CA, USA (13–15 June).

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Wolfspeed's revenue growth constrained by 200mm SiC material capacity ramp

Fiscal 2024 revenue forecast cut by 35% from \$1.6bn to \$1–1.1bn

For its fiscal third-quarter 2023 (to end-March), Wolfspeed Inc of Durham, NC, USA — which makes silicon carbide materials as well as silicon carbide (SiC) and gallium nitride (GaN) power-switching & RF semiconductor devices — has reported revenue of \$228.7m, up 6% on \$216.1m last quarter and up 22% on \$188m a year ago, and at the high end of the \$210–230m guidance range.

"Looking at RF products, we continue to see weaker demand, but within range of our prior estimates [about \$15m lower than initially expected]," says chief financial officer Neill Reynolds.

Power device product revenue grew more than 50% year-over-year. "We have achieved full capacity in our Durham wafer fab," notes Reynolds. During the quarter, Wolfspeed recognized initial revenue from its new Mohawk Valley fab (opened in April 2022). "While it's a relatively small number of devices shipped to an industrial off-board charging customer, it's an important proof point that we are now producing product on 200mm [SiC] substrates," says CEO Gregg Lowe. "The learnings from this first shipment will inform our ramp in devices as we continue to expand our capacity to address increasing demand," he adds.

"We saw strong revenue growth from our merchant 150mm silicon carbide substrates as we solved many of the production challenges we had on the taller boules, albeit at higher-than-expected costs," says Reynolds. "This results in a one-time inventory drain, and we expect revenue levels to return to more steady-state run-rate levels in fiscal Q4 and beyond."

Impacted by lower yields and higher costs on the firm's taller 150mm boules, plus a heavier mix of high-volume automotive customers running on the smaller 150mm wafers in the Durham fab, gross

margin (on a non-GAAP basis) has hence fallen further, from 36.3% a year ago and 33.6% last quarter to 32.3% (near the low end of the 32–34% guidance range).

As the revenue growth was offset by lower gross margins and higher investments in OpEx, net loss was \$16m (\$0.13 per diluted share), up from \$14.2m (\$0.11 per diluted share) last quarter and \$14.3m (\$0.12 per diluted share) a year ago.

Net cash used in operating activities was \$11m (cut from \$67m last quarter and \$28.4m a year ago). However, capital expenditure (CapEx) has more than doubled from \$102.8m a year ago and \$104.1m last quarter to \$233.9m. Free cash outflow was hence \$245m (up from \$171.1m last quarter and almost doubling from \$131.2m a year ago). During fiscal Q3/2023, cash, cash equivalents, and short-term investments therefore fell from \$2484.4m to \$2248.2m.

During the quarter, Wolfspeed incurred start-up costs (related primarily to the Mohawk Valley fab) of about \$45m. "Moving forward, we expect overall start-up and underutilization costs for Mohawk Valley to start winding down as we ramp the fab," says Lowe. For full-year fiscal 2023, Wolfspeed targets about \$160m of start-up and underutilization costs.

"Producing more silicon carbide epiwafers out of our Durham facility will be the governor on our Mohawk Valley ramp in the short term, and our longer-term outlook is supported by the ramp of the JP [John Palmour Manufacturing Center for Silicon Carbide, in Siler City, NC]," notes Lowe. "To support capacity expansion efforts, we've realigned the team with operations leaders now reporting directly to myself and Neill," he adds. "Missy Stigall is overseeing devices and our wafer fabs, while Adam Milton will lead the materials production for the

company. This will provide greater visibility into the ramp of substrates as well as our device footprint expansion."

Design-ins in fiscal Q3/2023 were \$1.7bn. Complementing \$700m for automotive applications, this includes a new quarterly record for non-automotive designs, which included a heat-pump application and an electric vehicle (EV) off-board charger. Year-to-date design-ins for fiscal Q1–Q3/2023 are \$6.7bn (greater than full-year fiscal 2022's record). Wolfspeed's cumulative total for design-ins secured since fiscal 2020 is now about \$18bn.

Reflecting the low single-digit revenue (about \$2m) from the Mohawk Valley fab, for its fiscal fourth-quarter 2023 Wolfspeed expects revenue of \$212–232m (slightly down quarter-on-quarter at the mid-point).

"We are essentially capped in Durham from a power device capacity perspective. Going forward, much of the incremental revenue we will generate will be from Mohawk Valley," notes Reynolds. "In addition, we will see lower materials revenue related to the one-time inventory drain in Q3 as we improved output on our taller 150mm boules that will not repeat in Q4," he adds.

As Wolfspeed continues to work through the cost recovery on the taller 150mm boules, and after shifting the Durham fab mix to higher-volume automotive customers initially slated to be produced in Mohawk Valley, gross margin is expected to fall to 29–31%.

With operating expenses of \$105–106m, operating loss should rise to \$34–43m. Including a non-operating net gain of about \$5m and after realizing \$8–10m of tax management, net loss is expected to rise to \$21–29m (\$0.17–0.23 per diluted share).

Scaling up SiC materials manufacturing to feed the Mohawk Valley is being slowed by two things, notes Lowe. "One is some infrastructure delays that we had — things like switchgear and things like that — as we expanded in our Building 10 facility in Durham, so basically supply chain issues with electrical infrastructure. That's been resolved, and we're now expanding inside Building 10. The second is a more methodical approach to growing the capacity."

Due primarily to the timing of facility spend related to the 200mm substrate expansion (particularly on the Siler City project), Wolfspeed has cut its forecast for CapEx in fiscal full-year 2023 from \$1bn to \$775m.

"In terms of our capital needs, we continue to evaluate multiple avenues of additional funding, including upfront customer payments or investment debt instruments and government funding in the USA and Europe. While we cannot comment on the timing or certainty of any government funding, we believe we have made great progress in this regard," says Reynolds. "In addition, we believe we need to secure

approximately \$1bn of additional non-government financing between now and the end of the calendar year to support an approximate \$2bn of CapEx in fiscal 2024. The majority of this investment will be for 200mm substrate facility construction and tool capacity both at JP in Siler City and our Durham campus in North Carolina, with the intention of leveraging this investment to ramp the Mohawk Valley fab as fast as possible," he adds.

"Given that our growth will be governed by how quickly we ramp 200mm substrate capacity and, in turn, the Mohawk Valley fab, we will target fiscal 2024 revenue between \$1–1.1bn [reduced by 35% from the \$1.6bn forecast given at last's October Analyst Day]," says Reynolds. "This outlook assumes we achieve 20% capacity utilization at Mohawk Valley by the fourth quarter of fiscal 2024, while our epi materials product line revenues remain closer to current levels as we focus our efforts and resources on ramping 200mm substrates in Mohawk Valley. Additionally, as a result of the ramp time-line and continued focus on

customer time-lines, we plan to run more auto-related products at a smaller 150mm diameter in the Durham fab for the foreseeable future," he adds. "As we are in the early stages of these critical EV ramps, it is important to support our customer ramp schedules. This will flatten the gross margin trajectory for the next several quarters until Mohawk Valley reaches critical mass. That said, as we reach 20% utilization at Mohawk Valley [beyond end-fiscal 2024], we would expect the trajectory for gross margin to improve because the unit economics are significantly more favorable than Durham."

"While we are currently investing a modest amount of design work for the German Saarland fab [announced in February], we don't expect to see significant facility-construction-related CapEx until calendar year 2024 while we await final incentive notification from European authorities," says Reynolds. "However, we have made good progress on this front and, as of now, expect final notification later this calendar year."

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Penn State and onsemi sign MOU for \$8m collaboration on silicon carbide growth

Materials Research Institute to gain Silicon Carbide Crystal Center

Power semiconductor IC supplier onsemi of Phoenix, AZ, USA has signed a memorandum of understanding (MOU) for an \$8m strategic collaboration that includes the establishment of the onsemi Silicon Carbide Crystal Center (SiC3) at Penn State University's Materials Research Institute (MRI). onsemi will fund SiC3 with \$800,000 per year over the next 10 years.

In addition to conducting SiC research at SiC3, Penn State and onsemi aim to raise awareness about the increasing demand for tech jobs in the semiconductor industry as part of their efforts to enhance the USA's share of global semiconductor manufacturing. They will also partner on workforce development initiatives such as internship and cooperative programs and include SiC and wide-bandgap crystal studies in Penn State's curriculum. The relationship with Penn State is part of onsemi's commitment to promoting STEAM (Science, Technology, Engineering, Arts and Mathematics) education, ranging from helping K-12 students in underserved communities to university collaborations that support the development of the workforce.

"onsemi is a proven innovator, delivering a comprehensive portfolio of intelligent power and sensing technologies to enable and accelerate sustainable solutions across multiple markets," comments Lora Weiss, Penn State senior VP of research.

"At the same time, as per the National Science Foundation's research expenditure rankings, Penn State is ranked first in materials science and second in materials engineering. We have world-class nanofab and characterization facilities that support research on thin films, silicon carbide and other materials used in semiconductors and other technologies. These complementary capabilities between onsemi and Penn State will have a strong impact



From left to right: Geanie Umberger, associate VP for research & director Office of Industrial Partnerships, Penn State; Sudhir Gopalswamy, senior VP & general manager, Advanced Solutions Group, onsemi; Nanofabrication Lab director Daniel Lopez, Liang Professor of Electrical Engineering & Computer Science, Penn State; Catherine Côté, VP & chief of staff to the CEO, onsemi; (front) Tracy Langkilde, dean of the Eberly College of Science, Penn State; (back) Penn State's executive VP & provost Justin Schwartz ; (back) onsemi's VP of university relations Scott Allen; (front) Zoubeida Ounaies, acting director, Materials Research Institute, Penn State; Joshua Robinson, professor, Materials Science and Engineering, Penn State; (front) Hrishikesh Das, senior director, Materials Group Leader, onsemi; (back) Penn State's acting dean of Engineering Anthony Atchley; (front) Penn's senior director of corporate & industry engagement Priya Baboo; (back) Penn State's interim associate VP for research Phil Savage; Penn State's interim senior director of development & alumni relations Tom Maatta.

on research and development, economic growth, and workforce development," she believes.

"Penn State is uniquely positioned to rapidly establish a silicon carbide crystal growth research program," comments Pavel Freundlich, chief technology officer of onsemi's Power Solutions Group. "The university offers a wide breadth of capability based on its current materials research, wafer processing capabilities in its nanofab facility, and a comprehensive, world-class suite of metrology instrumentation," he adds.

"Over the next decade, this collaboration will enable Penn State to become the nation's leading resource for semiconductor crystal science and workforce development," believes Justin Schwartz, Penn State executive VP & provost.

"This would not be possible without the relationship-building efforts of Priya Baboo, senior director of corporate and industry engagement, and the technical expertise of Joshua Robinson, professor of materials science and engineering, and their counterparts at onsemi," he adds.

"Penn State's expansion of its curriculum to offer specialty courses in SiC and wide-bandgap technology will play a key role in meeting onsemi's strategic workforce development goals and help to meet American semiconductor workforce goals as outlined in the recently signed CHIPS and Science Act," concludes Scott Allen, vice president, University Relations, at onsemi.

www.mri.psu.edu

www.onsemi.com

onsemi signs 10-year, \$1.9bn deal to supply SiC power devices for Vitesco's traction inverters and EV drives

Vitesco investing \$250m in onsemi's SiC production capacity expansion

Vitesco Technologies of Regensburg, Germany (which develops and manufactures drive technologies and electrification solutions for electro-mobility) and intelligent power and sensing technology firm onsemi of Scottsdale, AZ, USA have announced a 10-year long-term supply agreement worth \$1.9bn (€1.75bn) for silicon carbide (SiC) products to enable Vitesco's ramp in electrification technologies.

Specifically, Vitesco is providing an investment of \$250m (€230m) to onsemi for new equipment for SiC boule growth, wafer production and epitaxy to secure access to SiC capacity. The equipment will be used to produce SiC wafers to support Vitesco's growing SiC demand. In parallel, onsemi will continue to invest substantially into its end-to-end SiC supply chain.

Also, the two firms will collaborate on optimized customer solutions for Vitesco. onsemi's EliteSiC MOSFETs will be used by Vitesco to execute the recent orders as well as future projects for traction inverters and electric vehicle (EV) drives.

"Energy-efficient silicon carbide power semiconductors are at the beginning of a big surge in demand. That is why it is imperative for us to get access to the complete SiC value chain together with onsemi," says Vitesco's CEO Andreas Wolf. "With this investment we have a secure supply of a key technology over the next ten years and beyond," he adds.

"This collaboration will enable Vitesco Technologies to address their customers' demand for longer range and higher performance in electric vehicles," notes onsemi's

president & CEO Hassane El-Khoury. "onsemi provides superior performance and quality, supply assurance, and manufacturing at scale of SiC technologies based on decades of experience in manufacturing power semiconductor products in high-volume automotive applications."

Silicon carbide is a pivotal technology for electrification, enabling highly efficient power electronics leading to reduced charging times and longer range for electric cars. Especially at high voltage levels such as 800V, SiC inverters are more efficient than silicon models. Since 800V is the prerequisite for fast and thus convenient high-voltage charging, SiC devices are at the beginning of a worldwide boom, it is reckoned.

www.vitesco-technologies.com

www.onsemi.com

onsemi displays sustainable power solutions at PCIM

At the Power, Control and Intelligent Motion (PCIM) Europe 2023 event in Nuremberg, Germany in May, onsemi displayed its latest sustainable power-related innovations, focusing on three key areas with a total of five demo spaces, a showcase and a dedicated power wall:

- Enabling green energy solutions: An on-site power wall showed how households and small- to medium-sized enterprises can build an energy island with onsemi products, e.g. EV solutions (high-power DC and AC via on-board charging).
- Vertically integrated EliteSiC ecosystem: onsemi has full control of its silicon carbide manufacturing supply chain, from raw materials to delivery of the fully packaged SiC devices.
- Driving the industrial revolution: onsemi provides technologies for fully autonomous manufacturing environments, including intelligent sensing for robotics, scanning.

For automotive and industrial systems, the power wall showcased intelligent power solutions from 65W to 11kW and demonstrating its ability to provide full solutions for power supply applications. It also exhibited ultra-high-density (UHD) designs for the most critical, high-performance and space-constrained power designs.

Interactive demos included:

- AC EV charger: highlighting how EliteSiC technology can yield a highly efficient charging solution for use from the AC grid.
- 25kW DC charger eval-kit: showing how onsemi's intelligent power portfolio enables high efficiency with EliteSiC technology.
- Bidirectional EV charging: showing how an on-board charger (OBC) can return power to the grid, helping to stabilize the grid during times of peak demand.
- FS7 IGBT: Demonstration of highest-current IGBT (160A/1200V)

in a TO247 package.

onsemi also spoke about several key industry topics, including:

- 'EV-Traction Inverter Performance Optimization by Planar Technology and Packaging Improvements';
- 'The Sustainability of the EV-Traction SiC Revolution from a Technology, Manufacturing, Supply Chain and Cost Perspective';
- '1200V SiC Transfer Molded Power Modules for EV-Traction Application';
- 'Advanced SiC System Level Simulation through the New Online Elite Power Simulator and Self-Service PLECS Model Generator';
- Markt+Technik Panel Discussion 'SiC is sold out for 2023, can GaN help me?';
- Aspentec/Power Electronics Panel Discussion: 'Reliability and Quality Requirements for SiC and GaN Power Devices'.

www.mesago.de/en/PCIM/main.htm

onsemi 1200V EliteSiC M3S devices enhance efficiency of EV and energy infrastructure applications

New portfolio includes fast-switching MOSFETs and half-bridge power integrated modules with low $R_{ds(on)}$ per switch position in industry-standard packages

Power semiconductor IC supplier onsemi of Phoenix, AZ, USA has released the latest generation of 1200V EliteSiC silicon carbide (SiC) M3S devices. The new portfolio includes EliteSiC MOSFETs and modules that facilitate higher switching speeds to support the growing number of 800V electric vehicle (EV) on-board charger (OBC) and energy infrastructure applications, such as EV charging, solar and energy storage systems.

Also part of the portfolio are new EliteSiC M3S devices in half-bridge power integrated modules (PIMs) with low $R_{ds(on)}$ in a standard F2 package. Targeting industrial

applications, the modules are suitable for DC-AC, AC-DC and DC-DC high-power conversion stages.

They provide higher levels of integration with optimized direct bonded copper designs to enable balanced current sharing and thermal distribution between parallel switches. The PIMs are designed to deliver high power density in energy infrastructure, EV DC fast charging and uninterruptible power supplies (UPS).

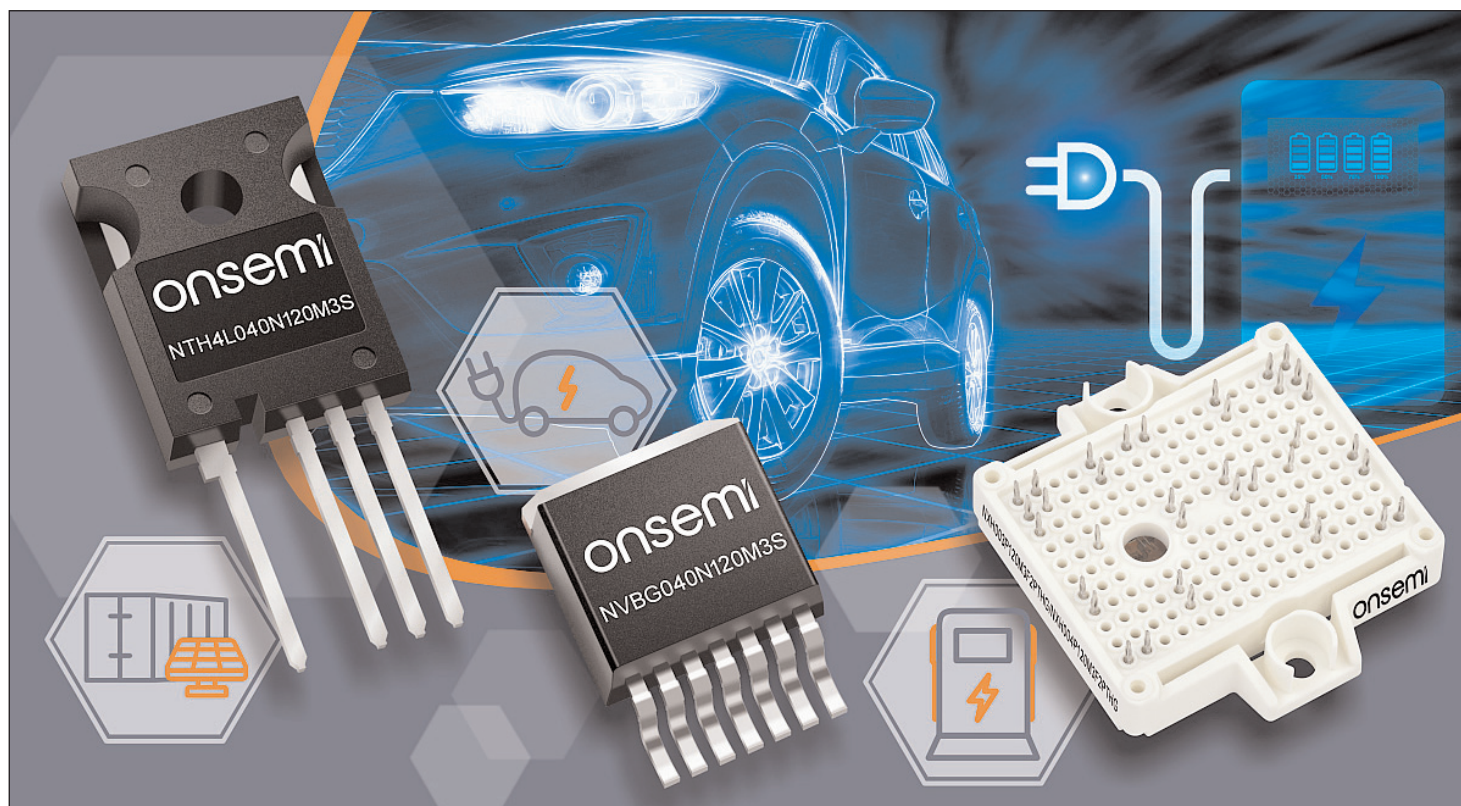
"onsemi's latest generation of automotive and industrial EliteSiC M3S products will allow designers to reduce their application footprint and system cooling requirements,"

says Asif Jakwani, senior VP & general manager of onsemi's Advanced Power Division.

"This helps designers to develop high-power converters with higher levels of efficiency and increased power densities."

The automotive-qualified 1200V EliteSiC MOSFETs are tailored for high-power OBCs up to 22kW and high-voltage to low-voltage DC-DC converters. M3S technology has been developed specifically for high-speed switching applications and has what are claimed to be the best-in-class figure of merits for switching losses.

www.onsemi.com



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onsemi and Kempower enter strategic agreement for EV chargers

EliteSiC MOSFET and diode technologies to be used in scalable electric vehicle fast-chargers

As part of a new strategic agreement, onsemi is to provide its EliteSiC MOSFETs and diodes for scalable electric vehicle (EV) chargers made by Finland-based Kempower. The ongoing collaboration between the two firms enables Kempower's suite of EV charging solutions with a variety of power semiconductor technologies, including onsemi's EliteSiC. These devices will be used in the active AC-DC front-end and in the primary and secondary DC-DC converters.

By incorporating onsemi's EliteSiC MOSFET technology, Kempower's EV charging solutions will benefit in terms of power, performance and reliability. With low ON-resistance and minimal gate and output capacitance, EliteSiC power devices are said to exhibit lower power

losses at high operating frequencies, leading to increased system efficiency and reduced end-system size. These advantages translate into higher power density and greater overall reliability for Kempower's EV charging solutions.

"onsemi EliteSiC power devices improve the efficiency and lower the size and weight of our EV charging solutions," comments Kempower's chief engineer Petri Korhonen. "In addition, onsemi's vertically integrated supply chain and broad portfolio of intelligent power solutions give us the stability needed to continue delivering world-class EV charging solutions to the market."

Under the strategic agreement, Kempower will incorporate the latest EliteSiC D3 diode and M3S

MOSFETs into its EV charging solutions. These chargers allow for dynamic load balancing, ensuring maximum power distribution. Kempower charging solutions are cloud-connected and scalable, giving the modularity that allows fleet and charging point operators to scale their systems in line with demand.

"Our strength in manufacturing and resilient SiC supply chain assure Kempower that we will deliver high-quality products in the agreed-upon volumes today and in the future," says Asif Jakwani, senior VP & general manager of onsemi's Advanced Power Division. "Incorporating highly reliable power devices leads to the dependable and durable EVCs that Kempower and its customers expect every time."

www.kempower.com

Sineng using onsemi's EliteSiC MOSFETs and IGBT-based power integrated modules

Utility-scale solar inverter and energy storage system to be developed

onsemi says that its EliteSiC MOSFETs and IGBT-based high-density power integrated modules (PIMs) will be integrated into the utility-scale solar inverter and industry-first 200kW energy storage system (ESS) of China-based Sineng Electric. The firms worked together to develop optimized solutions that maximize the performance of solar inverters, energy storage and power conversion systems.

Sineng's work with onsemi EliteSiC has led to the launch of a utility-scale solar string inverter, which is said to offer simplicity in design, reduced maintenance costs and lower downtime compared with a centralized inverter solution. The adoption of onsemi's highly optimized single-stage PIM

with multi-level topology in 200KW ESS enables what is claimed to be industry-leading system efficiency and lower total cost of ownership.

"onsemi supports us in solving the most challenging technical problems such as system-level design, simulations, thermal analysis and creation of sophisticated control algorithms," says Sineng Electric's chairman Qiang Wu. "Integrating the highly efficient EliteSiC technology enables us to develop and implement cutting-edge renewable energy solutions tailored to our customers' needs. In combination with onsemi's end-to-end SiC supply chain, we have the supply assurance to plan for long-term growth."

Both firms will continue to collaborate on the development of new

high-power products to enable a broader range of renewable energy solutions. As part of this, Sineng will adopt more EliteSiC products, benefitting from efficiency and scale.

"Together, we will leverage the benefits of onsemi's high-performance products and Sineng Electric's expertise in power electronics system design to deliver industry-leading solutions for sustainable energy applications," says Asif Jakwani, senior VP & general manager of onsemi's Advanced Power Division.

The two firms expect to extend their existing long-term supply agreement (LTSA), signed in late 2022, further demonstrating their commitment to collaboration and innovation.

<https://en.si-neng.com>

Coherent and Mitsubishi Electric collaborating to scale manufacturing of SiC power electronics

Coherent to develop 200mm n-type 4H-SiC substrates for new Mitsubishi Electric power devices fab

Materials, networking and laser technology firm Coherent Corp of Saxonburg, PA, USA (formerly II-VI Inc before it acquired Coherent in July 2022) and Tokyo-based Mitsubishi Electric Corp have signed a memorandum of understanding (MOU) to collaborate on a program to scale manufacturing of silicon carbide (SiC) power electronics on a 200mm technology platform.

The market for electric vehicles is expanding worldwide and is just one of several emerging applications driving exponential growth in SiC power devices, which have lower energy losses, higher operating temperatures and higher switching speeds than silicon power devices.

To meet the rapidly growing demand, in March Mitsubishi Electric announced an investment of about ¥260bn in the five-year period to March 2026. Of this, about ¥100bn will be used to construct a new

plant for SiC power devices, based on a 200mm-diameter wafer technology platform, and to enhance related production facilities. Under the MOU, Coherent will develop a supply of 200mm n-type 4H-SiC substrates for Mitsubishi Electric's future SiC power devices manufactured at the new facility.

"We have a long track record of supplying SiC substrates to Mitsubishi Electric and are looking forward to expanding our relationship with them to scale their new 200mm SiC platform," says Sohail Khan, executive VP, New Ventures & Wide-Bandgap Electronics Technologies at Coherent.

"Coherent has been for many years a reliable supplier of high-quality 150mm SiC wafer substrates to Mitsubishi Electric," comments Masayoshi Takemi, executive officer, group president Semiconductor & Device, at Mitsubishi Electric. "We

are delighted to enter into this close partnership with Coherent to scale our respective SiC manufacturing platforms to 200mm."

Coherent says that (as II-VI Inc) it demonstrated what was claimed to be the first 200mm conductive SiC substrates in 2015. In 2019, the firm began to supply 200mm SiC substrates under REACTION, a Horizon 2020 four-year program funded by the European Commission.

Over the years, Mitsubishi Electric has supplied SiC power modules for high-speed trains, high-voltage industrial applications, and home appliances. The firm launched the first SiC power modules for air conditioners in 2010, and became the first supplier of a full-SiC power module for Shinkansen high-speed trains in 2015.

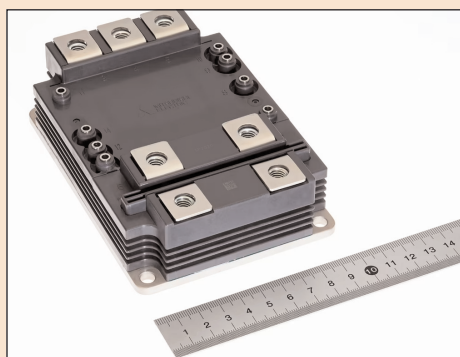
www.MitsubishiElectric.com/semiconductors
www.coherent.com

Mitsubishi Electric to ship samples of 3.3kV SBD-embedded SiC MOSFET module

Switching loss cut by 66% versus existing SiC power module

After already releasing four full-SiC modules and two 3.3kV high-voltage dual-type LV100 modules, Tokyo-based Mitsubishi Electric Corp has begun shipping samples of a new Schottky barrier diode (SBD)-embedded silicon carbide MOSFET module, featuring dual-type 3.3kV withstand voltage and 6.0kV_{rms} isolation voltage (dielectric strength).

The 100mm x 140mm x 40mm module FMF800DC-66BEW is expected to support superior power output, efficiency and reliability in inverter systems for large industrial equipment such as railways and electric power systems.



The SBD-embedded SiC-MOSFET and optimized package structure are said to reduce switching loss by 91% compared with the firm's existing silicon power module and by 66% compared with the existing SiC power module, reducing

inverter power loss and contributing to higher output and efficiency.

The SBD-embedded SiC-MOSFET and optimized current capacity are said to improve inverter reliability.

The optimized terminal layout enables parallel connection and supports various inverter configurations and capacities depending on the number of parallel connections. Also, a package structure with DC and AC main terminals in opposite poles helps to simplify circuit design.

The new module FMF800DC-66BEW was exhibited at the Power, Control and Intelligent Motion (PCIM) Europe 2023 event in Nuremberg, Germany (9–11 May).

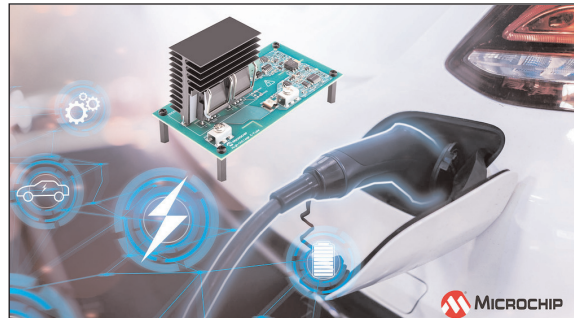
Microchip unveils SiC-based E-Fuse demonstrator for 400–800V battery systems

Faster, more reliable method for protecting power electronics in electric vehicle applications

High-voltage electrical subsystems throughout battery electric vehicles (BEVs) and hybrid electric vehicles (HEVs) require a mechanism to protect the high-voltage distribution and loads in the event of an overload condition. To provide BEV and HEV designers with a faster and more reliable high-voltage circuit protection solution, Microchip Technology Inc of Chandler, AZ, USA has announced the E-Fuse Demonstrator Board, enabled by silicon carbide (SiC) technology, available in six variants for 400–800V battery systems and with a current rating up to 30A.

The E-Fuse demonstrator can detect and interrupt fault currents in microseconds, 100–500 times faster than traditional mechanical approaches because of its high-voltage solid-state design. The fast response time substantially reduces peak short-circuit currents from tens of kilo-amps to hundreds of amps, which can prevent a fault event from resulting in a hard failure.

“The E-Fuse demonstrator provides BEV/HEV OEM designers with a SiC-based technology solution to jumpstart their development



process with a faster, more reliable method for protecting power electronics,” says Clayton Pillion, VP of Microchip’s silicon carbide business unit. “The E-Fuse solid-state design also alleviates long-term reliability concerns about electro-mechanical devices because there is no degradation from mechanical shock, arcing or contact bounce.”

With the E-Fuse demonstrator’s re-settable feature, designers can package an E-Fuse in the vehicle without the burden of design-for-serviceability constraints. This reduces design complexities and enables flexible vehicle packaging to improve BEV/HEV power system distribution.

OEMs can accelerate development of SiC-based auxiliary applications with the E-Fuse demonstrator

because of the built in Local Interconnect Network (LIN) communication interface. The LIN interface enables the configuration of the over-current trip characteristics without the need to modify hardware components, and it also reports diagnostic status.

The E-Fuse demonstrator leverages the ruggedness and performance of Microchip’s SiC MOSFET technology and PIC microcontrollers’ Core Independent Peripherals (CIPs) with a LIN-based interface. The companion components are automotive-qualified and yield a lower part count and higher reliability over a discrete design.

The E-Fuse Demonstrator Board is supported by MPLAB X Integrated Development Environment (IDE) to enable customers to quickly develop or debug software. The LIN Serial Analyzer development tool allows customers to send and receive serial messages from a PC to the E-Fuse Demonstrator Board.

The E-Fuse Demonstrator Board is available in limited sampling upon request.

www.microchip.com

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China's SICC and TanKeBlue to supply silicon carbide wafers and boules to Infineon

Infineon diversifying its silicon carbide supplier base; 150mm wafers in first phase, followed by 200mm

To diversify its silicon carbide (SiC) material supplier base and to secure additional SiC sources, Infineon Technologies AG of Munich, Germany has signed two separate agreements for China's SICC Co Ltd and TanKeBlue Semiconductor Co Ltd to supply 150mm SiC wafers and boules, each covering a double-digit share of expected long-term demand.

The deals focus on 150mm SiC material supply in the first phase, but both SICC and TanKeBlue will then also provide 200mm SiC for Infineon's transition to 200mm wafer diameter. It is reckoned that the deals will contribute to general supply chain stability, particularly regarding the growing demand for SiC devices for automotive, solar and electric vehicle (EV) charging applications as well as energy storage systems in the Chinese market. The deals will also generally support the rapid growth in the SiC industry.

"Infineon is significantly expanding its manufacturing capacities at its production sites in Malaysia and Austria to meet the growing demand for SiC," says Infineon's chief procurement officer Angelique van der Burg. "To offer the most comprehensive product range possible to our customers, Infineon is currently doubling down on its investments in SiC technology and product portfolio. In this context, we are implementing a multi-supplier and multi-country sourcing strategy to increase resilience to the benefit of our broad customer base, and are securing new competitive top-quality sources globally, matching the highest standards in the market."

"SiCC's substrates are widely used in the power SiC field. We are pleased to team up with Infineon as our customer, a global leader in power semiconductors," says SiCC's CEO Zong Yanmin. "SiCC will continuously

expand capacity to add more value for its global customers," he adds.

"We welcome the opportunity to team up with our customer Infineon, a global leader in power semiconductors," comments TanKeBlue's CEO Yang Jian. "TanKeBlue plans to continuously improve its SiC material and develop its next generation of 200mm wafer technology," he adds.

Infineon is currently expanding its SiC manufacturing capacity to achieve its target of a 30% global market share by the end of the decade. Its SiC manufacturing capacity will rise tenfold by 2027. A new plant in Kulim, Malaysia is due to start production in 2024, adding to existing manufacturing capacities in Villach, Austria. Infineon already provides SiC devices to more than 3600 automotive and industrial customers worldwide.

www.sicc.cc/en

www.tankeblue.com

Infineon introduces HybridPACK Drive G2 automotive power module for EV traction inverters

Infineon has launched the HybridPACK Drive G2 automotive power module, which builds on the HybridPACK Drive G1 concept of an integrated B6 package, offering scalability in the same footprint and extending it to higher power and ease-of-use. The G2 will be available with various current ratings, voltage levels (750V and 1200V) and Infineon's next-generation chip technologies EDT3 (silicon IGBT) and CoolSiC G2 MOSFET.

With a power range of up to 300kW within the 750V and 1200V classes, the G2 is said to provide high ease-of-use and new features, such as an integration option for a next-generation phase current sensor and on-chip temperature

sensing, which enable system cost improvements. The power module achieves higher performance and power density through improved assembly and interconnect technology. The adoption of new interconnect technology (chip sintering) and of new materials (new black plastic housing) enables a higher temperature rating, resulting in higher performance and longer product life.

The G1 first generation was introduced in 2017, using silicon EDT2 technology. It offers a power range of 100–180kW in the 750V class. In 2021, Infineon expanded its product family with the first generation of HybridPACK Drive Automotive CoolSiC MOSFETs, which

allowed the inverter design to achieve higher power up to 250kW within the 1200V class, longer driving range, smaller battery size and optimized system size and cost. With a track record of nearly 3 million units sold in various global electric vehicle platforms, the HybridPACK Drive is now Infineon's market-leading power module.

The lead products (FS1150R08, FS01MR08, FS02MR12) of the new HybridPACK Drive G2 are in production and will be available from May, with additional product variants to follow in 2023 and 2024. Evalkits and design-in support are available to enable fast and easy evaluation for customers.

www.infineon.com/hybridpackdrive

Infineon and Foxconn partner on silicon carbide for EVs

Technology to be implemented in automotive high-power applications

Infineon Technologies AG and Taiwan's Hon Hai Technology Group (Foxconn), the world's largest electronics manufacturing services (EMS) provider, aim to establish a long-term partnership in the field of electric vehicles to jointly develop advanced electro-mobility with efficient and intelligent features. The Memorandum of Understanding (MoU) focuses on silicon carbide development, leveraging Infineon's automotive SiC innovations and Foxconn's expertise in automotive systems.

"With the rapid growth of the EV market and the associated need for more range and performance, the development of electro-mobility must continue to advance and innovate," says Peter Schiefer, president of the Infineon Automotive Division.

"This collaboration will result in optimized architecture, product performance, cost competitiveness and high system integration to provide customers with the most competitive automotive solutions," believes Jun Seki, Foxconn's chief



Infineon Automotive Division president Peter Schiefer (left) and Jun Seki, Foxconn's chief strategy officer for EVs (right).

strategy officer for EVs.

According to the MoU, the firms will collaborate on the implementation of SiC technology in automotive high-power applications like traction inverters, onboard chargers, and DC-DC converters. Both parties intend to jointly develop EV solutions with outstanding performance and efficiency based on Infineon's automotive system understanding,

technical support and SiC product offerings combined with Foxconn's electronics design and manufacturing expertise and the capability of system-level integration.

In addition, the two companies plan to establish a system application center in Taiwan to further expand the scope of their cooperation. This center will focus on optimizing vehicle applications, including smart cabin applications, advanced driver assistance systems (ADAS) and autonomous driving applications. It will also address electro-mobility applications such as battery management systems and traction inverters. The collaboration spans a wide range of Infineon's automotive products, including sensors, microcontrollers, power semiconductors, high-performance memories for specific applications, human-machine interface and security solutions. The system application center is expected to be established within 2023.

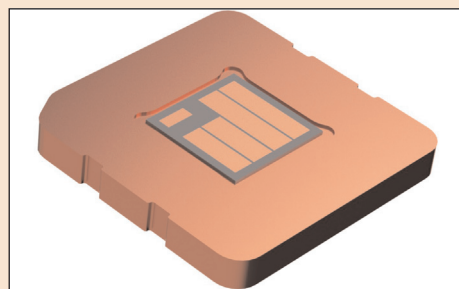
www.foxconn.com

www.infineon.com

Infineon and Schweizer extend cooperation in chip embedding for more efficient SiC automotive solutions

Infineon and Schweizer Electronic AG of Schramberg, Germany are collaborating on ways to further increase the efficiency of chips based on silicon carbide (SiC) by developing a solution to embed Infineon's 1200V CoolSiC chips directly onto printed circuit boards (PCB), which will increase the range of electric vehicles and reduce the total system costs.

The two firms have already demonstrated the potential of this new approach by embedding a 48V MOSFET in the PCB. This resulted in a 35% increase in performance. Schweizer contributes to this with its p²Pack solution, which enables power semiconductors to be embedded in PCBs.



