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COMPOUNDS & ADVANCED SILICON

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Investments and collaborations continue for silicon carbide

Vishay buys Newport Wafer Fab • CHIPS Act funding for BAE
Qorvo selling China back-end plants • BluGlass buys GaNWorks

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p17 Vishay has agreed to buy Newport Wafer Fab in South Wales, UK from Nexperia for $177m.

p26 The first CHIPS and Science Act funding from the US Department of Commerce is $35m for BAE Systems to modernize its Microelectronics Center in Nashua, New Hampshire.

Cover image: Coherent has closed the $1bn aggregate investment in its silicon carbide semiconductor business by Japan-based automotive supplier DENSO and Mitsubishi Electric that was announced on 10 October. **p14**

editorial

SiC-driven alliances and acquisitions

The last month has seen a wave of divestments and acquisitions, as some firms focus on core business while others refocus on high-growth sectors.

Just before the holiday period, US-based RF device maker Qorvo said that it was selling its assembly & test facilities in Beijing and Dezhou to China-based contract manufacturer Luxshare, while retaining its sales, engineering and customer support staff in China (see page 8). The divestment "furthers our efforts to reduce capital intensity while supporting our long-term gross margin objectives," Qorvo says. This follows US-based Wolfspeed completing the sale of its RF business to MACOM as it focuses exclusively on silicon carbide (SiC) materials and power devices (page 24). Gallium arsenide RF device markets should be aided by global smartphone production rebounding in third-quarter 2023 after eight quarters of year-on-year declines (page 7).

Meanwhile, US-based onsemi has opened an application test lab in Slovakia, focused on providing equipment for developing and testing silicon and SiC solutions in collaboration with automotive OEMs for electric vehicles (EVs) and providers of energy infrastructure power conversion systems (page 10).

Also, Japan's government is supporting a plan by ROHM and Toshiba to collaborate on investing in the production of silicon and SiC wafers and power devices (page 11). ROHM has also completed its acquisition of Tokyo-based Solar Frontier's Kunitomi Plant, which will become its main production site for SiC power devices, starting in 2024 (page 10). This enables "fast production expansion by utilizing existing infrastructure".

Japan-based Mitsubishi Electric and automotive supplier DENSO have also completed their $1bn collective investment in the SiC substrate and epiwafer manufacturing business of US-based Coherent (page 14).

Also, to co-develop SiC power semiconductors, Mitsubishi Electric is to develop and supply SiC MOSFET chips for discrete devices made by Netherlands-based Nexperia (page 15). The partnership has already yielded Nexperia's first SiC MOSFET products: 1200V discrete devices for industrial applications, with automotive-grade products to follow (page 16).

The partnership may help to offset Nexperia (which is owned by China-based Wingtech) being ordered by the UK Government in November 2022 to divest South Wales-based Newport Wafer Fab, on the grounds that its "potential reintroduction of compound semiconductor activities" with defense-related applications presented a threat to national security.

The automotive-certified, 200mm wafer fab is now being bought by US-based discrete semiconductor & passive electronic component maker Vishay, which aims to equip it to produce the firm's SiC trench MOSFETs and diodes. This is part of Vishay's plan to invest $1.2bn in capacity over three years (page 17). "Newport Wafer Fab brings together our capacity expansion plans for our customers in automotive and industrial end markets as well as the UK's strategic goal of improved supply chain resilience," Vishay adds. A key element of the firm's strategic shift since early 2023 is investment in "technologies and incremental capacity to position Vishay to capitalize on the megatrends in e-mobility and sustainability". Buying Newport Wafer Fab is "instrumental to achieving our goal of expanding capacity for our customers and to accelerating our SiC strategy," it adds.

Again, despite the SiC-specific equipment required, a factor is the lower investment required in infrastructure, when a compound semiconductor product line can be installed in an existing, fully depreciated fab, without constructing a state-of-the-art fab for leading-edge silicon, for example.

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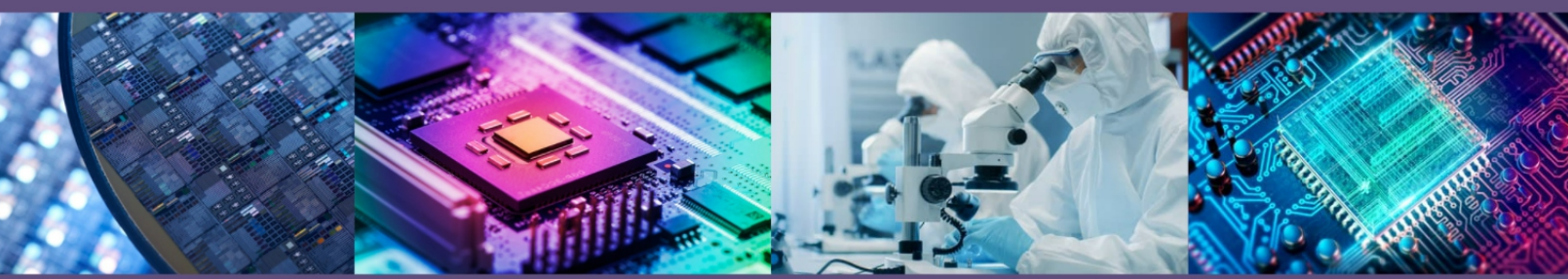

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Gallium nitride and silicon carbide to be essential for enabling scale and potential of AI

Adopting SiC or GaN for power supplies in data centers to cut energy consumption while freeing space for extra computing power

Decades old norms are being challenged in the power semiconductor industry as Omdia forecasts an explosion in novel semiconductors due to the electric vehicle (EV) revolution. "Will the artificial intelligence (AI) boom have a similar impact?," the firm questions.

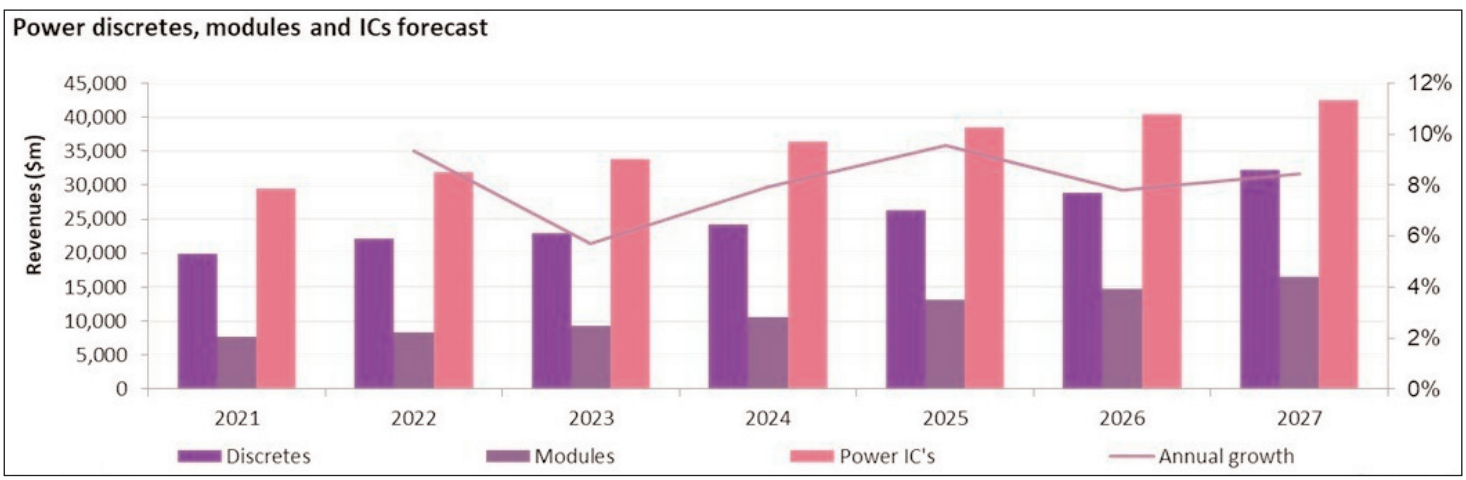
"An industry which has long relied on silicon technologies is being both challenged and enabled by devices fabricated from new materials," notes Callum Middleton, senior analyst for semiconductor components. "The development of both gallium nitride (GaN) and silicon carbide (SiC) power devices began in the previous century, but their technology maturity has matched with the sustainability movement, and devices manufactured from the new materials offer significant efficiency gains in our energy-hungry world," he adds.

The initial adoption of SiC devices into Tesla electric vehicles in 2018 catapulted the technology from laboratories and test designs into the mainstream. Since then, the EV market has taken off and more manufacturers are looking to include these technologies in their vehicles due to the benefits in performance, charging speed, and range.

This early adoption has allowed SiC to prove its performance and reliability in the real world, and phone and laptop chargers have done the same for GaN. As the AI boom gathers pace it is going to put added stress onto our energy supply and distribution systems, says Omdia. To ensure that the benefits of AI are fully enjoyed and that this is done so sustainably we will have to ensure that efficiency is maximized, but this does not have to be done at the cost of profitability, the firm adds. Adopting a SiC or GaN solution for power supplies in data centers can significantly reduce energy consumption while simultaneously freeing up space for extra computing power.

"These novel devices, and the decades of research, development, testing and engineering that has gone before them, may not grab the headlines but they will be essential for enabling the scale and potential of artificial intelligence," believes Middleton.

Middleton is presenting the market research firm's latest semiconductor research at the 2023 Omdia Korea Technology Conference in Seoul, South Korea (22–24 November).
www.ktconf.com



Smartphone production rebounds by 13% in Q3, after eight quarters of year-on-year declines

Further 5–10% growth expected in Q4, limiting full-year decline to under 3% to 1.16 billion units

Fueled by reduced channel inventories and spikes in seasonal demand, global smartphone production rose by 13% quarter-to-quarter to about 308 million units in third-quarter 2023, according to market research firm TrendForce. Although this figure has yet to reach pre-pandemic levels, it is up 6.4% year-on-year, ending an eight-quarter streak of annual declines.

Looking ahead to fourth-quarter 2023, e-commerce promotions and the year-end shopping boom — coupled with the customary end-of-year surge in production by smartphone brands — are likely to stimulate a further 5–10% quarter-on-quarter increase in production. The projected downturn in annual smartphone production for 2023 is expected to be limited to less than 3%, to about 1.16 billion units.

Huawei's market return puts pressure on Apple's market share in China for next year

Leveraging its presence in the flagship smartphone market, Samsung continues to lead the market (with market share of 19.5%) after recording an 11.5% increase in production to 60.1 million units in Q3. Despite Samsung's extensive global reach, the firm's conservative planning in light of global economic headwinds has narrowed its annual production lead over Apple to just 5 million units.

Apple, riding the wave of its latest flagship releases, saw its production climb by 17.9% to about 49.5 million units in Q3. However, the initial low yield rates of the CMOS image sensor (CIS) in the iPhone 15/15 Plus series adversely affected Apple's Q3 performance, resulting in a 1.5% year-on-year market share decline to 16.1%, with annual production expected to align with 2022 levels.

Ranking	Company	Production	QoQ	Market Share
1	Samsung	60.1	11.5%	19.5%
2	Apple	49.5	17.9%	16.1%
3	Xiaomi	42.8	22.3%	13.9%
4	Oppo	38.7	15.2%	12.6%
5	Transsion	26.5	5.6%	8.6%
6	Vivo	24.5	6.5%	8.0%

Total quarterly production and market shares of top six smartphone brands (in millions).

Huawei's re-entry with its flagship phones has made a significant impact on the high-end smartphone market in China, with Apple being the primary target. As Huawei aims to expand its high-end flagship series in 2024 with a focus on the Chinese domestic market, the company is set to directly challenge Apple. This strategy, coupled with prevailing geopolitical factors, positions Huawei as a formidable competitor and is expected to significantly impact Apple's production performance in the upcoming year.

Transsion outperforms Vivo in Q3 to clinch fifth place

Following the completion of channel inventory adjustments, Xiaomi (including Xiaomi, Redmi and POCO) has shifted to a more assertive stance in both device production and component stockpiling as the year draws to a close. Xiaomi's Q3 production jumped by 22.3% to about 42.8 million units — bolstered by the resurgence of the Indian market — solidifying its status as the world's third-largest producer (with 13.9% market share).

In China... Huawei... is expected to significantly impact Apple's production performance in the upcoming year

Oppo (including Oppo, Realme and OnePlus) saw a 15.2% rise in its output to 38.7 million units in Q3. Fueled by rising sales in markets like India and South America, this growth is expected to maintain its momentum into the fourth quarter.

Transsion (including TECNO, Infinix and itel) continued its robust performance from Q2 into Q3, with its production output rising by 5.6% quarter-to-quarter to 26.5 million units. This surge enabled Transsion to overtake Vivo again and secure the fifth place globally (with 8.6% market share). The brand has been thriving in emerging markets and steadily growing its market share since the second quarter. With the potential for an annual growth rate exceeding 40%, Transsion remains in close competition with Vivo for global rankings.

Vivo (including Vivo and iQoo) saw its production grow by 6.5% to 24.5 million units in Q3, placing it in the sixth spot (with 8% market share). In response to the global economic downturn, the firm adopted a more conservative production plan in first-half 2023. Even as the market in China — one of its primary regions — began to improve in the latter half of the year, Vivo maintained its strategy aimed at ensuring steady profits.

www.Trendforce.com

Qorvo sells Beijing and Dezhou assembly & test facilities to contract manufacturer Luxshare

Qorvo to maintain sales, engineering & customer support staff in China

Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has reached a definitive agreement for global contract manufacturer Luxshare Precision Industry Co Ltd of Dongguan City, Guangdong, China to acquire its assembly & test facilities in Beijing and Dezhou.

The companies anticipate completing the transaction by first-half 2024, subject to receipt of regulatory approvals and the satisfaction or waiver of other closing conditions. Upon closing, Luxshare will acquire each facility's operations and assets, which include the property, plant and equipment, as well as the existing workforce, to enable seamless continuity of operations. Qorvo will continue to maintain its sales, engineering and customer support employees in China to continue serving customers.

Following the close of the transaction, Luxshare will assemble and test products for Qorvo under a newly established long-term supply agreement. The Beijing and Dezhou facilities primarily support Qorvo's highly integrated advanced cellular products. Luxshare is described as a trusted supplier to many of the world's leading electronics companies and will provide flexible access to production capacity while expanding its offerings and capabilities.

Qorvo's assembly & test facility in Dezhou, China.

"The Beijing and Dezhou facilities have been an important part of our history and manufacturing network for decades. After carefully considering multiple alternatives over the past few years, we feel that we have found the right partner to continue supporting our customers from these factories," says Qorvo's president & CEO Bob Bruggeworth. "Given Luxshare's scale and well-established, high-volume manufacturing competency, we are confident that they will ensure continuity, maintain high levels of quality, and be another outstanding strategic partner in our supply chain that allows us to serve our customers worldwide," he adds.

"This transaction furthers our efforts to reduce capital intensity while supporting our long-term gross margin objectives and ensuring continuity for our customers in China," says Qorvo's chief financial officer Grant Brown.

The Beijing and Dezhou facilities will continue to operate as part of Qorvo's global manufacturing network until the closing of the transaction. After the closing, Qorvo's assembly, packaging and test network will continue to include its facilities in the USA, Costa Rica and Germany, as well as global outsourced semiconductor assembly & test (OSAT) partners.

www.luxshare-tech.com
www.qorvo.com

CDI to distribute products from AmpliTech Group MMIC Design Center

AmpliTech Group Inc of Hauppauge, NY, USA has agreed for Component Distributors Inc (CDI) to market and distribute all MMICs (in either die or packaged forms) released by its AmpliTech Group MMIC Design Center (AGMDC) Division in Plano, Texas, which was founded in 2021 and designs, develops and manufactures signal-processing components for satellite and 5G communications networks, defense, space and other commercial applications.

This is AGMDC's first distribution agreement, presenting an opportunity to reach not just domestic customers but also global customers that are currently being served by CDI.

"We specifically chose CDI to become our distribution channel given CDI's ample reach, engineering support and distribution capabilities," says AmpliTech's founder & CEO Fawad Maqbool. "This effectively sets the table for both our semiconductor packages and MMIC divisions to streamline their product offerings, paving the way for continued new product introductions in the SATCOM, 5G and quantum markets," he adds.

www.cdiweb.com

Modelithics and RFMW collaborate

Rapid access to device components and technical info for engineering designers, plus simulation models for suppliers

Modelithics Inc of Tampa, FL, USA — which provides standardized model libraries and custom modeling services for RF, microwave and millimeter-wave electronic device electronic design automation (EDA) — is collaborating with RFMW (a specialty electronics distributor providing RF, microwave and power components and semiconductors, as well as component engineering support) to expand the resources readily available to engineering designers and suppliers.

The collaboration offers engineering designers rapid access to obtain device components and technical information that includes device datasheets as well as highly accurate simulation models for suppliers including Qorvo, Marki Microwave, Smiths Interconnect, Knowles, Spectrum Control, and Guerilla RF.

"Collaborating with Modelithics will allow our customers to gain easy access to high-quality simulation models that will reduce design time and overall costs," says RFMW's president Joel Levine. "Facilitating an optimal development experience — from introduction to production — is a key part of our RFMW Value-Added Distribution strategy."

Via the Modelithics Vendor Partner (MVP) program, many suppliers are sponsoring free extended use of Modelithics models, for customers that do not already have access to the Modelithics' COMPLETE Library or its customized vendor-specific libraries, such as the Modelithics Qorvo GaN Library and the Modelithics MACOM GaN Library.

www.rfmw.com
www.modelithics.com

Altum RF expands backend infrastructure for production and reliability testing

Altum RF of Eindhoven, the Netherlands (which designs RF and millimeter-wave semiconductors for commercial and industrial applications) has unveiled its expanded backend production and reliability testing infrastructure, which supports growing business demands.

The investment in both production and reliability testing includes equipment and infrastructure to automate low- to medium-volume series production testing, allowing quick response to customer interest in Altum RF's products. Also, the firm has added more capability to perform extensive over-temperature product reliability testing. This equipment includes an automated pick-and-place IC test system for RF and DC production test and high-temperature operating life (HTOL) system for product reliability testing.

"We continue to focus on expanding our product portfolio, and with it comes increased customer requests for products that have been extensively tested," says CEO Greg Baker. "To support these customers, we are focused on the backend activities that will allow us to quickly respond to customer needs and ensure our products offer consistent performance with high reliability and quality."

www.altumrf.com

Guerrilla RF reports record deliveries in November

Guerrilla RF Inc (GRF) of Greensboro, NC, USA — which develops and manufactures radio-frequency integrated circuits (RFICs) and monolithic microwave integrated circuits (MMICs) for wireless applications —says that its shipments in November were up by more than 25.3% compared with its previous largest month and up 259.7% year-on-year.

"Our operations team processed and shipped the largest single-month volume in history during the month of November, as we delivered on previously announced purchase orders," says founder & CEO Ryan Pratt. "We are on track to deliver the highest revenue quarter in the company's history and we are really proud of our sales and operations team," he adds.

Guerrilla RF has reiterated its full-year 2023 revenue guidance of $14.7–15.2m, reflecting a minimum growth rate of 26.7% for the year. Also, it expects full-year 2024 revenue of $21–26m.

Guerrilla RF recently announced its first production purchase order (PO) and shipment to the satellite communications market (SATCOM) with a PO from a tier-1 SATCOM company. The initial PO was for $360,000, the majority of which is expected to be shipped by year-end. The firm expects SATCOM 2024 revenues to exceed $1m and the total market opportunity to exceed $560m.

Increasing sales and a continued focus on expense reduction is expected to enable Guerrilla RF to achieve operational cash flow breakeven by mid-2024 (excluding interest expense, and other non-operating and non-recurring expenses).

www.guerrilla-rf.com

onsemi opens systems application lab for EVs in Europe

Lab enables in-house testing to develop innovations for automotive and power conversion systems

Intelligent power and sensing technology firm onsemi of Scottsdale, AZ, USA has opened an application test lab in Piestany, Slovakia, focused on the advancement of system solutions for battery/plug-in hybrid/electric vehicles (xEVs) and energy infrastructure (EI) power conversion systems. The systems applications lab provides specialized equipment to develop and test next-generation silicon (Si) and silicon carbide (SiC) solutions in collaboration with automotive OEMs, tier-1s and energy infrastructure (EI) providers.

The new lab will play a central role in ensuring that the development of future power products results in highly differentiated, value-add solutions tailored to customers' specific requirements for highly efficient power conversion in xEV powertrains and charging, as well as applications in renewable energy.

The new facility consists of two high-voltage power labs that focus on systems- and device-level

development as well as evaluation of SiC/Si traction inverters and AC–DC/DC–DC power converters. Laser welding facilities, mechanical cleanrooms and workshops further enable fast prototyping and testing of next-generation system solutions.

Evaluation capabilities for the next-generation system solutions include:

- continuous 24/7 testing;
- internally developed and patented software and hardware solutions to support high-voltage power cycling via space vector modulation (SVM) and sinusoidal pulse width modulation (SPWM);
- high-accuracy logging devices for assessing SiC and Si health and reliability;
- simulation of the harsh conditions faced by inverters during operation, testing liquid-cooled devices at temperatures from –50°C to 220°C;
- a wider range of industry-recognized software allows for the programming of FPGAs and ARM microcontrollers on site, as well as qualification testing, data analysis and 3D modelling.

www.onsemi.com

ROHM completes acquisition of Solar Frontier plant

Plant to be ROHM's main production site for SiC power devices

Based on an agreement announced on 12 July, Japan-based ROHM Semiconductor has completed its acquisition of Tokyo-based CIS (copper indium selenium) thin-film photovoltaic (PV) module maker Solar Frontier K.K.'s former Kunitomi Plant in Japan, which covers 400,000m^2 and has a total floor area of 230,000m^2.

Operated by ROHM Group subsidiary LAPIS Semiconductor as its second Miyazaki plant, it will become the ROHM Group's main production site for silicon carbide (SiC) power devices and is aiming to start operation in 2024. Solar Frontier will continue to use part of the site and buildings as its business office (on a lease basis).

"This acquisition enables a fast production expansion by utilizing existing infrastructure. This way, ROHM will continue to supply its customers quickly and reliably," reckons Wolfram Harnack, president of ROHM Semiconductor Europe.

ROHM Group aims to continue to strengthen its production capacity in accordance with its Medium-Term Management Plan while keeping abreast of market conditions. The firm also aims to enhance its BCM (business continuity management) system to continue to ensure a stable supply of products to its customers.

www.solar-frontier.com
www.rohm.com

Toshiba and ROHM collaborate on silicon and SiC power device and wafer manufacturing

A plan by Japan-based ROHM Co Ltd and Toshiba Electronic Devices & Storage Corp (TDSC) to collaborate on the manufacture and increased volume production of power devices has been recognized and will be supported by Japan's Ministry of Economy, Trade and Industry (METI) as a measure supporting the Government's target of secure and stable semiconductor supply. ROHM and Toshiba Electronic Devices & Storage will respectively make intensive investments in silicon carbide (SiC) and silicon (Si) power devices, effectively enhance their supply capabilities, and utilize each other's production capacity.

Demand for power devices is expected to see continued growth for supplying and managing power supplies in all kinds of electronic equipment, especially for achieving a carbon-free, carbon-neutral society. In automotive applications, the development of more efficient, smaller and lighter electric powertrains has advanced alongside the rapid expansion in vehicle electrification. In industrial applications, a stable supply of power devices and improved characteristics are widely needed to support increasing automation and higher efficiency requirements.

ROHM expects its latest fourth-generation SiC MOSFETs to be adopted for numerous electric vehicles and industrial equipment. As one of its priority projects, the firm is working on SiC business, including continuous investment to increase the SiC production capacity and to meet the strong growth in demand.

For decades, Toshiba Electronic Devices & Storage has supplied silicon power devices, mainly for automotive and industrial markets, that have helped to achieve energy saving as well as equipment miniaturization. The firm started production on a 300mm wafer line last year and it is now accelerating investment to boost production capacity and to meet the strong growth in demand. It is also developing a broader lineup of SiC power devices, especially for automotive and power transmission and distribution applications, taking full advantage of the expertise it has cultivated in railway vehicle applications.

ROHM has already announced its participation in the privatization of Toshiba, but this investment did not serve as the starting point for the manufacturing collaboration between the two companies. Amid intensifying international competition in the semiconductor industry, ROHM and Toshiba Electronic Devices & Storage have been considering collaborating in the power device business for some time, resulting in the joint application.

As well as collaborating on manufacturing through investing in SiC and silicon power devices respectively (enhancing both companies' international competitiveness), ROHM and Toshiba Electronic Devices & Storage also aim to contribute to strengthening the resilience of semiconductor supply chains in Japan.

The maximum government subsidy of ¥129.4bn comprises a third of the plan's total investment of ¥388.3bn, consisting of:
(1) ¥289.2bn invested by ROHM Co Ltd in SiC power devices and SiC wafer production at its subsidiary LAPIS Semiconductor Co Ltd's Miyazaki Plant No.2; plus
(2) ¥99.1bn invested by Toshiba Electronic Devices & Storage Corp in Kaga Toshiba Electronics Corp's silicon power device manufacturing plant.

www.rohm.com
www.toshiba.semicon-storage.com

Toshiba expands range of 3300V SiC MOSFET modules

Japan-based Toshiba Electronic Devices & Storage Corp (TDSC) — which was spun off from Toshiba Corp in 2017 — has expanded its lineup of chopper SiC MOSFET modules by launching the MG800FXF1ZMS3 and MG800FZF1JMS3, which have ratings of 3300V and 800A using third-generation silicon carbide (SiC) MOSFET and Schottky barrier diode SBD chips for industrial equipment.

