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C O M P O U N D S & A D V A N C E D S I L I C O N

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US manufacturing gains government funding



Qorvo buying Anokiwave • Luminus launches its first lasers
Silvaco joins GaN Valley • BluGlass & Applied Energetics team



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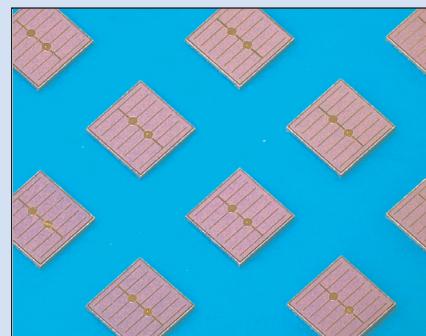
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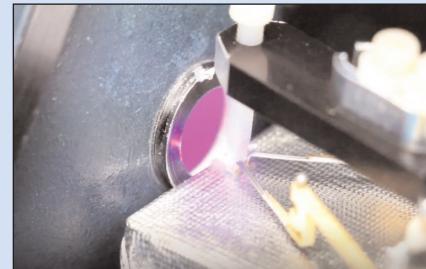
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p34 With funding of £11m from the EPSRC and Innovate UK, the new Innovation and Knowledge Centre REWIRE is led by Bristol University.



p49 Japan's Dowa Electronic Materials has released an SWIR LED chip series with record luminous efficiency in the peak wavelength range 1200–1900nm.



p53 Australia's BluGlass is to collaborate on its GaN DFB lasers being used by US-based Applied Energetics in its systems for next-generation military and commercial applications .



Cover image:
 US-based SK Siltron CSS is promised \$544m under the Department of Energy's Advanced Technology Vehicles Manufacturing Loan

Program to expand US manufacturing capacity for silicon carbide wafers at its plant in Bay City, Michigan, create up to an additional 200 jobs. **p41**

editorial

Funding for domestic supply chains

Since the \$50bn US CHIPS and Science Act was enacted in August 2022, much US government funding has been allocated for regenerating onshore manufacturing of semiconductors. Just this week, President Biden set an ambitious target for the USA to manufacture 20% of the world's high-end chips by the end of this decade. The country produced almost 40% of the world chips in the 1990s but less than 10% now, and none of the highest-end chips, which are mostly made by foundries in Taiwan and South Korea.

This concerns mostly mainstream silicon for advanced logic and memory ICs. But there is also consideration for key strategic industrial/automotive and defense application sectors such as power electronics and microwave/RF communications/radar, which require wide-bandgap compound semiconductor materials such as silicon carbide and gallium nitride.

Of the three CHIPS and Science Act awards announced so far, the first, last December, comprised \$35m for BAE Systems to modernize its Microelectronics Center in Nashua, NH, which includes a defense-centric gallium arsenide (GaAs) and gallium nitride (GaN) HEMT 6" wafer foundry. After a second award in early January of \$162m for Microchip Technology to triple its domestic production of silicon-based microcontrollers etc, the third award on 19 February is of \$1.5bn to GlobalFoundries — see page 8. Most of this is for the expansion of an existing fab, plus construction of a new fab there, tripling silicon chip production capacity at GF's site in Malta, NY. However, \$125m will contribute to GF's \$900m modernization of its plant in Essex Junction, Vermont to "upgrade existing facilities, expand capacity as well as create the first US facility capable of high-volume manufacturing of GaN semiconductors for use in electric vehicles, power grids, data centers, 5G and 6G smartphones and other critical technologies".

Also, the US Department of Energy (DOE) has just issued a conditional commitment for a loan of up to \$544m to compound semiconductor substrate maker SK Siltron CSS of Auburn, MI, USA (a subsidiary of South Korea-based wafer manufacturer SK Siltron) — see page 41. Specifically, the DOE's Advanced Technology Vehicles Manufacturing (ATVM) Loan Program aims to expand US manufacturing of silicon carbide wafers, citing their application in electric vehicle power electronics. The project is cited as "an important step towards ensuring a resilient and robust supply chain in the United States".

Most recently, on 26 February, the DOE's Office of Electricity launched the \$2.25m American-Made Silicon Carbide (SiC) Packaging Prize, which invites competitors to propose, design, build and test state-of-the-art SiC semiconductor packaging prototypes to enable SiC-based power modules to work more effectively in high-voltage environments such as energy storage — see www.semiconductor-today.com/news_items/2024/feb/doe-270224.shtml. The prize is part of the American-Made Challenges program, which fosters collaboration between the USA's entrepreneurs and innovators, DOE's National Labs, and the private sector.

Packaging is the step in the silicon chip manufacturing chain that, over the decades, has become most outsourced to low-cost manufacturing hubs overseas, particularly in Asia, including China. Trade war with China has led the USA to urgently onshore such functions. Compared with silicon, SiC and GaN wide-bandgap power devices are in the early stages of high-volume manufacturing. There is hence both as-yet unmet demand and the strategic need for companies to fill the gaps in the domestic supply chains that are being formed, where government funds are available.

Mark Telford, Editor

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Semiconductor Today covers the R&D and manufacturing of compound semiconductor and advanced silicon materials and devices (e.g. GaAs, InP and SiGe wafers, chips and modules for microelectronic and optoelectronic devices such as RFICs, lasers and LEDs in wireless and optical communications, etc).

Regular issues contain:

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- feature articles (technology, markets, regional profiles);
- conference reports;
- event calendar and event previews;
- suppliers' directory.

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LED packaging market to grow at 3.9% CAGR from \$16bn in 2024 to \$19.4bn in 2029

CSP package type and Asia Pacific region to see highest CAGRs

The LED packaging market will rise at a compound annual growth rate (CAGR) of 3.9% from US\$16bn in 2024 to US\$19.4bn in 2029, forecasts a new report from MarketsandMarkets.

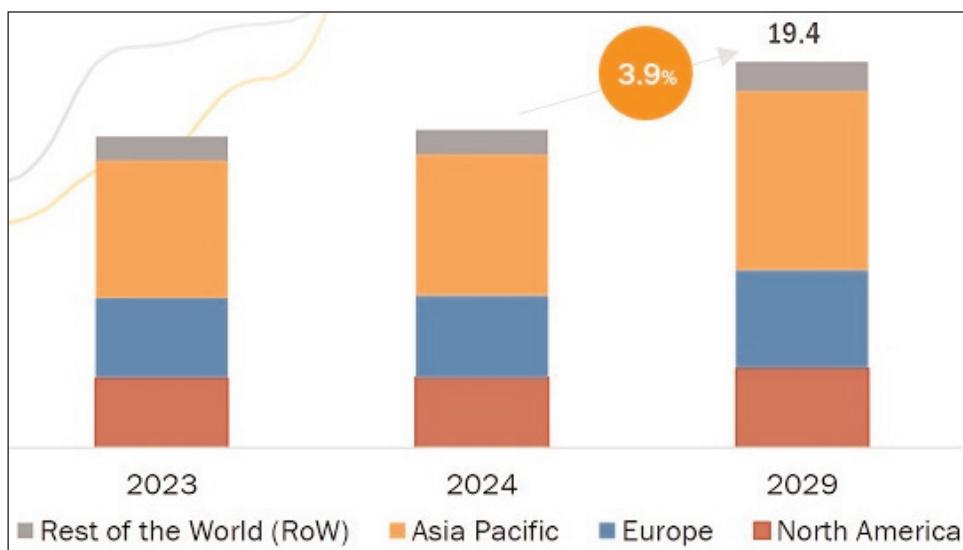
The major factors driving the growth of the LED packaging equipment market include the growing adoption in automotive lighting solutions and the surging prices of packaged LEDs. Additionally, the ongoing development of advanced LED packaging technologies is expected to create growth opportunities for the LED packaging market in the future.

CSP package type to see highest CAGR

The widespread adoption of chip-scale package (CSP) LEDs over surface-mounted device (SMD) LEDs is attributed to their numerous advantages such as minimized footprint, slim profile, cost-effectiveness, elevated lumen output, reduced weight, improved electrical performance, and an enhanced organized distribution of connections. These attributes contribute to effective utilization of the epitaxial manufacturing process. High-performance CSP LEDs can be used for applications that require high output, such as automotive, where conventional mid-powered LEDs were previously utilized. The CSP package type is hence expected to register the highest CAGR in the LED packaging market during the forecast period.

General lighting to have largest market size

The general lighting application is projected to dominate the LED packaging industry due to the increasing demand for LED lighting in commercial settings and the widespread adoption of LED technology as a replacement for tradi-



tional light sources, which results in reduced energy consumption.

The prominence of this market is growing further due to the efforts of governments and regulatory bodies to promote energy conservation, particularly in the residential and industrial sectors.

Asia-Pacific to see highest CAGR by region

The Asia-Pacific region's substantial share of the LED packaging market can be attributed to rapid infrastructure development, particularly in China. These infrastructure projects prioritize effi-

Major factors driving the growth of the LED packaging equipment market include the growing adoption in automotive lighting solutions and the surging prices of packaged LEDs. The ongoing development of advanced LED packaging technologies is expected to create growth opportunities for the LED packaging market in the future.

cency, paving the way for modernization. The ongoing modernization and expansion of infrastructure, which includes the establishment of smart cities, is expected to fuel demand for smart street-lighting, boosting the market for LED packages in the region. Additionally, Asia-Pacific has become a central hub for investment and business expansion in the LED packaging market, which is supported by favorable economic conditions and cost-effective labor. The Asia-Pacific is hence expected to be the region with the highest CAGR in the LED packaging market during the forecast period.

The report profiles key players in LED packaging such as Nichia Corp (Japan), ams-OSRAM AG (Austria), Samsung (South Korea), Lumileds Holding B.V. (US), Seoul Semiconductor Co Ltd (South Korea), MLS Co Ltd (China), Everlight Electronics Co Ltd (Taiwan), SMART Global Holdings Inc (USA), Foshan NationStar Optoelectronics Co Ltd (China), and LITE-ON Technology Inc (Taiwan).

www.marketsandmarkets.com/Market-Reports/led-packaging-market-217522990.html

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GlobalFoundries gains \$1.5bn in CHIPS and Science Act funding

Projects to expand New York fab, build new fab, and upgrade Vermont fab for high-volume GaN manufacturing

As part of the US CHIPS and Science Act, the US Department of Commerce has announced \$1.5bn in planned direct funding for New York-headquartered GlobalFoundries (GF), which is celebrating 15 years of operations and is the only US-based pure-play foundry with a global manufacturing footprint including facilities in the USA, Europe and Singapore. The investment aims to enable GF to expand and create new manufacturing capacity and capabilities to securely produce more chips for automotive, IoT, aerospace, defense and other vital markets.

GF is the first semiconductor pure-play foundry to receive a major award (over \$1.5bn) from the CHIPS and Science Act, which is designed to strengthen US semiconductor manufacturing, supply chains and national security. The proposed funding will support three GF projects:

- Expansion of GF's existing fabrication plant in Malta, NY, by adding critical technologies already in production in GF's Singapore and Germany facilities geared towards enabling the US auto industry. As vehicles transition from mechanical to electronic systems, the number of semiconductor chips in each car or truck continues to soar. This expansion is said to be key to ensuring supply chain resilience for the growing demand and to delivering for GF's automotive customers including General Motors. This will also continue to diversify GF's flagship Malta fab into new technologies and end markets.

- Construction of a new fab on the Malta campus to meet expected customer demand for US-made essential chips across a broad range of markets and applications including automotive, aerospace, defense and artificial intelligence (AI).

The new fab, which has already been granted some necessary permitting, will leverage the site's existing infrastructure and ecosystem, enabling a fast and efficient path from construction to production. The semiconductor market is expected to double over the next decade, and GF's new fab aims to be positioned to capture the feature-rich mature, essential chip segment, which is expected to continue to represent more than 60% of the semiconductor market. Combined with the expansion of GF's existing site, construction of the new fab is expected to triple the existing capacity of the Malta campus over the next 10+ years. These two projects are expected to increase wafer production to 1 million per year once all phases are complete.

- Modernization of GF's longest continuously operated fab and the nation's first and largest Trusted 200mm facility in Essex Junction, Vermont. The project will upgrade existing facilities, expand capacity as well as create the first US facility capable of high-volume manufacturing of gallium nitride (GaN) semiconductors for use in electric vehicles, power grids, data centers, 5G and 6G smartphones and other critical technologies

smartphones and other critical technologies.

Based on market requirements and demand, GF plans to invest more than \$12bn over the next 10-plus years across its two US sites through public-private partnerships with support from the federal and state governments as well as from its ecosystem partners, including key strategic customers.

In support of the two projects in Malta, New York, Governor Hochul has announced \$575m in planned direct funding for New York State Green CHIPS. Also announced was \$15m in planned funding for NYS Workforce Development activities for GlobalFoundries as well as \$30m in planned funding for NYS Infrastructure upgrades and Energy incentives provided by the New York Power Authority (NYPA).

Combined, these investments are expected to create over 1500 manufacturing jobs and about 9000 construction jobs over the life of these projects.

"GF is proud to announce this proposed funding from the Department of Commerce and New York State and appreciates the collaboration of the CHIPS Office and the Empire State Development Corporation throughout this process. These proposed investments, along with the investment tax credit (ITC) for semiconductor manufacturing, are central to the next chapter of the GlobalFoundries story and our industry. They will also play an important role in making the US semiconductor ecosystem more globally competitive and resilient and cements the New York Capital Region as a global semiconductor hub," says GF's president & CEO Dr Thomas Caulfield. "With new onshore capacity and technology on the horizon, as an industry we now need to turn our attention to

increasing the demand for US-made chips, and to growing our talented US semiconductor workforce," he adds.

"It was the shortages of semiconductors during the COVID-19 pandemic that raised prices for consumers and led to the shutdown of automobile manufacturing sites across the country," notes US Secretary of Commerce Gina Raimondo. "Thanks to the CHIPS and Science Act, we're working to onshore these critical technologies in order to bolster the supply of domestic chips that are essential to manufacturing cars, electronics and national defense systems in New York, Vermont, and states across the country," she adds.

"GlobalFoundries has reached a preliminary agreement for the largest award thus far from the CHIPS program I created for \$1.5bn in grant funding. This will triple production capacity of GlobalFoundries' already massive campus in Saratoga County, spur billions in public-private investment, and help bring thousands of new good-paying manufacturing and union construction jobs to the Capital Region," says Senator Chuck Schumer. "When I wrote the CHIPS & Science Law, I made sure there was funding especially for the feature-rich, legacy chips that GlobalFoundries produces in Malta and that are essential for America's auto industry and national defense. We all remember the days of the pandemic when chip shortages sky-rocketed car prices and created supply chain

issues, leading to months-long wait times for cars and electronics, and investments like this are how we can help prevent that from happening again. Ever since GlobalFoundries' first Fab 8 broke ground 15 years ago, I knew how significant the company would be for the Capital Region and Upstate NY," he adds.

To attract and cultivate a pipeline of semiconductor talent that will be needed in New York and Vermont, GF is creating and investing in numerous initiatives. The firm recently announced a new student loan repayment program to help current employees and new recruits pay down student loan debt. The new benefit program is part of the its multi-million-dollar investment to strengthen the semiconductor talent workforce by helping to ease the financial burden of higher education and training. GF is also partnering with a range of universities and community colleges nationwide to help to build a diverse workforce and semiconductor talent pipeline. As part of receiving CHIPS and Science Act funding, GF will continue to invest in and develop new workforce development efforts, including curriculum development, internship and apprenticeship programs, K-12 STEM outreach as well as additional education and training programs.

GF says that design and construction plans for its expansions and modernizations in New York and Vermont will reflect its ongoing

commitment to sustainable operations and comply with the firm's sustainability goals.

"This is a well-deserved recognition of GlobalFoundries' commitment to bolstering the on-shore growth of US-made chips," says Senator Peter Welch. "This investment, made possible by the CHIPS and Science Act and the White House and Secretary Raimondo's commitment to competitiveness and security, will create jobs while making our supply chains more resilient. Even more impressive, this new site will see its commitment to sustainability through with a plan to use carbon-free neutral energy practices," Welch adds.

"The first and largest 200mm semiconductor manufacturing facility of its kind in the US, GF's Vermont fab is a cornerstone of the state's economy and a key partner for the University of Vermont's work as a national research university," comments Kirk Dombrowski, VP for research and economic development at University of Vermont (UVM). "CHIPS funding will help ensure the commercial viability of this site for years to come and enable GF and UVM to build upon our recent [Economic Development Administration] EDA Tech Hub designation to create internships, apprenticeships, workforce development programs, and advanced research initiatives in the Green Mountain State."

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Skyworks reports record cash flow, despite quarterly revenue falling 9.6% year-on-year to \$1.2bn

Broad Markets revenue bottoms out, while Android-related Mobile begins recovery

For its fiscal first-quarter 2024 (to 29 December 2023) Skyworks Solutions Inc of Irvine, CA, USA (which manufactures analog and mixed-signal semiconductors) has reported revenue of \$1201.5m, down 1.4% on \$1218.8m last quarter and 9.6% on \$1329.3m a year ago, but slightly above the midpoint of the \$1175–1225m guidance.

Mobile products comprised 71% of total revenue (up from 65% last quarter), as Skyworks supported the ramp of new high-performance solutions at its largest customer. Android-related revenue with Google, Samsung and the Chinese OEMs grew modestly sequentially.

"After two challenging years across Android ecosystems [involving several quarters of inventory correction], we see signs that the industry is stabilizing," says chairman, CEO & president Liam K. Griffin. "Excess supply conditions are abating and inventory levels in the distribution channel and at the OEM level are normalizing," he adds. "Customers are starting to re-stock inventory, albeit gradually as supply and demand dynamics improve and new phones are introduced into the market."

Broad Markets products comprised 29% of total revenue (down from 35% last quarter), with revenue declining 18% sequentially, due mostly to some specific near-term inventory corrections in wireless infrastructure, automotive and industrial.

"We see cross-currents, but many factors are moving in the right direction," says Griffin. "In consumer IoT, we believe that we are past the bottom, as inventory levels in the channel have normalized and demand signals are improving. Furthermore, we are executing on the upgrade cycle to WiFi 6E and 7," he adds. "Taken

together, we anticipate December quarter represents the bottom in the Broad Markets business."

Driven by an unfavorable shift in product mix resulting from the lower Broad Markets revenue, gross margin (on a non-GAAP basis) has fallen further, from 51.5% a year ago and 47.1% last quarter to 46.4%. This was also impacted by Skyworks reducing its internal inventory further during the quarter, by \$193m from \$1120m to \$927m (beyond the targeted \$1bn).

Operating expenses were \$191m (15.9% of revenue), cut from \$193m a year ago and below the \$193–197m guidance range, given Skyworks' ongoing focus on managing discretionary expenses, while continuing to invest in technology and product roadmaps.

Net income has fallen further, from \$414.6m (\$2.59 per diluted share) a year ago and \$352.8m (\$2.20 per diluted share) last quarter to \$317m (\$1.97 per diluted share, although this exceeds the \$1.95 guidance).

"Skyworks continues to execute well and generate robust profitability in light of ongoing macro-economic volatility," says Griffin. Operating cash flow was a record \$774.9m,

After two challenging years across Android ecosystems, we see signs that the industry is stabilizing. Excess supply conditions are abating and inventory levels in the distribution channel and at the OEM level are normalizing. Customers are starting to re-stock inventory, albeit gradually

up from \$365.7m last quarter and surpassing the \$773.4m a year ago.

Driven by the strong profitability, working capital management and moderating CapEx intensity — cutting capital expenditure from \$70.1m last quarter to just \$22.2m (less than 2% of revenue) — free cash flow was a record \$752.7m (free cash flow margin of 62.6%), up on just \$295.6m (24.3% margin) last quarter and exceeding the \$709.9m (59.1% margin) a year ago.

During fiscal Q1, Skyworks repurchased \$32.7m of common stock, paid out \$108.9m in dividends, and repaid the remaining \$300m on its term loan, which had a variable interest rate and "was getting a little expensive" — this has reduced debt to \$993m.

Overall, cash and cash equivalents hence rose by \$310.9m, from \$718.8m to \$1029.7m. The net cash position is therefore positive, yielding an "optimal capital structure, providing us with superior flexibility and optionality".

Since the quarter-end, Skyworks' board of directors has declared a further cash dividend of \$0.68 per share of common stock, payable on 12 March to stockholders of record at the close of business on 20 February.

"We've made strategic investments in product development, positioning us to compete for design wins and share gains, focusing on highly integrated platforms for the leading mobile OEMs," says Griffin.

Highlights during fiscal Q1 included:

- securing several design wins in infrastructure, including optical transport products with a major operator in India and timing devices for 5G small cells for private networks;
- expanding the Wi-Fi design-win pipeline with Cisco's enterprise

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- access point, Linksys tri-band mesh router, and TP-Link's tri-band gaming router;
- increasing design-win momentum in automotive including telematics, infotainment systems, and on-board chargers across the leading OEMs; and
- in emerging IoT, delivering next-generation smart energy solutions with Google's Nest temperature sensors and Itron's residential gas meters.

"We see significant design-win momentum across our retail, carrier and enterprise channels. These systems carry substantially higher dollar content, because of the addition of the new 6GHz band and the inclusion of BAW filtering technology," says Griffin.

"We expect wireless infrastructure and traditional data center will remain a headwind throughout 2024, as OEMs continue to digest excess inventory. Despite this, we remain bullish on several new product cycles, including major design wins in Ethernet for high-bandwidth networks and 400G and 800G optical module upgrades," he adds.

"We see opportunities for growth in our automotive business driven by higher adoption rates of connectivity in the vehicle, along with growing EV penetration, driving demand for our power isolation products."

Outlook

For its fiscal second-quarter 2024 (to end-March), Skyworks expects revenue of \$1.02–1.07bn.

"We expect our Mobile business to be seasonally down, consistent with historical patterns, while in Broad Markets we anticipate modest growth off the December-quarter bottom [albeit down year-over-year, by 20%], as inventory levels are normalizing in certain end-markets," says senior VP & chief financial officer Kris Sennesael.

Gross margin is projected to fall to 45–46%, reflecting the firm's seasonally weakest quarter, as well as the after-effect of having reduced factory utilization to drive down internal inventory.

Operating expenses should rise to \$193–197m as Skyworks continues to make strategic investments in technology and product roadmaps in Mobile and Broad Markets to drive share gains and increased diversification.

At the \$1.045bn midpoint of the revenue range, the targeted diluted earnings per share are \$1.52.

"We are pleased with our competitive positioning and technology roadmap and are poised to return to growth when the markets recover," says Griffin.

"We are seeing signs that the Android smartphone market is recovering," notes Griffin. "In Broad Markets, there are several long-term secular growth dynamics that leverage our differentiated technology, including the proliferation of intelligent edge-connected

IoT devices, automotive, electrification and advanced safety systems, and AI-enabled workloads, driving cloud and data-center upgrades. Each of these trends require intricate connectivity engines underlying the need for speed, ultra-reliable low-latency performance," he reckons.

"In addition, 5G technology is expanding beyond the smartphone into more use cases in Broad Markets, including private cellular networks in

factories and stadiums, customer premise equipment supporting Verizon and T-Mobile, and multi-band, automotive, telematics, and wearables," adds Griffin.

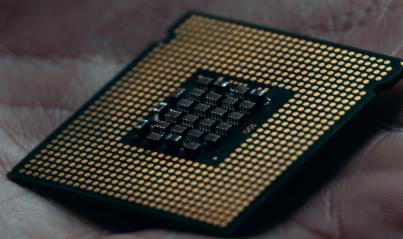
"We also remain bullish on the long-term RF content story in smartphones. Coupled with growing 5G penetration, we see increasing levels of complexity and content with each new generation. For example, 5G Advanced is driving higher RF content, including the addition of satellite bands 4x4 MIMO on the downlink and uplink, higher bandwidth, more carrier aggregation, upgrades to WiFi and GPS and other innovations. Lastly, we are energized about the prospect of generative AI migrating to the smartphone, sparking a potential major upgrade cycle. As the performance bar rises every year to support AI-enabled phones, the complexity requirements of RF will continue to increase, driving the need for more integration, lower power consumption, smaller footprint, and spectral efficiency."

"5G is the ideal standard for on-device AI applications, as it takes advantage of lower latency, faster transmission speeds and higher frequency ranges. In addition, AI-enabled workloads are driving demand for high-speed connectivity for data-intensive infrastructure and cloud upgrades, accelerating the demand for our high-precision timing products," concludes Griffin.

"We anticipate margin expansion during the remainder of 2024, benefiting from our disciplined management of our manufacturing and operational cost structure, both internal and external, along with higher factory utilization rates [as Skyworks no longer has to focus on reducing inventory]," says Sennesael. "We will also benefit from a favorable mix shift as our Broad Markets business recovers and accelerates," he adds. "Our long-term target model calls for 53% gross margin. There is no structural impairments in the business that will prevent that."

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Global Transport and Logistics

Qorvo to acquire Anokiwave

Silicon ICs for intelligent active array antennas expand opportunities in defense & aerospace, SATCOMs and 5G

Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has reached a definitive agreement to acquire Anokiwave Inc, which provides high-performance silicon integrated circuits (for intelligent active array antennas for defense & aerospace, SATCOM and 5G applications. The transaction is expected to close during the March quarter.

Anokiwave is based in Boston, MA, and operates design centers and sales offices in Boston and in San Diego, CA. The Anokiwave team will join Qorvo's High Performance Analog (HPA) segment and will continue to develop beamformers and IF-RF solutions for defense

phased array and AESA radar, electronic warfare (EW), satellite communications and 5G applications.

"Anokiwave's high-frequency beamforming and intermediate frequency (IF) to RF conversion ICs are a strong complement to Qorvo's RF front-end portfolio," says Philip Chesley, president of Qorvo's High Performance

The combination of our unique capabilities will enable us to supply highly integrated complete solutions and SiPs for defense, aerospace and network infrastructure applications

Analog segment. "The combination of our unique capabilities will enable us to supply highly integrated complete solutions and SiPs for defense, aerospace and network infrastructure applications," he adds.

"Anokiwave's innovative portfolio of active antenna ICs, combined with Qorvo's complementary products, global scale and significant market reach, will create exciting new opportunities to deliver customers superior levels of performance, efficiency and integration," says Anokiwave's chief technology officer, founder & chairman Nitin Jain.

www.anokiwave.com

www.qorvo.com

Qorvo launches automotive-qualified 9mΩ 750V silicon carbide FET in D²PAK-7L package

First in new family of pin-compatible SiC FETs with R_{DS(on)} up to 60mΩ

Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has unveiled an automotive-qualified silicon carbide (SiC) field effect transistor (FET) offering what is claimed to be an industry-best on-resistance R_{DS(on)} of 9mΩ in a compact D2PAK-7L package.

The 750V SiC FET is the first in a new family of pin-compatible SiC FETs from Qorvo with R_{DS(on)} options up to 60mΩ, making them well suited for electric vehicle (EV) applications, including on-board chargers, DC/DC converters and positive temperature coefficient (PTC) heater modules.

The UJ4SC075009B7S features a 9mΩ typical R_{DS(on)} at 25°C needed for reducing conduction losses and maximizing efficiency in high-voltage, multi-kilowatt

automotive applications. Its small, surface-mount package enables automated assembly flows and is said to reduce customer manufacturing costs.

The new 750V family complements Qorvo's existing 1200V and 1700V automotive SiC FETs in D2PAK packaging to form a complete portfolio addressing EV applications that span 400V and 800V battery architectures.

"The launch of this new family of SiC FETs demonstrates our commitment to providing EV powertrain designers the most advanced and efficient solutions for their unique automotive power challenges," says Ramanan Natarajan, director of product line marketing for Qorvo's Power Products.

These fourth-generation SiC FETs leverage Qorvo's unique cascode circuit configuration, in which a

SiC JFET is co-packaged with a silicon MOSFET to produce a device with the efficiency advantages of wide-bandgap switch technology and the simpler gate drive of silicon MOSFETs. Efficiency in SiC FETs is dependent on conduction losses, and Qorvo's cascode/JFET approach enables reduced conduction losses through industry-best R_{DS(on)} and body diode reverse voltage drop.

Key features of the UJ4SC075009B7S include:

- threshold voltage V_{G(th)} of 4.5V (typical), allowing 0–15V drive;
- low body diode V_{FSD} of 1.1V;
- maximum operating temperature of 175°C;
- excellent reverse recovery of Q_{rr} = 338nC;
- low gate charge: Q_G = 75nC;
- Automotive Electronics Council (AEC) Q101-qualified.

www.qorvo.com/go/gen4

Qorvo's quarterly revenue up 44.5% year-on-year

March quarter sees growth in end-market demand in Android ecosystem

For its fiscal third-quarter 2024 (to 30 December 2023), Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has reported revenue of \$1073.9m, down 2.7% on \$1103.5m last quarter but up 44.5% on \$743.3m a year ago. This exceeds the high point of the guidance range (of \$1bn, plus or minus \$25m) by \$49m. "Revenue continues to benefit from significant content gains at our largest customer," says chief financial officer Grant Brown.

By business segment, revenue comprised:

- Advanced Cellular Group (ACG) \$846.1m (down just 0.5% on \$846.1m last quarter but up 72.1% on \$491.5m a year ago), primarily for smartphones and other cellular devices including tablets and wearables;
- Connectivity & Sensors Group (CSG) \$108.9m (up 5.1% on \$103.6m last quarter and 12.5% on \$96.8m a year ago), over half of which is currently WiFi;
- High-Performance Analog (HPA) \$118.9m (down 20.6% on \$149.8m last quarter and 23.3% on \$155m a year ago), since base-station business — which typically has better-than-corporate gross margin — is currently much less than before.

On a non-GAAP basis, gross margin was 43.8%, up on 40.9% a year ago (and towards the top end of the 43-44% guidance range). However, this is down from 47.6% last quarter, as a larger portion of revenue was manufactured internally during the period of lower utilization, leading to higher unit costs.

During the quarter, Qorvo reduced its net inventory balance by \$113m from \$840m (138 days) to \$727m (118 days), reflecting the firm's commitment to efficient inventory management. "We continued to bring channel inventories down, and Qorvo shipments are now

more closely aligned to end-market demand," notes president & CEO Bob Bruggeworth. "The demand environment in the December quarter improved versus our November outlook, and this is reflected in our strong performance."