"Our joint goal is to take automotive power electronics to the next level," says Robert Hermann, product line head Automotive High-Voltage Discretes and Chips, at Infineon. "The low-inductive environment of a PCB allows clean and fast switching. Combined with the leading performance of 1200V CoolSiC devices, chip embedding enables highly integrated and

efficient inverters that reduce overall system costs," he adds.

"With Infineon's 100% electrically tested standard cells (S-Cell), we can achieve high overall yields in the p²Pack manufacturing process," comments Thomas Gottwald, VP technology at Schweizer. "The fast-switching characteristics of the CoolSiC chips are optimally supported by the low-inductance interconnection that can be achieved with the p²Pack. This leads to increased efficiency and improved reliability of power conversion units such as traction inverters, DC-DC converters, or on-board chargers."

www.schweizer.ag

www.mesago.de/en/PCIM/main.htm

Infineon adds CoolSiC power modules using 3.3kV MOSFETs in XHP 2 package, targeting traction applications

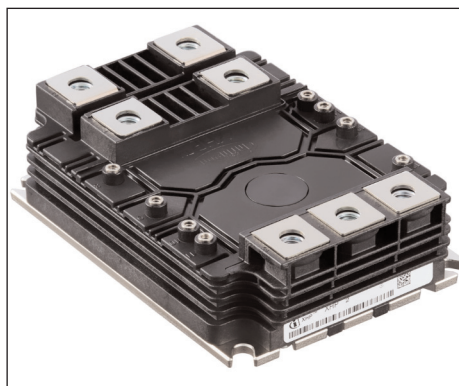
High-power modules offer drain–source on-state resistances of 2.0mΩ and 2.6mΩ

To meet global climate targets, transportation must shift to more environmentally friendly vehicles such as energy-efficient electrified trains. However, trains have demanding operating profiles with frequent acceleration and braking, while being expected to operate reliably over a long service life. Consequently, energy-efficient traction applications with high-power density, reliability and quality are required for implementation.

Infineon Technologies AG of Munich, Germany says that it is addressing these requirements by adding two new products to its CoolSiC power module portfolio.

The FF2000UXTR33T2M1 and FF2600UXTR33T2M1 power modules use newly developed 3.3kV CoolSiC MOSFETs and Infineon's .XT interconnection technology. The modules come in XHP 2 package and have been specifically tailored for traction applications.

Designed for demanding applications such as traction, the devices were presented at the Power, Control and Intelligent Motion (PCIM) Europe 2023 trade show in Nuremberg, Germany (9–11 May). "For environmentally friendly mobility, rail technology requires innovative semiconductor solutions designed specifically for these applications," says Dr Peter Wawer, division president of Infineon's Green Industrial Power Division.



Infineon's CoolSiC XHP 2 3.3kV high-power module.

"With low switching losses and the ability to enable higher switching frequencies, Infineon's new silicon carbide products contribute to greener and quieter trains, which are extremely important features for tomorrow's train traffic."

In addition to an efficient and robust silicon carbide (SiC) chip, power modules for traction drives require packaging that allow fast switching, along with interconnection technologies that enable a long service life time. Infineon says that its new power modules offer such features: the CoolSiC MOSFET chips with integrated body diodes in Infineon's XHP 2 packaging enable low switching losses while maintaining high reliability and power density.

The XHP 2 packaging also features low stray inductance, a symmetrical and scalable design, and high

current-carrying capability.

The FF2000UXTR33T2M1 module offers a drain–source on-state resistance of 2.0mΩ, while the FF2600UXTR33T2M1 features a drain–source on-state resistance of 2.6mΩ. Despite the demanding operating profiles of trains, Infineon's .XT interconnect technology improves power cycling capabilities.

Compared with conventional solutions, CoolSiC power modules enable overall energy consumption in the motor and converter of the train to be reduced by 10%, Infineon reckons. Additionally, train operators benefit from a more compact, lighter converter, along with a simplified cooling systems. While this is paying into the decarbonization efforts of Infineon, traction manufacturers and railway service operators, citizens also benefit from lower noise levels when trains go through a neighbourhood, says the firm. A SiC-based XHP 2 power module has been proven in a joint field test with streetcars conducted by Siemens Mobility and Stadtwerke München (SWM) in 2022. The test has shown that power semiconductors based on SiC significantly reduce engine noise during operation.

The CoolSiC XHP 2 3.3kV high-power modules are available as samples for selected customers.

www.mesago.de/en/PCIM/main.htm
www.infineon.com/coolSiC

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Infineon launches CoolGaN 600V GIT HEMT portfolio

Discrete and integrated power stage devices provides design flexibility

Infineon Technologies AG of Munich, Germany says that it has integrated the CoolGaN 600V hybrid-drain-embedded gate injection transistor (HD-GIT) technology into its in-house manufacturing. The firm is now releasing the complete portfolio of its GaN devices to the broader market.

Infineon says that, taking advantage of its fully owned and controlled supply chain, the expanded GaN portfolio includes a wide range of discrete and fully integrated GaN devices that far exceed JEDEC lifetime requirements. The new CoolGaN devices have been optimized for applications ranging from industrial switched-mode power supplies (SMPS) for servers, telecom and solar to consumer applications, such as chargers and adapters, motor drives, TV/monitor, and LED lighting systems.

The portfolio of CoolGaN discrete and integrated power stage (IPS) devices provides designers with the necessary flexibility to meet their specific needs for industrial applications complying with JEDEC standards (JESD47 and JESD22), says Infineon. The discrete CoolGaN GIT high-electron-mobility transistor (HEMT) devices are available in

DSO-20-85, DSO-20-87, HSOF-8-3, LSON-81- and TSON-8 packages and in multiple on-state resistance ($R_{DS(on),max}$) values ranging from 42m Ω to 340m Ω . The IPS solutions come in the form of half-bridge and single-channel devices. Half-bridge solutions integrate two GaN switches and are housed in a TIQFN-28 package with $R_{DS(on),max}$ values of (2x) 190–650m Ω . Single-channel solutions are available in a thermally enhanced TIQFN-21 package with $R_{DS(on),max}$ values in the range 130–340m Ω .

Infineon says that its CoolGaN GIT technology features a unique combination of a robust gate structure, internal electrostatic discharge (ESD) protection, and excellent dynamic $R_{DS(on)}$ performance. It fully exploits the intrinsic properties of GaN to deliver what is said to be exceptional figures of merit (FoM) compared with silicon technology, such as ten times higher breakdown field, two times higher electron mobility, ten times lower output charge, zero reverse recovery charge, and ten times lower gate charge with linear output capacitance (C_{OSS}).

These technical features are said to provide significant design advan-

tages such as very low $R_{DS(on)}$, improved efficiency in resonant circuits, the use of new topologies and current modulation, as well as fast and nearly lossless switching.

Infineon's range of CoolGaN 600V GIT discrete devices includes both top- and bottom-side cooled (TSC/BSC) JEDEC-compliant packages. CoolGaN TSC power packages are claimed to be unique in the market and address higher-power requirements. The benefits for designers ultimately lead to compact and lightweight products with high power density, improved energy efficiency, and reduced total system costs. Infineon claims that its commitment to quality standards ensures unmatched robustness and long-term reliability, lowering operating and maintenance costs for high-energy-consumption applications.

The CoolGaN devices are in volume production, and samples can be ordered now. The CoolGaN 600V GIT HEMT portfolio was showcased at the Power, Control and Intelligent Motion (PCIM) Europe 2023 event in Nuremberg, Germany (9–11 May).

www.mesago.de/en/PCIM/main.htm
www.infineon.com/coolgan

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Navitas doubles first-quarter revenue year-on-year, boosted by acquisitions

Strong growth in all target markets, with 50% backlog growth

For first-quarter 2023, gallium nitride (GaN) power IC and silicon carbide (SiC) technology firm Navitas Semiconductor of Torrance, CA, USA has reported revenue of \$13.46m, up 8% on \$12.3m last quarter and almost doubling from \$6.74m a year ago. This takes into account revenue from silicon carbide power semiconductor device designer and manufacturer GeneSiC Semiconductor Inc of Dulles, VA, USA (which was acquired in mid-August 2022).

"I am very pleased with our progress in the quarter across acquisitions, product launches, customer developments and market expansion," says CEO & co-founder Gene Sheridan. "A comprehensive portfolio of leading-edge GaN, SiC, digital isolators and low-voltage silicon system-control ICs is translating into significant customer value, market adoption and financial results."

Product highlights are as follows:

- **New GaNSense Control:** strategic integration of high-speed, high-voltage GaN and low-voltage silicon system-controller chips enables easy-to-use, high-efficiency, fast-charging power systems.

- **New GeneSiC SiCPak:** Navitas' entry into the high-power module and bare-die sales market, with a broad portfolio from 650V to 6500V for EV, solar, wind, rail and industrial markets.

- **New GeneSiC Gen-5 650V MPS diodes:**

industry-leading performance figure-of-merit for data center, home appliance and industrial motor drive.

On a non-GAAP basis, gross margin has risen from 40.6% last quarter to 41.1% in Q1/2023, although this is down on 44% a year ago.

Operating expenses have grown further, from \$12.5m a year ago and \$17m last quarter to \$17.8m.

Net loss has risen further, from \$9.65m last quarter to \$10.9m. During the quarter, cash and cash equivalents have hence fallen from \$110.3m to \$100.8m.

Navitas cites a customer pipeline of \$760m. Specific market highlights in Q1/2023 are listed as:

- **EV/e-mobility:**

25 on-board and roadside customer projects now in production or development, with a total customer pipeline value of over \$300m, including a Geely on-board charger (OBC) design estimated at \$15–20m in 2024.

- **Solar/ESS (energy storage systems):** over 35 customer projects in production or development, with revenue increasing and customer pipeline over \$150m.

- **Appliance/industrial:**

over 45 customer projects in production or development, with a customer pipeline of over \$150m,

fuelled by strong government funding and legislation in the USA, Europe and other regions driving clean-energy upgrades to homes and factories.

- **Data-center/enterprise:**

15 customer projects, starting to ramp in late 2023 and into 2024, with an overall customer pipeline worth over \$60m, accelerated by demand from artificial intelligence (AI), IoT and data in general.

- **Mobile/consumer:**

strong bookings going into Q2/2023, plus 20 new fast and ultra-fast mobile chargers launched in Q1/2023, including the latest Xiaomi 13 Pro and Ultra flagship phones (in-box) and Lenovo's 65W Thinkbook ultra-thin 'biscuit' laptop charger (just 12.8mm thick). Over 150 projects are in development, with a customer pipeline of \$100m.

Navitas expects revenue to grow to \$16–17m in second-quarter 2023 and to double for full-year 2023. Gross margin should rise by 25–50 basis points in Q2, and grow incrementally throughout the year, exiting 2023 in the mid-40s percent range. Operating expenses are expected to rise to about \$19m in Q2 then grow in the mid-high single digits on a quarterly basis throughout the year, albeit declining as a percentage of revenue as the business scales.

www.navitas.com

Vishay showcases power management solutions at PCIM 600V and 1200V planar SiC MOSFET technology on show

At the Power, Control and Intelligent Motion (PCIM) Europe 2023 event in Nuremberg, Germany (9–11 May), discrete semiconductor and passive electronic component maker Vishay Intertechnology Inc of Malvern, PA, USA showcased its portfolio of power management solutions addressing two increasingly important trends in

power electronics: electro-mobility and energy storage.

Vishay experts were available to discuss its range of passive and semiconductor solutions for these next-generation applications, including the development of 600V and 1200V planar silicon carbide (SiC) MOSFET technology; power inductors that enable high

efficiency in gallium nitride (GaN) DC/DC converters; and integrated power module solutions that combine high-efficiency fast body diode MOSFETs and SiC, FRED Pt, and MOAT diode technologies to enable higher power density than discrete solutions.

www.mesago.de/en/PCIM/main.htm
www.vishay.com

Navitas' follow-on public offering raises \$92m

Gallium nitride (GaN) power IC and silicon carbide (SiC) technology firm Navitas Semiconductor of Torrance, CA, USA says that its underwritten follow-on public offering of 10 million shares of Class A common stock (announced on 23 May) at \$8 per share has raised proceeds of \$80m.

Also, the underwriters have fully exercised their option to purchase an extra 1.5 million shares at the public offering price, raising an extra \$12m.

Total gross proceeds (before deducting underwriting discounts and commissions and offering

expenses) have hence risen to \$92m.

Navitas is to use the net proceeds for working capital and other general corporate purposes, including potential acquisitions or strategic manufacturing investments.

www.navitassemi.com

Navitas invests \$20m in three Aixtron G10-SiC reactors

Navitas has announced the first in a series of strategic manufacturing investments, in order to increase control, reduce costs and enhance revenue capacity for its GeneSiC silicon carbide power semiconductors.

An initial \$20m investment enables a three-reactor SiC epi-growth facility. The first G10-SiC epitaxy reactor from Germany's Aixtron, with 6" and 8" wafer capability, is expected to be fully qualified and in production in 2024. Navitas views the epi-growth services to be provided by its new facility as a critical process step that could support up to an additional \$200m in annual production. The firm expects to continue the use of third-party vendors for additional epi-growth, wafer fabrication and assembly operations.

"We are proud that an important technology innovator such as Navitas chose our new G10-SiC to further accelerate the adoption of SiC in the growing market for energy-efficient power devices," says Aixtron's CEO & president Dr Felix Grawert. "This is especially significant as Aixtron and Navitas are both firm believers and pioneers in the unstoppable advance of GaN and SiC over legacy silicon," he adds.

"Adding a high-quality SiC epilayer onto a raw SiC wafer is a critical process step prior to individual device manufacturing, and adding the Aixtron in-house epi capability to existing subcontract process flows expands available capacity, lowers finished wafer cost, increases quality and reduces cycle times," says Dan Kinzer,

Navitas' chief operating officer/ chief technology officer (COO/CTO) & co-founder. "The development and manufacturing business partnership with Aixtron includes ongoing technical and co-development support."

Navitas' investment in internal epi capacity is one of several initiatives in support of its recently announced \$760m customer pipeline of estimated potential future business, based on expressed customer interest for qualified programs. While the conversion of this pipeline into orders or shipments depends on many factors in addition to possessing available capacity, the firm expects that its epi capacity expansion will provide a favorable return on investment under most anticipated planning scenarios.

www.aixtron.com

Navitas being added to Russell 3000 Index

Navitas is to be added as a member of the broad-market Russell 3000 Index (effective after the US market opens on 26 June) as part of the 2023 Russell indexes reconstitution.

Annual reconstitution of the Russell indexes captures the largest US stocks as of 28 April, ranking them by total market capitalization. Membership of the Russell 3000, which remains in place for one year, means automatic inclusion in the large-cap Russell 1000 Index or small-cap Russell 2000 Index, plus the appropriate growth and value style indexes. FTSE Russell determines membership for its indexes mainly by objective, market-capitalization rankings and style attributes.

Founded in 2014, Navitas introduced the first commercial GaN power integrated circuits. Entering mass production in 2018, its proprietary GaNFast power ICs integrate GaN power and drive with control, sensing and protection circuits to enable faster charging, and greater power density and energy savings. Complementary GeneSiC power devices are optimized high-power, high-voltage and high-reliability silicon carbide solutions. Focus markets include mobile, consumer, data center, electric vehicle (EV), solar, wind, smart grid and industrial. Over 185 patents are issued/pending. Over 75 million GaN and 10 million SiC units have been shipped, and

Navitas introduced the industry's only 20-year GaN IC warranty. It was also the first semiconductor firm to be CarbonNeutral-certified.

"Inclusion in the Russell 3000 Index is an internationally recognized growth milestone, highlighting Navitas' leadership in next-generation power semiconductors," claims CEO & co-founder Gene Sheridan. "New GaN and SiC power technologies are rapidly replacing legacy silicon power chips, to bring more efficient, faster-charging, smaller, lighter and lower CO₂-footprint electronics to market, from EVs and data centers to solar, wind and industrial applications."

www.ftserussell.com

Navitas enters high-power markets with GeneSiC SiCPAK modules and bare die

Gallium nitride (GaN) power IC and silicon carbide (SiC) technology firm Navitas Semiconductor of Torrance, CA, USA has expanded its portfolio into higher-power markets with its silicon carbide power products in SiCPAK modules and bare die.

Target applications span centralized and string solar inverters, energy storage systems (ESS), industrial motion, electric vehicle (EV) on-board chargers, EV road-side fast chargers, wind energy, uninterruptible power system (UPS), bi-directional micro-grids, DC-DC converters, and solid-state circuit breakers.

Ranging from 650V to 6500V, Navitas claims to have the widest range of SiC technology. From an original line-up of discrete packages — from 8mm x 8mm surface-mount QFNs to through-hole TO-247s — the GeneSiC SiCPAK is an initial, direct entry point into higher-power applications. A comprehensive

power module roadmap — with high-voltage SiC MOSFETs and MPS diodes, GaN power ICs, high-speed digital isolators and low-voltage silicon control ICs — is planned.

"With a complete portfolio of leading-edge power, control and isolation technology, Navitas will enable customers to accelerate the transition from fossil fuels, and legacy silicon power products to new, renewable energy sources and next-generation semiconductors, with more powerful, more efficient, faster-charging systems," says Dr Ranbir Singh, executive VP for SiC.

SiCPAK modules use 'press-fit' technology to offer compact form factors for power circuits and deliver cost-effective, power-dense solutions to end users. The modules are built on GeneSiC die. Examples include a SiCPAK half-bridge module, rated at 6mΩ, 1200V, with trench-assisted planar-gate SiC MOSFET technology. Multiple configurations of SiC MOSFETs

and MPS diodes will be available to create application-specific modules. The initial release will include 1200V-rated half-bridge modules in 6mΩ, 12mΩ, 20mΩ and 30mΩ ratings.

Within the lead-free SiCPAK, each SiC chip is silver (Ag) sintered to the module's substrate for superior cooling and reliability. The substrate itself is 'direct-bonded copper' (DBC) and manufactured using an active-metal brazing (AMB) technique on silicon nitride (Si₃N₄) ceramics, suitable for power-cycling applications. This construction delivers what is claimed to be excellent strength and flexibility, fracture resistance, and good thermal conductivity for cool, reliable, long-life operation.

For customers who prefer to make their own high-power modules, all GeneSiC MOSFET and MPS diodes are available in bare die format, with gold (Au) and aluminium (Al) top-side metalizations. Parts are available now to qualified customers.

Navitas' GeneSiC MOSFETs adopted for Exide's industrial high-frequency chargers

Navitas' GeneSiC power semiconductors have been adopted by France-based Exide Technologies in order to ensure reliability, safety, ease-of-use and optimal charging in its high-frequency fast chargers for industrial material handling equipment.

As a provider of sustainable battery storage solutions for the industrial and automotive markets, Exide's range of lead-acid and lithium-ion solutions serve applications including traction batteries and charging solutions for material handling equipment and robotics, maximizing fleet uptime with minimized total cost of ownership.

As a wide-bandgap power semiconductor material, silicon carbide is rapidly replacing silicon chips in high-power, high-voltage applications such as renewable energy,

energy storage and micro-grids, electric vehicles (EVs) and industrial applications. GeneSiC 'trench-assisted planar-gate' SiC MOSFET technology delivers high-efficiency, high-speed performance, resulting in up to 25°C lower case temperature, and up to three times longer life than alternative SiC products, Navitas claims. With the highest-published 100%-tested avalanche capability, 30% longer short-circuit withstand time, and stable threshold voltage for easy paralleling, GeneSiC MOSFETs are suitable for high-power, fast-time-to-market applications, the firm adds.

Exide's high-frequency chargers convert 220V AC power to a battery-level voltage between 24V and 80V for lead-acid- and lithium-ion-powered industrial vehicles.

The 7kW module uses GeneSiC G3R60MT07D (750V) MOSFETs and GD10MPS12A (1200V) MPS Schottky diodes, with a frequency-optimized architecture. The same platform can be upgraded to 10kW, with four modules in parallel to provide 40kW of reliable fast-charging power.

"Exide Technologies delivers complete, carefully controlled fast charging with close system monitoring for critical material handling equipment, running 24/7," says Dr Dominik Margraf, director product management Motion at Exide. "Navitas' GeneSiC technology is easy-to-use, with excellent support, increased system efficiency, and cooler operation," he comments.

www.exidegroup.com
www.navitassemi.com

CGD launches second series of ICeGaN 650V HEMTs

Smart gate interface virtually eliminates typical e-mode GaN weaknesses

Fabless semiconductor company Cambridge GaN Devices Ltd (CGD) has launched the second series of its ICeGaN 650V gallium nitride high-electron-mobility transistor (HEMT) family.

H2 Series ICeGaN HEMTs employ CGD's smart gate interface that is said to virtually eliminate typical enhancement-mode (e-mode) GaN weaknesses, delivering significantly improved over-voltage robustness, higher noise-immune threshold, dV/dt suppression and ESD protection. Like previous-generation devices, the new 650V H2 ICeGaN transistors are driven similarly to silicon MOSFETs, eliminating the need for complex and inefficient circuits, instead using commercially available industry gate drivers. Finally, H2 ICeGaN HEMTs feature a QG that is 10x lower than silicon parts, and QOSS is 5x less. This

enables H2 ICeGaN HEMTs to greatly reduce switching losses at high switching frequencies, reducing size and weight. This results in what is claimed to be class-leading efficiency performance, 2% better than the best silicon MOSFETs in switch-mode power supply (SMPS) applications, it is reckoned.

"Independent research by Virginia Tech has proven ICeGaN to be industry's most rugged GaN devices and, in terms of ease-of-use, they can be driven like a standard silicon MOSFET, so the learning curve which can slow market acceptance is eliminated," says CEO & co-founder Giorgia Longobardi. "The efficiency of GaN is well known, and ICeGaN is impressive across the full load range."

ICeGaN H2 Series transistors feature an innovative NL3 (No Load and Light Load) circuit, integrated on-chip alongside the GaN switch,

resulting in what is claimed to be record-low power losses. An advanced clamping structure with integrated Miller clamp — also on-chip — eliminates the need for negative gate voltages, achieving true zero-volt turn-off, and improving dynamic $R_{DS(ON)}$ performance. These e-mode (normally off) single-chip GaN HEMTs include a monolithically integrated interface and protection circuit for unmatched gate reliability and design simplicity. Finally, a current sense function reduces power dissipation and allows direct connection to ground for optimized cooling and EMI.

"CGD has solved all the challenges that normally slow the adoption of a new technology," claims Longobardi. "Furthermore, we are now ready to satisfy the mass market with our H2 Series ICeGaN transistors, which are available through an established supply chain."

Next generation of ICeGaN HEMT unveiled at PCIM

Cambridge GaN Devices Ltd (CGD) — which was spun out of the University of Cambridge Department of Engineering's Electrical Power and Energy Conversion group in 2016 and designs, develops and commercializes power transistors and ICs that use GaN-on-silicon substrates — reflected its transition from start-up to scale-up with a significantly increased presence at the Power, Control and Intelligent Motion (PCIM) Europe 2023 event in Nuremberg, Germany (9–11 May). The firm unveiled the next generation of its ICeGaN high-electron-mobility transistor (HEMT) family, detailing innovations that support dual claims concerning ease-of-use and ruggedness, and providing a full suite of demonstrations.

"The world is eager for GaN to play a leading role in increasing sustainability in many aspects of our lives. CGD is playing a leading role in this movement, by delivering

GaN devices that are the easiest to use, while at the same time, being the most rugged and reliable," says co-founder & CEO Dr Giorgia Longobardi. "PCIM is an excellent stage for CGD to prove these statements, and we encourage every visitor to challenge us with their latest designs and applications."

On the Exhibitor Stage, Longobardi introduced the new HEMT family with a presentation 'CGD Introduce Next Level of Energy savings, Robustness & Reliability for 650V GaN with New ICeGaN Family of SoC Solutions'.

CGD presented data from Virginia Tech that prove the ruggedness and reliability of the firm's technology. Designers can also learn how they can easily evaluate CGD's ICeGaN HEMTs without redesigning their existing boards.

A full range of demonstrations at PCIM included:

- a 65W, 240mΩ QRF evaluation board using new ICeGaN devices

that supports CGD's claims of robustness and dV/dt immunity;

- an active live demo of the QRF reference design connected to power meters will compare the new CGD HEMTs with those of a competitor;

- a 350W, 55mΩ PFC2 demo will show the levels of monolithic integration that ICeGaN permits;
- a 100W PFC and QRF reference design, developed with JVD as an exemplar of the collaboration and partnerships CGD is forging with international partners that are leaders in their fields.

"CGD has all the elements in place — technology, products, manufacturing, infrastructure, distribution — to ensure that we can support the burgeoning GaN market," reckons chief commercial officer Andrea Bricconi. "We are ready to deliver our ICeGaN HEMTs in mass-production quantities for all markets."

www.mesago.de/en/PCIM/main.htm
www.camgandevices.com

Odyssey delivers product samples to customers in Q1

Product development agreements with lead customers underway; signed agreements expected in Q2

Odyssey Semiconductor Technologies Inc of Ithaca, NY, USA, which develops high-voltage vertical power switching components based on proprietary gallium nitride (GaN) processing technology, says that it accomplished its aggressive goal of delivering vertical GaN product samples to customers in first-quarter 2023. Results validate the leadership performance expected from vertical GaN power devices versus competing technologies, says the firm.

“Now that we’ve delivered product samples to lead customers, in Q2 we’re focused on delivering samples to additional customers and signing product development agreements with customers, which will lead to large-scale commercialization,” says CEO Mark Davidson.

“We are actively engaged in multiple product definition conversations with leading EV automotive customers, as well as industrial motor and renewable energy customers,” he adds. “Lead customers have collaborated along the way and have validated the performance metrics expected from vertical GaN for power applications.”

Odyssey is continuing to take product sample requests for its 650V and 1200V vertical GaN power devices.

The firm says that it is also converting a \$2m pipeline for foundry services to new business as it continues to pursue new opportunities.

Odyssey says that its approach to vertical GaN will offer even greater commercial advantages over silicon than silicon carbide or lateral GaN.

Vertical GaN offers a 10x advantage over silicon carbide (SiC) at performance enabling smaller and lighter power systems and cost levels unattainable by competing technologies, the firm adds. The market that it is pursuing is large and fast growing. The 650V segment is the larger market currently, expected to grow at a 20% compound annual growth rate (CAGR). The 1200V product market segment is expected to grow faster at a 63% CAGR and will become the larger market in the second half of this decade. Together, the 650V and 1200V power device market will grow at a combined CAGR of 40% to exceed \$5bn in 2027, forecasts market research firm Yole Group.

www.odysseysemi.com

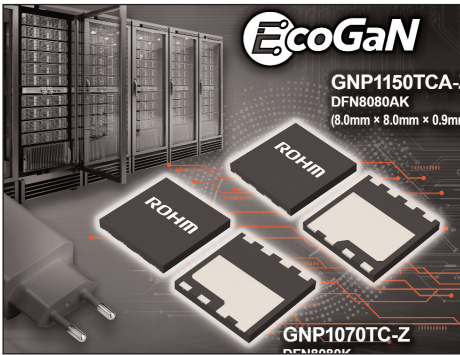
ROHM begins mass production of 650V GaN HEMTs

Increasing efficiency and miniaturization in power supply systems

Japan-based power semiconductor maker ROHM Co Ltd has begun mass production of the 650V gallium nitride (GaN) high-electron-mobility transistors (HEMTs) GNP1070TC-Z and GNP1150TCA-Z, which are optimized for a wide range of power supply systems in industrial equipment and consumer devices, including servers and AC adapters.

The products were co-developed with Ancora Semiconductors Inc (an affiliate of global power and thermal management solutions provider Delta Electronics Inc), which was founded in July 2022 to develop GaN devices and technology.

After initiating mass production of 150V GaN HEMTs (with a gate breakdown voltage of 8V) in 2022, in March ROHM established control IC technology for maximizing GaN performance. Now, ROHM has developed 650V GaN HEMTs with performance that contributes to higher efficiency and smaller size in a



wider range of power supply systems.

The GNP1070TC-Z and GNP1150TCA-Z deliver what is claimed to be industry-leading performance in terms of the GaN HEMT figure of merit $R_{DS(ON)} \times C_{iss} / R_{DS(ON)} \times C_{oss}$, translating to higher efficiency in power supply

systems. At the same time, a built-in ESD protection element improves electrostatic breakdown resistance up to 3.5kV, leading to higher application reliability. GaN HEMTs’ high-speed switching characteristics also contribute to greater miniaturization of peripheral components.

ROHM says that it continues to improve device performance through its new EcoGaN lineup of GaN devices, which contribute to energy conservation and miniaturization by maximizing GaN characteristics — to achieve lower application power consumption, smaller peripheral components, and simpler designs requiring fewer parts.

www.rohm.com

Part No.	Drain-Source Voltage V _{DS} [V]	Drain Current I _D [A] T _C =25°C	Drain-Source ON Resistance R _{DS(ON)} (Typ.) [mΩ]	Total Gate Charge Q _g (Typ.) [nC]	Input Capacitance C _{iss} (Typ.) [pF]	Output Capacitance C _{oss} (Typ.) [pF]	Package [mm]
New GNP1070TC-Z	650	20	70	5.2	200	50	DFN8080K [8.0×8.0×0.9]
New GNP1150TCA-Z		11	150	2.7	112	19	DFN8080AK [8.0×8.0×0.9]

BAE Systems and Eaton co-developing electric drive for medium-duty commercial trucks

Power-dense electric motor and SiC/GaN power electronics suite plus MD 4-speed EV transmission to provide integrated EV system

BAE Systems — which develops and services electric propulsion technology at its facilities in Endicott, NY, USA and Rochester, UK — is collaborating with intelligent power management firm Eaton to develop electric vehicle (EV) technology solutions. Through a memorandum of understanding (MoU) they will initially offer a solution for the medium-duty commercial truck platforms market. A Class-7 pickup and delivery demonstration vehicle is already in development.

BAE Systems will incorporate its power-dense electric motor and silicon carbide (SiC)/gallium nitride (GaN) power electronics suite with Eaton's MD 4-speed EV transmission to provide a comprehensive EV system for medium-duty vehicles,

such as those used for a variety of pick-up and delivery applications. The complete solution is intended to provide original equipment manufacturers with a durable, high-performance, compact, efficient and optimized system with flexibility to work with multiple zero-emission platforms.

"Our complementary strengths and industry knowledge in providing clean transportation solutions will address a critical need for new, clean technology options for the global truck market," says Steve Trichka, VP & general manager of Power & Propulsion Solutions at BAE Systems. "Together, BAE Systems and Eaton will enable electric drive systems that are efficient, modular and scalable," he adds.

"Our medium duty 4-speed EV transmissions are proven in the industry to offer class-leading performance through superior acceleration and gradeability, while delivering advanced efficiency for the EV system," claims Mark Kramer, business unit director, ePowertrain, Eaton's Vehicle Group.

The MoU joins two companies with what is said to be a deep understanding of electrification and mobility. BAE Systems has more than two decades of experience developing and integrating electric propulsion systems, including hybrid and fully electric technology. Eaton has extensive transmission expertise and a proven track record in drivetrain durability.

www.baesystems.com

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Transphorm appoints co-founders Primit Parikh and Umesh Mishra as president & CEO and chair

Retiring Mario Rivas to provide advisory services for next year

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 — says that its board of directors has appointed Dr Primit Parikh as president & CEO and as a member of the board. The board also appointed Dr Umesh Mishra as chair of the board. Both of these appointments are effective 15 May.

Parikh and Mishra, who co-founded the firm's main operating subsidiary Transphorm Technology Inc, succeed Mario Rivas, who has served

as CEO since February 2020 and chair of the board since May 2022, and as Transphorm Technology's CEO since October 2015. Rivas's retirement is part of the management succession planning. Rivas will enter into a consulting agreement to provide advisory services to the firm through 15 May 2024.

Parikh has served as president & chief operating officer since February 2020. He is a co-founder of Transphorm Technology and has served as Transphorm Technology's chief operating officer since 2007, as well as a member of the board of directors of Transphorm Japan Inc

since 2014. With over 25 years of semiconductor and entrepreneurial experience, his background includes experience with capital raises, international markets and strategic partnerships, products and manufacturing, intellectual property, GaN and semiconductor technology, and government contracting.

"We thank Mario for his mentorship, all-round contributions, and dedication to the company, and appreciate his continued involvement in an advisory capacity," comment Parikh and Mishra.

www.transphormusa.com

Transphorm releases simulation model of first 1200V GaN-on-sapphire device

Normally-off GaN platform for automotive & 3-phase power systems

Transphorm has announced the availability of its 1200V FET simulation model and preliminary datasheet. The normally-off TP120H070WS FET is claimed to be the only 1200V GaN-on-sapphire power semiconductor available, making its model the first of its kind.

Key preliminary device model specifications for Transphorm's TP120H070WS include:

- on-resistance ($R_{DS(on)}$) of 70m Ω ;
- efficient bidirectional current flow;
- $\pm 20V_{max}$ gate robustness;
- low 4V_{th} gate drive noise immunity;
- zero QRR;
- 3-lead TO-247 package.

Transphorm says the simulation model's release indicates the firm's ability to support future automotive power systems as well as three-phase power systems used in the broad industrial, datacom and renewables markets. These can benefit from the 1200V GaN device's higher power density and reliability along with equal or better performance at more reasonable cost points versus alternative technologies, says the

firm. Transphorm recently validated the GaN device's higher performance ability in a 5kW 900V buck converter switching at 100kHz. The 1200V GaN device achieved 98.7% efficiency, exceeding that of a similarly rated production silicon carbide (SiC) MOSFET.

The Verilog-A device model is recommended for use with the SIMetrix Pro v8.5 Circuit Simulator. A LTSpice model is in development and will be released in fourth-quarter 2023. Simulation modeling allows for fast and efficient power system design validation while reducing design iterations, development time, and hardware investments.

GaN in automotive power systems and charging ecosystem

While the 1200V GaN device is an optimal solution for various market applications, it offers an advantage especially for automotive systems.

The electric vehicle industry, especially at the higher-kilowatt nodes for larger vehicles, is moving toward 800V batteries in the latter half of this decade. As such, 1200V

power conversion switches will be used to deliver the required performance level. Transphorm reckons that its 1200V platform is therefore well positioned for next-generation onboard charger, DC-to-DC converters, drive inverters and pole charging systems.

"We're proving that GaN can very easily play in application markets previously slated for silicon carbide, which opens a wide range of market adoption potential for our business and GaN in general," says chief technology officer & co-founder Umesh Mishra.

The 1200V device was exhibited at the Power, Control and Intelligent Motion (PCIM) Europe 2023 event in Nuremberg, Germany (9–11 May). 1200V FET samples should be available by first-quarter 2024.

For current-model EVs using 400V batteries, Transphorm offers 650V normally-off SuperGaN FETs that are AEC-Q101 qualified to 175°C and in volume production.

www.transphormusa.com/en/news/1200vgan_devicemodel

Transphorm wins \$15m contract from US National Security Technology Accelerator

ECLIPSE project to establish GaN epi production and supply

Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and makes JEDEC- and AEC-Q101-qualified gallium nitride (GaN) field-effect transistors (FETs) for high-voltage power conversion — has been awarded a contract for up to \$15m from the National Security Technology Accelerator (NSTXL). The contract is for the project ECLIPSE ('Technology for Nitrogen-Polar Gallium Nitride: Epiwafers & Substrates'), under which Transphorm is commissioned to manufacture GaN epitaxial wafers. The contract proposal process was administered by the Strategic & Spectrum Missions Advanced Resilient Trusted System (S2MARTS) as an OTA

(Other Transaction Agreement), managed by NSTXL.

Transphorm says that its opportunity to contribute to this project underscores its IP, knowledge and expertise in the GaN materials sector as well as its metal-organic chemical vapor deposition (MOCVD) manufacturing infrastructure.

Transphorm's experience in GaN epiwafer design, development and production of high-voltage GaN platforms spans over ten years. These initiatives constitute multiple verticals for its Power and RF GaN businesses.

"The value of and potential for advanced GaN materials is clear in a wide range of applications. We've

developed multiple high-power-density platforms that generate record performance and efficiency advantages suited for power conversion and RF applications," says chief technology officer & co-founder Umesh Mishra. "This type of innovation is where Transphorm excels because of its strong core epi materials versatility coupled with its device and manufacturing capabilities," he adds. "We've worked to evolve and better all GaN technology aspects — materials, design, and process. We now look forward to strong execution on the ECLIPSE program, enhancing our capability to supply advanced GaN epiwafers."

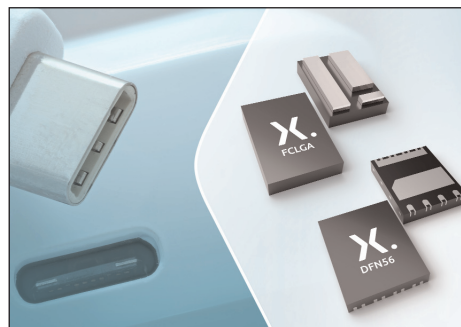
www.nstxl.org

Nexperia launches e-mode GaN FETs for 100/150V & 650V

Nexperia B.V. of Nijmegen, the Netherlands (a subsidiary of Wingtech Technology Co Ltd) has released its first power GaN FETs in e-mode (enhancement-mode) configuration for low (100/150V)- and high (650V)-voltage applications. By augmenting its cascode offering with seven new e-mode devices, the firm now provides designers with a choice of GaN FETs alongside its portfolio of silicon-based power electronics components.

The new portfolio includes five 650V-rated e-mode GaN FETs (with $R_{DS(on)}$ values between 80m Ω and 190m Ω) in a choice of DFN 5mm x 6mm and DFN 8mm x 8mm packages. They improve power conversion efficiency in high-voltage, low-power (<650V) datacom/telecom, consumer charging, solar and industrial applications. They can also be used to design brushless DC motors and micro server drives for precision with higher torque and more power.

Nexperia now also offers a 100V (3.2m Ω) GaN FET in a WLCSP8 package and a 150V (7m Ω) device



in a FCLGA package. The devices are suitable for various low-voltage (<150V), high-power applications to deliver, for example, more efficient DC-DC converters in data centers, faster charging (e-mobility and USB-C), smaller LiDAR transceivers, lower-noise class D audio amplifiers and more power dense consumer devices like mobile phones, laptops and games consoles.