The new MG800FXF1ZMS3 (with high-side SiC MOSFET; low-side: SiC SBD) and MG800FXF1JMS3 (with high-side SiC SBD; low-side: SiC MOSFET) adopt an iXPLV (intelligent fleXible Package Low Voltage) with Ag sintering internal bonding technology and high compatibility with mounting. These offer low conduction loss with low drain–source on-voltage (sense) of $V_{DS(on)sense}$=1.3V (typical, tested at I_D=800A, V_{GS}=+20V, T_{ch}=25°C). They also offer low turn-on switching loss (E_{on}) and turn-off switching loss (E_{off}) of 230mJ (typical), both tested at V_{DD}=1800V, I_D=800A, T_{ch}=175°C. These contribute to reducing the power loss of equipment and the size of cooling device.

Toshiba's lineup of iXPLV-packaged MOSFET modules now spans three products, including the existing product MG800FXF2YMS3 (3300V/800A/dual-SiC MOSFET module), providing a wide range for product selection. This can be used in 2-level inverters, buck/boost converters and 3-level inverters.

Toshiba says that it continue to meet the market needs for high efficiency and the downsizing of industrial equipment. Applications include inverters and converters for railway vehicles; renewable energy power generation systems; and motor control equipment for industrial equipment, etc.

www.toshiba.semicon-storage.com

Hitachi Power Semiconductor Device being transferred to MinebeaMitsumi

Hitachi subsidiary aims to expand production capacity and boost manufacturing efficiency

Tokyo-based Hitachi Ltd has agreed to transfer all the shares of its subsidiary Hitachi Power Semiconductor Device to MinebeaMitsumi Inc of Nagano, Japan.

Since being formed in October 2013 through the integration of Hitachi and Hitachi Haramachi Electronics Co, Hitachi Power Semiconductor Device has provided products utilizing high-voltage and low-loss power semiconductor technologies, with insulated-gate bipolar transistor (IGBT)/silicon carbide (SiC), high-voltage ICs and diodes as its three main product categories.

The firm's IGBT/SiC products are targeted at decarbonization market sectors where high growth is expected, such as electric vehicles (EVs) and inverters for wind power generators, as well as railroad applications. In high-voltage ICs for industrial and home appliance applications, Hitachi Power Semiconductor Device contributes to system efficiency improvement and noise reduction through motor control technology and software. It also provides diodes for automotive applications, which require high reliability over a long period of time.

After much discussion with parent firm Hitachi on measures to achieve further growth and enhance corporate value, it was concluded that the best way for Hitachi Power Semiconductor Device to continue its growth was as part of MinebeaMitsumi, which positions the analog semiconductor business as one of its core businesses.

Under MinebeaMitsumi, with whom Hitachi Power Devices has been collaborating for many years, Hitachi Power Semiconductor Device aims to enhance its strengths in high-voltage, low-loss technologies, expand its production capacity and improve manufacturing efficiency to provide higher-value-added products in larger quantities.

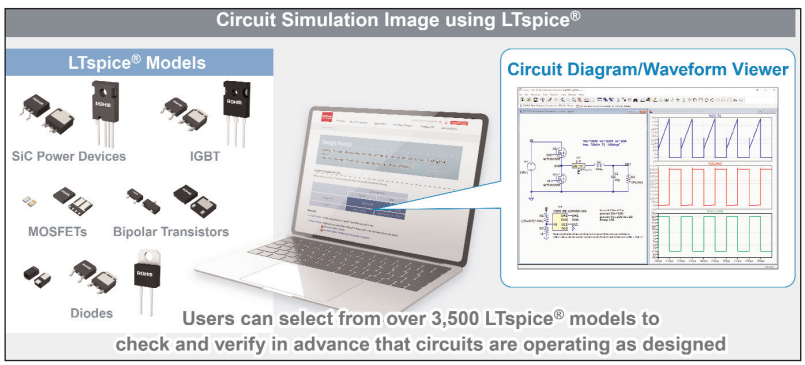
www.hitachi.com
www.minebeamitsumi.com

ROHM expands library of LTspice models to over 3500 by adding SiC and IGBTs

Design convenience improved by incorporating power devices in circuit simulations

Japan's ROHM has expanded its lineup of SPICE models for the LTspice circuit simulator, increasing its number of LTspice models to more than 3500 for discretes (which can be downloaded from product pages).

In addition to the existing lineup of bipolar transistors, diodes and MOSFETs, ROHM has added silicon carbide (SiC) power devices and insulated-gate bipolar transistors (IGBTs) to the library. This brings the coverage of LTspice models on ROHM's website to over 80% of all products, providing greater convenience to designers when using circuit simulators that incorporate discrete products, now including power devices. LTspice is also equipped with circuit diagram capture and waveform viewer functions that make it possible for designers to check and verify in advance whether the circuit operation has been achieved as designed.



In recent years, the increasing use of circuit simulation for circuit design has expanded the number of tools being utilized. Among these, LTspice is an attractive option for a range of users, from students to seasoned engineers at well-known companies.

Besides product pages, ROHM added a Design Models page in October that allows simulation models to be downloaded directly, supporting LTspice and other tool environments. Documentation on how to add libraries and create symbols (schematic symbols) is also available to facilitate circuit design and simulation execution.

Going forward, ROHM will continue to contribute to solving circuit design issues by expanding the number of models compatible with various simulators while providing web tools such as ROHM Solution Simulator to meet growing customer needs.

www.rohm.com/solution-simulator

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Coherent's silicon carbide business completes $1bn in investments from DENSO and Mitsubishi Electric

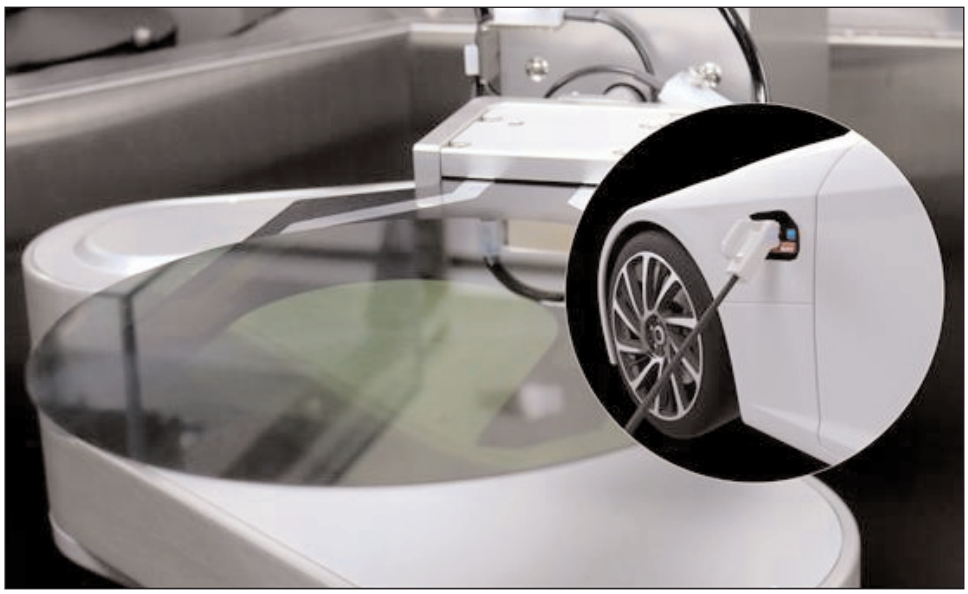
Long-term supply agreements for Coherent to support firms' 150mm and 200mm substrate and epi demand

Materials, networking and laser technology firm Coherent Corp of Saxonburg, PA, USA has closed the $1bn aggregate investment in its silicon carbide (SiC) semiconductor business by automotive supplier DENSO Corp of Kariya, Aichi prefecture, Japan and Tokyo-based Mitsubishi Electric Corp, announced on 10 October.

DENSO and Mitsubishi Electric each invested $500m in exchange for a 12.5% non-controlling ownership stake, with Coherent owning the remaining 75%. Coherent has separated and contributed the business to a new subsidiary that will operate it. Going forward, all operating and capital expenses will be funded by the business. Coherent will control and operate it, which will continue to be led by Sohail Khan, executive VP, Wide-Bandgap Electronics.

In connection with the transaction, the business has entered into arm's-length long-term supply arrangements with DENSO and Mitsubishi Electric that support their demand for 150mm and 200mm silicon carbide substrates and epitaxial wafers.

"We are excited to expand our strategic relationships with DENSO and Mitsubishi Electric to capitalize on the significant demand for silicon carbide," says Coherent's chair & CEO Dr Vincent D. Mattera Jr. "Such a close relationship with two leaders in SiC power devices and modules is the best path forward to maximize shareholder value and position the business for long-term growth. The investments from our strategic partners will be used to accelerate our capacity expansion plans and help sustain our leadership position, while ensuring the development of a robust and scalable supply for the rapidly growing market for SiC-based power electronics, largely driven by the explosive growth of the global electric vehicle market," he adds.



"Through this strategic relationship with Coherent, we will secure a stable procurement of SiC wafers, which are critical for battery electric vehicles, and contribute to the realization of a carbon-neutral society by promoting the widespread adoption of BEVs in all regions around the world," says Shinnosuke Hayashi, president & chief operating officer, representative member of the board at DENSO.

"Going forward, we will further strengthen our collaboration with Coherent, leveraging their capabilities in development and manufacturing of SiC substrates, to achieve solid growth of our SiC power device business and contribute to a more sustainable world through decarbonization," says Dr Masayoshi Takemi, executive officer, group president, Semiconductor & Device, at Mitsubishi Electric.

Strategic rationale

Market estimates indicate that the SiC total addressable market will grow at a compound annual growth rate (CAGR) of 28% from $3bn in 2022 to $21bn in 2030.

The transaction builds on Coherent's more than two decades of expertise in SiC materials. In recent years, the firm has invested to scale its manufacturing of 150mm and 200mm substrates to address this underserved market.

Over the past two years, Coherent has invested in capital and R&D for SiC. The closing of this $1bn combined investment into the business should accelerate the company's capital plans in the coming years. Specifically, the investment will fund the manufacturing expansion of the business and, in combination with the concurrent supply agreements, enhance its position in the market, it is expected.

The transaction enables Coherent to increase its available free cash flow to provide greater financial and operational flexibility to execute its capital allocation priorities, as it expects the aggregate $1bn investment will be used to fund future capital expenditure requirements of the business.

www.MitsubishiElectric.com/semiconductors
www.globaldenso.com
www.Coherent.com

Mitsubishi Electric and Nexperia to co-develop silicon carbide power semiconductors

Mitsubishi Electric to develop and supply SiC MOSFET chips for Nexperia discrete devices

Tokyo-based Mitsubishi Electric Corp and discrete device designer and manufacturer Nexperia B.V. of Nijmegen, The Netherlands (a subsidiary of Wingtech Technology Co Ltd) have entered into a strategic partnership to jointly develop silicon carbide (SiC) power semiconductors for the power electronics market. Mitsubishi Electric will leverage its wide-bandgap semiconductor technologies to develop and supply SiC MOSFET chips that Nexperia will use to develop SiC discrete devices.

The global expansion of the electric vehicle market is helping to drive the exponential growth of SiC power semiconductors, which offer lower energy loss, higher operating temperatures and faster switching speeds than conventional silicon power semiconductors. The high efficiency of SiC power semiconductors is expected to contribute significantly to global decarbonization and green transformation.

Mitsubishi Electric claims that it has established leading positions in applications such as high-speed trains, high-voltage industrial applications and home appliances, after launching the first SiC power modules for air conditioners in 2010 and becoming the first supplier of an all-SiC power module for Shinkansen bullet trains in 2015. Mitsubishi Electric says that it has accumulated expertise in the development and manufacturing of SiC power modules, which are known for their advanced performance and high reliability.

Going forward, Mitsubishi Electric expects to strengthen its partnership with Nexperia, whose devices are used in the automotive, industrial, mobile and consumer markets, contributing to decarbonization and sustainability. Mitsubishi Electric aims to continue to improve the performance and quality of its SiC chips and focus on the development of power modules using proprietary module technologies.

"This mutually beneficial strategic partnership with Mitsubishi Electric represents a significant stride in Nexperia's silicon carbide journey," believes Mark Roeloffzen, senior VP & general manager of Nexperia's Bipolar Discretes business group. "Mitsubishi Electric has a strong track record as a supplier of technically proven SiC device and modules. Combined with Nexperia's high quality standards and expertise in discrete products and packaging, we will certainly generate positive synergies between both companies — ultimately enabling our customers to deliver highly energy-efficient products in the industrial, automotive or consumer markets they serve," he adds.

"Nexperia is a leading company in the industrial sector with proven technologies for high-quality discrete semiconductors," comments Masayoshi Takemi, executive officer & group president, Semiconductor & Device at Mitsubishi Electric. "We are delighted to enter into this co-development partnership that will leverage the semiconductor technologies of both companies."

www.nexperia.com
www.mitsubishielectric.com/semiconductors/powerdevices

Nexperia launches discrete 1200V devices as its first silicon carbide MOSFETs

First products of Nexperia–Mitsubishi Electric partnership on silicon carbide power semiconductors

Discrete device designer and maker Nexperia B.V. of Nijmegen, The Netherlands (a subsidiary of Wingtech Technology Co Ltd) has announced its first silicon carbide (SiC) MOSFETs with the release of two 1200V discrete devices in 3-pin TO-247 packaging with $R_{DS(on)}$ values of 40mΩ and 80mΩ. The NSF040120L3A0 and NSF080120L3A0 are the first in a series of planned launches that will see Nexperia's SiC MOSFET portfolio quickly expand to include devices with a variety of $R_{DS(on)}$ values in a choice of through-hole and surface-mounted packages. This release addresses the market demand for the increased availability of high-performance SiC MOSFETs in industrial applications including electric vehicle (EV) charging piles, uninterruptible power supplies (UPS) and inverters for solar and energy storage systems (ESS).

"With these inaugural products, Nexperia and Mitsubishi Electric wanted to bring true innovation to a market that has been crying out for more wide-bandgap device suppliers," says Katrin Feurle, senior director & head of Product Group SiC at Nexperia. "Nexperia can now offer SiC MOSFET devices which offer best-in-class performance across several parameters, including high $R_{DS(on)}$ temperature stability, low body diode voltage drop, tight threshold voltage specification as well as a very well-balanced gate charge ratio making the device safe against parasitic turn-on. This is the opening chapter in our commitment to producing the highest-quality SiC MOSFETs in our partnership with Mitsubishi Electric," he adds.

"Together with Nexperia, we're thrilled to introduce these new SiC MOSFETs as the first product of our partnership," comments Toru

Iwagami, senior general manager, Power Device Works, Semiconductor & Device Group at Mitsubishi Electric. "Mitsubishi Electric has accumulated superior expertise of SiC power semiconductors, and our devices deliver a unique balance of characteristics," he claims.

For SiC MOSFETs, $R_{DS(on)}$ impacts conduction power losses. Nexperia says that it identified this as a limiting factor in the performance of many currently available SiC devices and used its process technology to ensure that its new SiC MOSFETs offer industry-leading temperature stability, with the nominal value of $R_{DS(on)}$ increasing by only 38% over an operating temperature range from 25°C to 175°C, unlike other many currently available SiC devices on the market, Nexperia claims.

The firm says that its SiC MOSFETs also exhibit very low total gate charge (Q_G), which brings the advantage of lower gate drive losses. Furthermore, Nexperia balanced gate charge to have a low ratio of Q_{GD} to Q_{GS}, which increases device immunity against parasitic turn-on.

Together with the positive temperature coefficient of SiC MOSFETs, Nexperia says that its SiC MOSFETs also offer ultra-low spread in device-to device threshold voltage, $V_{GS(th)}$, which allows very well-balanced current-carrying performance under static and dynamic conditions when devices are operated in parallel. Furthermore, low body diode forward voltage (V_{SD}) is a parameter that increases device robustness and efficiency while also relaxing the dead-time requirement for asynchronous rectification and free wheel operation.

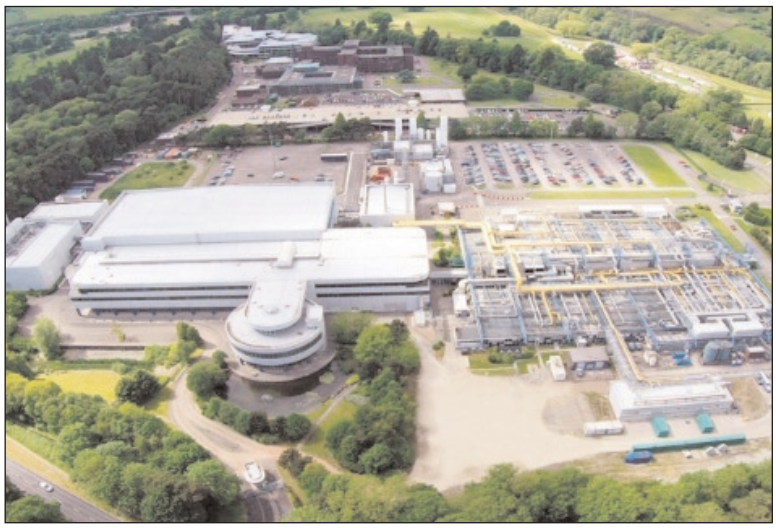
The NSF040120L3A0 and NSF080120L3A0 are available in production quantities now. Nexperia is also planning the future release of automotive-grade MOSFETs.

www.nexperia.com/sic-mosfets
www.mitsubishielectric.com/semiconductors/powerdevices

Vishay to buy Nexperia's Newport Wafer Fab for $177m

Added capacity to accelerate Vishay's SiC production plans

Discrete semiconductor and passive electronic component maker Vishay Intertechnology Inc of Malvern, PA, USA has agreed to acquire Newport Wafer Fab in South Wales, UK from Nexperia B.V. of Nijmegen, The Netherlands (a subsidiary of Wingtech Technology Co Ltd) for $177m in cash. ATREG Inc, the Seattle-based global firm for initiating, brokering and executing the exchange of semiconductor manufacturing assets, served as Nexperia's transaction advisors.



Located on 28 acres and the largest semiconductor manufacturing plant in the UK, Newport is an automotive-certified, 200mm wafer fab that supplies primarily automotive markets.

"Under new leadership in early 2023, Vishay set an ambitious goal of investing approximately $1.2bn in capacity over a three-year period in order to position the company to seize the opportunities created by the megatrends of e-mobility and sustainability needed for a Net Zero economy," says president & CEO Joel Smejkal. "While this transaction is supplemental to our capex investment strategy, adding Newport Wafer Fab to our manufacturing footprint will be instrumental to achieving our goal of expanding capacity for our customers and to accelerating our SiC [silicon carbide] strategy," he adds.

"By agreeing to acquire Newport Wafer Fab, our goal is to safeguard the positions of the highly skilled and dedicated employees and to invest the necessary capital to set up production for our SiC trench MOSFETs and diodes. With its solid balance sheet and ample liquidity, Vishay will immediately bring stability and its reliable cash flow generation to ensure the facility becomes a fully operational and profitable fab" reckons Smejkal.

"For Vishay, acquiring Newport Wafer Fab brings together our capacity expansion plans for our customers in automotive and industrial end markets as well as the UK's strategic goal of improved supply chain resilience. In addition to expanding capacity, we intend to collaborate with the Compound Semiconductor Cluster in South Wales and to join with key stakeholders committed to developing the semiconductor industry in the UK including university and community partners in the UK and particularly South Wales," concludes Smejkal. "We look forward to welcoming Newport Wafer Fab's employees into Vishay and to partnering with local authorities and the Welsh and UK Governments to both ensure long-term growth for the fab and deliver value to our customers and stockholders."

"Vishay's board made a critical decision last year to pivot the company toward profitable growth under new leadership, leveraging the company's solid cash flow generation, sound operational capabilities and broad product portfolio," notes executive chairman Marc Zandman. "A key element of this strategic shift is the investment in technologies and incremental capacity to position Vishay to capitalize on the megatrends in e-mobility and sustainability. Acquiring Newport Wafer Fab demonstrates Vishay's commitment to executing this strategic shift," he adds.

"Nexperia would have preferred to continue the long-term strategy it implemented when it acquired the investment-starved fab in 2021 and provided for massive investments in equipment and personnel," says Toni Versluijs, country manager Nexperia UK. "However, these investment plans have been cut short by the unexpected and wrongful divestment order made by the UK Government in November 2022. The UK Government's order, in combination with a weakness in the global semiconductor market, recently led us to announce the intention to reduce the number of employees at the site by at least 100. The site needs clarity about its future to avoid further losses," he adds. "Of all options, this agreement with Vishay is the most viable one to secure the future of the site as Vishay — like Nexperia — has a solid customer base for the fab's capabilities. For the site, Vishay's commitment to further make the Newport Wafer Fab a success story is encouraging. Nexperia's position with regards to the UK Government's order remains unchanged."

The closing of the Newport Wafer Fab transaction is subject to UK government review, the purchase rights of a third party, and customary closing conditions, and is expected to occur in first-quarter 2024.

Nexperia states that, while working to ensure that all conditions to the sale are met as soon as possible, it will continue to own and manage the site and support the employees.

www.vishay.com
www.nexperia.com

Infineon adds 62mm package to CoolSiC 1200V and 2000V MOSFET module families

Efficiency and power density allow mid-power applications from 250kW

Infineon Technologies AG of Munich, Germany has expanded its CoolSiC 1200V and 2000V MOSFET module families with a new industry-standard package. The proven 62mm device is designed in half-bridge topology and is based on the recently introduced M1H silicon carbide (SiC) MOSFET technology. The package enables the use of SiC for mid-power applications from 250kW — where silicon reaches the limits of power density with insulated-gate bipolar transistor (IGBT) technology. Compared to a 62mm IGBT module, the list of applications now additionally includes solar, server, energy storage, electric vehicle (EV) charger, traction, commercial induction cooking and power conversion systems.

The M1H technology enables a significantly wider gate voltage window, ensuring high robustness to driver and layout-induced voltage spikes at the gate without any restrictions even at high switching frequencies. In addition to that, very low switching and transmission losses minimize cooling requirements. Combined with a high reverse voltage, these devices meet another requirement of modern system design. By using Infineon's CoolSiC chip technology, converter designs can be made more efficient, the nominal power per inverter can be increased and system costs can be reduced, says Infineon.

With baseplate and screw connections, the package features a very rugged mechanical design optimized for highest system availability, minimum service costs and downtime losses. Reliability is achieved through high thermal cycling capability and a continuous operating temperature (T_{vjop}) of 150°C. The symmetrical internal package design provides identical switching conditions for the upper and lower switches. Optionally, the thermal performance of the module can be further enhanced with pre-applied thermal interface material (TIM).

The CoolSiC 62mm package MOSFETs are available in 1200V variants of 5mΩ/180A, 2mΩ/420A and 1mΩ/560A. The 2000V portfolio will include the 4mΩ/300A and 3mΩ/400A variants. The portfolio will be completed in first-quarter 2024 with the 1200V/3mΩ and 2000V/5mΩ variants.

An evaluation board is available for rapid characterization of the modules (double pulse/continuous operation). For ease of use, it provides flexible adjustment of the gate voltage and gate resistors. At the same time, it can be used as a reference design for driver boards for volume production.

www.infineon.com/coolsic

Purdue wins SiC patent lawsuit against ST

On 4 December, a patent lawsuit jury returned a verdict finding that STMicroelectronics infringed US patent 7,498,633 — which covers technology invented by Purdue University's James Cooper and his graduate student/postdoctoral researcher Asmita Saha — by selling infringing silicon carbide semiconductors. The jury awarded Purdue $32.5m in past compensatory damages, plus a running royalty on future sales.

"As the university's tech transfer and commercialization arm, we take managing and protecting Purdue intellectual property very seriously, and we hold ourselves and others accountable to the highest standards," says Brian Edelman, president of Purdue Research Foundation (PRF). "Our preference is to reach a licensing agreement, but we have a moral obligation to protect Purdue IP, and that includes going to court to defend our rights," he adds.

"Purdue University is a top-four patent-generating university in America. As a public land-grant institution, we support inventors and entrepreneurs to translate research to societal impact," notes Purdue's president Mung Chiang. "Through programs such as Purdue Innovates, we mentor students and faculty, foster a culture of discovery, license their world-changing technologies to market and protect their intellectual property rights as needed," he adds.

As a land-grant university, Purdue has the fiduciary and moral responsibility to protect inventions made by students and faculty. Purdue Research Foundation manages the Purdue Innovates Office of Technology Commercialization (OTC), which operates the technology transfer process. OTC vets invention disclosures from university personnel, applies for patents and other intellectual property protections, and licenses innovations to established and startup companies worldwide. In 2022, PRF secured 192 patents from the US Patent and Trademark Office, placing Purdue fourth among all US universities.

Under the Bayh-Dole Act, contractors of inventions arising from federal government-funded research, such as US universities, own, patent and commercialize inventions through licensing. At Purdue, revenues from licensing are distributed among the inventors, their affiliated departments and the Purdue Research Foundation, which reinvests back into the commercialization and innovation ecosystem.

www.prf.org/otc

European research project PROGRESSUS boosts power grid resilience

Infineon-led project integrated ultra-fast sensors and SiC MOSFETs into power converters

At the conclusion of the PROGRESSUS research project (which began on 1 April 2020, led by Infineon Technologies AG of Munich, Germany), the 22 project partners from industry and research presented the results at a meeting in Bari, Italy. Among other things, a solution was introduced that would make it possible to operate 10–15 times more electric car charging stations on a single network connection. In addition, a strategy for tracking electricity from generation all the way to consumption was presented. PROGRESSUS focused on three central topics: efficient energy conversion, intelligent electricity management and secure network monitoring.

The Electronic Components and Systems for European Leadership Joint Undertaking (ECSEL-JU) and the governments of Germany, Italy, the Netherlands, Slovakia and Spain supported PROGRESSUS with almost €20m.

"Decarbonization and electrification go hand in hand. Our power grids will have to perform better and become more stable if they are to handle the growing power volumes and fluctuations in the supply and demand of electricity. This means we need new solutions," says Thomas Zollver, senior VP technology & innovation of the Infineon Connected Secure Systems division. "PROGRESSUS has succeeded in developing a significant number of technologies that can make our existing networks more resilient," he adds. "The project is thus making an important contribution to freeing our modern lives from fossil energy sources and protecting our climate for future generations."