Operating expenses were \$234m, up on \$205.7m a year ago but cut from \$245.8m last quarter, due largely to R&D spending falling from \$163.4m to \$152.5m.

Operating income was \$236.5m (operating margin of 22% of revenue), down on \$279.4m last quarter but up on \$98.6m a year ago.

By operating segment (compared with last quarter), operating margin was just 1.3% for HPA (down from 17%), 31.2% for ACG (down slightly from 33.5%), and -23.5% for CSG (a slight improvement from -26.7%).

Net income was \$205.9m (\$2.10 per diluted share), down from \$235.5m (\$2.39 per diluted share) last quarter but up on just \$76.5m (\$0.75 per diluted share) a year ago, and well above the guidance of \$1.65 per diluted share.

"Qorvo exceeded the mid-point of December quarterly guidance for revenue, gross margin and EPS, reflecting strong content on customer programs and improving channel inventories," says Brown.

Qorvo generated record cash flow from operations **Qorvo** of \$492.9m. Capital expenditure was \$26.4m. Free cash flow was hence a record \$466.5m (up more than seven-fold from \$64.4m last quarter). Qorvo also repurchased about \$100m of stock. Cash and cash equivalents therefore rose during the **inventories**

quarter from \$706.8m to \$1072m. Long-term debt outstanding has been cut from \$2048.6m to about \$1550m.

In mid-December, Qorvo said that it was divesting its Beijing and Dezhou assembly & test facilities via a new multi-year partnership with Luxshare Precision Industry Co Ltd of Dongguan City, Guangdong, China (which, during first-half 2024, will acquire their operations and assets, including the property, plant and equipment, as well as the existing workforce to enable continuity of operations). Qorvo will continue to maintain its sales, product and test engineering, and customer support staff in China "Adding Luxshare as a strategic partner will strengthen our position to serve our customers globally," reckons Brown.

"As it relates to our manufacturing strategy, this is a further step in our ongoing efforts to reduce capital intensity," notes Brown. "This move aligns with previous actions, including the closure of our Florida manufacturing operations and the recent sale of our Farmers Branch facility in Texas. We are efficiently managing a complex supply chain, including our internal factories, which support all three operating segments and will remain an ongoing focus. We will leverage internal manufacturing where it uniquely differentiates our products and outsource production where we maintain a strong network of foundry and OSAT partners," he adds.

During the quarter, Qorvo also signed a definitive agreement to acquire Boston-based Anokiwave Inc (a supplier of high-performance silicon integrated circuits for intelligent active array antennas), expanding Qorvo's offerings for defense & aerospace, SATCOM and 5G applications. Based in Boston, MA, and with design centers and sales offices in Boston and in San Diego, CA, the Anokiwave team will join Qorvo's HPA segment. The ➤

transaction is expected to close during the March quarter.

"Our investments in our technology portfolio, product development, and advanced manufacturing will broaden our addressable market, diversify revenue, expand margin, and accelerate growth," reckons Brown.

Strategic highlights during the quarter

● High-Performance Analog (HPA)

In defense & aerospace (D&A), Qorvo won an expanded radar design with a major DoD contractor and received new standard product orders in support of several large domestic and international ground-based radar systems. It also saw increasing demand for solid-state power amplifier (PA) products and for its switch filter bank products across multiple customers and programs. "There are multi-year secular trends driving our D&A business, including the trend of one-to-many, and the transition of mechanical systems to active electronics scanning systems, both of which increased requirements for more advanced systems-level RF solutions," says Bruggeworth.

"In power management, we are extending our reach in markets where Qorvo enjoys a strong presence, such as wearables and other consumer products," he adds. The most recent award is a PMIC chipset with multiple placements for wearables and a charger at a leading Android OEM. Complementing this, the firm began to see a rebound in solid-state drives (SSDs) for PC and enterprise markets. "We are continuing to expand upon our strong position, with an additional power management win in support of a leading manufacturer of laptops."

In power devices, Qorvo is shipping into power supplies for blockchain applications, and design activity in data center continues to be strong. "We are also seeing increased activity in circuit protection, where our JFET technology brings unique advantages," says Bruggeworth.

In automotive, design activity remains strong, not only for on-board chargers but also for other emerging applications and electric vehicles.

"In infrastructure, Qorvo is leading the DOCSIS 4.0 upgrade cycle. We commence volume shipments of our newest DOCSIS 4.0 hybrid power doubler in support of multiple cable OEMs," says Bruggeworth. In the cellular base-station market, inventories continue to be consumed and Qorvo expects demand conditions to remain soft through calendar-year 2024.

● Connectivity & Sensors Group (CSG)

CSG customer activity for ultra-wideband is increasing in secure access automotive applications, notes Qorvo. It is also seeing new applications for ultra-wideband in automotive, including presence detection and other radar-based sensors. This momentum builds upon recent wins in ultra-wideband, including an in-vehicle car access platform and a flagship Android smartphone launch.

"As we demonstrated at CES, we are actively involved in a wide array of enterprise and connected home solutions, leveraging radar and ultra-wideband for applications such as door locks, smart lighting and indoor navigation," says Bruggeworth.

In force-sensing touch sensors, Qorvo received the first production orders for an automotive supplier in support of a leading Korea-based automotive OEM. "We are seeing increasing traction across a growing set of customers and markets, including automotive, laptop trackpads, wearables, and smart home," notes Bruggeworth.

In WiFi, design activity and collaboration remain strong across reference designs, customers and operators. Within the Android ecosystem, the demand environment for mobile WiFi is improving with the normalization of Android channel inventories. In access points, WiFi 6 volumes continue to grow with certain provider rollouts

in India. In WiFi 7, Qorvo secured design wins across operator, retail, enterprise and mobile segments.

● Advanced Cellular Group (ACG)

In ACG, Qorvo commenced shipments in support of the spring 2024 flagship smartphone launch by the leading Android smartphone OEM. "On our last earnings call, we highlighted our content gains in the flagship tier," says Bruggeworth. "In addition to the ultra-wideband, Qorvo content this year includes, the low band, mid-high band, ultra-high band, secondary transmit & receive, tuning, and WiFi. We are ramping up now and building upon our momentum with a broad set of design wins in this customer's high-volume mass-market portfolio."

Android mass-market smartphones are set to transition to 5G through the decade. "Our collaboration with Android customers on their long-term product roadmaps positions Qorvo to be a primary beneficiary," Bruggeworth believes. Qorvo was correspondingly recognized by the top four China-based Android 5G OEMs [Honor, OPPO, Xiaomi, and Vivo] with 2023 awards for innovation, quality, supply, technology and strategic partnership. "To simplify 5G adoption and sustain our position as the leading global strategic supplier to Android OEMs, we continue to launch new architectures and new products that enhance performance and reduce form factors," he adds. During the quarter, Qorvo expanded customer sampling of its newly launched main-path LMH power amplifier duplexer (PAD). Optimized for mass-market smartphones, this highly integrated solution combines, in a single placement, the low-, mid- and high-band main-path content traditionally offered in two placements, reducing surface area by 40%, simplifying design, and accelerating time to market.

"In addition to developing highly integrated solutions with increasing levels of functional density, we're also advancing technology in our

high-performance discrete portfolio, including our BAW [bulk acoustic wave] filters," says Bruggeworth. During the quarter, Qorvo received purchase orders for discrete BAW filters using its recently released next-generation BAW technology.

For calendar 2024, Qorvo expects total smartphone units to grow in the low single digits, with 5G units growing by over 10%. "To compete and win, we collaborate with customers on their three-year product roadmaps and we supply them industry-leading solutions," says Bruggeworth. "We enjoy our position as the preferred strategic RF supplier for all the customers we serve in the Android space, and we are very well positioned to benefit as their portfolios continue to transition to 5G," he reckons.

"Demand for Qorvo's products has improved, primarily due to our proactive efforts to align channel inventories with end-market demand and content gains on key customer programs," says Bruggeworth. "We are delivering customers industry-leading products and technologies, and design activity remains robust."

Outlook

Year-on-year revenue growth in all operating segments in March quarter, with incremental growth in Android ecosystem

For its fiscal fourth-quarter 2024 (to end-March), Qorvo expects revenue of \$925m, plus or minus \$25m. "We are seeing incremental improvement in end-market demand in the Android ecosystem, and we expect to achieve year-over-year revenue growth in all of Qorvo's operating segments in the March quarter," says Bruggeworth.

"In ACG, we expect substantial year-on-year growth despite the typical sequential decline associated with our largest customer's fall ramp. Partially offsetting that seasonal decline is healthier channel inventories and improving smartphone unit demand in China, as well as the flagship launch by

our largest Android customer," says Brown.

"In HPA, we expect year-over-year growth across all the businesses except base station, supporting our view for a return to year-over-year growth in HPA in the March quarter [following ACG and CSG achieving year-on-year growth in the September quarter]. From a mixed perspective, the more capital-intensive end-markets we serve — such as base station and some others including infrastructure — face headwinds due to the interest rate sensitivity of those customers and some of those larger build-outs. Consequently, defense & aerospace now represents over half of the HPA top line, making that segment a bit more sensitive to the timing of some of those defense programs quarter-to-quarter," Brown adds.

"In CSG, we also expect year-over-year growth in the March quarter, supported by our WiFi revenue. It'll be up meaningfully from Q4 last fiscal year," says Brown. "Slower-than-expected ramps in IoT-related areas are expected in March, probably persisting through the first half of 2024," he adds.

Although the auto market appears to be weakening, in general, our secular opportunities there lie in the automotive connectivity areas which are supported by the growing adoption of 5G, WiFi and ultra-wideband. We've already announced some significant design wins there in CSG for automotive and smart phone

band. We've already announced some significant design wins there in CSG for automotive and smart phone. And we're targeting additional areas including industrial enterprise and smart home."

Gross margin is expected to fall further to about 42% in fiscal Q4, but Skyworks expects continued improvement to days of inventory.

Operating expenses should rise to about \$245m, with variability related to labor-related expenses and the timing of program development spend. Diluted earnings per share should be about \$1.20 at the midpoint of revenue. CapEx is expected to rise in the March quarter (but remain well under 5% of revenue for the full-year).

"Relative to December, we expect March revenue to reflect a larger percentage of higher-cost inventories previously manufactured internally during periods of lower utilization. As these higher-cost previously manufactured inventories sell through, it paves the way for future gross margins that reflect increasing levels of utilization," says Brown. "We currently expect to have sold through most of these higher-cost inventories and associated costs by the second half of this calendar year... Beyond March, there is no change to our guidance of returning to 50%-plus gross margin over time," he adds.

"We continue to invest in new product development as it is a critical catalyst for driving multi-year growth across all three business segments," says Brown. "Alongside these growth-oriented investments, we continue to launch productivity initiatives across the enterprise. These initiatives also span multiple years, are designed to support future growth, augment productivity, and enhance profitability."

"Looking forward, we are capitalizing on global macro trends and multi-year technology upgrade cycles, and we expect this to support durable long-term growth," concludes Brown.

www.qorvo.com

Wolfspeed quarterly revenue grows 20% year-on-year, as design-wins hit a record \$2.9bn

Mohawk Valley Fab revenue triples sequentially; on track for 20% utilization in June quarter

For its fiscal second-quarter 2024 (to end-December 2023), Wolfspeed Inc of Durham, NC, USA — which makes silicon carbide (SiC) materials and power semiconductor devices — has reported revenue of \$208.4m, up 5.6% on \$197.4m last quarter and up nearly 20% on \$173.8m a year ago, and above the midpoint of the \$192–222m guidance range.

All figures are for continuing operations, after Wolfspeed completed the sale (announced on 22 August) of its radio frequency business Wolfspeed RF to MACOM Technology Solutions Holdings Inc of Lowell, MA, USA for \$75m in cash plus 711,528 shares of MACOM common stock (valued at \$50m based on its 30 trading day trailing average closing price through 21 August).

Power Device revenue was a record \$107.7m, up 6.4% on \$101.2m last quarter and 12.2% on \$96m a year ago, driven by strong demand for products and the contribution from the new Mohawk Valley Fab in Marcy, NY (the world's largest 200mm SiC wafer fab) tripling to \$12m from \$4m the prior quarter as it ramped up utilization (after starting revenue-generating production at the end of the fiscal Q4/2023 June quarter).

"We saw a sharp increase in electric vehicle (EV) revenue quarter-over-quarter [up 30%], fueled by the additional EV device products shipping out of Mohawk Valley," notes chief financial officer Neill Reynolds. "So far we've qualified over a dozen customer parts, including two of our most complicated automotive devices as well as the largest device we are currently producing at the facility... All of these MOSFETs qualified first-pass," says CEO Gregg Lowe. "We expect to continue to qualify more parts between now and the end of June, further supporting the Mohawk Valley revenue ramp," he adds. Also,

Mohawk Valley has received its IATF automotive certification (on its first attempt). "However, this was partially offset by lower demand and persistent weakness in our industrial and energy markets, particularly in China and across Asia," says Reynolds.

Materials Products revenue was a more-than-forecasted \$100.7m, up 4.7% on \$96.2m last quarter and 29% on \$77.8m a year ago. This was due partly to an additional week of product shipments compared to the prior quarter and prior year, but growth was also aided by continued strong manufacturing execution.

The new Building 10 at Wolfspeed's Durham campus — converted in less than a year from a basketball court, squash court and offices — was started up in March 2023 and is now producing 200mm SiC crystal boules and wafers with high quality and yield. "We've now installed all crystal growers necessary to achieve 20% utilization at the Mohawk Valley Fab by June," says Lowe, and probably about 25% by the end of calendar 2024 (well above original expectations).

On a non-GAAP basis, gross margin has risen from 15.6% last quarter to 16.4% (above the mid-point of the 12–20% guidance range), driven by increased revenue from Mohawk Valley and solid execution in the materials business. This is still less than half the 35.8% a year ago, but it includes a 1700-basis-point impact from \$35.6m of under-utilization costs during the ramp-up of the Mohawk Valley Fab (which began revenue-generating production at the end of fiscal 2023, so operating it is now reflected in cost of revenue rather than factory start-up costs). "Excluding the under-utilization over the last couple of quarters, we've seen strong underlying gross margin improvement," says Reynolds. "We've seen the cost on the

200mm substrate, the yields on those as well as the initial costs in Mohawk Valley on a unit basis be very much in line with what we had anticipated."

Operating expenses rose from \$119.6m last quarter to \$125.9m. However, this is partly due to increased factory start-up costs of \$10.5m from Wolfspeed's materials expansion efforts, related to the John Palmour Manufacturing Center for Silicon Carbide (JP) that is being built in Siler City, NC (named in memory of the firm's late founder & chief technology officer, who passed away on 13 November), which is having crystal growers installed starting early February and should begin qualifying furnaces in the September quarter, for boule production by the end of this year. "All the learnings with 200mm crystal growth at Building 10 will better position us to hit the ground running in Siler City, which we purposely kept less than an hour's drive from our [Durham] campus," says Lowe. "We wanted the same people who ramped Building 10 to ramp the JP, a purpose-built facility."

Net loss has hence risen from \$66.6m (\$0.53 per diluted share) last quarter to \$69.6m (\$0.55 per diluted share), almost doubling from \$35.9m (\$0.29 per diluted share) a year ago. However, this was better than the guidance of \$71–88m (\$0.56–0.70 per diluted share), due to the sequential gross margin improvement as well as tighter cost controls and higher interest income.

Operating cash flow was -\$182.9m in net cash used in operating activities (up from -\$112.7m last quarter and -\$63.2m a year ago). Capital expenditure (CapEx) has risen further from \$103.6m a year ago and \$404m last quarter to \$572.3m. Free cash flow has hence risen further, from -\$166.8m a year ago and -\$517m last quarter to -\$755.2m.

During the quarter, cash, cash equivalents and short-term investments hence fell from \$3348m to \$2635.7m on hand to support the firm's ramp and growth plans.

"Given our strong cash and liquidity position, our current focus is on government funding to further support our capacity expansion plans," says Reynolds. "We continue to have constructive discussions and correspondence with government authorities, including US CHIPS Act officials. We are on track with all necessary incentive considerations and are targeting to have our full applications complete within this quarter. As always, we will continue to seek out ways to manage and optimize our balance sheet and capital structure," he adds.

"Our successful scale-up of 200mm wafer production and continued qualification of high-quality EV products on 200mm substrates are critical steps in meeting the continued customer demand," says Lowe.

"We achieved \$2.1bn in [power device] design-ins this quarter, marking our third highest quarter on record, which clearly indicates continuing and growing robust demand for silicon carbide," says Lowe.

"Our steadfast commitment to our long-term goals is bolstered by the conversion of our design-ins into significant design-wins," he adds. Quarterly design-wins were a record \$2.9bn, over 75% related to EV applications in the automotive sector.

This includes 28 different EV models, for which Wolfspeed is the prime source on at least 27. "This diverse customer base across the global electric vehicle industry with multiple OEMs and tier-1s gives us confidence to continue with our expansion plans and further illustrates why we believe our supply will be continuing to work to catch up with demand over the next few years," says Lowe. "Over the next five years, based on our current design-ins, the number of EVs leveraging Wolfspeed devices will increase to nearly 120 different models across 30 different OEMs. This represents a significant growth from the small number of vehicles on the road using our silicon carbide devices today and demonstrates the opportunity ahead for us," he adds. "This solidifies our confidence in the electrification trend, which increasingly depends on the widespread adoption of SiC technology."

Outlook — doubling of revenue from Mohawk Valley offset by flat revenue from Durham device fab and materials

For fiscal third-quarter 2024 (to end-March), Wolfspeed targets revenue of \$185–215m, with both Power Devices and Materials up year-on-year.

At the midpoint of this guidance, Power Device revenue will be relatively flat sequentially on fiscal Q2, as a further 30% increase in EV revenue supported by a doubling of output from the Mohawk Valley Fab (to \$20–30m) will largely be offset by revenue from the Durham fab falling by about 15%, below the \$90–100m/quarter capacity, due to the continued softness and uncertainty in the industrial and energy markets in China and across Asia (and is expected to remain \$80–85m until at least calendar second-half 2024). "Much of the product we slated to ship there has a match elsewhere in our pipeline, and we continue to work through that inventory now," notes Reynolds.

Materials Product revenue will be at the previously stated capacity range of \$90–95m (down from fiscal Q2's \$101m, which benefited



Wolfspeed expands long-term 150mm silicon carbide wafer supply agreement with power-semi manufacturer Supply agreement now worth about \$275m

Wolfspeed has announced the expansion of an existing long-term silicon carbide wafer supply agreement with a "leading global semiconductor company". Now worth about \$275m in total, the expanded agreement calls for Wolfspeed to supply 150mm SiC bare and epitaxial wafers, reinforcing both companies' visions for an industry-wide transition from silicon to silicon carbide power devices.

"Wolfspeed is uniquely positioned to be a critical supplier of high-quality and advanced silicon carbide materials at scale. We will continue

to be an important partner to power device manufacturers who need the highest-quality silicon carbide wafers to service their customers," says Dr Cengiz Balkas, senior VP & general manager of Materials for Wolfspeed. "This agreement further strengthens our long-time partnership with a best-in-class power semiconductor manufacturer," he adds. "Our collective efforts are helping to address the rapidly expanding opportunity for silicon carbide and better address the unfulfilled demand that exists in the marketplace today."

The adoption of SiC-based power solutions is rapidly growing across multiple markets, including industrial and electric vehicles (EVs). Silicon carbide solutions enable smaller, lighter and more cost-effective designs, converting energy more efficiently to unlock new applications in electrification. Wolfspeed reckons that the supply agreement will enable silicon carbide applications in a broad range of industries, such as: renewable energy and storage, electric vehicles, charging infrastructure, industrial power supplies, traction and variable-speed drives.

► from an extra week of shipment in combination with strong operating execution). "Our production line is now balanced in that capacity, therefore we anticipate this being our materials capacity capabilities for the immediate future," says Reynolds.

Aided just by revenue growth from the Mohawk Valley Fab, gross margin should remain flat at 13–20%. However, at the midpoint of 16.5%, this includes \$36m (1800 basis points) of under-utilization related to the Mohawk Valley Fab.

Target operating expenses are \$109m, including increased factory start-up costs of \$13m, primarily related to the materials manufacturing capacity expansion at the JP. Net loss should rise to \$71–87m (\$0.57–0.69 per diluted share).

Despite 200mm SiC materials production capacity at Durham's Building 10 ramping up ahead of schedule (towards supporting 25% utilization at the Mohawk Valley Fab), the ramp cadence at Mohawk Valley has not changed. "The ramp normal challenges of ramping a brand new 200mm fab remain... this ramp will not be linear," notes Lowe.

"Our Mohawk Valley team continues to work on optimizing factory tool utilization and availability. This is the first time these tools have processed 200mm silicon carbide wafers, and tool integration is a critical step as we ramp production," he adds. "About 75% of the tools have second-of-a-kind tools, and we anticipate that the vast majority of the tools will have second-of-a-kind tools by the June quarter of this year. So that will help debottleneck things because, if a tool goes down, it basically stops production if there's not a second-of-a-kind tool."

"Under-utilization [cost] will be a little bit of a drag for us... up to a peak of about \$38m as you get into fiscal Q4 [to end-June]," says Reynolds. "While we are on track for 20% utilization at Mohawk Valley by the end of the June quarter, the full revenue benefit of \$100m per quarter from that 20% utilization level will be realized only in the December quarter [fiscal Q2/2005]. There is roughly a two-quarter lag between wafer starts and revenue contribution," he adds. "As Mohawk Valley Fab utilization increases, we'll start to see incre-

mentally less under-utilization [cost]," says Reynolds. Gross margin should be in the mid to high teens in the fiscal Q4/2024 June quarter (rather than the previously forecasted 20%) and then pushing back up to 20% or so in the September quarter (fiscal Q1/2025) after under-utilization peaks as Wolfspeed starts to push more product through the Mohawk Valley Fab, he adds.

"However, as the JP moves towards being ready for production, we will see incrementally more start-up costs [rising to about \$15m exiting the fiscal Q4/2024 June quarter] which hit different lines in our P&L [profit and loss]. Once the JP Phase 1 construction is complete, those start-up costs will come down and we will start to incur under-utilization costs at the JP [as it begins production, probably entering fiscal second-half 2025, i.e. calendar first-half 2025], similar to what has occurred at Mohawk Valley." The under-utilization costs (which go into gross margin) could rise from \$15m exiting the fiscal Q4/2024 June quarter to as much as \$25m.

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Bami Bastani appointed executive chairman of Sivers Semiconductors Inc

Strategic advisor nominated as chairman of Sivers Semiconductors AB

Chip and integrated module supplier Sivers Semiconductors AB of Kista, Sweden says that its subsidiary Sivers Semiconductors Inc has appointed Dr Bami Bastani as US executive chairman, and that he has also been nominated as the chairman of the board of directors of Sivers Semiconductors AB.

Bastani joined Sivers' team as strategic advisor to the board and the management team in August 2023. He has over 42 years of semiconductor industry experience, most recently as senior VP at GlobalFoundries and GlobalFoundries' board member at the Global Semiconductor Alliance (GSA). Previously, Bastani held president, CEO and board member positions at Meru Networks, Trident Microsystems, and ANADIGICS. He has over 20 years of experience of serving on boards of directors of public and

private companies.

Sivers' acquisition of fabless semiconductor company MixComm Inc of Chatham, NJ, USA (which designs millimeter-wave solutions for Satcom and 5G) has established the company with a presence in the USA. Bastani will assist group CEO Anders Storm in further strengthening Sivers' position in the USA with his network of executive contacts, sales opportunities, attracting talent, and overall strategies.

"Bami Bastani is currently the strategic advisor to the board of Sivers Semiconductors. He has provided the company with outstanding senior advice and networking in the semiconductor industry. The Nomination Committee sees Bami Bastani as an important resource in leading the board of directors as the chairman," comments Nomination Committee chairman Joachim

Cato. "The Nomination Committee greatly values that current chairman Tomas Duffy will continue his service on the board as vice chairman, thereby safeguarding continuity on the board. Tomas has served on the board since 2016 and as chairman since 2018," he adds.

"Bastani has been instrumental in opening new doors as an advisor to the company. With his vast business experience, he will provide valuable senior guidance, industry knowledge, and business contacts to Sivers' team," reckons Storm.

"Sivers is uniquely positioned at the heart of high-speed communication solutions that drive the megatrends that impact every aspect of our lives, such as AI, data centers, Satcom etc, with its leadership in mmWave and photonics technologies," comments Bastani.

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SemiQ adds full-bridge configuration to QSiC 1200V silicon carbide MOSFET module family

Modules designed to operate reliably in high-frequency and high-power environments such as solar inverters and EV charging

SemiQ Inc of Lake Forest, CA, USA — which designs, develops and manufactures silicon carbide (SiC) power semiconductors and 150mm SiC epitaxial wafers for high-frequency, high-temperature and high-efficiency power semiconductor devices — has unveiled the latest addition to its QSiC family. The QSiC 1200V SiC MOSFET modules in full-bridge configurations deliver near-zero switching loss, significantly improving efficiency, reducing heat dissipation, and allowing the use of smaller heatsinks.

With a high breakdown voltage exceeding 1400V, the QSiC modules in full-bridge configurations withstand high-temperature operation at $T_j = 175^\circ\text{C}$ with minimal $R_{ds(\text{On})}$ shift across the entire temperature spectrum. Crafted from high-performance ceramics, SemiQ says that its modules achieve exceptional performance levels, increased power density, and more compact designs — especially in high-frequency and high-power environments. Consequently, they are well suited for demanding applications that require bidirectional power flow or a broader range of control, such as solar inverters, drives and chargers for electric vehicles (EVs) DC-DC converters and power supplies.

In solar inverter applications, SemiQ says that its technology empowers designers to achieve greater efficiency — reaching as high as 98% — as well as more compact designs. It helps to reduce



heat loss, improve thermal stability, and enhance reliability, backed by over 54 million hours of HTRB/H3TRB testing. The 1200V MOSFETs are also said to maximize efficiency gains in DC-DC converters while enhancing reliability and minimizing power dissipation.

To guarantee a stable gate threshold voltage and premium gate oxide quality for each module, SemiQ conducts gate burn-in testing at the wafer level. In addition to the burn-in test, which contributes to mitigating extrinsic failure rates, various stress tests — including gate stress, high-temperature reverse bias (HTRB) drain stress, and high humidity, high voltage, high temperature (H3TRB) — are employed to attain the necessary automotive- and industrial-grade quality standards.

The devices also offer extended short-circuit ratings. All parts have undergone testing surpassing 1400V.

"Our commitment lies in the meticulous optimization and customization of each module, ensuring they not only meet but exceed the unique demands of high-efficiency, high-power applications," says president Dr Timothy Han.

SemiQ debuted its QSiC product family in SOT-227, half-bridge, and full-bridge packages at the Applied Power Electronics Conference (APEC 2024) in Long Beach, CA, USA (25–29 February).

SemiQ's new 1200V modules in full-bridge packages are available in 20mΩ, 40mΩ and 80mΩ SiC MOSFETs categories.

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Sinexcel using Infineon's 1200V CoolSiC MOSFETs

Infineon has formed a partnership in which it will provide its 1200V CoolSiC MOSFET power semiconductor devices — in combination with EiceDRIVER compact 1200V single-channel isolated gate drive ICs — to Sinexcel Electric Co Ltd of Shenzhen, China (a provider of core power equipment and solutions for the energy Internet) to boost the efficiency of energy storage systems.

Driven by the carbon peaking and carbon neutrality strategy and the new energy wave, the domestic energy storage market has maintained sustained and rapid development in recent years. According to the Chinese Ministry of Industry and Information Technology, in first-half 2023 the newly installed capacity of energy storage reached 8.63GWh, equivalent to the total installed capacity of previous years. The efficiency and power density of energy storage systems are important factors of product competitiveness, while the size, weight and cost of energy storage systems are closely related to the energy conversion efficiency and directly affect the product cost, notes Infineon.

Power semiconductor components hence play a crucial role.

"The SiC power solution is an important component for future green energy production and storage applications," says Yu Daihui, senior VP of Infineon Technologies and head of the Green Industrial Power Division in Greater China. "Infineon's cooperation with Sinexcel in the field of energy storage inverters enables energy storage systems to achieve advantages such as high efficiency, small size and light weight, providing a solid guarantee for high-reliability and high-performance energy storage systems," he adds.

"By using Infineon's SiC devices, Sinexcel's energy storage products are obviously more compact and flexible, with significantly higher efficiency and lower losses, which reduces the heat dissipation cost of systems, is conducive to the long-term efficient and stable operation of products, and helps end-users improve their operational stability and shorten their return-on-investment cycle," says Sinexcel's deputy general manager Wei Xiaoliang.

"This greatly improves the system competitiveness of our products and enhances the trust of clients in our energy storage products and the brand awareness of Sinexcel."

Infineon says that, due to their high power density, its 1200V CoolSiC MOSFETs can reduce losses by 50% and provide ~2% additional energy without increasing the battery size, which is especially beneficial for high-performance, lightweight and compact energy storage solutions. By using 1200V CoolSiC MOSFETs and EiceDRIVER compact 1200V single-channel isolated gate drive ICs, Sinexcel's energy storage converters achieve high power density, minimal electromagnetic radiation and interference, high protection performance and high reliability, claims Infineon. This allows industry-leading system efficiency of up to 98% (1% higher than that of traditional solutions, it is reckoned), better meeting the needs of on-grid and off-grid energy storage applications in both domestic and overseas markets.

<https://sinexcel.com>

www.infineon.com/ev-charging

VMAX using Infineon's CoolSiC hybrid discrete

Infineon's new CoolSiC hybrid discrete with TRENCHSTOP 5 Fast-Switching IGBT and CoolSiC Schottky diode has been chosen by VMAX (a Chinese maker of power electronics and motor drives for electric vehicles) for its next-generation 6.6kW OBC/DC-DC on-board chargers. The D2PAK package combines ultra-fast TRENCHSTOP 5 IGBTs with half-rated free-wheeling SiC Schottky barrier diodes to achieve the optimum cost-performance ratio for both hard and soft-switching topologies. Due to the performance, optimized power density and quality, the power devices are suitable for VMAX's on-board chargers.