GaN FETs offer the highest power efficiency with the most compact solution size in many power conversion applications, substantially reducing the bill of materials (BOM). As a result, GaN devices are increasingly entering mainstream power electronics markets, including server computing,

industrial automation, consumer, and telecom infrastructure. GaN-based devices offer the fastest transition/switching capability (highest dv/dt and di/dt) and deliver superior efficiency in low- and high-power conversion applications. Nexperia says that the switching performance of its e-mode GaN FETs is attributable to very low Q_g and QOSS values, while their low $R_{DS(on)}$ enables more power-efficient designs.

With the release, Nexperia says that it now supplies a broad offering of GaN FET products to suit the wide range of power applications best suited to the technology, including cascode devices for high-voltage, high-power applications, 650V e-mode devices for high-voltage, low-power applications and 100/150V e-mode devices for low-voltage, high-power applications. Furthermore, its e-mode GaN FETs are fabricated on an 8" wafer-line for increased capacity and qualified for industrial applications according to JEDEC standards.

www.nexperia.com/gan-fets

EPC sues Innoscience for patent infringement

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA has filed complaints in the US District Court for the Central District of California and in the US International Trade Commission (ITC) asserting four patents of its foundational patent portfolio against Innoscience (Zhuhai) Technology Co Ltd of Suzhou, China and its affiliates, and seeking damages and barring Innoscience from importing its infringing GaN products into the USA.

The patents cover core aspects of the design and manufacturing process of EPC's proprietary enhancement-mode gallium nitride power semiconductor devices. They encompass innovations that enabled GaN-based power devices to mature from a research project to a mass-producible high-volume alternative to silicon-based transistors and integrated circuits.

EPC claims that, in 2010, it put the first commercial GaN transistors and integrated circuits into mass production. The firm now holds 57 US patents and 172 patents worldwide, and has over 100 ICs and discrete transistors available for off-the-shelf delivery.

The complaint recounts how, soon

after Innoscience recruited two EPC employees to serve as its chief technology officer and head of sales & marketing, it introduced a suite of products "visibly identical to EPC's, boasting virtually equal performance across key performance metrics". Innoscience has claimed that many of its products have "pin-to-pin compatibility with existing products", including EPC's, in an aggressive campaign to market its suite of products to EPC's customers, the firm adds.

Innoscience responds: "This action by EPC constitutes illegal competition tactics aimed at undermining Innoscience's competitive advantage. Innoscience reserves the right to pursue legal liability for the losses caused by this".

Innoscience states its intellectual property rights are "clear, traceable and free from infringement", having filed 753 relevant patents globally, with 129 patents granted. Innoscience has "promptly conducted a thorough analysis and confirmed that there is no infringement of EPC's intellectual property rights".

"In comparison to Innoscience, EPC has a significant disparity in terms of business scale, scope of

operations, and technological strength. The allegations of technology plagiarism, based on the job changes of a few employees, are purely speculative and lack factual basis... They did not serve as chief technology officer and head of sales & marketing," Innoscience claims.

"Innoscience is an IDM (integrated device manufacturer) semiconductor company with its core competence lying in the full vertical integration of the semiconductor industry.... Innoscience is globally recognized for its pioneering 8-inch GaN mass-manufacturing process," the firm states. "EPC is a fabless design company whose product designs primarily rely on a 6-inch foundry process platform. EPC does not possess its own wafer fabrication facilities or corresponding manufacturing processes."

Innoscience states that its GaN products span a wide voltage range, from low (15V) to high (700V), whereas EPC's product range is limited to "only a few low-voltage devices, which represents only a small fraction of Innoscience's product portfolio", it claims.

www.epc-co.com

www.innoscience.com

Innoscience and Bern develop reference demo

Innoscience Technology of Suzhou, China has collaborated with the Bern University of Applied Sciences (BFH) to deliver a reference demo that employs its 650V InnoGaN gallium nitride high-electron-mobility transistor (HEMT) devices in a multi-level topology to address 850V_{DC} applications such as e-mobility motor drivers, solar and industrial inverters, electric vehicle fast chargers and potentially EV drivetrains.

The three-level ANPC (Active Neutral Point Clamped) converter uses Innoscience's readily available INN650D080BS 650V, 80mΩ HEMTs in the 8mm x 8mm DFN package. No snubber capacitors or expensive silicon carbide (SiC) diodes are

required, reducing system cost.

"At higher voltages, classic two-level topologies such as a half-bridge are not practical as the 650V-rated HEMTs will fail," says BFH professor Timoth   Delaforge, who worked on this development with professor S  bastien Mari  thoz. "But there are many other topologies which mean that we can keep the operating voltage of the HEMT well below its rated voltage, while working with much higher DC bus voltages. In this case we chose the ANPC topology because it enables us to switch 850V_{DC} without needing SiC. 850V is high enough for many industrial and e-mobility applications — even potentially EV drivetrains —

if enough care is taken on the circuitry design to minimize parasitics. We chose Innoscience's InnoGaN HEMTs as they are very high efficiency and reliable, whilst also being the most cost-effective devices available on the market," he adds.

"Although this design uses six HEMTs, because we are switching at much higher frequency, we can reduce the size of the filter and hence shrink the overall size of the converter," says Dr Denis Marcon, Innoscience's general manager, Europe. "Also, with our InnoGaN HEMTs we can achieve inverter efficiencies of 99%, increasing system reliability and decreasing cost."

www.bfh.ch

GaN Systems showcases products at Data Center World Firm presents 'Efficiency and Profitability in the Data Center with GaN'

GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) exhibited GaN solutions and presented 'Efficiency and Profitability in the Data Center with GaN' at Data Center World 2023 conference in Austin, Texas, USA (8–11 May).

Data centers currently account for 2% of the world's energy use, with ever-increasing costs. Offsetting these trends, for each set of 10 racks in the data center, GaN-based power supplies can increase profits by \$3m, decrease data-center operating expenses, and reduce CO₂ emissions by more than 100 metric tons per year, it is thought.

At Data Center World, GaN Systems showcased power supply unit (PSU) solutions that can enable data centers to enhance profitability, reduce operating costs, and reduce energy consumption. Power supplies developed with GaN Systems transistors have double the power density of legacy PSUs and enable up to 20% energy savings in data centers, it is reckoned.

Solutions on display included:

- the world's first 100W/in³ with 80-Plus Titanium efficiency power supply;
- 2700W high-power-density power supply;
- 3kW PFC + LLC GaN-based reference design.

Director business development Julian Styles delivered a 'Solution

Spotlight: Bringing Efficiency and Profitability to the Data Center with GaN' in the Data Center Live Theater, Expo Hall.

"The increasing demand for more data and power combined with the critical focus on sustainability is driving massive changes in the data-center industry," notes CEO Jim Witham. "We are delighted to be at Data Center World to showcase our latest innovations for the data-center ecosystem, where we see customers increasingly switching to GaN power transistors to take advantage of their undeniable operating, financial and environmental benefits," he adds.

www.datacenterworld.com
www.gansystems.com

NXP launches top-side-cooled RF amplifier modules New packaging enables smaller, thinner and lighter radio units, supporting faster and easier deployment of 5G base stations

NXP Semiconductors N.V. of Eindhoven, The Netherlands has launched a family of top-side-cooled RF amplifier modules, based on a packaging innovation designed to enable thinner and lighter radios for 5G infrastructure. These smaller base stations can be more easily and cost-effectively installed, and blend more discretely into their environment. NXP's GaN multi-chip module series, combined with the industry's first top-side-cooling solution for RF power, helps to reduce not only the thickness and weight of the radio by more than 20% but also the carbon footprint for the manufacture and deployment of 5G base stations.

"Top-side cooling represents a significant opportunity for the wireless infrastructure industry, combining high-power capabilities with advanced thermal performance to enable a smaller RF subsystem," says Pierre Piel, VP & general manager for Radio Power at NXP.



"This innovation delivers a solution for the deployment of more environmentally friendly base stations, while also enabling the network density needed to realize the full performance benefits of 5G."

NXP's new top-side-cooled devices are said to deliver significant design and manufacturing benefits, including the removal of the dedicated RF shield, use of cost-effective and streamlined printed circuit board, and separation of thermal management from RF design. These features help networking solution

providers to create slimmer and lighter 5G radios for mobile network operators, while reducing their overall design cycle.

NXP's first top-side-cooled RF power module series is designed for 32T32R, 200W radios covering 3.3–3.8GHz

frequencies. The devices combine the firm's in-house LDMOS and gallium nitride (GaN) technologies to enable high gain and efficiency with wideband performance, delivering 31dB gain and 46% efficiency over 400MHz of instantaneous bandwidth.

The A5M34TG140-TC, the A5M35TG140-TC and the A5M36TG140-TC products are available now.

The A5M36TG140-TC will be supported by NXP's RapidRF reference board series.

www.nxp.com

CSA Catapult and Cardiff University showcase high-performing GaN power amplifier for satcoms

Gallium nitride satcoms power amplifier tested and characterized operating at 26–31GHz with output over 6W

A high-performing gallium nitride (GaN) power amplifier for use in satellite communication applications has been developed by a collaboration including a team of engineers at the Compound Semiconductor Applications (CSA) Catapult and Cardiff University in South Wales.

Presenting their results at the European Space Agency's '1st Space Microwave Week' conference (8–12 May), the team says that the GaN power amplifier has performed extremely well on new state-of-the-art linearity tests developed by CSA Catapult to help test the technology before it makes its way into real-world applications.

When designing satellite communication systems, one of the most critical factors is the linearity of the power amplifier. A linear power amplifier preserves the information content and quality of the signal and reduces the interference with other signals in the same frequency band. This is crucial to reduce distortion and ensure that the signal's information can be transmitted over the air and accurately recovered by a receiver.

The CSA Catapult team say this is an important step towards develop-

ing GaN power amplifiers for broadband satellite communication applications that are data-intensive, such as video streaming and the Internet of Things (IoT), as well as integration with the 5G mobile communication system and a pathway beyond 5G.

By using compound semiconductors such as GaN instead of silicon to fabricate a power amplifier, more energy-efficient systems can be built, and hardware size and weight can be reduced.

However, engineers are continuously wrestling with the challenge of creating an efficient and linear power amplifier, with the two factors often conflicting.

Being able to test the linearity of GaN power amplifiers with real data signals is therefore of upmost importance and is what led CSA Catapult and Cardiff University to develop a testbed that can carry out these measurements automatically.

CSA Catapult tested and characterized a GaN satellite communication power amplifier operating in the 26–31GHz band with an output power greater than 6W.

"With the increasing demand for

high-speed and reliable communication, satellite communication systems are becoming more advanced and sophisticated," notes Ehsan Azad, an RF engineer at CSA Catapult who led the research and presented it at the ESA conference. "As these systems continuously evolve through increased bandwidths and more complex signals being transmitted, it becomes more challenging to maintain linearity specifications whilst continuing to focus on efficiency improvements," he adds. "As we move toward the more energy-efficient power amplifier architectures, alongside the use of relatively new GaN technology, a lot of the assumptions made on power amplifier linearity are being invalidated. Similarly, there are still concerns about the linearity of the GaN-based power amplifier. That is why it is critically important that state-of-the-art tests such as ours are developed to determine the suitability of compound semiconductor materials for building the next generation of satellite communication applications."

<https://atpi.eventsair.com/space-microwave-week-2023>

<https://csa.catapult.org.uk/space>

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Orbray and MIRISE Technologies collaborating on vertical diamond power devices for electric vehicles

Orbray to develop p-type conductive diamond substrate; MIRISE to develop high-voltage device structure

Tokyo-based Orbray Co Ltd (which makes precision jewel parts, DC coreless motors, fiber-optic components, and medical devices) and automotive semiconductor research company MIRISE Technologies Corp of Minamiyama, Aichi Prefecture, Japan (a joint venture founded in April 2020 by DENSO and Toyota) have begun collaborating on vertical diamond power devices.

Over the three-year period of the project, Orbray and MIRISE aim to use their respective technologies, resources and expertise in diamond substrates and power devices to develop the technologies needed

to deploy vertical diamond power devices in a wide range of electric vehicles in the future.

In the research collaboration, Orbray will be responsible for developing a p-type conductive diamond substrate, while MIRISE will take charge of developing a high-voltage-operating device structure to demonstrate the feasibility of a vertical diamond power device. At the end of the project, the firms plan to discuss the next stage of collaboration, such as further R&D.

Compared with existing mainstream semiconductor materials

such as silicon, silicon carbide (SiC) and gallium nitride (GaN), diamond is considered to be the ultimate semiconductor material because it has higher-voltage operating capability and superior thermal conductivity (heat dissipation). In the future, the development and mass production of next-generation automotive semiconductors using diamond is expected to improve the fuel efficiency and power consumption of electric vehicles, and to reduce battery costs.

www.mirise-techs.com/en
www.orbray.com/en

South Wales Compound Semiconductor Cluster CSconnected forges links with SMARTNano Northern Ireland

SMARTNano NI's Mark Gubbins visits Swansea University's Centre for Integrated Semiconductor Materials

During a recent review meeting of the South Wales Compound Semiconductor Cluster project CSconnected hosted by professor Paul Meredith at the new £50m Centre for Integrated Semiconductor Materials (CISM) at Swansea University, CSconnected hosted a visit by Mark Gubbins (director of development at Seagate Technology) — representing the SMARTNano Northern Ireland (NI) Cluster — as well as the Strength in Places Fund Programme Team.

"Collectively, CSconnected and SMARTNano NI represents 4000–5000 high-value-add manufacturing jobs which deliver a significant contribution to the UK economy, and both Clusters are globally recognized for delivering cutting-edge research, innovation and manufacturing," says CSconnected chair Dr Wyn Meredith. "This is the first step in forging closer links between the Northern Ireland and



CSconnected chair Dr Wyn Meredith (left) and SMARTNano NI's Mark Gubbins (right) at CISM.

South Wales in the area of advanced semiconductors, nanomaterials and associated manufacturing processes," he adds.

Administered by the UK Research and Innovation (UKRI), the £316m Strength in Places Fund helps areas of the UK to build on existing strengths in research and innovation

to deliver benefits for their local economy. Projects focus on a self-defined area anywhere in the UK, not limited by nations or regions, with a defined critical mass of expertise, infrastructure and capability.

"UKRI has made an investment of >£65m to accelerate economic growth in these Clusters and we have a lot to learn from each other in complimentary areas of research, skills development and manufacturing scale up," says SMARTNano NI's Dr Mark Gubbins. "We are particularly keen to act as a single voice to UK government to stress the importance of supporting compound semiconductors and associated nanomaterials in the recently announced UK Semiconductor strategy."

<http://csconnected.com>
www.smartnanoni.com
www.swansea.ac.uk/campus-development/developing-bay/

IQE raises £31.1m in share placing and retail offer and extends \$35m revolving credit facility

Funds to enable investment in growth markets including GaN power electronics and micro-LED displays

Epiwafer and substrate maker IQE plc of Cardiff, Wales, UK has raised £30m in gross proceeds (before expenses) through the issue — to institutional investors and certain directors of the firm — of 150 million new ordinary shares at a price of 20 pence per ordinary share (a discount of about 14.9% on the closing price of 23.5 pence per existing ordinary share on 17 May).

Admitted for trading on the London Stock Exchange's AIM market, the new ordinary shares that were issued collectively represented about 18.6% of the existing ordinary share capital of the firm.

Also, in a retail offer to existing retail investors, IQE has issued 5,492,730 new ordinary shares at 20 pence each, raising a further £1.1m.

As highlighted in the trading update on 9 March, the semiconductor industry is experiencing a temporary downturn as a result of heightened inventory levels that built up during the pandemic, coupled with softer consumer demand. This has resulted in a reduction in orders and forecasts from IQE's customers.

Against this backdrop, the firm's raising of £30m via the placing and up to £1.1m via the retail offer ensures that the firm can continue to invest to execute on its strategy, meet its near-term liquidity requirements and deliver a sustainable balance sheet position going forward.

IQE has also entered into an agreement with its lending bank HSBC to extend the term of its \$35m revolving credit facility (RCF) from April 2024 to May 2026, conditional on completion of the placing, ensuring sufficient headroom in the event that the macroeconomic headwinds persist through second-half 2023.

In light of the challenging market conditions, IQE has implemented several cost control and cash preservation measures, including a 10% reduction in labour costs for fiscal year 2023 and minimization of property, plant & equipment (PP&E) capital expenditure. In total, overheads are forecast to reduce by 7% year-on-year in 2023.

IQE has prioritized growth CapEx on investment in gallium nitride (GaN) manufacturing capacity. This will enable the firm to diversify into the high-growth markets of power electronics devices (which has a five-year CAGR of 50%) and micro-LED display devices (which has a five-year CAGR of 150%+).

This investment in GaN manufacturing capabilities is reckoned to represent a significant opportunity to gain scale in power electronics, through the purchase of four Aixtron G5+ GaN metal-organic chemical vapor deposition (MOCVD) reactors. The first two of these will be installed at IQE's existing facility in Massachusetts, and the second two in either the USA or the UK.

The new reactors will be deployed on customer-funded R&D programs initially and will provide incremental margin improvement, diversify the product portfolio, build the resilience of the firm, and reduce customer concentra-

tion. IQE has secured preferential delivery and payment terms to stagger this investment across fiscal 2023–2025.

The return on the investment is expected to be incremental to margins and consistent with IQE's target EBITDA (earnings before interest, tax, depreciation and amortization) margin of >30% set out at the Capital Markets Day in 2022.

IQE says that it has a strong pipeline of strategic and long-term partnerships and new business opportunities that will underpin growth in second-half 2023 and beyond. Despite the current cyclical downturn, the semiconductor industry has consistently demonstrated growth over many decades and the fundraising is expected to ensure that the firm remains well positioned to capitalize on the significant opportunities ahead.

Net debt rises to £24m

In its unaudited preliminary results, IQE reported annual revenue growth of 9% from £154.1m in 2021 to £167.5m for 2022, or £151.2m on a constant-currency basis.

Impairment of goodwill was £62.7m, relating to the firm's wireless operating segment, where reductions in sales volumes — linked principally to lower levels of smartphone-related demand and continuing weakness in 5G infrastructure — is forecast to result in lower levels of capacity utilization and operating segment profitability. The non-cash impairment results from the near-term softness in forecasts for wireless products as a result of the industry-wide semiconductor downturn, driven by inventory build-up throughout the supply chain.

Due primarily to the non-cash impairment of goodwill of £62.7m, operating loss has risen from £20m

The semiconductor industry is experiencing a temporary downturn as a result of heightened inventory levels that built up during the pandemic, coupled with softer consumer demand. This has resulted in a reduction in orders and forecasts from IQE's customers

to £73m. However, adjusted operating loss (excluding the impairment) has been cut from £6.5m to £3.6m.

Net cash flow from operations has more than halved from £18.9m to £8.9m, reflecting cash generated through IQE's resilient trading performance offset by adverse working capital movements and the cash impact of adjusted non-operational items.

Adjusted net debt (excluding lease liabilities) rose from £5.8m to £15.2m during 2022. By end-March, net debt was £24m.

First-half revenue to be down by £30m, but rebound expected in second-half 2023

IQE says that current trading is affected by the temporary semiconductor industry downturn, with

reduced customer forecasts, orders and associated revenue.

First-half 2023 revenue is expected to be £50–56m (down on first-half 2022's £86.2m). However, full-year 2023 revenue should be in line with management expectations set out in March, which include a return to year-on-year growth during second-half 2023.

Diversification into the high-growth markets of power electronics and micro-LED displays targets GaN growth opportunities in 2024 and beyond.

IQE expects PP&E CapEx related to essential maintenance and health & safety items and existing commitments to be about £7.4m in full-year 2023. In addition, the diversification strategy will lead to

investment in GaN of about £8.3m.

"Our industry is currently experiencing a downturn cycle but it has demonstrated consistent growth over many decades, which is forecasted to continue," says CEO Americo Lemos. "As macro technology trends drive an increased need for compound semiconductors, IQE is strategically positioned to serve the global market and underpin the next wave of innovation," he adds. "This fundraise enables our investment in new growth markets including power electronics and micro-LED display, in line with our strategy. As a result, we are well-placed to capitalise on our excellent pipeline and global footprint as we emerge from the current cycle."

www.iqep.com

IQE launches 200mm red–green–blue epitaxy for micro-LED display qualification

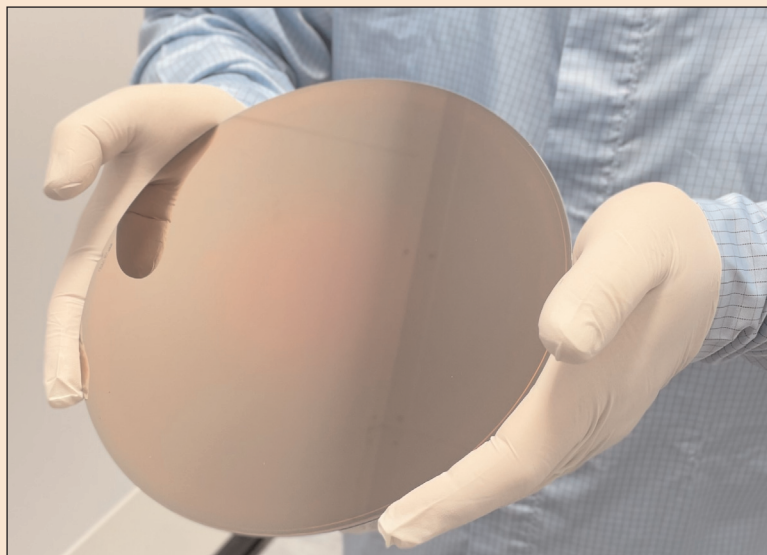
Technology roadmap being scaled from 200mm to 300mm

Epiwafer and substrate maker IQE plc of Cardiff, Wales, UK has launched a new portfolio of 200mm (8") red, green and blue (RGB) epitaxial wafer products for micro-LED display qualification.

Micro-LEDs based on gallium nitride (GaN) and gallium arsenide (GaAs) provide new display technology that is being designed into multiple new platforms such as wearables, augmented reality/virtual reality (AR/VR) headsets and large-format displays, says the firm.

IQE claims that its GaN and GaAs epitaxy is critical in enabling faster adoption of micro-LEDs because its technology, high-volume manufacturing platforms and resulting scale provide customers with a commercial advantage.

The launch of the micro-LED wafer products will provide faster time-to-market options for display-level qualification, the firm adds. With multi-wavelength solutions available at wafer diameters including new options



RGB epiwafer for micro-LED display qualification.

at 200mm (8"), IQE is delivering qualified foundry capacity from its multi-continent operations, which it claims is a significant point of difference as it provides customers with epitaxy supply chain diversification.

Also, by scaling the technology roadmap from 200mm (8") to 300mm (12"), IQE aims to provide

a cost-effective solution.

"We are pleased to offer our customers the industry's broadest range of materials technology platforms for micro-LED display qualification," claims Dr Mark J. Furlong,

executive VP of business development. "IQE can play a critical role in accelerating the deployment of micro-LEDs across many end-applications, and the launch of this new portfolio is in line with our strategy to diversify into GaN technologies, in the high-growth display market."

www.iqep.com

AXT's Q1 revenue halved year-on-year

InP inventory correction hits while GaAs starts to stabilize

For first-quarter 2023, AXT Inc of Fremont, CA, USA — which makes gallium arsenide (GaAs), indium phosphide (InP) and germanium (Ge) substrates and raw materials — has reported revenue of \$19.4m, down 27.6% on \$26.8m last quarter and 51.1% on \$39.7m a year ago, and towards the lower end of the \$19–21m guidance range.

“Revenue took a step back in Q1 as the inventory correction that we began to see in gallium late last summer accelerated in phosphide applications,” notes CEO Morris Young.

Indium phosphide revenue was \$7.1m, almost halving from last quarter's \$14m, reflecting market softening. “Indium phosphide held fairly firm through January and then experienced a meaningful decline in February and March, most notably in the data-center and consumer applications,” says Young.

Gallium arsenide revenue has fallen further, from \$12m a year ago and \$5.5m last quarter to \$5m, reflecting the overall slowdown across a number of applications, particularly in China. “We are seeing positive signs that our revenue is stabilizing and that certain applications within gallium arsenide such as power amplifiers are beginning to show some improvements,” says Young. “This makes sense as these were among the first applications to experience weakness beginning in September of last year.”

Germanium substrate revenue rebounded further, from \$1.3m last quarter to \$1.4m, following resolution of a payment issue with one of AXT's customers.

In addition, revenue was \$5.9m from AXT's two consolidated raw materials 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, as well as InP poly and other

materials). This was down on \$7.9m a year ago but roughly stable with \$6m last quarter, as gallium raw material pricing remained approximately flat.

Of total revenue in Q1, the proportion from the Asia-Pacific region was 68% (down on 70% last quarter), Europe was 18% (up from 15%) and North America was 14% (down slightly from 15%).

The top five customers generated just 28% of total revenue (down from 41% last quarter), with no customers over 10%.

On a non-GAAP basis, gross margin has fallen further, from 33.8% a year ago and 32.5% last quarter to 26.9%, due to the lower InP revenue in the product mix. However, this was better than the expected 21%. “We have continued to focus on manufacturing efficiencies, and are having increasing success in our recycling efforts, which benefited our gross margin performance,” says Young.

Operating expenses were \$8.7m, up slightly from \$8.6m a year ago but cut from \$9m last quarter.

Net loss was \$2.4m (\$0.06 per share), compared with net income of \$2.1m (\$0.05 per share) last quarter and \$4.3m (\$0.10 per share) a year ago. However, this is better than the expected net loss of \$0.10–0.12 per share.

Capital expenditure (CapEx) has been cut back beyond the targeted \$3–5m to just \$2.7m (mostly related to facilities and InP equipment). During Q1/2023, cash, cash equivalents and investments rose slightly, from \$52.8m to \$53.6m.

Net inventory was \$91.7m. Of this, 45% is raw materials, 51% is work-in-progress (WiP), and just 3% is finished goods.

“We had a very successful quarter in our recycling efforts, which benefited our margins in our ESG [environmental, social and governance] efforts. But when we grow new ingots with recycled InP, it adds to the inventory. Almost half

of the increase in inventory is still recycling,” notes chief financial officer Gary Fischer. “Inventory reduction remains a key focus for us this year, and we expect to bring it down as the demand environment improves,” he adds.

Given the continuing inventory correction, for Q2/2023 AXT again expects revenue of \$19–21m. Product mix is likely to include growth in GaAs substrates and continued weakness in InP with no improvement in data-center and consumer applications (although they appear to be stabilizing). Net loss is expected to rise to \$0.10–0.12 per share.

“As we look forward, we believe that the trends that have driven our revenue and customer expansion remain intact,” says Young. “We continue to excel in our technical capabilities and are readying our business to support new applications and future growth. Further, we continue to work towards improving our efficiency, and are focusing on accelerating our return to profitability,” he adds. “CapEx for the whole year will be below \$5m. So we've really sort of put a lid on things,” notes Fischer.

Regarding micro-LEDs, Young says that AXT continues to be encouraged by industry progress, as well as its own progress in preparing for this opportunity. “We're already delivering 8-inch GaAs wafers to customers and generating modest revenue. While formal qualification for the flagship program with our large customer won't occur until sometime in the second half of 2023, we have visibility into the likely technical specification that will be required... We're ready to ramp up production for them sometime in 2024,” Young says. “In addition, our 8-inch line for GaAs crystal growth is up and running at our Kazuo facility, and we are very excited by our progress in driving improved efficiency there.”

www.axt.com

Hardinge demonstrating BoulePro-200AX for forming wafer-ready silicon carbide puck

Automated single-setup solution speeds process to 2–3 hours

Hardinge Inc of Elmira, NY, USA (which designs, manufactures and distributes high-precision, computer-controlled machine tools) says that its BoulePro-200AX, with its Single-Step Dual-plane Compensation (SSDC) capability, has streamlined the silicon carbide fabrication process of shaping an as-grown boule to wafer-ready puck.

Hardinge says that the BoulePro, launched in December 2022, has generated interest from nearly all global SiC producers due to improving an existing fabrication process that can take over 24 hours (from boule to puck) down to just 2–3 hours using an automated single-setup solution. The firm has estimated a nearly 70% total cost reduction when taking labor, manufacturing footprint, scrap, capacity efficiency, and consumables into account.

This year, customers worldwide have been visiting Hardinge's facility Elgin, Illinois, to see the BoulePro in action. "Our Elgin facility is home to Hardinge's Usach brand of specialized application

grinding machines" says Hardinge Elgin site director David Yan. "Our team of engineers and application specialists were able to quickly get a prototype BoulePro up and running to demonstrate the machine's capability and show how the production process will function on the final machine design expected to ship later this year," he adds.

"Customers were eager to see the BoulePro in action — even in its prototype form — given the market's rapid expansion," says Jeff Gum, Advanced Material Specialist at Hardinge. "Given the markedly different crystal geometries from supplier to supplier, the Hardinge team was challenged with seeing boules for the first time in person and needing to demonstrate how the BoulePro can perform a production process. Our customers were excited to see how our engineering and application experts were able to adjust to their demands and how flexible the BoulePro can be."

Due to its built-in x-ray diffraction (XRD) machine, the BoulePro-200AX has precise accuracy.

"Because of how tightly various parameters are controlled, our machine produces the angular correction on crystal orientation up to 100 times more accurately than the manual process currently used today," claims Gum. This can enable SiC producers to meet and exceed their customer's expectations and requirements as specifications evolve.

Hardinge has expansion plans underway to deal with increased volumes. Demonstrations will be ongoing in 2023, with customer machines hitting the floor before year-end. Hardinge aims to utilize its global footprint to meet customer demand and after-market needs to ensure BoulePro supply and support services match customer requirements.

Hardinge is exhibiting at the SEMICON West 2023 show in San Francisco, CA (11–13 July) and plans to attend the International Conference of Silicon Carbide Related Materials (ISCRM 2023) in Sorrento, Italy (17–22 September).

www.hardinge.com

Asian order for Riber MBE 6000 production system

Client gains production capacity for telecom/datacom electronic devices

Riber S.A. of Bezons, France — which makes molecular beam epitaxy (MBE) systems as well as evaporation sources — says that a new industrial customer in Asia has placed an order worth several million euros for a MBE 6000 production system,

for delivery in 2024, giving it production capacity for advanced electronic components for both telecoms and datacoms applications.

Riber says that the new firm order is in line with the current dynamics of industrial MBE markets.

With about 40 machines in operation, the MBE 6000 is claimed to be the benchmark MBE system for mass producing electronic and optoelectronic components used in telecoms and in fiber-optic networks.

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Veeco’s semiconductor-related revenue up 20% year-on-year in first-quarter 2023

Compound Semiconductor segment to rebound in Q2

For first-quarter 2023, epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has reported revenue of \$153.5m, roughly level with \$153.8m last quarter but down slightly on \$156.4m a year ago. However, this was above the \$130–150m guidance range, driven by sales to semiconductor customers.

The Semiconductor segment (Front-End and Back-End, as well as EUV Mask Blank systems and Advanced Packaging) contributed \$93m (60% of total revenue). This is up 20% on \$78m (49% of revenue) a year ago, led by laser spike anneal (LSA) systems. “Our laser annealing business is gaining momentum, as demonstrated by recent orders for additional annealing steps at leading logic customers,” says CEO Bill Miller. “We’re also seeing traction within the memory market for advanced nodes, which represents a significant long-term growth opportunity for the company.”

The Compound Semiconductor segment (Power Electronics, RF Filter & Device applications, and Photonics including specialty, mini- and micro-LEDs, VCSELs, Laser Diodes) contributed \$21m (14% of total revenue). This is down on \$25m last quarter and \$37m (24% of revenue) a year ago. System shipments for photonics applications were the primary contributor.

The Data Storage segment (equipment for thin-film magnetic head manufacturing) contributed \$22m (14% of total revenue), level with a year ago but up on \$17m (11% of revenue) last quarter.

The Scientific & Other segment (research institutions and other applications) contributed \$18m (12% of total revenue), level with last quarter but down on \$20m (13% of revenue) a year ago.

By region, revenue from China comprised 40% of total revenue (up on 19% last quarter) driven primarily by LSA systems to

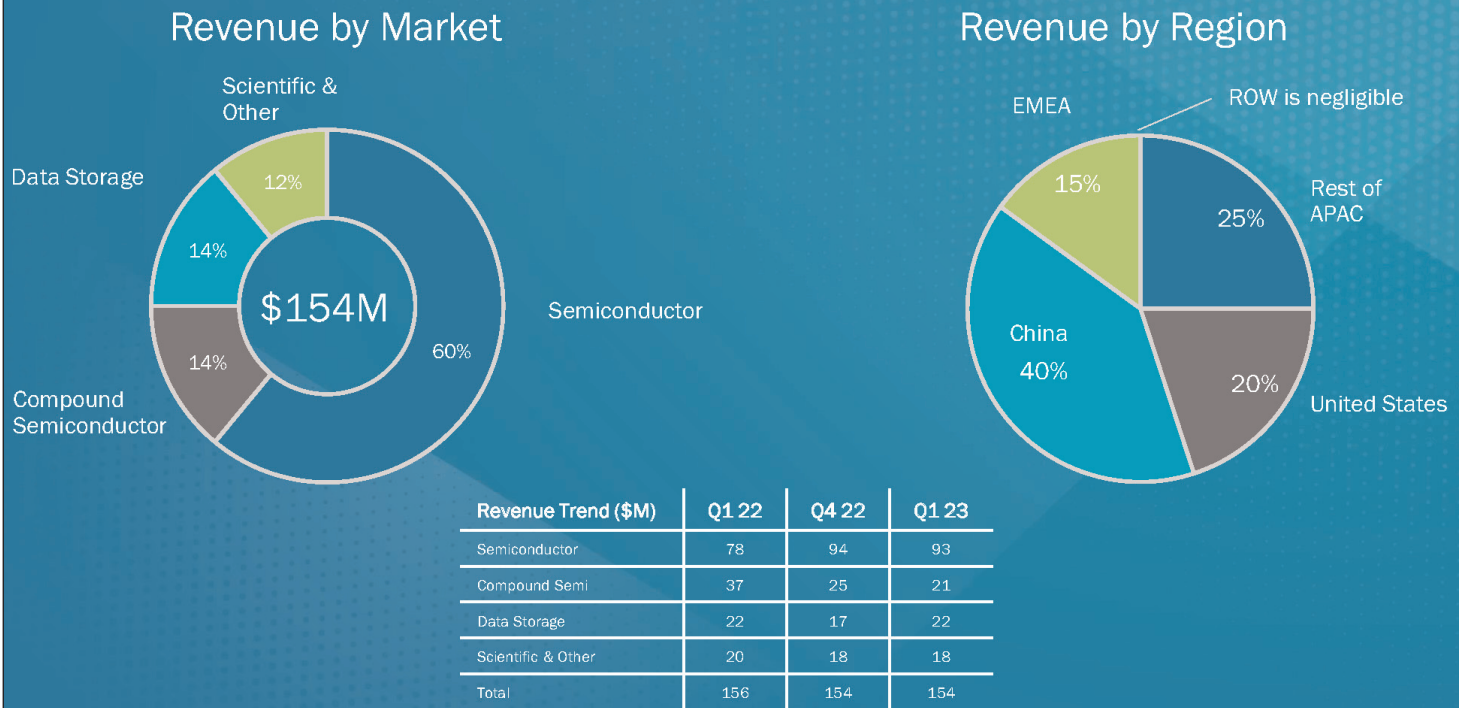
trailing-edge semiconductor nodes; the Asia-Pacific region (excluding China) 25% (down from 42%) led by Semiconductor system sales; the USA 20% (down on 25%); and Europe, Middle-East & Africa (EMEA) 15% (up slightly on 14%).

On a non-GAAP basis, gross margin has fallen further, from 43.1% a year ago and 42.3% last quarter to 41.5%. However, this is above the 39–41% guidance range, boosted by a favorable product mix and operation spending.

Operating expenses were \$43.3m. “We continue to be cautious in adding expenses in the current macroeconomic environment, while funding our growth initiatives to expand our served available market,” says senior VP & chief financial officer John Kiernan.

Net income was \$16.9m (\$0.30 per diluted share), down on \$21.9m (\$0.38 per diluted share) last quarter. However, this outperformed the \$6–15m (\$0.12–0.28 per diluted share) guidance range.

Q1 2023 Revenue by Market & Region



Cash flow from operations was \$14m (down from \$33m last quarter). Capital expenditure (CapEx) was \$7m.

Veeco ended the quarter with cash and short-term investments of \$253m, down by \$50m from \$303m after using \$30m for the acquisition of silicon carbide (SiC) chemical vapor deposition (CVD) system maker Epiluvac AB of Lund, Sweden and paying \$20m for extinguishing the remaining 2023 convertible senior notes. Long-term debt was \$254.7m, represents the carrying value of the outstanding \$258m in convertible notes (comprising \$133m due 2025 and \$125m due 2027).

During the quarter, inventory rose by \$19m from \$207m to \$226m (from 196 days to 213 days of inventory). This was driven by an increase in inbound materials to support higher expected revenue in second-half 2023 and to build the level of safety stock that was depleted as a result of supply chain challenges.

"Our team did an excellent job of managing the supply chain," comments Miller. "While material lead-times remained elevated, our suppliers' on-time deliveries have improved. We're starting to see some signs that material lead times could improve in the second half of the year."

"As we look ahead in 2023, we remain committed to investing in the semiconductor and compound semiconductor markets with differentiated solutions positioning Veeco for long-term growth," says Miller.

For second-quarter 2023, Veeco expects revenue to be roughly level at \$145–165m. Specifically,

the firm expects growth in the Semiconductor segment to \$105m and in the Compound Semiconductor segment to \$25m, while the Data Storage segment drops back to about \$15m and Scientific & Other revenue will almost halve to about \$10m. Gross margin is expected to be about 42%. With operating expenses of \$44–46m, net income should be \$14–20m (\$0.26–0.34 per diluted share).

"While China revenue in Q2 is forecasted to remain elevated, we expect a sequential decline from Q1 and a further decline in the second half of the year," says Kiernan. "In the second half of the year, we expect revenue growth to be led by tier-1 advanced semiconductor and data storage customers."