The project developed highly efficient electric power converters that minimize loss while integrating

battery storage systems and renewable energy sources such as photovoltaics: The converters integrate ultra-fast sensors and silicon carbide (SiC) MOSFETs, which can be switched at considerably higher speeds. This makes them suitable for use in new, innovative charge management systems for battery-electric vehicles that reduce the peak power consumption at the site level by as much as 90%, without significantly longer charging times. As an alternative the intelligent charging algorithm can support 10–15 times more charging stations on the same network connection.

Hardware-based security solutions provide the best possible protection of the communications and data in the power network's critical infrastructure against manipulation. These solutions also serve as a basis for tracking the energy provided from the point of generation all the way to its consumption. This makes it possible for consumers to prove that they are using green electricity.

Joint energy management of multiple buildings can also help to relieve power networks. PROGRESSUS project partners have simulated this kind of energy management system based on real data from 16 buildings with photovoltaic systems and energy storage systems. The result: This kind of joint energy management could reduce electricity peak demands present in the public network by an average up to 80%, without a negative impact on customers' needs. This value for the case investigated depends on the season, weather conditions and the configuration of the PV and storage systems.

The 22 partners of the PROGRESSUS research project are:

- Ceus UG (DE)
- Centre Tecnològic de Telecomunicacions de Catalunya (ES)
- devolo AG (DE)
- ElaadNL (NL)
- Enel X Way S.r.l. (IT)
- Friedrich-Alexander-Universität Erlangen-Nürnberg (DE)
- Greenflux Assets BV (NL)
- Heliox (NL)
- Hybrid Energy Storage Solutions S.L. (ES)
- Infineon Technologies AG (DE)
- Iquadrat Informatica S.L. (ES)
- Consorzio Nazionale Interuniversitario per la Nanoelettronica (IT)
- Acondicionamiento Tarrasense (LEITAT) (ES)
- Mixed Mode GmbH (new company name: Ingenics Digital GmbH) (DE)
- Politecnico di Bari (IT)
- R-DAS, s.r.o. (SK)
- STMicroelectronics S.r.l. (IT)
- Slovak University of Technology in Bratislava (SK)
- TH Köln (DE)
- Delft University of Technology (NL)
- Eindhoven University of Technology (NL)
- University of Messina (IT)

https://progressus.automotive.oth-aw.de
www.infineon.com/coolsic

A*STAR and centrotherm partner on 200mm SiC

centrotherm's thermal processes tools to aid IME's process integration and device characterization

A partnership has been announced that combines the 200mm open R&D silicon carbide (SiC) pilot line of the Institute of Microelectronics (IME) at Singapore's Agency for Science, Technology and Research (A*STAR) with the diffusion and annealing tools of centrotherm International AG of Blaubeuren, Germany.

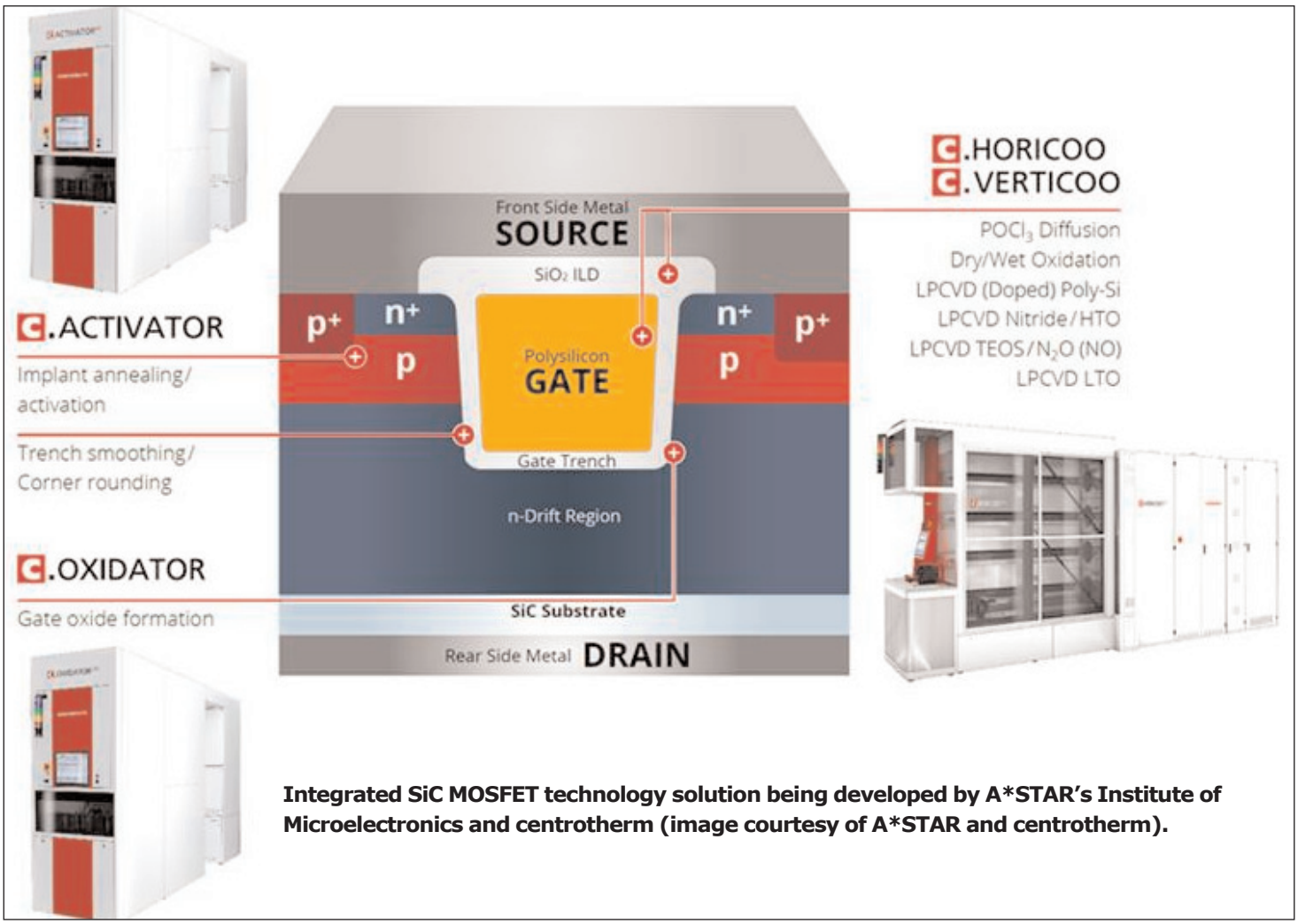
Compared with traditional silicon-based semiconductors, the greater energy efficiency and higher switching frequencies of SiC-based semiconductors enable smaller power electronics modules to be built. SiC-based power modules can be found in a wide range of power applications, such as electric vehicles (EVs), electric trains, data centers and power grids. However, SiC substrates currently have a large number of defects that need to be skilfully managed.

The collaboration aims to leverage IME's process integration and device characterization capabilities and centrotherm's specialized tools to develop thermal processes for SiC-based device fabrication, such as optimizing trench and gate oxide formation, so as to enhance the performance and reliability of SiC-based devices, such as MOSFETs and diodes. As part of the partnership, centrotherm will establish a dedicated technology team in Singapore to offer technological know-how, process recipes, and on-site support.

"Through the combination of IME's 200mm SiC R&D pilot line with centrotherm's advanced tools, we can accelerate R&D to better address the industry's needs," says Terence Gan, executive director of A*STAR's IME.

"The shared vision, expertise and resources of both organizations promise to drive innovation, elevate industry standards and foster local growth in the field of semiconductor manufacturing," says centrotherm's chief technology officer Helge Haverkamp. "As we move towards the future of SiC and power electronics, we plan to further enhance diffusion and annealing specialization in wide-bandgap process modules and expand expertise into SiC, GaN and other innovative wide-bandgap materials."

www.a-star.edu.sg/ime/Research/power-electronics
www.centrotherm.de



Integrated SiC MOSFET technology solution being developed by A*STAR's Institute of Microelectronics and centrotherm (image courtesy of A*STAR and centrotherm).

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Wolfspeed reports quarterly revenue, gross margin and EPS at high-end of guidance ranges

Mohawk Valley Fab on track for 20% utilization in June 2024 quarter

For its fiscal first-quarter 2024 (to end-September 2023), Wolfspeed Inc of Durham, NC, USA — which makes silicon carbide materials as well as silicon carbide (SiC) and gallium nitride (GaN) power-switching & RF semiconductor devices — has reported revenue from continuing operations of $197.4m, down 16.3% on $235.8m last quarter but up 4.2% on $189.4m a year ago.

This was above the midpoint of the updated guidance range of $185–205m, which was reduced from $220–240m after the announcement on 22 August that radio frequency business Wolfspeed RF is being sold to MACOM Technology Solutions Holdings Inc of Lowell, MA, USA for about $75m in cash (subject to a customary purchase price adjustment) plus 711,528 shares of MACOM common stock (valued at $50m based on its 30 trading day trailing average closing price through 21 August). "When the sale is finalized, we will have completed the path towards portfolio optimization that we've been on since 2018, when we were predominantly a lighting company," notes chief financial officer Neill Reynolds. "Wolfspeed is now the world's only pure-play vertically integrated silicon carbide company, and we can focus all our collective efforts on the silicon carbide materials and power device businesses."

Power Products revenue was $101.2m, down 3.2% on $104.5m a year ago. Of this, the new Mohawk Valley Fab contributed $4m in revenue, up from $1m last quarter. "Power device revenue was impacted by slower industrial and energy demand, primarily in China and the broader Asian market," says Reynolds (adding that China represents about 20% of total company revenue, primarily in the industrial and energy space). This was partially offset by the revenue ramp from the Mohawk Valley Fab.

In contrast, Materials Product revenue was $96.2m, up 13.3% on $84.9m a year ago. "Materials 150mm substrate revenue achieved a record quarter, above our expectations, driven by continued strong demand and record manufacturing performance by our Durham materials operations team," says Reynolds.

On a non-GAAP basis, gross margin has fallen further, from 38.8% a year ago to 15.6%. However, this includes an impact of 1740 basis points (17.4%) from $34.4m of under-utilization costs, since the Mohawk Valley Fab began revenue-generating production at the end of fiscal 2023 and operating it is now reflected in cost of revenue rather than factory start-up costs. It is also towards the high end of the 10–18% guidance range, due largely to improved materials manufacturing performance resulting in better-than-expected 150mm materials costs and yields, as well as the Mohawk Valley Fab under-utilization costs being better than the expected $37m. Also, this is before excluding about 200 basis points of impact from under-utilization in the RF business.

Operating expenses have been cut from $131.2m a year ago to $119.6m in fiscal Q1/2024. This included $8.4m of factory start-up costs from the materials expansion efforts, primarily related to the JP materials facility (John Palmour Manufacturing Center for Silicon Carbide) that is being built in Siler City, North Carolina.

Adjusted net loss from continuing operations has risen from $30.1m ($0.24 per diluted share) a year ago to $66.6m ($0.53 per diluted share). However, this is significantly better than the guidance range of $75–94m ($0.60–0.75 per diluted share) due to the higher-than-expected revenue and gross margin as well as lower operating expenses.

Operating cash flow was –$112.7m in net cash used in operating activities. Capital expenditure (CapEx) remained high, at $404m (up from $66m a year ago). Free cash flow was hence –$517m.

During the quarter, cash, cash equivalents and short-term investments rose from $2955m to $3348m. "In the last year, we have raised approximately $5bn of low-dilution capital across a number of vectors, including customers, governments, private financing and capital markets," notes Reynolds. "In conjunction with federal funding, we are in good position to execute our capacity expansion plans, but we will remain nimble to optimize our capital structure for the long-term."

"We kicked off our fiscal year with a strong quarter in both execution and market share," says president & CEO Gregg Lowe.

Wolfspeed secured its third highest quarterly total of device design-ins at $2.2bn. It also converted a record $1.4bn of device design-wins (more than 230 projects, many of which are converting sooner than expected), "illustrating our customers' willingness to move into volume production and projects that we've won over the past few years," Lowe adds.

"Our design-in to design-win conversion rate is ahead of our original expectations," notes Reynolds. "Based on the design-ins we've already secured, we have the next few years of expected revenue covered by our existing book of business."

"We have clear focus on the ramp of our Mohawk Valley Fab," says Lowe. "At Mohawk Valley, we have an outstanding operations team in place, Building 10 on our Durham campus is producing enough

200mm wafers ahead of the needs of Mohawk Valley, and we already have enough qualified product to satisfy our 20% utilization goals," he adds.

In 2018, the silicon carbide device market was estimated to be about $400m. Five years later the market size is $6bn. "This further validates our strategy to invest now to capitalize on the immense opportunities at hand, and the significant opportunity in the future," Lowe continues. "We have amassed significant materials expertise over the decades which, combined with the capacity of our new materials factory in Siler City, will increase our wafer production by 10x when fully operational, and creates significant competitive advantages over our peers and new entrants. We will be better positioned to support our customers' needs going forward and cater to a whole host of new applications for silicon carbide technology. As the only pure-play silicon carbide company in the market today, we believe that we are best positioned to capitalize on a decades-long tailwind that represents a $20bn addressable market by 2030."

"This is part of the reason we announced and are now in the process of completing the sale of our RF business to MACOM, which we expect to close by the end of the calendar year," says Lowe. "The growth of Wolfspeed will come from our leadership in silicon carbide and power devices and this marks a definitive milestone in allocating all of our investments, R&D and technology into these business areas," he adds.

Durham's Building 10 200mm crystal growth ramp-up to enable 20% utilization at Mohawk Valley Fab

For fiscal second-quarter 2024 (to end-December 2023), Wolfspeed targets revenue from continuing operations of $192–222m, driven largely by revenue from the Mohawk Valley Fab more than doubling to about $10–15m. This will be partially offset by continued softer demand for industrial and energy products, primarily in the China and broader Asia markets. "However, we will look to purpose the supply to where end-demand remains strong," says Reynolds. "Demand remained strong across the business outside of the industrial and energy markets, particularly in China and Asia."

Gross margin is expected to be 12–20%. At the 16% midpoint, this includes about $35m or –1700 basis points of under-utilization costs as the Mohawk Valley Fab is ramped up.

"We are ahead of plan in our ramp of Building 10 crystal growth for 200mm substrates. By the end of this quarter, we will be producing enough material to support 15% utilization at Mohawk Valley, putting us nicely on track for our goal of 20% utilization by the June quarter of 2024," says Lowe.

Targeted operating expenses for fiscal Q2/2024 are about $109m, including $11m of factory start-up costs, primarily related to the JP materials facility in Siler City (which is expected to be producing material in fiscal first-half 2025, for which more than 100 new staff are already being trained).

Net loss from continuing operations is targeted to be $71–88m ($0.56–0.70 per diluted share).

"At Mohawk Valley, we remain on pace for the larger step-up in revenue [doubling again] as we transition into fiscal Q3/2024," says Reynolds.

"We've now doubled the number of products qualified in the last 90 days, and all of those MOSFETs achieved qualifications on the first pass through the fab, which is a strong indication of the underlying capability of the fab," says Lowe. "Those products we have already qualified have sufficient demand to more than satisfy our short-term 20% utilization target," he adds. "There will be a lag between 20% utilization and $100m of quarterly revenue [at the end of the quarter to end-December 2024] due to the time between fab starts and shipments to our customers," Lowe cautions.

www.wolfspeed.com

Wolfspeed completes sale of RF business to MACOM for $75m cash plus $60.8m in stock

Former Cree now the only pure-play vertically integrated silicon carbide company

Wolfspeed Inc of Durham, NC, USA — which makes silicon carbide materials as well as silicon carbide (SiC) and gallium nitride (GaN) power-switching & RF semiconductor devices — has completed the sale of its radio frequency business (Wolfspeed RF) to MACOM Technology Solutions Holdings Inc of Lowell, MA, USA (which designs and makes RF, microwave, analog and mixed-signal and optical semiconductor technologies). Wolfspeed received about $75m in cash (subject to a customary purchase price adjustment) and 711,528 shares of MACOM common stock, worth about $60.8m (based on its closing price on 1 December, as reported on the Nasdaq Global Select Market).

"The completed sale of Wolfspeed RF is the final step in our transformation," says president & CEO Gregg Lowe. "Wolfspeed is now the only pure-play silicon carbide semiconductor manufacturer in the industry," he adds. "As demand continues to accelerate across the automotive, industrial and renewable energy markets, we can now focus on innovation and capacity for our materials and power device businesses."

As demand continues to accelerate across the automotive, industrial and renewable energy markets, we can now focus on innovation and capacity for our materials and power device businesses

Wolfspeed says that it continues to drive the industry transition to silicon carbide with its ongoing capacity expansion, including the final build-out of its Mohawk Valley Fab in New York, and construction of the John Palmour Manufacturing Center (the JP, the world's largest silicon carbide materials factory) in Siler City, North Carolina. The multi-billion-dollar facility is targeted to generate a more than 10-fold increase from Wolfspeed's current silicon carbide production capacity on its campus in Durham, NC.

MACOM reckons that the RF business is highly complementary to its portfolio. "Going forward, we are committed to supporting all product and foundry customers and building upon the RF business' established technology to strengthen our leadership position," says MACOM's president, CEO & chair Stephen G. Daly.

MACOM announces passing of chairman John Ocampo

Co-founder of both technology investment company GaAs Labs andpreviously Sirenza Microdevices

MACOM Technology Solutions Inc of Lowell, MA, USA (which designs and makes analog RF, microwave, millimeter-wave and photonic semiconductors, components and subassemblies) has announced the passing of John Ocampo, chairman of its board of directors.

As co-founder & president of technology investment company GaAs Labs LLC since February 2008, Ocampo served as a director and chairman of MACOM since its inception in March 2009. Prior to creating GaAs Labs, he co-founded Sirenza Microdevices Inc, a Nasdaq-listed supplier of RF semiconductors and components for the communications, aerospace and defense markets. While leading Sirenza through an IPO and eventual sale to RF Micro Devices Inc, he served in key roles, including as Sirenza's president & CEO, chief technology officer and chairman.

John Ocampo.

"John was a man of integrity, curiosity, intellect, compassion and generosity," comments MACOM's president & CEO Stephen G. Daly. "He was a mentor and friend, and we all learned many invaluable lessons from him over the years," he adds. "John's passing will be profoundly felt across MACOM and the many people and lives he impacted. On behalf of the board and all MACOM employees, I would like to extend our deepest condolences to Susan Ocampo and their family and friends during this difficult time."

www.macom.com

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First US CHIPS and Science Act funding to modernize BAE Systems' Microelectronics Center

Upgrades to increase on-shore technology development to benefit national defense

The US Department of Commerce has announced about $35m in initial funding for BAE Systems — which develops and services electric propulsion technology at its facilities in Endicott, NY, USA and Rochester, UK — to modernize its Microelectronics Center (MEC) in Nashua, New Hampshire. This is the first funding announcement as part of the CHIPS and Science Act, which was designed to strengthen the USA's manufacturing, supply chains and national security. Modernizing BAE Systems' microelectronics center helps to support this vision and the continued development and manufacturing of cutting-edge technology to serve customers' missions.

BAE Systems' MEC is a 110,000ft^2 Department of Defense (DoD)-accredited chip fabrication and foundry facility that produces technology for DoD applications, developing semiconductor technologies beyond those available commercially to meet demanding military requirements. It is one of few domestic defense-centric 6-inch gallium arsenide (GaAs) and gallium nitride (GaN) high-electron-mobility transistor (HEMT) wafer foundries.

"Microelectronics are at the heart of the technology and products we make for our defense and aerospace customers — from next-generation aircraft and satellites to military-grade GPS and secure communications," says BAE Systems Inc's president & CEO Tom Arseneault. "This funding will help modernize our Microelectronics Center and fulfill the promise of the CHIPS and Science Act by increasing our capacity to serve national defense programs, growing our technical workforce, and helping to strengthen the nation's onshore supply chain. This initiative is the result of a strong partnership with federal, state and local government," he adds.

"The CHIPS for America Program is about advancing our national security and strengthening domestic supply chains, all while creating good jobs supporting long-term US economic growth. As national security becomes as much about the chips inside of our weapons systems as the weapons systems themselves, this first CHIPS announcement shows how central semiconductors are to our national defense," says US Secretary of Commerce Gina Raimondo. "Thanks to President Biden's Investing in America Agenda, we have reached preliminary terms to make a substantial investment in New Hampshire's expanding defense industrial base, which will help make our country and supply chains more secure and bolster the economy of the Granite State," she adds.

Local and state commitments contributed to the funding application. As a result, both the state of New Hampshire and the City of Nashua are offering workforce incentives through Nashua Community College (NCC). The state of New Hampshire will provide tuition assistance for NCC's microelectronics bootcamp and the Nashua City Council is providing funds to establish a new cleanroom training course at NCC.

The new funding will "ensure our military continues to have access to American-made semiconductor technology," says US Senator Jeanne Shaheen, chair of the US Senate Appropriations Subcommittee that funds the Department of Commerce. "These modernization efforts will strengthen New Hampshire's integral role in the nation's defense manufacturing industry for years to come," she adds.

The approximately $35m in funding will be coupled with ongoing investment in modernization and R&D by BAE Systems. The funding will help to purchase new, more efficient manufacturing tools to mitigate supply chain risk, increase production capacity, and reduce time-to-build product. The increased efficiency will enable a scale-up in production to meet increasing demand for DoD technology and provide critical microelectronics to non-defense industries including satellite communications, and test & measurement equipment markets.

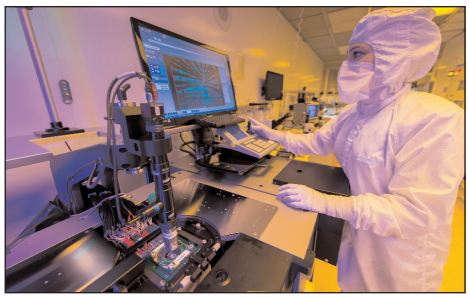
www.baesystems.com

Raytheon wins $15m four-year DARPA THREADS contract to boost RF sensors

Partnering with NRL, Stanford and Diamond Foundry on higher-output GaN transistors

US-based Raytheon, a business of aerospace & defense company RTX, has been awarded a four-year, $15m contract from the US Defense Advanced Research Projects Agency (DARPA) to increase the electronic capability of radio frequency sensors with high-power-density gallium nitride transistors. The improved transistors will have 16 times higher output power than traditional GaN with no increase in operating temperature.

Raytheon claims to be the world's leading manufacturer of military-grade gallium nitride which, when used in radar systems, improves range and radar resource management handling. This new prototyping work is being performed under DARPA's program THREADS (Technologies for Heat Removal in Electronics at the Device Scale).



Raytheon's improved high-power-density GaN transistors will have 16 times higher output than traditional GaN with no increase in operating temperature.

"Our engineers have unlocked a new way to produce gallium nitride, where thermal management is no longer a limiting factor," says Colin Whelan, president of Advanced Technology at Raytheon. "These new system architectures will result in sensors with enhanced range."

Raytheon is partnering with the US Naval Research Laboratory, Stanford University and Diamond Foundry to grow diamond, the best thermal conductor, for integration with military-grade GaN transistors and circuits. Cornell University, Michigan State University, the University of Maryland and Penn State University are also providing technology and performance analysis.

For nearly 25 years, Raytheon has invested in gallium nitride R&D, using it in defense systems like the Patriot, LTAMDS/GhostEye family of radars, APG-79(v)4 and SPY-6 family of radars.

Work on this contract is being conducted in Andover, Massachusetts.

www.raytheon.com/capabilities/products/antpy2
www.rtx.com/raytheon/what-we-do/sea/sm-6-missile

BAE Systems awarded $5m ONR contract for COALESCE program

FAST Labs to develop custom GaN MMICs and modules for radar, electronic warfare and communication applications

BAE Systems — which develops and services electric propulsion technology at its facilities in Endicott, NY, USA and Rochester, UK — says that its FAST Labs research and development organization has been awarded a $5m contract by the US Office of Naval Research (ONR) for the program COALESCE (Common-architecture Amplifier for Low-cost, Efficient, SWaP-Constrained Environments), whose objective is to develop the world's highest-efficiency high-power amplifier module in its frequency band.

FAST Labs will develop gallium nitride (GaN)-based monolithic microwave integrated circuit (MMIC) and module electronics. The RF modules will then transition to small-form-factor US Navy payloads, enabling longer range and greater effectiveness in active electronic warfare applications.

"The COALESCE program closes the gap between commercial electronics and customized electronics to meet the Department of Defense's space and power requirements and enable next-generation solutions," says Ben McMahon, technology development manager at BAE Systems' FAST Labs. "Together with the Office of Naval Research, we will deliver these electronic solutions to increase survivability for our warfighters."

BAE Systems will provide capabilities above and beyond what can be found commercially, and its solution is designed specifically for harsh DoD operating environments. The technology's high power and ultra-small form factor will enable next-generation radar, electronic warfare (EW), and communication applications.

MMICs and modules for the program will be fabricated at BAE Systems' Microelectronics Center Foundry in Nashua, New Hampshire. The FAST Labs organization in Merrimack, New Hampshire will work to ensure the technology is relevant across multiple DoD branches, applications, and businesses.

www.baesystems.com

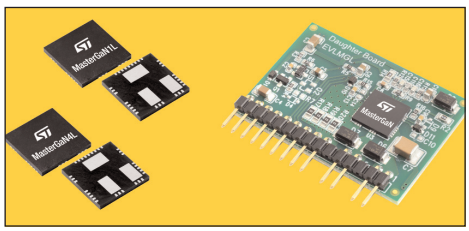
ST extends MasterGaN performance with new 200W and 500W devices

MasterGaN1L and MasterGaN4L HEMTs pin compatible with MasterGaN1 and MasterGaN4

STMicroelectronics of Geneva, Switzerland says that its new MasterGaN1L and MasterGaN4L introduce the next generation of integrated gallium nitride (GaN) bridge devices that simplify power supply design leveraging wide-bandgap technology to achieve the latest eco-design targets.