"We are proud to choose Infineon's CoolSiC Hybrid device in our next-

generation OBC, achieving higher reliability, stability, improved performance, and power density," says Jinzhu Xu, product line director & chief engineer R&D Department at VMAX. "This deepens our already strong partnership with Infineon."

"Together, we will continue to drive e-mobility advancements, providing efficient solutions that meet the requirements of the industry in terms of performance, quality and system cost," says Robert Hermann, VP for Automotive High Voltage Chips and Discretes at Infineon.

Infineon says that, with its fast, hard-switching TRENCHSTOP 5 650V IGBT co-packed with zero reverse recovery CoolSiC Schottky diode, the hybrid discrete benefits from very low switching losses at

switching speeds above 50kHz. This makes the device suitable for high-power EV charging systems. Also, the fifth-generation CoolSiC Schottky diode offers increased robustness against surge currents, maximizing reliability. Further, the diffusion soldering of the SiC diode has improved thermal resistance to the package for small chip sizes, yielding increased power-switching capability. These features enable optimum system reliability and longevity, meeting the stringent requirements of the automotive industry, says Infineon. To further maximize compatibility with existing designs, the product also has a pin-to-pin compatible design based on the widely used D²PAK package.

www.infineon.com

Infineon highlights power solutions portfolio at APEC

At the IEEE Applied Power Electronics Conference & Exposition (APEC 2024) in Long Beach, CA, USA (25–29 February), Infineon Technologies AG of Munich, Germany detailed its plans to highlight what it claims is the industry's broadest range of power electronic devices — spanning silicon, silicon carbide (SiC) and gallium nitride (GaN) materials — including wide-bandgap solutions offering the highest efficiency and power density.

Infineon's two booths (Infineon + GaN Systems) featured demonstrations of a broad range of applications. Infineon's first booth was organized in six application zones:

- **USB-C/Charging.** Infineon's latest AC/DC and DC/DC USB-C PD chargers were to be seen along with system power solutions for next-generation applications such as laptops and notebooks.

- **Motor controls.** The firm's latest

brushless DC (BLDC) motor drive solutions for future power tools and robotic applications were on display. Rad-hard reaction wheel motor drives for satellites and space applications are also being demonstrated.

- **Data centers.** Infineon demonstrations included a complete artificial intelligence (AI) server solution, a digital power hot-swap solution, and a liquid-cooled high-density power supply optimized for next-generation applications. Also on show were Infineon's latest high-density dual-phase power modules that reduce the total cost of ownership in generative AI data centers.

- **Electric vehicles (EVs).** Infineon's latest 50kW and 22kW EV chargers were to be seen, along with SiC- and GaN-based on-board charging solutions, and the company's latest Hybrid PAK-based inverter for next-generation EVs.

- **Renewables & energy storage.** Highlighting critical energy applications, this demonstration area featured the company's latest solar DC/DC maximizers, along with DC-to-AC inverters, a bi-directional PFC/inverter, and DC-to-DC converters.

- **Industrial control.** Infineon's growing portfolio of solid-state relays and circuit breakers used to replace electromechanical switches were highlighted.

Infineon's second booth (GaN Systems) showcased its expanded portfolio of GaN solutions, such as class D audio amplifiers, data-center power supplies, and consumer reference designs.

Infineon was also a contributor to the conference program, participating in more than 30 industry and technical sessions.

www.apec-conf.org

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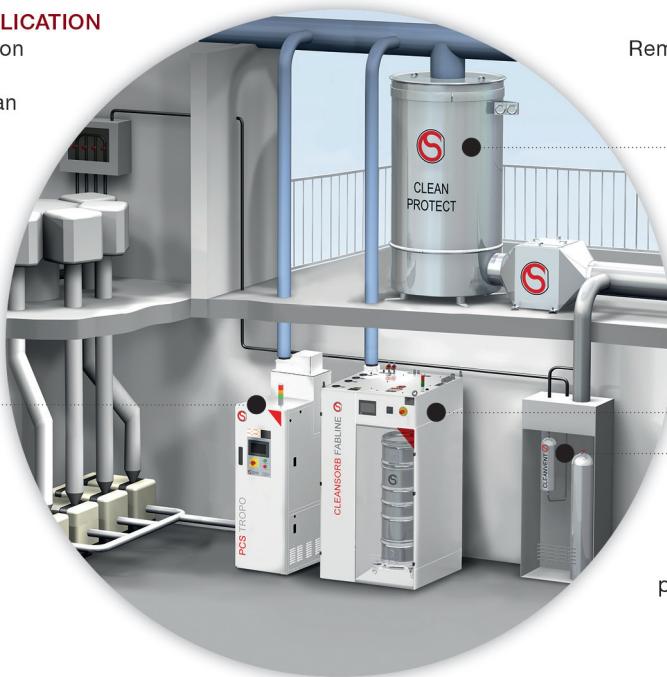
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Transphorm quarterly product revenue falls by 11% due to short-term demand pushouts

...but design-ins continue to rise, by 20%

For its fiscal third-quarter 2024 (to end-December 2023), 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 reported revenue of \$4.67m, up 3.9% on \$4.49m a year ago but down 6.8% on \$5m last quarter.

Product revenue was \$3.2m, down 11% on last quarter and 20% on a year ago, due to short-term demand pushouts. Government revenue was \$1.5m, roughly level with last quarter but up 180% on a year ago.

Gross margin was 1.6%, an improvement on -59.4% a year ago but down from 23.4% last quarter, impacted by a \$250,000 consumption tax adjustment and \$170,000 in non-recurring scrap.

On a non-GAAP basis, operating expenses have risen further, from \$6.42m last quarter to \$7.35m. However, this increase is driven largely by legal expenses related to the definitive agreement announced on 10 January for Transphorm to be acquired by a subsidiary of Japan-based Renesas Electronics Corp for about \$339m.

Net loss was \$10m (\$0.20 per share), up from \$7.13m (\$0.12 per share) last quarter but cut slightly from \$10.46m (\$0.18 per share) a year ago.

Adjusted EBITDA was -\$6.9m (\$0.11 per share), compared with -\$4.98m (\$0.08 per share) last quarter but an improvement on

-\$8.52m (\$0.15 per share) a year ago.

During the quarter, cash, cash equivalents and restricted cash rose from \$6.152m to \$7.95m. However, this was only after Transphorm raised \$3m through the exercise of existing warrants and \$2.1m of short-term debt.

"While our third quarter product revenue decreased marginally on a sequential basis, we continued to experience strong momentum in building our revenue pipeline and securing design-ins," says CEO & co-founder Primit Parikh.

Highlights during the quarter are listed as:

High-power segment

- Increased total design-ins for higher power (300W–7.5kW) to over 120 (with over 35 in production), an increase of 20% from the prior update in November of 100.
- Announced two new SuperGaN devices in a 4-lead TO-247 package, a drop-in replacement for SiC FETs and offering a 35mΩ and 50mΩ on-resistance and a benefit of more efficient, switching capabilities with 25% lower energy losses in recent internal tests, increasing socket penetration opportunities with new and existing solutions.
- Announced a collaboration with Allegro MicroSystem's AHV85110 Isolated Gate Driver and Transphorm's SuperGaN FETs to increase GaN power system performance for high-power applications, using Transphorm's recently released 650V/70mΩ TOLL device.

● Launched three Transphorm FETs in surface-mount devices (SMD) TOLL packages supporting higher-power applications for power-hungry artificial intelligence (AI) applications, server power, energy and industrial markets, positioning GaN as optimal devices for these kilowatt-class power-hungry applications and proving its high-voltage, high-power dynamic reliability.

● Launched the SuperGaN TOLT FET, which is claimed to be the industry's first top-sided-cooled surface-mount GaN device in the JEDEC-standard (MO-332) TOLT package, delivering superior thermal and electrical performance for computing, AI, energy and automotive power systems.

● Released two battery charger reference designs for electric vehicle (EV) charging applications, suitable for two- and three-wheeled EVs.

● On track for 1200V engineering samples by the middle of calendar year 2024.

Low-power segment

● Increased total design-ins for power adapters and fast chargers (<300W) to over 125 (with over 30 in production), an increase in ongoing design-ins of 8% from the prior update in November of 115.

● Announced with Weltrend Semiconductor Inc a 100W USB-C PD power adapter reference design, using Transphorm's WT7162RHUG24A SuperGaN system-in-package to achieve 92.7% efficiency in a quasi-resonant fly-back topology.

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JEDEC publishes guidelines for reverse-bias reliability evaluation of GaN power conversion devices

Suggested stress conditions and test parameters for evaluating TDB

The JEDEC Solid State Technology Association (which develops standards for the microelectronics industry) has published 'JEP198: Guideline for Reverse Bias Reliability Evaluation Procedures for Gallium Nitride Power Conversion Devices'. Developed by the JC-70.1 Gallium Nitride Subcommittee of JEDEC's JC-70 Wide Bandgap Power Conversion Semiconductor Committee (which was formed in October 2017 with 23 member companies, rising to over 80 now), JEP198 is available for free download from the JEDEC website.

JEP198 presents guidelines for evaluating the time-dependent breakdown (TDB) reliability of GaN power transistors. It is applicable to planar enhancement-mode, depletion-mode, GaN integrated power solutions, and cascode GaN power transistors.

The publication covers suggested stress conditions and related test parameters for evaluating the TDB reliability of GaN power transistors using the off-state bias. The stress conditions and test parameters for

both High Temperature Reverse Bias Stress and Application Specific Stress-Testing are designed to evaluate the reliability of GaN transistors over their useful lifetime under accelerated stress conditions.

"We are becoming more dependent on power electronics in all facets of our daily lives. As such, the technologies behind those systems are advancing and so too must the device-specific qualification processes. The new GaN-focused Guideline for Reverse Bias Reliability Evaluation is a critical step toward achieving that goal," says Ron Barr, Transphorm's VP of quality & reliability and co-chair of the Task Group 701_1. "This was a collaborative effort conducted by both GaN semiconductor and end-product manufacturers... It is an important framework to ensure cross-industry uniformity that will, in the end, provide power system manufacturers the necessary confidence when designing with GaN devices," he adds.

"With the rise of renewable energy and electrification of our lives, the

efficiency of power semiconductors is becoming more critical. This is where GaN power semiconductors have proven to be a valuable technology. The Guideline for Reverse Bias Reliability Evaluation is another step in improving confidence in GaN technology and the products that are on and being brought to market," says JC-70.1 chair Dr Kurt Smith, VP of reliability & qualification at VisIC Technologies. "This document was developed through collaboration of the multi-corporation team of industry experts to represent the best practices for evaluating GaN devices. It was a long multi-year process to reach consensus, and the team is to be commended for the quality document and all of the hard work that went into it."

The next JC-70 committee meeting was held on 26 February during the Applied Power Electronics Conference & Exposition (APEC 2024) in Long Beach, CA, USA.

www.apec-conf.org

www.jedec.org/standards-documents/docs/jep198

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Navitas celebrates tenth anniversary

In a series of events during 2024, beginning with the IEEE Applied Power Electronics Conference & Exposition (APEC 2024) and 'GaNFast Blast!' celebration in Long Beach, CA, USA from 26 February, gallium nitride (GaN) power IC and silicon carbide (SiC) technology firm Navitas Semiconductor Corp of Torrance, CA, USA is marking 10 years of innovation and growth in a broad range of fast-growing markets, from ultra-fast mobile charging to artificial intelligence (AI) data centers, renewable energy and EVs.

"From a trailer to a \$1bn+ IPO in record time and a worldwide presence with a 300-strong, highly skilled team, we've so far delivered over 150 million devices and saved over 200,000 tons of CO₂," says CEO & co-founder Gene Sheridan. "Growth awards from Deloitte and Forbes highlight our revenue growth, and a long-term guidance to grow many times faster than the market," he adds.

"From our founding in 2014 as a next-generation power semiconductor pioneer, Navitas has amassed over 250 patents across 'wide-bandgap' technologies gallium nitride and silicon carbide, as well as patented, enabling high-speed controller and digital isolators,"

notes co-founder & chief operating officer/chief technology officer Dan Kinzer. "Leading-edge technology, key talent and a passion for innovation are critical factors in Navitas' success to-date, and a strong foundation for further technology and continued market leadership."

With each new generation of GaN IC in only 15–18 months, Navitas cites GaN technology milestones during its first decade including the launch of the world's first integrated GaNFast power IC; GaNSense — the first integrated precision current-sensing GaN chip; GaNSafe — the most protected GaN power device for high-reliability systems; and the unveiling of a new bi-directional GaN power IC platform with up to 9x smaller chip size than legacy silicon MOSFETs or IGBTs.

For higher voltages and higher-power applications, Navitas offers what it claims is the industry's broadest

From a trailer to a \$1bn+ IPO in record time and a worldwide presence with a 300-strong, highly skilled team, we've so far delivered over 150 million devices and saved over 200,000 tons of CO₂

range (650–6500V) of SiC bare die and packaged devices, with best-in-class efficiency, ruggedness and high-frequency operation, based on GeneSiC technology. This enables Navitas to supply both SiC and GaN power semiconductors to markets ranging from consumer electronics, AI data centers and electric vehicles to renewable energy and industrial automation.

In 2021 the company went public with a \$1bn+ IPO on the Nasdaq exchange, and 2023 marked the shipment of over 100 million GaN devices. In the same year the firm was recognized by Forbes as one of America's top 50 most successful small companies and was ranked 72nd in the Deloitte Technology Fast 500 list of fast-growing North American companies. Navitas also offers what is claimed to be the industry's first 20-year warranty for its technologies, and it was the first semiconductor company to achieve CarbonNeutral-company certification from Climate Impact Partners.

Last year Navitas officially opened its new headquarters. About 100 staff are employed in Torrance for all aspects of GaN and SiC design, applications, test, characterization and quality, alongside specialists in finance, marketing and HR.

www.navitassemi.com

Navitas powers Samsung Galaxy S24 with integrated AI GaNFast technology enables Super-Fast Charging

Navitas says that its GaNFast power ICs are driving Samsung's 25W 'Super-Fast Charging' (SFC) for the new, AI-enhanced Galaxy S24 smartphone.

Flagship hardware specifications include a 2340 x 1080 (FHD+) dynamic AMOLED 2X, and 120Hz screen, plus the Galaxy S24 delivers innovative and practical AI features. Galaxy AI features like Live Translate, Chat Assist and new 'Circle to Search' with Google.

The 25W GaNFast unit delivers

50% charge to the high-capacity 4000mAh battery in only 30 minutes, while the USB PD 3.0 (Type-C) specification makes it compatible with other Samsung products including Galaxy Buds2 audio, Galaxy Z Fold5, Galaxy Flip and Galaxy A23.

Designed with sustainability in mind, the 25W power adapter features a 75% reduction in power consumption sleep mode. Navitas' GaNFast technology is deployed in a high-frequency, quasi-resonant

(HFQR) topology running at 150kHz — 3x faster than standard silicon designs — and delivers a 30% size shrink versus conventional charger designs.

"Deploying GaNFast ICs has allowed Samsung to create an ultra-compact, lightweight and efficient 25W adapter that can rapidly re-charge the new Galaxy S24 and a variety of other phones and accessories in the Samsung range," notes David Carroll, senior VP worldwide sales for Navitas.

Navitas highlighting GaN and SiC applications at APEC

In its 'Planet Navitas' booth at the Applied Power Electronics Conference (APEC 2024) in Long Beach, CA, USA (26–29 February), gallium nitride (GaN) power IC and silicon carbide (SiC) technology firm Navitas Semiconductor Corp of Torrance, CA, USA is highlighting how GaN and SiC technology is enabling the latest solutions for fully electrified housing, transportation and industry. Examples range from TV power to home-appliance motors and compressors, electric vehicle (EV) charging, solar/micro-grid installations, and data-center power systems. Each highlights end-user benefits, such as increased portability, longer range, faster charging, and grid-independence, plus a focus on how low-carbon-footprint GaN and SiC technology can save over 6Gtons/year CO₂ by 2050.

"Complementary GaNFast and GeneSiC portfolios, with comprehensive, application-specific system design support, accelerates customer time-to-market with sus-

tainable performance advantages," says chief operating officer/chief technology officer & co-founder Dan Kinzer. "Planet Navitas' represents the very real, inspiring implementation of GaN and SiC across the vast \$22bn/year market opportunity."

Major technology updates and releases include GaNSafe (claimed to be the world's most-protected, most-reliable and highest-performance GaN power), Gen-4 GaNSense Half-Bridge ICs (the most integrated GaN devices), Gen-3 Fast SiC power FETs (for high-power performance), and bi-directional GaN (for motor drive and energy-storage applications).

Technical presentations by Navitas at APEC

- IS05.2, 'Reducing System Cost with GaN HEMTs in Motor Drive Applications' by Alfred Hesener (senior director Industrial & Consumer);
- PSTT02.6, 'A High Density 400W DC/DC Power Module with Integrated Planar Transformer and Half

Bridge GaN IC' by Bin Li (director Applications);

- PSTT01.9, 'An Optimization Method for Planar Transformer Winding Losses in GaN Based Multi-Output Flyback Converter' by Xiucheng Huang (senior director);
- exhibitor presentation "Electrify Our World" with Next-gen GaNFast and GeneSiC Power', by Dan Kinzer.
- IS19, 'SiC & Package Innovations in Power Modules', session chair Stephen Oliver (VP corporate marketing & IR);
- PSTIS21.2, 'GaN Half-Bridge Power IC and AHB/Totem-Pole Topologies Enable 240W, 150cc, PD3.1 Solution with 95.5% Efficiency' by Tom Ribarich (senior director Strategic Marketing);
- IS27, 'Emerging Applications for Power Electronics', session chair Llew Vaughan-Edmunds (senior director GeneSiC);
- IS27-3, 'High-Voltage SiC Optimized for Megawatt Charging in EV Long-haul Trucking' by Stephen Oliver and Llew Vaughan-Edmunds.

www.navitassemi.com

Navitas powers NIO Phone with fast charging and electric vehicle interaction GaNFast technology charges NIO's first ever phone, with optimized Vehicle-to-Person integration

Navitas Semiconductor Corp of Torrance, CA, USA says that new-energy vehicle maker NIO Inc has released its inaugural smartphone, the NIO Phone with a 66W fast charger featuring its GaNFast power ICs equipped with GaNSense technology. This enhancement delivers flagship-level charging efficiency, providing end users with better vehicle-centric mobile interconnection.

Using NIO Link panoramic-interconnection technology, the NIO Phone integrates with smart EVs and NIO's in-car system. With a single click, the driver can

control over 30 functions and, equipped with ultra-wideband technology, it can completely replace traditional car keys.

To support such powerful and comprehensive features, the NIO Phone is equipped with a large 5200mAh battery and an in-box GaNFast charger offering up to 66W of charging power. In a high-frequency quasi-resonant (HFQR) topology with loss-less current sensing and ultra-fast autonomous short-circuit protection, the NV6136 GaNFast power IC measures only 57mm x 57mm x 30mm (97.5cc), delivering power density of 1.03W/cc.

"Navitas' GaNFast ICs deliver top power-density performance with easy-to-use features," comments Wu Gongli, general manager of R&D for TenPao, the manufacturing partner for the NIO Phone. "The combination of high efficiency and fast design accelerates our time-to-market," he adds.

"This is just the beginning of our collaboration," says Yingjie (Charles) Zha, VP & general manager of Navitas China. "In the future, Navitas will spare no effort to deeply-integrate energy-saving, sustainable, world-leading GaN and SiC technology into NIO Phone's DNA."

Soctera demos superior thermal performance in GaN HEMTs for next-gen telecoms and radar

Third-party-verified III–nitride transistors, fabricated on 4-inch wafers produced at IQE, moving towards commercial production with standard foundry processes

Soctera of Ithaca, NY USA (a developer of thermally optimized III–nitride millimeter-wave power amplifiers) has demonstrated high-electron-mobility transistors (HEMTs) exhibiting a peak surface temperature rise of just 59°C while dissipating 10.4W/mm. Typical gallium nitride (GaN) HEMTs reach the standard operating temperature limit of 225°C when dissipating about 5W/mm. This dramatic improvement in thermal performance could substantially reduce thermal solution costs, enhance reliability, and increase peak power output in next-generation telecommunications (5G and beyond) and defense radar arrays, it is reckoned.

"Reduced heat buildup redefines what is possible for the high-performance communications industry," says CEO Austin Hickman. "We are delighted with these third-party results and are working now to quickly scale our technology via commercial production methods."

Built on a thermally optimized III–nitride material stack that is fully compatible with standard GaN foundry processes, Soctera's HEMTs use 20x less gallium per device, insulating the firm's products from supply chain disruptions or price increases arising from potential future restrictions of gallium supply from China. The HEMTs were fabricated at the Cornell Nanoscale Facility

and the surface temperature profile was measured with sub-micron resolution via thermo-reflectance by Microsanj LLC.

The 4-inch wafers used in the tests were produced by global epitaxy manufacturer IQE, with whom Soctera has partnered for commercial-scale development. Towards building out end-to-end commercial manufacturing, Soctera has started HEMT fabrication with a DoD-approved GaN foundry.

Soctera's technology maturation efforts were recently bolstered with \$750,000 in non-dilutive funding awarded by the Defense Business Accelerator pitch competition.

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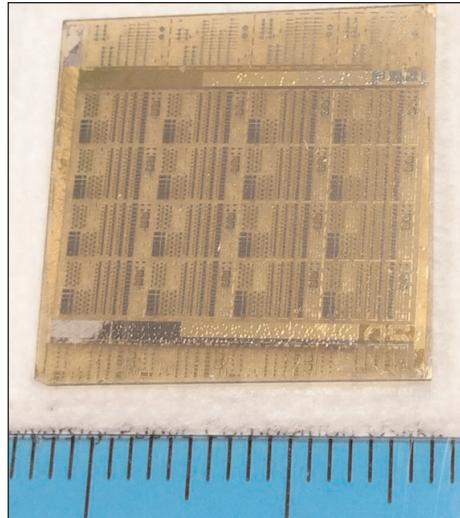
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GaN HEMTs on diamond demonstrates twice the heat dissipation of GaN-on-SiC

Layer of 3C-SiC between GaN and diamond reduces thermal resistance of interface

A research team led by associate professor Jianbo Liang and professor Naoteru Shigekawa of the Graduate School of Engineering at Japan's Osaka Metropolitan University has fabricated gallium nitride (GaN) high-electron-mobility transistors (HEMTs) using diamond as a substrate ('High Thermal Stability and Low Thermal Resistance of Large Area GaN/3C-SiC/Diamond Junctions for Practical Device Processes', published in 'Small' DOI: 10.1002/smll.202305574, 14 November 2023).

With the increasing miniaturization of semiconductor devices, problems arise such as increases in power density and heat generation that can affect the performance, reliability and lifetime of the devices. Effective thermal management is hence crucial. Diamond, which has the highest thermal conductivity of all natural materials, is an ideal substrate material but has not yet



Integration of a 3C-SiC layer between GaN and diamond significantly reduces thermal resistance at the interface and improves heat dissipation, allowing better performance.

Courtesy of Jianbo Liang, Osaka Metropolitan University.

been put to practical use due to the difficulties of bonding diamond to

GaN elements.

The technology developed at Osaka Metropolitan University is reckoned to have more than twice the heat dissipation performance of transistors of the same shape fabricated on a silicon carbide (SiC) substrate. To maximize the high thermal conductivity of diamond, the researchers integrated a layer of cubic polytype 3C-SiC between GaN and diamond. This technique significantly reduces the thermal resistance of the interface and improves heat dissipation.

"This new technology has the potential to significantly reduce CO₂ emissions and potentially revolutionize the development of power and radio frequency electronics with improved thermal management capabilities," says Liang.

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EPC Space launches first rad-hard GaN power stage IC

Single-chip 50V, 6A design integrates driver, eGaN FET half-bridge

EPC Space LLC of Haverhill, MA, USA (which provides high-reliability radiation-hardened enhancement-mode gallium nitride power management solutions for space and other harsh environments) has launched a 50V, 6A rad-hard GaN power stage IC designed for space applications. The EPC7011L7SH is a single-chip driver plus eGaN FET half-bridge power stage IC in a compact aluminium nitride ceramic surface-mount technology package. Integration is implemented using EPC's proprietary GaN IC technology. Input logic interface, level shifting, bootstrap charging and gate drive buffer circuits along with eGaN output FETs configured as a half-bridge are integrated within a monolithic chip with high-speed switching capability of 2+MHz.

IC products make it easy for designers to take advantage of the



significant performance improvements made possible with GaN technology. Integrated devices in a single chip are easier to implement, easier to lay out, easier to assemble, save space on the PCB, and increase efficiency, says EPC.

"Integrated rad-hard GaN-on-silicon offers higher performance in a smaller footprint, while meeting all radiation hardness requirements for space applications," says EPC Space's CEO Bel Lazar.

The EPC7011L7SH is part of a family of space-level rad-hard ICs that EPC and EPC Space will be launching starting this year. Rad-hard ICs are the next significant stage in the evolution of rad-hard GaN power conversion, from integrating discrete devices to more complex solutions that offer in-circuit performance beyond the capabilities of silicon solutions and enhance the ease of design for power systems engineers.

Applications of the EPC7011L7SH include single- and multi-phase motor drivers for reaction wheel assemblies (RWAs), robotic actuators and point-of-load converters.

For 1000-unit quantities, engineering models are priced at \$445, and rad-hard space-qualified are priced at \$665.

<https://epc.space/documents/data-sheets/EPC7011L7SH-datasheet.pdf>

EPC Space's rad-hard GaN used in development kits for space data processing

Alpha Data development kit developed in collaboration with TI

EPC Space is collaborating with Alpha Data — which provides FPGA-based acceleration boards used in high-performance computing and rugged embedded computing — on the development of the ADK-VA601 Versal AI Core Development Kit for Space 2.0. Featuring a fully radiation-tolerant reference design in a deployable VPX format, the kit accelerates the development of adaptable processors for space applications.

The ADK-VA601, an adaptive System on Module (SoM), supports on-board processing (OBP) and on-orbit reconfiguration, enabling multi-sensor data fusion, capacity growth, and the convergence of ground and space networks. ADK-VA601 was developed in collaboration with Texas Instruments, EPC Space and other industry leaders, and it uses EPC Space's



EPC7019G, which is part of EPC Space's latest generation of radiation-hardened devices.

"We're offering this as a complete development kit but in an already deployable format which makes it more relevant to customers and streamlines the adaptation process for specific mission requirements," says EPC Space's managing director David Miller. "The industry is moving from custom hardware

towards modular standards that enable shorter design cycles and cost reduction. End users may still want to do some fine tuning and customization, but if 90% of the work has already been done by us, they can get to space much quicker. That's the core concept behind this product," he adds.

"In addition to our efforts in designing in radiation-hardened (rad hard) GaN solutions in all new space power sockets as a viable alternative to the aging rad-hard silicon devices, we are also addressing rad-hard solutions for space-bound development kits such as the next generation of on-orbit processing that accelerates the development timeline of space missions," says CEO Bel Lazar.

www.epc.space

University of Arkansas professor receives \$300,000 NSF grant to research Ga₂O₃-based EV traction inverters

Xiaoqing Song collaborating with NREL on power module packaging, gallium oxide power devices and high-density, high-temperature traction inverter

The National Science Foundation (NSF) has given a \$300,000 grant to Xiaoqing Song, an assistant professor in the University of Arkansas' Electrical Engineering and Computer Science Department, to support his research project focused on advancing high-density and high-operation-temperature traction inverters. His project explores the integration of gallium oxide (Ga₂O₃) packaged power modules to enhance the power density and temperature range of electric vehicles (EVs).

Collaborating with the National Renewable Energy Laboratory (NREL), the project aims to innovate power module packaging, establish reliable strategies for Ga₂O₃ power devices and demonstrate the capabilities of a high-density, high-temperature traction inverter.

"By eliminating technical barriers for gallium oxide device integration, this project will foster the development of next-generation, high-density and high-operation-temperature power converters," says Song.

Responsible for converting stored direct current (DC) power into alternating current (AC) power to drive electric motors, the traction inverter stands to benefit significantly from Ga₂O₃ technology. "Gallium oxide can make the traction inverter smaller, lighter, more efficient and capable of operating across a wider range of temperatures," notes Song. "Gallium oxide has a larger bandgap energy compared to conventional silicon and wide-bandgap semiconductors. It enables high breakdown electrical strength, low intrinsic carrier concentration and correspondingly high operation temperatures," he adds.

One challenge addressed in the project is the low thermal conductivity of Ga₂O₃, which hinders



Xiaoqing Song, assistant professor of electrical engineering and computer science at the University of Arkansas.

efficient heat removal. Song outlines the plan to develop advanced power module packaging techniques that enable low thermal resistance, low parasitic inductances and high-temperature operation capability.

"NREL has significant experience in power module simulation, fabrication and characterization, as well as world-class experimental and lab capabilities for evaluating and designing efficient and reliable power electronics systems," says Song. "The principal investigator [PI] will collaborate with them to design and develop a Ga₂O₃-based high-density and high-temperature traction inverter for automotive applications, fostering a long-term partnership that can drive further research in ultra-wide-bandgap power semiconductor devices

inverter for automotive applications," he adds. "This project will help establish a long-term partnership with NREL that can catalyze further research and development of ultra-wide-bandgap power semiconductor devices."

The collaboration with the NREL aims to design and develop a Ga₂O₃-based high-density and high-operation-temperature traction inverter for automotive applications, fostering a long-term partnership that can drive further research in ultra-wide-bandgap power semiconductor devices. "Other applications include power grids, data centers, renewable energy, space and defense, etc," Song says.

The success of the project, he believes, will provide valuable insights into Ga₂O₃ device modeling, packaging, gate driving, protection and application in power converters. This is expected to catalyze progress in transport electrification and the deployment of Ga₂O₃ technology in challenging environments.

"The research achievements and experiences gained in the fellowship will sustain and promote the PI's future multi-disciplinary research activities in semiconductor devices, multi-physics analysis, power module packaging and high-performance power electronics," Song says.

"Other broader impacts also include the education and development of the next-generation workforce in STEM (science, technology, engineering and math), the encouragement of more women and under-represented minorities in electrical engineering, especially in the area of wide- and ultra-wide-bandgap semiconductor devices, power module packaging and power electronics with hands-on lab experiences."