Based on current backlog and visibility, Veeco's revenue outlook for full-year 2023 remains relatively flat on 2022 at \$630–670m, with revenue in the second half exceeding that of the first half, based on the scheduled shipments of order backlog. The firm continues to target diluted earnings per share of \$1.15–1.35.

"Our wet-processing business has been weak over the last 6–9 months due to softness in the smartphone market. Timing of the market recovery is not yet clear. However, the power electronics and photonics markets offer promising opportunities for growth," says Miller.

"In power electronics, we're focused on GaN with our legacy MOCVD technology and with CVD silicon carbide [Epiluvac], which we recently acquired," he adds.

"Integration of the acquired CVD technology is progressing well

[having shipped the demo tool from Sweden to Veeco's demo lab in Somerset, New Jersey], with our system expected to be demo ready in the second half of 2023. Our system represents a significant opportunity for a differentiated solution to address growing power electronics demand in the electric vehicle market. We'll continue to engage our customers through evaluation system shipments and remain focused on penetrating the rapidly growing silicon carbide market. We would expect to have eval systems for some tier-1s in 2024 and then also start selling directly to some tier-2 customers as well. So, we're planning for some modest revenue in 2024, but I think we have more meaningful revenue in 2025," Miller says.

"We do have an evaluation system for GaN power electronics. It's for the transition from 6-inch to 8-inch. The product is running. Our customers asked us to extend that evaluation through this year. So it's a little slower taking off than we had originally planned. We probably won't see any meaningful GaN-on-silicon power activity beyond where we are today until the 2024 time-frame."

"We also have GaN-on-silicon for micro-LED, where we're working with a few customers on opportunities there. Our epitaxy equipment to address micro-LED applications continues to display promising long-term growth potential," continues Miller. "We're making ongoing investments in this area, including R&D, supporting customer demos and evaluations to penetrate these market opportunities."

www.veeco.com

Veeco raises \$230m in private offering of convertible senior notes

Veeco has raised \$200m in a private offering of 2.875% convertible senior notes (due 2029) plus \$25m of notes in a 30-day option that was fully exercised.

Of the \$223.3m net proceeds (after deducting the initial purchasers' discounts and commissions and the offering expenses payable by Veeco), the firm used \$198.8m to fund the cash portion

of note exchanges (involving its outstanding 3.50% convertible senior notes due 2025 and its 3.75% convertible senior notes due 2027). The remainder is being used for general corporate purposes.

Aixtron's first-quarter shipments roughly halved by delays in export licensing

Equipment order backlog up 60% year-on-year; three-quarters of order intake for GaN- & SiC-based power electronics

For first-quarter 2023, deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany has reported revenue of €77.2m, down 58% on €183.2m last quarter and 13% on €88.6m a year ago. This was due mainly to delays in the issue of export licenses, pushing shipment of €70m worth of finished tools out of the quarter.

Of total revenue, 73% came from equipment sales, while 27% came from after-sales service & spare parts.

Of the equipment revenue, metal-organic chemical vapor deposition (MOCVD)/chemical vapor deposition (CVD) equipment for making gallium nitride (GaN)- and silicon carbide (SiC)-based power electronics devices comprised 64% (up from just 33% a year ago); MOCVD equipment for manufacturing optoelectronics devices (telecoms/datacoms and 3D sensing lasers for consumer electronics, solar and wireless/RF communications) comprised 23% (down from 42%); and MOCVD equipment for making LEDs comprised 12% (down from 23%).

On a regional basis, 47% of revenue came from Asia (down from 67% a year ago), 28% from Europe (down from 22%) and 25% from the Americas (up from just 11%).

Gross margin was 40%, down from 45% last quarter and 41% a year ago.

Operating expenses were €27.6m, up on €21.7m a year ago, due mainly to higher R&D spending and personnel expenses. Staffing (full-time equivalent employees) has risen further, from 737 a year ago and 895 at the end of 2022 to 974 at the end of Q1/2023.

The operating result (earnings before interest and taxes) was €3.5m (EBIT margin of 5%), down from €57.1m (31% margin) last quarter and €14.2m (16% margin) a year ago.

Net profit was €3.5m (€0.03 per share), down from €50.3m (€0.44 per share) last quarter and €13.8m (€0.12 per share) a year ago, due mainly to the timing effects resulting in the shift of tool deliveries.

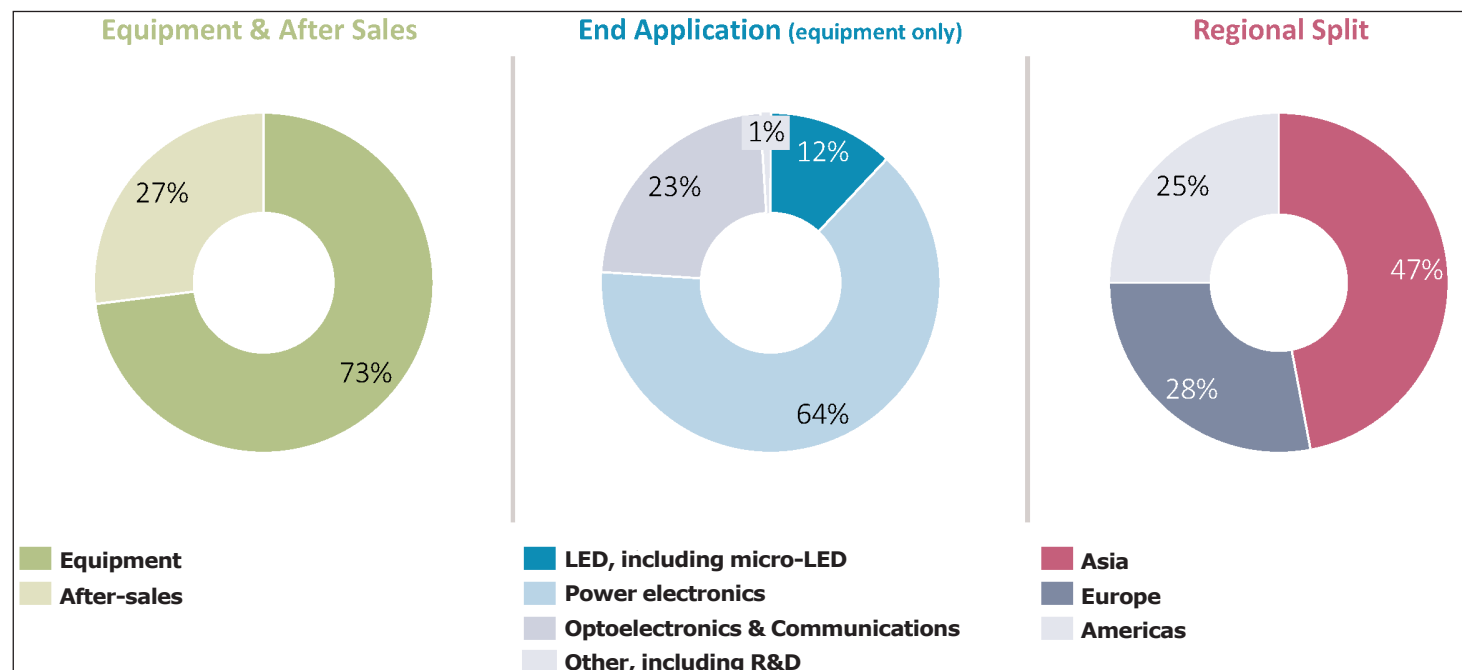
Operating cash flow was €5.8m (an improvement on -€0.1m last

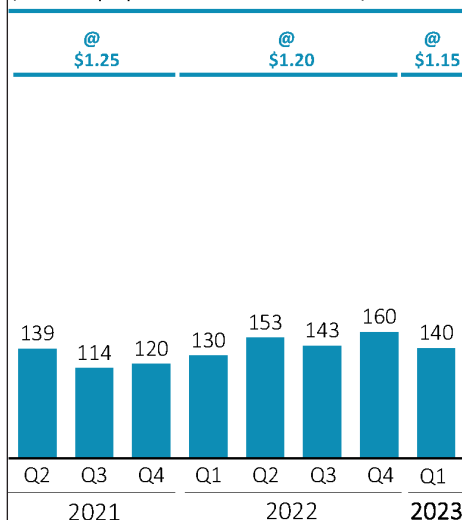
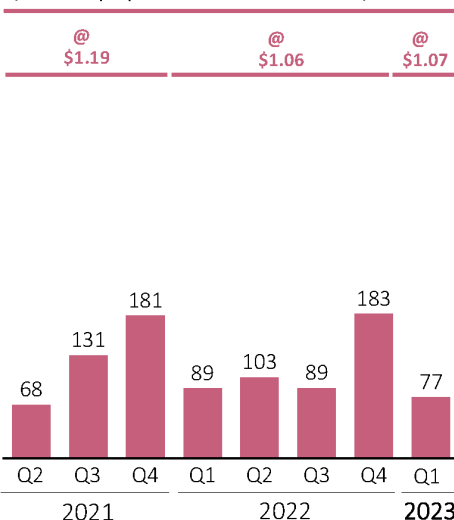
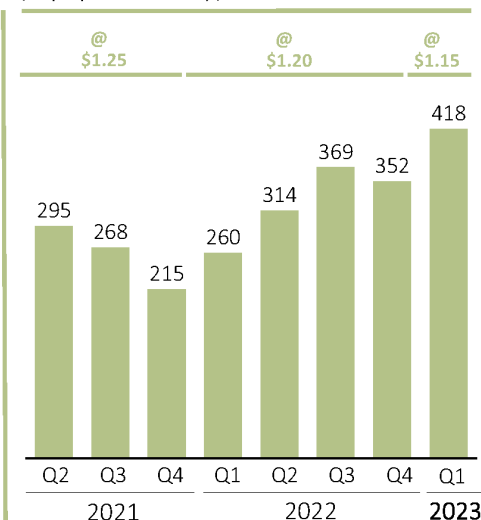
quarter). Capital expenditure (CapEx) was €3.9m. Free cash flow was hence just €1.9m (down on €22.4m a year ago, due mainly to the lower profit and a further increase in inventories).

Trade receivables have fallen from €119.7m at the end of 2022 to €62.5m at the end of March, due mainly to the collection of receivables from Q4/2022 shipments. Advanced payments received from customers at quarter-end were €160m (39% of order backlog), doubling year-on-year.

However, the strong cash inflows from receivables and down-payments were almost fully offset by the increase in inventories from €223.6m at the end of 2022 to €295m at end-March (roughly doubling year-on-year) — about 50–60% of order backlog — which is due mainly to preparation for the higher expected business volumes in the upcoming quarters plus the delayed issuance of export licenses.

"Our strategy to prepare our complete supply chain well in advance for further growth has



Order Intake(incl. equipment & after sales)¹¹ USD order intake and backlog were recorded at the prevailing budget rate (2021: \$1.25/€; 2022: \$1.20/€; 2023: \$1.15/€)² USD revenues were converted at the actual period average FX rate (2021: \$1.19/€; Q2/2022: \$1.08/€; Q3: \$1.02/€; Q4/2022: \$1.00/€; Q1/2023: \$1.07/€)**Revenues**(incl. equipment & after sales)²**Order Backlog**(equipment only)¹

proved highly effective over the last two years," comments chief financial officer Dr Christian Danninger. "We are very consciously managing our inventories to enable us to offer acceptable delivery times to our customers," he adds. "Our ability to ship is highly appreciated by our customers and has repeatedly enabled us to win against competitors."

During the quarter, cash and cash equivalents (including other financial assets) hence rose only slightly, from €325.2m to €327.5m. Of this, €237m was invested into funds following a very conservative diversification strategy. The equity ratio as of end-March was 72%.

About three-quarters of order intake for power electronics applications

Aixtron says that it has seen continued strong demand for equipment from all areas of the compound semiconductor industry, but particularly GaN- and SiC-based power electronics, which is seeing a further acceleration of growth. A number of large customers have chosen Aixtron to set up their high-volume manufacturing facilities for GaN and SiC, the firm adds. "This is yet another evidence for the success of our strategy and our development from a niche supplier to a reliable partner enabling industrial-scale production in the semiconductor industry," says CEO & president Dr Felix Grawert.

Due to the increased adoption of GaN in power electronics, order momentum continues to grow for GaN epi tools, comprising more than a third of equipment order intake in Q1. One reason is that customers are using GaN for new, additional applications, most recently with fast-growing volumes in the medium-voltage class as well as residential solar photovoltaics.

In addition, to create the required production capacities, several major customers are systematically establishing high-volume manufacturing facilities, relying on Aixtron as their core supplier.

Due to the increased adoption of GaN in power electronics, order momentum continues to grow for GaN epi tools, comprising more than a third of equipment order intake in Q1. One reason is that customers are using GaN for new, additional applications, most recently with fast-growing volumes in the medium-voltage class as well as residential solar

One of these leading semiconductor manufacturers, Texas Instruments (TI), in April honored Aixtron with its 2022 Supplier Excellence Award, acknowledging close partnership in establishing its high-volume production capacity, as well as honouring the new G10-GaN MOCVD system, which it is already using. This system, which offers improved performance with much higher productivity, lower cost per wafer, and a completely new design with a considerably reduced clean-room footprint, will be officially launched later this year.

Silicon carbide business also continues to see strong growth, driven by the ongoing expansion of electro-mobility. Also here, several of Aixtron's customers continue to build up their high-volume production capacities based on the firm's equipment. The new G10-SiC system (launched in Q3/2022) is proving to be very successful, also when integrated in already running operations at customer's sites, notes Aixtron. This is yet another proof point that this SiC tool will become the top-selling product in 2023, adds the firm. In addition, Aixtron continues to win further customers with this new product.

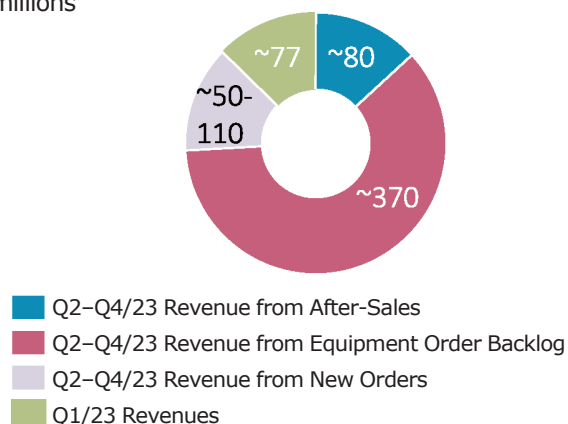
In addition, optoelectronics-related orders, particularly for lasers — whether for 3D sensing or optical datacoms — remains healthy. "In micro-LEDs, we see the

2023 Guidance¹

Total Order Intake	EUR 600m – 680m
Revenues	EUR 580m – 640m
Gross Margin (%)	Around 45%
EBIT Margin (%)	25% – 27%

Revenue Guidance FY/2023

€ millions



► research activities to develop next-generation displays based on micro-LEDs continuing worldwide with strong momentum,” says Grawert.

Order intake was hence €139.9m (up 7% on €130.2m a year ago), of which about three-quarters was for GaN- and SiC-based power electronics applications.

Equipment order backlog has accordingly risen further to €417.9m, up 19% on €351.8m at the end of Q3/2022 and up 60% on €260.4m a year ago.

“We have been asked by the authorities to add an additional layer of protection in our tools that ensures that they can only be used

for the end-applications that export licenses are requested for,” notes Grawert. “This additional mechanism has been implemented in Q1/2023 and, based on this, we expect to receive the outstanding licenses shortly. Hence, we are planning to ship the respective backlog of tools [\$70m] in the course of the subsequent quarters.”

Full-year 2023 growth guidance reaffirmed

Due to the continued strong demand and stable supply chains, for full-year 2023 Aixtron continues to expect over 9% year-on-year growth in order intake to €600–680m, based on the budgeted exchange rate of \$1.15/€ (versus \$1.20/€ in 2022).

Based on Q1’s €77m of revenue, plus equipment order backlog (convertible into 2023 revenue) of about €370m as of end-March, joined by a forecasted €50–110m in new order intake that should be convertible into revenue during 2023, plus a forecasted €80m in after-sales revenue,

Aixtron also continues to expect double-digit growth in full-year revenue to €580–640m in 2023 (including the shift of some units assembled in 2022 and shipped in 2023).

The firm also expects full-year gross margin of about 45% and EBIT margin of 25–27% for 2023.

www.aixtron.com

Aixtron introducing new Executive Committee to support CEO and CFO

New post of senior VP operations to be created

In October, deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany will introduce a new Executive Committee to support chief executive officer (CEO) Dr Felix Grawert and chief financial officer Dr Christian Danninger. Due to personal reasons, current chief operating officer Dr Jochen Linck will not renew his contract, which ends in September.

“During his time at Aixtron, Dr Jochen Linck, together with his team, has realized key initiatives like the launch of the G10 family

enabling further growth. As a result, Aixtron is well positioned and prepared for the future,” comments Kim Schindelbauer, chairman of the Supervisory Board.

The future Executive Committee will consist of the Executive Board and selected executives of Aixtron’s leadership team. The Committee will support the CEO and CFO in strategic and operational matters and will have decision-making power. This means that, for decisions, the company will draw even more on the experience of its leadership team, which

it reckons will be of great advantage in a dynamic environment like the semiconductor industry.

“With this setup, Aixtron is well positioned for the further positive development and growth in the years to come,” believes Grawert.

As of October, the Executive Board will thus consist of CEO Grawert and CFO Danninger. No new Executive Board member will be appointed to succeed Linck. Instead, the new position of senior VP operations will be created, who will be a member of the Executive Committee.

Aixtron investing €100m to build new innovation center

Aixtron has gained approval from its Supervisory Board to invest €100m in building a new innovation center at its headquarters in Herzogenrath, near Aachen, Germany.

With 1000m² of cleanroom space, the new building will create further R&D capacity for the next product generations that are already in preparation, as well as for further product development beyond that.

"With our products, we address the megatrends of digitalization, electro-mobility and energy efficiency and are experiencing a strong and steadily growing demand," says CEO Dr Felix Grawert. "Technical innovations and product developments that precisely address the needs of our customers are the key to our success. And our dynamic environment offers us further

growth opportunities," he adds. "This project will enable us to create the foundation for further product developments and for future growth."

Aixtron says that the importance of product development in the semiconductor industry is demonstrated by its new G10 system generations. In the first year after market introduction, Aixtron expects to generate more than 40% of its annual revenues with this new product generation. Soon after its official launch, the new tool for the silicon carbide material system (G10-SiC) has already generated a high order intake. Also, it is expected to continue to drive further growth all throughout 2023 and beyond.

Also, Aixtron's new solution for the gallium arsenide/indium phosphide

material system (G10-AsP) was launched at the beginning of 2023 and is already seeing strong demand. For the first time, it enables the high-volume production of micro-LEDs and photonic components such as lasers on wafers with a diameter of up to 200mm. Later in the year, the new G10 system for gallium nitride will be launched.

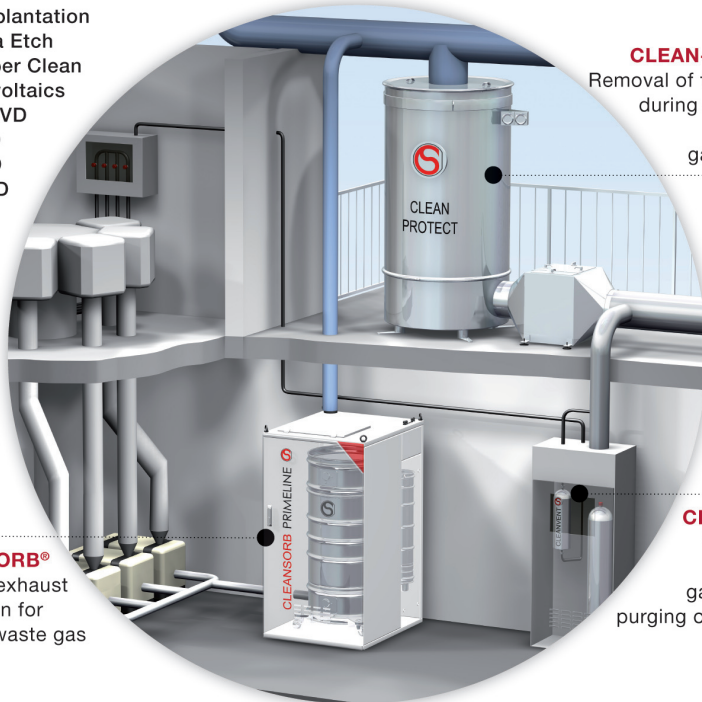
The SiC and GaN material systems have the potential to fully cover the complete range of power electronics, from electro-mobility to renewable energy technologies to fast data transmission. Due to their material properties, they can enable a significant reduction in global CO₂ emissions in these areas and help electro-mobility to achieve a breakthrough, says Aixtron.

www.aixtron.com



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EVG and Dymek form joint venture in Malaysia

EV Group Malaysia Dymek to provide customer support in SE Asia

EV Group of St Florian, Austria — a supplier of wafer bonding and lithography equipment for semiconductor, micro-electro-mechanical systems (MEMS) and nanotechnology applications — and Dymek Co Ltd of Hong Kong, an equipment distributor for the semiconductor, biomedical, data storage, photovoltaic and aerospace industries, have established a new joint venture company in Penang, Malaysia.

EV Group Malaysia Dymek Sdn Bhd will be charged with managing EVG's customer support operations in Malaysia. Hermann Waltl, executive sales & customer support director and member of the executive board at EVG, will serve as director of the new joint venture, and Sean Lim from Dymek will serve as managing director.

Working closely with EVG's headquarters, EV Group Malaysia Dymek will be responsible for numerous key regional customer support activities, including equipment installation, technical service and

support, spare-parts management and supply, and process development support. The company will be fully operational in July.

"Malaysia has been an important center for semiconductor and microelectronics packaging, test and assembly for several decades. As global investments from leading chip manufacturers and outsourced semiconductor assembly & test companies in the region continue to ramp up, it is vital that EVG strengthen its customer support infrastructure here as well," says Waltl. "Dymek has been a key strategic partner for EVG in several countries in Asia already for many years, and we look forward to partnering with them to enhance our customer support in Malaysia as well," he adds.

"This strategic move by EV Group to establish a more direct presence in Malaysia will be well received by the semiconductor and microelectronics industries of Southeast Asia," Stanley Lam, managing director Asia Pacific at Dymek Company.

"Companies here already recognize EVG as a market and technology leader in semiconductor process equipment, and now knowing they can receive local support from local engineers will only further increase their confidence and trust in EVG," he adds. "We are pleased to be working closely with EVG to grow and enhance their customer support infrastructure in Malaysia and across Southeast Asia."

EVG at SEMICON Southeast Asia

EVG was a sponsor and program speaker at SEMICON Southeast Asia at the Setia SPICE Convention Centre in Penang (23–25 May). Attendees heard about EVG's latest developments in heterogeneous integration at the Advanced Packaging Forum, where Dr Thorsten Matthias, regional sales director Asia-Pacific for EVG, presented on state-of-the-art and upcoming requirements in wafer-to-wafer and die-to-wafer hybrid bonding.

www.EVGroup.com

www.dymek.com

Aehr appoints Chris Siu as CFO & executive VP of finance

Semiconductor production test and reliability qualification equipment supplier Aehr Test Systems of Fremont, CA, USA has appointed Chris Siu as chief financial officer, executive VP of finance & secretary. He succeeds Ken Spink, who announced his planned retirement after 15 years with the firm. To ensure an orderly transition, Spink is staying on through the completion of Aehr's fiscal 2023 year (to end-May) and annual 10-K filing.

Siu has over 27 years of finance and accounting experience in the semiconductor, medical equipment, and public accounting sectors.

Before joining Aehr, he most recently served four years in senior finance executive positions at publicly traded Ultra Clean Technologies (a developer and supplier of critical subsystems, components

and parts, and ultra-high-purity clean and analytical services primarily for the semiconductor and semiconductor equipment industry) including senior VP of finance, corporate treasurer, and chief accounting officer.

Prior to Ultra Clean, Siu held senior management roles at PDFSolutions and also GlobalFoundries, where he served for eight years including leading all global accounting functions as corporate controller for four years.

He was also chief accounting officer and director of finance at Trident Microsystems and served in several senior finance management positions at medical device and software manufacturer Varian Medical Systems.

Siu also worked for three years with Deloitte and left as an audit manager, and began his career in

public accounting serving over five years with EY. He is a Certified Public Accountant (inactive) in California. Siu holds a Bachelor of Science degree in Accounting from Brigham Young University in Hawaii and a Master of Business Administration degree from the University of California at Berkeley.

"He is a seasoned executive with a proven track record of delivering strong financial and operating results with several public companies serving the semiconductor and semiconductor equipment industries," comments Aehr's president & CEO Gayn Erickson. "His wealth of knowledge and experience will be of great benefit as we continue to focus on the tremendous growth opportunities ahead for Aehr," he adds.

www.aehr.com

Aehr receives first FOX-XP order for production wafer-level burn-in of silicon photonics ICs

New FOX system configuration expands market opportunities

Aehr Test Systems of Fremont, CA, USA has received the first order for a new high-power configuration of its FOX-XP system for production wafer-level burn-in of next-generation silicon photonics integrated circuits (ICs) from an existing major silicon photonics customer.

This FOX-XP multi-wafer test and burn-in system is configured to enable cost-effective production test of the next generation of silicon photonics ICs, which can require up to 2–4 times as much power for full wafer test, burn-in and stabilization of the silicon photonics devices. Shipment of this new higher-power-configured FOX-XP is scheduled for first-quarter 2024.

"We are excited to receive this first order for this system configuration from one of the world's largest semiconductor manufacturers and expect them to order additional production systems as they ramp capacity for these devices," says president & CEO Gayn Erickson. "This new FOX production system configuration expands the market opportunities of the FOX-XP system, as it's able to test, burn-in and stabilize up to nine 300mm wafers in parallel with up to 3.5kW of power per wafer, which is beyond the wafer parallelism and power capacity of any system on the market. The system is also configured to allow direct docking to Aehr's new fully automated FOX WaferPak Aligner and material handling system."

"Multiple major semiconductor suppliers and foundries have announced their plans to manufacture and integrate silicon photonics into multi-chip packages, often now referred to as co-packaged devices or heterogenous integration, such as high-performance micro-processors, graphics processors, and processor to peripheral device chipsets," continues Erickson.

"These new devices have been predicted to dramatically improve the communication bandwidth between semiconductor devices beyond the bottleneck of traditional electrical interfaces used today. The challenge is that the devices individually can require a long production burn-in to weed out early failures or long stress tests to stabilize them before they can be assembled in the package with the other devices. This drives the need for high-volume, low-cost burn-in of these devices in wafer form, which is exactly what Aehr's FOX-XP family of test and burn-in systems have been proven to successfully achieve."

Aehr says that its FOX-XP system uses proprietary thermal chucks with a very high thermally conductive heat transfer fluid that allows direct thermal conduction transfer to apply and/or remove the wafer heat extremely efficiently and uniformly. This enables the system to control each wafer temperature very accurately at a temperature that ensures that the maximum stress conditions are applied without over-stressing any devices in the middle or at the edges of the wafer, where typical issues would occur on such high-power wafers.

"FOX systems use our proprietary and patented WaferPak full-wafer contactors that contact each device under test using precision current and voltage sources and independent measurement instruments to detect and ensure 100% traceability that every device was tested properly to the test recipe for voltage, current, power and temperature," says Erickson.

The FOX-XP with the optional fully integrated FOX WaferPak Aligner uses these proprietary WaferPak

full-wafer contactors and enables high-volume, hands-free operation using Front Opening Unified Pods (FOUPs), factory integration with SECs/GEM communication protocols, and is capable of automated material movement of wafer FOUPs with mobile robots or overhead material handling systems. The integrated WaferPak Aligner supports 100mm, 150mm, 200mm and 300mm wafer sizes using industry-standard wafer cassettes and FOUPs, which allows customers to easily support multiple wafer sizes and to move and align the wafers automatically into Aehr's proprietary WaferPaks and place the WaferPaks into and out of multi-wafer FOX-XP systems that test and burn-in up to 18 wafers at a time.

"Adding automation through our new Aligner gives our wafer-level test and burn-in offering even greater value, as well as opens up several large incremental markets to Aehr such as high-volume processors and chipsets with integrated photonics transceivers, flash and DRAM memories, and also higher-mix devices requiring extremely high reliability and 100% burn-in such as automotive microcontrollers and sensors," says Erickson.

The FOX-XP system, available with multiple WaferPak Contactors (full-wafer test) or multiple DiePak Carriers (singulated die/module test) configurations, is capable of functional test and burn-in/cycling of integrated devices such as silicon carbide (SiC) power devices, silicon photonics as well as other optical devices, 2D and 3D sensors, flash memories, gallium nitride (GaN), magnetic sensors, micro-controllers, and other leading-edge ICs in either wafer form factor, before they are assembled into single- or multi-die stacked packages, or in singulated die or module form factor.

www.aehr.com

Shipment of this new higher-power-configured FOX-XP is scheduled for Q1/2024

CompoundTek and Hyper-silicon collaborate on silicon photonics high-volume wafer edge coupling test for datacom products

Identifying known good dies on wafer, reducing die-level testing

Singapore-based silicon photonic (SiPh) foundry services provider CompoundTek Pte Ltd has formed a strategic collaboration with China-based data-center transceiver provider Ningbo Hyper-silicon Technology Co Ltd (founded in 2019) to establish cost-effective high-volume SiPh wafer edge coupling test.

The partnership leverages CompoundTek's existing wafer test solutions portfolio and aims to address the growing need for cost-effective testing capabilities with comprehensive coverage to identify known good dies at the wafer level and eliminate or reduce the need to perform die-level testing. It also taps into performance testing of the edge coupler, which is conducted in simulations akin to real-world or end-user applications, enabling SiPh product companies like Hyper-silicon to have faster yield feedback. Capturing potential excursions in the fab earlier minimizes the cost of yield dropouts in the later stages of the packaging process.

"We have been working to push the present technical boundaries in SiPh testing that allow for SiPh mass production and are excited to work with like-minded customers like Ningbo Hyper-silicon," says CompoundTek's CEO Raj Kumar (founder & CEO of holding company

IGSS Ventures). "CompoundTek believes technology innovations in cost-effective and efficient test strategies capable of detecting defective dies or dies that do not meet the expected performance at the wafer level are key to wider adoption in the SiPh wafer-level edge coupling test space," he adds.

"The high growth of demand for our product requires us to test our SiPh chips in both timely and cost-efficient ways to meet our end customer demand," says Ningbo Hyper-silicon's founder Yang Ming. "A repeatable and reliable SiPh wafer-level electro-optical testing test platform is critical to achieving this goal. CompoundTek's edge coupling wafer test solution meets our criteria, leading to improved quality control for the manufactured chips and identifying failures in the earlier assembly steps, allowing us to focus on Hyper-silicon's core competencies in chip architecture and design."

Integrating optical with electrical components on a single chip creates multiple new challenges in wafer-level testing of SiPh devices as large volumes of optical, electrical and opto-electrical device performance data are required at various stages of the product development life cycles, from prototyping to qualification and subsequently into

production. Most companies have homegrown SiPh bench solutions, typically sufficient for small-scale engineering characterization during the initial design verification phase but inefficient for the high-throughput and low-cost test required for testing from risk production to the mass-production phase. Wafer-level edge coupling gives a higher test coverage than vertical coupling, traditionally used for coupling the light during wafer testing.

An agnostic SiPh wafer test service provider with a cost-efficient wafer test solution is needed to address market gaps, including for the largest SiPh product companies that have had to cope with modified testers and limited in-house capabilities, says CompoundTek.

CompoundTek has a portfolio of 20 commercial customers and collaborates with over 20 research institutes and universities in applications such as telecoms, automotive radar, datacoms, bio-sensing, artificial intelligence, quantum computing and smart sensors. The firm claims to be one of few in the world with a dedicated SiPh wafer testing clean-room offering state-of-the-art testing capabilities through multiple collaborations with specialized SiPh hardware testing companies.

www.nc-opto.com

<https://compoundtek.com>

LayTec extends managing board contracts Roadmap working on product diversification for new applications

Optical in-situ metrology system maker LayTec AG of Berlin, Germany says that its supervisory board has extended the contracts of the two members of the managing board ahead of schedule. Volker Blank and Dr Kolja Haberland were appointed for an additional five years to continue in their current

roles. LayTec says that the decision of the Supervisory Board is a clear signal of continuity and stability, essential for the firm's further growth and development.

"As part of our roadmap, we are intensively working on product diversification by implementing new products for new applications to

position LayTec even more strongly for the future," says Haberland.

"Our focus is to continue and strengthen the successful and fruitful cooperation with our customers, partners and suppliers to provide the best possible solutions at the highest quality," adds Volker Blank.

www.laytec.de



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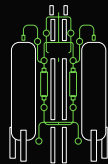
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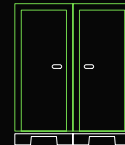
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NS Nanotech reports record red nano-LED performance

Efficiency of submicron-scale LED sufficient for commercial micro-display applications

NS Nanotech Inc of Ann Arbor, MI, USA has reported record performance for its nano-LED technology, demonstrating the first submicron-scale red LED efficient enough for commercial applications. The red nano-LED, with external quantum efficiency (EQE) greater than 8% was fabricated in the University of Michigan laboratory directed by NS Nanotech co-founder professor Zetian Mi.

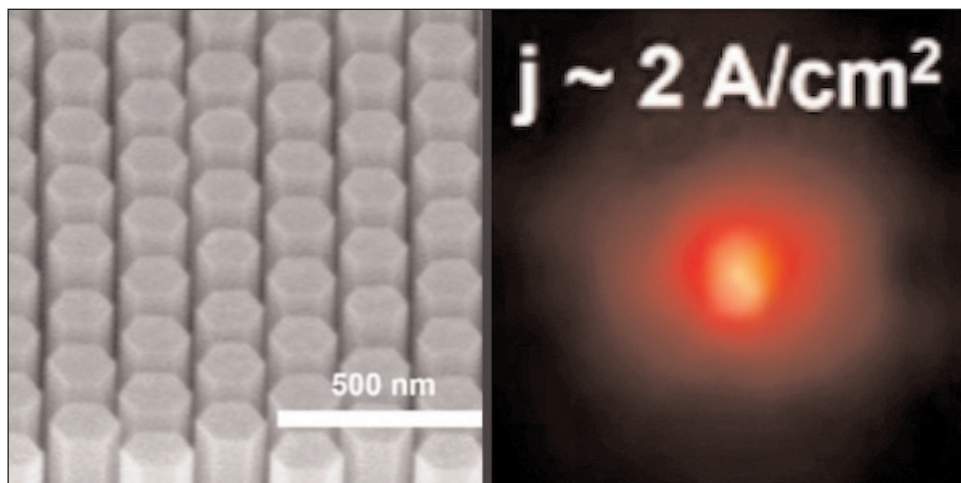
The LED is based on patented technology enabling fabrication of components that will be smaller and draw far less power than existing LED solutions, it is reckoned, while emitting brighter, more saturated, more stable and more directional light. NS Nanotech, which has exclusive licenses to LED technologies developed by Mi's research teams, is working to enable commercial manufacturing of the nano-LEDs.

The results of the demonstration and description of methods used to grow red-emitting gallium nitride (GaN) nanowire crystals were published by Mi's team in *Applied Physics Letters* (Ayush Pandey et al, 'A red-emitting micrometer scale LED with external quantum efficiency >8%', *Appl. Phys. Lett.* 122, 151103 (2023)).

Nano-LEDs capable of disrupting AR/VR micro-display market

"Our nano-LED performance breakthroughs have the potential to disrupt important emerging markets, especially for augmented reality and virtual reality headset displays," says NS Nanotech's CEO & co-founder Dr Seth Coe-Sullivan. "AR/VR eyeglasses will require easily manufactured high-performance nano-LEDs that are orders of magnitude smaller than current LEDs, and we are on a straightforward development path to get there over the next several years."

Based on exclusively licensed patent portfolios from McGill University and the University of Michigan, NS Nanotech's technology is said to



GaN nano-LEDs less than a micron in diameter (left) can be tuned to emit various wavelengths (right).

introduce new methods for growing nano-LEDs and their resulting structures. The firm intends to bring costs below the threshold required for integration of nano-LEDs into micro-displays and countless other end-products, with breakthroughs in cost and efficiency delivering performance equivalent to chips that today are ten times the size or more.

In addition to red nano-LEDs, NS Nanotech says it has demonstrated how its technologies have the potential to close the 'green gap' in efficiency that currently limits the effectiveness of green LEDs for many applications. In an article published in *Nanoletters*, Mi's group described successful fabrication of a submicron-scale green nano-LED with EQE greater than 25%, a new record

AR/VR eyeglasses will require easily manufactured high-performance nano-LEDs that are orders of magnitude smaller than current LEDs. We are on a straightforward development path to get there over the next several years

(Ayush Pandey et al, 'An Ultrahigh Efficiency Excitonic Micro-LED', *Nano Lett.* 2023, 23, 5, 1680).

UVC nano-LEDs for disinfection of COVID-19 and other pathogens

NS Nanotech says that its nano-LED technology also has the potential to deliver invisible ultra-violet-spectrum UVC light that has been proven effective in water and air purification and sterilization of medical equipment. By delivering UVC LEDs featuring the same breakthroughs in cost and performance that it delivers for multi-color micro-displays, the firm will be positioned to enable new classes of anti-viral and anti-microbial purification solutions.

"UVC light effectively deactivates numerous pathogens, including those causing viral airborne diseases such as COVID-19 and influenza," Coe-Sullivan says. "Building low-cost, high-performance UVC light emitters into the world's public and private buildings, transportation systems, schools, homes and other infrastructure where people gather will have the potential to dramatically reduce or avoid future epidemics and pandemics."

<https://pubs.acs.org/doi/full/10.1021/acs.nanolett.2c04220>
www.nsnanotech.com

Hon Hai collaborates with Ennostar and Unikorn to develop 6500PPI micro-LED micro-display with blue light brightness of 200,000 nits

Efficiency improved by optimizing micro-LED chip structures and using new thin-film protection technology

In collaboration with fellow Taiwan-based firms Ennostar and Unikorn Semiconductor Corp, at Touch Taiwan 2023 in Taipei (19–21 April), Hon Hai Precision Industry Co Ltd (Foxconn) announced the development of a new 0.12-inch micro-display with a pixel density exceeding 6500PPI and a blue light brightness of 200,000 nits, using micro-LED technology.