ST's MasterGaN family combines 650V GaN high-electron-mobility transistors (HEMTs) with optimized gate drivers, system protection and an integrated bootstrap diode that helps to power the device at startup. Integrating these features saves designers tackling the complex gate-drive requirements of GaN transistors. Housed in a compact power package, the devices are also said to enhance reliability, cut the bill of materials, and ease circuit layout.

The latest devices contain two GaN HEMTs connected in half-bridge configuration. The arrangement is suitable for building switched-mode power supplies, adapters, and chargers with active-clamp flyback, active-clamp forward and



resonant converter topologies. The MasterGaN1L and MasterGaN4L are pin compatible with MasterGaN1 and MasterGaN4, respectively. Compared with the earlier devices, they have a newly optimized turn-on delay that allows working at higher frequency and higher efficiency with low load, especially in resonant topologies.

The inputs accept signal voltages from 3.3V to 15V, with hysteresis and pull-down that facilitate connecting directly to a controlling device such as a micro-controller, digital signal processor (DSP) or Hall-effect sensors. A dedicated shutdown pin helps designers to save system power and the two GaN HEMTs have accurately matched timing with an interlocking circuit to prevent cross-conduction conditions.

The MasterGaN1L HEMTs have 150mΩ $R_{DS(on)}$ and 10A-rated current, for use in applications up to 500W. Consuming just 20mW no-load power, and enabling high conversion efficiency, they enable designers to meet stringent industry targets for standby power and average efficiency. The MasterGaN4L HEMTs target applications up to 200W, with 225mΩ $R_{DS(on)}$ and rated current of 6.5A.

The EVLMG1LPBRDR1 and EVLMG4LPWRBR1 demonstration boards are available to help evaluate the features of each device. These boards contain a GaN-based half-bridge power module fine-tuned to work in an LLC application. They help to quickly create new topologies leveraging the MasterGaN1L and MasterGaN4L devices without needing a complete PCB design.

Both devices are in production now in 9mm x 9mm x 1mm GQFN, priced from $4.40 for MasterGaN1L and $3.78 for MasterGaN4L.

www.st.com/mastergan1l

TI expands low-power GaN portfolio, allowing AC/DC power adapters to shrink 50%

New GaN devices compatible with most common topologies in AC/DC power conversion

Dallas-based Texas Instruments (TI) has expanded its low-power gallium nitride (GaN) portfolio, designed to help improve power density, maximize system efficiency and shrink the size of AC/DC consumer power electronics and industrial systems. TI's overall portfolio of GaN field-effect transistors (FETs) with integrated gate drivers addresses common thermal design challenges, keeping adapters cooler while pushing more power in a smaller footprint.

"Today's consumers want smaller, lighter and more portable power adapters that also provide fast, energy-efficient charging," says Kannan Soundarapandian, general manager of High Voltage Power at TI. "With the expansion of our portfolio, designers can bring the power-density benefits of low-power GaN technology to more applications that consumers use every day, such as mobile phone and laptop adapters, TV power supply units, and USB wall outlets," he adds. "TI's portfolio also addresses the growing demand for high efficiency and compact designs in industrial systems such as power tools and server auxiliary power supplies."

The new portfolio of GaN FETs with integrated gate drivers, which includes the LMG3622, LMG3624 and LMG3626, offers what is claimed to be the industry's most accurate integrated current sensing. This functionality helps designers achieve maximum efficiency by eliminating the need for an external shunt resistor and reducing associated power losses by as much as 94% compared with traditional current-sensing circuits used with discrete GaN and silicon FETs.

Maximize energy efficiency and simplify thermal design

TI says that its GaN FETs with integrated gate drivers enable faster switching speeds, which helps to prevent adapters from overheating. Designers can reach up to 94% system efficiency for <75W AC/DC applications or above 95% system efficiency for >75W AC/DC applications. The new devices can help designers to reduce the solution size of a typical 67W power adapter by as much as 50% compared with silicon-based solutions.

The portfolio is also optimized for the most common topologies in AC/DC power conversion, such as quasi-resonant flyback, asymmetrical half-bridge flyback, inductor-inductor–converter (LLC), totem-pole power factor correction (PFC) and active clamp flyback.

For more information on the benefits of TI's GaN for the most common AC/DC topologies, see the technical article "The benefits of low-power GaN in common AC/DC power topologies."

Long-term investment in GaN manufacturing

TI has a long history of globally owned, regionally diverse internal manufacturing operations, including wafer fabs, assembly & test factories, and bump and probe facilities across 15 worldwide sites. The firm has been investing in manufacturing GaN technology for more than 10 years.

With plans to manufacture more than 90% of its products internally by 2030, TI says that it can provide customers with dependable capacity for decades to come.

Package, availability and pricing

Production quantities of the LMG3622 and LMG3626 and pre-production quantities of the LMG3624 are available for purchase now on TI.com/GaN.

Available in an 8mm by 5.3mm, 38-pin quad flat no-lead package, pricing starts at US$3.18 in 1000-unit quantities.

Evaluation modules, including the LMG3624EVM-081, start at US$250. Pin-to-pin devices without integrated current sensing, LMG3612 and LMG3616, are also available.

www.ti.com/power-management/gan/overview.html

VisIC launches top-side-cooled isolated package

V22TG D³GaN targeted at automotive power electronics

VisIC Technologies Ltd of Ness Ziona, Israel — a fabless supplier of power conversion devices based on gallium nitride (GaN) transistors — has introduced the V22TG D³GaN gull-wing leaded top-side-cooled isolated package. Samples will be available in first-quarter 2024.

With a small footprint of 19.7mm x 13.6mm (including leads) and targeted at the automotive AEC-Q101 standard, the compact power package is said to provide automotive manufacturers with flexibility in system design and integration. It can also be used in the high-reliability fields of server power supplies, data centers, solar inverters, and a wide range of industrial applications.

Key features and benefits are cited as:

● *Leaded top-side-cooled isolated package*:
The V22TG D³GaN is encased in a leaded top-side-cooled isolated package, which enhances thermal management, ensuring optimal performance and reliability in demanding automotive environments. Moreover, the isolated package eases assembly due to not requiring additional isolation.

● *Automotive and high-voltage capability*:
The V22TG D³GaN is rigorously tested to meet automotive industry standards, making it suitable for a wide range of applications such as onboard chargers (OBCs), fuel cell, and hybrid electric vehicles. With a voltage capability of 650V, the SMD power package can handle high-voltage requirements with efficiency.

● *High power density and low on-resistance*:
Offering a low on-resistance of 22mΩ, the V22TG D³GaN delivers high power density, enabling automotive manufacturers to create more compact and lightweight systems without compromising performance. This power density ensures maximum efficiency and reduced energy losses.

VisIC's V22TG D3GAN top-side-cooled isolated package.

● *Versatile and easy to implement*:
The V22TG D³GaN is designed to support various system configurations, including paralleling of devices, full-bridge, half-bridge topologies, and power factor correction (PFC) circuits. This flexibility allows for seamless integration into a wide array of power electronics applications.

"This advanced power package not only offers exceptional performance and reliability but also provides the versatility and ease of implementation required for emerging automotive and industrial applications," says CEO & co-founder Dr Tamara Baksht.

www.visic-tech.com

Odyssey names co-founder, CTO & board member Rick Brown as CEO

CEO Mark Davidson and chief accounting officer Laura Krauss move to consulting roles amid cost-cutting

Odyssey Semiconductor Technologies Inc of Ithaca, NY, USA — which develops high-voltage vertical power switching components based on proprietary gallium nitride (GaN) processing technology — says that co-founder, chief technology officer & board member Rick Brown has been appointed as CEO. He replaces Mark Davidson, who has stepped down as CEO and board member, and is no longer employed at Odyssey.

Due to cost-reduction actions, both Mark Davidson and chief accounting officer Laura Krauss have moved to consulting roles for the company going forward. As stated previously, Odyssey is currently looking for longer-term financing and exploring strategic alternatives and continues to be financially constrained.

"We have continued to make progress with scaling our vertical GaN technology and developing the manufacturing process to build a larger device that can handle higher current. This larger device will enable us to more widely sample to customers to demonstrate the technology operating at a level which is more likely to be used by customers," says the firm. "Odyssey's approach to vertical GaN will offer even greater commercial advantages over silicon, silicon carbide or lateral GaN. Vertical GaN offers a 10x advantage over silicon carbide (SiC) at performance enabling smaller and lighter power systems and cost levels we believe are unattainable by the competing technologies," it adds. "We are also making progress with foundry services projects. Our pipeline has grown with initial work being completed providing revenue in Q4 with good potential volume, recurring revenue clients for 2024 and beyond. This has also led to some rebalancing of resource deployment between internal product development and externally focused foundry service projects. We are also continuing to review strategic opportunities to address longer-term financing needs."

www.odysseysemi.com

Navitas' revenue grows 22% sequentially in Q3

Launch of four new technology platforms across GaN and SiC to drive above-market revenue growth

For third-quarter 2023, gallium nitride (GaN) power IC and silicon carbide (SiC) technology firm Navitas Semiconductor Corp of Torrance, CA, USA has reported revenue of $22m, up 22% on $18.1m last quarter. This is also up 115% on $10.2m a year ago, aided somewhat by the acquisition in August 2022 of silicon carbide power semiconductor device designer and manufacturer GeneSiC Semiconductor Inc of Dulles, VA, USA.

"Our gallium nitride and silicon carbide technologies continue to displace legacy power silicon in traditional markets and enable and accelerate new energy markets," says CEO & co-founder Gene Sheridan.

On a non-GAAP basis, gross margin has grown further, from 38.4% a year ago and 41.5% last quarter to 42.1%.

Operating expenses have risen further, from $14.2m a year ago and $17m last quarter to $18m, due to R&D spending rising from $6.3m to $10.5m, while selling, general & administrative (SG&A) expenses were cut from $7.9m to $7.4m.

Net loss has been cut further, from $9.2m ($0.07 per share) a year ago and $8.65m ($0.05 per share) last quarter to $7m ($0.04 per share).

During the quarter, cash and c ash equivalents fell slightly, from $177.7m to $176.7m.

Market, customer and technology highlights during Q3/2023

"GaN is moving from a beachhead to the mainstream for mobile fast chargers, with continued strength and upside led by major China OEMs Xiaomi and Oppo," notes Navitas. "We expect 30% of their total mobile charger shipments in 2024 will utilize GaN, and GaN has been adopted by Samsung for the latest Galaxy S23 and other models, contributing to Q3 and expected Q4/2023 revenue ramp," it adds.

New Gen-4 GaNSense half-bridge ICs, targeting ultra-fast chargers of 100W or more, are projected to contribute another $10m per year in revenue ramping in 2024. "The new GaNSense products replace dozens of components with a single GaN IC and enable switching frequencies up to 2MHz to reduce footprint and simplify designs," the firm says.

Q4/2023 will also see the introduction of new bi-directional GaN. Each GaN power IC will replace up to four discrete power transistors, dramatically reducing component count, cost and complexity

Launched in September, GaNSafe is claimed to be the world's most protected, most reliable and highest-performance GaN power semiconductor, with advanced sensing, protection, higher-power capability and cool operation, enabling GaN to enter high-power, high-reliability markets such as artificial intelligence (AI) data centers, solar, electric vehicles (EVs) and industrial. GaNSafe power ICs are featured in a new 6.6kW, 800V on-board charger (OBC) platform from Navitas' dedicated EV system design center, which claims to set industry benchmarks in system efficiency, density and cost. The OBC is a 'hybrid' platform, featuring GaNSafe and a new, Gen-3 Fast (G3F) GeneSiC MOSFET platform, with silicon carbide power and switching performance that is claimed to be up to 50% better than competition.

Rapid adoption of AI has created unprecedented demand for more power, higher efficiency and greater power density, notes Navitas. The firm's data-center design center has developed a new 4.5kW AC–DC system platform design, with efficiency exceeding the 96% 'Titanium Plus' standard, and with twice the power density of previous, best-in-class, legacy silicon designs, it is reckoned. GaNSafe and Gen-3 Fast SiC are again used to optimize these high-power applications, with significant growth in the number of customer pipeline projects.

Solar, appliance and industrial markets also show robust growth in the customer pipeline, with broad interest in the new Gen-3 Fast MOSFETs, says Navitas. The Gen-4 GaNSense half-bridge portfolio now includes new application-specific ICs for motor drives, compressors and pumps up to 1kW, with sensing, autonomy and programming functionality for easy EMI.

Fourth-quarter 2023 will also see the introduction of new bi-directional GaN. Each GaN power IC will replace up to four discrete power transistors, dramatically reducing component count, cost and complexity, and delivering major speed and efficiency benefits, says Navitas. Bi-directional GaN technology is expected to usher in major advances in energy storage, grid infrastructure, motor drives and many other emerging topologies and architectures across multiple markets.

Revenue growth to far exceed market growth rate

For fourth-quarter 2023, Navitas forecasts revenue to grow to $25–26m. Gross margin is expected to rise to 42.5% (plus or minus 30 basis points), with operating expenses increasing further to about $20m.

"It's a very exciting time at Navitas as we launch four major new technology platforms across GaN and SiC," comments Sheridan. "We expect Navitas' revenues to far exceed market growth rates in 2024 and for years to come."

www.navitassemi.com

CGD forms GaN ecosystem with Chicony Power and Cambridge University Technical Services

Expertise in systems and applications, research and devices to yield GaN-based notebook and data-center power products

Cambridge GaN Devices Ltd (CGD) — which was spun out of the University of Cambridge Department of Engineering's Electrical Power and Energy Conversion group in 2016 and designs, develops and commercializes power transistors and ICs that use GaN-on-silicon substrates — has signed a tripartite agreement with Taiwan-based Chicony Power Technology Co Ltd and Cambridge University Technical Services (CUTS, a subsidiary of Cambridge Enterprise) to conceive and develop efficient, high-power-density adapters and data-center power products using gallium nitride.

Chicony Power is a provider of power electronics systems focusing on power supplies (including switch-mode power supplies) and adapters for applications including notebooks, desktop computers, gaming devices, and server/cloud solutions.

Lead consultant on behalf of CUTS is professor Florin Udrea, head of Cambridge University's High Voltage Microelectronics and Sensor (HVMS) group, which has a 25-year history in power device design, TCAD simulations and characterization of power devices. The three parties will collaborate on a technical project 'Innovative low power and high power SMPS (switch-mode power supplies) with advanced GaN solutions'.

CGD has historic and ongoing links with Cambridge University via chief executive officer Giorgia Longobardi and chief technology officer Florin Udrea, who also still leads the HVMS group.

The project is expected to deliver SMPS prototypes for highly efficient, high-density adapters for notebooks — where Chicony Power is said to be the market leader — and Titanium+ efficiency/high-power-density (>100W/inch^3) CRPS and OCP power shelf (3~6kW) power supply unit for data-center and artificial intelligence (AI) server applications.

"Chicony Power is one of the leading SMPS manufacturers in the world, so this agreement represents an incredible milestone in CGD's journey to deliver an efficient power device technology both to our customers and to society in general," believes CEO & co-founder Giorgia Longobardi. "The combined strengths of our businesses together with the world-renowned HVMS group at Cambridge University will accelerate the development and adoption of high-energy-density power solutions in wide-ranging applications," she adds.

"Chicony Power intends to collaborate with CGD and HVMS because of their significant expertise in GaN," comments Chicony Power's president Peter Tseng. "CGD has already delivered its second series of ICeGaN HEMT [high-electron-mobility transistor] devices, which offer top-notch performance in terms of ruggedness and ease-of-use," he adds. "And because of its roots and still strong links with Cambridge University, CGD can call upon 25 years of academic experience – more than many other established GaN companies."

Recently, CGD launched the second series of its ICeGaN 650V gallium nitride HEMT family. H2 Series ICeGaN HEMTs employ CGD's smart gate interface that is said to virtually eliminate typical e-mode GaN weaknesses, delivering significantly improved over-voltage robustness, higher noise-immune threshold, dV/dt suppression and ESD protection. Like previous-generation devices, the new 650V H2 ICeGaN transistors are simple to drive using commercially available industry gate drivers. Finally, H2 ICeGaN HEMTs feature a Q_G that is 10x lower than silicon parts and a Q_{OSS} that is 5x less. This greatly reduces switching losses, with corresponding reductions in size and weight.

www.camgandevices.com
www.chiconypower.com

Navitas ranked top 50 in Forbes' 2024 list of America's Most Successful Small Companies

Navitas has been ranked 49th on Forbes' 2024 America's Successful Small Companies list, recognizing the strong demand for its high-efficiency, wide-bandgap (WBG) GaN and SiC power components, across growing and diverse global markets and an expanding customer base.

Forbes' evaluation was on earnings growth, sales growth, return on equity, and total stock return over the preceding five years, with a specific focus on the last 12 months, including Navitas' 115% increase in revenue (Q3/2022 to Q3/2023).

"GaN and SiC are accelerating the transition away from fossil fuels to 'Electrify Our World' with renewable sources and efficient uses of electricity," says co-founder & CEO Gene Sheridan.

www.forbes.com/lists/best-small-cap-companies

Transphorm quarterly product revenue grows 18%

For its fiscal second-quarter 2024 (to end-September 2023), Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and manufactures JEDEC- and AEC-Q101-qualified gallium nitride (GaN) field-effect transistors (FETs) for high-voltage power conversion — has reported revenue of revenue of $5.01m, down 15% on $5.883m last quarter but up 36.5% on $3.67m a year ago.

Product revenue was a higher-than-expected $3.55m, up 12% by $0.4m on a year ago and 18% on about $3m last quarter.

Government contract revenue was $1.46m, halving from $2.9m last quarter but up by $1m year-on-year.

Gross margin was a more-than-expected 23.4%, down from 35.5% last quarter due to lower mix of government contract revenue, but up by 11.5% year-on-year. "We continue to progress toward our long-term model of gross margins in excess of 40%," says chief financial officer Cameron McAulay.

On a non-GAAP basis, operating expenses were $6.4m, up from $5.2m a year ago but cut from $6.83m last quarter.

Net loss was $7.1m ($0.12 per share), up from $6m ($0.10 per share) a year ago but cut from $7.4m ($0.22 per share) last quarter.

Adjusted EBITDA was –$5m ($0.08 per share), up from –$4.5m ($0.08 per share) last quarter and –$4.6m ($0.08 per share) a year ago.

During the quarter, cash, cash equivalents and restricted cash rose from $3.3m to $6.152m, after a rights offering of common stock at the end of July raised $7.94m.

"We meaningfully reduced cash burn from $6.8m for the first quarter of fiscal 2024 to $5.1m for Q2 fiscal 2024, and we continue to have zero debt on our balance sheet, which puts us in a strong position to secure additional non-dilutive funding," says McAulay.

"We engaged BofA Securities to advance our previously announced strategic review process, and we are continuing this process as we seek to enhance stockholder value, pursuing multiple options that include the potential merger or sale of the company," says CEO & co-founder Dr Primit Parikh.

Highlights during the quarter were:

High-power segment

- Increased total design-ins for higher power (300W–7.5kW) to over 100 (with over 35 in production), an increase of more than 30% from the prior update in August of 75, with an estimated 75% plus conversion rate in the markets from design-in to in production.
- Breakthrough production win with solar inverter player — Transphorm's GaN platform is powering the world's first integrated photovoltaic (PV) systems from DAH Solar Co Ltd (Anhui Daheng New Energy Technology Co Ltd), enabling it to produce smaller, lighter and more reliable solar panel systems that also offer higher overall power generation with lower energy consumption.
- Introduced three SuperGaN FETs in surface-mount devices (SMD) TOLL packages supporting higher-power applications operating within an average range of 1–3kW typically found in high-performance segments such as computing (AI, server, telecom, data center), energy and industrial (PV inverters, servo motors), and other broad industrial markets.
- Expanded the firm's package option portfolio launching the SuperGaN TOLT FET with an on-resistance of 72mΩ, the industry's first top-side-cooled surface-mount GaN device in the JEDEC-standard (MO-332) TOLT package.
- Initial sampling of the TO-247-4 lead package (drop in with silicon and silicon carbide solutions), with recent internal tests demonstrating 25% lower losses versus similar SiC MOSFET offerings from a global top-3 supplier, increasing the socket penetration opportunities with new and existing solutions.
- Transphorm is actively engaged with multiple global customer partners for high-power GaN in these new surface-mount packages, a global leader in the micro-inverter space, lead customers in server and storage power, an innovative manufacturer for off-grid power solutions and a leader in satellite communications.
- Released 300W and 600W Electric 2- and 3-wheeler charger power supply designs and successfully designed into two of the top five India OEMs in 2-wheeler battery chargers.

Low-power segment

- Increased total design-ins for power adapters and fast chargers (<300W) to over 115 (with over 30 in production), an increase in ongoing design-ins of 15% from the prior update in August.
- Expanded the system-in-package (SiP) strategy to over five IC partners, to enable faster growth in this segment.
- Continued to expand sockets at two of the top three worldwide laptop OEMs in multiple power levels – both at 65W and higher range from 100W to 360W.

Five-year pipeline increased from $450m to $475m

Transphorm continued to grow its five-year pipeline opportunity — now at over $475m, of which about 70% is in high power, and also up 5% from the prior update in August of $450m. With traction in design-ins and opportunities entering or nearing production, the firm expects a continuation of its sequential product revenue growth in fiscal third-quarter 2024.

"We were pleased with the continued growth of our pipeline and our design wins, highlighted by record growth in high-power design wins," says Parikh. "We anticipate continued strong growth in product revenue in our third fiscal quarter as we realize the benefits of converting our burgeoning design-ins into revenue-generating contracts."

www.transphormusa.com

Transphorm and Allegro team up to increase GaN power system performance for high-power applications

Purpose-built isolated gate drivers aid adoption of GaN in data centers, renewables, electric vehicles

Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and manufactures JEDEC- and AEC-Q101-qualified gallium nitride (GaN) field-effect transistors (FETs) for high-voltage power conversion — and Allegro MicroSystems Inc, which provides power and sensing semiconductor technology for motion control and energy-efficient systems, have announced a collaboration including Transphorm's SuperGaN FETs and Allegro's AHV85110 isolated gate driver to enable the expansion of GaN power system design for high-power applications.

Transphorm's SuperGaN FETs are designed to work in various topologies and are available in several different packages to support a wide power range while also satisfying diverse end-application requirements. SuperGaN FETs are used in commercial products including higher-power systems where they are proven to increase reliability, power density, and efficiency, says Transphorm.

Allegro's self-powered, single-channel isolated gate driver IC is optimized for driving GaN FETs in multiple applications and circuits. The AHV85110 is proven to enhance driver efficiency by as much as 50% compared with competing gate drivers. This unique solution simplifies system design, reduces noise by 10x and common mode capacitance by 15 times compared with other solutions on the market.

"Allegro's AHV85110 high-voltage gate driver provides a highly compact and efficient power-stage implementation that helps to achieve an approximate 30% footprint reduction with the least number of external components and bias supply requirements around Transphorm's power devices," comments Tushar Dhayagude, VP of worldwide sales & FAE, Transphorm. "Combined with SuperGaN's highest reliability and superior dynamic switching performance over competing technologies, the end result is a more efficient, more robust solution with increased power density in critical applications such as server, data centers, renewables and electric vehicles."

The collaboration "further supports Allegro's focus towards helping customers optimize GaN-based system development and design," says Vijay Mangtani, VP & general manager of High Voltage Power, Allegro MicroSystems. "We are looking forward to the opportunity to combine our high-voltage isolated gate driver AHV85110 with Transphorm's SuperGaN FET to enable higher power density, higher efficiency and higher power output in smaller form factors and provide value to both our and Transphorm's customers."

Those interested in testing the collaborative solution can do so via Allegro's APEK85110KNH-06-T evaluation board, which incorporates both the AHV85110 designed to work in various applications along with Transphorm's TOLL package (launched in October) available in three devices with on-resistances of 35mΩ, 50mΩ and 72mΩ.

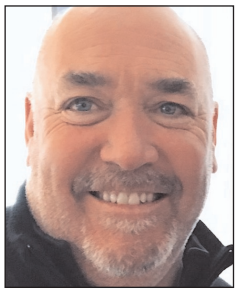
www.transphormusa.com
www.allegromicro.com/en/products/motor-drivers/gate-

QPT adds former GaN Systems' EMEA sales director Tony Astley as business advisor

Power electronics company Quantum Power Transformation (QPT) of Cambridge, UK (which was founded in 2020) has expanded its team with the addition of Tony Astley. as a business advisor. Previously, he was director of EMEA sales at GaN Systems for nine years, following several senior sales roles over 29 years at Texas Instruments.

"We have created a breakthrough technology that solves a massive problem in power electronics by enabling GaN to be run at high switching speeds to deliver its promised power savings without the problems of RF and overheating that currently limit it to speeds of 100KHz," says founder & CEO Rob Gwynne. "These challenges mean that SiC is often viewed as the preferred choice for future high-speed, high-power applications. Our technology changes that future to one based on GaN. Tony's extensive sales contacts and experience will help us rapidly get the story out there."

"QPT's revolutionary approach to power conversion, unleashes the full potential of GaN and opens up vast new markets for which there



Tony Astley.

is no current solution," says Astley. "Having worked with GaN for nine years, I understand the market needs and I also know that much of the market does not currently realise the amazing benefits that this unleashed GaN could bring to their applications. QPT's next generation GaN solution is an elegant and revolutionary way for customers to quickly and easily get the absolute maximum benefits of this remarkable technology."

A slow switching transition wastes energy because, during the switching time, when the transistor is neither on nor off, it dissipates huge amounts of power, resulting in energy losses and overheating issues. The higher the switching speed, the less time is spent in transition, and the less energy is lost. GaN transistors can quickly transition from on to off at 1–2ns instead of 20–50ns for silicon and SiC transistors. However, achieving maximum performance is challenging in many high-voltage, high-power applications without significant RF interference issues or overheating.