<https://research.uark.edu>

UK's £11m REWIRE Innovation and Knowledge Centre to develop wide/ultrawide-bandgap high-voltage power electronics

Project lead Bristol University supported by partners Universities of Cambridge and Warwick

With funding of £11m from the UK Engineering and Physical Sciences Research Council (EPSRC) and Innovate UK (both part of UK Research and Innovation), the new Innovation and Knowledge Centre (IKC) REWIRE is being led by professor Martin Kuball and his team at the University of Bristol, with support from partners at the Universities of Cambridge and Warwick, as well as industry partners including Ampaire, BMW, Bosch, Cambridge GaN Devices (CGD), Element-Six Technologies, General Electric, Hitachi Energy, IQE, Oxford Instruments, Siemens, STMicroelectronics and Toshiba.

The IKC aims to accelerate the UK's progress towards net-zero by transforming the next generation of high-voltage power electronics devices using wide/ultrawide-bandgap (WBG/UWBG) compound semiconductors, as well as enhancing the security of the UK's semiconductor supply chain.

Compound semiconductor WBG/UWBG devices have been recognized in the UK National Semiconductor Strategy as key elements to support the net-zero economy through the development of high-voltage and low-energy-loss power electronic technology as building blocks for developing all-electric trains, ships and heavy-goods electric vehicles, better charging infrastructure, renewable energy and high-voltage direct-current grid connections, as well as intelligent power distribution and energy supplies to telecom networks and data centers.

"The REWIRE IKC will focus on power conversion of wind energy, electric vehicles, smart grids, high-temperature applications, device and packaging, and improving the



Professor Martin Kuball (front, third from right) at the launch event for the IKC.

efficiency of semiconductor device manufacture," notes Bristol IKC lead Kuball.

"The REWIRE IKC will play a prominent role within the UK's semiconductor strategy in cementing the UK's place as a leader in compound semiconductor research and development, developing IP to be exploited here in the UK, rebuilding the UK semiconductor supply chain, and training the next generation of semiconductor materials scientists and engineers," says professor Peter Gammon, head of

research and deputy head of school, School of Engineering, University of Warwick.

Bristol is one of two new IKCs being funded by the EPSRC and Innovate UK. The second IKC at the University of Southampton aims to improve development and commercialization of silicon photonics technologies in the UK.

"This investment marks a crucial step in advancing our ambitions for the semiconductor industry, with these centers helping bring new technologies to market in areas like net zero and AI, rooting them right here in the UK," says Saqib Bhatti, UK Minister for Tech and the Digital Economy.

The University of Bristol team specializing in semiconductors was also recently awarded £5m from the EPSRC to develop the next generation of aluminium gallium nitride (AlGaN) solid-state circuit breakers. It is anticipated that these will greatly improve efficiency and voltage range, potentially enabling global energy savings of up to 20% compared with continuing with existing technologies.

www.bristol.ac.uk

QPT gains a second GaN Systems co-founder as advisor

Former GaN Systems' CEO Girvan Patterson joins former VP of business development Geoff Haynes

Independent power electronics firm Quantum Power Transformation (QPT) of Cambridge, UK (which was founded in 2019) says that a second co-founder of GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications), Girvan Patterson, has joined his fellow co-founder Geoff Haynes, former VP of business development at GaN Systems, as an advisor to QPT. Patterson was CEO at GaN Systems (now part of Infineon) for over eight years and has been the founder of three major start-ups and led seven IPOs and M&A transactions.

"It is a testament to our vision and technology that two founders of GaN Systems have joined QPT," says QPT's CEO Rupert Baines.



Girvan Patterson.

"They have an incredible understanding of GaN technology and the market which they will be using to accelerate the growth of the company and the deployment of our award-winning qGaN technology into key companies in the market," he adds.

"Geoff and I are passionate about GaN and are really excited to be working on GaN again as it starts the next exciting phase of its development," says Patterson. "GaN in high-power, high-voltage, hard-switching applications has issues of overheating and RF interference, preventing it from being driven over 100kHz," he adds.

"QPT has solved these problems with its qGaN technology that will open up new markets. Now GaN can be driven at significantly higher speeds, which are around 23 times faster than SiC [silicon carbide], and thus deliver unprecedented energy savings by slashing the electricity wastage that currently happens in motor drives. As 45% of the world's electricity is used by electric motors, which is a major contributor to CO₂ levels, QPT's mission is to drive the fast, mass adoption of qGaN technology, which can cut energy wastage by around 10% and thus have a tangible effect on reducing climate change. QPT's commitment to this mission was the clincher for me joining the company as it means that I can personally help make a difference."

www.q-p-t.com

CGD addresses challenges of data centers at APEC

At the IEEE Applied Power Electronics Conference & Exposition (APEC 2024) in Long Beach, CA, USA (25–29 February), fabless firm Cambridge GaN Devices Ltd (CGD) had its largest ever booth, as well as presenting papers including an analysis of how gallium nitride (GaN) can help to support the exponential growth in power demanded by data centers as the use of artificial intelligence (AI) proliferates.

"With data centers now demanding 100kW per rack and predicting even more in the very near future, power system designers are looking to employ GaN devices in new architectures," notes CEO & co-founder Giorgia Longobardi. "We are addressing this challenge with new devices and reference designs... along with many other applications where GaN can play a huge role in enabling sustainable electronics solutions that are more efficient, have high performance and are more compact."

At APEC, CGD gave three papers:

- 'How ICeGaN technology can address the datacentre challenges that digitalisation brings', with chief commercial officer Andrea Bricconi and VP of business development (Americas) Peter Di Maso;
- 'Evaluation of GaN HEMT dv/dt Immunity and dv/dt induced false turn-on energy loss', with application engineer Nirmana Perera;
- 'Monolithic integration addresses the design challenges of GaN Power devices', with director of business development & technical marketing Di Chen.

CGD presented a range of demos designed to showcase what it claims is the first easy-to-use and scalable 650V GaN HEMT family. ICeGaN H2 single-chip eMode HEMTs can be driven like a MOSFET, without the need for special gate drivers, complex and lossy driving circuits, negative voltage supply requirements or additional clamping components.

Addressing the increase in power required by server and industrial applications, CGD showed a 350W PFC/LLC reference design using ICeGaN (650V, 55mΩ, H2 series). With a board power density of 23W/in³, the bridgeless CrM totem-pole PFC plus half-bridge LLC design has a peak efficiency of 95% (93% average) and a no-load power consumption of 150mW.

"GaN is now accepted as a reliable and proven technology that is able to deliver high efficiency and power density simultaneously," says chief commercial officer Andrea Bricconi. "Data centers, with their insatiable need for power, are an obvious application for GaN, but there are many other consumer, industrial and automotive applications where GaN can also demonstrate the ability to be a disruptive technology," he adds. "CGD has delivered industry's most easy-to-use GaN technology: ICeGaN."

www.camgandevices.com

CSA Catapult's achievements over 2018–2023 outlined in independent report

Three-quarters of projects make gain in Technology Readiness Levels

A new independent impact evaluation report spanning 2018–2023 undertaken by UK-based full-service research and evaluation agency Harlow Consulting on behalf of Compound Semiconductor Applications (CSA) Catapult outlines significant achievements by CSA Catapult since its inception in 2018, despite facing many challenges due to the COVID-19 pandemic.

Established by UK Government agency Innovate UK (which provides funding and support for business innovation as part of UK Research and Innovation), CSA Catapult is a centre of excellence with equipment that specializes in the measurement, characterization, integration and validation of compound semiconductor technology across four areas: power electronics, advanced packaging, radio frequency (RF) and microwave, and photonics. As a not-for-profit organization, it is focused on accelerating the adoption of compound semiconductors. Headquartered in Newport, South Wales, it works across the UK in a range of industry sectors, from automotive to medical, and from digital communications to aerospace.

The report recognizes CSA Catapult for its achievements, including the creation of world-leading facilities at the Innovation Centre in Newport despite the logistical challenges of the pandemic.

Since then, CSA Catapult has grown its in-house expertise and helped to strengthen the UK's semiconductor supply chain by developing key relationships with global businesses as well as a range of SMEs.

The report outlines how CSA Catapult has a clear strategic direction, particularly in two focussed markets: Net Zero and Future Telecoms. It also highlights CSA Catapult's success in helping UK industries to translate fundamental research into commercially ready products.

Over the last five years, three-quarters of the projects supported by CSA Catapult have experienced a positive increase in their Technology Readiness Levels (TRLs) — a measure of the maturity of a technology.

Job creation and an increase to gross value added (GVA) are also highlighted in the report as examples of CSA Catapult's success.

Between 2018 and 2023, a total of 2827 jobs have been created or safeguarded within organizations that have worked with CSA Catapult.

Companies that have engaged with the Catapult have collectively secured, on average, £107m of annual private investment and £11m of annual public sector investments.

"The report recognises the significant achievements we've made over the last five years, including the creation of our Innovation Centre in Newport and the rapid growth of the CSA Catapult team," says CSA Catapult's CEO Martin McHugh. "The report demonstrates the benefit to UK businesses of working with the Catapult and the role we're playing in supply chain growth and strengthening the UK economy overall," he adds. "With a clear strategy in place for the next five years, we're confident in building on this success and continuing to deliver long-term benefit to the UK economy."

www.harlowconsulting.co.uk
www.csa.catapult.org.uk/wp-content/uploads/2024/02/CSA_Report_Final-190124-compressed.pdf

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UK tech firms start commercial negotiations at SEMICON Korea 2024

Government-funded UK–APAC Tech Growth Programme introduces tech scale-ups to potential Korean customers and partners

Alongside a UK Government Department for Business & Trade mission at the SEMICON Korea 2024 event in Seoul (31 January – 2 February), as part of the Government-funded UK–APAC Tech Growth Programme seven British tech companies had 51 introductory business development meetings with South Korean corporations, resulting in several now being engaged in commercial negotiations with potential Korean customers and partners.

The companies include:

- Cambridge-based Paragraf, which is claimed to be the first company in the world to mass produce graphene-based electronic devices using standard semiconductor processes;
- Cambridge-based Pragmatic, the developer of a flexible integrated circuit platform using thin-film semiconductors rather than silicon;
- Oxford Instruments, which supplies a range of scientific equipment; and
- QuInAs, a Lancaster University spin-out using compound semicon-

ductors and quantum mechanics to produce a universal memory that is ultra efficient in terms of power and speed.

The other participating companies — EpiValence, Moisture Control & Measurement (MCM) and the National Physical Laboratory (NPL) — also had constructive initial discussions on which they plan to build in the coming months.

"The UK–APAC Tech Growth Programme team provided an invaluable and effective service in facilitating key strategic meetings with companies in the Korean memory sector," comments QuInAs' founder & CEO James Ashworth-Pook.

"The thirst for UK technology in Korea was underlined by the response to the innovative technologies offered by all the UK companies we supported during SEMICON Korea," says Jeremy Shaw, head of the UK–APAC Tech Growth Programme at international business development consultancy Intralink. "We look forward to helping many more UK tech scale-ups realise their potential

in the APAC region during 2024," he adds.

Backed jointly by the UK Government's Department for Business & Trade and the Department for Science, Innovation & Technology initiative and delivered by Intralink, the UK–APAC Tech Growth Programme aims to help UK tech scale-ups with significant international growth potential to explore and secure commercial opportunities in the APAC region. Specifically, it provides support for UK firms to expand in 11 APAC markets: South Korea, Japan, Taiwan, Singapore, Vietnam, Malaysia, the Philippines, Thailand, Indonesia, Australia and New Zealand. Intralink's teams on the ground in APAC can identify participants' business opportunities, provide market entry advice and help companies to sell their products, forge partnerships and raise investment.

Companies can apply to participate in the UK–APAC Tech Growth Programme via

www.intralinkgroup.com/TGP
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Silvaco joins GaN Valley ecosystem

Silvaco Group Inc of Santa Clara, CA, USA (which provides electronic design automation software and semiconductor design IP for process and device development) has joined GaN Valley to help advance the state of the art in designing efficient gallium nitride (GaN) power devices and enable its customers to innovate with its Victory TCAD (technology computer-aided design) platform.

As a technology hub in Europe specializing in gallium nitride technologies, GaN Valley targets a growing industry for electronic systems in which energy supply and usage of electrical energy needs to be increasingly more efficient (reduced energy waste), smaller, lighter, and lower cost.

Silvaco's Victory TCAD platform provides a simulation environment that incorporates various numerical methods, physical models, SPICE model generation, and a modern graphical user interface. The plat-

form enables customers to innovate and efficiently design and optimize the performance of power devices and is specifically tailored for the latest generation of GaN-based power devices. The integration of various tools and methodologies, combined with artificial intelligence, in a user-friendly environment enables engineers and researchers to iterate quickly through the design and simulation phases.

"With rapidly evolving GaN technology and an expected \$2bn market by 2027, GaN is taking its place in the power semiconductor market," notes Dr Marnix Tack, co-founder of GaN Valley & chief technology officer of BelGaN Foundry. "GaN Valley is a new and unique ecosystem developing in Europe, currently having close to 60 members active along the GaN value chain in Europe. Through connecting and collaboration, GaN Valley will accelerate innovation and business development of a GaN-based industry in

Europe and beyond. Recognizing the increasing importance of GaN technologies for the transition to a lower-energy-consuming society and a carbon-neutral future, GaN Valley is pleased to welcome Silvaco as a member to enable advancement of tools and methodologies for innovation and designing GaN semiconductors," he adds.

"Silvaco has a long history of developing TCAD technologies targeting GaN semiconductor process and device innovations with its Victory TCAD platform," says Dr Eric Guichard, senior VP & general manager of the TCAD business unit at Silvaco. "By joining GaN Valley we will share know-how and collaborate with leading research teams within the GaN Valley members to bring new innovative solutions to the design community and help build a strong ecosystem for designing GaN-based semiconductors."

www.silvaco.com

www.ganvalley.org

Aehr receives \$23m in new follow-on orders

Semiconductor production test and reliability qualification equipment supplier Aehr Test Systems of Fremont, CA, USA has received new follow-on orders totaling \$23m from existing customers for FOX wafer-level test & burn-in products to be used for production and engineering qualification needs for wafer-level burn-in and screening of their silicon carbide devices. Customer-requested shipping dates for these orders range from immediate shipment through the end of Aehr's fiscal year on 31 May.

The orders include numerous FOX WaferPak full-wafer Contactors for existing design capacity increases as well as new device designs that are expected to drive additional orders in calendar-year 2024 and beyond.

FOX WaferPak Contactors are used in conjunction with the firm's FOX-NP and FOX-XP wafer-level test & burn-in systems to contact

100% of the die on a wafer up to several thousand devices at a time. These proprietary WaferPak designs are specific to a customer's application as well as die layout and unique electrical contact pads. Aehr's FOX systems and WaferPaks are currently being used on wafer diameters of 4", 6", 8" and 12" and can be configured for a wide range of device applications.

"Our proprietary WaferPak Contactors are unique to each end-customer's device design and grow with the number of device designs and capacity needed for volume production of those devices," notes president & CEO Gayn Erickson. "As we have stated in the past, we are able to quickly ship a large quantity of WaferPaks with very short lead-times with our increased design resources, optimized supply chain, and manufacturing and test processes," he adds. "We continue

to believe our WaferPak business will grow in absolute revenue and also as a percent of the overall revenue for the company. In addition, we have increased our material availability and manufacturing capacity to shorten lead-times on our FOX-NP and FOX-XP test & burn-in systems and automated FOX WaferPak Aligners."

The FOX-XP and FOX-NP systems and proprietary WaferPaks are capable of functional test & burn-in/cycling of silicon carbide and gallium nitride power semiconductors, silicon photonics integrated circuits as well as other optical devices, 2D & 3D sensors, flash memories, magnetic sensors, microcontrollers, 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

SK Siltron CSS secures conditional commitment from US DOE for \$544m loan

Silicon carbide wafer manufacturing capacity expansion at Bay City facility to add 200 jobs

Compound semiconductor wafer maker SK Siltron CSS of Auburn, MI, USA (a subsidiary of South Korea-based wafer manufacturer SK Siltron, a part of South Korea's second-largest conglomerate SK Group) has secured a conditional commitment from the US Department of Energy (DOE) for a loan of up to \$544m.

The loan to be made under the Advanced Technology Vehicles Manufacturing (ATVM) Loan Program administered by the DOE's Loan Programs Office (LPO) is meant to expand US manufacturing of silicon carbide (SiC) wafers, citing their use in electric vehicle (EV) power electronics. The loan will increase manufacturing capacity at SK Siltron CSS' facility in Bay City, Michigan and create up to an additional 200 jobs, for an estimated total of 450 workers by project completion in 2027.

"This project is an important step towards ensuring a resilient and robust supply chain in the United States," says SK Siltron CSS' CEO Jianwei Dong Ph.D. "Completion of our facility with support from ATVM funding not only strengthens our nation's manufacturing technology but also fuels job creation, laying the foundation for innovation and economic growth in Michigan and the broader United States."

SK Siltron CSS has already doubled the initial estimated number of jobs it would create in Michigan, currently employing 250 workers across its facilities in Bay City and Auburn, following a \$300m investment in the Bay City facility announced in 2021.

The high-quality SiC wafers required to maximize the performance improvements for EVs — greater efficiency at handling high power and conducting heat than incumbent silicon, enabling faster charging times and 5–10% further



SK Siltron CSS' facility in Bay City, Michigan.

driving range — are currently under-supplied, and demand is expected to rise with EV sales.

Final approval of the loan remains subject to completion of certain closing conditions. If finalized, the financing will help SK Siltron CSS to leverage its two existing Michigan manufacturing plants to address this market gap. Much of the

This project is an important step towards ensuring a resilient and robust supply chain in the United States. Completion of our facility with support from ATVM funding not only strengthens our nation's manufacturing technology but also fuels job creation, laying the foundation for innovation and economic growth in Michigan and the broader United States

historic R&D for the manufacturing process has occurred at the company's facility in Auburn, Michigan. The expanded Bay City plant will use technology developed in Auburn to create the high-quality wafers to support the EV market.

SK Siltron acquired DuPont's Compound Semiconductor Solutions business in March 2020 to support the growing global demand for power electronics components in high power density applications like electric vehicles. Since then, SK Siltron CSS has focused on rapidly expanding its production capacity and has already increased by several multiples since the acquisition, including through the purchase and initial investment in the new Bay City facility that is being outfitted. As a result of SK Siltron CSS' rapid expansion in the market, the company has entered into agreements with industry-leading customers. In November 2022, SK Siltron CSS announced a long-term supply agreement with Qorvo; in January, another long-term supply agreement was announced with Infineon Technologies AG.

www.sk-siltron.com

AXT's quarterly revenue rebounds by 18% in Q4/23

GaAs & InP substrate revenue recovering from inventory corrections

AXT Inc of Fremont, CA, USA — which makes gallium arsenide (GaAs), indium phosphide (InP) and germanium (Ge) substrates and raw materials — says that its full-year revenue fell by 46.3% from \$141.1m in 2022 to \$75.8m in 2023.

However, despite being down 23.1% on \$26.8m a year ago, quarterly revenue has rebounded by 18% from \$17.4m third-quarter 2023 to \$20.4m in fourth-quarter 2023, exceeding the \$16–19m guidance.

"We are now beginning to see a recovery in our markets," says CEO Morris Young. "While the overall demand environment remains somewhat soft, we are seeing increased orders for indium phosphide for both artificial intelligence (AI) and fiber-optic applications," he adds.

Indium phosphide revenue was \$5.4m, still well down on \$14m a year ago but up by 10% on \$4.9m last quarter, reflecting a stabilizing market with continued improvement in artificial intelligence, passive optical networks (PONs) and data-center applications.

Gallium arsenide revenue was \$6m, rebounding by 42% from \$4.2m last quarter and up on \$5.5m a year ago. "The gallium arsenide market, which was the first of our markets to go into a correction, appears to have largely worked through excess inventory and is now reflecting truer demand," says Young, citing increasing strength in both wireless and LED applications as well as continued success in attaining export permits from China for most of AXT's customers.

"We're seeing new demand for HBT [heterojunction bipolar transistor] applications, where we historically have had very little market share. We believe this is the result of both improving market conditions and the desire among customers to diversify their supply base," says Young. "We are also seeing improv-

ing demand geographically in China across a variety of applications, including LEDs, wireless switches and high-power lasers," he adds.

Germanium substrates were \$1.1m, down slightly from \$1.2m last quarter and \$1.3m a year ago.

Revenue was \$7.9m from the two consolidated raw material joint venture companies: BoYu (which makes high-temperature pyrolytic boron nitride crucibles and pBN-based tools for organic light-emitting diodes) and JinMei (which supplies high-purity materials including gallium and germanium, as well as InP poly and other materials). This was up 13% on \$7m last quarter and up 31.7% on \$6m a year ago, with continued gross margin improvement. Overall, the pricing environment remains relatively stable.

Of total revenue in Q4/2023, the proportion from the Asia-Pacific region fell back from 82% last quarter to 77%, while Europe rebounded from 14% to 16% and North America recovered from 4% to 7%.

The proportion of total revenue contributed by the top five customers has fallen back from 31% last quarter to 28%. Again, no customer comprised more than 10%. The proportion of total revenue contributed by the top five customers has fallen back from 31% last quarter to 28%. Again, no customer comprised more than 10%.

On a non-GAAP basis, full-year gross margin has fallen from 2022's 37.2% to 18.1% for 2023. Quarterly gross margin was 23.2%, down on 32.5% a year ago. However, this was a recovery from

just 11.3% last quarter, driven mainly by higher volume, product mix, and the improved gross margins at both JinMei and BoYu raw material joint ventures.

Operating expenses have been cut further, from \$9m a year ago and \$7.8m last quarter to \$7.5m in Q4/2023, reducing full-year OpEx from \$35.9m in 2022 to \$31.8m for 2023. "We have maintained spending discipline in our operating expenses to align with the current environment," notes chief financial officer Gary Fischer.

Compared with net income of \$19.8m (\$0.46 per share) in 2022, full-year 2023 yielded a net loss of \$14.3m (\$0.34 per share). Likewise, compared with quarterly net income of \$2.1m (\$0.05 per share) a year ago, Q4/2023 yielded a net loss of \$2.8m (\$0.07 per share). However, this was cut from \$4.9m (\$0.12 per share) last quarter, and much better than the expected \$0.13–0.15 per share.

Depreciation and amortization remained \$2.2m in Q4/2023. Capital expenditure (CapEx) was \$4m for a second consecutive quarter. During the quarter, cash, cash equivalents and investments rose from \$43.6m to \$52.3m

Net inventory was roughly flat quarter-to-quarter, at about \$86.5m. Of this, 38% is raw materials (down from 41% last quarter), 58% is work-in-progress (WIP, up from 55%), and only 4% is finished goods.

"In 2023, not only did we successfully navigate the export control license process on behalf of our customer, we delivered breakthrough innovation in the development of large-diameter gallium arsenide and indium phosphide substrates," says Young. "In addition, we implemented a recycling program that both advances our ESG commitment and improves our efficiency."

For Q1/2024, AXT expects revenue of \$20–22m. Raw materials revenue will fall back substantially

(with no major changes in the pricing environment), but this will be offset by further growth in both GaAs and InP substrate revenue and stable revenue from germanium. Net loss should be steady at \$0.06–0.08.

"The trends that have driven our revenue and customer expansion remain very much intact, with new catalysts such as AI providing strong incremental opportunity," says Young.

"We view AI as an emerging new application for indium phosphide that will develop in exciting ways over the coming years. Today, AI applications are primarily using gallium arsenide VCSELs, which requires a relatively small amount of substrate material. But, as the industry moves to 800G and then 16 terabyte speeds, we expect that there will be a necessary transition to indium phosphide. AI will drive up the need for massive data-transfer requirements with increased bandwidth, low attenuation and low distortion. We believe this will result in increased demand for

indium phosphide as the best platform for rapid data transfer," Young adds.

"We are already seeing development work happening today with next-generation silicon photonics devices and electro-absorption modulated lasers (EML) for high-speed data-center transceivers. Early revenue from these applications contributed to our indium phosphide growth in Q4 and will help drive our expected growth in Q1. This interest in indium phosphide for AI applications is intensifying the market demand for 6-inch indium phosphide. As the market grows, the customer wants the scale and cost benefit of large-diameter substrates. We're excited by the progress we are making in our R&D efforts and expect to continue to lead our industry with the best-in-class material," continues Young.

"The micro-LED market continues to solidify. Several tier-1 companies are driving this adoption and the new product could come to market

as soon as next year," says Young. "We have been investing in our 8-inch gallium arsenide technology in support of these applications. And we have recently made groundbreaking advancements in both our defect density and yields. This innovation positions us strongly to gain a leading share in the market while efficiently supporting growing market demand," he believes.

"We will continue to prioritize cost savings and efficiency, and are focused on accelerating our return to profitability," says Young. "Beyond the near term, we remain confident that we can get [gross margin] back to the mid-30% range as the environment strengthens through higher overall volume, more favorable product mix and the benefits of our recycling programs, along with continued efficiency improvements throughout our business," concludes Fischer. Full-year 2024 revenue is expected to be up on 2023, to "probably better than \$85m", reckons Young.

www.axt.com

Update on Tongmei's application to list on STAR Market

On 10 January 2022, AXT announced that its China-based wafer manufacturing subsidiary Beijing Tongmei Xtal Technology Co Ltd had applied to list its shares on the Sci-Tech innovAtion boaRd (STAR Market) of the Shanghai Stock Exchange (SSE) and that the application had been accepted for review. Subsequently, Tongmei responded to several rounds of questions received from the SSE.

On 12 July 2022, the SSE approved the listing of Tongmei's shares in an initial public offering (IPO) on the STAR Market. On 1 August 2022, the China Securities Regulatory Commission (CSRC) accepted Tongmei's IPO application for review. The STAR Market IPO remains subject to review and approval by the CSRC and other authorities. AXT notes that the process of

going public on the STAR Market includes several periods of review and, therefore, is a lengthy process. Nevertheless, Tongmei hopes to accomplish this goal in the coming months.

"We need to resolve one open item," notes Fischer. "Although it is moving slower than we expected, we are making progress and are confident that Tongmei remain an excellent candidate for listing."

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Veeco's Q4 semiconductor revenue up 17% sequentially

Compound Semi focus in 2024 on investment in evaluation systems

For fourth-quarter 2023, epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has reported revenue of \$173.9m, down 2% on \$177.4m last quarter but up 13% on \$153.8m a year ago. It is also near the top of the guidance range (which had been raised in mid-January from \$155–175m to \$165–175m), driven by growth in semiconductor applications.

The Semiconductor segment (Front-End and Back-End, as well as EUV Mask Blank systems and Advanced Packaging) contributed a record \$115m (66% of total revenue), up 17% on \$98m (56% of revenue) last quarter and up 22.3% on \$94m a year ago. "Our strong results included multiple laser annealing systems for advanced DRAM devices, despite industry-wide CapEx reductions, as well as our first HVM [high-volume manufacturing] laser annealing systems to our third leading logic customer," says CEO Bill Miller.

"We've also experienced increased demand from mature-node customers as they've achieved performance benefits from adopting laser annealing technology [at the 28nm node, and even 40nm node]."

The Compound Semiconductor sector (Power Electronics, RF Filter & Device applications, and Photonics including specialty, mini- and micro-LEDs, VCSELs, laser diodes) contributed \$16m (10% of total revenue), down on \$26m (14% of revenue) last quarter and \$25m (16% of total revenue) a year ago.

The Data Storage segment (equipment for thin-film magnetic head manufacturing) contributed \$19m (11% of total revenue), almost halving from \$34m (19% of revenue) last quarter but up on \$17m a year ago.

The Scientific & Other segment (research institutions and other applications) has grown further, from \$18m a year ago and \$20m last quarter to \$23m (13% of total revenue).

By region, China comprised 38% of revenue (rebounding from 23% last quarter and doubling from 19% a year ago) due to mature-node semiconductor sales. Led by sales to semiconductor customers, the Asia-Pacific (excluding China) rebounded from 29% of revenue last quarter to 34% (although this is still down on 42% a year ago). The USA comprised 22% of revenue (down on 33% last quarter), contributed mainly by data storage and semiconductor customers.

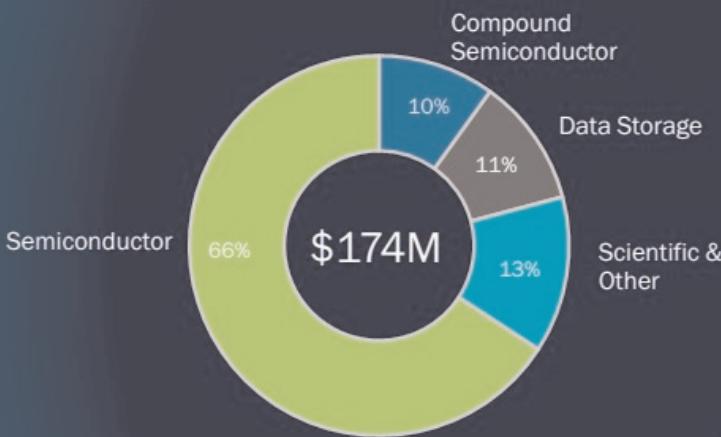
Europe, Middle-East & Africa (EMEA) fell from 15% of revenue last quarter to just 6% of revenue.

Full-year revenue has grown by 3% from \$646.1m in 2022 to \$666.4m for 2023, near the top of the guidance range (which had been raised in mid-January from \$648–668m to \$658–668m).

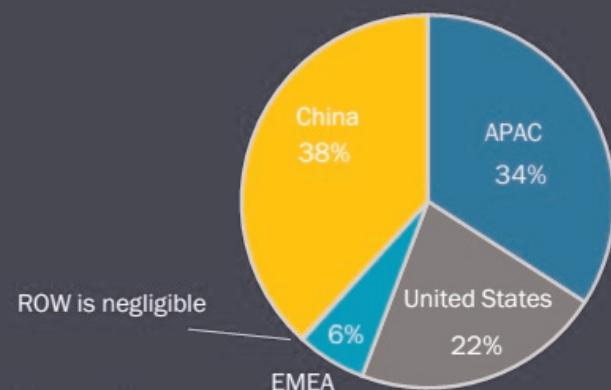
This was driven primarily by Semiconductor revenue growing by 12% year-on-year — outperforming WFE (wafer fab equipment) market growth for the third

Q4 Revenue by Market & Region

Revenue by Market



Revenue by Region



Revenue Trend (\$M)	Q4 22	Q3 23	Q4 23
Semiconductor	94	98	115
Compound Semi	25	26	16
Data Storage	17	34	19
Scientific & Other	18	20	23
Total	154	177	174

consecutive year — from \$369m (57% of total revenue) in 2022 to \$413m (62% of total revenue) in 2023, led by laser annealing systems.