The purpose of the collaboration is to improve micro-LED efficiency by optimizing the structure of micro-LED chips and adopting a new thin-film protection technology, reducing surface defects, improving external quantum efficiency, and increasing product reliability.

Considering the high-brightness requirements of augmented reality (AR) applications, Unikorn — which has expertise in III-V semiconductor manufacturing and advanced process technology — was responsi-

ble for optimizing the micro-LED chip efficiency in this joint development to ensure a balance between brightness and chip power consumption during subsequent full-color conversion. Hon Hai, on the other hand, used its own developed color conversion technology to further achieve full-color display effect at 3600PPI.

For general high-PPI full-color displays, the small pixel pitch cannot provide enough quantum dot optical density, causing leakage of blue light in high-brightness scenes, resulting in blue halo and color shift among pixels, notes Hon Hai. The firm says that its micro-LED manufacturing technology, based on a semiconductor process, uses high-efficiency quantum dot color conversion and a self-developed reflective inter-pixel light shield technology to provide sufficient optical density of quantum dots and prevent color shift among pixels,

producing high-purity red and green light for full-color display effect.

Hon Hai collaborated with Ennostar and Unikorn Semiconductor for blue micro-LED process development and foundry services, and to enhance the development of a high-efficiency blue light pixel process with a pixel pitch of 4μm. The long-term goal is to invest resources in applications with the growth potential to achieve differentiation and technological innovation.

The new product can be widely used in smart glasses and AR/VR devices, and Hon Hai targets collaboration and technological innovation to expand business opportunities in the fields of virtual reality, augmented reality, and other metaverse applications.

www.touchtaiwan.com/en

www.ennostar.com

www.foxconn.com

Lumileds launches CS range of chip-on-board LEDs, joining Core and CX ranges of CoBs

LUXEON CoB LEDs now span all three common board footprints

Since there are no industry standards for the footprint or board size for chip-on-board (CoB) LEDs, over the years companies that manufacture CoB holders and optics have largely designed their products to support the three board formats that are widely adopted by lighting manufacturers, notes LED product and lighting maker Lumileds of San Jose, CA, USA. However, the firm says that, with its introduction of LUXEON CS CoBs, it now offers a full range of LUXEON CoBs in each of the common board footprints.

"OEMs choose to implement LUXEON CoBs for better efficacy, color stability and/or reliability, but

they don't want to have to redesign their system," says global product manager Noman Rangwala. "Now, with the CS CoB range, it's easy for lighting manufacturers using many of the common square board configurations to switch to LUXEON."

The LUXEON CS CoBs incorporate all the

Now, with the CS chip-on-board LED range, it's easy for lighting manufacturers using many of the common square board configurations to switch to LUXEON

advances that Lumileds has implemented and match the performance of the firm's Core and CX CoBs. The CS range is a general-purpose, high-performance CoB portfolio. The CS Pro CoBs are spectrally tuned for retail lighting where a "brighter and sharper" effect on merchandise is desired. The CS HE delivers even higher levels of efficacy for applications where energy efficiency is the driving characteristic.

The new LUXEON CS range CoBs are available now through Lumileds' global distribution network.

www.lumileds.com/products/cob-leds

Porotech unveils first monolithic full-color μ LED displays

Active-matrix 0.26-inch micro-LED display offers 1280x720 resolution

Porotech (a spin off from the Cambridge Centre for Gallium Nitride at the UK's University of Cambridge that has developed porous GaN material) has announced what it says is the first single-panel, full-color micro-display suitable for augmented reality (AR) applications.

The micro-display is based on Porotech's Dynamic Pixel Tuning (DPT) technology, where DPT micro-LED pixels can emit any visible color when driven with a specific current density. Porotech unveiled the 0.26-inch monolithic full-color micro-display, along with an AR development platform, during SID Display Week 2023 in Los Angeles (21–26 May).

Having already demonstrated how a DPT pixel can create a full range of visible colors, Porotech is now unveiling the new active-matrix 0.26-inch micro-LED display offering 1280x720 resolution, which utilizes a proprietary driving method developed by Porotech that rapidly displays red, green and blue light to enable a full-color RGB display and richly saturated colors.

Removing key manufacturing barriers

Based on existing backplane technology, the 3.5 μ m micro-LEDs are



The first single-panel, full-color micro-display suitable for AR applications, based on Porotech's Dynamic Pixel Tuning technology.

fabricated on a 4.5 μ m pixel pitch. Porotech says that its micro-LEDs emitter size can be larger while keeping the resolution because subpixels are no longer required. With DPT technology, full color native micro-LED displays can now be unlocked with a single LED epitaxial growth and a one-step wafer-to-wafer bonding to the CMOS backplane. This removes complex and low-yield manufacturing barriers inherent with alternative approaches, the firm adds.

The future of displays

Micro-LEDs are claimed to represent the leading viable solution for the future of displays in AR glasses,

offering benefits such as improved brightness, energy efficiency, contrast ratio, longer device lifetimes, reduced display size, along with greater pixel densities and resolutions. Many AR developers have been searching and waiting for a single-panel full-color solution with high pixel density and minimum form factor.

"This new single-panel full-color micro-display marks a significant milestone for Porotech and the entire micro-LED industry, as only DPT pixels can meet the specification, performance, reliability and cost required for AR glasses," reckons Porotech founder & CEO Tongtong Zhu. "Also, Porotech's DPT technology opens the market for additional display applications using micro-LEDs beyond AR/VR including smart watches, smart phones, tablets, flat-panel TVs to large panel displays for commercial outdoor signage," he adds. "We welcome potential partners and customers to co-develop and design monolithic full color micro-display panels, projectors and light engines for next-generation AR glasses or any other display applications that can leverage Porotech's DPT technology."

www.porotech.co.uk

Porotech wins People's Choice Award for Best New Display Component

Porotech has received the People's Choice Award for Best New Display Component at Display Week 2023 in Los Angeles.

What is claimed to be the first single-panel, full-color micro-display suitable for augmented reality (AR) applications, the micro-display is based on Porotech's Dynamic Pixel Tuning (DPT) technology, where DPT micro-LED pixels can emit any visible color when driven with a specific current density. Having already demonstrated how

a DPT pixel can create a full range of visible colors, Porotech unveiled the new active-matrix 0.26-inch micro-LED display offering 1280x720 resolution, which utilizes a proprietary driving method developed by Porotech that rapidly displays red, green and blue light to enable a full-color RGB display and richly saturated colors.

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www.DisplayWeek.org

Mojo Vision develops first 300mm GaN-on-silicon blue LED wafer for micro-LED display

Light-up of 300mm wafer marks progress towards micro-LED manufacturing at 300mm CMOS fabs

Mojo Vision Inc of Saratoga, CA, USA has announced a development and process milestone with the light-up of what it claims is the first 300mm GaN-on-silicon blue micro-LED array wafer, marking progress towards maturing micro-LED manufacturing at 300mm CMOS fabs.

This is Mojo Vision's fourth record in the past five years for the display industry, after setting records for the smallest, densest dynamic display including 14k pixels per inch (PPI), 20k PPI and 28k PPI.

Micro-LEDs provide critical performance, efficiency and form-factor advantages essential to applications in extended reality (XR), wearables, automotive, consumer electronics, and high-speed communications.

Mojo Vision says that it overcame extensive supply chain and wafer qualification issues, such as wafer bow and contamination concerns, to get GaN-on-silicon wafers allowed into the 300mm facility.

"At Mojo Vision we are focused on disrupting the existing display ecosystem, paving the way for scalability of the technology, and driving broader adoption in consumer and enterprise markets," says CEO Dr Nikhil Balram.

"Achieving cost-effective, large-scale manufacturing is the gap we are working to bridge with this breakthrough," he adds.

"Mojo Vision's advancements establish a roadmap for commercial scaling of micro-LED technology

using processes compatible with industry-standard 300mm fabs," comments Dr Rajeeva Lahri, advisory board member, who has over 40 years of experience in operations, R&D and business management in the semiconductor industry, including senior leadership roles at Globalfoundries, Freescale Semiconductor, National Semiconductor and Intersil.

Mojo Vision has received over \$22.4m in new Series A funding at initial close, accelerating the development and commercialization of what it claims is the world's smallest, densest micro-LED display technology for consumer, enterprise and government applications.

www.mojo.vision

Mojo Vision & DigiLens partner on AR glasses products

Mojo Vision Inc of Saratoga, CA, USA — which is developing and commercializing micro-LED display technology for consumer, enterprise and government applications — has partnered with DigiLens Inc (a developer of head-worn holographic display and waveguide technology) to integrate its micro-LED technology with DigiLens' surface relief gratings (SRG) technology and holographic waveguides for peak optimization. The partnership aims to accelerate the development of products for the augmented reality (AR)/extended reality (XR) market, combining the capabilities of each company's technology.

Mojo Vision has already debuted industry-first technology including the smallest, densest dynamic display for the first AR smart contact lens.

Micro-LED displays are a critical component for powering AR/XR immersive, experiential products

and systems. Mojo says that its high-performance micro-LED display technology has the capability to deliver the necessary resolution, performance and efficiency for advanced AR/XR systems, especially in form factors like smart glasses. Together, Mojo Vision and DigiLens aim to deliver on these requirements and enhance DigiLens' existing products for best-in-class performance in the near-term, while collaborating to drive commercialization and adoption of the next generation of AR/XR products in the long term.

"Bringing our technologies together will raise the bar on display performance, and efficiency in the AR/XR industry," reckons Mojo Vision's CEO Nikhil Balram.

"Partnering with DigiLens brings AR glasses closer to mass-scale consumer electronics. These devices require a single-panel RGB micro-LED display with very small pixels, high brightness and

efficiency, and a holographic waveguide with great uniformity, large field of view, minimal eye glow in a lightweight, compact form factor," he adds.

"Mojo's proven micro-LED technology stands out from the competition, providing the high-resolution, integrated RGB panel solution that enables a form factor small enough for AR smart glasses," comments DigiLens' CEO Chris Pickett. "Combined with DigiLens' advanced SRG+-based waveguide displays, which produce best-in-class optical efficiencies and performance, the total form factor of the AR glasses can finally be small and light enough for consumers to wear for long periods of time and bright enough to allow them to see the super-imposed digital information — even on a sunny day — without needing to darken the lenses," he concludes.

www.mojo.vision

Seoul Semi gains permanent injunction in Europe against infringing LED products

German court ruling to extend to 17 European countries from June

South Korean LED maker Seoul Semiconductor Co Ltd says that the Higher Regional Court in Düsseldorf, Germany, has issued a final judgement confirming a permanent injunction for infringement of its patent against multiple LED companies' LEDs.

The judgement extends to LED products from Everlight Electronics Co Ltd, which were distributed globally through Mouser Electronics Inc, as well as LED products from LED Engin merged into Osram GmbH. The German Supreme Court also confirmed the validity of Seoul's patent in July 2022 by dismissing a patent invalidation lawsuit brought by the accused infringer.

From June, the Unitary Patents system will be implemented in Europe. So, infringement judgements from the Unified Patent Court will simultaneously take effect in 17 European countries, including Germany, France and Italy. Hence, the deterrent effect of patent infringement judgements has significantly increased, contributing to establishing a culture that respects intellectual property rights, says Seoul Semi.

Seoul and its affiliates have hence obtained 14 permanent injunction judgements against manufacturers and distributors of infringing products in the USA and Europe over the past five years. These judgements

also include permanent injunctions, an order of recall and destruction against filament LED bulbs manufactured by a Phillips brand affiliate.

"While emphasizing ESG management, some large LED companies are merely buying and distributing infringing products under their brands in the market without manufacturing activities," says Seoul Semi's CEO Myeng-Ki Hong. "Also, some global finished goods companies continue to purchase and use these infringing products, despite being aware of the infringement," he adds. "Seoul will continue to take necessary measures against infringing companies."

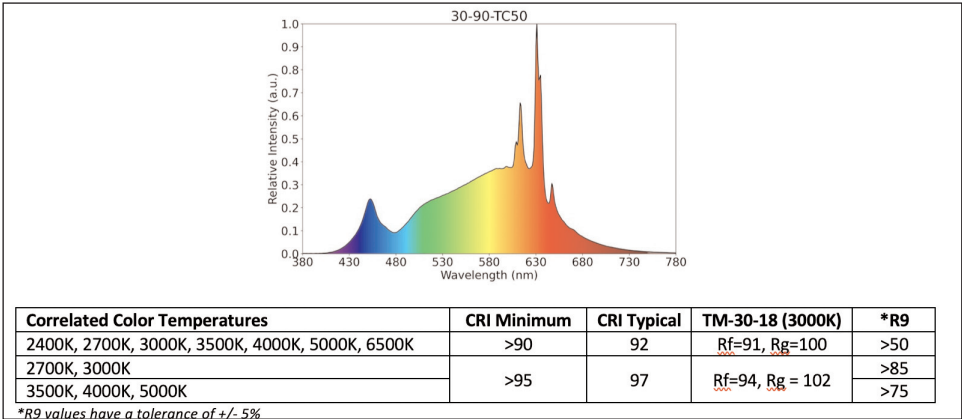
www.SeoulSemicon.com

Luminus releases LUX COB LEDs with 90 and 95 CRI

Luminus Devices Inc of Sunnyvale, CA, USA — which designs and makes LEDs and solid-state technology (SST) light sources for illumination markets — has announced the immediate availability of the LUX COB series of LEDs.

The new COBs are available with a minimum color-rendering index (CRI) of both 90 and 95 and light-emitting surface (LES) sizes from 4mm to 22mm in a variety of flux densities and a full range of correlated color temperatures (CCTs). The 90 CRI minimum delivers high-quality light with the lumen/watt efficacy of an 80 CRI source, enabling luminaire makers to reduce SKUs by eliminating the need for 80 CRI products. Both the 90 and 95 CRI minimum versions use narrow-band red phosphor (current KSF) technology to deliver what is claimed to be outstanding performance and quality of light for a variety of lighting applications including retail, residential, hospitality, architectural, museum, downlights, track lights and spotlights.

"The LUX COB series is an exciting

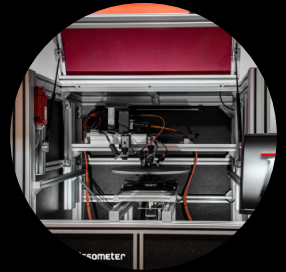
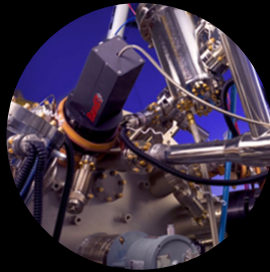
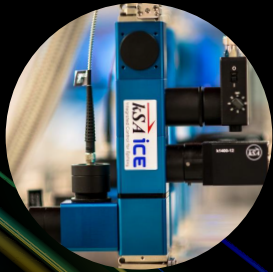


addition to the Luminus COB portfolio as they are available in not only 90 CRI minimum but we went a step further to offer an optional 97 CRI typical, 95 CRI min, with efficacy similar to what our competitors' 80 CRI COBs have been delivering in recent years," says COB product line director Dave Davito. "For example, the LUX 95 CRI min CLM-22 provides 157lm/W and the 90 CRI version reaches an amazing 176lm/W," he adds. "Luminaire makers who received prototype samples have already been loading orders on us faster than any new product in our 10-year COB history."

Luminus says lighting designers are specifying it in projects where their end-users are most discerning and demanding, such as retail lighting, museums, hospitality and high-end residential. The launch of the LUX COB series further solidifies Luminus' position without having to sacrifice efficacy. European customers in particular are planning to leverage LUX COBs to help their end-customers qualify for energy-efficiency rebates, which require the entire fixture system (including optics and drivers) to achieve 120lm/W.

www.luminus.com/products/cobarrays/lux-cob

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Sparrow Quantum raises €4.1m in seed funding

InAs/GaAs quantum dots emitting at 920–980nm form single-photon source on 3mmx3mm chip

Sparrow Quantum of Copenhagen, Denmark has secured DKK31m (€4.1m) in a seed funding round led by London-based venture capital firm 2xN joined by LIFTT and the European Innovation Council (EIC).

Sparrow Quantum targets light-matter interfaces for quantum technologies by bringing foundational quantum photonic components to market. Deterministic light-matter interfaces have widespread applications in quantum technology; they constitute foundational hardware allowing fully secure quantum communication, a quantum internet for wiring up the world with quantum entanglement, or a scalable quantum computer based on photons.

Based on indium arsenide/gallium arsenide (InAs/GaAs) quantum dot structures embedded in photonic crystal waveguides emitting at wavelengths of 920–980nm, Sparrow's first product is an on-chip (3mmx3mm) single-photon source that provides long strings of more than 100 single photons without deteriorating quality and at a rate of more than 20 million single photons per second in fiber that can be directly

deployed for, for example, multi-photon quantum simulations or quantum key distribution experiments. Offering what is claimed to be record efficiency and photon indistinguishability, Sparrow's single-photon sources are expected to promote new avenues for research and enable photonic quantum technology researchers to conduct their experiments more efficiently and cost-effectively. Furthermore, Sparrow plans to become a trusted component provider in the quantum industry supply chain by teaming up with developers of quantum technology systems to incorporate its single-photon sources into large-scale commercial quantum systems.

Sparrow's technology results from over two decades of research by founder professor Peter Lodahl and his quantum photonics research group at the Niels Bohr Institute (NBI) in Copenhagen. Lodahl was the first to demonstrate that light emission can be fully controlled using intricate photonic nanostructures. He currently heads the Hybrid Quantum Networks Hy-Q Center of Excellence, which is

developing new quantum hardware for quantum-information science, such as deterministic single-photon sources, spin-photon interfaces, and photonic quantum gates.

With this seed investment, Sparrow aims to accelerate the development of its products and services, expand its team, and strengthen its position in quantum light-matter interfaces and next-generation single-photon sources for commercial quantum technologies.

"Thanks to this investment, we can continue to develop our single-photon source and accelerate its market entry," says Lodahl.

"Moreover, we can start executing our roadmap of how to make our foundational technology the chosen approach in advanced quantum systems applications within quantum communication and quantum computing."

"This funding will allow us to advance our development of light-matter interfaces for commercial quantum technologies and bring our next-generation products to market faster," says Sparrow's CEO Kurt Stokbro.

www.sparrowquantum.com

BluGlass secures GaN laser purchase orders for testing in quantum sensing and surgical applications

BluGlass Ltd of Silverwater, Australia — which makes gallium nitride (GaN) blue laser diodes based on its proprietary low-temperature, low-hydrogen remote-plasma chemical vapor deposition (RPCVD) technology — has secured two new GaN laser purchase orders from a "quantum photonics pioneer" and a "leading medical device manufacturer".

Orders span BluGlass' 405nm, 420nm and 450nm GaN laser product suite and include the first order of its early prototype higher-powered 405nm 3W multi-mode lasers in flexible form factors.

"Our lasers will be used for testing in novel quantum sensing and surgical applications," says CEO Jim Haden. "Our single-mode lasers in violet and blue wavelengths are increasingly sought after as they are ideal for biomedical, robotics and quantum applications," he adds.

"We are also experiencing strong interest in our advanced roadmaps and higher-powered lasers, securing the first order of 50 alpha 3W multi-mode violet prototypes for deployment in medical applications," Haden continues. "Ongoing enhancements to our launched product offering

are driving conversion efficiency and reliability improvements. If our alpha lasers test well then, once the company moves to volume production of more mature devices, these customers have the potential to place large, recurring purchase orders for high-volume applications."

BluGlass says these initial orders are immaterial from a revenue perspective. The firm has begun fulfilling customer orders and is in advanced discussions with multiple potential customers across its key market segments.

www.bluglass.com.au

The UCS300-SC Wafer Cleaning System from Optimal Technologies provides unquestionable results

The fully automated ultrasonic cleaning system removes any contaminants and particles that have been deposited on the wafer surface, this is achieved through a precise combination of:

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- Proven Cleaning technology
- Batch processing up to 300mm



The high performance UCS300-SC provides unmatched cleaning capabilities to ensure maximum productivity and a contamination free surface every time

NUBURU delivers first blue-laser-powered area 3D printer light engine

Laser delivered to technical partner for US Air Force contract

NUBURU Inc of Centennial, CO, USA — which conducts research, development, design and manufacturing of high-power, high-brightness industrial blue lasers — says that in first-quarter 2023 it delivered what it claims is the world's first blue-laser-powered area 3D printer light engine to its technical partner under a contract with the US Air Force.

The goal of this Direct to Phase II contract is to use the absorption advantages of the blue laser and combine it with the ability to project an image onto the powder bed

using a Texas Instruments Digital Light Projector to dramatically increase the speed of 3D printing of metal parts. NUBURU delivered the light engine to its partner to integrate it into a 3D printer.

The speed increase is the result of using an image that is up to 30,000 times larger than the single spot used today while delivering the same resolution as today's printers. This 3D printing architecture can be scaled to enable high-density materials to be printed at speeds of 100x or greater while dramatically reducing CO₂ emissions. In a

separate study, NUBURU has shown up to a 2.75 times reduction in CO₂ emissions when printing stainless-steel parts compared with an infrared laser.

NUBURU says that its investment in these technologies has helped it to develop what it reckons is a robust intellectual property platform, including over 190 patents and patent applications. These patents broadly cover laser technology including certain IP that has been deemed classified by the US government.

www.nuburu.net

NUBURU reports Q1 revenue of \$0.47m

Full-year 2023 guidance reiterated after additional cash raised

For first-quarter 2023, NUBURU Inc of Centennial, CO, USA has reported revenue of about \$0.47m (up on \$0.09m a year ago) after it launched and began taking orders for the new BL Series laser.

Founded in 2015, NUBURU is a developer and manufacturer of industrial blue lasers that leverage their high-brightness, high-power design to produce fast, high-quality laser materials processing.

"We have seen continued forward progress in our key markets of welding, 3D printing and defense," says CEO & co-founder Dr Mark Zediker.

During Q1/2023, NUBURU continued to deliver units to Essentium as part of a multi-year partnership focused on metal 3D printing for the aerospace,

automotive and defense markets.

The firm also delivered the world's first blue 3D printer light engine to a technical partner under a contract with the US Air Force.

"Our work with the US Air Force and our ongoing partnerships underscore the building momentum in our commercial pipeline," says Zediker.

In addition, NUBURU was selected by the US Department of Defense for participation on a firm-fixed-price, indefinite-delivery/indefinite-quantity, multiple-party award contract with a maximum ceiling of \$75m.

"Our performance in the first quarter highlights the continued customer adoption of our blue laser technology in critical applications and materials," comments Zediker.

Net cash used in operating activities during Q1/2023 was \$4.05m (more than doubling from \$1.9m a year ago). Capital expenditure (CapEx) was \$0.345m (up from \$0.1m a year ago). Free cash flow was hence -\$4.4m (more than doubling from -\$2m a year ago).

As of end-March, cash and cash equivalents were \$1.52m. However, additional cash has since been received by the company.

NUBURU has reiterated its full-year 2023 guidance of revenue in excess of \$3m, EBITDA (earnings before interest, taxes, depreciation and amortization) in the range of -\$21m to -\$23m, and free cash flow in the range of -\$24m to -\$26m. The firm believes that it has access to sufficient sources of capital to fund this business plan.

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NUBURU and GE Additive sign joint development agreement

Blue laser technology to improve speed and accuracy of laser-based metal additive manufacturing

NUBURU Inc of Centennial, CO, USA — which conducts research, development, design and manufacturing of high-power, high-brightness industrial blue lasers — has signed a joint technology agreement with metal additive design and manufacturing firm GE Additive (part of GE) to explore the speed, accuracy and commercial benefits of blue laser-based metal 3D printing.

"As we continue to advance our proprietary blue laser technology, we have further increased both power and brightness to open up new applications. We've achieved key performance milestones that open new possibilities for significant advances in metal 3D printing," says NUBURU's CEO & co-founder Dr Mark Zediker. "Working with GE Additive, and their expertise in metal additive manufacturing, will

allow us to rapidly optimize our innovative area printing approach. That will accelerate the further expansion of our pioneering blue laser into innovative metal 3D printing solutions which have the potential to change the landscape of military logistics; aerospace manufacturing; medical device fabrication, and beyond," he adds.

"As an industry leader in metal 3D printing and having been on the leading edge of qualifying parts in regulated industries, we're excited to evaluate NUBURU blue industrial laser technology and its benefits," says Chris Schuppe, general manager Engineering & Technology at GE Additive.

NUBURU's approach to additive manufacturing is built on the foundation of blue light absorption by metals, a fundamental physical

advantage that offers the highest-efficiency laser-based melting for a wide range of industrially important metals. Combining the blue laser module with an optical conditioning system, the NUBURU light engine is at the heart of the expected performance improvements.

GE Additive will provide a powder bed system and expertise in the integration and characterization of this next-generation prototype light engine, to quantify the performance improvements over existing technology.

The joint development agreement is in addition to an agreement with GE Additive to support NUBURU's previously announced AFWERX Small Business Innovation Research (SBIR) Phase II contract awarded to NUBURU in 2022.

www.ge.com/additive

NUBURU delivers first blue laser units to additive manufacturing firm Essentium

Initial execution of a multi-year, multi-million-dollar agreement

NUBURU says that multiple units were delivered to industrial additive manufacturing (AM) firm Essentium Inc. This signifies the initial execution of a multi-year, multi-million-dollar agreement (jointly announced in May 2022) to develop and manufacture a blue laser-based metal AM platform. As a result of this technology integration, Essentium expects strong growth across new applications and markets.

Essentium has begun integrating NUBURU's proprietary blue laser technology with its High Speed Extrusion (HSE) 3D printing technology. The new AM platform is designed to deliver breakthrough throughput for extremely high part quality and broad-scale use in

major industrial markets, including automotive, aerospace and defense.

"We look forward to delivering additional units [to Essentium] over the course of 2023 and the coming years," says NUBURU's CEO & co-founder Dr Mark Zediker.

Essentium launched EPOD (Essentium Parts on Demand), an in-house production service using its HSE 3D printing technology, in March. The service offers fast and cost-effective production of parts at scale as well as access to Essentium's open AM ecosystem of solutions. NUBURU is supporting Essentium's growth through partnerships with existing additive manufacturing service providers and manufacturing marketplaces.

"NUBURU's unparalleled expertise and leadership in blue laser technology have been instrumental in advancing our cutting-edge 3D printing platform," comments Essentium's chief technology officer & co-founder Elisa Teipel Ph.D. "The arrival of the latest units this year and our partnership with NUBURU will help us continue to drive innovation in the AM industry," she adds.

Essentium is also said to be leveraging access to NUBURU's intellectual property related blue laser technology, including patents granted in the USA, Japan, China and South Korea.

www.essentium.com/3d-printers
www.nuburu.net

TRUMPF expanding laser production site VCSELs enabling proximity sensor in Apple iPhone

TRUMPF Photonic Components GmbH of Ulm, Germany (part of the TRUMPF Group) has been highlighted by Apple as a key supplier for its work supporting the proximity sensor in iPhone, which turns off the screen when it detects an object that is close by (e.g. when a user holds iPhone up to their ear), saving power and preventing inadvertent touches.

"We have already shipped over 1 billion of our vertical-cavity surface-emitting lasers (VCSELs) to Apple," notes CEO Berthold Schmidt.

TRUMPF's components have long been used for a number of Apple



products. "This success points out the huge potential of our VCSEL technology. Therefore, we plan to further expand our production site in Ulm with about 750m² within the next year, to guarantee high-volume, high-end manufacturing of

laser components for our customers," Schmidt says.

TRUMPF has already invested more than €40m into the high-end facility since it took over the business in 2019. With the manufacturing equipment, TRUMPF implemented a new technology platform, to yield a highly reliable process and high-performance laser components. Further investments to be made within the next five years will amount to tens of millions of euros, depending on project developments.

www.trumpf.com/s/VCSEL-solutions
www.apple.com

PARALIA to develop LiDAR/radar optical multi-beam beam-forming platform based on multi-port linear optical operator architectures using InP and SiN integration Thessaloniki-led European Union HORIZON project targets automotive and aerospace applications

PARALIA (Photonic Multi-beam Beamforming Technology enabling RADAR/LiDAR Multisensor Fusion platforms for Aerospace and Automated Driving applications) is a new EU HORIZON Research and Innovation Actions Project launched on 1 January that aims to develop fundamental innovations in automotive and aerospace applications. Funded under the HORIZON-CL4-2022-DIGITAL-EMERGING-01-03 Call (project number 101093013), PARALIA is coordinated by Greece's Aristotle University of Thessaloniki and runs from January 2023 through to June 2026.

The milestones achieved in the on-going global race for highly automated or autonomous vehicles are setting the stage for major transformations across the transportation industry, led primarily by the expected wide adoption of Level 2 and Level 3 automated driving systems in next-generation automotive vehicles, the forward-looking roadmaps of major technol-

ogy vendors, predicting next-generation consumer-centric fleets of robo-taxis and the growing maturity and expected proliferation of autonomous or Enchanted Flight Vision System (EFVS)-augmented Urban Air Mobility. However, transforming these technological concepts into tangible reality has been proving challenging, with recent studies urgently calling for a new generation of integrated, cost-effective and multi-domain sensory systems, capable of providing machine learning (ML) algorithms with the required heterogeneous environmental information in a low-energy envelope.

PARALIA aims to demonstrate breakthrough performance by enabling an agile, low-cost and energy-efficient multi-sensor that combines radar and light detection & ranging (LiDAR) technologies and by re-architecting the sensors ecosystem, enabling ultra-high resolution at ultra-long distances, which is crucial for existing and

future automotive and aerospace applications.

PARALIA aims to develop a powerful common LiDAR/radar optical multi-beam beam-forming platform based on best-in-class multi-port linear optical operator architectures exploiting the synergy of indium phosphide (InP) and silicon nitride (SiN) integration platforms.

The consortium brings together six leading industrial partners, and three academic and research institutes in the photonic integrated circuit (PIC) and photonic system value chain. Project participants are the Aristotle University of Thessaloniki and the Institute of Communication and Computer Systems (Greece), Argotech a.s (Czech Republic), Collins Aerospace Ireland (Ireland), LioniX International (Netherlands), SIKLU Communication Ltd (Israel), Sivers Semiconductors (Sweden), VALEO Autoklimatizace K.S. (Czech Republic) and Fraunhofer Heinrich Hertz Institute (Germany).

<https://paralia-horizon.eu>

Sivers initiates Photonics foundry capacity project and makes management changes

Possible new fab site in EU or USA, including strategic partnerships

Sivers Photonics of Glasgow, Scotland, UK (a business unit of IC and integrated module supplier Sivers Semiconductors AB of Kista, Sweden) is evaluating how to expand its capacity to meet volumes of over 1000 wafers per week. To make this possible Sivers Semiconductors has formed a strategic business development project, hired an advisor, and made changes in Photonics management.

For almost five years, Sivers Photonics has been working with what are described as very significant customers that are now getting closer to possible volume production. So far, these customers have spent more than \$15m in development to secure the path to volume production. For Sivers Photonics to reach volume production with one or several of these customers, it

needs to expand capacity and production capabilities.

Sivers Semiconductors has hence formed a strategic project to look at a possible new fab site within the European Union (EU) or the USA, including strategic partnerships in the Photonics space. Sivers has hired a new advisor to lead this project, and the current Photonics managing director William McLaughlin will join the project to capture what Sivers believes is a significant market opportunity. Sivers Photonics' chief technology officer & co-founder Dr Andrew McKee will assume the role of interim managing director of Sivers Photonics.

The project will also look at possible funding alternatives including Chip Act funding announced by both the EU in the EU Chips Act (involving €43bn to boost chip pro-

duction within EU) as well as by the US government with the CHIPS and Science Act (including \$39bn for chip manufacturing on US soil).

"With the first order of approximately 30,000 chips that will be delivered in this quarter, we are now seeing a clearer path towards volume production," says Sivers Semiconductors' group CEO Anders Storm. "By forming a strategic project, hiring an advisor, and giving Billy [William McLaughlin] the possibility to focus on developing capacity and capabilities of the Photonics business unit, we believe that we have the best possibility to secure the right solution for the next phase," he adds. "In addition, Andy McKee will secure the stability and performance of the existing Photonics business."

www.sivers-semiconductors.com

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Hamamatsu Photonics constructing new building at Miyakoda factory to boost laser production

Completion in July 2024 targets operation by October

In May, Japan-based Hamamatsu Photonics K.K. held a groundbreaking ceremony for the construction of a new building (costing about ¥4bn) at its Miyakoda Factory site in Shinmiyakoda, Kita-ku, Hamamatsu City, Shizuoka Prefecture.

Scheduled for completion in July 2024 followed by starting operation that October, the 1780m² Building No. 4 (with four storeys, providing total floor space of 6720m²) will accommodate about 160 staff and increase production capacity to about 25 million lasers per year (converted to single chips) in response to the increasing demand for semiconductor lasers essential in light detection & ranging (LiDAR) applications.

Hamamatsu Photonics develops, manufactures and sells semiconductor lasers and laser oscillators used in fields including measurement, analysis, laser processing, factory automation and medical applications. This includes optoelectronic devices requiring a broad range of laser types.

Sensing technologies using light are now utilized in a vast range of diverse applications including LiDAR, which uses semiconductor lasers for contact-free and high-precision measurement of the position and shape of objects over long distances, and is currently applied to autonomous driving. They are also present in many other applications including public transportation infrastructure, automated transport, and autonomous mobile robots.



Artist's impression of Miyakoda Factory Building No. 4.

A vast expansion in the LiDAR product market can hence be expected in the future, says Hamamatsu.

Hamamatsu's new building at the Miyakoda Factory site will consolidate post-processing steps (after wafer process) in semiconductor laser manufacture. Currently, these are dispersed to different locations in the factory site. Construction of the new factory building will expand production space to meet ever-increasing product demand. This newest building will allow the firm to optimize workflow lines between production processes and also install the latest in manufacturing and inspection equipment. This will promote process automation and efficiency, hence improving productivity, reckons the firm.

The factory has an earthquake-resistant design to make it more disaster resilient and proactively incorporates eco-friendly measures such as heat-insulating structures and solar power generation systems.

"We are one of the very few companies in the world that manufactures both photodetectors and light sources," claims Hamamatsu Photonics. "This gives us the advantage of being able to propose an optimum set of photodetectors and light sources that are specifically designed, developed and manufactured to match each application," it adds. "Taking this advantage, we aim to expand sales of semiconductor lasers, including those for LiDAR."

www.hamamatsu.com

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Lynred breaks ground on €85m site for infrared detector manufacturing

Production capacity to rise 50% by 2025 then double by 2030

Lynred of Grenoble, France, which designs and manufactures infrared detectors for aerospace, defense and commercial applications, has broken ground on its biggest construction investment since it began manufacturing in 1986 — a new €85m (\$93.7m) 'Campus' industrial site for producing infrared technologies.

Financed by loans from the CIC bank and Bpifrance, the project will double Lynred's existing cleanroom footprint, totaling 8200m² (88,264ft²), primarily to meet two strategic objectives:

- obtain an optimal cleanroom cleanliness classification for its new high-performance products (hybrid detectors);
- increase the production capacity for its more compact industrial products (bolometers) used in multiple fields, including the automotive industry.

Lynred reckons that the investment will consolidate its position as European market leader in infrared detection (and the world's second largest IR detector manufacturer). It enables the firm to play a key role in the European defense industrial and technological base, innately woven into strengthening French and European forces, for whom infrared detection is hugely important. With this, Lynred is taking a step up in responding to the French government's call to reorient European industry towards a 'rearmament economy'.

"This will enable us to respond to growing market demand for next-generation infrared technologies, including in the automotive sector.



It will allow us to contribute to bolstering France's industrial sovereignty and, more generally, to improve our overall industrial performance," said Lynred's chairman Jean-François Delepau, who thanked the firm's partners for support, particularly shareholders Thales and Safran. "Lynred is embarking on a new strategic pathway, both in terms of technology and dynamic growth," he added.

Building is due for completion in the first trimester of 2025, with the site fully operational by the following October. The industrial facility will comprise 8200m² (88,264ft²) of interconnected cleanrooms (twice the existing surface area), 3400m² (36,600ft²) of laboratories, a 2300m² (24,756ft²) logistics area, and a tertiary and technical area of 10,800m² (11,625ft²).

Lynred aims to increase its production capacity by 50% by 2025, in particular for its bolometer

products, with a view to doubling capacity by 2030.

With these new cleanrooms the company will house all of its French production lines in a single location, enabling synergies among core competences and optimizing production flows, it is reckoned.

The new buildings will be located on the existing Lynred site in Veurey-Voroize, in the Grenoble area. They have been designed to ensure optimized energy management and environmental performance: even with 13,600m² (146,400ft²) under construction, the volume of permeable surface will increase. The firm will cut its carbon footprint by 33% and will install 1800m² (19,375ft²) of solar panels. Moreover, the site will accommodate an additional 320 trees, and over 100 charging stations for electric vehicles (cars and bicycles) will be put in place, with more cycle parking added.

www.lynred.com

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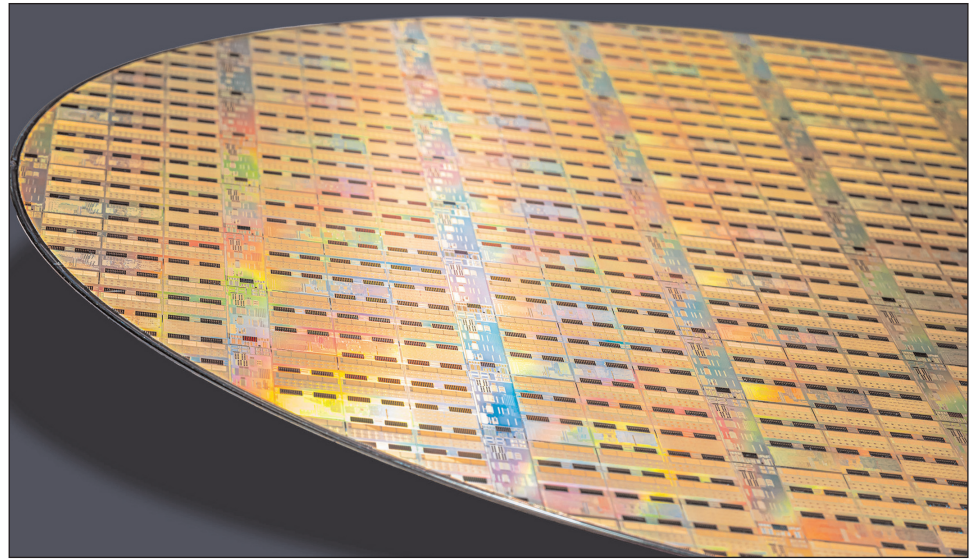
Ayar Labs adds \$25m in expansion of \$130m Series C funding round

Funding fuels acceleration of optical I/O roadmap supporting generative AI, machine learning and HPC applications

Silicon photonics-based chip-to-chip optical connectivity firm Ayar Labs of Santa Clara, CA, USA has raised an additional \$25m in Series C1 funding, bringing its total Series C raise to \$155m. The oversubscribed up-round was led by new investor Capital TEN. VentureTech Alliance also entered the Series C expansion that included participation by previous investors Boardman Bay Capital Management, IAG Capital Partners, NVIDIA, and Tyche Partners. Past strategic and financial investors include Applied Ventures, GlobalFoundries, Hewlett Packard Pathfinder, Intel Capital and Lockheed Martin Ventures.