QPT's qGaN module solution enables the GaN transistors to be run at their full potential of up to 20MHz with nanosecond switching to deliver better operational precision. QPT's technology in a Variable Frequency Drive (VFD) enables motors to be driven at up to 99.7% efficiency at peak load with hardly any decrease in efficiency at lower loads. This is a challenge for conventional designs today, where the efficiency can drop off rapidly at lower loads. In addition to superior efficiency, the higher convertor frequency significantly reduces the size and weight of the power electronics, by 10x or more, as well as reducing the manufacturing costs due to the removal of expensive filters that are normally required to protect the motor. Application areas include heat pumps, industrial motors, HVAC systems and electric vehicles.

www.q-p-t.com

QPT wins ABB Power Density Start-up Challenge 2023

QPT is one of two winners the ABB Power Density Start-up Challenge 2023 for motor drive products.

"We are seeking innovative and forward-thinking start-ups to join us in pushing the boundaries of drives and motors. Today, motors and drives are largely viewed as two independent devices. The winner will collaborate with us to develop an integrated solution that optimizes resources and combines motors and drives into a single, seamless solution," says ABB of Zurich, Switzerland, which focuses on electric power engineering and industrial automation. "We are looking for motivated and disruptive minds to work with ABB's experts to create an integrated motor drive technology for a more efficient future. Key factors that we are looking for are improvements in power density, thermal management, sustainable supply, overall simplicity and cost effectiveness to redefine the operational boundaries and improve the efficiencies of drives and motors," the firm adds.

"Our technology enables drive controls or variable frequency drives (VFDs) to be made much smaller as we achieve the best power densities and efficiencies of any current technology by now enabling GaN to be hard-switched at 1ns to 2ns," says QPT's founder & CEO Rob Gwynne. "Current VFDs are bulky, which means that they are invariably located away from the motor itself and then connected by copper cables that are big and heavy to cope with the hundreds of Amps or so going through them and also waste energy in the process. QPT's gallium nitride technology shrinks the size of a VFD to around a twentieth of the size so that it can be integrated beside the motor. The need for big, costly filters that silicon, silicon carbide (SiC) or slow existing GaN alternatives require and preclude easy integration is also eliminated, further reducing the overall size, which further helps integration," he adds.

www.collaborateandcommercialize.com/abb-power-density-startup-challenge-2023

OKI develops GaN lifting-off/bonding technology on Shin-Etsu's QST substrates

Adoption of vertical GaN power devices to enable breakdown voltages of 1800V

In collaboration with Shin-Etsu Chemical Co Ltd, Tokyo-based Oki Electric Industry Co Ltd has developed technology that uses its CFB (crystal film bonding) technology to lift off only the gallium nitride (GaN) functional layer from Shin-Etsu Chemical's QST (Qromis Substrate Technology) substrate (a composite material substrate developed by California-based Qromis Inc and licensed exclusively for GaN growth to Shin-Etsu in 2019) and bond it to a different material substrate.

The technology enables the vertical conduction of GaN and is expected to contribute to the realization and commercialization of vertical GaN power devices capable of controlling large currents. The two firms will work further together to develop vertical GaN power devices that can be implemented by partnering with companies that manufacture these devices.

GaN devices combine high-performance device characteristics with low power consumption, such as power devices that require high breakdown voltages of 1800V or more, high-frequency devices for Beyond5G, and high-brightness micro-LED displays. In particular, demand for vertical GaN power devices is expected to grow significantly as they can improve the basic performance of electric vehicles by enabling extended driving ranges and shortened power supply times. However, two major challenges hinder the implementation of vertical GaN power devices: the diameter of the wafers must be increased to improve productivity and vertical conductivity must be realized to enable large current control.

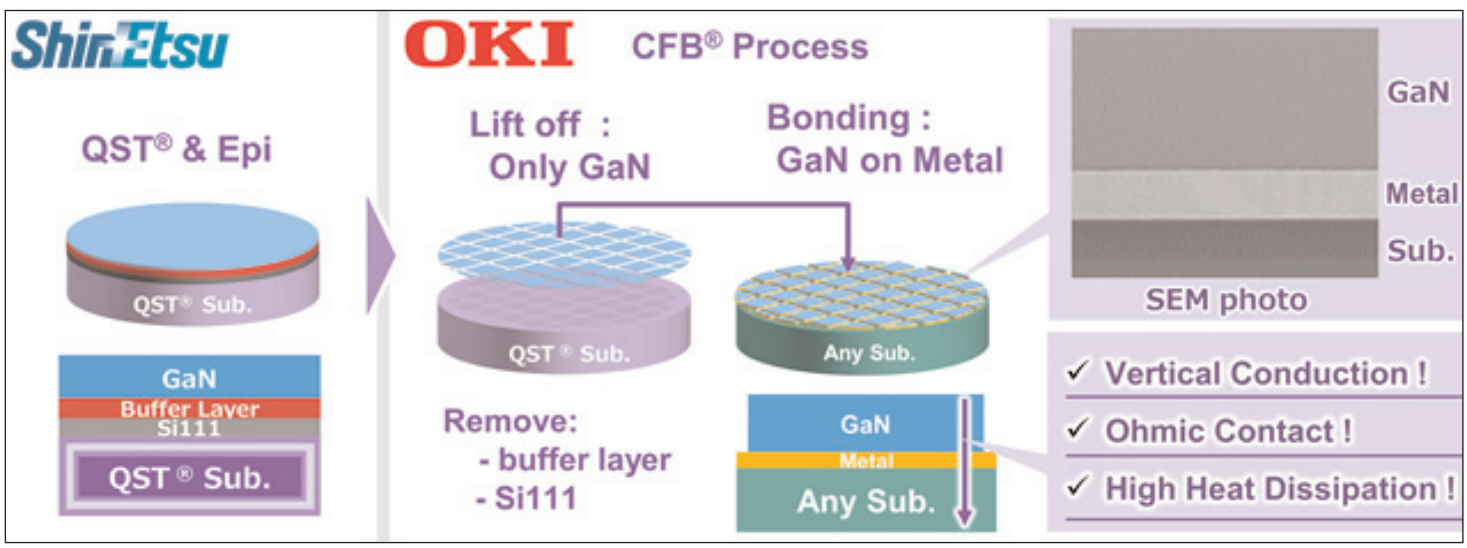
The coefficient of thermal expansion of Shin-Etsu Chemical's QST substrate is equivalent to that of GaN, so it can suppress warpage and cracking. This enables the crystal growth of thick GaN films with high breakdown voltages even on wafers larger than 8-inches, enabling the production of wafers with larger diameters.

The coefficient of thermal expansion of QST substrate is equivalent to that of GaN, so it can suppress warpage and cracking

In addition, OKI's CFB technology can lift off just the GaN functional layer from the QST substrate while maintaining high device performance characteristics. The insulating buffer layer required for GaN crystal growth can be removed and bonded to various substrates via metal electrodes that allow ohmic contact. Bonding of these functional layers to a conductive substrate with high heat dissipation will enable both high heat dissipation and vertical conductivity. It is reckoned that the combined technologies of Shin-Etsu Chemical and OKI can hence solve the above two major challenges, paving the way for the implementation of vertical GaN power devices.

In the future, the two companies aim to contribute to the widespread use of vertical GaN power devices through Shin-Etsu Chemical's provision of QST substrates or GaN grown QST substrates to companies manufacturing GaN devices and OKI's provision of CFB technology through partnering and licensing. Furthermore, OKI hopes to use CFB technology to provide added value to semiconductor devices that go beyond the framework of single materials.

www.shinetsu.co.jp
www.oki.com



An overview of the new jointly developed technology.

Diamond Foundry creates the first 100mm single-crystal diamond wafer

Firm aims to reduce defect density to textbook semiconductor figure of merit

Diamond Foundry Inc (DF) of San Francisco, CA, USA says that it has created the world's first 100mm single-crystal diamond wafer.

A culmination of work that DF team members started three decades ago, creating the first diamond wafer required the development of technologies including a single-crystal lattice on scalable substrates, large-area diamond ingot growth, diamond singulation technology, and precision-surface processing.

No wafer-sized diamond exists, so DF had to create the "mother of all diamond wafers" then use it to produce more. Employing diamond heteroepitaxy — which creates single-crystal diamond on scalable substrates — and combining it with other technologies, the firm created the first ever wafer that is a single crystal of diamond. Prior simulants existed effectively in the form of compressed powder of diamond but with properties not matched by a single crystal, the firm adds.

In comparison with natural resources, the largest rough diamond ever mined on Earth (the Cullinan Diamond) has a largest dimension of 5.89cm, which is more than 4cm smaller than DF's diamond.

DF says that its next goal is to further reduce the defect density of its diamond wafer — to realize the textbook semiconductor figure of merit of diamond, which is 17,200 superior to silicon and 60 times superior to silicon carbide.

Diamond Foundry creates first diamond-based electric car inverter

Diamond wafer combined with silicon carbide die yields sixfold miniaturization

Diamond Foundry has created an electric car inverter leveraging its diamond wafer technology to enable greater efficiency.

Tesla led the power electronics revolution in electric cars by leading the adoption of silicon carbide. But the new power electronics unit is reckoned to be six times smaller than that of a Tesla 3 while delivering more power more efficiently. This level of miniaturization is enabled through a design enabled by diamond wafers in combination with established silicon carbide dies.

The design of power semiconductors is essentially driven by two factors: thermal conductivity (the path to cool them down) and electrical conductivity (the path to carry high currents). Though the electrical path has been worked on for many years more or less successfully, the thermal path has always been the main challenge. Further, power semiconductors need to be isolated from the rest of the environment because of safety required with high voltages. Voltage isolation barriers usually demonstrate poor thermal conductivity.

The firm says that diamond wafers can now be employed using two of its extreme properties: extreme thermal performance plus extreme electrical insulation. It adds that the advent of cost-efficient diamond wafers creates fundamental new design opportunities for power electronics that were not possible before.

www.DF.com

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First non-destructive SiC defect inspection system

Spirox Corp of Hsinchu, Taiwan, in collaboration with its subsidiary Southport Corp, has jointly launched the industry-first JadeSiC-NK non-destructive defect inspection system, which uses non-linear optical technology for whole wafer scanning of SiC substrates, identifying killer defects within the substrate. By replacing the existing high-cost, destructive KOH (potassium hydroxide) etching detection method, it leads to increased production yields and process improvement. Based on the need to etch two substrates for each SiC ingot, JadeSiC-NK can save a substrate manufacturer with 100 crystal growth furnaces about US$7.68m in annual costs incurred due to etching losses, it is reckoned.

SiC crystal growth is slow, and substrate crystal defects currently can only be inspected by sampling and mathematic interpolation with the destructive KOH etching method, making the cost of SiC chip manufacturing processes consistently high. Major SiC substrate makers worldwide are investing in capacity expansion and process improvement to increase their market share. If SiC substrate and component manufacturers can implement comprehensive non-destructive inspection of materials in the manufacturing process, it will not only reduce the usage of harmful chemical solutions associated with KOH etching but also allow for the early detection of defects. This, in turn, enables effective process improvement and enhances yield.

Existing optical technologies on the market can only detect surface non-crystalline defects, notes Southport's general manager Jay Wang. However, JadeSiC-NK utilizes non-linear optical technology, allowing for a whole-wafer surface scan to a specific depth to provide crystal structure information, offering detail on crystal defect density and distribution, and enabling customers to effectively assess substrate quality to ensure the stability of the quality and performance of components produced.

Wang further explains that the JadeSiC-NK non-destructive defect inspection system focuses on efficiently and stably identifying killer defects (BPD, TSD, micro-pipe, stacking fault). Compared to the existing KOH etching method, which involves inspecting two substrates from sliced SiC ingots, JadeSiC-NK can significantly save inspection time and substrate costs. For example, a crystal growth furnace producing four ingots per month, with JadeSiC-NK, each ingot can save the cost of two substrates (calculated at $800 per each 6-inch substrate), resulting in an estimated annual savings over $70,000 per furnace. For a substrate manufacturer with 100 furnaces, this amounts to annual savings of $7.68m, it is reckoned. Furthermore, JadeSiC-NK enables a 100% wafer inspection for the same ingot, facilitating detailed ingot analysis and batch traceability analysis which will assist customers in accelerating process and yield optimization in the high-tech compound semiconductor market.

The JadeSiC-NK system launched by Spirox and Southport applies non-linear optical technology to the inspection and analysis of compound semiconductors, says Dr Hao-Chung Kuo, chair professor of the Department of Optoelectronic Engineering at Taiwan NCYU. This innovation is expected to break through the current industry's technical bottlenecks in mass production and process improvement, providing significant impetus to the development of the industry chain. It is hoped that JadeSiC-NK, with its more effective and stable inspection technology, will establish industry standards for SiC substrate inspection. This, in turn, can lead continuous innovation and breakthroughs in market applications.

"Considering the instability of distribution and the pursuit of a better profit structure, Spirox has been continuously enlarging its investment in own-brand to develop solutions to fulfill customer needs," says Spirox's CEO Paul Yang. "Through the acquisition of Southport, Spirox aims to accelerate the development process of our own-brand products, expanding from semiconductor packaging and testing equipment to optical inspection. The initial focus is on the highly promising defect inspection of compound semiconductor materials. "

Since the collaboration between Spirox and Southport in distribution, there has been a mutual understanding of mutual reinforcement, says Yang. The establishment of the Advanced Opto-Material Inspection Laboratory allows the unique optical inspection technology to quickly enter the industry field. Through repeated verification by customers, product specifications are adjusted to meet their needs. In addition to applying non-linear optical technology in the newly launched JadeSiC-NK, there are plans to accelerate the commercialization of advanced optical inspection technologies in areas such as micro-LEDs, metamaterials, silicon photonics etc, in the future. Spirox says that it will continue to increase R&D efforts, effectively integrating group resources to maximize synergies.

"It's a great pleasure to see two Taiwanese local companies creating synergy through a mutually beneficial collaboration, generating tremendous value for the industry," comments Ken Tai, chairman of the Photonics Industry and Technology Development Association (PIDA). "The JadeSiC-NK launched by Spirox and Southport represents a groundbreaking technological breakthrough," he reckons. "It is not only a revolutionary product for the global compound semiconductor industry, capable of significantly reducing costs and increasing production capacity, but also showcases Taiwan's technological leadership."

www.spirox.com
www.southport.com.tw

Aehr wins first order for FOX-NP wafer-level test & burn-in system for gallium nitride

Existing customer expanding from using FOX systems for SiC

Semiconductor production test and reliability qualification equipment supplier Aehr Test Systems of Fremont, CA, USA has received an initial customer order for a FOX-NP wafer-level test & burn-in system and a FOX WaferPak Aligner (for shipment and installation this quarter) to be used for gallium nitride (GaN) power devices. The customer is a leading global supplier of semiconductor devices used in electric vehicles and power and adds another major customer to the list of companies using Aehr's FOX products for wafer-level test & burn-in of wide-bandgap compound semiconductors.

As its first gallium nitride customer to order a system, Aehr says that this firm chose it due partly to its unique ability to offer a total solution that allows customers to apply thermal and electrical stress conditions to thousands of devices while still in wafer form. Aehr's technology provides critical geolocation information across the wafer while inducing the extrinsic (early-life) failures that would otherwise fail in the field without reducing the long-term reliability or life of the good devices.

"After seeing the positive results from their long and extensive evaluation of our FOX wafer-level test systems for their silicon carbide devices, this customer decided to first move forward with our FOX-NP system to test their gallium nitride devices' long-term reliability failure rates, as well as qualify the production extrinsic failure screening process for their devices in applications where safety, reliability and/or security are critical," says president & CEO Gayn Erickson. "A key consideration behind their decision is that the FOX-NP system is 100% compatible with the Aehr FOX-XP system that is targeted for high-volume production and can support all the test modes needed for both gallium nitride and silicon carbide device testing and burn-in, including high-voltage testing of up to 2000V with full-wafer test without electrical arcing that can damage the wafer, which is a distinct advantage of our unique patented technology," he adds.

"Similar to silicon carbide, gallium nitride semiconductor MOSFETs are considered wide-bandgap devices with much higher efficiencies in terms of power conversion than silicon, with gallium nitride being particularly good for lower-power devices such as under 1000W power converters used in consumer devices such as cell phones, tablets and laptop computers, as well as being targeted for automotive power converters for all the electrical systems in automobiles, whether electric vehicles or traditional gasoline automobiles. Gallium nitride MOSFETs are also believed by many industry analysts and technical communities to likely take over silicon as the power converter of choice for photovoltaic (solar panel) applications," Erickson continues.

"Gallium nitride and silicon carbide devices both have excellent long-term intrinsic reliability, making them very good for automotive and industrial applications. But both also experience higher-than-acceptable early-life or extrinsic failures related to the material and processing steps. Gallium nitride and silicon carbide semiconductor suppliers can add a special stress or screening test known as burn-in on 100% of the devices to identify and remove these early-life failures so that they can meet the end-customers' target reliability needs. This 100% burn-in requirement is not unique to these devices, as it is also the case with microprocessors and microcontrollers, dynamic random-access memories (DRAM), flash non-volatile memories, as well as many sensors used in automotive and other industrial applications," he adds.

This customer decided to first move forward with our FOX-NP system to test their gallium nitride devices' long-term reliability failure rates

Aehr says it enables its customers to cost-effectively implement the needed testing and qualification process for devices that experience early-life failures by not only applying the electrical stress condition to every device on the wafer but by also testing up to 18 wafers at a time using the FOX-XP production test & burn in system. These electrical tests are done with up to thousands of precise calibrated electrical source and measurement instruments per wafer. These tests are performed while maintaining the temperature at an accurately programmed thermal temperature across each of the wafers using a direct conduction thermal transfer via a proprietary patented precision thermal chuck per wafer.

The FOX-NP complements Aehr's production FOX-XP system by using the exact same test 'Blades' that are in the FOX-XP to allow 100% correlation between the results on the FOX-NP to the FOX-XP.

The FOX-XP and FOX-NP systems, available with multiple WaferPak Contactors (full-wafer test) or multiple DiePak Carriers (singulated die/module test) configurations, are capable of functional test & burn-in/cycling of devices such as silicon carbide and gallium nitride power semiconductors, silicon photonics as well as other optical devices, 2D and 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

CSconnected welcomes UK's £160m semiconductor investment zone in South Wales

Cluster to work with Welsh Government and Cardiff Capital Region

A recently announced investment zone in the UK is to focus on further strengthening the CSconnected compound semiconductor cluster based in and around South Wales.

Welsh Government Economy Minister Vaughan Gething recommended that Wales should be home to two of the 12 investment zones across the UK and that the South Wales zone should focus on strengthening the CSconnected semiconductor cluster.

In his Autumn Statement, Chancellor of the Exchequer Jeremy Hunt confirmed the go ahead for the £160m investment zone for semiconductors in South Wales.

Investment zones form part of the UK's levelling-up strategy to focus on a small number of high-potential clusters linked to strong research, innovation and manufacturing capabilities. The South Wales semiconductor cluster is recognised as a key capability that can provide a path to stronger economic growth in Wales and the UK as a whole.

"Our dependence on semiconductors became abundantly clear during the COVID pandemic when demand for technologies enabled by our sector created severe shortages across many end-markets," says CSconnected's director Chris Meadows. "Specializing in compound semiconductor technologies, Wales plays a key role within this essential industry sector that is at the heart of our digital world from handsets to data centers, mobility and net-zero applications, healthcare, robotics and AI," he adds.

"We look forward to continuing working closely with the Welsh Government and Cardiff Capital Region to design the Investment Zone interventions that will accelerate growth in prosperity, talent and economic value from our thriving semiconductor sector across our region and beyond," says Wyn Meredith, chair of CSconnected's management group.

www.csconnected.com

CSA Catapult highlights role of compound semiconductors in the green hydrogen ecosystem

Compound semiconductors have the potential to play a crucial role in enhancing the efficiency and reliability of the UK's hydrogen ecosystem, according to a new white paper issued by the Compound Semiconductor Applications (CSA) Catapult.

The new report outlines five areas where compound semiconductors could significantly enhance the hydrogen ecosystem:

- renewable energy generation;
- power electronics for electrolysis;
- applications in transportation;
- enhanced microgrids;
- advanced sensors for hydrogen detection.

Compared with traditional silicon-based devices such as higher power density, faster switching speeds and reduced power losses, the superior material properties of compound semiconductors makes them an ideal choice for green energy applications including electric vehicles, renewable energy systems and power grids, notes the report.

Compound semiconductors can also enhance the performance of energy storage systems and smart grids and can therefore play an important role in transitioning towards a more sustainable energy system.

The report identifies fuel-cell electric vehicles (FCEV), which use hydrogen fuel cells to generate electricity for the vehicle's electric motor, as the most promising area for compound semiconductors. Power electronics components built using compound semiconductors can significantly improve the efficiency, reliability and overall performance of the FCEV powertrain.

"Hydrogen is considered a crucial element in decarbonizing the UK industry, promoting clean growth and enhancing our long-term energy security," says David Chow, head of market intelligence at CSA Catapult. The UK government's Hydrogen Strategy sets out an approach to develop a thriving low-carbon hydrogen sector in the UK to meet its ambition for 10GW of low-carbon hydrogen production capacity by 2030. "Compound semiconductors offer significant benefits for green hydrogen applications, particularly in FCEVs across the transport spectrum, ranging from HGVs to trains and aircraft," adds Chow. "Though other applications may take longer to become commercially viable, it is clear that compound semiconductors will be crucial in improving the generation, transportation and consumption of hydrogen and helping the UK meet its hydrogen goals."

The new report is an output of the Hydrogen Innovation Initiative (HII) — a cross-Catapult project aimed at creating an interconnected ecosystem that leverages the strengths, resources and regional presence of organizations to advance the development of a green hydrogen economy in the UK.

HII's mission is to support UK industry to anchor high-value jobs, boost resilience and drive decarbonization by accelerating the development of critical technologies and supply chains for the fast-growing hydrogen economy.

www.csa.catapult.org.uk

Cardiff University and IQE extend strategic partnership

Cardiff University and epiwafer and substrate maker IQE plc have extended their strategic partnership in a move that will invest in developing talent in compound semiconductors and help to fuel the expansion of IQE's South Wales manufacturing operations. The new agreement provides a further five-year commitment from both partners to expand research capacity in compound semiconductor technologies.

Two new professorial chairs in compound semiconductors will be established: one in the University's School of Physics and Astronomy and one in the School of Engineering. Both will utilize the facilities available in the recently commissioned Institute for Compound Semiconductors based at the University's Translational Research Hub development on Maindy Road.

The agreement will also help to improve skills provision at postgraduate and doctoral levels of study, funding two postdoctoral researchers and at least six PhD students, with some drawn from under-represented groups.

"The close and focused partnership between IQE plc and Cardiff University has already delivered results, helping position south Wales as a leader in the field of semiconductor research and development," says professor Rudolf Allemann, head of the University's College of Physical Sciences and Engineering and Pro Vice-Chancellor, International. "Over the next five years, we will build on that success, with the partnership further benefiting industry and the regional economy."

Beyond the funding commitments, Cardiff University and IQE have also agreed to establish a Strategic Collaboration Committee, which will act to align R&D interests and establish a joint roadmap for future collaborative research. The committee will also evaluate external funding opportunities to leverage added value for joint activities.

"People are at the heart of innovation in the semiconductor industry and there is a recognised shortage of talent worldwide," notes IQE's CEO Americo Lemos. "By strengthening our partnership with Cardiff University, we are creating a talent pipeline for the benefit of IQE and the wider South Wales semiconductor industry to underpin growth," he adds. "By supporting university-level training and collaborating on research and development, together we will continue to build a resilient and competitive world-class compound semiconductor ecosystem."

The original collaboration between IQE and Cardiff University led to the creation of the Compound Semiconductor Centre (CSC), to focus on the commercialization of R&D in compound semiconductor materials and device technologies. The CSC uses research undertaken at Cardiff University to develop innovative new materials and technologies that aim to enable a range of new photonic and microelectronic applications, providing a complete capability chain from R&D through to product and process innovation, to high-volume manufacturing via IQE's global facilities.

"Since 2016, the CSC business model has delivered over £80m of collaborative research activity in compound semiconductor technologies for emerging applications in quantum systems, consumer electronics, future communications, and efficient electronics for net zero," notes CSC's founding director professor Wyn Meredith. "This agreement will allow CSC to accelerate commercialization of our IP, further extend our research and development roadmap, and steer doctoral-level training activity for the benefits of the local semiconductor industry."

www.cardiff.ac.uk/institute-compound-semiconductors

New board members from TSMC and GlobalFoundries

IQE plc of Cardiff, Wales, UK has appointed Bamdad (Bami) Bastani and Maria Marced to its board as independent non-executive directors from 1 January 2024, when Sir Derek Jones KCB steps down.

Bastani has spent seven years at GlobalFoundries, first as senior VP & general manager of the Mobile & Wireless Infrastructure business unit and then senior VP & senior advisor to the CEO. He also spent seven years as a board member of the Global Semiconductor Alliance (GSA) and has held president and CEO roles at Meru Networks, Trident Microsystems and ANADIGICS.

Marced is currently the president of Taiwan Semiconductor Manufacturing Company (TSMC) Europe, a role she has held for over 16 years. Prior to that, she held senior VP roles at NXP Semiconductors and spent 19 years as VP & EMEA general manager at Intel Corp.

"Together they bring decades of combined expertise in the global semiconductor industry," comments IQE's CEO Americo Lemos. "Their deep understanding of manufacturing excellence, technology leadership and customer centricity, coupled with their strategic management of business operations, will be instrumental in our continued growth and success," he believes.