The Compound Semiconductor segment contributed \$87m (13% of total revenue), down 14.7% on 2022's \$121m (19% of revenue), due primarily to a decrease in wet processing systems for 5G RF devices resulting from softness in the handset market.

The Data Storage segment contributed \$88m (13% of total revenue), level with 2022.

Scientific & Other contributed \$78m (12% of total revenue), up 15% on 2022's \$68m (11% of total revenue) after shipping a large molecular beam epitaxy (MBE) research tool for making qubits for quantum computing applications.

By region, China comprised 33% of revenue (up from 2022's 19%), driven by mature-node semiconductor sales (especially laser annealing). The Asia-Pacific (excluding China) fell from 36% to 31% of revenue, with most of that coming from semiconductor customers. The USA

fell further, from 31% to 24% of revenue, mostly from data storage and semiconductor customers. EMEA fell from 14% to 12% of revenue.

"Veeco reported another year of top and bottom line growth, with results coming in near or above the high end of our updated 2023 guidance," notes Miller. "Our team's execution allowed us to grow non-GAAP gross margin, operating income, and EPS."

Benefiting from higher volume and a favorable product mix, gross margin (on a non-GAAP basis) has risen further, from 42.3% a year ago and 44.2% last quarter to 45.4% (exceeding the expected 43–44%). Full-year gross margin hence rose from 41.9% in 2022 to 43.5% for 2023.

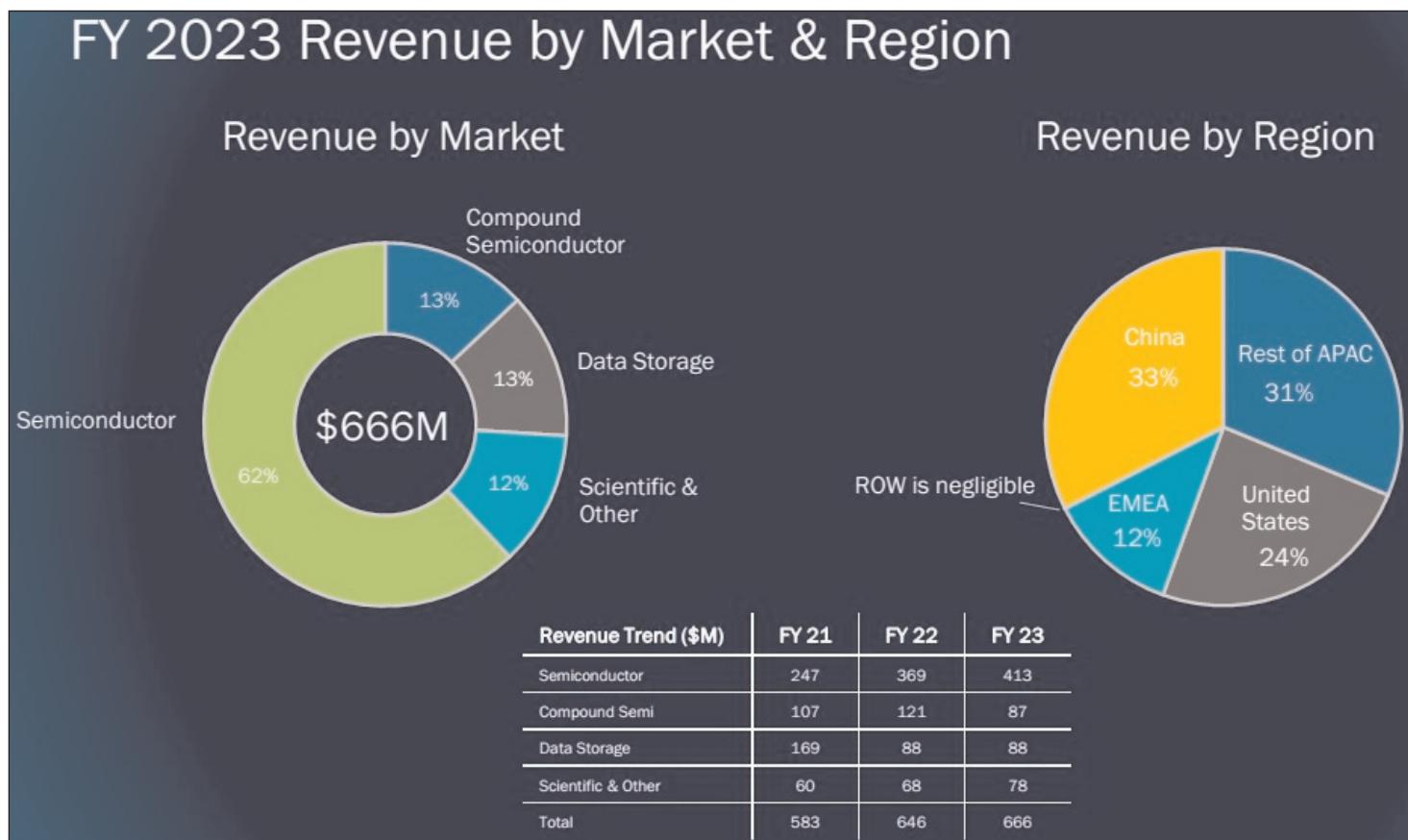
Quarterly operating expenses have increased further, from \$41.3m a year ago and \$45.7m last quarter to \$46.9m. Full-year operating expenses have hence risen by 5% from \$171.2m in 2022 to \$180.6m in 2023, as Veeco increased R&D investment.

Operating income was \$32.1m in

Q4/2023, down slightly from \$32.7m the prior quarter but up on \$23.8m a year ago. Full-year operating income has hence risen by 10% from \$99.8m for 2022 to \$109.6m in 2023.

Quarterly net income was \$29.8m (\$0.51 per diluted share), down from \$31m (\$0.53 per diluted share) last quarter but up from \$21.9m (\$0.38 per diluted share) a year ago, and exceeding the guidance (which had been raised in mid-January from \$0.35–0.45 to \$0.40–0.45 per diluted share). Full-year net income has risen from \$89.6m (\$1.57 per diluted share) in 2022 to \$98.3m (\$1.69 per diluted share) for 2023, also exceeding the guidance (which had been raised from the initial \$1.15–1.35 to \$1.30–1.50 then \$1.55–1.65, then again, in mid-January to \$1.58–1.65).

Cash flow from operations has more than quadrupled from just \$7m last quarter to \$29m in Q4/2023. CapEx almost doubled from \$6m to \$11m in Q4 (raising full-year CapEx to \$28m). During the quarter, cash and short-term



► investments hence rose by \$19m from \$287m to \$306m.

Long-term debt remains \$275m, representing the carrying value of \$282m of convertible notes.

"We successfully grew the business, improved profitability, and most importantly, laid the groundwork for future growth by advancing our product roadmaps," says Miller. "We achieved a significant milestone by shipping evaluation systems for two important core technologies. First, we launched our next-generation nanosecond annealing [NSA] solution. Second, we launched our ion beam deposition system for low-resistance metals. Each of these technologies enables our customer to fabricate devices with higher performance and lower power consumption," he adds. "We continue to allocate capital towards organic growth initiatives. In the second half of 2023, we shipped multiple evaluation systems of key technologies [including four evaluation systems shipped in Q4/2023: two ion beam deposition systems for memory, and two nanosecond annealing systems for advanced logic] and expect to further the valuation program in 2024. We believe these investments will lead to significant served available market expansion."

Outlook — investment in evaluation systems

For first-quarter 2024, Veeco expects revenue of \$160–180m, down about 2% sequentially at the mid-point. The Semiconductor segment is expected to fall back slightly from Q4/2023's record \$115m to about \$105m. Veeco is looking for "a bit of a rebound" in Compound Semiconductors, to about \$25m, shipping a couple more systems, with some strength in photonics applications. Data Storage revenue is expected to rise to about \$25m, due to shipping one more system. After shipping the very large research tool in Q4/2023, there should be a sizable drop off in Scientific & Other revenue in Q1/2024, to about \$15m.

Gross margin is expected to fall back to 43–44%. "Gross margin improvement continues as a focus, with actions targeted to achieving our 45% target model in the future," notes senior VP & chief financial officer John Kiernan.

With operating expenses of \$46–48m, operating income should be \$24–41m. Net income is expected to fall to \$21–27m (\$0.36–0.46 per diluted share).

Based on its current visibility, Veeco reiterates its full-year 2024 revenue outlook of \$680–740m (about 6.5% growth on 2023, driven by 5–10% growth in both the Semiconductor and Compound Semiconductor segments, with the Data Storage segment flat to up 10%). China is expected to contribute about 30% of total revenue.

"We expect revenue in the second half of the year to exceed revenue in the first half, based upon timing of scheduled shipments from our backlog, as well as forecasted orders," notes Kiernan.

"Mix might shift a little more towards the leading edge from the lagging edge in China," adds Miller.

"With the Semiconductor market, we're growing our served available market by investing in advanced-node logic

and memory applications and winning new customers because LSA [laser spike annealing] technology is gaining share at customers' advanced nodes as new device architectures and shrinking geometries require precise annealing to increase performance," says Miller.

"Compound Semi this year in 2024 is going to be a year of investment for evaluations. We have four going out in Compound Semi: two in silicon carbide, one in GaN-on-silicon 300mm, and one in micro LED.... Veeco is focused on several long-term opportunities within power electronics and photonics," says Miller.

"In power electronics, we're actively working with a number of tier-1 customers in silicon carbide and are planning to place two evaluation systems in the field in 2024. We believe our unique system design and extensive go-to-market infrastructure position us well to capture share in this high-growth market. For GaN power, we are working with tier-1 power device customers and positioning ourselves at 200mm and 300mm wafer sizes for GaN-on-silicon solutions. We expect to ship a 300mm evaluation system to a power device customer in 2024. The fourth evaluation system we're planning is actually in micro-LED, probably in the second half of 2024. So, we have a fair amount of new products we're planning to put into the field in 2024."

"We are making a significant investment with this evaluation program," notes Kiernan. "Investments we're making ahead of revenue is about 50–75 basis points [of gross margin] in 2024."

Full-year 2024's gross margin is expected to be similar to 2023's. "We are making margin improvements in other areas, but we are turning around and reinvesting that ahead of revenue in our evaluation program."

Veeco continues to forecast diluted EPS of \$1.60–1.90 for full-year 2024.

www.veeco.com

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Veeco is focused on several long-term opportunities within power electronics and photonics

Veeco ships GEN20-Q MBE system to Taiwanese semiconductor and opto client Hermes-Epitek

Automated multi-chamber MBE platform to be used for quantum computing applications

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has shipped a GEN20-Q molecular beam epitaxy (MBE) system to Hermes-Epitek, a semiconductor and optoelectronics client based in the Hsinchu Science Park in Taiwan.

As a purpose-built, multi-chamber system designed for the growth of quantum devices, the GEN20-Q MBE system will be used for the epitaxial growth of superconductor and semiconductor materials exhibiting excellent crystalline and superconducting properties. This process capability should further advance key device characteristics and enable the scaling from research & development to high-volume production.

"This GEN20-Q system shipment represents Veeco's continued contribution to revolutionizing

quantum computing technologies," says Matthew Marek, senior director of marketing for Veeco's MBE Group. "Leading technology companies recognize the knowledge and process capabilities we have here to support quantum technologies with not only MBE platforms but also atomic layer deposition. These are essential technologies that will help drive industry

Leading technology companies recognize the knowledge and process capabilities we have here to support quantum technologies with not only MBE platforms but also atomic layer deposition

progress," he notes. "We look forward to continued innovations with partners like Hermes-Epitek."

Investment in quantum technologies has surpassed \$30bn, with about 75% of that going to quantum computing hardware, according to the 'Quantum Technologies 2023' report published by Yole Group.

Veeco's GEN20-Q MBE system utilizes a tailored design to support research and production of multiple quantum computing techniques including superconductive materials, spintronics, and high-speed optical modulation. The system incorporates production design technology that allows direct scalability to Veeco's multi-wafer high-volume manufacturing MBE systems.

www.hermes.com.tw

www.veeco.com

Riber's revenue grows by 41% to €39.2m in 2023, as systems revenue almost doubles

Orders rebound for Services & Accessories; full-year revenue to grow further in 2024

For fourth-quarter 2023, molecular beam epitaxy (MBE) system maker Riber S.A. of Bezons, France has reported revenue of €23m, up 48% on €15.6m in Q4/2022 a year ago, and following revenue of just €3.7m, €8.5m and €4m in Q1, Q2 and Q3/2023, respectively.

Full-year revenue hence grew by 41% from €27.8m in 2022 to €39.2m for 2023 (63% coming from Asia, 24% from Europe and 13% from North America).

This was driven by Systems revenue almost doubling, rising by 96% from €14.8m in 2022 to €29m in 2023, as deliveries grew from

just six systems (including four production systems) to 13 systems (including five production systems).

In contrast, Services & Accessories revenue fell by 21% from €13m in 2022 to €10.3m in 2023.

Order book developments

Orders for Services & Accessories rose by 16% from €5.3m at the end of 2022 to €6.1m at the end of 2023.

However, following the major deliveries in Q4/2023, the order book for MBE systems is down 18% from €24.6m at the end of 2022 to €20.2m at the end of 2023. This comprises six systems (including

five production systems), although this excludes an order for a production system for Europe announced on 8 January plus a major order for three production systems for Asia announced on 24 January.

The consolidated order book hence fell by 12% from €29.9m at the end of 2022 to €26.3m at the end of 2023.

Outlook for 2024

Given the composition of the order book, and the outlook for orders to be delivered in 2024, Riber is forecasting further full-year revenue growth.

www.riber.com

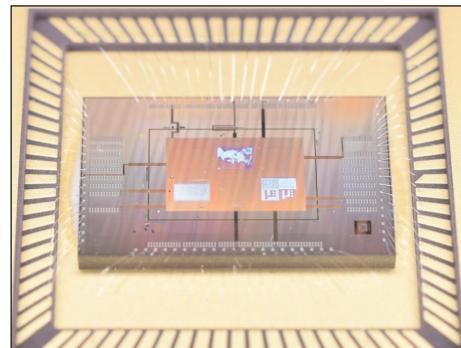
MICLEDI demos device-ready µLEDs with micro-lenses

Green and blue arrays for ultra-compact monochrome enable fully immersive augmented reality

MICLEDI Microdisplays B.V. of Leuven, Belgium — a fabless developer of micro-LED display modules for augmented reality (AR) glasses that was spun off from nanoelectronics research center IMEC in 2019 — showcased its range of red, green and blue (R, G and B) µLEDs at the SPIE AR-VR-MR 2024 exhibition in San Francisco, CA, USA (30–31 January), colocated with Photonics West 2024.

The demonstrations highlighted what is claimed to be excellent color performance in each color point across the full range of drive currents. Designed for a variety of AR display appliances that demand ultra-compact display modules, the firm's micro-LED displays address the requirements of emerging applications without the deficiencies of current technologies, it is claimed — opening the door to a broader offering of display module performance parameters.

The demand for AR solutions continues to grow, with users desiring elevated experiences with enhanced immersion and information-rich content. Most existing market-ready AR headsets offer monochrome, and sometimes monocular, micro-LED



Device-ready images on passive backplane.

displays or low-resolution color. This is due to the challenges presented by space restrictions, limited pixel density, and lack of readiness of full-color intrinsic arrays with green being the most common 'single' color choice. MICLEDI is hence bringing to market micro-LED displays with high quality and brilliant green and blue arrays, enabling fully immersive AR.

MICLEDI's strategy is to enable feature-rich AR glasses and head-gear by making the best individual color-performing µLEDs which, when coupled with its proprietary micro-lenses, can be integrated into full-color 3-panel µLED display modules. Different applications

(true consumer, industrial, automotive, and others) require different optimal performance parameters, and MICLEDI says that it addresses the full range of requirements.

Highlights of MICLEDI's SPIE AR-VR-MR exhibit included:

- two versions of MICLEDI's blue and green µLED arrays: passive-matrix 'LED test device' and passive-matrix 'LED display test device' with pixel density of 9150ppi with and without micro-lenses;
- one version of MICLEDI's red µLED arrays (red GaN);
- 300mm micro-LED production wafers; and
- green & blue µLED display devices driving a large visible image (480 x 320) with a projector.

Coming in 2024, MICLEDI will make available full-color modules with an active backplane. The firm is developing configurations of all three basic intrinsic color arrays with quantum dot filtering on already brilliant green and blue arrays. Also, MICLEDI will introduce its first demo glasses in the first-half Q2/2024.

<https://spie.org/conferences-and-exhibitions/ar-vr-mr>

www.micledi.com

Nichia launches chip-scale LED with horizontal light distribution for thinner, lighter lighting fixtures

Nichia Corp of Tokushima, Japan has commercialized a chip-scale LED (NFSWL11A-D6) that achieves a horizontal light distribution.

Conventional LEDs are known as directionally efficient light sources and are therefore often used in a variety of lighting fixtures by controlling the light with secondary optics. However, due to their strong frontal light, there is a tendency for the emitting surface of the lighting fixture to be grainy. Therefore, lighting fixtures using conventional

LEDs are designed to be thicker to avoid uneven lighting patterns.

The NFSWL11A-D6 white LED realizes horizontal light distribution by combining Nichia's expertise and technology in phosphors and LEDs. Nichia believes the NFSWL11A-D6 will contribute to thinner and lighter lighting fixtures and reduce the use of resources for lighting fixture designs as well as the building materials in which they are installed. In addition, the strong horizontal light creates a soft, low-glare light that

envelops the entire environment.

Nichia reckons that these unique features will bring new possibilities to the design of lighting fixtures. New value can be added to solid-state lighting by saving resources and improving building safety by reducing the weight of lighting fixtures and ceilings. Nichia expects that the NFSWL11A-D6 will contribute to the realization of completely new lighting fixture designs and lighting environments.

www.nichia.co.jp

Feit Electric begins patent enforcement action against Ledvance

Injunction sought to bar importation and sale of white LED filament light bulbs

California-based global lighting and smart home brand Feit Electronic Company Inc has commenced patent infringement action against Ledvance LLC in the United States District Court for the Eastern District of Kentucky. Feit Electric says that, despite being warned, Ledvance imported and then sold white LED filament light bulbs marketed under the brand name Sylvania.

Feit Electric introduced light bulbs with white LED filaments in

August 2022. "Not only did we widely announce to the industry that Feit Electric owns a set of patents directed to covering the yellow material used on LED filaments, but we also specifically and directly informed Ledvance as well as retailers and other manufacturers," says Feit Electric's president Alan Feit. "Despite those warnings, Ledvance went forward with infringing products," he claims.

Feit Electric is seeking an injunction to bar the further importation and sale of infringing white LED filament light bulbs, for damages, and for enhanced damages and attorney fees for willful infringement.

"While we would prefer that our competitors respect our patents, we are committed to enforcing our patents against infringers if they do not," says Feit.

www.ledvance.com

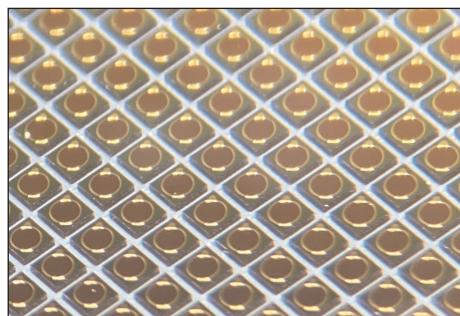
www.feit.com

Dowa Electronic Materials unveils SWIR LEDs with record efficiency

Output power of 170mW from 1mm square chip at 1350nm wavelength

Dowa Electronic Materials Co Ltd of Tokyo, Japan has developed and released a high-efficiency short-wavelength infrared (SWIR) LED chip series with what is claimed to be record luminous efficiency in the peak wavelength range 1200–1900nm.

LED-based optical sensors offer smaller size, lower power consumption, and longer lifetime. In addition, near-infrared (NIR) and SWIR light is highly penetrative to organisms. SWIR LEDs can be applied to agriculture/food analysis, drug discovery and healthcare. In healthcare applications, implementing SWIR LEDs into medical sensors enables non-destructive, non-contact and non-blood-drawing sample analysis. As a result, it reduces the load on the test subject's body and helps the progress of protective medicine. The SWIR LED healthcare market is hence expected to grow in the future. **Figure 1. Output power at 1350nm.**



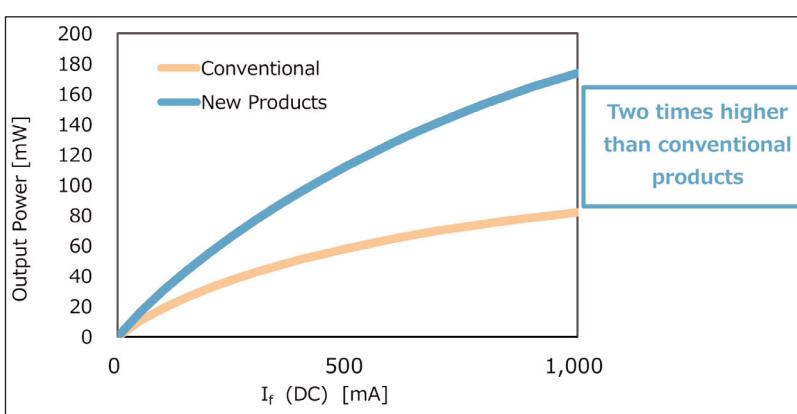
Dowa has developed the SWIR LEDs based on its proprietary crystal growth and processing technologies. Due to its higher luminous efficiency, the new chip achieves 170mW output power (Figure 1) with a 1mm square chip at 1350nm, two times

higher than comparable products, it is reckoned. Even at 1900nm, where it is considered difficult to improve luminous efficiency, the 1mm square chip achieves 45mW, 30% more power compared with conventional devices. Such a significant power increase can improve analysis and testing accuracy, and reduce power consumption.

In addition to the 350μm square and 1mm square chip sizes, Dowa is introducing a 250μm square version to its SWIR-LED series. When paired with a Dowa indium gallium arsenide (InGaAs) photodiode already in mass production, the

new SWIR LED can be used in sensors. Being offered in three different sizes, Dowa SWIR LEDs can be used in a wide range of applications, from telecoms equipment and wearables that require device miniaturization to machine vision where high radiant power is required.

www.dowa-electronics.co.jp/
semicon/e/epi/index.html



ams OSRAM launches SYNIOS P1515 low-power sidelooker automotive signaling LEDs

ams OSRAM GmbH of Premstätten, Austria and Munich, Germany has launched a series of sidelooker, low-power LEDs that, it claims, simplify design, are easier to implement and enables the creation of a homogeneous appearance in extended light bars and other automotive rear lighting applications.

An automobile rear combination lamp (RCL) currently requires a complex and deep optical assembly consisting of diffusers and light guides to spread the bright points of light from conventional toplooker LEDs without producing visible dark and bright spots.

By replacing toplooker LEDs with the SYNIOS P1515 sidelookers, automotive manufacturers can achieve a smooth, homogeneous appearance across the width of the vehicle. With the same number of LEDs as in a toplooker-based arrangement, an RCL or turn indicator can be produced with a far thinner and simpler optical assembly. This opens up new potential to

create dramatic and distinctive shapes in new RCL designs.

Alternatively, a homogeneous appearance can be achieved with the same depth of optical stack as for toplooker LEDs, but with substantially fewer LEDs and LED drivers. With this option, the lamp manufacturer benefits from a reduced bill-of-materials cost and a simpler circuit configuration.

"With the introduction of this sidelooker innovation, ams OSRAM is bringing new value to manufacturers of automotive rear lighting — it enables superior optical performance at lower cost," says Michael Lobenhofer, product marketing manager for automotive exterior lighting. "ams OSRAM simulations indicate a design based on the SYNIOS P1515 can reduce the number of LED units and drivers required by as much as 66% compared to equivalent toplooker-based designs while maintaining a very high level of homogeneity," he adds.

"The innovative operation of the SYNIOS P1515 LEDs also enables the design of new super-sleek rear light bars that enhance the aesthetic appeal of the product to discerning car buyers."

The AEC-Q102-qualified SYNIOS P1515 LEDs produce a side-emission output with uniform 360° light intensity all round the device. Light is also emitted from the top of the LED, but at lower intensity than from the sides, to ensure that applications such as extended rear light bars can be easily realized with no bright or dark spots.

The side-emission pattern of the SYNIOS P1515 LEDs is enabled by proprietary ams OSRAM optical packaging technology. The firm's sidelooker LEDs are already widely used in the backlighting for high-performance automotive displays.

The SYNIOS P1515 family of LEDs is available for sampling in red (621nm), super-red (633nm) and yellow (587nm) colours. Production volumes are available now.

ams OSRAM adds 920nm variant to OSLON Black and SYNIOS P2720 IR LED ranges Compromise between sensor sensitivity and reddish glow with 850nm and 940nm infrared LEDs

ams OSRAM's OSLON Black and SYNIOS P2720 infrared (IR) LED series, which are mainly deployed in industrial facilities, are now also available with an emission wavelength of 920nm. The technologies are used primarily in biometrics (e.g. 2D face recognition) and consumer applications (e.g. smart doorbell). Brighter IR illumination at the optimum wavelength of 920nm enables the IR camera to see a better image of a person by optimizing the necessary compromise between sensor sensitivity and reddish glow.

The new variant of the product series is thus a suitable choice

especially for customers working on camera-based illumination systems who are looking for the ideal compromise between an 850nm and a 940nm high-power IR LED.

The OSLON Black high-power infrared emitters are therefore now available in the 850nm, 920nm and 940nm wavelengths. The devices combine a particularly high total optical flux and small housings with base area of only 3.75mm x 3.75mm for a high-density assembly.

Further advantages include a very high total radiant flux at a current of 1A DC, low thermal resistance for operation at high ambient tem-

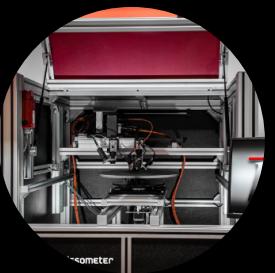
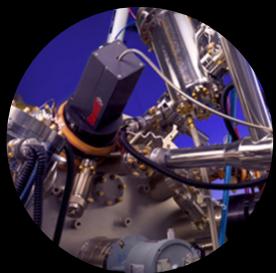
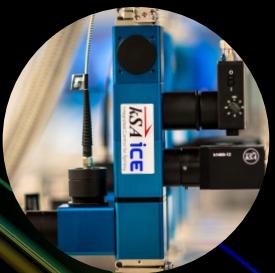
peratures, as well as high-current DC operation.

The SYNIOS P2720 products have a very low height of 0.6mm and are thus suitable for narrow applications that still require high efficiency. The products do not come with an integrated lens, but secondary optics are available for narrow beam angles.

The compact design with high power output makes the infrared LED suitable for security applications, 2D face recognition, and gesture recognition in consumer and industrial applications.

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BluGlass secures \$4.3m via share placement, and launches share purchase plan offer to raise up to \$9m

Funds to be used for product delivery, fab equipment, working capital and product development

BluGlass Ltd of Silverwater, Australia — which develops and manufactures gallium nitride (GaN) blue laser diodes based on its proprietary low-temperature, low-hydrogen remote-plasma chemical vapor deposition (RPCVD) technology — has received \$4.3m in commitments from institutional and sophisticated investors via a share placement at an issue price of \$0.037 per share.

BluGlass is also undertaking a share purchase plan (SPP) offer to enable eligible shareholders in Australia and New Zealand to acquire up to \$100,000 worth of shares on the same terms.

Funds will be used to scale and speed production and delivery of BluGlass' visible lasers to fulfil new and existing contracts. The raise will also support additional fab equipment, working capital, and the development of next-generation products to increase market com-

petitiveness and sales.

"The continued support of institutional and sophisticated investors reflects growing confidence in BluGlass' visible laser technology, experienced management, and significant growth runway," believes chair James Walker.

"BluGlass has made significant commercialization progress over

Funds will be used to scale and speed production and delivery of BluGlass' visible lasers to fulfil new and existing contracts.
The raise will also support additional fab equipment, working capital and the development of next-generation products

the past year, launching our first laser products, vertically integrating our manufacturing supply chain, growing customer engagement across all our target verticals, and securing our largest ever revenue contract," says CEO Jim Haden.

"This funding supports scaling our operations as we grow project revenues, enabling us to invest in additional equipment and capabilities to accelerate laser production and delivery to meet customer demand," he adds.

"We're also strategically investing in the development of novel, next-generation products that further strengthen our competitive advantages. Our recent sub-contract with the US Department of Defense for the development of distributed feedback (DFB) lasers is a good example, highlighting the significant demand for novel, better performing lasers that are also higher value."

Placement of new shares to raise \$4.3m

The placement comprises an offer of 116,216,216 new fully paid ordinary shares in BluGlass at an issue price of \$0.037. The issue price represents a 19.6% discount to the last closing share price on 8 February and a 24.3% discount to the 15-day volume-weighted average market price of the company's shares.

The placement includes one free attaching listed option for every new share, exercisable at \$0.046 and expiring on 28 February 2025. Each free attaching option exercised will include one fully paid BLG share and one additional option (piggy-back option), exercisable at \$0.06 and expiring on 28 February 2027. The attaching options are subject to

shareholder approval at an extraordinary general meeting on 4 April.

New shares under the placement will rank equally with BluGlass' existing ordinary shares. BluGlass intends to list the attaching options on the ASX.

Bell Potter Securities Ltd is lead manager and bookrunner to the placement and SPP offer.

Share purchase plan offer to raise \$9m

BluGlass is undertaking an SPP offer to raise up to a further \$9m before costs on the same terms as the placement to shareholders with addresses in Australia or New Zealand as at 7pm, 9 February. Each eligible shareholder may apply for up to \$100,000 of new fully paid ordinary shares in the company at

an issue price of \$0.037.