"Future computing solutions will include large-scale use of silicon photonics for data communications, and have been following Ayar Labs for some time now," comments Pin-Nan Tseng, general partner at Capital TEN. "Given our deep expertise in the semiconductor industry and the Taiwan semiconductor ecosystem, we believe Ayar Labs has the technology solution, people, capital and broad support to lead in the transition from copper to optical interconnects for scale-out computing and memory applications."

Ayar Labs' patented optical I/O approach uses industry-standard, cost-effective silicon processing techniques to replace traditional electrical I/O with fast, high-density, low-power optical I/O chiplets and multi-wavelength light sources. Moving data between chips using light instead of electricity breaks the performance, power and distance limitations of copper interconnect, critical for latency-sensitive applications such as high-performance computing, artificial intelligence (AI) and machine learning. Optical I/O will also impact other areas that require rapid transfer of data, such as cloud



and data center, telecommunications, and aerospace and defense.

"This C1 adds sophisticated investor partners that will allow us to accelerate our strategic roadmap, and is further validation of our technology and plan to bring silicon photonics-based interconnect solutions to market at scale," says Ayar Labs' CEO Charles Wuischpard.

Ayar Labs will use the funds to accelerate the implementation and commercialization of its optical I/O solutions to address the power consumption, latency, reach and system bandwidth bottlenecks that threaten future advances in generative AI, while also expanding the

firm's product offerings and development efforts.

NVIDIA, which participated in Ayar Labs' earlier Series C raise in April 2022, increased its investment in the company. "NVIDIA is reimagining the data center with integrated hardware, software and networking for accelerated computing," says Craig Thompson, VP of business development for NVIDIA's Networking business unit. "Generative AI models with trillions of parameters are accelerating demand for this platform, which is why we are increasing our investment in Ayar Labs."

Recently named one of America's Best Startup Employers by Forbes, the funds will also help the firm to increase its hiring plans by up to 50% this year. Also in recent months, Ayar was recognized as an honoree in Fast Company's most recent 'Next Big Things in Tech' awards. In addition, co-founder, chief technology officer & senior VP of engineering Mark Wade was recently appointed to Global Semiconductor Alliance's CTO Council. Wade was also recently named to Electro Optics' inaugural 'The Photonics 100 2023' list.

www.ayarlabs.com

Ayar Labs will use the funds to accelerate the implementation and commercialization of its optical I/O solutions to address the power consumption, latency, reach and system bandwidth bottlenecks that threaten future advances in generative AI

POET Starlight launched for AI market

Advanced purchase order received from Celestial AI

POET Technologies Inc has launched POET Starlight, a packaged light source solution for AI applications.

The firm has also entered into an agreement with Celestial AI of Santa Clara, CA, USA, creators of the Photonic Fabric, for the development and production of POET Starlight packaged light sources and has received an advanced purchase order for initial production units.

"POET's Starlight chips and its technology roadmap are complementary to our advanced silicon photonics and system-in-package technologies," notes Celestial AI's co-founder & chief operating officer Preet Virk. "We are pleased to continue our collaboration with POET Technologies, building on its optical interposer technology to enable us to meet our performance, scale and cost targets."

Starlight products are packaged light engines based on POET's LightBar platform, demonstrated at March's Optical Fiber Communication Conference (OFC) in San Diego. Chip developers are working to re-design the core of computer architecture to incorporate light for communication between chips or to

perform complex computations, all in an effort to eliminate the bandwidth and power-efficiency bottlenecks inherent in electronic devices. Each such chip requires one or more light sources able to provide several frequencies of light integrated into the fabric of the device.

Starlight products integrate active components like lasers and certain other passive optical and electrical components into the optical interposer to provide a complete light source solution that can be integrated on a host board and connected to chips and ASICs with built-in silicon photonics. POET achieves its low-cost solution through the use of features and benefits of the POET Optical Interposer platform and the 'semiconductorization' of photonics fabrication processes.

"External light sources for artificial intelligence applications has been one of the key verticals for POET," says chairman & CEO Dr Suresh Venkatesan. "We are delighted to continue to work with Celestial AI to provide a high-volume manufacturable solution for their optical interconnect technology platform," he adds. "The ability for POET to

passively attach high-power CW [continuous wave] lasers on its optical interposer at wafer scale enables the use of single known-good laser chips and eliminates the need for laser arrays, which can be cost prohibitive for high-volume applications. The POET team has worked closely with Celestial AI to define a low-cost packaging solution that is up to 75% lower in cost than competing solutions and is highly scalable for the volumes that Celestial AI is projecting."

Starlight C- and O-band LightBar products incorporate monolithically integrated passive components like multiplexers, demultiplexers, splitters, combiners and waveguides. Known-good high-power CW lasers and monitor photodiodes are flip chipped and passively attached to the optical interposer platform. POET expects to complete design verification testing and reliability qualification of the Starlight engines by the end of 2023 and start production in second-half 2024. The size of the AI chip market is projected by Allied Market Research to reach \$263bn by 2031.

www.poet-technologies.com

POET cuts losses in first-quarter 2023

For first-quarter 2023, POET Technologies Inc of Toronto, Ontario, Canada — designer and developer of the POET Optical Interposer, photonic integrated circuits (PICs) and light sources for the data-center, telecom and artificial intelligence (AI) markets — has reported non-recurring engineering revenue (NRE) of \$181,000 (down from \$200,000 last quarter but nil a year ago). This comprised services to multiple customers (one of which continued to contract services from last year) relating to unique projects utilizing the capabilities of the POET Optical Interposer.

Net loss has been cut from \$6.3m (\$0.17 per share) last quarter to

\$5.3m (\$0.14 per share), with R&D costs cut from \$2.7m to \$2.3m.

Operating cash flow was -\$4.4m, up from -\$2.7m last quarter. However, since 1 January, the firm has received \$7.4m from the exercise of warrants by insiders and warrant holders.

"We've made significant progress on our commercialization roadmap with the recent purchase orders from world-class customers as well as our introduction of important new products," says chairman & CEO Dr Suresh Venkatesan. "Our work with leading companies like Celestial AI and Beijing FeiYunYi Technology further validate the commercial viability of our optical

engines and other optical interposer-based products," he adds. "POET's Infinity optical chiplet solution received wide praise when demonstrated as part of a highly integrated 800G transceiver module at the OFC 2023 conference in March. Additionally, we announced our POET Starlight products, which are packaged light engines based on our LightBar platform and an ideal solution for AI applications. The creation of this product, while significant, was a seamless modification of the POET Optical Interposer, underscoring the flexibility of our core technology and its relevance across a wide spectrum of data communications applications."

Emcore doubles revenue projection for last-time buys of Broadband products to \$20m

Majority of InP wafer operations to finish by end-August

Emcore Corp of Alhambra, CA, USA — which provides inertial navigation products to the aerospace & defense sector from manufacturing facilities in Budd Lake, NJ and Concord, CA — expects revenue from last-time buys of Broadband products to be about \$20m, up from the projected \$10m. Margins should be consistent with the historical margin performance for these products.

"In our fiscal second-quarter 2023 earnings release, we indicated that last-time buys for products in our broadband business would total approximately \$10m. As of today, our Broadband backlog stands near

\$20m, with some opportunity for additional upside," says president & CEO Jeffrey Rittichier. "Shipments of these products are being scheduled and are expected to largely be complete by the end of the calendar year 2023."

Emcore expects indium phosphide (InP) wafer production supporting Broadband products to conclude by end-July, and most InP wafer operations to finish by end-August. Electronics manufacturing services (EMS) assembly for Broadband products should be complete by about the end of 2023.

During this period, Emcore

expects to complete its planned headcount reduction of about 100 employees (primarily in Alhambra and China) as Broadband operations wind down. Emcore is consolidating facility space by downsizing the space being occupied at the Alhambra campus from five to two buildings, relocating personnel in Concord, to the operations area from the adjacent office building, and closing the manufacturing support and engineering center in China. The firm expects restructuring actions to be substantially completed by end-September.

www.emcore.com

First volume purchase order for POET's optical engines

POET Technologies Inc of Toronto, Ontario, Canada — designer and developer of the Optical Interposer, photonic integrated circuits (PICs) and light sources for the data-center, telecom and artificial intelligence (AI) markets — says that the first volume production order for its optical engines have been placed with 80%-owned joint venture firm Super Photonics Xiamen (SPX).

Valued at more than US\$3m, the purchase order was placed by Beijing FeiYunYi Technology Ltd (BFYY), which will produce optical transceiver modules using POET-designed optical engines for sale to telecom and data-center markets globally. This initial volume purchase order was placed against BFYY's 3-year forecast of US\$30m in expected optical engine purchases.

With deep connections to the telecom sector in China, BFYY is investing heavily in transceiver module design and manufacturing to build, market and sell optical transceiver modules specifically focused on large telecom and data-center service providers. The modules incorporate Optical Interposer-based optical engines which are assembled with compo-

nents, tested and sold by POET's 80%-owned JV company SPX.

"POET and Super Photonics have demonstrated the superior performance and design of these optical engines," comments BFYY's CEO Wei Zhang (Wesley Zhang). "There is ongoing close collaboration among our engineering and manufacturing teams to complete the design and start production. Feedback from our customers is extremely positive and we want to quickly ramp to high-volume production to service the telecom market."

POET had previously unveiled the POET ONE single-chip optical engine solution incorporating complete transmit and receive functionalities for implementation in a 100G optical transceiver. POET ONE offers what is said to be significant performance advantages and minimizes the transceiver design cycle time for BFYY. In addition to the cost benefits of POET's wafer-scale assembly, POET ONE will enable BFYY to speed the design and qualification cycle with customers and ramp to high-volume production and sales.

"With this purchase order, POET and SPX have both achieved major

commercial milestones for our optical engines and for the companies overall," says Vivek Rajgarhia, president & general manager of POET and vice-chairman of SPX.

"A production order of this size validates the commercial viability of our optical engines and other POET Optical Interposer-based products that are specifically designed to be scalable in volume, cost and power consumption, well ahead of current industry demands," he adds. "Our fundamental differentiation in bringing wafer-scale die attach, passive optical assembly, and chip-scale manufacturing represents the true 'semiconductorization' of photonics. Our partnerships with world-class component vendors, combined with the POET Optical Interposer platform, allows us to serve the needs of customers like BFYY in a highly competitive market with a truly differentiated technology."

POET and SPX expect to complete the design verification testing and reliability qualification of POET ONE by Q4/2023 and then start production shipments to BFYY in early 2024.

www.poet-technologies.com

Lumentum's quarterly revenue falls 24.2% sequentially due to customer inventory digestion

Telecom & Datacom demand to rebound starting late 2023

For its fiscal third-quarter 2023 (ended 1 April), Lumentum Holdings Inc of San Jose, CA, USA (which designs and makes optical and photonic products for optical networks and lasers for industrial and consumer markets) has reported revenue of \$383.4m, down 24.2% on \$506m last quarter and 3% on \$395.4m a year ago, and below the initial \$430–460m guidance.

"Customers who had built up large inventories due to supply concerns are bringing down inventories as supply risks and constraints are easing," says president & CEO Alan Lowe. "We are currently under-shipping end-market demand across our business," he believes.

The Commercial Lasers segment contributed \$48.3m (12.6% of total revenue), down 15.6% on \$57.2m last quarter and 5.7% on \$51.2m a year ago, due to lower shipments of fiber lasers and solid-state lasers. However, there was over 70% year-on-year revenue growth for ultrafast lasers, driven by new applications (particularly in solar cell manufacturing). "We expect that, as these new laser applications grow, we will gain further share in ultrafast lasers," says Lowe.

The Optical Communications segment contributed \$335.1m (87.4% of total revenue), down 25.3% on \$448.8m last quarter and 2.6% on \$344.2m a year ago, due mainly to the inventory dynamics. Specifically:

- Telecom & Datacom revenue was up 20% year-on-year but down 24% sequentially, with declines across most major product lines due to customer inventory digestion. The ongoing shortages in supply of IC components from third parties did not significantly limit revenue, as IC purchases at third-party brokers declined to nominal levels.

Revenue from reconfigurable optical add/drop multiplexers (ROADMs) was down sequentially

	Q3 FY23	Q2 FY23	Q3 FY22
\$ in millions			
Revenue	\$383.4	\$506.0	\$395.4
Optical Communications	335.1	448.8	344.2
Telecom & Datacom	293.3	384.2	243.5
Industrial & Consumer ⁽¹⁾	41.8	64.6	100.7
Commercial Lasers	48.3	57.2	51.2
Gross Margin (Non-GAAP)	40.8 %	44.9 %	49.5 %
Optical Communications	40.8 %	43.9 %	49.0 %
Commercial Lasers	40.4 %	52.4 %	52.9 %

due to customers digesting the inventory build-up, but up year-on-year, driven by broader adoption of next-generation ROADMs by market-leading customers along with improved IC supply (after the supply of FPGAs, for example, had been constrained during much of 2022).

"We have a growing set of cable, MSO and wireless network customers that are turning to our tunable access modules to expand data bandwidth in metro access, fiber deep and wireless 5G fronthaul application," says Lowe. Revenue from these products grew 17% sequentially and doubled year-on-year to a new quarterly record.

● Industrial & Consumer revenue was down both sequentially and year-on-year due to smartphone seasonality and end-market demand. However, beyond the smartphone market, Lumentum continues to ramp new automotive and industrial sensing applications for an expanding set of customers. Automotive-related applications comprised about \$3m, "which, at the chip level, is significant", says Chris Coldren, senior VP & chief strategy and corporate development officer. This reflects a significant contributions from early adopters of automotive light detection and ranging (LiDAR) in China.

On a non-GAAP basis, gross margin has fallen further, from 49.5% a year ago and 44.9% last quarter to

40.8%, due mainly to the lower revenue and the product mix.

Specifically, Optical communications segment gross margin of 40.8% was down both sequentially and year-on-year, due mainly to lower revenue and the impact of product margins from 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 (acquired in August 2022).

Commercial Lasers segment gross margin of 40.4% was down both sequentially and year-on-year, due primarily to an inventory reserve resulting from lower volumes and a fiber-laser product transition (although product margins should recover after shipments are fully shifted to the new laser platform and manufacturing volumes return).

"As we navigate current demand, we are prioritizing expense controls, accelerated attainment of acquisition synergies, and cash generation, while we continue to deliver on our new product and technology roadmaps and customer satisfaction," says Lowe.

Operating expenses totaled \$104.9m (27.4% of revenue), cut by \$5.4m from \$110.3m last quarter, as seasonal increases were more than offset by tight expense controls and synergies. Specifically, selling, general & administrative (SG&A) expenses

were cut from \$45.9m to \$42.8m, and R&D expenses from \$64.4m to \$62.1m.

Operating income has more than halved from \$104.9m (operating margin of 26.5% of revenue) a year ago and \$116.7m (23.1% margin) last quarter to \$51.4m (13.4% margin).

Net income was \$51.8m (\$0.75 per diluted share), down from \$104.1m (\$1.52 per diluted share) last quarter and \$88.9m (\$1.19 per diluted share) a year ago.

During the quarter, total cash, cash equivalents and short-term investments fell by \$13.2m, from \$1680.4m to \$1667.2m.

For fiscal fourth-quarter 2023, Lumentum expects revenue to fall further to \$350–380m, as Commercial Laser revenue will be roughly flat quarter-to-quarter, while modest growth in the Telecom & Datacom sector will be offset by a decline in Industrial & Consumer. Further declines are expected in operating margin to 8.5–11.5% and in diluted earnings per share to \$0.45–0.65.

"While there's a mixed outlook among our markets and product line, current visibility indicates that Telecom & Datacom demand will start to recover from this customer inventory correction late in the second half of the calendar 2023," says Lowe.

"Our new 25G tunable access module will be a key enabler for customers upgrading legacy fiber nodes in metro access networks leveraging next-generation distributed access architecture. However, as we transition customers from 10G to 25G in the coming quarters, we may see some revenue lumpiness," cautions Lowe. "Our advanced ROADMs are key enablers of our customers' next-generation network architectures that are just starting to be deployed, giving us confidence in continued market share growth and future demand," he adds.

"We expect Commercial Lasers demand to be softer over the next

<i>\$ in millions except for EPS, % of revenue</i>	Q3 FY23 Actual	Q4 FY23 Guidance
Revenue	\$383.4	\$350 - \$380
Operating Margin	13.4%	8.5% - 11.5%
Diluted EPS	\$0.75	\$0.45 - \$0.65
Diluted Shares – M	68.7	69.0
<div> <div> ▪ Mid-point revenue projection assumes: <ul style="list-style-type: none"> – Telecom & Datacom slightly up Q/Q – Industrial & Consumer down Q/Q – Commercial Lasers approximately flat Q/Q </div> <div> ▪ Other mid-point assumptions: <ul style="list-style-type: none"> – 14.5% non-GAAP effective tax rate </div> </div>		

several quarters due to the macro factors impacting end-market and customer inventory digestion," notes Lowe.

"To accelerate the integration of NeoPhotonics products into our global manufacturing footprint and attain synergies without impacting customer deliveries, we plan to carry elevated inventories for a period of time. However, we expect inventories to decline by approximately \$40m exiting calendar year 2023 as we continue to focus on cash generation. That is going to have an impact on overall gross margins, at least in the back half of the calendar year," says chief financial officer Wajid Ali. "Also, we expect a moderation in CapEx spending over the next few quarters."

"Although we expect the overall demand environment is likely to be challenging in the near term, I'm very confident about Lumentum's mid- to long-term prospects, given that fundamental end-market and technology trends driving our growth expectations are unchanged," says Lowe.

"The adoption of coherent pluggable modules by network operators is another significant long-term opportunity for us," says Lowe. "We are highly vertically integrated across the photonics and electronic components that enable high-speed pluggable form factors.

At OFC or 800G ZR product demo was very well received by our customers. Cloud data centers are being designed to support artificial intelligence and machine learning applications, which bodes well for

us as we extend our technology leadership to an even broader array of products that enable higher capacity and lower power consumption and latency, as we highlighted at OFC. We are on track with our

200 gig per lane EMLs for 800 gig and 1.6 terabit per second applications and expect to enter production in the second half of calendar 2023 and ramp throughout calendar 2024," he adds.

"Our high-speed VCSELs are starting to be deployed for short-reach connections within data centers, where optical communications are replacing copper connections due to data speed requirements," Lowe continues. "Also, as we highlighted at OFC, Lumentum is uniquely positioned to develop new photonics solutions, including high-power laser array engines in coordination with leaders in the high-performance computing market. Given the fast pace of innovation and the increasing demands placed on photonics technologies, we expect that the photonics market for AI will rapidly grow, reaching the size of the existing Ethernet photonics market within the next five years."

"We expect our fiscal year 2024 3D sensing revenue will be lower than that of fiscal 2023 due to our expectations around 3D sensing end-market demand, pricing and the possibility of an additional competitor on a certain socket opportunity in fiscal 2024," says Lowe. However, regarding automotive applications: "Recent engagements with a global set of tier-1 customers gives us confidence in new LiDAR revenue opportunities over the coming years, as well as our confidence in our ability to significantly grow our revenue in this market," he concludes.

www.lumentum.com

First Solar acquires Swedish perovskite PV firm Evolar CdTe PV maker to develop tandem PV modules

Cadmium telluride (CdTe) thin-film photovoltaic (PV) module maker First Solar Inc of Tempe, AZ, USA has acquired perovskite technology firm Evolar AB of Uppsala, Sweden. The purchase price is about \$38m paid at closing and up to an extra \$42m to be paid subject to certain technical milestones being achieved in the future. The impact to 2023 operating expenses is expected to be \$2-4m, excluding the impact of purchase price accounting.

The acquisition is expected to accelerate the development of next-generation PV technology, including high-efficiency tandem devices, by integrating Evolar's expertise with First Solar's existing R&D streams, intellectual property portfolio, and expertise in developing and commercially scaling thin-film PV.

"Along with our new innovation center in the United States and long-standing commitment to R&D, we are investing not just in First Solar's future but the future of solar energy," says CEO Mark Widmar. "We anticipate that high-efficiency tandem PV modules will define the future, speeding up decarbonization by allowing us to convert sunlight into clean electricity more efficiently," he adds. "This acquisition supplements our existing R&D streams with expertise in thin-film semicon-

ductors that complement CadTel.

We expect that it will accelerate our efforts to develop tandem technology."

Under the agreement, Evolar's laboratory in Uppsala will continue to conduct research activity, marking the first time that First Solar will have an R&D facility in Europe. Upon closing of the transaction, about 30 of Evolar's R&D staff will transition to First Solar, working with the firm's team of about 60 scientists at its research technology center in Santa Clara, California, and the development teams in Perrysburg, Ohio.

"By connecting our advanced research lab in California with Europe and building the Western Hemisphere's largest PV R&D innovation center in Ohio, we are effectively establishing and leading a uniquely transatlantic effort to develop and commercialize the next generation of photovoltaics," says Widmar.

Founded in 2019 by veterans of the copper indium gallium selenide (CIGS) industry, Evolar focused on developing solutions, including manufacturing equipment, for commercializing a tandem solar technology utilizing perovskite thin films. Evolar has achieved several thin-film efficiency records, including the existing 23.6% record for CIGS

research solar cells. Its team works closely with leading European research institutions, including Uppsala University.

"As we approach over 20GW of global nameplate capacity by 2025, First Solar's track record in scaling thin-film photovoltaics speaks for itself," says First Solar's chief technology officer Markus Gloeckler.

"The future of PV clearly lies in thin-film semiconductors, and few other solar technology companies are as well placed to develop and commercialize future solar technologies as First Solar is," he claims.

In October 2022, First Solar announced that it would construct a new R&D innovation center in Perrysburg, Ohio. Representing an investment of up to \$370m, the facility is believed to be the first of its scale in the Western Hemisphere and is expected to accelerate the development and production of thin-film PV. Scheduled to be completed in 2024, the new R&D center will be located near First Solar's existing Perrysburg manufacturing facility, covering an area of about 1.3 million square feet. It will feature a pilot manufacturing line allowing for the production of thin-film and tandem PV modules.

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Annealing InP quantum dot MBE structures for laser

Researchers achieve threshold current density comparable to MOCVD structures.

Researchers in the USA report progress in molecular beam epitaxy (MBE) and post-growth annealing of indium phosphide (InP) quantum dot (QD) structures for deployment in near-infrared and visible red laser diodes with low threshold current density (J_{th})

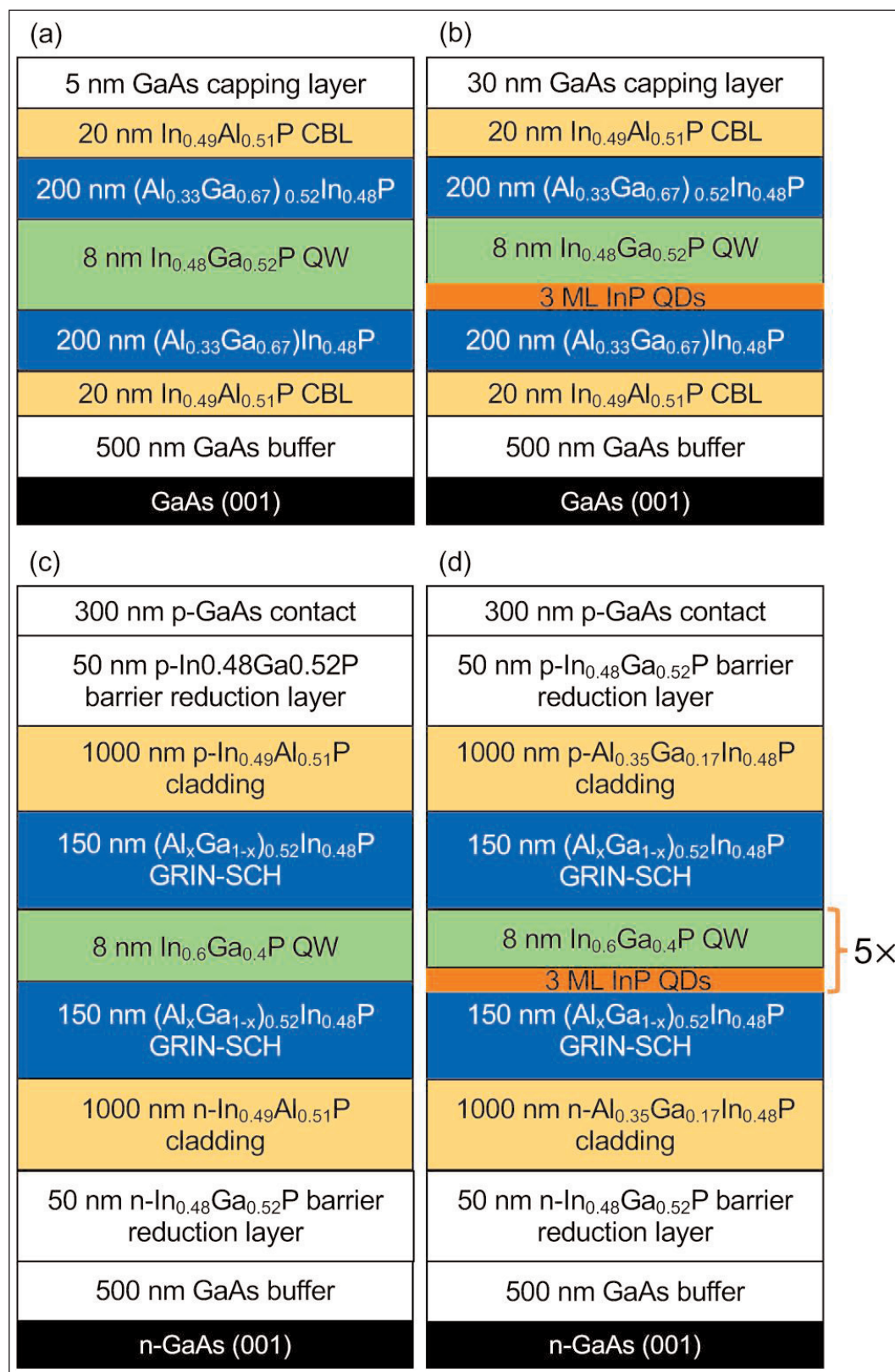
[Pankul Dhingra et al, J. Appl. Phys., v133, p103101, 2023].

"After annealing, J_{th} per QD layer is 99.8A/cm², >7x lower than previous reports by MBE and comparable to their MOCVD-grown counterparts," claims the team from University of Illinois Urbana-Champaign and University of Texas at Austin.

The researchers add: "Among the few reports of the molecular beam epitaxy (MBE) growth of InP QD lasers, the lowest published J_{th} value is ~2000A/cm², >10x higher than with MOCVD."

The low growth temperature of MBE relative to metal-organic chemical vapor deposition (MOCVD) leads to challenges in terms of optical quality of the complete epitaxial structure, which included quaternary aluminium gallium indium phosphide (AlGaInP) alloy barriers for the InGaP

Figure 1. PL structures for (a) In_{0.48}Ga_{0.52}P QW and (b) InP QDs grown on GaAs (001) substrates. Laser design for (c) In_{0.6}Ga_{0.4}P SQW and (d) InP MQD graded-index separate-confinement heterostructure (GRIN-SCH) lasers.



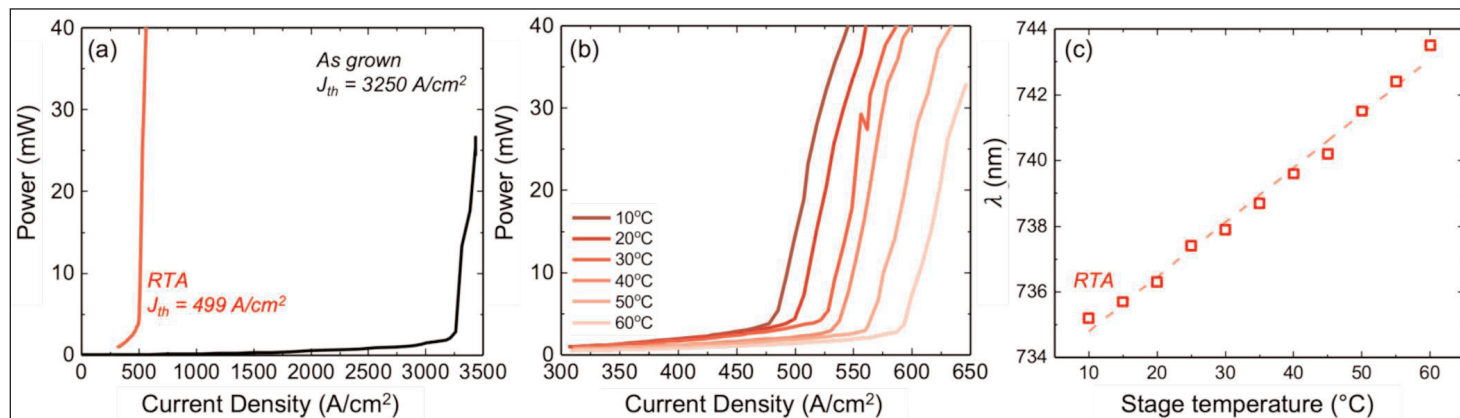


Figure 2. (a) Pulsed light output power–current density characteristics of InP MQD laser at room temperature. (b) Temperature-dependent performance. (c) Temperature dependence of emission wavelength.

quantum wells (QWs) in which the QDs were placed.

The team reports: "InP/AlGaInP QDs show greater thermal stability, with ~50x increase in the PL intensity due to improvement in the optical properties of InP QDs, InGaP QWs, and AlGaInP barriers. Thermal annealing is a crucial step toward developing visible red lasers that will allow integrated photonics to expand into areas such as quantum computing, optogenetics, and next-generation displays."

The researchers add: "While the atomic origin of the improvement remains unclear, deep-level transient spectroscopy studies of InGaP/AlGaInP QWs show a substantial reduction of signals related to phosphorous vacancy complexes after rapid thermal annealing (RTA) at 875°C."

The attraction of MBE is that it allows easier growth control of the QD layers themselves. In MOCVD, the substrates need to be offcut to encourage high dot density with uniform size.

The researchers grew four solid-source MBE structures on gallium arsenide (GaAs) (001) substrates with a view to photoluminescence (PL) and laser diode (LD) experiments (Figure 1). The substrate temperature during the growth was 460–480°C. The V/III ratio was in the range 15–30.

For the PL experiments, the protective GaAs capping layer was removed by etching. The QW and three monolayer (ML) QD active regions were sandwiched between carrier-blocking layers (CBLs) consisting of undoped indium aluminium phosphide (InAlP) to reduce surface recombination. The well barriers were AlGaInP rather than the more usual InGaP.

These layers translated with suitable doping and thickness/composition adjustments into suitable components of the laser diodes. Some of the adjustments aimed at creating compressive strain in the QW — rather than the unstrained condition of the PL structure — with a view to reducing the threshold current of the broad-area stripe lasers with 800–1560µm cavity lengths. The laser mirror facets were uncoated.

The PL study focused on tuning the post-growth

annealing, aiming at high-intensity, stable wavelength emission from the structures. The team performed comparisons based on rapid thermal annealing (RTA) and furnace annealing (FA) techniques. The use of quaternary AlGaInP barriers reduced indium out-diffusion, enabling longer annealing times at higher temperature.

Laser diodes fabricated from the single-quantum-well (SQW) epitaxial material had 1.5x reduced threshold current density, from 340 to 200A/cm², after RTA at 950°C for 1s. Using a heat-sink, the threshold current was maintained at 200A/cm² even in continuous-wave operation, "among the lowest reported values for In_{0.6}Ga_{0.4}P SQW lasers by any growth technique", the team points out. The RTA blue-shifted the as-grown emission wavelength from 690nm to 683nm.

The researchers comment: "Changes in the emission wavelength can be attributed to group-III intermixing after RTA, heating of the active region at high current density, and current-induced wavelength shift, typically observed in broad-area lasers."

The same RTA process reduced the threshold current density by 6.5x, from 3250A/cm² to 499A/cm², in the multiple quantum dot (MQD) laser structures (Figure 2). Measurements of the threshold between 10°C and 60°C gave a characteristic temperature of 230K for the RTA laser diodes, representing an increase from 477A/cm² to 586A/cm² with temperature.

The researchers comment on the temperature-dependent measurements, "there are no previous reports describing the high-temperature operation of MBE-grown InP QD lasers for comparison to these results."

The near-infrared (NIR) wavelength of the RTA MQD lasers also red-shifted with temperature. The as-grown InP MQD lasers did not operate past 20°C.

Unspecified "further improvements in the fabrication" and heat-sinking enabled continuous-wave operation of annealed MQD lasers with 565A/cm² threshold.

The researchers expect similar performance gains from furnace annealing, based on their PL studies. ■

<https://doi.org/10.1063/5.0136621>

Author: Mike Cooke

Re-assessing assumptions on internal quantum efficiency

Research suggests internal quantum efficiency values grossly over-estimated, especially in LED wafers with high defect levels.

YC Chiu and C Bayram of University of Illinois at Urbana-Champaign in the USA have presented measurements that question the usual assumption that internal quantum efficiencies (IQEs) of light-emitting diode structures are close to 100% at low temperature [Appl. Phys. Lett., v122, p091101, 2023].

IQEs at room temperature (~300K) are often estimated (Figure 1) based on photoluminescence experiments that compare the emission intensity with that at low temperature (~10K). These IQEs are then used to estimate other factors such as light extraction efficiency etc.

Not being able to adequately track down the blockages toward higher-efficiency devices could slow progress to more sustainable and comfortable societies around the world that can meet the challenge of climate instability brought on by higher carbon dioxide (CO₂) and other greenhouse gas levels.

Chiu and Bayram write: "Continual efficiency improvements in LEDs are needed per the DOE 2035 roadmap, which sees the blue LED efficiencies increase from 70% to 90% and furthering energy and CO₂ emission savings by 450TWh and 154 million metric tons, respectively."

Chiu and Bayram considered the emissions from multiple quantum well (MQWs) from photon excitation of valence electrons to the conduction band and subsequent relaxation as occurring through four channels: red (RL) and yellow (YL) luminescence, nonradiative, and the desired 2.79eV MQW emission from electron recombination with holes in the valence band (Figure 2). The RL and YL channels proceed through mid-gap defect levels, and are less energetic than the MQW emission, hence the different colors.

In photoluminescence experiments there are also ultraviolet luminescence (UVL) and near-band-edge (NBE)

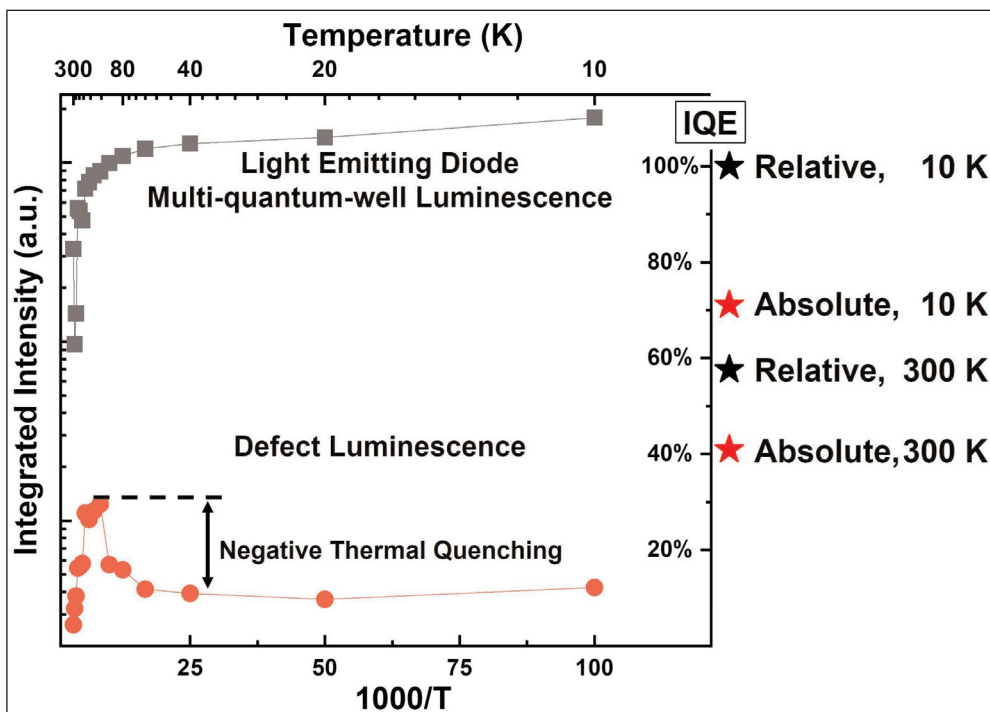


Figure 1. Impact of estimating absolute IQE from low-temperature value. Relative IQEs: 100% at 10K and 58% at 300K. Absolute IQEs: 71% at 10K, 41% at 300K. One would point out that high temperature is to left of graphs here (and below).

emissions, but these are not included in considerations of the IQE of MQW structures, although they do affect external quantum efficiency and wall-plug efficiency.

Since the non-radiative recombination is effectively invisible to photoluminescence detectors, the researchers had to extract estimates of the low-temperature IQE from considering the variations of the visible emissions with temperature. In particular, they studied the negative thermal quenching (NTQ) of the RL and YL channels (Figure 3). TQ describes a decrease in emission with temperature, while NTQ occurs with an increase in luminescence through a channel.