Jones is stepping down as a non-executive director having joined the IQE board in December 2017. "His advisory oversight, operational perspective and financial understanding have been hugely valuable to the company throughout his tenure, and he will be missed," comments IQE's chairman Phil Smith. "We're also very pleased to welcome Bami and Maria, who will no doubt complement the diversity of expertise and experience on the IQE board."

www.iqep.com

EVG completes construction of Manufacturing V building at corporate HQ

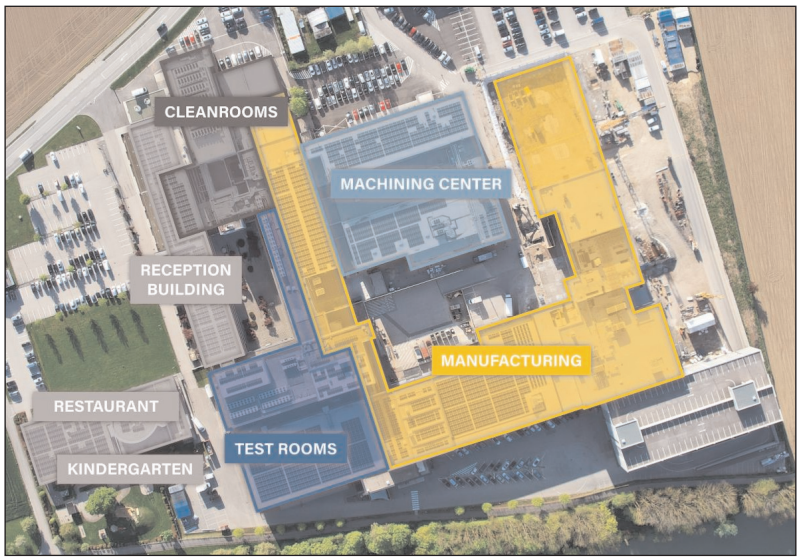
Extra 1200m² of production floor space and more than 1200m² of warehouse space

EV Group of St Florian, Austria — a supplier of wafer bonding and lithography equipment for semiconductor, micro-electro-mechanical systems (MEMS) and nanotechnology applications — has completed construction work for the next expansion phase of its corporate headquarters. The new 'Manufacturing V' facility, which is now open and serves as the manufacturing department for EVG equipment components, provides a significant increase in production floor and warehouse space.

The opening of the Manufacturing V facility is the latest in a series of expansion phases and investments driven by continued strong demand for EVG's hybrid bonding and other process solutions and process development services to support the rapidly growing advanced packaging and 3D/heterogeneous integration market.

The Manufacturing V facility adds more than 1200m^2 of additional production floor space (for a total of more than 8100m^2 of production area) and more than 1200m^2 of warehouse space. Two new floors of office space have also been added above the manufacturing floor. In parallel, the existing Manufacturing II building was converted to offer nine new test rooms for the final assembly & test of EVG's high-precision systems, as well as for technical source inspection of the systems by customers. This has resulted in a 30% increase in test room area, bringing the total test room space at EVG's headquarters to nearly 2800m^2.

The opening of the Manufacturing V facility follows the company's previous expansion phase, Manufacturing IV (completed at the end of last year), which itself added nearly 1800m^2 of production space and additional warehouse space.



Overhead view of EVG's corporate HQ. Source: EVG.

Since embarking on these two most recent growth phases, EVG has expanded its production capacity by more than 60%.

Manufacturing VI, EVG's next phase of expansion that provides for an additional 1400m^2 of production and an equal amount of warehouse space, is already under construction, with completion scheduled for second-half 2024.

"New applications fueling the semiconductor industry, such as AI, high-performance computing and autonomous driving, require massive innovations in advanced packaging," says Dr Werner Thallner, executive operations & financial director and member of the executive board. "As key process enablers for 3D/heterogeneous integration, fusion and hybrid bonding have been transformed into the new scaling mechanism for semiconductor manufacturing. EVG is at the forefront in developing fusion and hybrid bonding and other process solutions that our customers need to support their current and future capacity ramps as well as their long-term product roadmaps," he adds. "The growth in demand for our products over the years has led us to make major investments in expanding EVG's manufacturing and cleanroom capacity to meet our customers' evolving needs. We fully expect this demand growth to continue in the years ahead."

Heterogeneous integration solutions

EVG's wafer bonding, lithography and metrology solutions enable the development and high-volume manufacturing of technology innovations in advanced packaging — including backside-illuminated CMOS image sensors and other 3D-IC stacked devices — as well as in MEMS and compound semiconductors. Recent breakthroughs in hybrid bonding to address the needs for 3D device integration, wafer bond alignment technology to address future 3D-IC packaging requirements, IR laser release technology to eliminate glass substrates for advanced packaging and enable thin-layer 3D stacking, maskless exposure for fan-out wafer-level packaging (FOWLP), and nanoimprint lithography NIL and resist processing to support wafer-level optics (WLO) manufacturing, are just a few examples of EVG's technology for heterogeneous integration and wafer-level packaging.

www.EVGroup.com

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AXT's Q3 GaAs revenue hit by China export restrictions, offset by rebound in InP

First China export licenses received in second-half September, but inventory digestion to continue into 2024

For third-quarter 2023, AXT Inc of Fremont, CA, USA — which makes gallium arsenide (GaAs), indium phosphide (InP) and germanium (Ge) substrates and raw materials — has reported a further decline in revenue, from $18.6m last quarter to $17.4m, more than halving from $35.2m a year ago.

By product category, revenue for gallium arsenide has fallen further, from $8.1m a year ago and $5.4m last quarter to $4.2m.

"In September Tongmei, our subsidiary in China received initial export licenses and was able to resume shipping gallium arsenide substrates and germanium substrates in the second half of September to a number of our customers," says CEO Dr Morris Young. "We made good progress in filling customer orders and minimizing disruptions," he adds.

"We continue to work through that process on behalf of a growing number of our gallium arsenide customers," says vice president & chief financial officer Gary Fischer.

Germanium substrate revenue rebounded by $1.2m from last quarter's $1m, after receiving the export permits from China on behalf of customers and being able to ship accordingly. "The overall satellite solar cell market is navigating similar cyclical headwinds as the other markets. But we are confident that this area of our business will recover as the market strengthens," says Young.

Although it is still well down on $17.7m a year ago, indium phosphide revenue has rebounded from $4.6m last quarter to $4.9m, reflecting a stabilizing market with modest improvement in data-center applications.

"The demand environment in the third quarter of 2023 remained stable, and we were pleased to see some encouraging early signs of improvement in the data-center market, resulting in modestly higher indium phosphide revenue," says Young.

In addition, revenue was $7m 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 down slightly on $7.6m last quarter and $8.3m a year ago. "Overall, the pricing environment remains relatively stable. We don't expect any major changes in Q4," says Young.

Of total revenue in Q3/2023, the proportion from the Asia–Pacific region has rebounded further, from 75% last quarter to 82%, while Europe has fallen back further from 16% to 14% and North America from 9% to 4%.

The proportion of total revenue contributed by the top five customers has rebounded from 24% last quarter to 31%. Again, no customer comprised more than 10%.

On a non-GAAP basis, gross margin was 11.3%, down on 42.2% a year ago but up from 9.8% last quarter, driven by volume, product mix, and an improvement in raw material business gross margin.

Operating expenses were $7.8m, level with last quarter but cut from $9.2m a year ago. "With the reduction in overall revenue, we have maintained spending discipline in our operating expenses to align with the current environment," notes Fischer.

Net loss was $4.9m ($0.12 per share), up from $4.2m ($0.10 per share) last quarter and compared with net income of $6.8m ($0.16 per share) a year ago. Depreciation & amortization was $2.2m. Capital expenditure (CapEx) has increased from just $750,000 last quarter to $4m. During the quarter, cash and cash equivalents and investments hence fell from $49.6m to $43.6m.

Net inventory was reduced further, by $700,000 from $87.1m to $86.4m. Of the net inventory, 41% is raw materials, 55% is work-in-progress (WIP), and only 4% is finished goods. "We've looked at historic inventory levels when maybe we were doing $25–30m [in revenue] per quarter. We should be able to take inventory down. We should shrink it by at least $10m," says Fischer.

For Q4/2023, AXT expects revenue to be roughly level, at $16–19m. Net loss should grow to $0.13–0.15.

"As we navigate the near-term environment, we will continue to prioritize cost savings and efficiency, and are focused on accelerating our return to profitability," says Young.

"While inventory rationalization may persist into the New Year, we believe that the trends that have driven our revenue and customer expansion remain very much intact. Further, we have executed well in our development of larger-diameter substrates that will pave the way for our opportunities in next-generation devices spanning data-center, consumer and other markets," he adds.

"The market for gallium arsenide remains weak but stable… Inventory digestion is likely to continue into 2024. That said, we are actively preparing for a new wave of innovation in our markets," notes Young. "We are pleased by the progress we're making in our 8-inch gallium arsenide for customers. This consumer high-end display and automotive application

is for micro-LEDs… today our customers' specifications for micro-LEDs are exponentially more stringent than they were when our 8-inch development began. Yet we have been able to meet these requirements. We feel very confident in our ability to serve this emerging market. We believe that there will be a growing number of use cases in development. Our expectation is that product development from multiple customers is likely to ramp throughout 2024, with the first micro-LED products come into market in 2025 and beyond."

"As the data-center market prepares to move to 800Gbps data rates, we are seeing increased development around next-generation silicon photonics devices and electro-absorption modulation laser (EMLs) for high-speed data-center transceivers," notes Youg. "The growing adoption of AI technology is providing a strong catalyst for the industry transition to higher speed, and we are excited to be engaging with customers for new opportunities as the market expands. Our proven performance in optical devices for the data center, coupled with our success in developing 6-inch indium phosphide substrates, is putting us in a solid position for both current and future generations of data-center optical devices. We are also seeing positive development activities in both consumer and healthcare applications for indium phosphide. This further reinforces our conviction that we are very early stage in our adoption of this material across a multitude of emerging applications," he adds. "Our early success not only validates indium phosphide as the material of strategic importance, it validates AXT as a world-class supplier to tier-one companies. The next two years we'll see the further expansion into these and other areas."

"Beyond the near term, we r emain 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.

www.axt.com

STAR Market listing update

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.

www.axt.com

Riber receives order from Asia for two MBE 6000 production systems

Systems to produce HEMT epiwafers for mobile communications, plus antimony-based optoelectronic components for RF & optoelectronic communication

Riber S.A. of Bezons, France — which makes molecular beam epitaxy (MBE) systems as well as evaporation sources — says it has received a major order from an industrial customer in Asia for two MBE 6000 multi-wafer production systems, for delivery in 2024. The reactors will be used to produce high-electron-mobility transistor (HEMT) epiwafers for mobile communications, as well as antimony-based optoelectronic components for RF and optoelectronic communication devices.

Riber says that its MBE 6000 was selected for its high performance in producing superior quality heterostructure layers. The system's ability to operate in automatic mode for 24 hours a day, 7 days a week — combined with its very high reliability, with uninterrupted production rates of over ten months — will enable the customer to significantly increase its production capacity.

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

www.riber.com

Veeco's Q3 revenue and profits exceed guidance

Full-year 2023 revenue and profit guidance raised again

For third-quarter 2023, epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has reported revenue of $177.4m, up 10% on $161.6m last quarter and up 3.2% on $171.9m a year ago, driven by continued strength in the Semiconductor business and sequential growth in Data Storage business. This exceeded the $155–175m guidance range, after shipping one or two more systems than forecasted at the end of Q3 rather than the beginning of Q4. "Our on-time delivery for systems was, if not 100%, extremely close to 100%," notes CEO Bill Miller Ph.D.

After a record $106m in Q2, revenue from the Semiconductor segment (Front-End and Back-End, as well as EUV Mask Blank systems and Advanced Packaging) was a still strong $98m (56% of revenue), including shipping multiple laser spike annealing (LSA) systems to leading tier-1 logic and memory customers. "Shipments remained elevated during the quarter due to broad-based demand from logic and memory customers," says Miller.

The Data Storage segment (equipment for thin-film magnetic head manufacturing) contributed $34m (19% of revenue), up from $14m last quarter and $28m a year ago.

The Scientific & Other segment (research institutions and other applications) contributed $20m (11% of total revenue), up on $17m last quarter and $16m a year ago.

The Compound Semiconductor sector (Power Electronics, RF Filter & Device applications, and Photonics including specialty, mini- and micro-LEDs, VCSELs, laser diodes) contributed $26m (14% of revenue), down on $28m a year ago but up on $24m last quarter.

By region, the USA rose further, from 22% of revenue last quarter to 33%, due to an increase in shipments to Data Storage customers. Revenue from the Asia-Pacific (excluding China) region fell back, from 36% to 29% of total revenue due to a decline in Semiconductor sales following the significant increase in Q2. As forecasted, China fell further, from 31% to 23% of revenue. Europe, Middle-East & Africa (EMEA) returned to 15% of revenue, after a dip to 11% last quarter.

On a non-GAAP basis, gross margin has risen further, from 42% a year ago and 42.7% last quarter to 44.2% (exceeding the 42–43% guidance), positively impacted by higher volume and a more favorable product mix.

Operating expenses have risen further, from $43.9m a year ago and $44.8m last quarter to $45.7m, in line with the $45–47m guidance as the firm maintains its focus on cost management while also prioritizing investment for future growth opportunities.

Net income was $31m ($0.53 per diluted share), up from $20.6m ($0.36 per diluted share) last quarter and $26m ($0.45 per diluted share) a year ago, and exceeding the guidance range of $17–23m ($0.30–0.40 per diluted share).

Cash flow from operations has fallen further, from $11m last quarter to $7m. After being reduced to $4m last quarter, capital expenditure (CapEx) was increased to $6m. Overall, cash and short-term investments remained about $287m.

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

Inventory rose further, by $8m from last quarter's $244m to $252m, while days of inventory outstanding (DIO) fell from 225 days to 222 days, due to continued investment in the firm's evaluation program and to support revenue growth in second-half 2023.

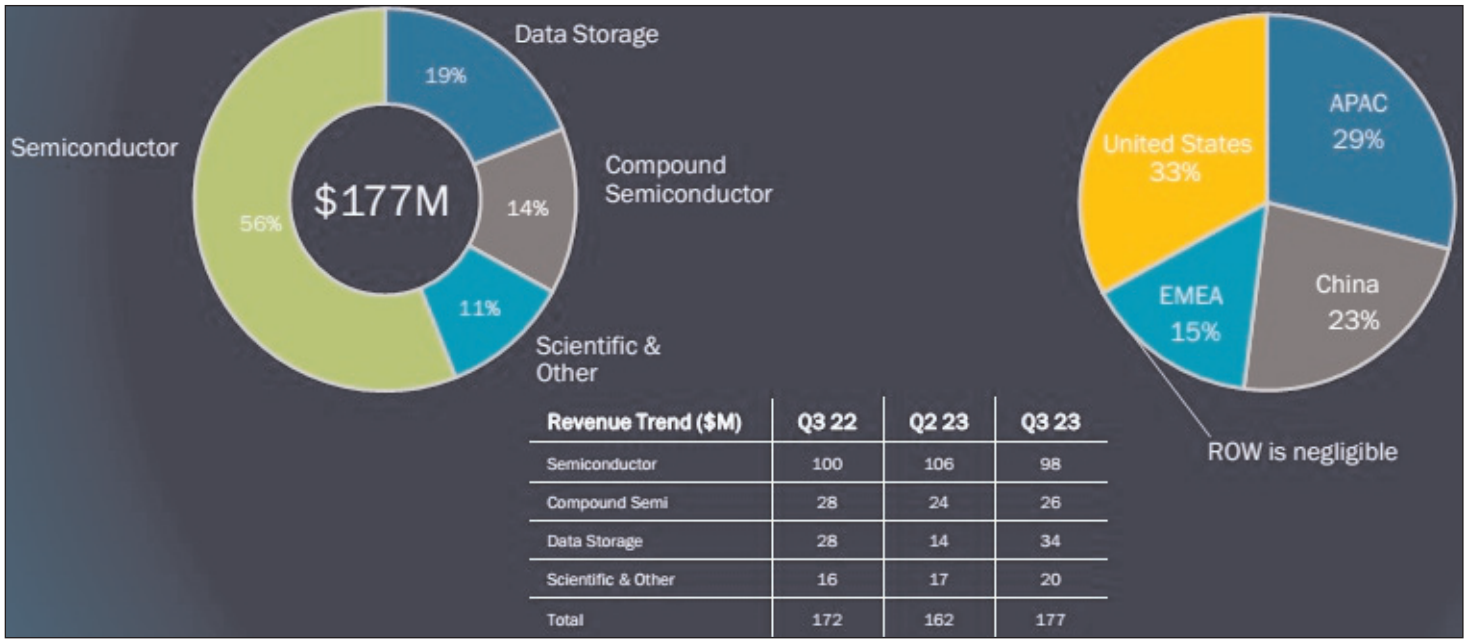
"Veeco reported another quarter of strong top- and bottom-line results, both above the high-end of our guidance," comments Miller. "In addition, our strategic initiative to grow in the Semiconductor market continues to gain traction."

"Veeco's laser annealing technology is growing in criticality at our customer's most advanced nodes as traditional technology struggle to meet performance requirements. For example, new gate-all-around architectures and shrinking devices require precise higher-temperature annealing technology to increase performance and minimize damage," says Miller. "In comparison to traditional lamp approaches, our laser annealing system has several advantages. These include a lower thermal budget, higher dopant activation, and pattern insensitivity to annealing. Veeco's laser annealing system continues to be adopted by new and existing customers for new applications, with recent wins validating our position," he adds. "Looking ahead, we're focused on gaining further adoption in new markets and applications."

In particular, Veeco had several key business wins during the quarter. The firm received its first laser annealing system order for a new application to serve the automotive market. It also received its first low-defect-density (LDD) ion beam deposition (IBD) system order for a new extreme ultraviolet (EUV) pellicle mask blank application.

"We continue to make progress with our nanosecond annealing and ion beam deposition products for wafer-level semiconductor manufacturing," says Miller.

Veeco shipped its first nanosecond annealing system to a tier-1 logic customer, for one-year evaluation. "Pull from tier-1 logic and memory customers is strong, and we plan another evaluation shipment in the coming months," says Miller. "If successful, [this] can significantly expand our served available market… We see potential for initial high-volume manufacturing orders in late 2024 or 2025," he adds. "Compared to traditional annealing



Revenue Trend ($M)	Q3 22	Q2 23	Q3 23
Semiconductor	100	106	98
Compound Semi	28	24	26
Data Storage	28	14	34
Scientific & Other	16	17	20
Total	172	162	177

solutions, our nanosecond annealing system can achieve a lower thermal budget enabled by a dwell time that can be up to 1000 times shorter than today's most advanced anneals. Our nanosecond annealing system can rapidly heat the surface of the wafer and only affect tens to hundredths of nanometers into the wafer. This may enable new applications such as backside power delivery, and contact anneal for advanced nodes. It also may enable new applications requiring material modification such as void removal, recrystallization, and grain growth," Miller says. "After working on the technology for a number of years, this as an important milestone in expanding laser annealing into a broad range of new Semiconductor applications," he adds.

"Veeco's low-defect-density ion beam deposition system is the technology of choice to deposit defect-free films for EUV mask blank production, and we are well positioned to serve growing demand from adoption of EUV lithography," reckons Miller. "While we continue to see this market at about 3–5 systems per year [at a rate of one Veeco system for every 10–15 EUV lithography scanners shipped by ASML], we see potential to expand our business beyond the current application space in areas such as pellicle deposition."

"In advanced packaging, our wet processing solutions are used for photo-resist strip, solvent cleans and flux removal for high-bandwidth memory and temporary bond material strip," says Miller. "During the quarter, leading foundry and memory customers placed orders for several Flux Clean systems that support advanced packaging for AI."

For fourth-quarter 2023, Veeco expects revenue of $155–175m (including about $105m in the Semiconductor segment). Gross margin should fall slightly to 43–44%. With operating expenses of $45–47m, the firm forecasts a decline in net income to $20–27m ($0.35–0.45 per diluted share).

"We expect an increase in China revenue in Q4 [to the high-30% range of total revenue] as customers are continuing to make investments in several areas for mature nodes," says senior VP & chief financial officer John Kiernan. Full-year revenue from China is expected to rise to the low-30% range (compared with about 20% over the past couple of years), driven mostly by the laser annealing product line.

Full-year 2023 revenue guidance has now been tightened and increased from the prior range of $630–670m to $648–668m (up on 2022's $646.1m), including about $405m in the Semiconductor segment. "Based on our strong year-to-date results and outlook, we expect our Semiconductor business to outperform the wafer fab equipment (WFE) market and be up about 10% for the year," says Miller.

Previously, in August, Veeco raised its full-year gross margin guidance from 41–42% to 42–43%. "We are again raising our profitability outlook for the year to account for higher revenue, stronger gross margin, and lower tax rate," says Kiernan. So, after in August raising its guidance for diluted earnings per share (EPS) from $1.15–1.35 to $1.30–1.50, Veeco has now raised this to $1.55–1.65 (versus $1.57 for 2022).

Based on market conditions and visibility, Q1/2024 revenue is looking to be in a similar range to quarterly revenue in second-half 2023.

In the Compound Semiconductor segment, Veeco reckons the market for epitaxy equipment provides a substantial growth opportunity.

"We are on track with our plan post our silicon carbide [chemical vapor deposition] epi equipment company acquisition [of Epiluvac AB of Lund, Sweden] in January," says Miller. "We have a tool operating in Somerset, New Jersey. We are running films. We've demonstrated high growth rate, we've demonstrated good film quality, good uniformity, morphology etc, and we are building out our demo bingo sheet, if you will, and making progress there. Our plan is to be

demo ready by year-end, so we are feverishly working toward that with the goal of putting a few silicon carbide evaluation systems out in the field next year," he adds. "Because I feel we're on track with the original plan we laid out, we've spoken to a lot of tier-1 customers in the industry," continues Miller. "Interest in our single-wafer solution is strong, with several evaluation shipments to tier-1 customers planned for next year. Looking ahead, our unique system design, years of experience with epitaxy technology and extensive go-to-market infrastructure, position us well to capture share," he reckons.

"Likewise, we are also investing in GaN power and micro-LED, as the long-term fundamentals in these markets remain positive," says Miller.

"We have a long-term opportunity to capitalize on growing demand in the compound semiconductor equipment market for power electronics and photonics applications," he concludes.

www.veeco.com

CVD Equipment's Q3 revenue down 23.2% year-on-year due to lower system revenue

For third-quarter 2023, CVD Equipment Corp of Central Islip, NY, USA (a designer and maker of chemical vapor deposition, thermal processing, physical vapor transport, gas and chemical delivery control systems, and other equipment and process solutions for developing and manufacturing materials and coatings) has reported revenue of $6.2m, up 21.6% on $5.1m last quarter but down 23.2% on $8.1m a year ago due mainly to lower system revenue.

However, as a result of a modification to certain customer contracts, revenue recognition for certain contracts changed from 'point in time' to 'over time'. The firm hence recorded an increase in revenue of $0.8m during Q3/2023 that was deferred as of 30 June and recognized on the date of the contract modification.

"Our order and revenue levels have historically fluctuated, which is often typical in the highly cyclical process equipment industry. While we saw a year-over-year decline in third-quarter revenue of $1.9m, our year-to-date 2023 revenue of $20m was 7.6% higher than [the $18.6m of] the corresponding period in the prior fiscal year," notes president & CEO Emmanuel Lakios. "While we are disappointed with our third-quarter revenue, we continue to see opportunities in key strategic markets of high-power electronics, battery materials/energy storage and aerospace & defense," he adds.

Gross margin was consistent with recent quarters at 25.6%, but less than 29.8% a year ago due principally to lower revenue and changes in contract mix.

Operating loss was $0.99m, compared with an operating profit of $0.12m a year ago.

Net loss has been cut from $1.1m ($0.16 per share) in Q2/2023 to $0.75m ($0.11 per share) in Q3/2023, but this compares with net income of $63,000 ($0.01 per share) a year ago. Cash and cash equivalents at the end of Q3/2023 was $14.29m.

Order intake was $4.1m in Q3/2023, including about $2m from continued demand from the aerospace sector, expected to be delivered over the next 12 months. Also contributing were orders of about $0.9m from research institutions. Nevertheless, during Q3/2023 order backlog fell from $18.8m to $16.6m.

CVD Equipment continues to make investments in both R&D and sales & marketing, focused on the firm's three key strategic markets.

In the high-power electronics market, there were no PVT150 system orders received in the first nine months of 2023. The firm expanded its marketing efforts, including direct outreach to multiple potential customers as well as attendance at key silicon carbide-related trade shows and conferences including the International Conference on Silicon Carbide and Related Materials (ICSCRM 2023) in September. The engaged customers include both silicon carbide wafer manufacturers as well as fully integrated wafer and device manufacturers. "The success of our PVT150 and PVT200 systems marketing efforts is dependent on the performance of our equipment in the field, overall market conditions, our customers' ability to qualify their end product with their customers, and our customers' ability to obtain the funding necessary to purchase our equipment," says CVD Equipment.

During Q3/2023, Ms Deb Wasser and Dr Ashraf Lotfi were added to the board of directors. Wasser brings extensive experience in corporate governance and financial communications. Lotfi brings an in-depth knowledge of the power electronics market.

On 8 August, CVD Equipment entered into a purchase and license agreement with a third party to sell certain assets and license certain proprietary information of MesoScribe in exchange for $0.9m, payable in several installments and contingent upon certain performance metrics and other milestones. The firm expects the transaction to be completed in Q4/2023 with the shipment of the equipment to the purchaser.