Participating shareholders will receive one free attaching option for every new share, exercisable at \$0.046 and expiring on 28 February 2025. In addition to one fully paid BLG share issued, every free attaching option exercised will include one piggyback option,

exercisable at \$0.06 and expiring on 28 February 2027. The attaching options are also subject to shareholder approval at an extraordinary general meeting, on 4 April.

Eligible shareholders may take up their entitlement to acquire new shares in full, in part, or not at all.

www.bluglass.com

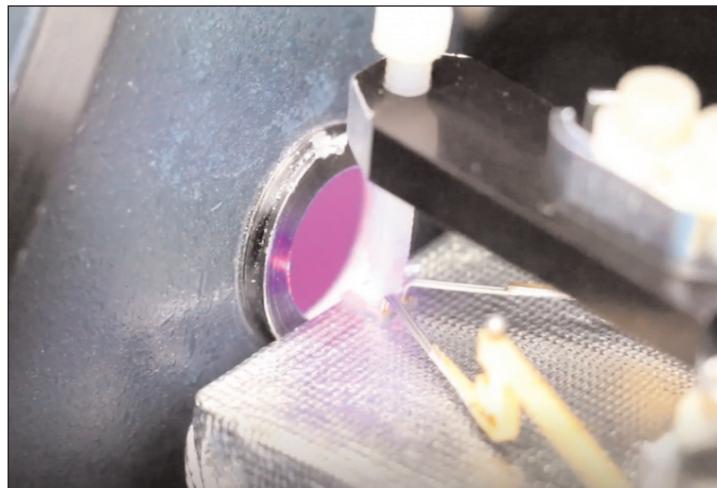
BluGlass and Applied Energetics sign MoU to collaborate

GaN DFB lasers to be used in advanced systems for national security, aviation and commercial applications

BluGlass Ltd of Silverwater, Australia — which develops and manufactures gallium nitride (GaN) blue laser diodes based on its proprietary low-temperature, low-hydrogen remote-plasma chemical vapor deposition (RPCVD) technology — has signed a memorandum of understanding (MoU) to collaborate on its GaN distributed feedback (DFB) lasers being used by US-based advanced defence and dual-use photonics company Applied Energetics Inc in its advanced systems development for next-generation military and commercial applications.

Applied Energetics specializes in developing next-generation ultra-short pulse (USP) optical systems for the US Department of Defense, defense primes, the intelligence community, as well as addressing the commercial, medical and space markets. The firm's USP laser and photonic products span deep-ultra-violet through to infrared wavelengths.

The two companies say that they combine complementary expertise and technologies and, through the collaboration, plan to develop innovative solutions that address critical



technology needs in emerging dual-use and national security markets, including bringing to market new laser wavelengths, and higher-performance solutions that deliver more efficient and cost-effective products. The MoU sets out the framework for collaboration, but is not a definitive agreement with commercial terms and timelines.

"This collaboration will advance strategic capabilities and next-generation integrated photonics, addressing the evolving needs of the national security and commercial sectors," says BluGlass' CEO Jim Haden. "A pioneer in ultrashort pulse photonics, Applied Energetics

has complementary laser technology which can deepen our reach into the government, security and intelligence sectors. Importantly, the MoU aligns with and strengthens our existing product roadmap and growth strategy," he adds.

"With the rapid growth of the laser market and the associated need for unique wavelengths and high-performance output, the development of next-generation lasers and optical systems must continue to advance and innovate," comments Applied Energetics' CEO & president Dr Gregory Quarles. "This collaboration will support our long-term strategic goals of optimizing architectures, increasing wavelength coverage, and improving product performance to provide customers with the most competitive and effective solutions."

www.appliedenergetics.com
www.bluglass.com

NUBURU evaluating strategic alternatives

Blue laser maker assessing sale, merger, divestiture, recapitalization, going private transaction, additional financing, and other significant transactions

NUBURU Inc of Centennial, CO, USA — which was founded in 2015 and develops and manufactures high-power industrial blue lasers — has engaged Northland Capital Markets as its financial advisor in connection with its evaluation of strategic alternatives. With assistance from Northland and its other advisors, the NUBURU will assess a full range of strategic alternatives, including a sale, merger, divestiture,

recapitalization, going private transaction, additional financing, and other significant transactions.

NUBURU has not set a timetable for the conclusion of its evaluation of strategic alternatives and has not made any decisions related to strategic alternatives at this time.

The firm notes that there can be no assurance that this evaluation will result in any definitive documentation to consummate one or more trans-

actions, or other strategic changes or outcomes, or that the terms of any such transactions, changes or outcomes will be favorable. Even if it enters into a definitive agreement, NUBURU may not be successful in completing a transaction, change or outcome, or, if it completes such a transaction, change or outcome, it may not ultimately enhance value or deliver expected benefits.

www.nuburu.net

Luminus launches its first laser products

LED maker expands photonics portfolio with green and blue lasers

Luminus Devices Inc of Sunnyvale, CA, USA — which designs and makes LEDs and solid-state technology (SST) light sources for illumination markets — has expanded its product portfolio with the introduction of green and blue lasers catering to a wide range of applications including entertainment lighting, laser projection display, leveling and measurement, and biometric monitoring.

The new green laser has a typical peak wavelength of 515nm, an output power of 80mW (CW), efficient operation in pulsed and CW mode, and single-mode diode laser technology. Moreover, it offers high-speed modulation capabilities and comes in a TO-56 package with a photodiode.

The blue laser has a typical peak wavelength of 455nm and an output power of 100mW (CW). Like its green counterpart, it operates efficiently under pulsed and CW mode, incorporates single-mode diode laser technology, and provides high-speed modulation. It also comes in a TO-56 package with a photodiode.

"The launch of our first laser portfolio signifies our commitment to expand our product span in optoelectronic solutions that meet the evolving needs of our customers," says Chun-Jui Lee, Laser business line director. "With these new green and blue laser products, we aim to serve a wide range of industries with

distinctive performance and reliability."

The lasers deliver what is claimed to be excellent wall-plug efficiency that can benefit battery-powered systems and contribute to making laser light sources accessible to a wide range of applications in consumer, medical, life-sciences and industrial markets.

Luminus plans to soon significantly expand its laser portfolio with the introduction of additional wavelengths and advanced packaging solutions providing its customer base with a comprehensive array of LED and laser platforms tending to their specific market and application needs.

www.luminus.com

FBH appoints new scientific managing director

Patrick Scheele succeeds retiring Günther Tränkle

Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH) of Berlin, Germany has appointed professor Patrick Scheele as scientific managing director, a management role that is linked to the W3 professorship of Microwave and Optoelectronics at Technische Universität Berlin. Together with administrative managing director Dr Karin-Irene Eiermann, Scheele will form the joint executive management of FBH gGmbH (a not-for-profit limited-liability company).

Scheele succeeds long-standing scientific managing director professor Günther Tränkle, who retired at the end of 2023. Scheele is a "proven expert in high-frequency electronics and an experienced leadership personality," comments Tränkle.

"With its research topics in photonics, III-V electronics and quantum technologies combined with its excellent manufacturing capabilities, the Ferdinand-Braun-Institut is very well positioned," reckons Scheele. "I see this broad spectrum



FBH's new scientific managing director professor Patrick Scheele (photo courtesy of FBH/P. Immerz).

as a great opportunity to combine the developments from these areas of expertise even more closely and transfer them into applications in line with demand."

Scheele previously worked at Hensoldt Sensors GmbH in Ulm and has known FBH for many years. From April 2015 to April 2023, he was a member and from 2017 also chairman of its scientific advisory board. As VP & head of radar engineering at Hensoldt, he most recently led several large R&D teams with up to 950 staff. In addition to high-frequency electronics including circuit and antenna development, he was responsible for digital electronics and mechanical

design along with environmental testing and the EMC laboratory. Over the past few years, he has also been responsible for software development and radar systems engineering. In previous professional positions, he worked on mobile communications components and highly reliable space sensors, among other things.

Senior Senate Counselor Bernd Lietzau, chairman of the Ferdinand-Braun-Institut's supervisory board, thanked Tränkle for his cooperation over more than two decades.

"He actually made the direct transition in FBH's scientific management possible in the first place by postponing his well-deserved retirement several times," Lietzau notes. "Patrick Scheele has known the FBH for many years and has helped set the institute's course," he adds. "He will certainly contribute with his industrial experience to maintaining and expanding the transfer activities and thus continue the successful work of his predecessor."

www.fbh-berlin.de/en

Coherent's Mattera to retire as CEO

Board retains executive search firm to identify new CEO

Materials, networking and laser technology firm Coherent Corp of Saxonburg, PA, USA says that Dr Vincent (Chuck) D. Mattera Jr is to retire as CEO following the commencement of employment of his successor.

Coherent's board of directors has retained an executive search firm to immediately begin a search process, which will include evaluating internal and external candidates, to identify a new CEO. A subcommittee of the board has been formed to oversee the search process.

Mattera, 68, has served with Coherent for 20 years, the last eight of which have been as CEO. He is the firm's third CEO since its founding in 1971 as II-VI Inc. He has also served as chair of the board of directors since November 2021. During his tenure, Mattera led the transformation of II-VI, a supplier of engineered materials and optoelectronic components, into Coherent Corp., a global, diversified company enabling multiple megatrends in the industrial, communications, electronics and instrumentation markets. Over his 20 years, annual revenue grew from \$150m in fiscal 2004 to more than \$5bn in fiscal 2023.

"Since the strategic combination of II-VI and Coherent two years



Coherent's chair & CEO Dr Vincent D. (Chuck) Mattera, Jr.

ago, I am most proud of the tremendous progress we have made to integrate our two organizations, optimize synergies, and place the company in an advantaged position for accelerated growth. With Coherent on a clear path to improved margins and continued profitable growth, its track record of product leadership, customer intimacy, operational excellence, and the unstoppable imagination of our world-class people, I believe that now is the right time to look toward the next chapter of the company's transformation," says Mattera. "I look forward to transitioning to the next generation of leadership to execute new value creation opportunities and continue to unlock longer-term profitable growth," he adds. "Coherent's extraordinary track record of financial and operational excellence, and its broad and deep foundation in materials, networking

and lasers, will pave the way for our sustained success."

"Throughout Chuck's tenure, he played a critical role in leading the development and execution of our strategic growth plans, helping transform the company into a true market leader and redefine the future through breakthrough technologies," comments lead independent director Enrico DiGirolamo. "He has spent his entire career in and around the industry and has been instrumental in advancing the sector into one that is fundamental in today's ever-changing environment. As CEO since 2016, Chuck has driven an over 700% increase in the company's market capitalization, to over \$9bn," he adds. "The markets we serve are changing rapidly, and, as we look ahead to our next chapter, we will continue to best position ourselves to capitalize on those areas where we see the greatest opportunities for growth and value creation. This includes finding the right new CEO, supported by seasoned business leaders and our exceptional leadership team, to steer our company forward, enhance our operating performance, and further strengthen our financial foundation."

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Lumentum's quarterly revenue falls 27.5% to \$366.8m

Cloud & AI data-center demand to drive recovery from September quarter

For its fiscal second-quarter 2024 (to 30 December 2023), Lumentum Holdings Inc of San Jose, CA, USA has reported revenue of \$366.8m, down 27.5% on \$506m a year ago but up 15.5% on \$317.6m last quarter, and above the midpoint of the \$350–380m guidance. However, \$59.5m of this came from a partial quarter (about eight weeks) of revenue after the acquisition on 7 November of Cloud Light Technology Ltd of Hong Kong (which designs and makes optical transceiver modules for automotive sensors and data-center interconnect applications), mostly from very strong shipments of 800G transceivers for artificial intelligence (AI) platforms.

Lumentum's three existing greater-than-10% customers (two in the Networking segment and one in the Industrial Tech segment) have been joined by a fourth, primarily due to the added Cloud Light revenue from that customer.

Driven by strong cloud data-center demand and boosted by the contribution from the Cloud Light acquisition, Lumentum's Cloud & Networking segment hence contributed \$286.7m (78.2% of total revenue), up 24.8% on \$229.7m (72.3% of total revenue) last quarter. However, this is still down 25.1% on \$382.9m a year ago, due to broad-based softness across most of the firm's telecom networking product lines as a result of the continued inventory correction at network equipment customers.

Lumentum's Industrial Tech segment contributed \$80.1m (21.8% of total revenue), down 8.9% on \$87.9m (27.7% of total revenue) last quarter (driven by seasonality in 3D sensing business and inventory consumption at a large industrial laser customer) and down 34.9% on \$123.1m a year ago (due mainly to more competition for market share on a certain 3D sensing socket and overall macroeconomic softness).

On a non-GAAP basis, gross margin has fallen further, from 44.9% a year ago and 34.9% last quarter to 32.6%, driven by factory under-utilization and product mix.

Due partly to the Cloud Light acquisition, operating expenses have risen by \$6.6m from last quarter to \$106.7m (29.1% of revenue). Despite this, Opex is still down by \$3.6m from \$110.3m a year ago due to tight expense controls and continued synergy attainment. Specifically, while research & development (R&D) spending of \$68.3m is up from \$61m last quarter, sales, general & administrative (SG&A) expense has been cut further, from \$45.9m a year ago to \$38.4m.

Operating income was \$13m (operating margin of 3.5%), down from \$116.7m (23.1% margin) a year ago but up from \$10.6m (3.3% margin) last quarter, and above the mid-point of the 2–4% guidance range.

Net income has fallen further, from \$104.1m (\$1.52 per diluted share) a year ago and \$23.4m (\$0.35 per diluted share) last quarter to \$21.7m (\$0.32 per diluted share, although this is also above the mid-point of the \$0.25–0.35 guidance range).

During the quarter, Lumentum completed the acquisi-

tion of Cloud Light for a total purchase price of \$728.5m, of which \$705m of cash was paid on the closing date of 7 November, plus about \$8m of normal course expenses incurred in association with the transaction.

Total cash, cash equivalents and short-term investments hence fell by \$720.3m during the quarter, from \$1944.3m to \$1224m.

"Late last year, we were notified by certain critical IC suppliers that service the industry broadly that their products do not comply with the latest [US] export regulations. Consequently, in December, we stopped the majority of our product shipments to the largest networking equipment manufacturer in China," notes executive VP & chief financial officer Wajid Ali. "Our assumption is that these export regulations will continue indefinitely, and result in a \$40–50m reduction in calendar year 2024 revenue from our prior expectations. Longer-term, we believe geopolitical factors could pose a benefit to our revenue opportunity given our larger product footprint within other customers who are expected to be end-market share-gainers over time."

Business outlook

For fiscal third-quarter 2024 (to end-March), Lumentum expects revenue to be roughly flat, at \$350–380m.

Cloud & Networking segment revenue should rise, despite an impact of more than \$10m from the export regulations, due to strong cloud demand and an even stronger, full-quarter contribution from Cloud Light.

Industrial Tech segment revenue is expected to be down by nearly \$40m sequentially at the midpoint due to 3D-sensing seasonality and share dynamics, as well as inventory digestion by one of Lumentum's largest industrial laser customers.

"We expect revenue of 3D sensing for consumer applications to contribute about 5% or less of company revenue in Q3 and Q4 of fiscal 2024," says president & CEO Alan Lowe.

Operating margin should be 2–5%, and diluted earnings per share is expected to be \$0.20–0.35.

"While cloud data centers are forecasting double-digit CapEx growth in calendar 2024, we are navigating challenging market conditions in other parts of our business," notes Lowe. "Based on sluggish carrier CapEx spending and our latest customer discussions, we now expect customer inventory digestion to extend through the balance of fiscal 2024. Nevertheless, we are highly confident in our market position and the ultimate recovery and growth in this business," says Lowe.

Also: "Given a mid-calendar-year product transition planned by our largest data-center customer, we expect revenue from data-center transceivers to temporarily dip in the June and September quarters, and then grow significantly through the end of the year and into calendar year 2025, as this transition completes and other new customer programs start to ramp," notes Lowe.

Manufacturing efficiency, inventory management, and cost control

"We are focused on lowering our fixed-cost base so that, as the revenue recovers, operating margin dollars will expand faster than revenue," says Ali. "To this end, we have made significant progress on manufacturing synergies by hitting key milestones on closing two NeoPhotonics factories in China this past December [following Lumentum's acquisition of NeoPhotonics Corp in August 2022]. The benefit will accrue to our financial position as we ramp production of most of those products at our Thailand facility. Additionally, our Japan wafer fab consolidation plans are progressing well. We expect to execute this plan by the first-half of fiscal 2025, allowing us to attain

significant additional synergies in both manufacturing and operating expenses beginning in the fiscal third-quarter 2025," he adds.

"We had pre-built inventory of NeoPhotonics products [worth nearly \$30m] to enable these factory transitions. In [fiscal] Q2, we reduced Lumentum's overall inventory levels by about \$20m sequentially, excluding the increase in inventory related to Cloud Light," says Ali.

"We continue to see incremental synergy and efficiency opportunities within our operating expenses," he continues. "Consequently, we are increasing our synergy attainment expectations to \$100m, up from the prior target of \$80m [following the NeoPhotonics acquisition]. To date, we have achieved about \$60m in annual run-rate savings and expect to achieve the remaining \$40m as we execute against our plan."

"Our combined efforts on manufacturing efficiency, inventory management, and cost control will pave the way for continued improvements in gross and operating margins as telecom revenue recovers and our cloud revenue continues to grow," concludes Ali. "We are confident about our market position and growth opportunities across our surge markets."

Capacity expansion in Thailand

"Given the surging data demands of AI data centers and our strong traction on new transceiver opportuni-

We are focused on lowering our fixed-cost base so that, as the revenue recovers, operating margin dollars will expand faster than revenue.
We have made significant progress on manufacturing synergies by hitting key milestones on closing two NeoPhotonics factories in China

ties, we are strategically expanding our leading-edge transceiver manufacturing capacity," says Lowe. "As a key part of this expansion, we are investing in state-of-the-art production lines at our manufacturing facility in Thailand. Our Thai factor has proven photonics manufacturing capabilities, and has received numerous customer accolades, giving us confidence in our ability to ramp rapidly. This capacity will come online this summer, and we expect to lead the first wave of 1.6 Terabit transceivers from multiple customers at this site," he adds.

"In addition to this new capacity expansion in Thailand, we will be leveraging Lumentum's components in new Cloud Light transceiver designs. We believe the combination of our established history of customer partnership, proven manufacturing leadership, and unrivaled breadth of differentiated photonic component capabilities puts us at an excellent position to accelerate top-line revenue growth and margins in this rapidly growing cloud transceiver market."

Industrial Tech sector recovery in second-half 2024

"In the Industrial Tech segment, we are very excited about our traction on new products serving new applications, particularly for our ultra-fast lasers. These are ramping up and are adding to our customer end-market diversification in our Industrial Tech segment," says Lowe. "That said, we do expect a period of lower demand over the coming quarters, driven by typical seasonality in our consumer business and by macro softness in the industrial market, along with elevated customer inventory levels at one of our large laser customers. We expect the industrial laser inventory to be corrected over the next six months, around the same timeframe as the seasonal uptick in our consumer business. This, combined with our wins at new customers in new markets, should lead to an Industrial Tech segment recovery during second-half of the calendar year."

www.lumentum.com

Report analyses economic impact of First Solar's US manufacturing and supply chain investments

Firm to add \$5bn in value and over \$10bn in output to 2026 US economy

Cadmium telluride (CdTe) thin-film photovoltaic (PV) module maker First Solar Inc of Tempe, AZ, USA has released what is believed to be the first comprehensive economic analysis of a vertically integrated solar manufacturer's value chain in the USA. Commissioned by First Solar and conducted by the Kathleen Babineaux Blanco Public Policy Center at the University of Louisiana at Lafayette, the study used IMPLAN economic software to analyze First Solar's actual and forecasted US spending in 2023 and 2026, when the company expects to have 14GW of annual nameplate capacity across Alabama, Louisiana and Ohio.

The study found that in 2023:

- First Solar supported an estimated 16,245 direct, indirect and induced jobs across the USA, representing \$1.59bn in annual labor income. With 2700 staff and almost \$490m in direct labor income, every non-construction First Solar job supported six direct, indirect and induced jobs across the US economy, and every dollar directly spent on wages created \$3.3 in labor income.
- The fully vertically integrated solar manufacturer, which exited 2023 with over 6GW of annual nameplate capacity, added \$2.75bn in value and \$5.32bn in output to the US economy during the year, including direct, indirect and induced effects.

● The company's construction activity in Alabama, Louisiana and Ohio supported an estimated 5765 direct, indirect and induced jobs, representing over \$600m in labor income. Construction activity is estimated to have added over \$900m in economic value and almost \$2bn in economic output in 2023.

Analyzing First Solar's forecasted US spending in 2026, the study projects that:

- With the company expected to directly employ 4100 people, it would support an estimated 30,060 direct, indirect and induced jobs across the country in 2026. The study estimates that every First Solar job will support 7.3 jobs across the country, representing an estimated total labor income of \$2.78bn, including direct, indirect and induced effects.
- First Solar would add an estimated \$4.99bn in value and \$10.18bn in output to the US economy in 2026 alone. The findings are based on the firm's expectation that it will have 14GW of operational nameplate capacity in the USA in 2026 and include direct, indirect and induced effects.

The study's findings are unique to First Solar, which operates fully vertically integrated solar manufacturing facilities that produce thin-film photovoltaic (PV) solar panels in a single process that integrates the manufacturing of wafers and cells. The process allows the company to transform a sheet of glass into a fully functional solar panel in approximately four hours. Additionally, First Solar relies primarily on an American value chain for the raw materials, including glass and steel, that enable its US manufacturing operations.

"This report reflects the real value of solar technology made in America for America, with materials sourced from businesses across the country, and not simply assembled here using imported components," says First Solar's CEO Mark Widmar. "We know that our investments, catalyzed by the Inflation Reduction Act, are enabling jobs and bringing prosperity to communities in places such as Lawrence County, Alabama, Iberia Parish, Louisiana, and Crawford County, Pennsylvania, and this report helps to quantify the extent of our contribution to the US economy in real terms."

In addition to expanding its Ohio footprint to over 7GW of annual nameplate capacity this year, First Solar expects to invest over \$2bn in new manufacturing facilities in Alabama and Louisiana, which are expected to come online in 2024 and 2026, respectively. Additionally, it is investing up to \$450m in R&D infrastructure in Perrysburg, Ohio, which is expected to be operational in 2024.

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Compound semiconductor substrate market growing at 17% CAGR to \$3.3bn in 2029

Markets fueled by strong growth in power electronics and photonics, says Yole Développement.

The compound semiconductor substrate market is growing at a compound annual growth rate (CAGR) of 17% to \$3.3bn in 2029, according to the report 'Status of Compound Semiconductors Industry 2024' by market analyst firm Yole Group.

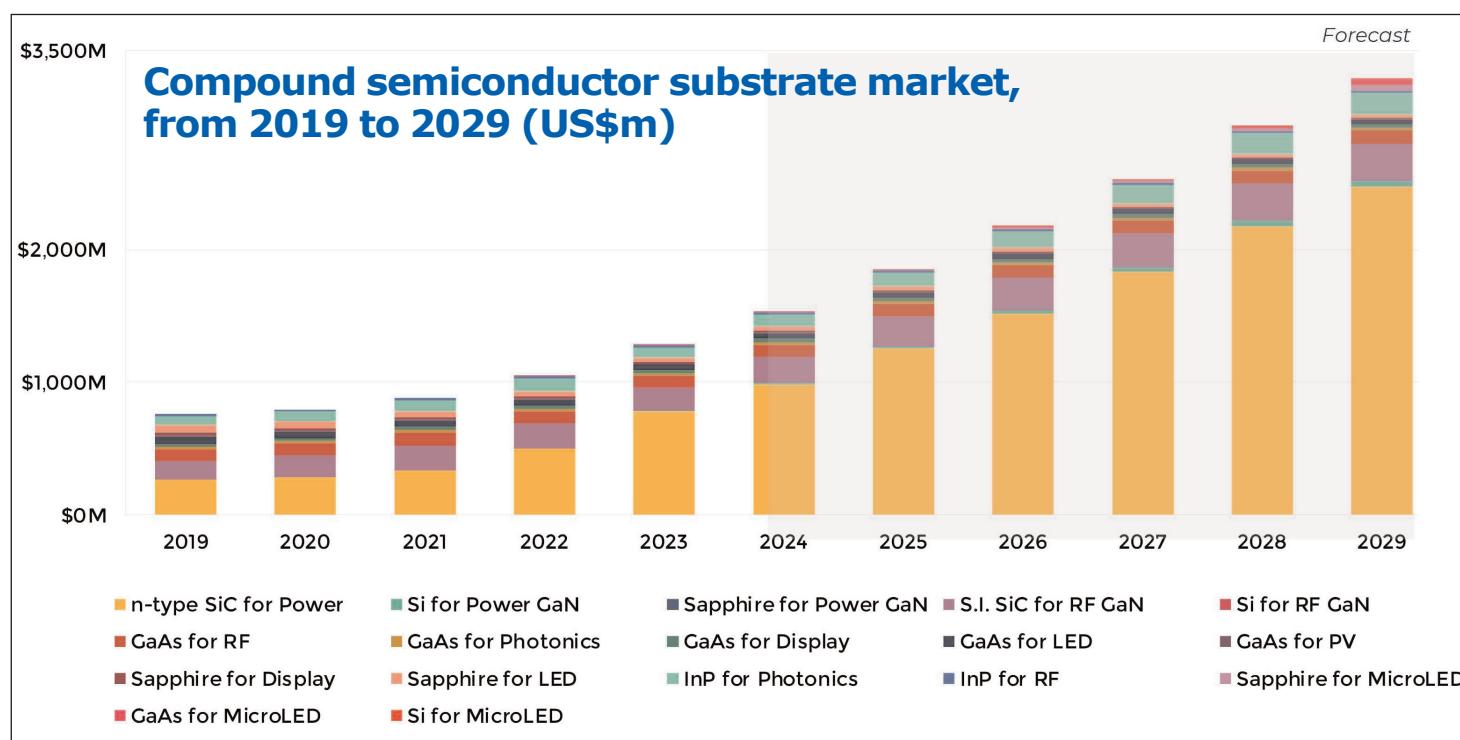
Compound semiconductors have emerged as a transformative influence across various industries. The dominance of silicon carbide (SiC) in the automotive sector, especially in the domain of 800V electric vehicles (EVs), is driving a billion-dollar market. Simultaneously, gallium nitride (GaN) power electronics are expanding their presence in both the consumer and automotive fields. Yole Group analysts foresee a billion-unit opportunity in smartphone over-voltage protection (OVP). In anticipation of a resurgence, radio-frequency gallium arsenide is aligning itself with 5G and automotive connectivity, while RF GaN is establishing its presence in defense, telecoms and space industries, targeting high-power applications.

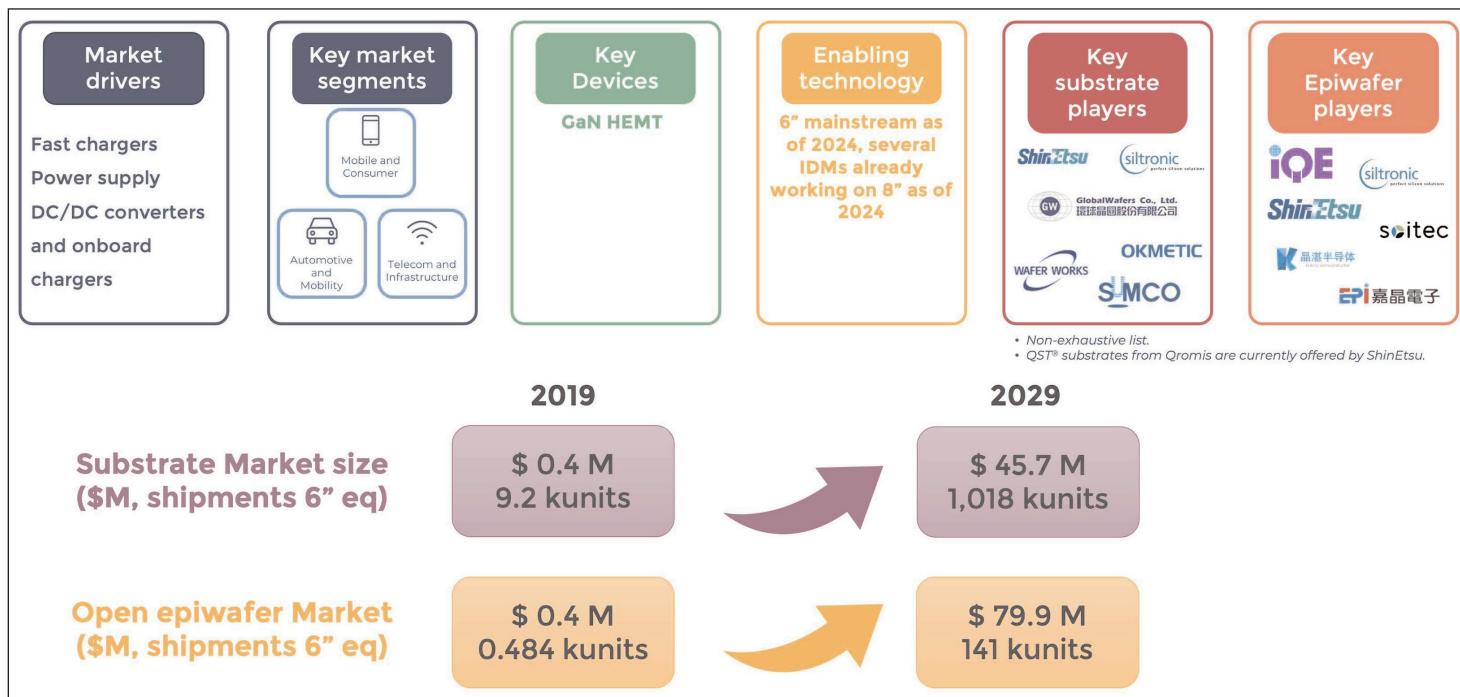
In the photonics sector, indium phosphide (InP) and gallium arsenide (GaAs) are taking the lead, with InP

experiencing a resurgence fueled by artificial intelligence (AI) applications, while GaAs photonics is seeing more modest growth influenced by various market dynamics. Although micro-LEDs show potential, their widespread adoption is gradual.