The estimates were based on the work of Michael A. Reshchikov of Virginia Commonwealth University and Roman Y. Korotkov of Northwestern University in the USA, which relates the low-temperature IQE to the amount of NTQ in defect-related emission channels. For LED epitaxial layers on sapphire the NTQ ratio (R) reached 1.38x the low-temperature intensity for YL, while it reached 3.46x for a similar structure on Si(111).

The low-temperature IQE is estimated by $(R-1)/R$: 27.5% on sapphire and 71.1% on Si(111). These values are clearly far from the usual assumption of 100% IQE.

Chiu and Bayram comment: "If the PL quenching mechanism of a highly luminescent channel is of the type first proposed by Reshchikov, which involves multiple recombination pathways, negative thermal quenching could be observed in channels that are not simultaneously quenched (i.e. have different quenching temperatures)."

Studies of the excitation-power dependence of the emissions at 10K and 300K (room temperature) were consistent with the LED/sapphire wafer having higher defect density and hence lower IQE, relative to that on silicon substrate. Also, materials analyses showed that the sapphire-based structure had 1.57nm surface roughness and $6.3 \times 10^9/\text{cm}^2$ defect density, compared with 1.45nm and $5.4 \times 10^8/\text{cm}^2$ for the LED layers on silicon. The sapphire wafer also had higher compressive stress in the LED layers.

Chiu and Bayram comment: "These findings suggest that reducing the defect density and lowering the compressive stress in LEDs are essential for high-efficiency LEDs." ■

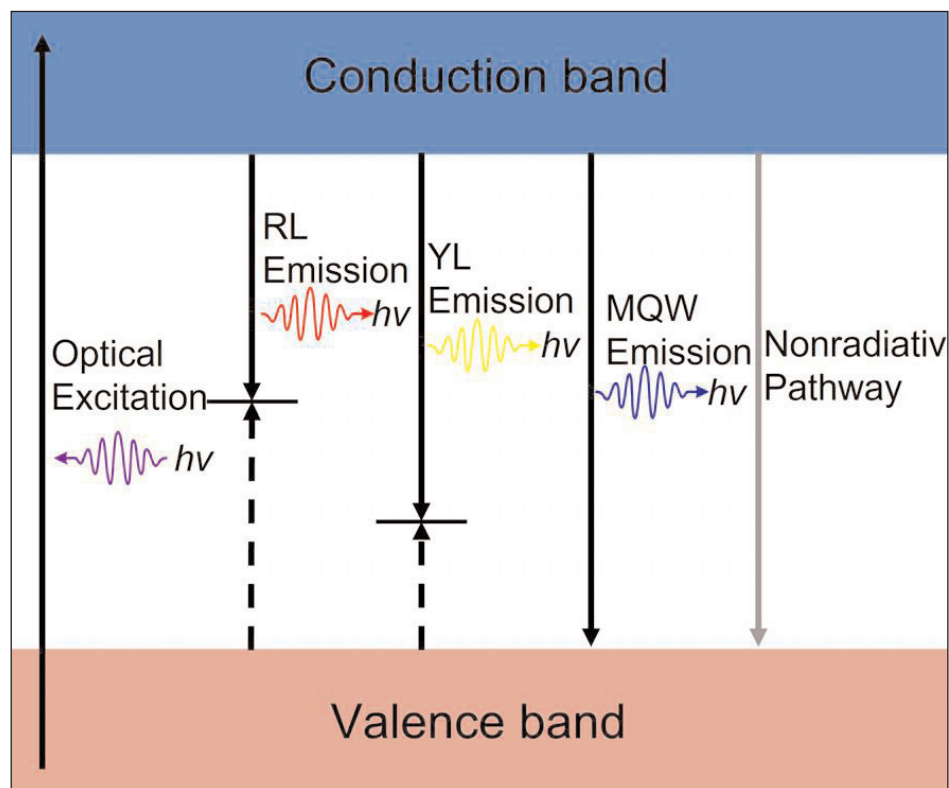


Figure 2. Representative band diagram of recombination within MQWs from optical excitation by laser ($h\nu \sim 4.66\text{eV}$, $\lambda \sim 266\text{nm}$) through three luminescent recombination pathways, and non-radiative recombination.

<https://doi.org/10.1063/5.0142701>

<https://doi.org/10.1002/pssa.202000101>

<https://link.aps.org/doi/10.1103/PhysRevB.64.115205>

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Mike Cooke

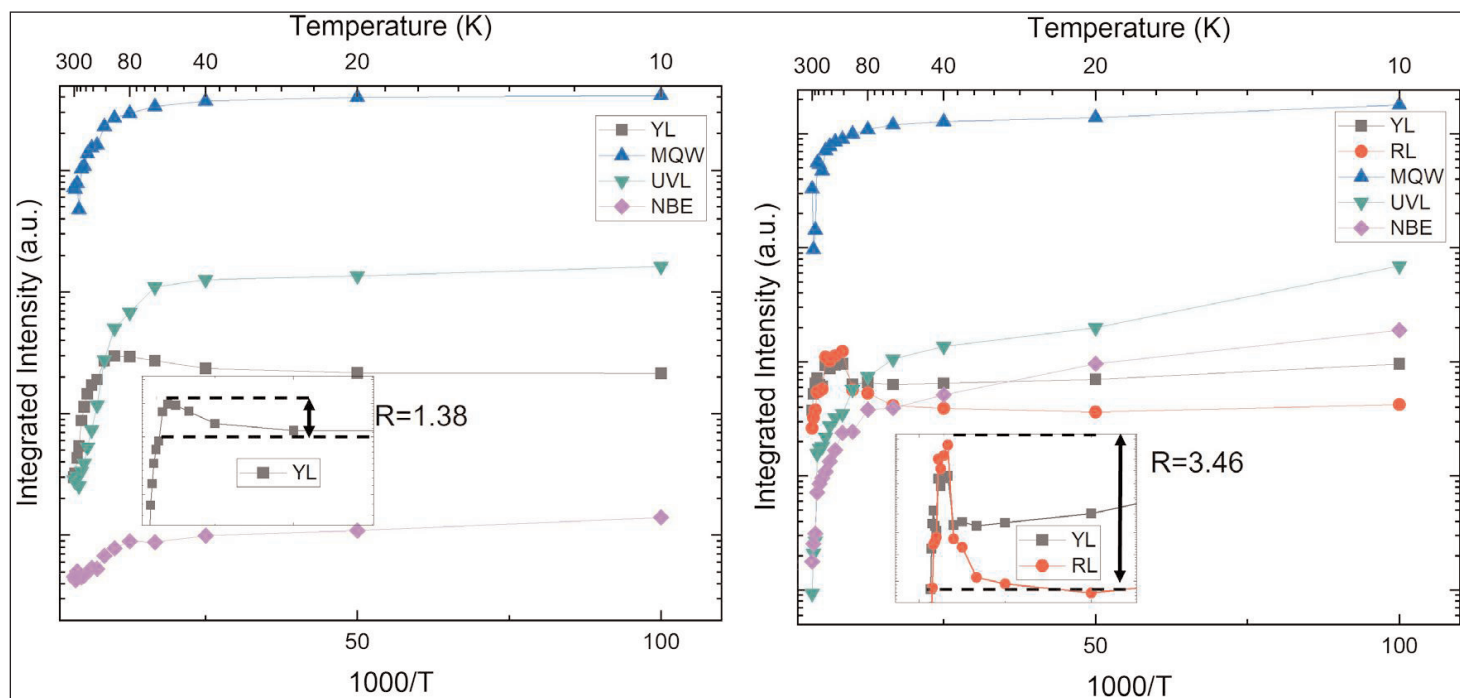


Figure 3. Integrated photoluminescent intensities of different luminescent bands of LEDs on sapphire (left) and Si (111) (right) as function of temperature. Insets: zoom-in on NTQ regions of defect luminescence bands of LED layers on sapphire (YL) and silicon (YL and RL).

Red InGaN LEDs for visible light communications

Performance shifts with current injection could also lead to color displays.

Fudan University and Jiangxi Latticepower Semiconductor Corp in China claim the first report of red-emission micro-sized light-emitting diodes (micro-LEDs) on silicon substrates for visible light communication [Xinyi Lu et al, Journal of Lightwave Technology, published online 27 March 2023]. The team also studied the wavelength/color shifts from red to green with increased current for various sizes of micro-LED with a view to displays and multi-wavelength data transmission.

The researchers see potential deployment in multi-color displays and high-speed visible light communication, especially for wearable products. Of course, the use in displays would require careful management of pulsed operation to compensate the lower light output power at low current injection relative to high current injection.

The wavelength/color shifts to the bluer part of the visible spectrum arise from effects that are not desired in other application contexts such as band-filling and the quantum-confined Stark effect (QCSE). Band-filling refers to the filling of energy levels as the current injection increases, creating a larger energy drop for

electrons recombining into holes. The QCSE arises from electric fields due to charge polarization of the chemical bonds in III-nitride materials, which arise both spontaneously and from piezoelectric strain effects in heterostructures.

The researchers used metal-organic chemical vapor deposition on silicon (111) substrates to grow the indium gallium nitride (InGaN) epitaxial material for the red LEDs (Figure 1). The active region consisted of three InGaN quantum wells (QWs) targeting red emissions.

Square-pixel LEDs were fabricated with sides varying between 20µm and 150µm. The researchers classified the 150µm device as a 'mini-LED', and the smaller ones as 'micro-LEDs'.

The fabrication began with deposition of a 30nm transparent conducting layer, consisting of indium tin oxide (ITO), for current spreading from the p-electrode. The device mesas were formed by inductively coupled plasma reactive ion etching (ICP-RIE). A 300nm plasma-enhance chemical vapor deposition (PECVD) of silicon dioxide was used for passivation. The n- and p-electrodes were titanium/gold.

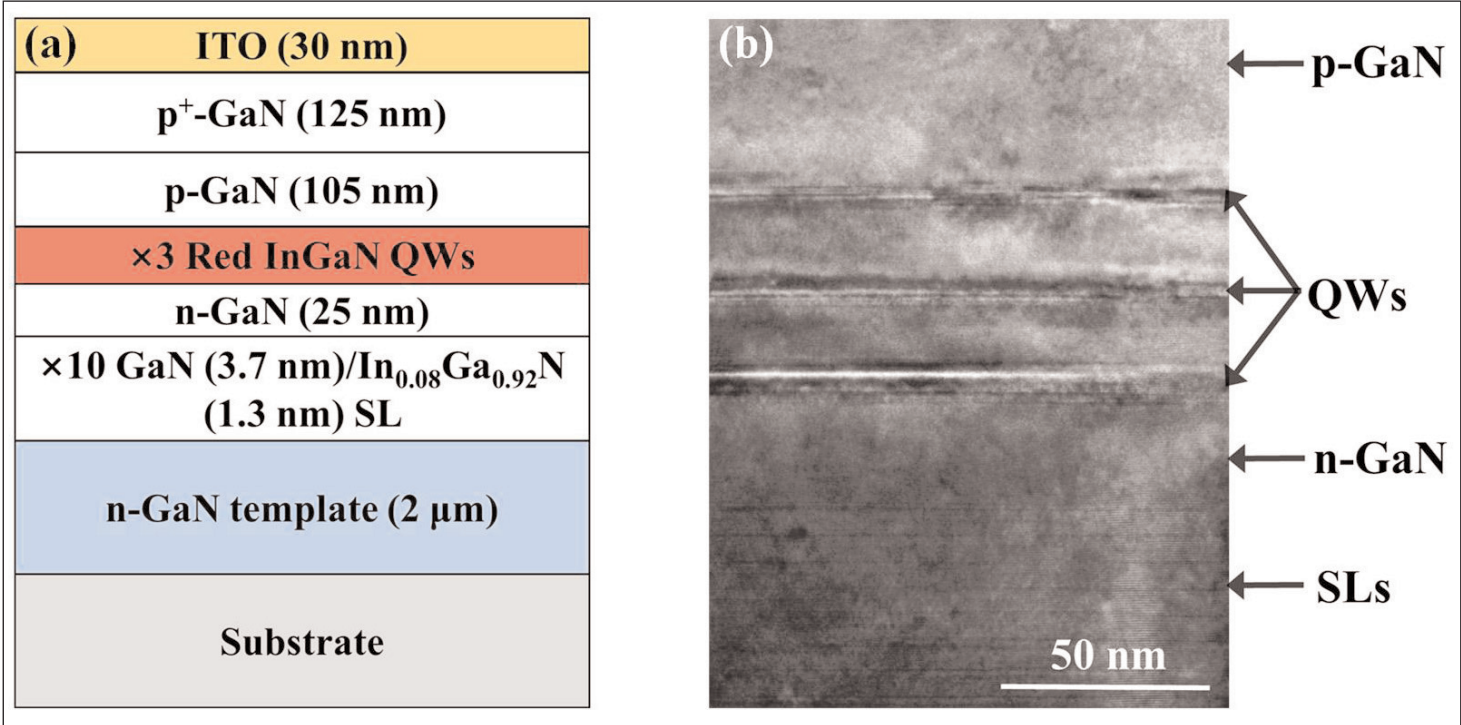


Figure 1. (a) Schematic diagram and (b) cross-sectional transmission electron microscope (TEM) images of InGaN-based red LED epitaxial structure.

Figure 2. (a) EL peak wavelength versus current density for all chip sizes. (b) EL spectra of 20 μm pixel from 50A/cm² to 13,000A/cm². (c) Light output power density versus injection current density for all chip sizes.

Although the series resistance of the smaller devices was higher, due to the smaller cross-sectional area, the forward voltage for 10A/cm² injection current density was lower: 3.24V for the 20 μm micro-LED, compared with 3.84V for the 150 μm mini-LED. In other words, the smaller devices have higher conductivity.

The smallest 20 μm LED suffered from high leakage current under reverse bias, attributed to side-wall defects acting as current leakage channels. In numbers, the leakage for the 20 μm LED was $2.7 \times 10^{-5} \text{A/cm}^2$ at 5V reverse bias, compared with $2.44 \times 10^{-6} \text{A/cm}^2$ for the 150 μm LED.

Increasing the current injection shifted the peak electroluminescence (EL) wavelength in the shorter-wavelength blue direction, due to screening of the piezoelectric fields, and band-filling, spanning the range 670nm (red) down to 520nm (green) for the 20 μm LED (Figure 2).

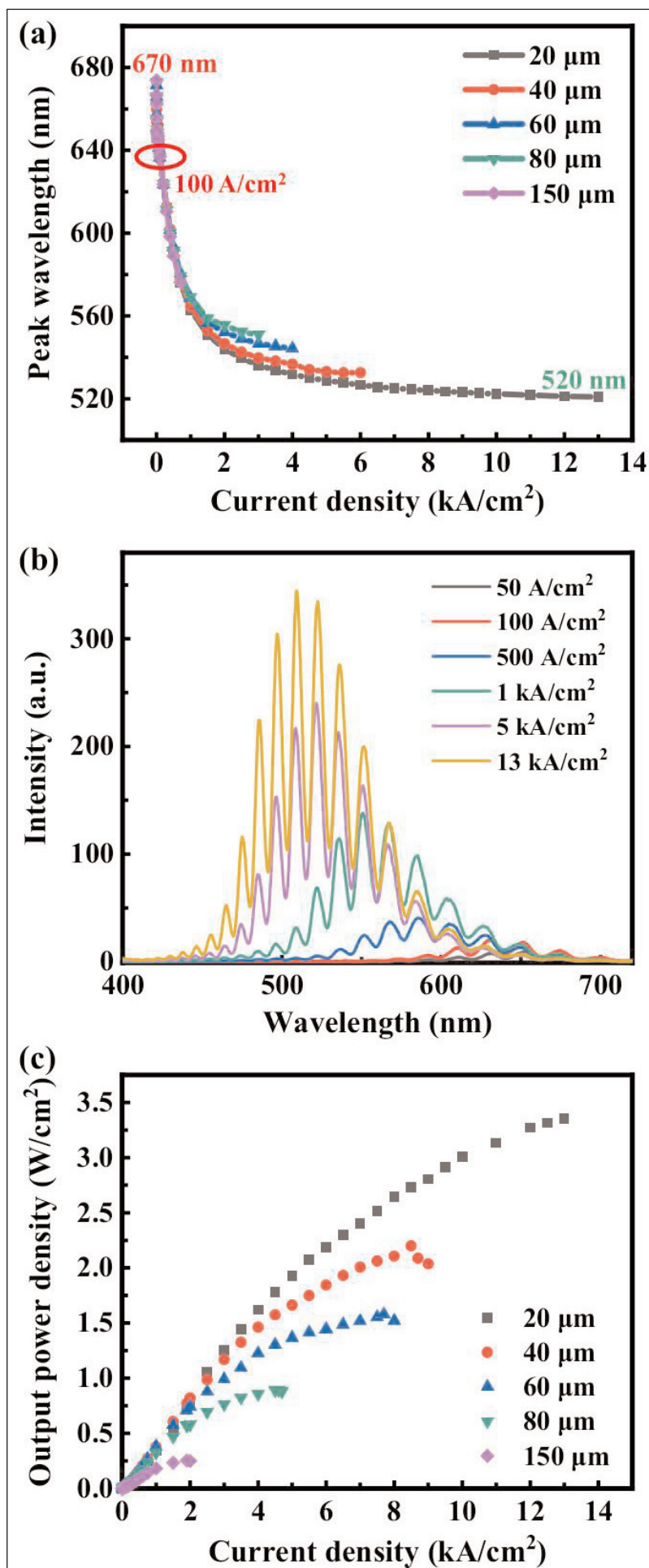
The combination of silicon substrate and small pixel size enabled the 20 μm LED to reach current densities of 13kA/cm². In particular, the silicon substrate is more thermally conductive than sapphire, which reduces junction temperatures. The reduced junction temperature also enables a wider blue-shift range: "High junction temperature causes red shift, which compensates for the blue shift, so for smaller pixels, red-shift compensation is weaker and the blue shift looks stronger," the team explains.

The researchers also report: "The smallest pixel (20 μm) exhibits a maximum optical power density of about 3.36W/cm², which is 14 times higher than that of the largest pixel (150 μm)."

The team points out that these results might not extend to arrays of pixels: "For micro-LED arrays, due to the thermal effect, different pixels will strongly affect each other as the current density increases."

The researchers further report on the external quantum efficiency (EQE) of a larger 80 μm LED, since the integrating sphere measurements would be more accurate with the higher output power. The EQE reached 0.19% at 2A/cm² injection. At 100A/cm², the EQE was 0.14%.

The team points out that the silicon substrate absorbs almost half the emissions, constituting a major impact on the light extraction efficiency, which could be ameliorated by removing the substrate and adding a mirror to the backside of the device.



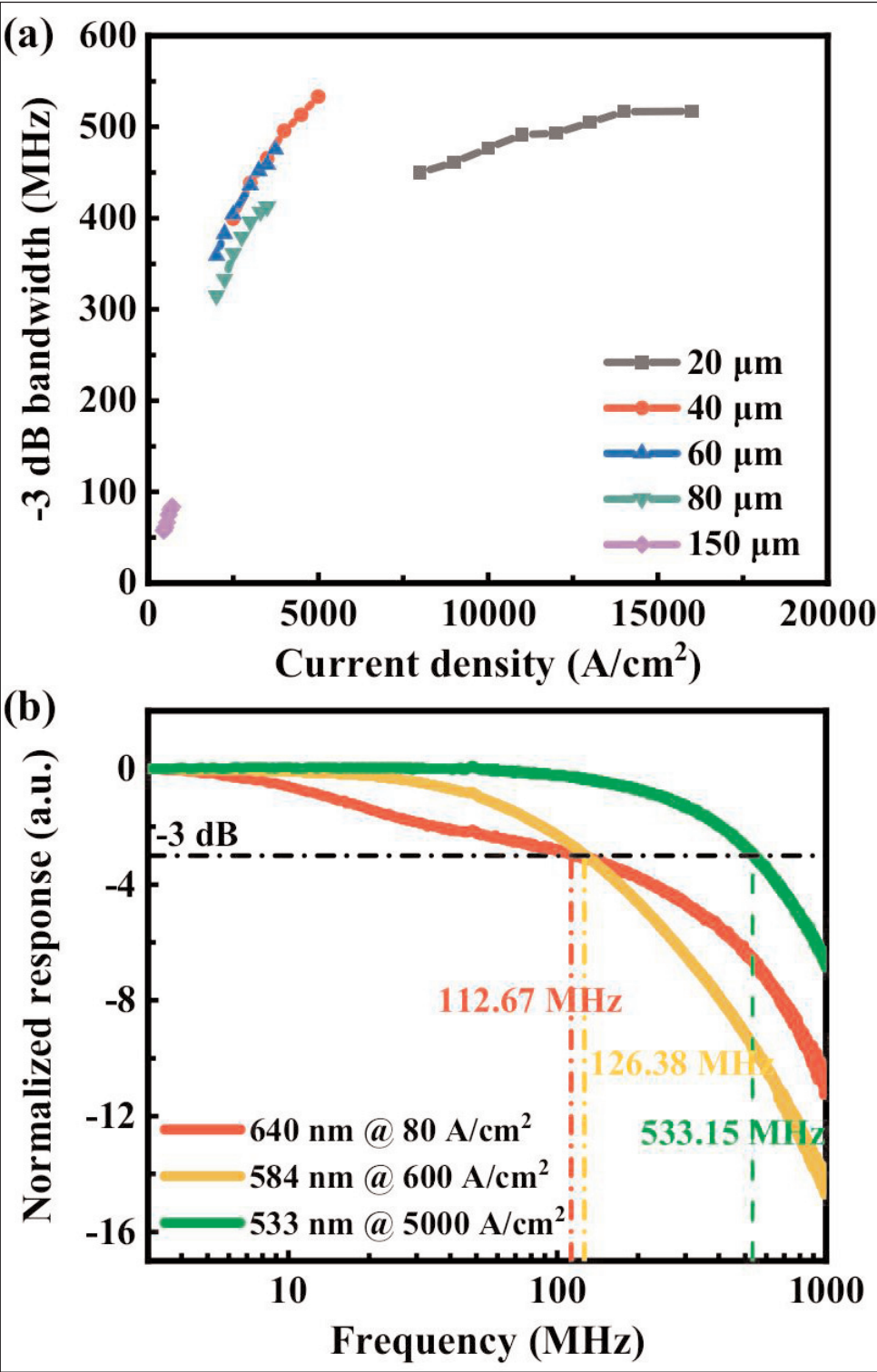


Figure 3. (a) -3dB modulation bandwidth versus current density for all five pixels. (b) Frequency responses of 40µm pixel.

Other factors giving the low EQE result include high defect density/poor crystal quality, and the strong QCSE expected in high-indium-composition red QWs.

With a view to data transmission, the researchers also report on the -3dB modulation bandwidths (Figure 3). Excepting the 150µm mini-LED, the bandwidth exceeded 400MHz under suitable current injection. The maximum reached 533MHz for 40µm pixels at 5kA/cm². At that current density, the pixel was emitting green light. The bandwidth for red light was 113MHz, and for yellow 126MHz.

The researchers comment: "Green emission exhibits higher modulation bandwidth compared to red and yellow emission, which can be attributed to the reduced carrier lifetime due to the higher operating current density required."

The researchers also tested a proof-of-concept monolithic, multi-color wavelength division multiplexing (WDM)-optical wireless communication (OWC) scheme using emissions from three micro-LEDs with red 647nm and yellow 581nm light being supplied by 80µm pixels and green 541nm from a 40µm pixel. The respective current densities were 90A/cm², 500A/cm² and 1750A/cm², and corresponding bandwidths of 79MHz, 105MHz and 324MHz.

The maximum data rates for the three channels, subject to a forward error correction limit of 3.8×10^{-3} , were 486Mbps/s (Mbps) for red, 758Mbps yellow, and 1103Mbps green, or 2.35Gbps combined. ■

<https://doi.org/10.1109/JLT.2023.3261875>

Author: Mike Cooke

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Thick single quantum well InGaN LEDs with high external quantum efficiency and low droop

Optimized doped barriers have been used to reduce internal electric fields.

University of California Santa Barbara in the USA and École Polytechnique in France have reported improved external quantum efficiency (EQE) and reduced efficiency droop in c-plane light-emitting diodes (LEDs) with thicker indium gallium nitride (InGaN) single quantum wells (SQW) [Y. C. Chow et al, J. Appl. Phys., v133, p143101, 2023].

The team used doped barriers to reduce the internal electric field in the well region. Such fields tend to separate holes and electrons, reducing radiative recombination into photons. Instead, the energy of the injected carriers is dissipated in non-radiative recombination processes: Shockley–Read–Hall (SRH) through recombination center defects at low injection, and Auger three-body interactions at high current and carrier density, creating (non-thermal) efficiency droop.

A thick QW would allow reduced Auger recombination for the same output — in theory. However, thin QWs are used for to bring the electrons and holes closer together, increasing their chances of recombining into photons.

The electric fields arise from charge polarization contrasts between the GaN and InGaN chemical bonds, resulting in polarization charges at the GaN/InGaN interfaces. Doped barriers would introduce a countervailing component to the

electric field from the depletion of the doped regions, leaving ionized impurities. Another approach is to begin with non-polar or semi-polar substrates; however, these are much more expensive than the sapphire typically used to grow c-plane GaN/InGaN.

As usual, life is not straightforward. Doped material tends to have higher SRH-inducing defect densities. Hence, the research team performed a wide range of preparatory simulation and experimental work to find the right balance of parameters. Key ones were the doping concentration, and the separation of the doped regions from the quantum well.

The researchers grew a range of epitaxial LED structures on patterned sapphire substrates, using

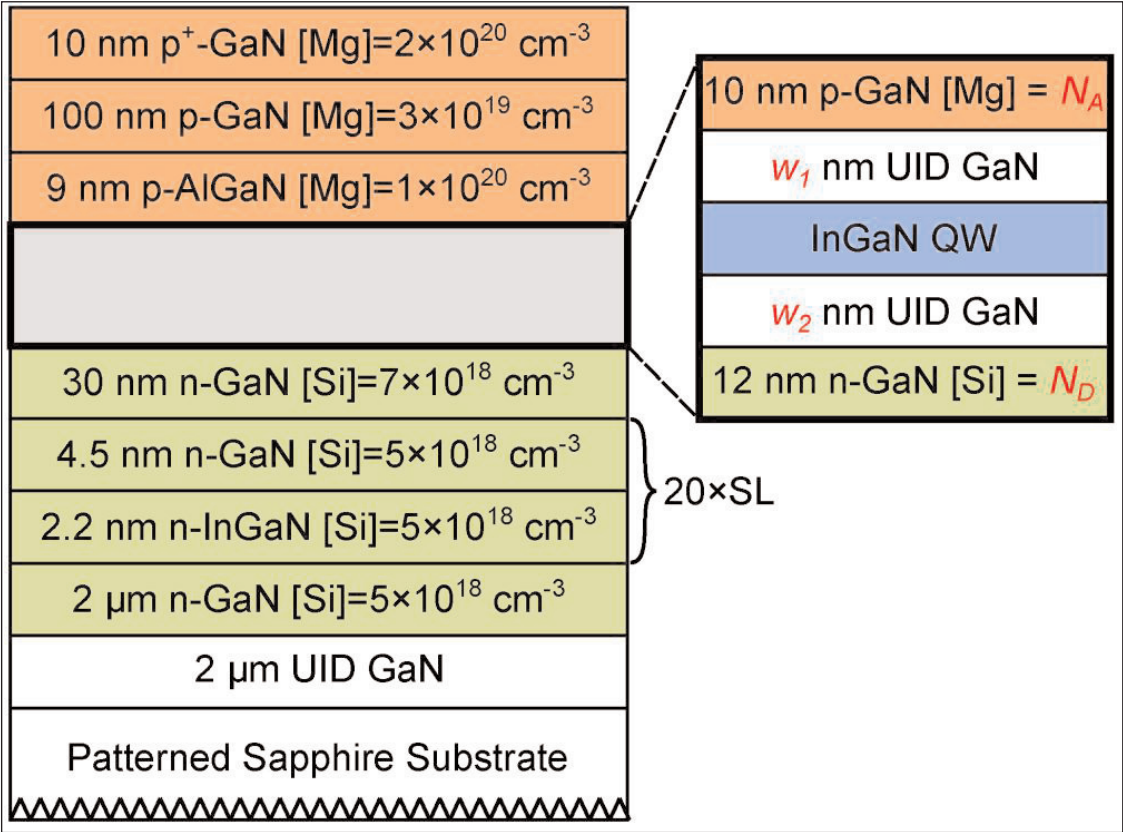


Figure 1. Schematic epitaxial LED structure.

metal-organic chemical vapor deposition (Figure 1). The inner active region around the QW was varied in terms of acceptor and donor doping levels of the GaN barriers (NA and ND) and the unintentionally doped (UID) GaN interlayer thicknesses (w1 and w2).

After describing a number of experiments with such differences, the team comments: "In general, we found that the n-side UID interlayer is less important than the p-side UID interlayer, where the complete removal of the n-side UID interlayer is beneficial to the device performance of thick SQW LEDs. On the other hand, the optimized thickness of the p-side UID interlayers depended on the doping levels of the p-GaN doped barriers."

The work resulted in two optimized devices with 7nm and 9nm SQWs with 16% and 13.5% indium content, respectively. The p-GaN was separated from the SQW by 2nm of UID GaN. The p- and n-type doping levels of the barriers were 1.7×10^{19} and $1.5 \times 10^{19}/\text{cm}^3$, respectively.

The packaged devices included indium tin oxide (ITO) current-spreading layers, and dielectric omnidirectional reflectors. Apart from increasing the light emission from the back-side of the wafer, the reflectors served as metal insulation for the metal contacts. Sidewall passivation was provided by atomic layer deposition (ALD) silicon dioxide. The diced LED chips were wire-bonded and encapsulated in silicone.

The EQE was measured in an integrating sphere (Figure 2). Above 50 A/cm^2 current density, the injection was pulsed to avoid thermal effects. The shorter-wavelength 'violet' LED reached an EQE of 49% at 40 A/cm^2 . The higher-indium-content, longer-wavelength 'blue' LED peaked at 39% EQE with 30 A/cm^2 injection. The devices peaked in EQE at current densities higher than the $<10/\text{cm}^2$ typical of c-plane LEDs with thin QWs.

The researchers comment: "The lower efficiency of the blue LED is likely related to poorer material quality and a higher piezoelectric field in the QW with a higher indium composition."

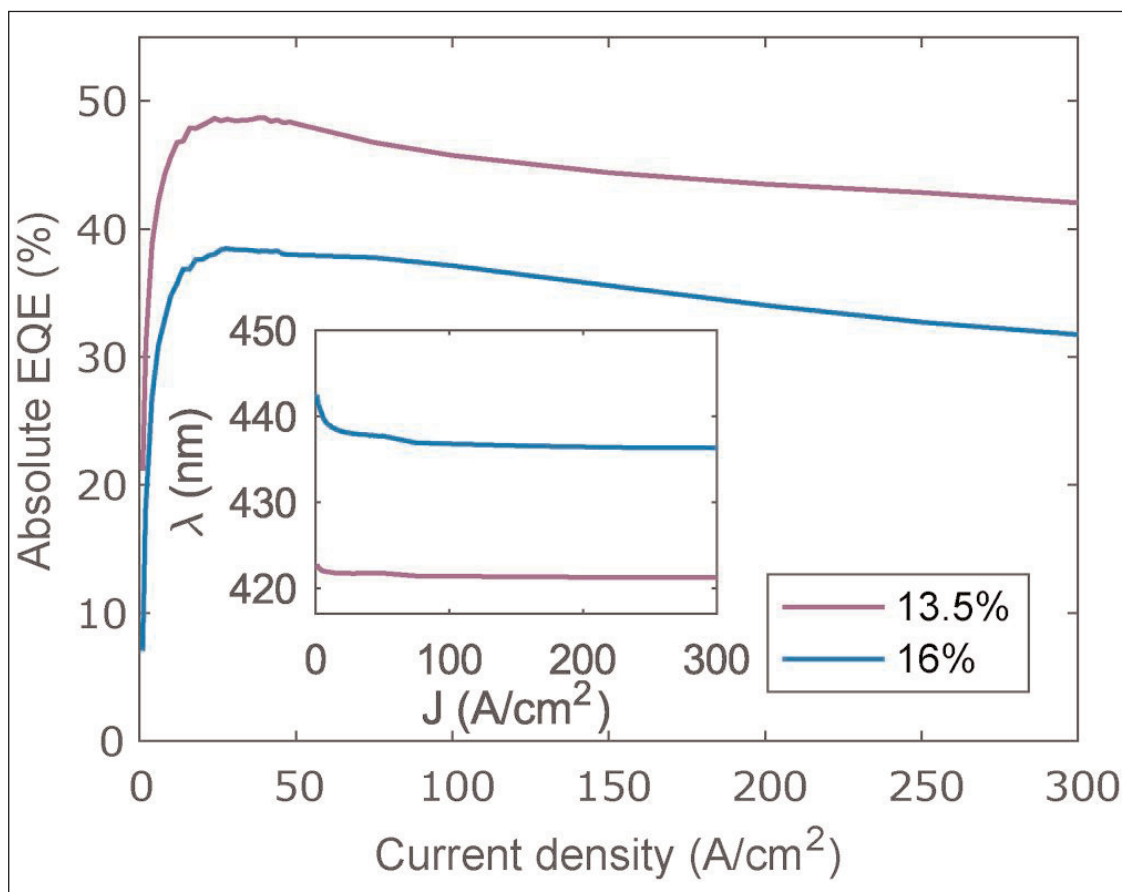


Figure 2. EQE versus current density of two thick SQW LEDs with doped barriers. Inset: EL peak wavelength versus current density.

The droop at 100 A/cm^2 was 6% and 3% for the violet and blue LEDs, respectively. The corresponding droops at 300 A/cm^2 were 14% and 17%. Thinner 3nm QW LEDs with similar peak EQEs tend to droop 40–60% by the time 300 A/cm^2 injection is reached.

The researchers comment: "The low efficiency droop of our devices can be attributed to a lower n [carrier density] as a result of a larger active region volume. These c-plane thick SQW LEDs also have comparable or better droop performance and peak EQE when compared to the non-polar and semi-polar LEDs reported in the literature. Nonetheless, they are still significantly lagging behind the state-of-the-art commercial c-plane LEDs in terms of the peak EQE (~80%)."

The blue-shifts of the violet and blue LEDs in going to higher current were 1.5nm and 6nm, respectively. The relatively small shifts suggest a lower quantum-confined Stark effect due to a lower electric field in the well. LEDs grown in the c-plane direction usually have shifts of more than 10nm.

The team writes: "There is less electric field to be screened by injected carriers, resulting in a smaller variation in wavelengths with respect to the current density." ■

<https://doi.org/10.1063/5.0142035>

Author: Mike Cooke

QPT's modules enable GaN to operate at up to 20MHz without overheating or RF issues

QPT's technology opens up new application areas for GaN power electronics.

Founded in 2020, Quantum Power Transformation (QPT) of Cambridge, UK claims to be the first company to create the technologies needed to enable GaN to operate at well over the existing limitations of 100kHz right up to 20MHz in high-power, high-voltage applications that use hard switching such as motor drive systems for HVAC, robotics etc. The technology opens up this important section of the GaN market that no-one else currently has solutions to address, the firm adds.

In high-voltage, high-power applications there is a practical limit of 100kHz for GaN beyond which the issues of overheating and RF interference become too great. The existing solution is to throttle GaN back to under 100kHz, which means that the performance is similar to silicon carbide and there are no benefits to using GaN as it is not running at high switching speeds or frequencies where it actually delivers power savings.

"Power engineers are focused on being an expert in one field and have developed skills and design approaches that work at 10–100kHz switching, which is where silicon and SiC transistors operate," notes founder & CEO Rob Gwynne. "I was able to look at the problem as an RF engineer and create a solution that enables the GaN transistors to be run at their full potential of up to 20MHz with nanosecond switching to deliver better operational precision without RF interference issues or overheating and thus, for the first time, deliver their promised efficiencies," he adds.

QPT has integrated its technology into two modules so that it can be easily implemented by customers with minimal effort and changes to existing designs. The qGaN module contains a 650V GaN transistor with the company's qDrive that is claimed to be the world's fastest, most accurate, highest-resolution, low-jitter isolated GaN transistor gate drive. The second module is qSensor, which combines the firm's ZEST and qSense technologies, providing the sensing and control that enables GaN to be driven at super-high frequencies for the first time.



Figure 1: QPT's founder & CEO Rob Gwynne with a qGaN module.

In addition, QPT has developed its WisperGaN construction system, which includes a reference design for how the modules and the ancillary electronics can be assembled together in a Faraday cage so that there are no heating or RF issues. The resulting solution unlocks the ability of GaN to now operate at ultra-high frequencies and provides up to 80% reduction in power usage compared with existing solutions that have to operate at much lower frequencies, it is reckoned.

The first qGaN module (Q650V15A-M01) will handle 15A RMS current driving 380V three phase motors. The roadmap will have qGaN modules to handle various different power loads to suit different application area requirements. Together with the other QPT technology modules, turnkey solutions can be easily assembled according to the reference design, the firm says.