"We remain committed to stay the course on our strategy to achieve consistent long-term profitability, with a focus on growth and return on investment," says Lakios. "Our return to profitability is subject to our ability to receive additional system orders and continue our efforts to reduce our overall operating costs."

www.cvdequipment.com

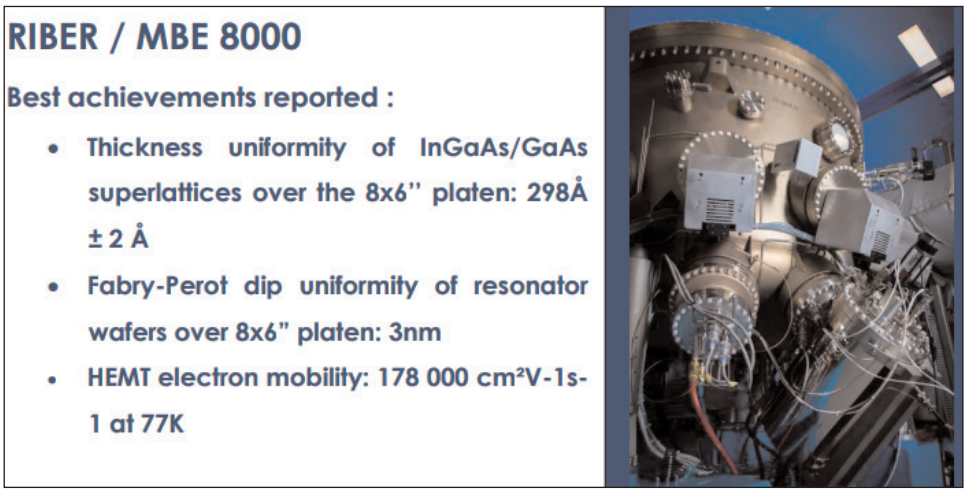
Riber launches MBE 8000 for epiwafer mass production

Productivity doubled versus existing products

Riber S.A. of Bezons, France — which makes molecular beam epitaxy (MBE) systems as well as evaporation sources — has announced final qualification of its MBE 8000 production platform by leading US epitaxial wafer manufacturer.

The MBE 8000 is claimed to deliver twice the productivity of existing products on the market while enabling outstanding performances. The flexibility of MBE technology enables the MBE 8000 to address all compound semiconductor growing markets from vertical-cavity surface-emitting lasers (VCSELs), transistors and sensors requiring a high level of performance in terms of uniformity, reproducibility, and stability.

The system is capable of growing batches of eight 150mm (6-inch) or four 200mm (8-inch) wafers, increasing capacity by 50% over the existing products. As cell design, system geometry and process control are identical, it ensures process transfer within a minimum of time and easy handling for Riber machine operators.



The final qualification step has validated the MBE 8000 in terms of process, robustness, stability, ergonomics, and control. As an example, defect density over 30 runs is less than 50 particles per cm^2 measured on a VCSEL-type structure for particles of 0.8–8µm.

With an optimum cost of ownership and large capacity, Riber reckons that the MBE 8000 system presents strong prospects for business development in the future.

www.riber.com/product/mbe-8000

Aixtron's Q3 revenue and earnings up year-on-year

Demand driven SiC and GaN power electronics

For third-quarter 2023, deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany has reported revenue of €165m, down 4.9% on €173.5m last quarter but up 86% on €88.9m a year ago.

For the first nine months of the year, revenue grew 49% year-on-year from €279.9m in 2022 to €415.7m in 2023 (with 84% coming from equipment sales and 16% from after-sales service & spare parts).

SiC and GaN drive revenue

Metal-organic chemical vapor deposition (MOCVD)/chemical vapor deposition (CVD) systems for making efficient gallium nitride (GaN)- and silicon carbide (SiC)-based power electronics devices comprised 82% of equipment revenue in the first nine months of 2023 (€286.4m, up from just 37% in the first nine months of 2022, with SiC growing strongly). "The comparative figures from 2022 underline how strongly the demand in this area has picked up," notes Aixtron.

MOCVD systems for making optoelectronics devices (telecoms/datacoms and 3D sensing lasers for consumer electronics, solar, and wireless/RF communications) comprised 11% of equipment revenue in the first nine months of 2023 (down year-on-year from 36%). MOCVD systems for making LEDs comprised just 6% (down from 25%).

On a regional basis for the first nine months of 2023, 44% of revenue came from Asia (down year-on-year from 66%), 33% from Europe (up from 16%) and 23% from the Americas (up from 17%).

Operating profit doubles year-on-year

Due to the improved product mix, gross margin was 46% in Q3/2023, up from 42% in Q2/2023 and 44% a year ago. For the first nine months of the year, gross margin rose from 40% in 2022 to 43% in 2023.

With a strong focus on R&D, quarterly operating expenses have risen further, from €23.1m in Q3/2022 and €28.9m in Q2/2023 to €30.9m in Q3/2023. OpEx for the first nine months of the year were consequently up by 34% from €65.4m for 2022 to €87.4m in 2023, due mostly to R&D costs rising by 44% from €41.4m to €59.8m.

Quarterly operating profit (earnings before interest and taxes) has improved from €16.2m (18% margin) in Q3/2022 and €44.6m (26% margin) in Q2/2023 to €45.3m (EBIT margin of 27%) in Q3/2023. This drove EBIT for the first nine months of the year to almost double, from €47.6m (17% margin) in 2022 to €93.4m (22% margin) in 2023.

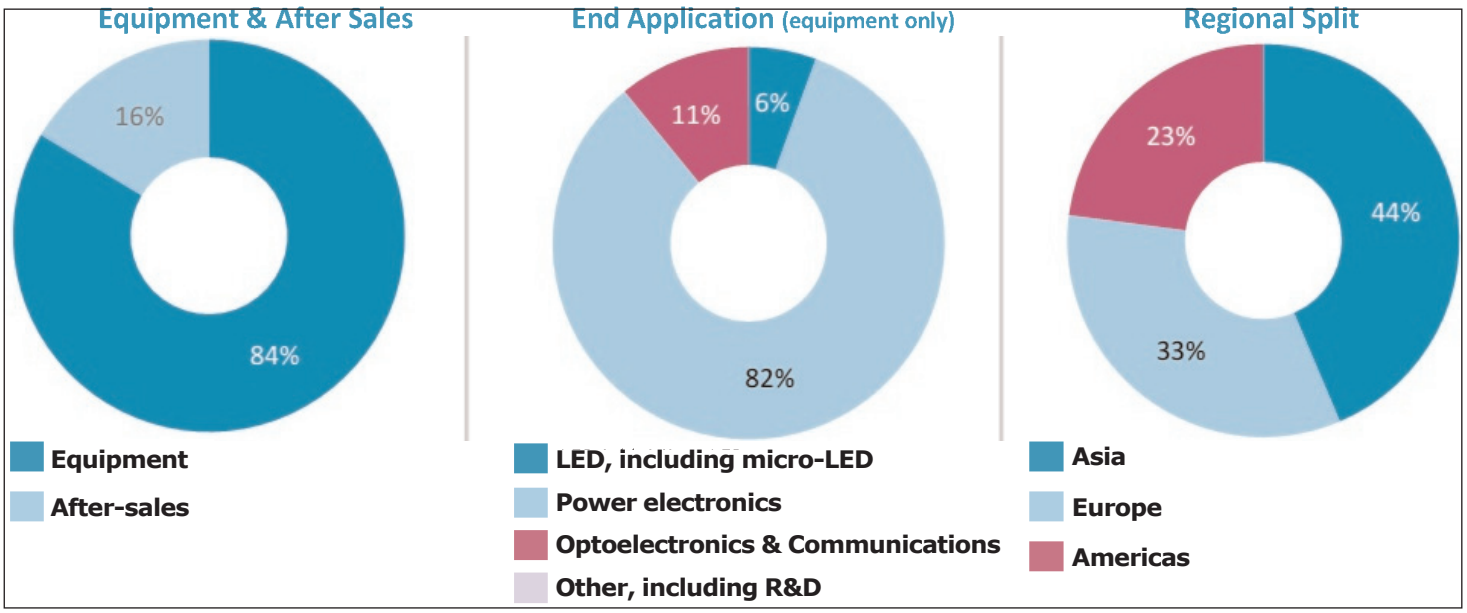
Inventories increased prior to expected rise in volume

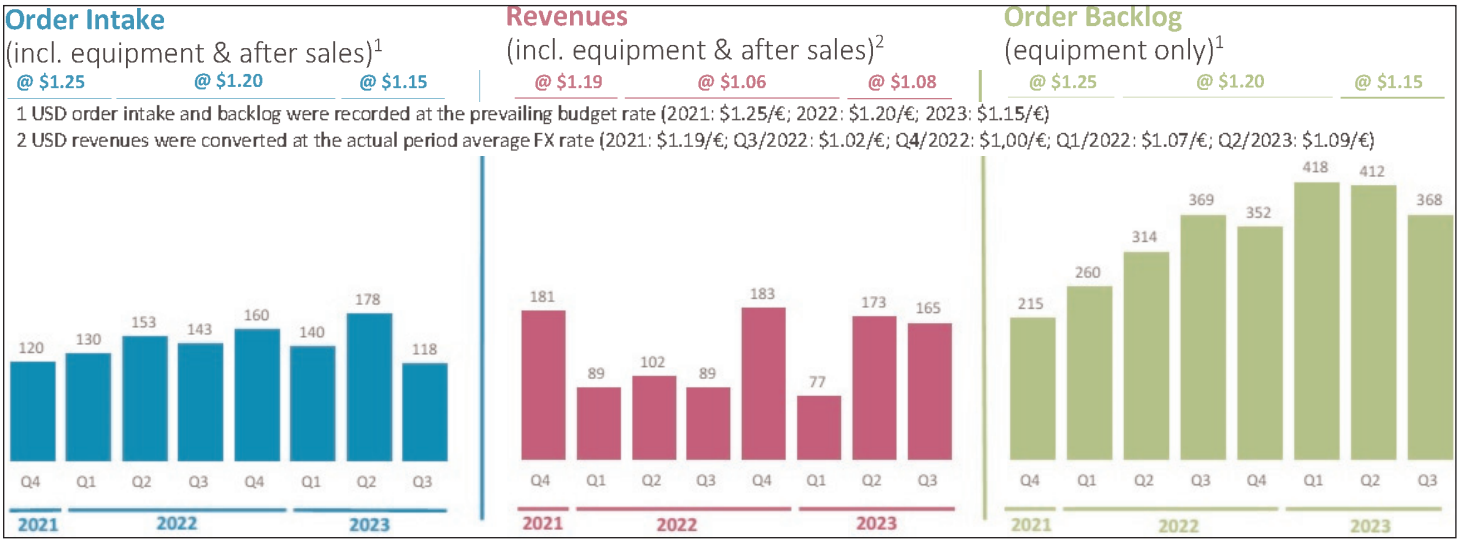
Free cash flow for the first nine months of the year has gone from €20.4m in 2022 to –€82.3m in 2023, but this was driven primarily by an increase in inventories from €223.6m to €380.5m in preparation for the correspondingly high business volume expected in the following quarters. Most recently, quarterly free cash flow has improved from –€82m in Q2/2023 to –€2.2m in Q3/2023.

Including the increase in inventories and the dividend of €34.8m paid in May, cash and cash equivalents (including other current financial assets) hence fell during the first nine months of 2023 from €325.2m then €210.4m at the end of Q2 to €209.9m. However, underlining the firm's financial strength, the equity ratio has risen further, from 73% to 76%. Reflecting Aixtron's strongly growing core business, full-time-equivalent staffing has grown by 26% year-on-year, from 842 to 1057.

New G10-GaN completes G10 product generation

A key factor in Q3/2023's strong performance was that in September Aixtron completed its G10 product portfolio by adding to the G10-SiC system (for SiC-based power electronics) and the G10-AsP system (for micro-LED and laser devices)





with the launch of the G10-GaN, a compact cluster system that can be equipped with up to three process modules, giving record capacity of 15x200mm wafers. The system offers much improved material uniformities, extended uptime, reduced cleanroom footprint and a cost reduction of more than 25% per wafer compared with previous products and all competitors, it is reckoned. In Q3/2023, Aixtron received orders for the G10-GaN from many existing customers as well as new customers. The firm expects the G10-GaN to generate more than 50% of its total GaN revenues in 2024.

Order intake to resume growth in Q4/2023

Order intake for the first nine months of year grew by a further 2% year-on-year, from €425.6m in 2022 to €436.2m in 2023. This is despite Q3/2023's €118.5m being down on €177.8m in Q2/2023 and down 17% on €142.8m in Q3/2022.

Equipment order backlog correspondingly fell during Q3 from €412.5m to €368m, but this is on a par with €369.4m a year ago.

However, as demand for efficient power electronics in particular remains strong, Aixtron expects a correspondingly higher order intake in fourth-quarter 2023.

Increased full-year growth guidance confirmed

Due to the unabated strong demand, the executive board expects the strong growth — especially for efficient power electronics — to continue for the remainder of 2023. Accordingly, Aixtron says that it is fully on track to achieve its recently raised guidance for full-year 2023.

Order intake is expected to be €620–700m (raised in late July from prior guidance of €600–680m), which would be up about 11% on 2022's €585.9m (based on the budgeted exchange rate of $1.15/€ for 2023, versus $1.20/€ in 2022).

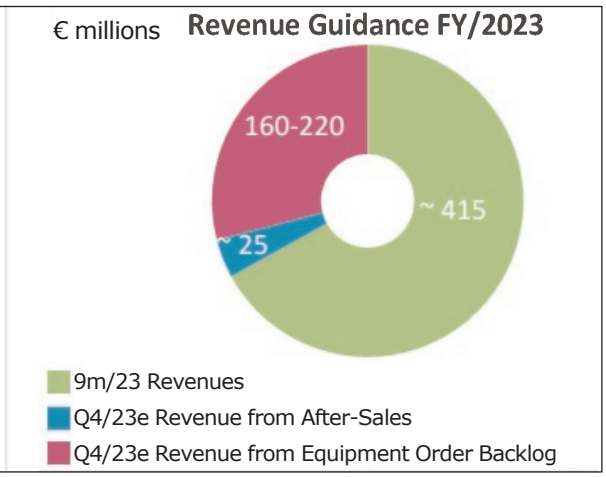
Based on revenue in the first nine months of 2023 of €415.7m, plus equipment order backlog (convertible into 2023 revenue) of €160–220m as of end-September, joined by a forecasted €25m in after-sales revenue, the forecast for full-year revenue is €600–660m (raised from the prior guidance of €580–640m), which would be up about 36% on 2022's €463.2m.

Aixtron continues to expect gross margin of about 45% and EBIT margin of 25–27%.

"Our technology enables the leading global megatrends of electrification and digitalization as well as renewable energies," notes chief financial officer Dr Christian Danninger. "In all these areas, wide-bandgap materials such as SiC and GaN will become the mainstream technology and, with our products, we are playing a decisive role in supporting and enabling the roll-out of these energy-efficient solutions."

www.aixtron.com

FY/2023 Guidance	
Total Order Intake	EUR 620m – 700m
Revenues	EUR 600m – 660m
Gross Margin (%)	Around 45%
EBIT Margin (%)	25% – 27%



Aixtron to deliver G10-GaN MOCVD system to BelGaN by end-2023

Belgian gallium nitride foundry adds epi to GaN processing line

Deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany says that it is enabling automotive-qualified gallium nitride (GaN) open foundry BelGaN of Oudenaarde, Belgium to expand its business into the growing GaN market and to accelerate GaN technology innovation. For this strategic step, BelGaN is relying on Aixtron's new G10-GaN metal-organic chemical vapor deposition (MOCVD) system, which offers what is claimed to be best-in-class performance, an all-new compact design, and overall lowest cost per wafer. Starting with an 8x150mm-wafer configuration, the system will be delivered to BelGaN before the end of 2023 and will in the future migrate to 5x200mm.

The fab in Oudenaarde started as MIETEC in 1983, was acquired by Alcatel in 1990 then AMI Semiconductor in 2002, and sold to ON Semiconductor in 2008. The team there started GaN development in 2009 and has been building expertise in production of automotive semiconductors for over 30 years.

Established in September 2021, BelGaN acquired what was ON Semiconductor Belgium BV from onsemi in early 2022, The site in Oudenaarde has since been transforming from a silicon fab to a GaN fab. BelGaN recently announced the production start of its first-generation 650V eGaN technology. The Gen1 platform is designed for the requirements of energy-efficient applications for sustainability and carbon neutrality.

The G10-GaN will be used to further extend the range of power chips with voltage ratings from 40V to 1200V, using GaN-on-Si, GaN-on-SOI, and novel GaN-on-engineered substrates. It will be applied both on lateral as well as vertical power-GaN products, with a focus on high performance, automotive quality and reliability, high yield, and low costs.

"GaN epitaxy using MOCVD is a most critical process in any power-GaN technology, both to innovate device architectures, boost performance, yield and quality, and to cut down the cost of GaN products. This drives a paradigm shift in power electronics, opening up fast-growing markets in e-mobility, datacom, energy conversion etc, on a road to an electrified, carbon-neutral society," says Dr Marnix Tack, BelGaN's chief technology officer & VP business development. "We have been impressed by the high levels of productivity, uniformity and low cost of ownership of Aixtron's new G10 platform… The proximity of Aixtron, in the midst of the GaN Valley ecosystem, and the collaboration with its team is essential for us to rapidly achieve our innovation and production objectives," he comments. BelGaN is the founder of the GaN Valley ecosystem, gathering over 55 firms and research institutes active along the GaN value chain in Europe.

"GaN power devices are rapidly adopted in a wide range of applications, and many customers are adding GaN capabilities to their silicon lines," notes Aixtron's CEO & president Dr Felix Grawert.

Launched in September, the G10-GaN cluster solution builds on the fundamentals of Aixtron's existing tool of record, the G5+ C, while extending each performance metric: the new platform delivers twice the productivity per cleanroom area while enabling greater material uniformities. Cost of ownership is reckoned to be more than 25% lower than for any other equipment on the market. The G10-GaN also guarantees the highest throughput per m^2/cleanroom and, with full automation end-to-end, it is claimed to be the only MOCVD system fully designed for silicon fabs.

www.belgan.com
www.aixtron.com
www.ganvalley.org

Aixtron begins constructing €100m innovation center

First systems to be installed in second-half 2024, for official handover in early 2025

Deposition equipment maker Aixtron SE has officially begun construction of the new innovation center at its headquarters in Herzogenrath, Germany. The firm is investing about €100m in 1000m^2 of cleanroom, with additional space for the required metrology equipment. The first systems are scheduled to move into the new building during second-half 2024. The official handover is planned for early 2025.

A symbolic ground-breaking ceremony was attended by representatives from politics, science and research as well as key suppliers of the company, in the context of a celebration in honor of Aixtron's 40th year since its founding in December 1983 as a spin-off from RWTH Aachen University.

"We have just completely renewed our portfolio with our successful G10 product family. The demand from our customers is already very high, so we are in the middle of a volume ramp," says Aixtron's CEO Dr Felix Grawert. "We are now also starting to work on the next generation of innovative technical solutions. With this, we will successfully drive forward the electrification of the world with the megatrends of digitalization, electromobility, and energy efficiency," he adds. "The new innovation center provides us with essential capacities for all of this."

The cleanroom area of the innovation center will be of class ISO 6, expandable up to ISO 4. The new complex will have two sub-levels. The first sub-level accommodates, for example, the pump filter cabinets of the systems, while the facility level houses all supporting processes and systems for the entire infrastructure. This type of space utilization increases cleanroom efficiency by a factor of up to three compared with the previously used cleanroom areas.

www.aixtron.com

OIPT wins orders from Japanese HEMT foundries

ALE with Etchpoint plus ALD optimized for GaN-surface plasma pre-treatment to support power electronics and RF markets

Oxford Instruments Plasma Technology (OIPT) of Yatton, near Bristol, UK says that it has received significant orders for plasma atomic layer deposition (ALD) and atomic layer etch (ALE) systems for gallium nitride (GaN) high-electron-mobility transistor (HEMT) device production from several market-leading Japanese foundries. The systems will support high-growth GaN power electronics and radio frequency markets, with consumer fast-charging and data-center applications at the forefront for power electronics, and 5G/6G communication applications for the RF market.

Oxford Instruments says that its ALD technology delivers high-throughput, low-damage plasma processing with enhanced film and interface quality, and is positioned globally at market-leading GaN HEMT device manufacturers. Its ALE solution for p-GaN HEMTs is production-qualified and combines low-damage etching with what is claimed to be unmatched accuracy with Etchpoint, a unique end-point detection collaboration with in-situ metrology system maker LayTec AG of Berlin, Germany.

Etchpoint, an exclusive collaboration between Oxford Instruments and LayTec, allows automated switching from standard high-rate etch processing to low-damage ALE to support improved device reliability. In addition, ALE enables partial aluminium gallium nitride (AlGaN) recess etches with a critical target depth, to an unparalleled accuracy of ±0.5nm, for next-generation GaN MISHEMT E-mode device functionality. These technologies can be clustered on an automated handler that enables multi-chamber processing without breaking vacuum, which can potentially improve device performance and deliver more good wafers per day at lower cost.

"Japan is delivering a significant ramp in GaN HEMT production for key power electronics and RF markets, and we are benefitting from this by expanding our install base at existing and new customers," says GaN product manager Dr Aileen O'Mahony. "It is exciting to see our implemented at leading Japanese and global GaN HEMT manufacturers," she adds. "Our complete GaN HEMT solution is designed to solve complex customer device challenges, with production-class throughput, reliability and up-time."

www.semiconjapan.org
www.plasma.oxinst.com

Centrotherm clean solutions acquired by Busch

Vacuum pump and systems maker Busch Vacuum Solutions of Maulburg, Germany has acquired industrial gas abatement systems firm centrotherm clean solutions. It joins recent acquisition Pfeiffer Vacuum as part of the Busch Group.

"The acquisition of centrotherm clean solutions is a crucial step in our long-term strategy to advance sustainable technologies and solutions together with Pfeiffer Vacuum," says Busch Vacuum Solutions' co-CEO & co-owner Sami Busch. "The innovative gas abatement systems from centrotherm clean solutions are a perfect addition to the Busch and Pfeiffer Vacuum product portfolio. Integrating the companies under one umbrella will enable us to serve our customers even better in the future and offer complete sustainable vacuum solutions. Additionally, the companies already collaborate successfully on individual projects in the field of service. Therefore, the customers of centrotherm clean solutions will also benefit from our worldwide service network in more than 45 countries."

Centrotherm clean solutions manufactures gas abatement systems, which are primarily used in the semiconductor industry but also, for example, in the production of MEMS, LEDs, solar cells, and flat panel displays. In addition to industrial customers, the firm also has customers within research institutions and universities. Products include standardized gas abatement systems as well as individual customized systems. With dry bed absorbers, wet scrubbers, thermal gas treatment systems and particle filters, the product range includes all common gas abatement technologies.

With headquarters in Blaubeuren, Germany, centrotherm clean solutions is present at other locations throughout Europe, and in America and Asia. It employs over 300 people worldwide. Busch has confirmed that centrotherm's headquarters and production site in Blaubeuren, as well as all worldwide locations and jobs, will be retained following the acquisition.

"Centrotherm clean solutions has achieved significant growth thanks to its technological leadership in recent years. In order to continue this successful development, a strategic partner is of great benefit," emphasizes the founder and former owner of centrotherm clean solutions, Robert Hartung. "I found this partner in the Busch family and their company Busch Vacuum Solutions. The technologies and products from Busch, Pfeiffer Vacuum and centrotherm clean solutions complement each other perfectly. The timing of the acquisition is just right, as the companies can now strategically prepare for upcoming investments in new semiconductor factories."

www.buschvacuum.com
www.centrotherm-cs.de

Panalytical acquires Freiberg x-ray diffraction product line

Spectris group firm Malvern Panalytical of Malvern, UK, a supplier of analytical instrumentation, has acquired the product line for six x-ray diffraction (XRD) products from Freiberg Instruments GmbH.

Founded in 2005 as a university spin off from TU Bergakademie — University of Resources, Freiberg Instruments' products cover a broad spectrum of applications in fields such as semiconductor, microelectronics, photovoltaic, dosimetry, medical research, luminescence dating, x-ray diffraction and material research.

As semiconductor manufacturing relies on a variety of crystalline substrate materials that are required to create thin wafers, as production processes become more advanced, and production volumes continue to grow, these wafers need to be produced quickly and efficiently, and precise crystal orientation and offcut angles are increasingly important, says Malvern Panalytical. The acquired XRD systems allow rapid orientation of ingots and wafers, accelerating and simplifying the preparation of semiconductor substrates before epitaxy or lithography. This enhances yield, minimizes waste and reduces costs which supports our customers' sustainability ambitions, adds the firm.

"The addition of these specialized products to our analytical portfolio enables innovative crystal orientation control. When combined with Malvern Panalytical's global presence and expertise, this provides a significant boost to the semiconductor wafer industry," says Lars Grieger, business development manager of Semiconductor Metrology at Malvern Panalytical.

"Our XRD solutions, with their ultra-fast Omega Scan technology, have consistently demonstrated their value to semiconductor manufacturers. Their speed, robustness, and reliability make them an excellent addition to Malvern Panalytical's portfolio and I'm excited to see these unique technologies made available to customers across the globe,"says Freiberg Instruments' CEO/owner Kay Dornich. "We will continue to support our existing customers and maintain our offering of specialized solutions, including those for automated workflows, which complement Malvern Panalytical's newly acquired x-ray diffraction instruments."

"The acquisition of these six x-ray diffraction instruments from Freiberg Instruments GmbH underpins our commitment to our semiconductor customers and demonstrates our desire to become the chosen instrument supplier within this exciting area of analysis," says Panalytical's president Mark Fleiner.

www.malvernpanalytical.com

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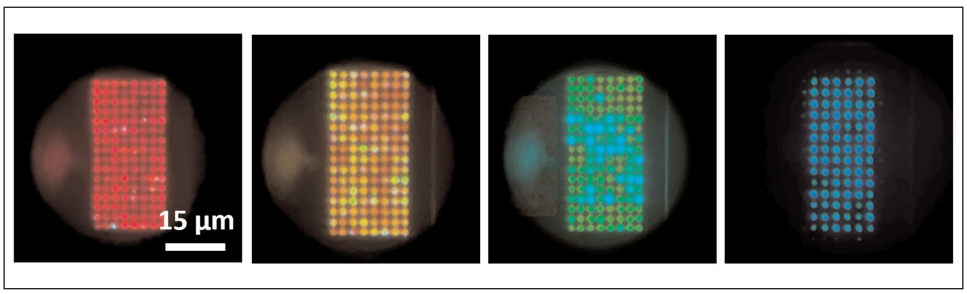
Q-Pixel develops smallest full-color pixel and demos first 10,000PPI full-color micro-LED display

Micron-diameter tunable polychromatic light-emitting diode technology an alternative to RGB LED subpixels

Q-Pixel Inc of Los Angeles, CA, USA has developed what it claims is the world's smallest full-color pixel and demonstrated it in the first ever 10,000PPI, full-color micro-LED display (surpassing the firm's previous record 5000PPI full-color display, announced in May).