"The compound semiconductor industry is at the corner to transition to larger-diameter substrates," notes Ali Jaffal Ph.D., technology & market analyst Semiconductor Substrates & Materials, at Yole Group. "In the photonics sector, AI is driving the demand of high-data-rate lasers, which could accelerate the transition to 6" InP substrates. On the other side of the coin, GaAs explores 8" manufacturing for micro-LEDs — which is competing with organic light-emitting diodes (OLEDs) — facing yield and efficiency challenges, questioning its success but gaining momentum with substantial investments."

Suppliers of GaAs and InP substrates, including Freiberger, Sumitomo Electric Device Innovations Inc (SEDI) and AXT, are playing a central role in the transition to larger-diameter substrates. Photonics is





Technology trends for power GaN — focus on substrates and epiwafers.

part of this story, and the power and RF markets further complement this narrative.

Leading the change to supply SiC substrates for power electronics applications is Wolfspeed, which has recently transitioned to larger 8" wafer fabs and is expanding its material capacity in line with its strategic vision.

Coherent, another leading player, is focusing on photonic devices and dominates the SiC substrate market for both power and RF applications. It has made a number of strategic alliances, for example with SEDI in RF GaN, to reinforce its position and has started supplying power SiC devices. Following these actions, it spans the whole value chain from substrates to advanced devices. The landscape is continuously evolving, with multiple innovations on many fronts and strategic partnerships, notes Yole.

"Compound semiconductor technologies are advancing across sectors, notably in the booming SiC industry," says Taha Ayari Ph.D, technology & market analyst,

Semiconductor Substrates & Materials. "While 6" wafers are still standard, Wolfspeed's \$1.2bn investment in MHV fab is pioneering the transition to 8" wafer size. Other efforts focus on improving SiC wafer yield and supply, with innovations like engineered substrates from Soitec and Sumitomo Mining. Power GaN sees a shift to 8-inch GaN-on-Si, driven by expansion at Innoscience, STMicroelectronics, and Infineon Technologies," he adds.

"RF GaN-on-Si is benefiting from synergies with the relatively more mature power GaN to enter the telecom market and compete with established RF GaN-on-SiC technology," says Aymen Ghorbel, technology & market analyst, Semiconductor Substrates & Materials. "Additionally, major changes in the RF GaN ecosystem, such as the Wolfspeed RF business being acquired by MACOM, could impact the RF GaN industry," he concludes. ■

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Red InGaN micro-LEDs on freestanding substrates

Researchers claim the first reports for such devices below 5µm.

Tsinghua University and Beijing National Laboratory for Condensed Matter Physics in China have reported on the use of freestanding gallium nitride substrates (FGS) for red indium gallium nitride (InGaN) micro-light-emitting diodes (LEDs) in terms of efficiency and uniformity across arrays of devices [Luming Yu et al, Appl. Phys. Lett., v123, p232106, 2023]. The researchers claim that InGaN red micro-LEDs with etching-defined mesa size <5µm have not previously been reported.

Although it is difficult to achieve high efficiency using indium gallium nitride (InGaN) in the red section of the visible light spectrum, there has been much effort in recent times, particularly for micron-sized devices as used in arrays for micro-displays aimed at augmented-reality and virtual-reality (AR/VR) applications, such as head-up displays (HUDs) in military aircraft pilot helmets.

The advantages of InGaN over the more traditional red LED materials, such as aluminium indium gallium phosphide (AlInGaP), include easier integration with green and blue InGaN LEDs, and better scaling to smaller device sizes due to less migration of carriers to sidewall defects, where recombination tends to be non-radiative.

Device materials were grown on FGS from Nanowin and reference material was grown on patterned sapphire substrate (PSS) by metal-organic vapor phase epitaxy (Figure 1). The n-GaN buffer/contact was 2µm thick on the FGS sample and 5µm on PSS.

The structure included pre-strain layers consisting of a 24-period InGaN/GaN superlattice (SL) and two blue InGaN quantum wells (QWs), separated by GaN quantum barriers (QBs). The red-emitting part of the structure consisted of a single QW and a three-stage structure of two GaN barrier and aluminium gallium nitride (AlGaN) capping layers. Hole injection was provided by p-doped AlGaN electron-blocking layer (EBL) and GaN contact layers.

Single devices and arrays of red InGaN LEDs were fabricated using direct-write electron-beam lithography patterning, inductively coupled plasma etch, and plasma-enhanced chemical vapor deposition (PECVD) of silicon nitride passivation. The devices were not intentionally optimized.

Electrical testing was on-wafer using contact probes. Light was collected through the substrate in a 60° half-angle cone.

Reverse-current leakage measurements indicated significant sidewall damage of the devices, which

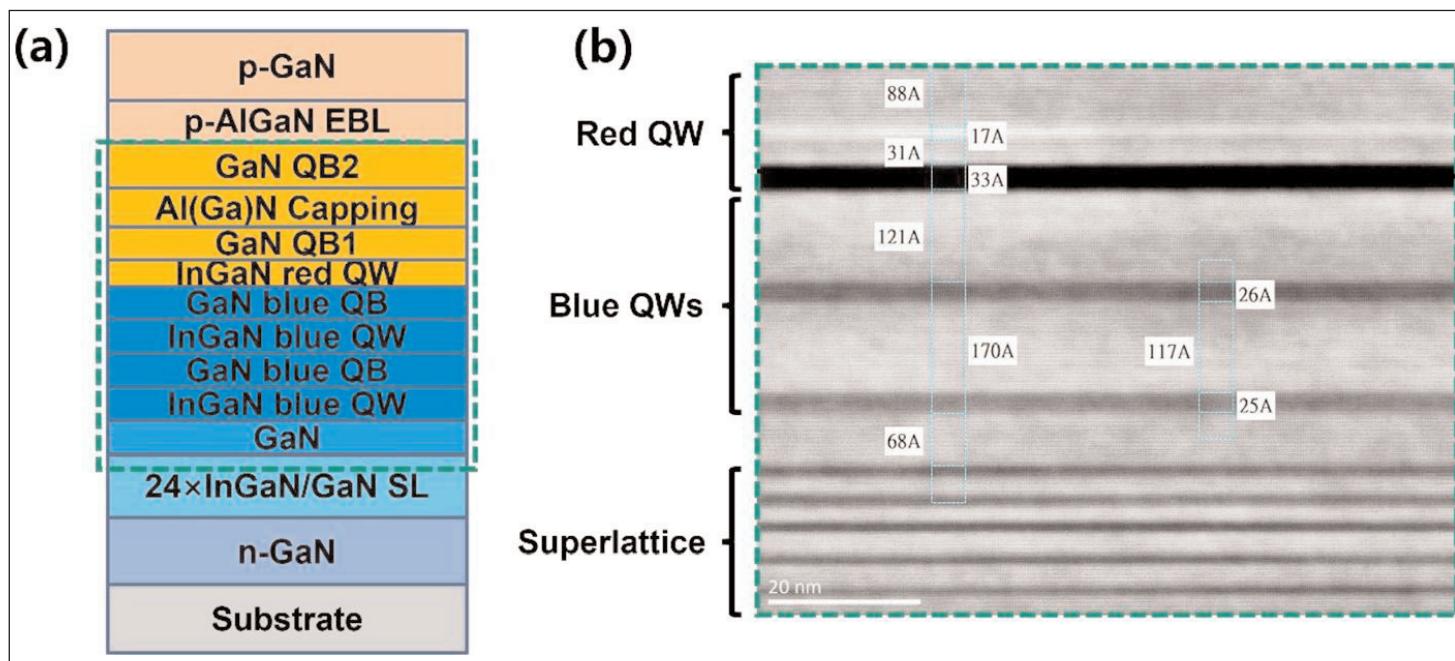


Figure 1. (a) Schematic epitaxial structure. (b) Enlarged transmission electron microscope (TEM) image of green box in (a).

dominates performance at smaller device sizes. The reverse leakage at $-5V$ increased from $10^{-3}A/cm^2$ to $1A/cm^2$ as the devices reduced in size from $20\mu m$ to $1\mu m$. With $5A/cm^2$ forward current injection, the peak wavelength was $631nm$ on FGS (sample A) and $603nm$ on PSS (sample B). Both spectra showed a full-width at half maximum (FWHM) of about $60nm$.

The researchers comment: "The longer wavelength of sample A is attributed to the larger lattice constant of FGS, which is conducive to the incorporation of indium."

Emission from the blue QWs ($\sim 460nm$) was approximately more than a factor of 10 less intense. Some even shorter wavelength radiation $\sim 400nm$ was attributed to electrons overcoming the EBL and reaching the p-GaN contact layer before recombining.

The peak external quantum efficiency (EQE), achieved at $50A/cm^2$, on sample A was 1.73% for a $20\mu m$ device and 0.86% for a $1\mu m$ device. The peak wavelength was of order $614nm$. The peak EQEs for sample B were 1.05–1.62% at the same injection, but the

wavelength had blue-shifted to $590nm$. In general, the LEDs based on sample B (PSS) had peak wavelengths some $40nm$ shorter than those based on sample A (FGS).

On the basis of ray-tracing simulations, the researchers estimate the total peak EQE of the $1\mu m$ LEDs to be 1.95% on sample A and 2.78% on sample B. The corresponding internal quantum efficiencies (IQEs) were estimated to be 7.09% and 6.00%.

In 10×10 array formats, the $1\mu m$ LEDs from sample A showed a relative brightness variance of 0.27 at $10A/cm^2$ injection, and 0.13 at $100A/cm^2$ (Figure 2). The respective values on sample B were 0.79 and 0.29.

The researchers attribute the higher variances on B to its higher threading dislocation density: estimated at $2.29\times 10^8/cm^2$, according to x-ray diffraction analysis, compared with the $3.5\times 10^5/cm^2$ specification of

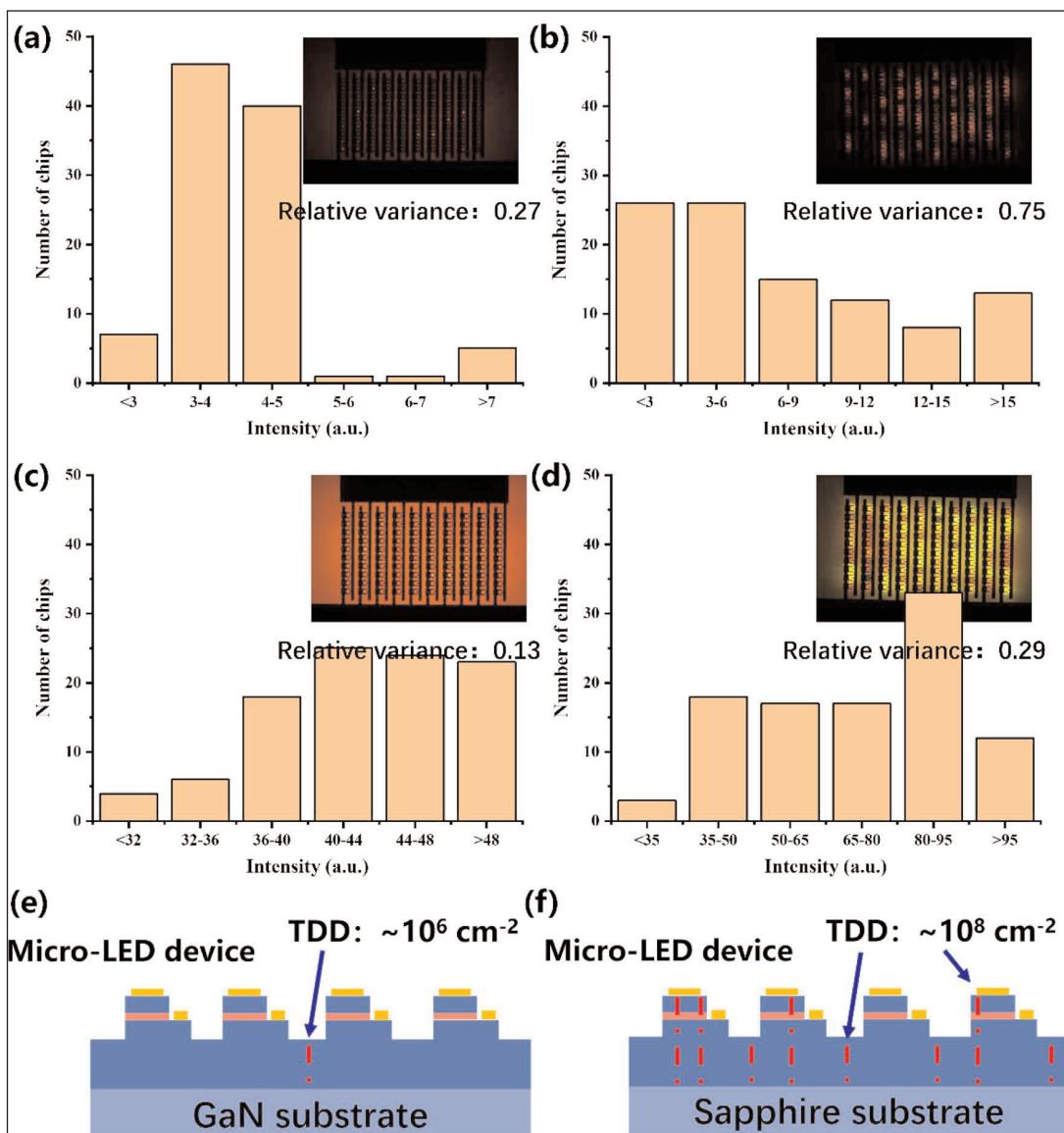


Figure 2. (a)–(d) The brightness distribution of 10×10 arrays of $1\mu m$ micro-LEDs under different conditions. (a) Sample A and (b) sample B at $10A/cm^2$. (c) Sample A and (d) sample B at $100A/cm^2$. Insets: electroluminescence (EL) photos at corresponding current density. (e) and (f) Schematic diagrams of micro-LED chips on different substrates according to defect densities.

Nanowin's FGS. The researchers admit that the TDD after epitaxy will likely be higher than the spec, but it is difficult to estimate using x-ray analysis when the FWHM of rocking curves is no longer dominated by the impact of threading dislocations on the uniformity of the crystal structure.

At a TDD of order $10^8/cm^2$ there would be on average one dislocation per $1\mu m$ LED. However, random fluctuations will lead to some having no dislocation and others two dislocations (Poisson distributed?). Such variations lead to a higher level of brightness non-uniformity for sample B, compared with the lower-TDD sample A. ■

<https://doi.org/10.1063/5.0177137>

<http://en.nanowin.com.cn>

Author: Mike Cooke

V-defects for improved red InGaN LED performance

UCSB reports 6.5% peak external quantum efficiency on patterned sapphire.

University of California Santa Barbara in the USA has been exploring the potential for V-defects to improve the performance red/orange light-emitting diode (LED) devices with high-indium-content indium gallium nitride (InGaN) multiple quantum wells (MQWs) [Jacob J. Ewing et al, Optics Express, v31, p41351, 2023].

The team reports 6.5% peak external quantum efficiency (EQE) for a device on patterned sapphire substrate (PSS), "which is one of the highest reported efficiencies in the academic literature for red/orange InGaN LEDs on PSS," adding: "This result is important because PSS is widely used in the LED industry and represents a cost-effective, high-light-extraction substrate for mass production of InGaN LEDs."

Although much effort has been expended on reducing defect formation in the InGaN system, for long-wavelengths V-defects that nucleate on threading dislocations have been found to improve hole injection efficiency through $\{10\bar{1}1\}$ semi-polar sidewalls in an

inverted pyramid formation.

V-defects nucleate more readily in III-nitride structures grown on silicon (Si). Indeed, Nanchang LED company has reported 27.5% wall-plug efficiency (WPE) at around 600nm wavelength and 16.8% WPE at 620nm at $0.8\text{A}/\text{cm}^2$ injection by using a GaN-on-Si template and V-defect engineering.

Implementing V-defect benefits on PSS is much more challenging. InGaN on PSS tends to have lower defect densities compared with materials grown on silicon or flat sapphire. On the other hand, PSS devices tend to have higher light extraction efficiency due to light scattering from the patterned sapphire surface, which reduces total internal reflection. With flat top and bottom surfaces, total internal reflection impedes light being emitted from InGaN LED structures.

The UCSB team used atmospheric-pressure metal-organic chemical vapor deposition on GaN on PSS and (111) silicon (Si) to grow the epitaxial structure (Figure 1) for the InGaN LEDs. The GaN on PSS

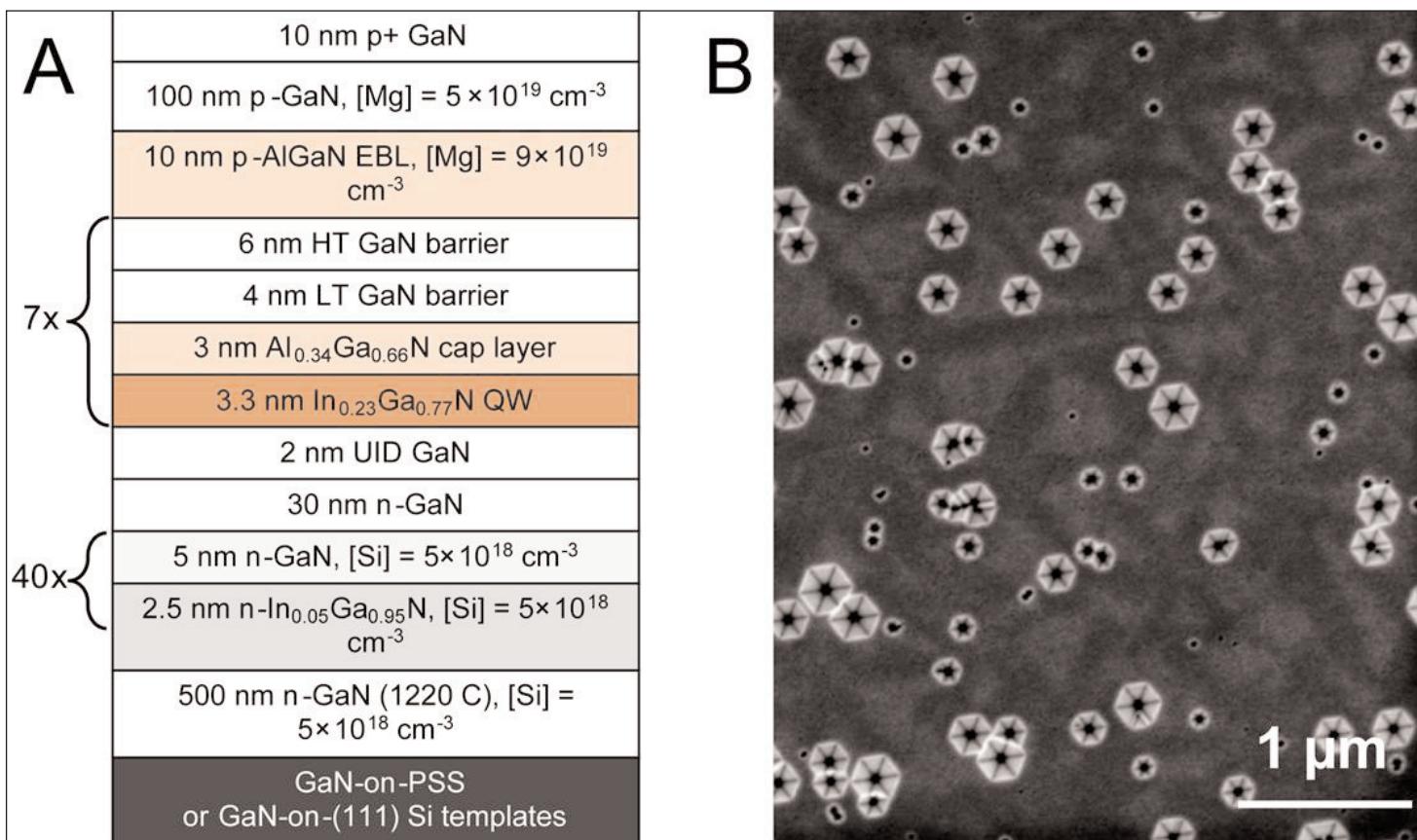


Figure 1. (a) Epitaxial structure for red InGaN LEDs; (b) SEM image of growth surface showing unfilled V-defects.

template consisted of $2.75\mu\text{m}$ Si-doped n-GaN. The GaN-on-Si was supplied by Enkris Semiconductor Inc (800nm buffer, $2\mu\text{m}$ unintentionally doped, and $2\mu\text{m}$ Si-doped).

The UCSB structure included a 40-period superlattice designed to nucleate large V-defects and capture impurities before the 7-period MQW active region. The superlattice and MQW layers were grown at 920°C and 775°C , respectively, according to thermocouple readings. The barriers between the wells were grown in low- and high-temperature steps (LT and HT). An aluminium gallium nitride (AlGaN) cap on the wells suppressed indium desorption during the higher-temperature barrier growth. The structure was completed with magnesium-doped electron-blocking (EBL) and p-contact layers.

LEDs and μ LEDs were fabricated with 110nm indium tin oxide (ITO) transparent p-contact, 700nm -high mesas, silicon dioxide/tantalum pentoxide/aluminium oxide ($\text{SiO}_2/\text{Ta}_2\text{O}_5/\text{Al}_2\text{O}_3$) omnidirectional reflector (ODR), and atomic layer deposition (ALD) SiO_2 sidewall passivation. The metal contacts were aluminium/nickel/gold.

Photoluminescence from the quantum wells fell mainly in the range $500\text{--}650\text{nm}$. Some emissions around 420nm came from the sidewalls of the V-defects where the QWs are thinner and contain less indium. The epitaxial material on GaN/Si exhibited intensity oscillations from Fabry-Pérot interference between light reflected at the flat top and bottom surfaces. The material on PSS had a smoother PL spectrum since light scattering from the patterned surface interrupted the Fabry-Pérot effect.

The researchers report peak external quantum efficiency (EQE) and wall-plug efficiency (WPE) of 6.5% and 3.5%, respectively, for a packaged and fully encapsulated LED of area 0.1mm^2 . The EQE peaked at $28\text{A}/\text{cm}^2$ injection, and the WPE at $20\text{A}/\text{cm}^2$. Between $20\text{A}/\text{cm}^2$ and $28\text{A}/\text{cm}^2$ the wavelength blue-shifted from 595nm to 590nm . At lower injections the wavelength exceeded 600nm , while at $100\text{A}/\text{cm}^2$ the wavelength shortened to around 575nm .

The researchers comment: "The blue shift is a result of screening of the large electric field in the QWs by injected carriers. The high efficiency is attributed to lateral injection through the semi-polar sidewalls of V-defects as well as the enhanced light extraction from PSS. It's also plausible that the V-defects could enhance light extraction by roughening the top surface. However, if the p-GaN growth conditions are optimized to fill the V-defects completely then this effect would be mostly eliminated."

With a view to future improvement, the team

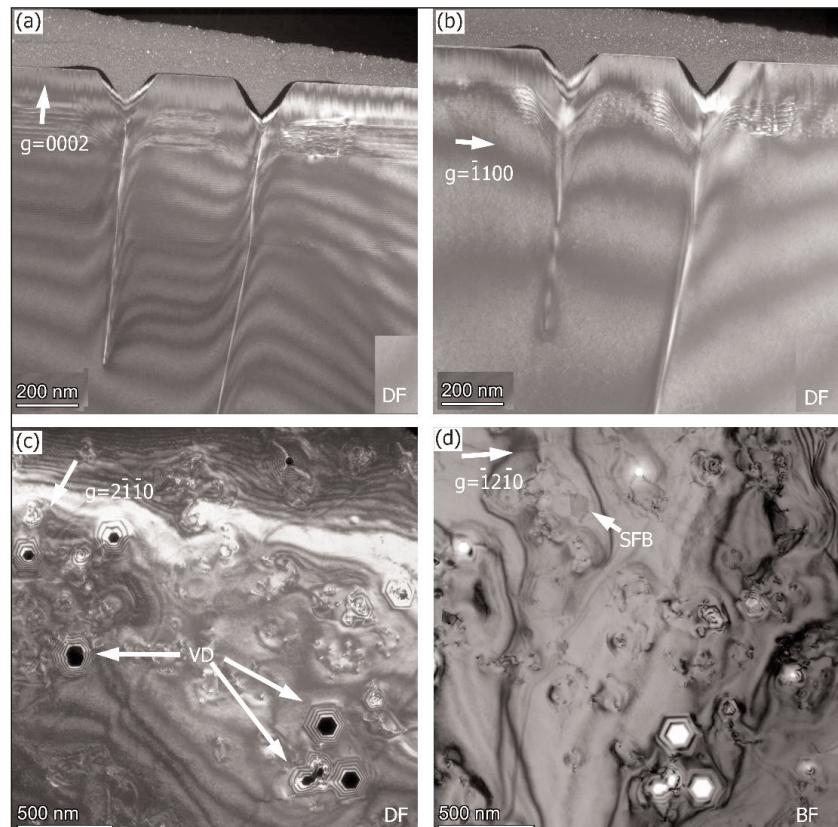


Figure 2. (a) Zone-axis and (b) non-zone-axis dark field (DF) scattering contrast transmission electron microscope (TEM) images of red LED on PSS. (c) Dark-field plan-view TEM image. (d) Bright-field (BF) plan-view TEM image.

performed a range of analyses of the epitaxial material on PSS. In TEM imaging the researchers found large V-defects (VD) and a number of other defects. The latter likely enable non-radiative recombination of electron and holes, reducing light output power and efficiencies in LED devices. In particular, the TEM imaging showed the presence of a stacking fault box (SFB), "very likely to be a significant non-radiative center," according to the team. The researchers hope that improved growth techniques will lead to the elimination of SFB and reduced numbers of undesired defects.

Another concern was the relatively low density of V-defects: around $1\times 10^8/\text{cm}^2$. The researchers comment: "This density is much lower than the density achieved on (111) Si by the Nanchang LED company and may be one of the reasons for increased voltage and lower WPE on the PSS LEDs. To achieve complete lateral injection the spacing of V-defects needs to be lateral diffusion length which is $\sim 100\text{nm}$." At the density seen in the TEM images, the average distance between V-defects is around $1\mu\text{m}$, about 10x the diffusion length. In particular, at this distance the holes find it difficult to distribute themselves uniformly through the wells, due to alloy fluctuation effects. ■

<https://doi.org/10.1364/OE.503732>

<http://en.enkris.com>

Author: Mike Cooke

Virtual body concept for 650V GaN-on-silicon ICs

A new technique suppresses dynamic on-resistance and substrate-induced cross-talk between transistors.

Peking University in China has presented a new virtual-body concept for screening p-gate gallium nitride high electron-mobility transistor (VB-HEMTs) integrated circuits from silicon-substrate-induced cross-talk at the recent IEEE International Electron Devices Meeting (IEDM 2023) in December [Junjie Yang et al, Technical Session 9-6]. The team demonstrated the benefit of using VB-HEMTs in a basic monolithic half-bridge IC.

Although 650V-rated discrete GaN power transistors are commercially available, it is a challenge to boost power densities by fabricating GaN power ICs due to back-gating effects from the substrate. In discrete devices this can be avoided with source-substrate interconnection.

One of the researchers, Jin Wei, an assistant

professor at Peking University, comments: "Unfortunately, for the GaN-on-Si platform, if a half-bridge IC is built, there must be at least one of the transistors that

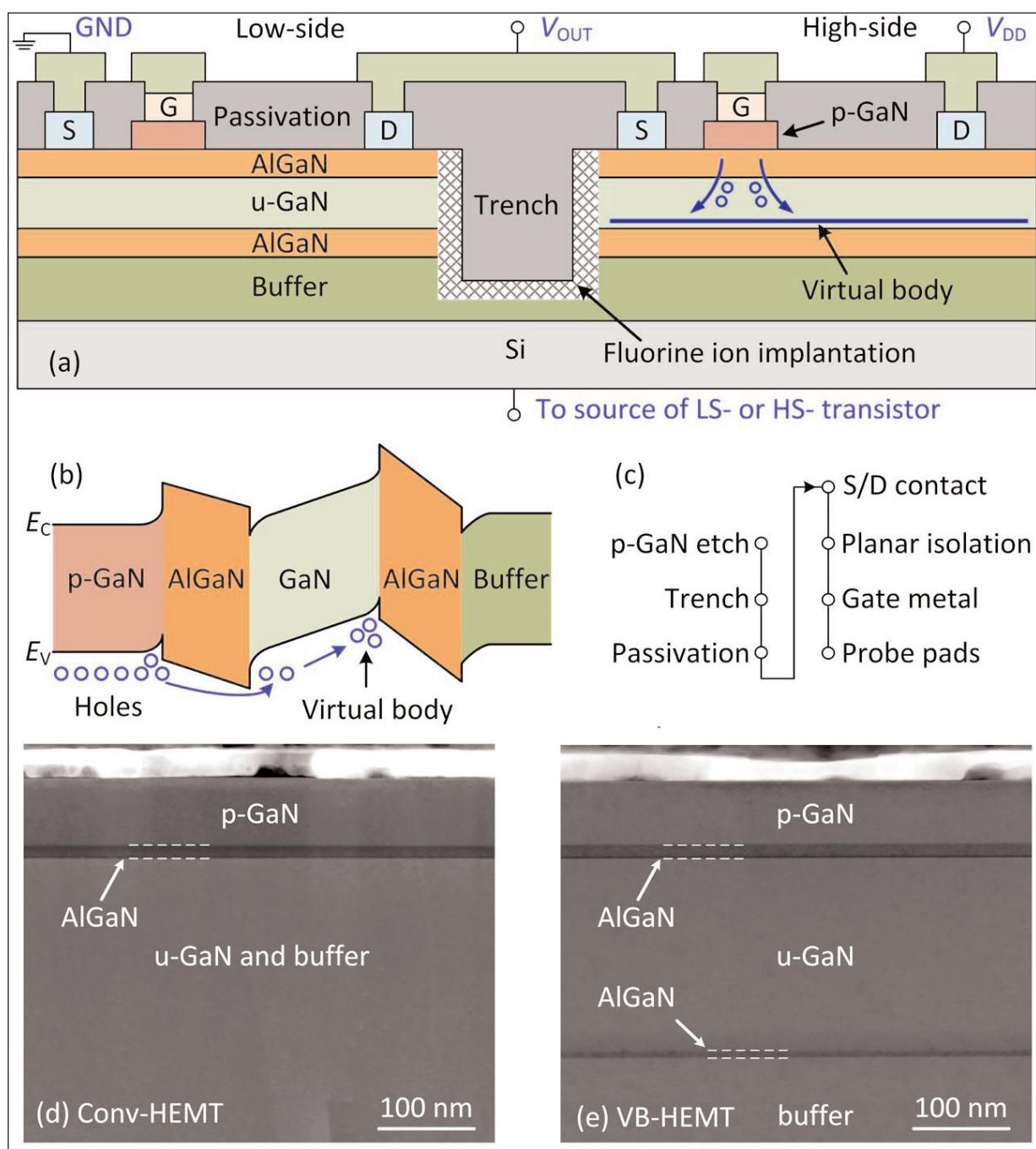


Figure 1. (a) Cross-section of 650V GaN power IC platform. (b) Energy-band diagram in gate region. (c) Process flow for proposed platform. (d, e) Transmission electron microscope (TEM) images of gate region of fabricated (d) conventional- and (e) VB-HEMTs.

fails to have substrate-to-source connection. Thus, the substrate-to-source voltage difference (i.e. back-gating effect) results in a severe dynamic on-resistance R_{ON} degradation."