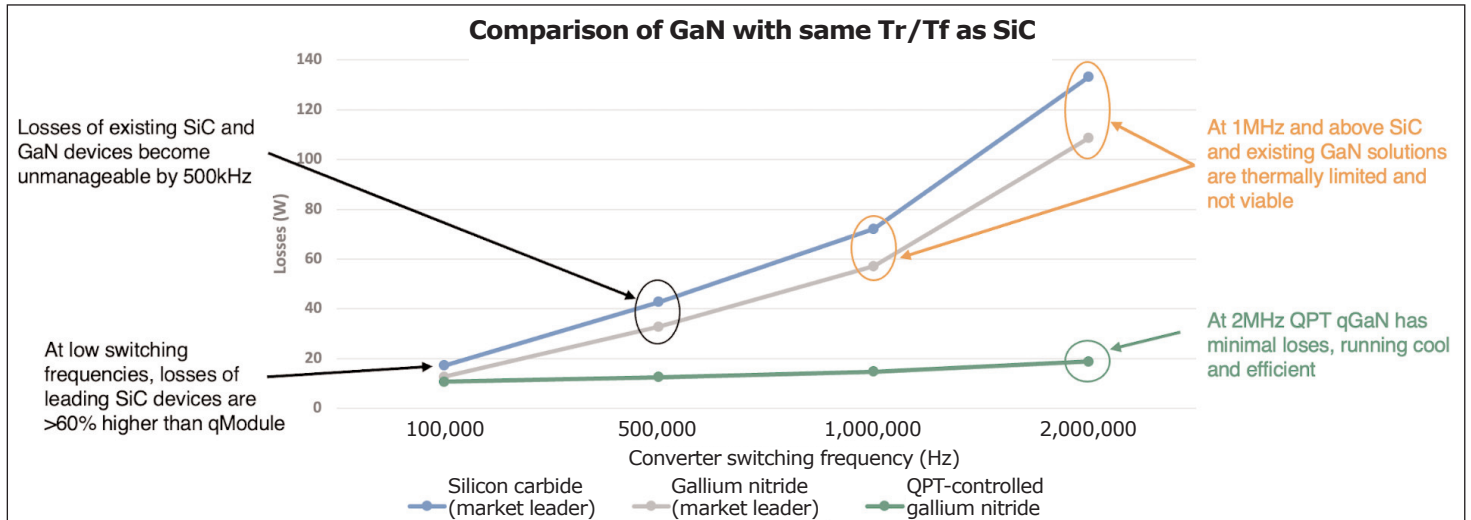


Figure 2: Comparison of SiC, GaN and QPT-controlled GaN.

The reference design is a drop-in replacement for the power stage of existing variable-frequency drives (VFDs) without the need for any specialist expertise in EMC or thermal cooling.

"The rest of the existing system such as the micro-processor and software stack stay the same. This makes upgrading a genuine plug-and-play solution with the benefits of needing less power, so it effectively pays for itself in weeks," says Gwynne. "In addition, there are further savings as the new bill of materials (BOM) is less than existing solutions as it does not require external filters," he adds. "Companies who want to upgrade from their current silicon solutions to be more

power efficient can leapfrog over the hassle of developing a SiC solution in-house and simply use our unleashed GaN solution. Combining the VFD power saving of around 80% with the motor usage gives around 10% reduction in overall power usage, which increases in applications where the motor is frequently at low speeds where the current solutions are inefficient."

QPT estimates that the high-voltage, high-power application markets where its new technology can provide significant power savings has a total addressable market (TAM) of \$365bn. A key segment of that is HVAC and especially heat pumps that are being deployed exponentially around the world, so the TAM

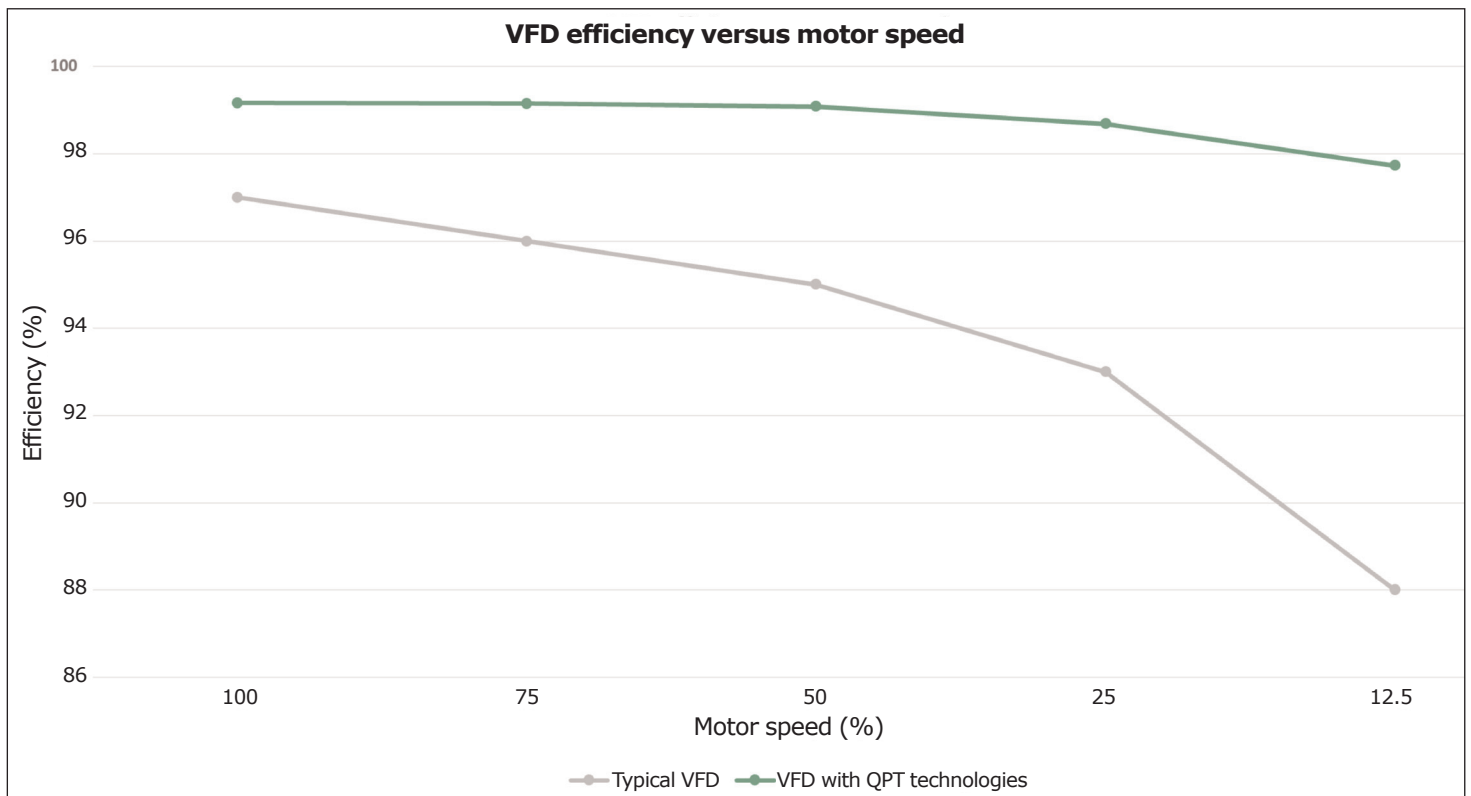


Figure 3: How typical VFD efficiency drops off dramatically and wastes energy as motor speed drops, unlike with QPT technology.

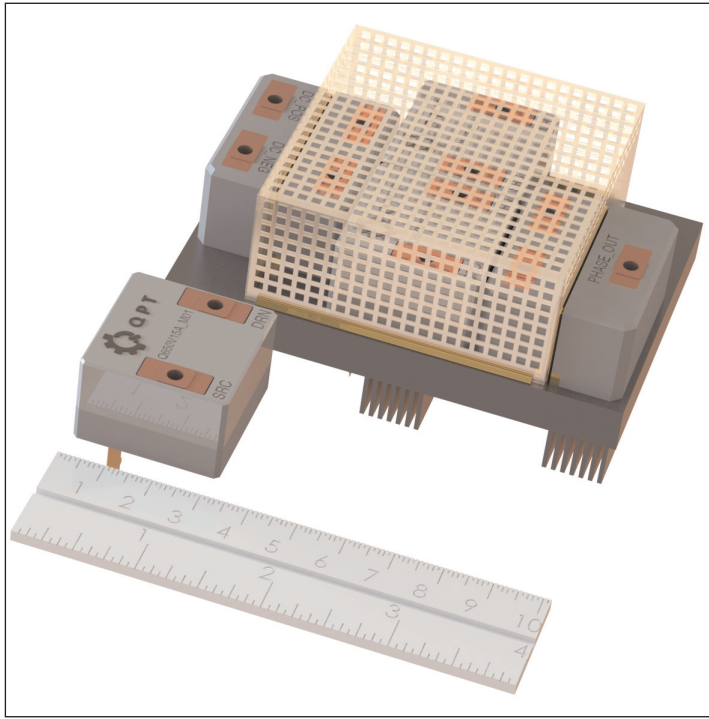


Figure 4: QPT's reference design for a VFD using its modules with a qGaN module in the foreground.

will continue to increase. "Electric motors account for 45% of global electricity usage, and our technology can make them more efficient and that means less carbon dioxide emissions which helps combat climate changes," says Gwynne.

Variable frequency drives

The key application area is in control electronics for motor drives, where their high level of efficiency can play a key role in saving energy. Market researchers

estimate that 11 billion electric motors are added annually, accounting for 45% of total electrical energy use, so more efficient motor controls could provide significant global energy savings and reductions in CO₂ generation.

VFDs work by chopping the incoming power to create a frequency that can be changed to adjust the speed of the motor. Energy is lost every time chopping occurs and, currently, manufacturers believe this to be minimal, hence their quoted 97% efficiency figure. However, this figure is at full speed but, in reality, the speed varies and the efficiency drops significantly as the speed drops, which is what happens in a real-world operational cycle and is quietly ignored by manufacturers (similar to car manufacturers only quoting fuel usage at the optimal speed and not mentioning the real-world figures of an urban cycle).

To reduce the energy wasted and therefore be more efficient, the chopping needs to be fast, transitioning from off to on or on to off, as quickly as possible. This is because, during the switching time when the transistor is neither on nor off, it is dissipating huge amounts of power, and this accounts for most of the energy losses.

GaN transistors with QPT technology are now capable of running at frequencies of up to 20MHz to provide ultrafast switching in 1–2ns, as opposed to 20–50ns for GaN when constrained to under 100kHz to avoid heating and EMC issues. Thus, they are in this high-energy-loss region for very little time and, consequently, they waste very little energy chopping the DC up into variable-frequency AC to drive the motor across the complete range of different speeds. ■

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Infineon launches European Union projects for power electronics and artificial intelligence

45 partners from 12 countries are collaborating in the €60m project ALL2GaN for 'Affordable smart GaN IC solutions for greener applications'.

Infinion in Villach, Austria is launching two European research projects involving 98 partners from 18 countries, with total funding over three years (until April 2026) of €130m from industry investments, grants from the individual countries involved, and the European Key Digital Technologies research program.

The project ALL2GaN (*Affordable smart GaN IC solutions for greener applications*) is about easily integrated energy-saving chips made of gallium nitride. They have the potential to improve energy efficiency by 30% in a wide range of applications and thus save an extrapolated 218 million tons of CO₂ worldwide.

The project AIMS5.0 (*Artificial Intelligence in Manufacturing leading to Sustainability and Industry 5.0*) focuses on artificial intelligence (AI) to create resource-efficient manufacturing across industries as well as optimize supply chain management in Europe.

Through the 'Green Deal', the European Union (EU) aims to make Europe the first climate-neutral continent by 2050. Smart, low-emission technologies with a digitally strong, competitive and sustainable industry in Europe are hence needed more than ever. Research and innovation in pacemaker technologies such as power electronics are crucial catalysts in the implementation of the Green Deal, it is reckoned.

"Investments in key technologies are essential for achieving the climate targets. This can be achieved through research, cooperation with the best partners and innovations with real impact - as extrapolated here with a savings potential of 218 million tons of CO₂," says Infineon Technologies Austria AG's CEO Sabine Herlitschka. "With these two projects, we are doing just that. Together, we can develop sustainable products and processes faster and make a decisive contribution to decarbonization and digitization," she adds. "The results strengthen industry and Europe as a location in global competition. They bring more strategic autonomy for Europe and our society, secure supply chains and are a turbo for an energy-efficient future."

New generation of energy-saving chips reduces emissions

Led by Infineon Technologies Austria AG, ALL2GaN brings together 45 partners from 12 countries with a total budget of about €60m. The aim is to fully exploit the energy-saving potential of highly efficient power semiconductors made of gallium nitride, to integrate them easily and quickly into many applications, and thus to reduce emissions.

GaN chips: energy efficiency reduces CO₂ footprint

Generating, controlling and using energy efficiently is a decisive lever for CO₂ reduction. The less energy that is wasted, the lower the emissions. Intelligent technologies and semiconductor materials such as GaN play a key role. They deliver more power in a small space, convert energy highly efficiently and thus minimize the CO₂ footprint in digital devices.

Variable 'toolbox' for fast integration

Following the development of cost-efficient GaN chips at Infineon-Villach, the research team is now working on a crucial milestone: the GaN power semiconductors will be modular and easily embedded in many applications through the integration toolbox. The research extends from individual chip elements, high-performance GaN modules, to chip designs and novel system-on-chip approaches. The advantage: variably adaptable GaN system solutions mean faster integration into applications, rises in energy efficiency, and a drop in CO₂ emissions.

Telecommunications, data centers and server farms can benefit from the new, highly integrable GaN chip generation 'Made in Europe', as can e-mobility, renewable energies and highly efficient smart grid solutions. Projections show that this new GaN chip generation can reduce energy losses in applications by an average of 30% (roughly equivalent to 218 megatons of CO₂ saved worldwide).



From left to right: Johannes Schoiswohl, senior VP & general manager Business Line EPIC, Division Power & Sensor Systems, Infineon Technologies Austria AG; Infineon Technologies Austria AG CEO Sabine Herlitschka; Henriette Spyra, section head Innovation and Technology, Austrian Ministry for Climate Protection; and KDT JU programme manager Francisco Ignacio.

"GaN technologies are paving the way for applications that drive decarbonization. Applications such as mobile charging, data-center power supplies, residential solar inverters and onboard chargers for electric vehicles are at the tipping point," says Adam White, division president Power and Sensor Systems, at Infineon Technologies AG. "With the All2GaN research project, energy-saving chips made of gallium nitride can now be developed even faster and easily embedded in many applications thanks to the integration toolbox," he adds. "The research project opens up enormous application potential and creates sustainable benefits."

Green Industry 5.0 with artificial intelligence

In AIMS5.0, research is being conducted on smart AI technologies for resource-efficient manufacturing in Europe. A 53-partner strong consortium of producers, suppliers, research institutions and AI specialists from 12 countries is thus paving the way for an economical, ecologically sustainable Industry 5.0 and the European Green Deal. Led by Infineon Technologies AG in Munich, the project has funding of €70m.

AI technologies bring efficiency boost

Efficiency is one of the main economic principles and can be further improved through safe AI methods. More efficiency in processes brings lower resource consumption in manufacturing, better product quality and also robust supply chain management through intelligent networking along the value chain. In line with the Industry 5.0 approach, the skills of employees are being qualified for AI use and young students are already being introduced to the required AI skills in practice by academic partners.

The AIMS5.0 team is taking a common AI approach across industries and applications for the first time. It is about the development and production of hardware and software components and a secure AI networking platform. The results are aimed at strengthening manufacturing in mechanical engineering, semiconductors, electronics as well as in the automotive industry and creating resilient supply chains in Europe.

"With AI research, we are supporting a modern and sustainable industry," says Thomas Morgenstern, executive director Frontend at Infineon Technologies AG. "This benefits the partners directly and subsequently

many other manufacturing sectors. It strengthens the entire industry and know-how location as well as the technological sovereignty in Europe," he adds. "At the same time, the project also develops the AI skills of employees through training and qualification methods and improves human-machine interaction."

Research starts at Infineon site in Villach

The kick-off event and thus the official start of both projects is taking place on 23 May at Infineon's Villach site. Both EU projects are co-funded by the KDT-JU (Key Digital Technologies Joint Undertaking) program of the European Union and the participating countries.

"The two Infineon projects show us very well that in many seemingly specific, individual and technical optimization processes, such as the use of new semiconductor materials for power electronics or the use of advanced AI for the management of complex supply chains, there is enormous potential for achieving sustainability goals," comments Henriette Spyra, section head for Innovation and Technology at the Austrian Ministry for Climate Protection. "These must be uncovered and implemented. Then these pacesetting technologies can act as 'Tech4Green', as drivers for long-term sustainability transformations," she adds.

"The projects make an extremely important contribution to the implementation of the KDT JU portfolio," says KDT JU director Yves Gigase. "They address the top priorities of current European policies, such as the Green Deal. They are about the development of power electronics for energy-efficient applications and European digital autonomy with the introduction of AI in the industrial value chain to increase productivity and more sustainable production," he adds. "With the European Chips Act, the results of these projects will play an even more important role in many digital applications."

ALL2GaN – Affordable smart GaN IC solutions for greener applications

The 45 partners in 12 countries are:

Austria: Infineon Technologies Austria AG, Fronius International GmbH, KAI GmbH, Silicon Austria Labs GmbH, Graz University of Technology, Vienna University of Technology

Belgium: imec, MinDCet NV

Czech Republic: Thermo Fischer Scientific, Brno University of Technology

Denmark: Aalborg University, Ballard Power Systems Europe

Germany: AIXTRON SE, CE-LAB GmbH, Chemnitzer Werkstoffmechanik GmbH, Fraunhofer Gesellschaft (IAF, IMWS, IZM), Heraeus Deutschland GmbH & Co KG, Infineon Technologies AG, IMS Chips, IMST GmbH, NanoWired GmbH, NaMLab GmbH, Chemnitz University of Technology

Greece: Institute of Electronic Structure and Laser, Foundation for Research and Technology — Hellas

Netherlands: Applied Micro Electronics 'AME' B.V., Nexperia BV, Signify, Delft University of Technology, Eindhoven University of Technology

Norway: Delta electronics (Norway) AS

Slovakia: Nano Design Ltd, Slovak University of Technology in Bratislava

Spain: For Optimal Renewable Energy, IKERLAN, University of Mondragon, Premium S.A., Universidad Politécnica de Madrid

Sweden: AlixLabs AB, Chalmers University of Technology, Ericsson AB, RISE Research Institutes of Sweden AB, SweGaN AB.

Switzerland: Attolight AG, Corintis SA, Ecole Polytechnique Fédérale de Lausanne EPFL

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Germany: Infineon Technologies AG, AI Dig+ Solutions, Bayrische Motoren Werke BMW, Cetto, Fabmatics, Fern-Universität Hagen, Institut für Integrierte Produktion Hannover, Fraunhofer Gesellschaft, Hochschule Stralsund, Hochschule Zittau/Görlitz, Infineon Technologies Dresden, Systeme Systementwicklung, Technische Universität Dresden, Universität Lübeck

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Greece: Idryma Technologies Kai Erevnas, Harokopio University

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Progress towards complementary GaN on silicon

Researchers have boosted the performance MOCVD-grown p-FETs alongside n-FETs.

Researchers in the USA, Bangladesh and the United Arab Emirates report progress in developing complementary transistor technology (CT) on a metal-organic chemical vapor deposition (MOCVD) gallium nitride (GaN) on silicon (Si) substrate platform [Qingyun Xie et al, IEEE Transactions on Electron Devices, v70, p2121, 2023].

The team from Massachusetts Institute of Technology in the USA, Bangladesh University of Engineering and Technology, and Technology Innovation Institute in the United Arab Emirates, report: "To the best of the authors' knowledge, the best p-FET in this work features the highest current density among MOCVD III-N p-FET ($>2\times$ the previous record, $\sim 140\text{mA/mm}$), as well as competitive performance compared with GaN/AlN molecular beam epitaxy (MBE) counterparts"

The p-channel field effect transistors (p-FETs) were integrated with n-FETs with a view to wafer-level heterogeneous integration of GaN complementary circuits (based on a silicon substrate) with silicon complementary metal-oxide semiconductor (CMOS)

technology to achieve multi-functional chips.

Complementary circuits using p-FETs and n-FETs in enhancement mode (normally off) reduces static power consumption, and has been key to the success of mainstream silicon electronics. Transferring this capability to GaN could extend their reach beyond compact, efficient power management — deployed in data centers, power adapters, electric vehicles (EVs), and 5G/6G telecommunications — to more sophisticated applications requiring control loops and analog mixed-signal blocks. The use of p-FETs in GaN circuits could also enable higher switching speeds for more efficient and higher-density power converters.

The researchers found that scaling the p-FETs with reduced gate length (L_G) greatly improved the maximum drain current ($I_{D,\text{max}}$) performance: "The p-FET of this work achieved $-I_{D,\text{max}} \times L_G = 52.5\mu\text{A}$, which is a record for MOCVD-based (single GaN/AlGaIn epitaxial layer) p-FETs, and is close to the values for the record MBE-based p-FETs and MOCVD superlattice (multiple GaN/AlGaIn epitaxial layers) p-FETs."

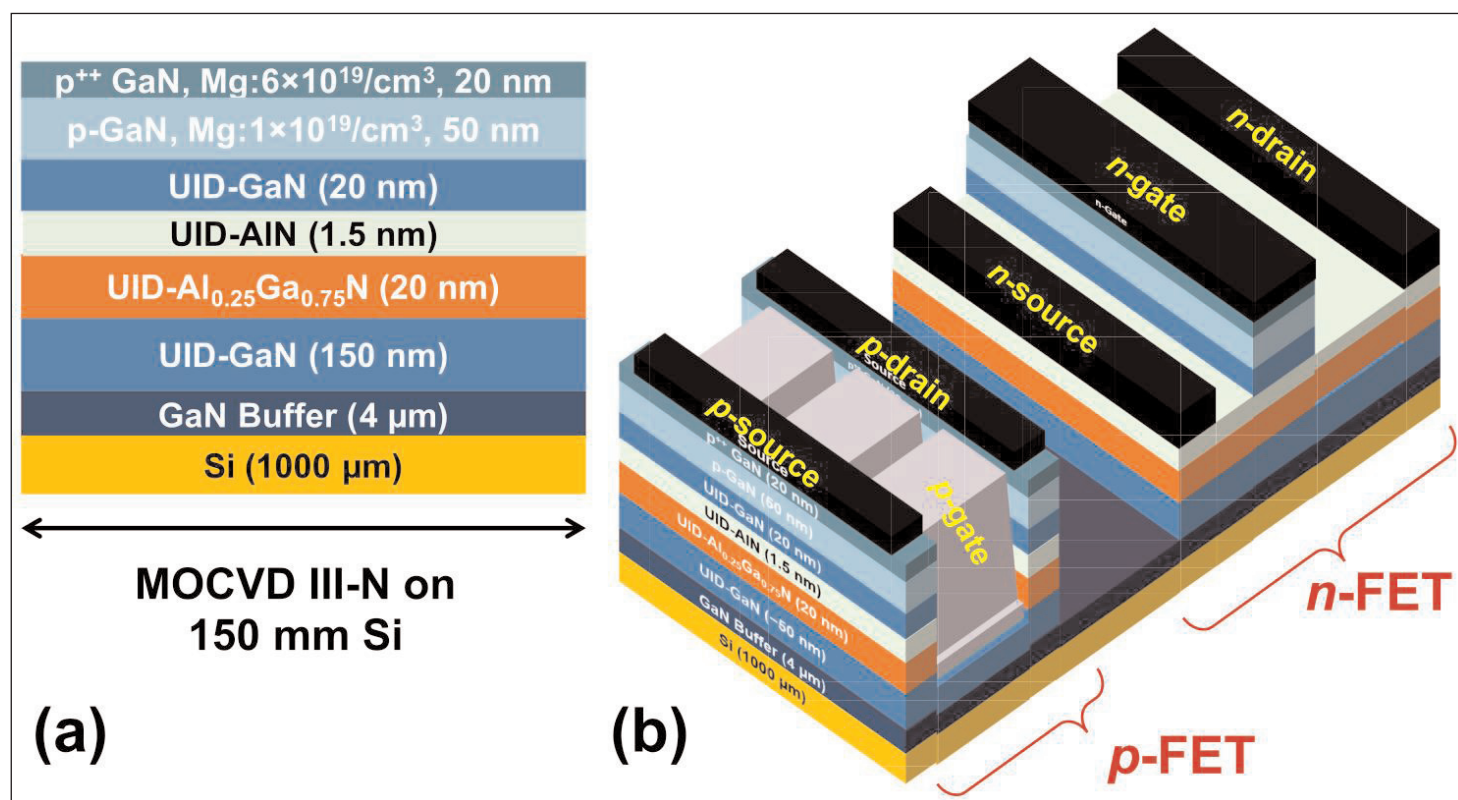


Figure 1. (a) Epi structure. (b) Device structures of p-FET (SA FinFET) and n-FET (SA-gate p-GaN-gate HEMT).

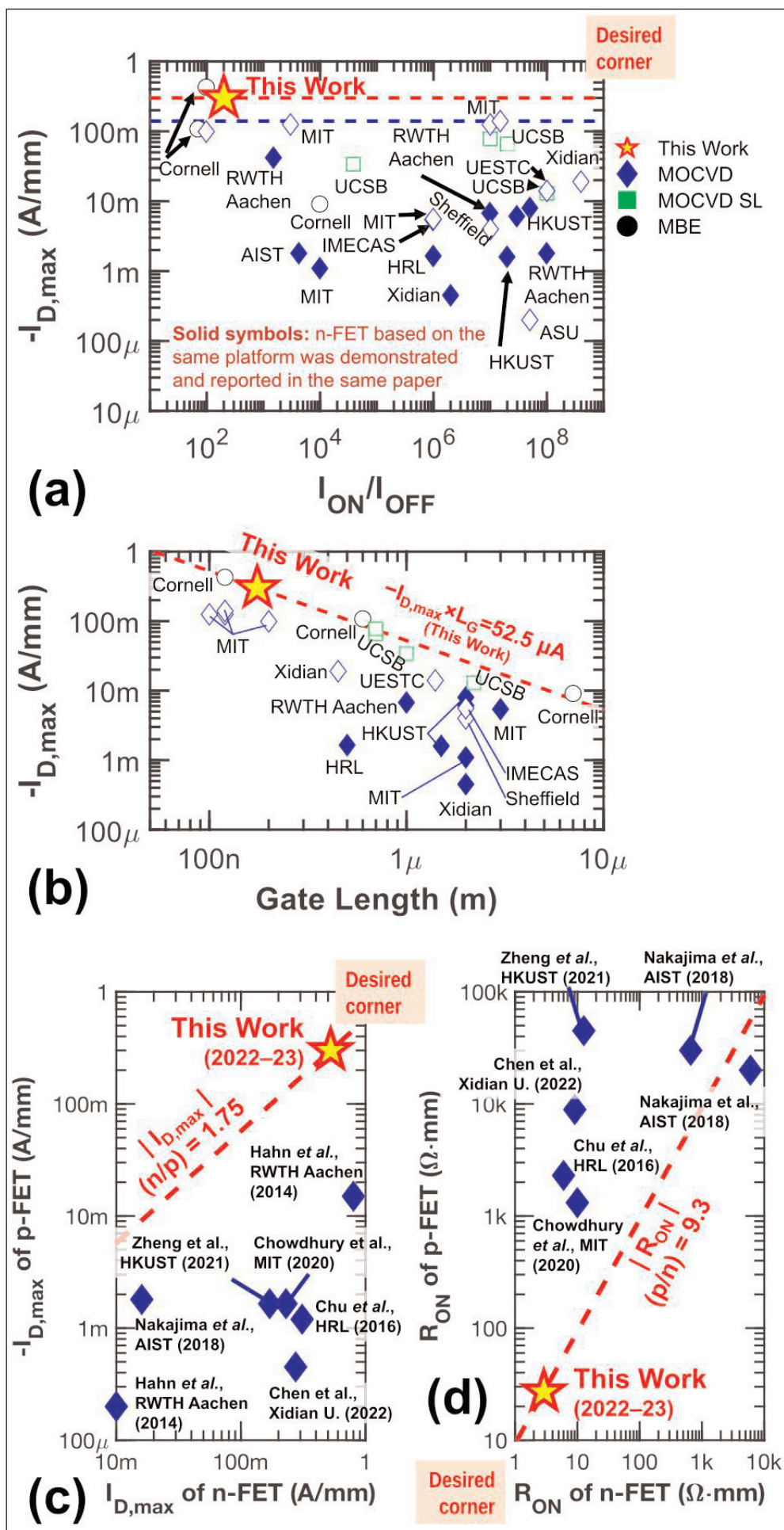
Figure 2. Benchmarks with other published works. (a) GaN p-FETs in terms of ON-current and ON/OFF ratio. (b) Trade-off between current density and gate length. (c) and (d) GaN CTs (complementary transistors reported in same article) in terms of current densities and R_{ON} respectively. Solid symbols indicate complementary transistors (p-FET and n-FET) on the same platform demonstrated and reported in the same article.

The wafers for the transistors were supplied by Dr Kai Cheng of China-based Enkris Semiconductor Inc. The epitaxial structure was grown on 6-inch silicon wafers (Figure 1). A 1.5nm AlN layer was inserted to boost hole mobility through charge polarization effects from the ionic nature of the III-V chemical bond. The AlN also served as an etch-stop layer in the device fabrication processes.

The p-FET devices used a fin architecture to enable channel scaling in an effort to overcome the low, less than $30\text{cm}^2/\text{V}\cdot\text{s}$ hole mobility in GaN. The fin structure also improved acceptor ionization, increasing hole density, through the polarization-induced fields.

The fabrication was carried out at MIT's own facility with some work being carried out at Rensselaer Polytechnic Institute in the USA by Bryant C. Colwill. The p-FET fabrication used a self-aligned (SA) process with the ohmic nickel/gold/nickel metal source/drain electrodes being applied first to also serve as part of the masking and alignment for subsequent etching of the fin channels and gate structures.

The fin patterning was through electron-beam lithography on hydrogen silsesquioxane (HSQ) resist. The fins were etched through reactive-ion etch (RIE). The fin direction was chosen to be in the m-plane, ensuring smoother sidewalls. Further steps were taken



to reduce etch damage, in particular, tetramethylammonium hydroxide (TMAH) exposure at 75°C for 5 minutes, and 500°C annealing in nitrogen atmosphere for 30 minutes. These treatments were found to reduce channel on-resistance (R_{ON}) by 15%.

The researchers report: "The optimized process was capable of achieving the fin widths of 20nm at an L_{SD} of <200nm. The SA architecture ensures that the access region (and therefore access resistance) is negligible, and that the entire length of the fin ($=L_{SD}$) is gated."

The gate stack consisted of atomic layer deposition (ALD) of 15nm silicon dioxide (SiO_2) and radio frequency (RF) sputtering of titanium/gold gate metals. The 250°C ALD oxide came from tris(dimethylamino)silane (TDMAS) and O_2 plasma precursors.

The best p-FET device demonstrated a maximum drain current of -300mA/mm, 27m Ω -mm R_{ON} , 3V threshold, and 13mS/mm peak transconductance. The on/off current ratio was only 200 due to gate leakage through the dielectric. The poor oxide quality also impacted gate control and drain-induced barrier lowering (DIBL). Destructive breakdown occurred around 20V.

The p-FETs were affected by the gate recess depth, where a second threshold was seen with deep recessing. Simulations suggest that the second threshold comes from a second bulk sub-channel forming in addition to the desired two-dimensional hole gas (2DHG) channel near the p-GaN/AlGaIn interface. In deeply recessed structures the overlying p-GaN is thinner, reducing hole concentrations and the transconductance of the 2DHG sub-channel.

The researchers comment: "The p-channel in the epitaxial structure is buried, and therefore a simple top gate is not sufficient to exert electrostatic control over the entire channel. A recessed gate structure, while adding design flexibility to p-FETs, requires special consideration in the design (recess depth and geometric profile) and fabrication (e.g. reducing etch-induced damage)."

For the n-FET a gate-first SA strategy was used. The p-GaN gate structure was masked using patterned nickel/gold/nickel on a blanket layer of sputtered tungsten. Tungsten has high thermal stability and forms a Schottky contact with p-GaN.

The p-GaN not under the gate structure was then selectively etched away before application of the titanium/aluminium/nickel/gold source/drain electrodes. The gate stack was placed in the middle of the source/drain gap, and there were no electric field management structures to improve performance. The resulting devices are therefore described by the team as 'proof of concept'.

N-FET devices with 200nm gate length showed good saturation with 525mA/mm maximum drain current and 2.9m Ω -mm R_{ON} . The threshold was positive at +1.6V, giving enhancement-mode, normally-off performance. The peak transconductance (g_m) of 265mS/mm "reflects good gate control using the proposed gate metallization stack", the team comments. Destructive breakdown occurred at 50V.

The device structure had improved performance when fabricated on an epitaxial structure not designed to support p-FETs. In particular, the 1.5nm AlN and 20nm GaN layers were not present, and the AlGaIn was reduced from 20nm to 15nm: the drain current reached 750mA/mm with 1.3m Ω -mm R_{ON} . The sub-threshold swing was also reduced from 123mV/decade (with AlN/GaN insertions) to 100mV/decade (without). The closer proximity of the gate to the channel improved the electrostatic control.

The researchers benchmarked their work against other reports working towards similar complementary technology goals (Figure 2). The team particularly highlights reports where the p-FET and n-FET were produced on the same platform. The researchers point out that all these reports used MOCVD rather than MBE. The MIT et al devices had a ratio of the maximum drain current of the n-/p-FET of 1.75, closer to unity than the other reports. The p/n-FET ratio for R_{ON} was 9.3, obviously quite far from 1, but only one other report was inside that.

The researchers comment: "A ratio approaching unity ($=1$) is desired to achieve reasonable transistor sizing. The current density of the reported GaN CT is comparable with that of 5V-rated silicon CMOS in an industry 0.13 μ m bipolar-CMOS-DMOS (BCD) process published in 2016 ($I_{D,max\{n,p\}} = \{520, -323\}$ mA/mm)." ■

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Microwave Week

11–13 June 2023

2023 IEEE Radio Frequency Integrated Circuits Symposium (RFIC 2023)

San Diego Convention Center,
San Diego, CA, USA

E-mail: support@mtt.org

www.rfic-ieee.org

11–16 June 2023

2023 IEEE/MTT-S International Microwave Symposium (IMS 2023)

San Diego Convention Center,
San Diego, CA, USA

E-mail: exhibits@horizonhouse.com

www.ims-ieee.org/ims2023

11–16 June 2023

43rd Symposium on VLSI Technology & Circuits

Rihga Royal Hotel, Kyoto, Japan

E-mail: vlsisymposium@jtbcom.co.jp (Asia and Japan) or
vlsi@vlsisymposium.org (North America and Europe)

www.vlsisymposium.org

13–16 June 2023

Intersolar Europe 2023

Messe München, Munich, Germany

E-mail: info@intersolar.de

www.intersolar.de

25–29 June 2023

World of PHOTONICS CONGRESS — International Congress on Photonics in Europe

ICM — Internationales Congress Center München,

Munich, Germany

E-mail: info@photonics-congress.com

www.photonics-congress.com/en

29 June – 1 July 2023

SEMICON China

Shanghai New International Expo Centre (SNIEC), China

E-mail: semichina@semi.org

www.semiconchina.org

11–13 July 2023

SEMICON West 2023

Moscone Center, San Francisco, CA, USA

E-mail: semiconwest@semi.org

www.semiconwest.org

23–26 July 2023

AVS 23rd International Conference on Atomic Layer Deposition (ALD 2023), featuring the 10th International Atomic Layer Etching Workshop (ALE 2023)

Hyatt Regency Bellevue in Bellevue,
Washington (East Seattle), WA, USA

E-mail: della@avs.org

www.ald2023.avs.org

6–8 September 2023

CIOE 2023 (The 24th China International Optoelectronic Exposition)

Shenzhen World Exhibition & Convention Center, China

E-mail: cioe@cioe.cn

www.cioe.cn/en

6–8 September 2023

SEMICON Taiwan 2023

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TaiNEX 1&2, Taipei, Taiwan

E-mail: semicontaiwan@semi.org

www.semicontaiwan.org

17–22 September 2023

International Conference on Silicon Carbide and Related Materials (ICSCRM 2023)

Hilton Sorrento Palace Conference Centre, Sorrento, Italy

E-mail: info@icscrm-2023.org

www.icscrm-2023.org

17–22 September 2023

26th European Microwave Week (EuMW 2023)

Berlin Messe, Germany

E-mail: eumwreg@itnint.com

www.eumweek.com

1–5 October 2023

European Conference on Optical Communication (ECOC 2023)

Glasgow, Scotland, UK

E-mail: postmaster@theiet.org

<https://ecoc2023.theiet.org>

14–18 October 2023

2023 IEEE BiCMOS and Compound Semiconductor Integrated Circuits and Technology Symposium (BCICTS)

Monterey, CA, USA

E-mail: cs@cshawevent.com

www.bciets.org

14–17 November 2023

SEMICON Europa 2023

Messe München, Munich, Germany

E-mail: semiconeuropa@semi.org

www.semiconeuropa.org

9–13 December 2023

69th annual IEEE International Electron Devices Meeting (IEDM 2023) – ‘Devices for a Smart World Built Upon 60 Years of CMOS’

Hilton San Francisco Union Square Hotel, San Francisco, CA, USA

Paper-submission deadline: 13 July

E-mail: iedm-info@ieee.org

www.ieee-iedm.org

13–15 December 2023

SEMICON Japan 2023

Tokyo Big Sight, Tokyo, Japan

E-mail: semicon@sakurain.co.jp

www.semiconjapan.org

18–22 February 2024

2024 IEEE International Solid- State Circuits Conference (ISSCC 2024)

San Francisco, CA USA

E-mail: Issccinfo@yesevents.com

www.isscc.org

12–23 June 2024

2024 IEEE Symposium on VLSI Technology and Circuits

Hilton Hawaiian Village Waikiki Beach Resort, Honolulu, HI, USA

E-mail: vlsi@vlsisymposium.org

www.vlsisymposium.org

16–21 June 2024

2024 IEEE/MTT-S International Microwave Symposium (IMS 2024)

Washington DC, USA

E-mail: exhibits@horizonhouse.com

www.ims-ieee.org/about-ims/past-and-future-ims

22–26 September 2024

European Conference on Optical Communication (ECOC 2024)

Frankfurt am Main, Germany

E-mail: michelle.dampier@nexusmediaevents.com

www.ecocexhibition.com/future-dates

October 2024

SEMICON West 2024

Moscone Center, San Francisco, CA, USA

E-mail: semiconwest@semi.org

www.semiconwest.org

16–20 February 2025

2025 IEEE International Solid- State Circuits Conference (ISSCC 2025)

San Francisco, CA USA

E-mail: Issccinfo@yesevents.com

www.isscc.org

15–20 June 2025

2025 IEEE/MTT-S International Microwave Symposium (IMS 2025)

San Francisco, CA, USA

E-mail: exhibits@horizonhouse.com

www.ims-ieee.org/about-ims/past-and-future-ims

7–9 October 2025

SEMICON West 2025

Phoenix, AZ, USA

E-mail: semiconwest@semi.org

www.semiconwest.org



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