Although other research teams have reduced the impact on dynamic R_{ON} in high-frequency power switching from substrate cross-talk up to 200V by using special substrates, the Peking device uses low-cost standard bulk silicon. The team sees the VB approach as a cost-effective way to boost GaN-on-Si power IC performance to provide a 650V platform based on thick GaN epitaxial films.

The VB-HEMT devices were fabricated using III-N material on 6-inch (150mm)-diameter low-resistivity silicon (Si) wafers (Figure 1). The virtual body material consisted of a 5.2 μ m buffer, 10nm buried aluminium gallium nitride ($Al_{0.2}Ga_{0.8}N$), 200nm undoped GaN, 15nm $Al_{0.2}Ga_{0.8}N$ barrier, and 80nm p-GaN gate layers. Conventional devices were also fabricated for comparison, using material without the buried AlGaN layer.

The fabrication consisted of gate and 350nm-deep trench etching, 50nm plasma-enhanced chemical vapor deposition (PECVD) silicon dioxide passivation, deposition and annealing of titanium/aluminium/nickel/gold source/drain (S/D) contacts, multi-energy fluorine ion implants, nickel/gold ohmic gate contact deposition and annealing, and contact pad formation.

The VB-HEMT's ohmic p-GaN gate contact injects holes in the ON-state that accumulate and spread above the buried AlGaN layer to form the virtual body under the two-dimensional electron gas (2DEG) channel near the top AlGaN barrier layer.

The threshold voltage of the VB and conventional HEMTs was 1.4V for 10 μ A/mm drain current in both devices. The positive threshold means that the devices operate in enhancement-mode (normally-off), as desired for reduced power losses.

The dynamic on-resistance (R_{ON-dyn}) after 650V drain bias stress in the off-state was a factor of 3.66 higher than the static resistance ($R_{ON-stat}$) in the conventional device. By contrast, the VB-HEMT $R_{ON-dyn}/R_{ON-stat}$ factor was as low as 1.28. The VB-HEMT ratio was dependent on the gate potential: 1.28 for 3.5V, but 4.29 for 2V.

The researchers explain the mechanism suppressing R_{ON-dyn} in the VB-HEMT: "The buffer trapping is screened by the holes injected from gate and spread along the virtual body. The surface trapping is likely to

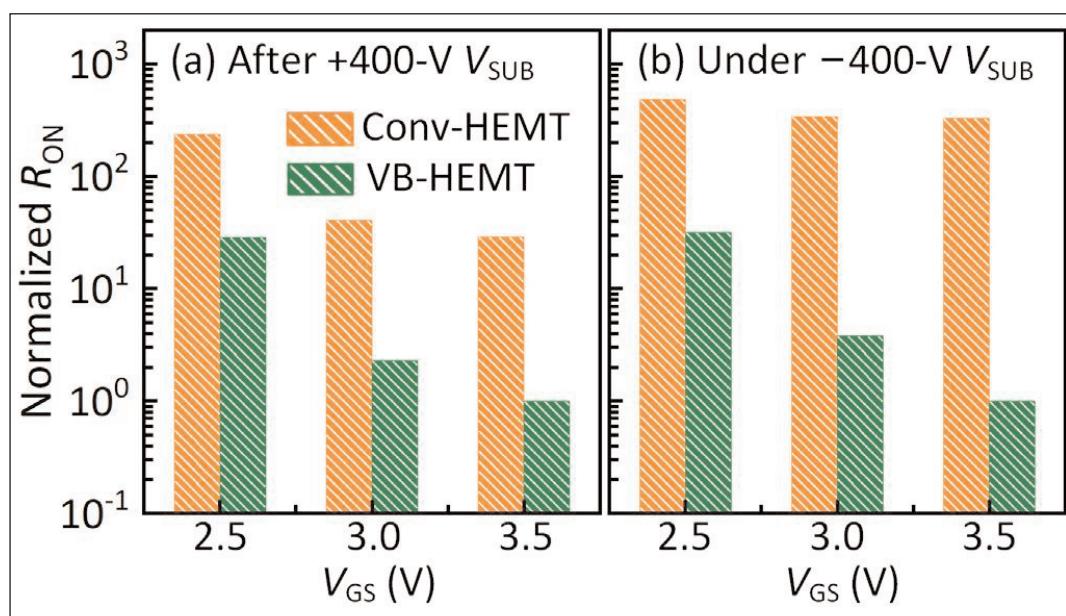


Figure 2. Performance of conventional and VB HEMTs: normalized R_{ON} (a) after +400V and (b) during -400V V_{SUB} biases.

be mitigated by the recombination of holes from virtual body with electrons from 2DEG, emitting photons to accelerate the recovery of surface trapping."

Although one might worry that hole injection might increase dynamic OFF-state leakage in the VB-HEMT, the team found that the virtual body mechanism did not in fact increase the OFF current.

In the half-bridge configuration, the VB suppresses cross-talk between the transistors by shielding the channel from the back gate effect of the silicon substrate. With conventional HEMTs, if the low-side transistor's source contact is connected to the substrate this induces a negative back gate on the high-side device. Connection of the substrate to the high-side source produces a negative gate effect on the low-side device. Both these effects impact performance, increasing the R_{ON} , and hence increasing power loss.

The team confirmed VB screening from substrate back-gating effects by biasing the substrate with 10kHz pulses of ± 400 V and determining the R_{ON} of a half-bridge IC at various gate potentials (Figure 2). The high-side drain was connected to a 3V V_{DD} power supply through a 300Ω load resistor. The low-side source was connected to ground. Various gate potentials (V_{GS}) were used.

Since the half-bridge (R_{ON}) was connected in series with the load (R_L), $R_{ON} = R_L V_{DS} / (V_{DD} - V_{DS})$, where V_{DS} was the measured voltage across the half-bridge. The performance of the VB-HEMT device was not impacted by the substrate stresses when the gate was at 3.5V, unlike with conventional p-gate HEMTs. ■

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Author: Mike Cooke

Dynamic performance of vertical GaN JFETs

First study shows no shift in R_{ON} or V_{TH} , according to researchers.

Virginia Polytechnic Institute and State University and NexGen Power Systems Inc in the USA have claimed the first experimental characterization of dynamic on-resistance (R_{ON}) and threshold voltage (V_{TH}) stability in vertical gallium nitride (GaN) power transistors [Xin Yang et al, IEEE Transactions On Electron Devices, vol.71, issue 1 (January 2024), p720]. The researchers studied NexGen junction field-effect transistor (JFET) devices rated at up to 1200V (1.2kV).

Dynamic R_{ON} describes the increased resistance of switched transistors relative to the value in a steady

DC state. The team comments: "This issue can induce a higher conduction loss of the device and a degraded device lifetime in applications."

The researchers compared the performance of NexGen's 650V/200mΩ- and 1200V/70mΩ-rated GaN JFETs (Figure 1) against that of commercial 650V and 1200V silicon carbide (SiC) metal-oxide-semiconductor field-effect transistors (MOSFETs, IMZA65R083M1H, C3M0075120D), and 650V GaN high-electron-mobility transistor with Schottky-type p-GaN gate (SP-HEMT, GS-065-011-1-L).

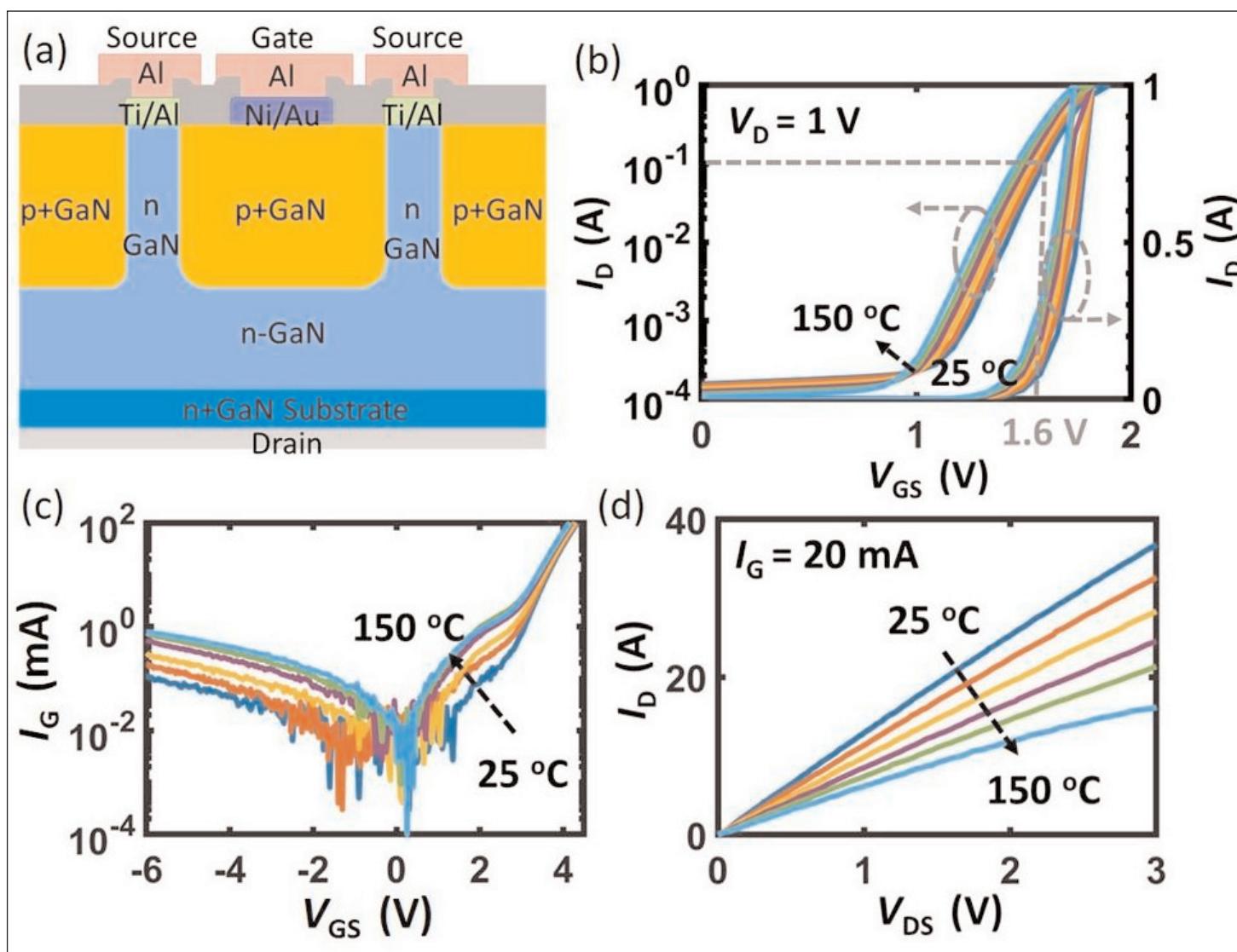


Figure 1. (a) Schematic of vertical GaN JFET. Characteristics at 25–150°C with 25°C incremental step of 1.2kV device: (b) transfer, drain current (I_D) versus gate potential (V_{GS}) on log and linear scales; (c) I_G versus V_{GS} ; and (d) output.

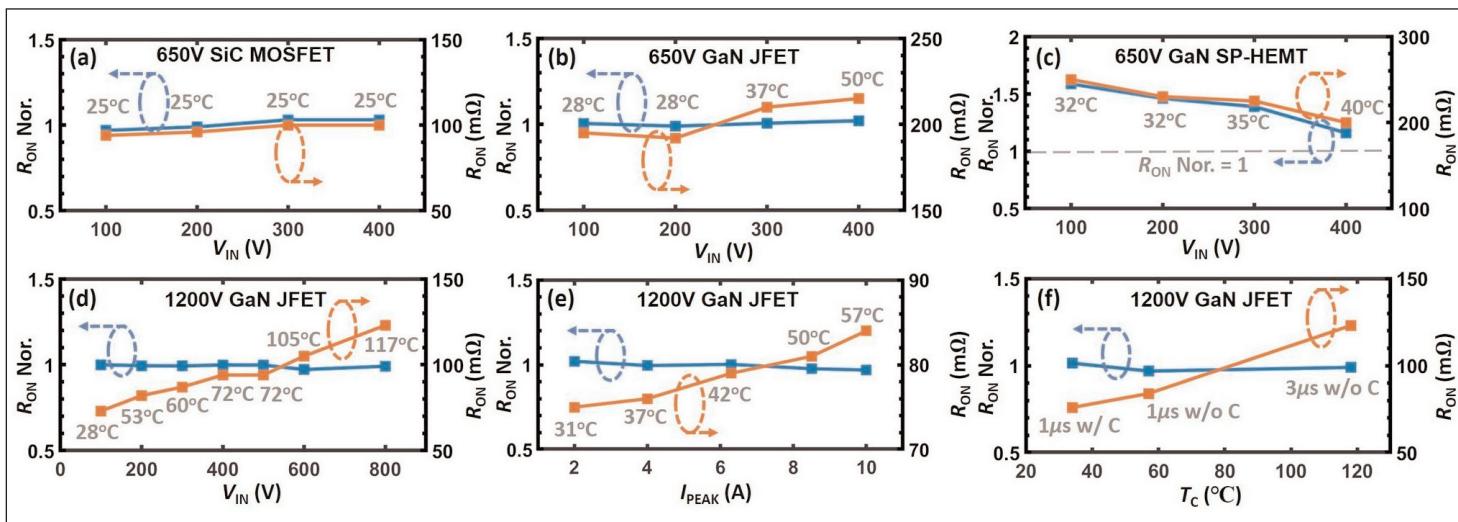


Figure 2. Extracted dynamic R_{ON} and normalized dynamic R_{ON} versus V_{IN} with 3 μ s pulse width for 650V-rated (a) SiC MOSFET, (b) GaN JFET, (c) GaN SP-HEMT, and (d) 1200V GaN JFET. (e) and (f) Dynamic R_{ON} performance of 1200V GaN JFET at 800V V_{IN} (10A steady state) versus 1 μ s pulse peak drain current and T_c with/without cooling, respectively.

NexGen's devices were fabricated on 100mm bulk n⁺-GaN substrates. The fin channels were around 1 μ m high and sub-micron in width. The gate consisted of implanted p-GaN regions between the fins. The drift region between the fin channels and the drain was around 8 μ m and 10 μ m for the 650V and 1200V devices, respectively. The corresponding avalanche breakdown voltages were estimated to be 800V and 1500V.

The threshold voltage (V_{TH}) of the 1.2kV JFET was 1.6V at 25°C, decreasing to 1.45V at 150°C. The R_{ON} at 20mA IG was around 70m Ω at 25°C, increasing to 150m Ω at 150°C.

The researchers used continuous, hard-switching double pulse tests (DPTs) with an active measurement circuit to assess the dynamic R_{ON} performance (Figure 2). The devices were assembled in dual flat no-lead (DFN) packages, and case temperature (T_C) was determined using thermal imaging. Fan cooling was applied to the SiC MOSFET and GaN SP-HEMT comparison devices, but not to the GaN JFETs. The R_{ON} values were normalized according to the static R_{ON} at the measured T_C .

The researchers comment: "The results show 650V and 1200V GaN JFETs are both dynamic R_{ON} free."

The researchers also performed static stress testing to determine how stable the R_{ON} and V_{TH} values were,

as relevant to application scenarios where the power device is mostly off. The maximum V_{TH} and R_{ON} shifts for the 1200V JFET were 0.05% and 1.38%, respectively. By contrast, a 650V GaN SP-HEMT has corresponding shifts of order 20% and 10%.

The researchers also compared simulations of JFET and HEMT structures to analyze the difference in dynamic R_{ON} and static stability performance. The team suggests that a key difference arises in the position of the peak electric field, which usually arises near the edge termination. In the HEMT structure, the peak field is only 20–30nm from the device surface, while in the JFET peak E is buried about a 1 μ m away from the surface. Combined with the lower defect density in epitaxial layers grown on bulk GaN, surface and buffer traps are largely suppressed, reducing delays in state changes, which almost eliminates the dynamic R_{ON} in the GaN JFET, it is thought.

The researchers add: "Finally, the native p-n junction gate in JFET has no band discontinuities, enabling the more efficient carrier supply or extraction as compared to the p-GaN/AIGaN/GaN hetero-gate in the HEMTs (particularly with the Schottky contact to p- GaN in SP-HEMT)." ■

<https://doi.org/10.1109/TED.2023.3338140>

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Lateral polarity structure GaN Schottky barrier diodes

Selective wet etching of N-polar material reduces reverse leakage through mesa sidewalls.

Ningbo Institute of Materials Technology and Engineering, and University of Chinese Academy of Sciences in China have reported a high-performance quasi-vertical gallium nitride (GaN) Schottky barrier diode (SBD), using a lateral polarity structure (LPS) with an active III-polar region surrounded by N-polar material [Yijun Dai et al, Appl. Phys. Lett. v123, p252110, 2023].

The resulting devices featured a high 10^7 on/off current ratio and low leakage under reverse biases up to a 290V breakdown. Vertical GaN SBDs feature low turn-on voltage and high-speed switching characteristics, relative to lateral devices.

The SBD LPS material was grown on 0.5°-misoriented (0001) sapphire (Figure 1). The III-polar active region was grown on a circular patterned aluminium

nitride (AlN) nucleation layer. The material grown on bare sapphire was N-polar. The metal-organic chemical vapor deposition (MOCVD) layer sequence consisted of a 3μm buffer layer, a 2μm n⁺-GaN current-spreading layer, and a 3μm n⁻-GaN drift layer.

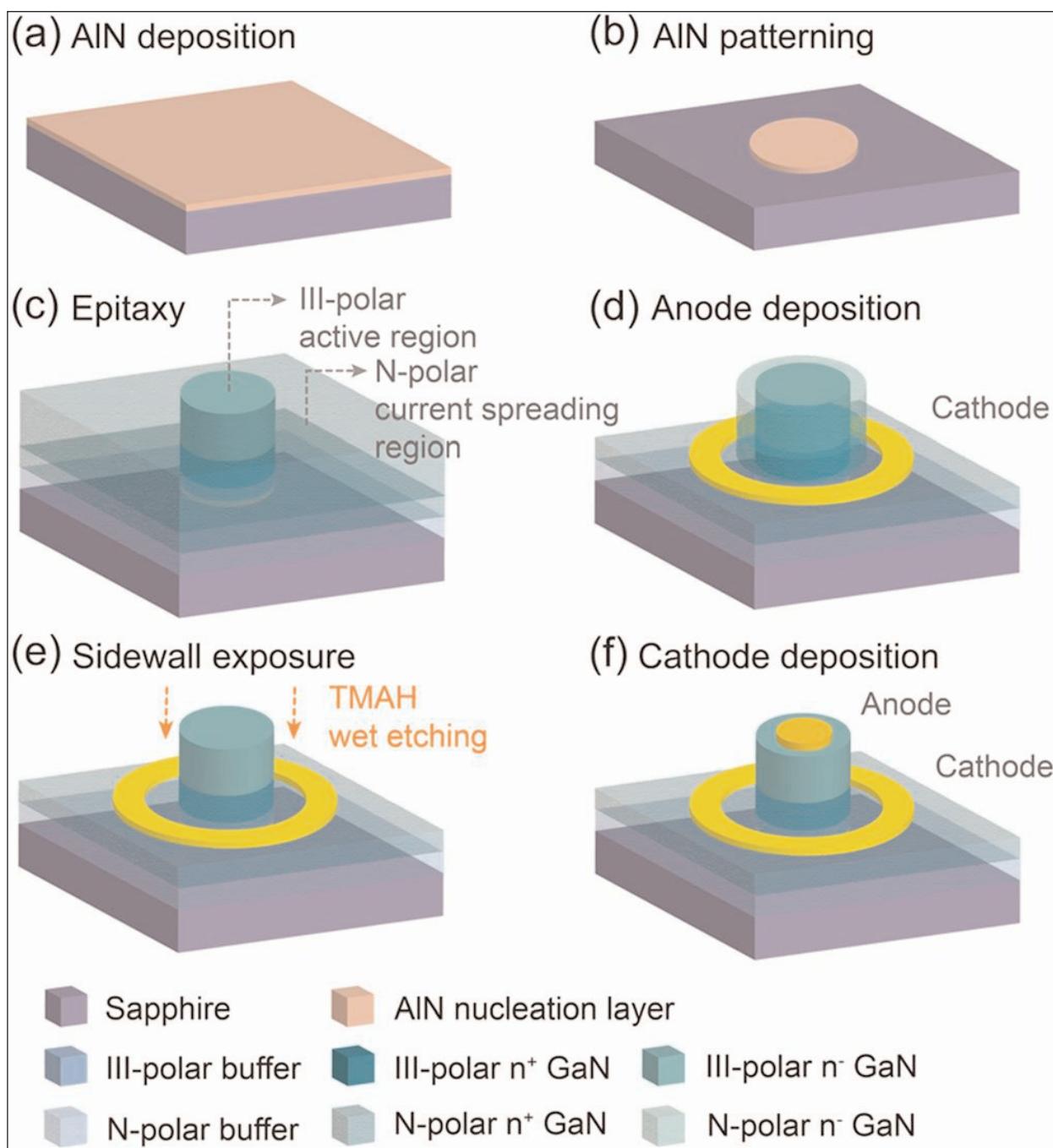


Figure 1. Process scheme for quasi-vertical GaN SBD based on LPS platform.

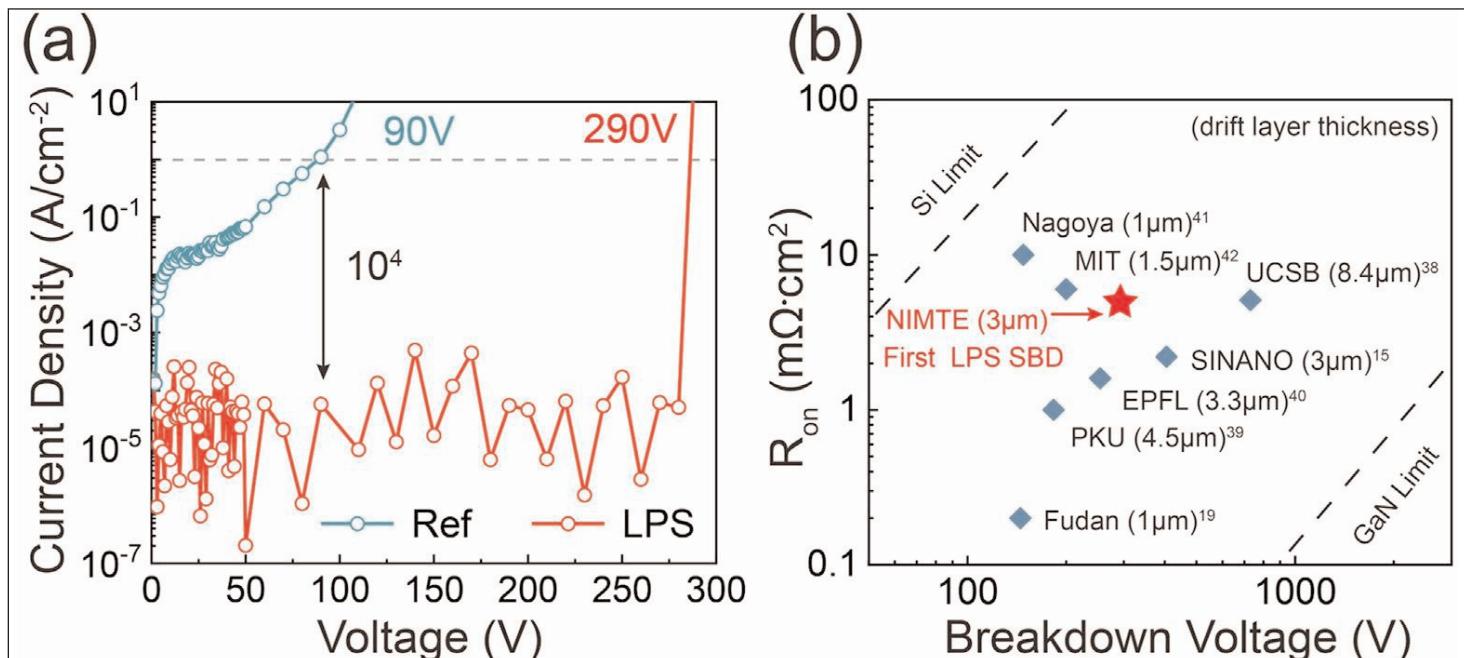


Figure 2. (a) Off-state breakdown characteristics of reference and LPS SBDs. (b) Benchmarks of R_{on} versus breakdown voltage of LPS device together with other reports.

Fabrication began with plasma etch of the N-polar region down to the current-spreading layer, using a nickel hard mask. This avoided rough N-polar surfaces with hexagonal hillocks that tend to occur in wet etching. An ohmic ring-contact cathode consisting of titanium/aluminium/nickel/gold was deposited using electron-beam evaporation and annealed in nitrogen.

The III-polar mesa sidewall was exposed by selective etching away of the N-polar sheath around the Ga-polar active region with tetramethylammonium hydroxide (TMAH) alkali solution for 20 minutes at 85°C. The OH⁻ ions in the alkali solution interact with the dangling bonds of the surface nitrogen atoms, forming ammonia (NH₃) and breaking up the N-polar material. By contrast, with a Ga-polar surface the nitrogen atoms are buried away and it is less easy for the OH⁻ ions to gain access.

The Schottky anode contact, deposited on the drift layer, consisted of nickel/gold. The anode metal contact had a radius of 100μm, while the mesa radius was 110μm. A reference SBD was produced using only plasma etch, but with the same contact structures.

The on/off current ratio of the LPS SBD was of order 10⁷, and the reverse leakage current was reduced by two orders of magnitude relative to the

reference device. The ideality factors for the LPS and reference SBDs were 1.03 and 1.09, respectively.

The team comments: "The lower ideality factor for the LPS SBD indicates strong suppression of defect-related leakage paths and recombination centers, which are typically responsible for the non-ideality in GaN diodes."

The LPS and reference turn-on voltages were 0.5V and 0.6V, respectively. The one area where the LPS device performed less well than the reference was in terms of differential specific on-resistance (R_{on}): 6.5mΩ·cm² for the LPS and 2.1mΩ·cm² for the reference diodes.

The researchers explain the difference: "The higher R_{on} value of the LPS SBD can be ascribed to the undercut and wet etching of the N-polar domain beneath the Ohmic contact."

The Schottky barrier height was extracted using temperature-dependent measurements: 0.82eV for the LPS diode.

The LPS SBD had a 200V higher breakdown voltage (BV) than the reference device: 290V compared with 90V (Figure 2). The peak electric field in the LPS device was estimated at 2.1MV/cm. At 90V, the reverse leakage current in the LPS device was four orders of magnitude smaller than the reference device's 1A/cm².

Further enhancement of breakdown voltage would depend on tackling leakage currents associated with trap-assisted tunneling (TAT) and variable range hopping (VRH). In turn, suppressing these mechanisms would depend on reducing threading dislocations in the active GaN epitaxial layers, which may form a bottleneck on the road to higher BVs in LPS SBDs, says the team. ■

<https://doi.org/10.1063/5.0174847>

Author: Mike Cooke

suppliers' directory

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E-mail: registration@csmantech.org
www.vlsisymposium.org**28–30 May 2024****SEMICON Southeast Asia (SEMICON SEA 2024)**MITEC, Kuala Lumpur, Malaysia
E-mail: semiconsea@semi.org
www.semiconsea.org**7–10 June 2024****LOPS 2024: 4th Edition of Annual Conference on Lasers, Optics, Photonics, Sensors, Bio Photonics, Ultrafast Nonlinear Optics & Structured Light**DoubleTree Resort by Hilton Hollywood Beach,
Fort Lauderdale, FL, USA
E-mail: lopsannual@gmail.com
<https://excelev.com/photonoptics>**9–14 June 2024****52nd IEEE Photovoltaic Specialists Conference (IEEE PVSC 2024)**Seattle, WA, USA
E-mail: Registration@ieee-pvsc.org
www.ieee-pvsc.org/PVSC52**Microwave Week****16–18 June 2024****IEEE Radio Frequency Integrated Circuits Symposium (RFIC 2024)**Washington DC, USA
E-mail: support@mtt.org
www.rfic-ieee.org**16–20 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**9–11 July 2024****SEMICON West 2024**Moscone Center, San Francisco, CA, USA
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www.semiconwest.org**17–21 July 2024****4th European School on Crystal Growth (ESCG4)**Jachranka near Warsaw, Poland
E-mail: escg4@unipress.waw.pl
<https://eccg8.syskonf.pl/escg-4-about>**21–25 July 2024****8th European Conference on Crystal Growth (ECCG-8)**Warsaw, Poland
E-mail: info@eccg8.pl
<https://eccg8.syskonf.pl>**22–24 July 2024****38th North American Conference on Molecular Beam Epitaxy (NAMBE 2024)**Tufts University, Boston, MA, USA
E-mail: della@avs.org
www.nambe2024.avs.org**23–26 July 2024****5th International Congress on Advanced Materials Sciences and Engineering (AMSE-2024)**University of Rijeka, Opatija, Croatia
E-mail: eve@istci.org
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