Resolution of 10,000PPI has previously been exhibited only in monochromatic, single-color displays. However, for the first time, Q-Pixel has achieved 10,000PPI resolution in full color using its proprietary tunable polychromatic light-emitting diode (TP-LED), which can emit the full range of visible light within a single pixel. Using TP-LED, Q-Pixel now has the unique capability of fabricating extremely small, fully color-tunable single pixels with diameters as small as 1μm.

Micro-LED technology offers several key benefits over existing OLED and LCD display technologies, notably, longer lifetime, superior brightness and energy efficiency. However, the complex, costly and labor-intensive process of assembling full-color micro-LED displays using monochromatic red, green and blue (RGB) LED subpixels remains a major barrier to both high-resolution displays and commercially viable displays. Ultra-high-resolution, full-color displays are especially sought after for near-eye applications, such as those used in augmented-reality/virtual-reality (AR/VR) devices.



Q-Pixel reckons that showcasing the smallest full-color pixel and 10000PPI full-color display highlights the advantages of TP-LED pixel technology over RGB micro-LED subpixels.

The results were presented in the TechBlick event 'Mini- & Micro-LED Displays: Markets, Manufacturing Innovations, Applications, Promising Start-ups' on 29–30 November.

www.quantum-pixel.com
www.techblick.com/event/microled2023

Q-Pixel joins Silicon Catalyst to accelerate full-color micro-LED display development

Semiconductor incubator's ecosystem to aid engagement with clients

To accelerate development of its full-color displays manufactured with tunable polychromatic LEDs, fabless micro-LED display innovator Q-Pixel Inc of Los Angeles, CA, USA has joined Silicon Valley-based Silicon Catalyst, the world's only incubator focused exclusively on accelerating early-stage semiconductor hardware companies.

Q-Pixel has developed a single LED pixel that can be tuned across the full color spectrum rather than requiring three pixels (red, green, blue) to achieve full color. This enables Q-Pixel's displays to deliver higher resolution and more brightness with less power consumption and lower cost, it is claimed. Earlier this year, Q-Pixel demonstrated the highest micro-LED density in the world, the firm adds. Its technology targets high-resolution displays for screen sizes ranging from personal (smartphones and wearable devices) to large (greater than 100 inch).

The Silicon Catalyst ecosystem — which includes a coalition of in-kind and strategic partners that reduce the cost and complexity of development along with a network of experienced advisors that coach and connect startup entrepreneurs — helps early-stage semiconductor hardware companies to address the challenges of moving from idea to realization while simultaneously de-risking the companies for investors.

"Q-Pixel is delighted to join Silicon Catalyst as a portfolio company. We expect their extensive ecosystem will help us engage with customers and build a profitable business around our technology," says Q-Pixel's co-founder & CEO J.C. Chen.

"We are impressed with the company's vision and progress," comments Silicon Catalyst's chief operating officer Nick Kepler. "Our comprehensive ecosystem of advisors, strategic & in-kind partners, and investors look forward to helping them on their journey to deliver innovative products to their target markets."

www.siliconcatalyst.com
www.quantum-pixel.com

Porotech and Foxconn partner to speed commercialization of micro-LED micro-display for AR applications

Aim is to establish first complete end-to-end, viable supply chain

Fabless micro-LED company Poro Technologies Ltd (a spin off from the Cambridge Centre for Gallium Nitride at the UK's University of Cambridge that has developed porous GaN material and has an R&D center in Hsinchu, Taiwan) and Hon Hai Technology Group (Foxconn) of Taipei, Taiwan (the world's largest electronics manufacturer and technology service provider) have announced a strategic partnership in micro-LED micro-displays for augmented reality (AR) applications.

The partnership will assemble Porotech's technologies in PoroGaN MicroLED-on-Silicon (uLEDoS), Dynamic Pixel Tuning (DPT), GaN-on-silicon platform, and Foxconn's proprietary technologies in semiconductor wafer manufacturing, packaging, IC drivers, CMOS backplanes, module assembly and system assembly. The end-product will target ultra-high-density and energy-efficient micro-LED micro-displays for AR applications, wearable, and smart devices.

The first single-panel, full-color micro-display suitable for AR applications.

"The micro-LED device for AR applications has great potential, but at the same time is quite challenging," says Porotech. "It involves multiple disciplines including wafer manufacturing, hybrid bond, IC design, optoelectronics, quantum physics, and optics. Integration across these different fields is difficult and progress has been slow. In the past, no single company has possessed such a big portfolio of expertise. "With this partnership, we expect to expedite the research and productization of micro-LED technology and push the AR application to a new era," it adds. "Foxconn's strength in supply chain management is also expected to contribute at the mass-production stage."

"Our strategic alliance with Porotech will accelerate development of micro-LED micro-displays," says Dr Bob Chen, general manager of Foxconn's semiconductor business group. "It is one step closer to tapping into the tremendous opportunities that AR can bring to the world," he adds. "We are excited to collaborate with Porotech to integrate many technologies from different fields."

www.porotech.co.uk
www.foxconn.com

Luminus expands ultraviolet LED wavelength options into the UVC range

Gen2 XBT-3535 series' 265nm variant boosts disinfection efficiency by 22% versus 275nm and 56% versus 280nm

Luminus Devices Inc of Sunnyvale, CA, USA — which designs and makes LEDs and solid-state technology (SST) light sources for illumination markets — has added to its portfolio of UV LEDs by launching its Gen2 XBT-3535 series, with wavelength options including 265nm, 275nm, 285nm, 308nm and 340nm.

The Gen2 XBT-3535 series complements Luminus's existing UVA and near-UV portfolio, which includes 365nm, 385nm, 395nm, 405nm and 415nm. In a significant expansion into the UVC wavelength range, the XBT-3535 series is now available in 265nm, alongside the previously offered 275nm, specifically tailored for air, water and surface disinfection applications. A lower-power, cost-effective Mini version is also available in 275nm with a power output of 20mW at a current of 150mA.

"What sets the 265nm wavelength apart is its remarkable 56% improvement in disinfection efficiency compared to 280nm, surpassing even the 22% increase achieved with 275nm," says Murali Kumar, business line director. "Delivering an impressive output power of more than 60mW at 500mA, the XBT-3535 series outperforms its Gen 1 275nm predecessor, in both disinfection performance and cost-effectiveness ($/mW)."

In the UVB range, the XBT-3535 series introduces two options: 285nm and 308nm. Designed for horticulture and analytical instruments, the 285nm variant offers a performance exceeding 85mW at 500mA. On the other hand, the 308nm variant, available in the Mini version, offers a cost-effective solution for phototherapy and horticulture, delivering a power output of more than 30mW at 150mA.

Catering to medical and analytical applications, the XBT-3535 at 340nm provides a powerful 90mW output at 500mA.

Currently, the 265nm, 275nm, and 285nm wavelengths are in production and available, with orders now also being accepted for the 308nm and 340nm variants, slated for production in first-quarter 2024.

www.luminus.com

ams OSRAM launches multi-LED package that boosts heart rate and blood oxygen measurements for wearables

SFH 7018 red/green/IR LED increases total radiant intensity by 40% over prior-generation product

ams OSRAM GmbH of Premstätten, Austria and Munich, Germany has launched a new multi-LED package that offers more than 40% higher radiant intensity than the previous-generation product, resulting in higher-accuracy PPG (photoplethysmography) measurements in smart watches, wristbands and other wearable devices.

The SFH 7018 features a highly reflective QFN (quad flat no leads) package for significantly increased light output. In addition, an improved two-cavity design separates the green LED from the red LED and infrared (IR) LED: the spacing and optical isolation ensure that the light sources are optimally placed relative to their photodiodes and reduce interference between the green light (for heart-rate measurements) and the red light and IR source (for blood oxygen saturation, or SpO_2, measurements). Furthermore, the green chip does not cause the red and IR chips to fluoresce due to cross-excitation from the shorter wavelength.

The optimized form factor of the surface-mount QFN package — just 0.6mm high — makes it easy to integrate the module into any type of wearable device. Despite its compact size, the SFH 7018 provides dual driving capability with optimized forward voltage headroom and reduced overall power consumption.

"By using the new SFH 7018, manufacturers of wearable devices can dramatically improve the quality of the optical signals on which heart rate and blood oxygen measurements are based, making them more accurate and reliable in all operating conditions," says senior staff system architect Dr Sergey Kudaev. "The SFH 7018 can help to transform vital signs measurements into accurate and absolute determinations of heart rate, blood oxygen levels and even more advanced parameters, such as blood pressure."

Higher radiant intensity increases signal-to-noise ratio

The SFH 7018's improvement in radiant intensity is said to be dramatic: the red and IR LEDs are more than 40% brighter than in the existing SFH 7016, and the green LED in the SFH 7018A version of the product is 80% brighter, while in the SFH 7018B version the green LED is more than twice as bright. The brightness of the SFH 7018 at each of the red, green and IR wavelengths also greatly exceeds that of today's best-performing competing product, it is claimed.

Since all vital signs monitoring devices face the challenge of detecting small modulations in already small light signals, the result of scattering and absorption in tissue (depending on various factors), the amount of light emitted by the LEDs strongly affects system performance. When more light is modulated by the blood flow and subsequently reaches the photodiode, signal quality improves, yielding higher accuracy and better repeatability of measurements. The SFH 7018 enables this superior performance by emitting more light into the body.

The SFH 7018 is available in two versions: SFH 7018A is optimized for low forward voltage at high currents, allowing for operation without a costly voltage booster. SFH 7018B is optimized for maximum radiant intensity. Both variants are in volume production now.

www.ams-osram.com

Lumileds names Tom Constantino as new CFO

Experience to aid growth as automotive, after-market and general illumination markets expand

LED product and lighting maker Lumileds of San Jose, CA, USA says that Tom Constantino has joined it as chief financial officer (CFO). Constantino has over 35 years of finance leadership experience at leading technology companies in Silicon Valley.

Constantino's experience includes work with both public and private companies, including HP, Hitachi, Western Digital, and A10 Networks, as well as several early-stage technology companies.

Lumileds' new CFO Tom Constantino.

"His breadth of experience will help Lumileds' future growth as our automotive, after-market and general illumination markets expand and as we bring new micro-LED technologies forward to drive growth in the decades ahead," says CEO Steve Barlow.

"Lumileds advances have significantly shaped the world we live in and travel through, and I am thrilled to be joining the company as it continues to innovate and shape the future of illumination in all its forms," comments Constantino.

www.lumileds.com

Nichia adds in-house production of red laser chips to production of blue and green

Packaged products with own red laser chip to be sold from spring 2024

Nichia Corp of Tokushima, Japan, the world's largest gallium nitride (GaN)-based light-emitting diode/laser diode (LED/LD) manufacturer and inventor of high-brightness blue and white LEDs, has started in-house production of a high-power red laser diode chip and will sell laser packaged products including this high-power red LD chip from spring 2024.

Compared with those using conventional lamps or LED light sources, laser projectors with the three primary colors of red, green and blue have the advantage of a much wider color reproduction range, as well as the ability to achieve high brightness while maintaining compact size and high efficiency. In recent years, the demand for such projectors has been increasing rapidly, not only for high-luminance movie theater projectors but also for individual consumers such as laser TVs and small smart projectors.

Laser diodes play an important role in determining the specifications of projectors, and Nichia says that it has been required to flexibly respond to various customer requests for the performance of each RGB color LD. Nichia had been manufacturing blue and green LD chips in-house, but the red LD chips had been procured from outside suppliers. So, the quality, cost and supply of red LD chips were dependent on suppliers, and the challenge was how to meet the various needs of customers.

Nichia started development of watt-class high-power red LD chips and is now producing them in-house. It has also made upfront investments in mass-production facilities and secured production capacity to meet the demand for RGB LDs. In addition to blue and green LD chips, in-house production of red LD chips will enable Nichia to manufacture all three primary color LD chips, allowing it to flexibly consider and respond to various requests from customers.

Nichia will start selling laser diode packages utilizing its in-house manufactured red laser chips from spring 2024. In addition, the red LD chips used in existing products will be gradually replaced with internally produced chips, rather than those procured from external suppliers. For example, Nichia's QuaLas RGB product has multiple RGB laser diode chips densely mounted in one small package, and will be one of the firm's main products with in-house red LD chips. QuaLas's optical output power in each RGB color is 8.3W for blue (typical wavelength 465nm), 4.8W for green (typical wavelength 525nm), and 10.0W for red (typical wavelength 643nm), suggesting a suitable combination for providing a good white balance for the display (see Figures 1 and 2).

To address the increasing market demand and advancements in performance for laser projectors, as well as explore further application possibilities, Nichia aims to accelerate the development and commercialization of red LD products with improved efficiency and output power by implementing in-house manufacturing.

www.nichia.co.jp

LD Product	LD Wavelength (Typ.)	LD rated optical output power (Typ.)
QuaLas™ RGB	Blue: 465nm Green: 525nm Red: 643nm	8.3W 4.8W 10.0W

Figure 1. Examples of LD packaged products including in-house high-power red LD chips

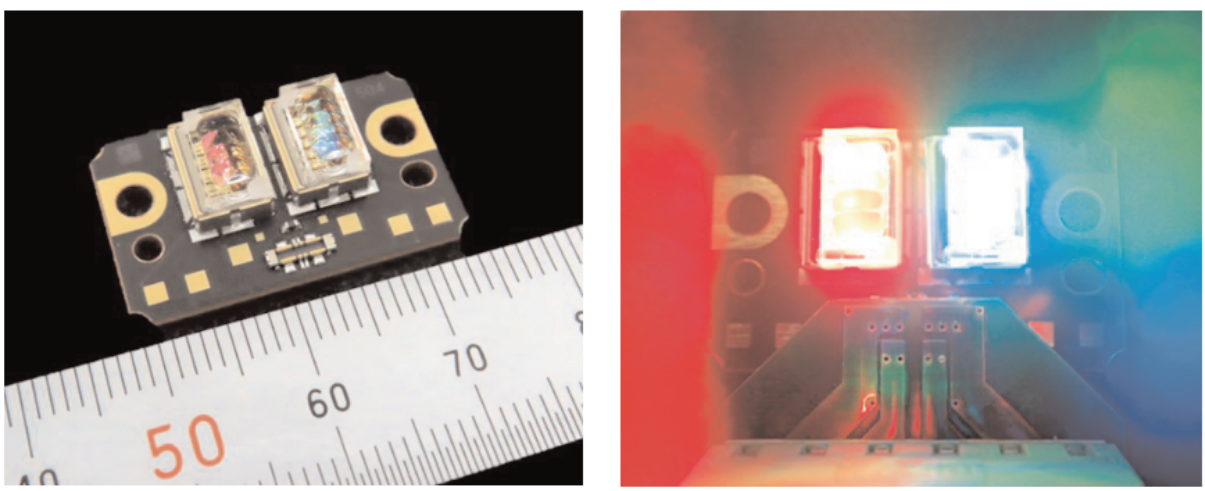


Figure 2. QuaLas™ RGB

BluGlass acquires contract manufacturer GaNWorks Foundry for US$800,000

Transfer of equipment and processes completes vertical integration of Silicon Valley laser fab

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 reached an agreement to acquire its Silicon Valley-based commercial contract manufacturing partner GaNWorks Foundry Inc for US$800,000, comprising 85% in 17,436,556 new BLG ordinary shares (US$680,000) issued from within the firm's existing capacity under ASX listing rule 7.1, plus 15% in cash (US$120,000, funded by the receipt of the firm's $7.3m R&D rebate).

The acquisition includes core, speciality GaN wafer processing equipment and processes for n-side metallization, wafer thinning and laser bar cleave capabilities, which are both critical and complex processes in BluGlass' laser manufacturing supply chain. These processes have previously been outsourced to GaNWorks — BluGlass' only remaining wafer processing contract manufacturer. The equipment is expected to complete installation and process transfer at BluGlass' Silicon Valley fab by 30 December. GaNWorks will provide transitional engineering services for 30 days from the acquisition date to complete process and knowledge transfer to BluGlass, completing the vertical integration of BluGlass' laser fabrication facility in Fremont, CA, USA.

In addition, the transaction includes the transfer of an engineer with more than 10 years' GaN processing experience to US-based BluGlass Inc, ensuring complete knowledge and process transfer. In-sourcing of n-side wafer thinning and laser bar cleave processes will speed development and production cycles of these steps by over 30% and are expected to deliver annualized savings of more than US$400,000. Operationally, vertical integration will further fast-track the firm's growth strategy, increase laser production capacity, and accelerate advanced technical roadmaps.

"Bringing GaNWorks in-house is another incredibly rare opportunity. These processes are critical to our manufacturing supply chain, with the equipment alone costing on the order of US$3m to purchase new," says BluGlass' CEO Jim Haden. "Our acquisition of GaNWorks represents exceptional shareholder value, providing us with the necessary equipment, along with invaluable process, knowledge transfer and hands-on expertise. As one of just a handful of gallium nitride laser diode manufacturers globally, our acquisition of a specialist GaN contract manufacturer also increases barriers to entry for new players," he adds.

"The acquisition represents the final step in our plan to in-source wafer processing, and further accelerates our long-term growth plans within the fast-growing GaN market, forecast to reach US$2.5bn by 2025," Haden continues. "Vertical integration eliminates operational complexity, reduces process variability, and speeds product development. Dedicated in-house resources will further improve the quality and consistency of our lasers, while also enabling us to execute our strategic vision of becoming the industry's easiest-to-use laser light, offering product development and manufacturing flexibility."

www.bluglass.com.au

BluGlass to receive full $7.3m R&D rebate from Australian Taxation Office

R&D rebate increased more than 80% over prior year

BluGlass has received confirmation from the Australian Taxation Office that it will receive its full $7.3m rebate for R&D activities carried out across its Australian and US facilities in fiscal year 2023. The firm expects to receive the funds within 10 business days.

"Our R&D rebate has increased more than 80% over the prior year, reflecting our significant step-up in development activities following our acquisition of a purpose-built production facility in Silicon Valley," says CEO Jim Haden.

"This R&D work has enabled us to launch our first suite of visible lasers, commence customer engagement and product qualification and secure our commercial role as part of the CLAWS Hub ['Commercial Leap Ahead for Wide-bandgap Semiconductors'] in the US Microelectronics Commons," he adds.

"At the same time, we continue to improve the quality, consistency and performance of our launched products, and expedite the development of next-generation lasers," Haden continues. "The R&D rebate is a non-dilutive cash injection that supports our ground-breaking technology development and helps offset our operational costs as we commercialize our gallium nitride laser technology."

BluGlass a commercial partner in US Microelectronics Commons regional innovation hub CLAWS

'Commercial Leap Ahead for Wide-bandgap Semiconductors' funded by $39.4m from US Department of Defense

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 been named a member of the 'Commercial Leap Ahead for Wide-bandgap Semiconductors' (CLAWS) Hub, one of eight Microelectronics Commons regional innovation hubs announced by the US Department of Defense, aiming to develop next-generation photonic devices with significant commercial and strategic defence applications in the decades ahead.

The US DoD awarded US$238m in CHIPS and Science Act funding in fiscal year 2023 for the establishment of eight regional innovation hubs, as part of the US$2bn allocated to the ME Commons Program from fiscal years 2023–2027. The Microelectronics Commons is focused on bridging and accelerating the lab-to-fab transition and mitigating supply chain risks and aims to boost America's ability to develop, prototype, manufacture and produce cutting-edge microelectronics at scale.

Led by North Carolina State University (NCSU), the CLAWS Hub has been awarded US$39.4m for the base year of performance and consists of seven hub members: North Carolina State University (Hub Lead), Adroit Materials, BluGlass, Coherent, General Electric, Kyma, North Carolina A&T State University, and Wolfspeed.

"The work we will be contributing to the hub perfectly aligns with BluGlass' wide-bandgap and extended-wavelength roadmaps and will leverage the benefits of our proprietary RPCVD technology," says BluGlass' CEO Jim Haden.

"We are delighted to be partnering with BluGlass in the NCSU-led CLAWS Hub, working together to innovate next-generation III–N photonic and optoelectronic solutions with BluGlass further adding a path to commercialization," says Fred Kish, MC Dean Distinguished Professor of Electrical and Computer Engineering. "The photonic technologies in the hub hold the potential to enable quantum technologies, communications, artificial intelligence applications, position/navigation/timing, biotechnical and medical, materials processing, displays, and a host of additional defense needs," he adds. "They are also important for national security applications by providing energy efficiency, size, weight, power and performance advantages in critical application areas including weapons systems, war fighter outfitting, and a host of additional defense needs."

www.bluglass.com.au

NCSU awards US$1.775m contract for laser development

Contract part of US$39.4m Microelectronics Commons CLAWS Hub

BluGlass has signed a US$1.775m (AUS$2.6m) contract with North Carolina State University (NCSU) for BluGlass' laser development as part of the Commercial Leap Ahead for Wide Bandgap Semiconductors (CLAWS) Hub. This initial contract is for development work in fiscal year 2024 (to end-September) and supports the Microelectronics Commons program.

"We are thrilled to have secured our first contract as part of the CLAWS Hub, where we will be collaborating with recognised industry leaders to develop and commercialize next-generation wide-bandgap photonic and optoelectronic devices," says BluGlass' CEO Jim Haden.

"This core development contract for fiscal year 2024 aligns with BluGlass' GaN expertise and supports our longer-term product roadmaps, leveraging the benefits of our proprietary RPCVD technology. Our laser development within the CLAWS Hub has the potential to create significant advancements across our target verticals, including materials processing, sensing, quantum applications, and critical defence capabilities. At the same time, our collaboration with NCSU and Microelectronics Commons provides BluGlass with growing revenues and industry profile, specifying us as an approved US commercial manufacturing supplier of GaN laser epitaxy, fabrication, packaging and testing. The collaboration with NCSU as part of the CLAWS Hub has the potential to become a game-changing partnership over the next five years," he adds.

"Part of the purpose of CLAWS is to accelerate the development of dual-use technologies," says John Muth, director of the CLAWS Hub, and Distinguished Professor of ECE. "BluGlass is an important part of our roadmap to manipulate UV- and visible-spectrum light on a chip as a photonic integrated circuit. We see the ability to deliver high-quality, reliable single-frequency DFB lasers as well as blue and violet lasers to the DoD and the research community as important first steps toward a wide variety of commercial applications."

www.ece.ncsu.edu

NUBURU's Q3 hit by supply chain restrictions and delays in shipping products

For third-quarter 2023, NUBURU Inc of Centennial, CO, USA — which was founded in 2015 and develops and manufactures high-power industrial blue lasers — has reported revenue of $0.187m, down 78% on $0.868m a year ago, due mainly to a decrease in the number of laser system sales.

"Results reflect supply chain restrictions mostly in-line with our expectations entering the second half of 2023," comments CEO Brian Knaley. "We however faced additional headwinds from the integration of our systems into customer applications and subsequently experienced delays in the shipment of our products. I'm confident that the solutions we have developed will not only enhance our BL-250 product offering but also streamline the manufacturing process to improve the application and integration of our technologies within their respective end-markets going forward," he adds.

Gross margin was –497%, compared with –111% a year ago, driven by decreasing revenue but partially offset by lower cost of revenues following the retirement of the AO series.

Operating expenses have risen from $2.92m to $4.22m, due mainly to increased professional fees associated with legal, compliance and accounting matters associated with the cost of operating a public company, plus increased R&D personnel expenses and the addition of a new chief marketing & sales officer in March.

Net loss has increased from $3.92m ($0.71 per share) to $5.09m ($0.14 per share), primarily due to the rise in operating expenses.

EBITDA (earnings before interest, taxes, depreciation and amortization) of –$4.825m is up from–$3.783m a year ago, but cut from –$6m last quarter.

Net cash used in operating activities has almost doubled from $2.56m to $4.56m. Driven mainly by the increase in production capabilities to support additional product lines, capital expenditure has risen from $0.097m a year ago to $0.317m. Free cash flow was hence –$4.88m, due mainly to the decreasing revenue and the increase in operating expenses. During the quarter, cash and cash equivalents fell from $5.1m to just $1.63m. However, subsequent to the quarter-end, NUBURU agreed a secured bridge loan worth $5.5m with existing investors and a new institutional investor in order to finance the firm until it secures long-term credit financing, which is expected in the near term.

During the quarter, NUBURU:

- announced completion of a contract awarded by the US Air Force following successful demonstration of blue laser-based area printing, supported by GE Additive, to develop scalable 3D printing manufacturing systems;
- was awarded a purchase order for delivery of a BL-250 laser from a major multi-national electronics manufacturer in an R&D capacity to demonstrate the integration of NUBURU's laser welding capabilities;
- positioned the executive management team to scale commercialization with the appointment of Brian Knaley as chief executive officer and Ron Nicol as executive chairman, following the addition of former National Security Advisor John Bolton to the board.

"The purchase order we've received from a major multi-national electronics manufacturer stands as a testimony for the unbroken inbound of interest in our cutting-edge blue laser technology," says executive chairman Ron Nicol. "Our focus is now on further strengthening our distribution network. Combining the current growing end-markets with our extensive IP and upcoming 1kW blue laser system, NUBURU is well positioned to drive commercial success and execute against its long-term growth strategy," he reckons.

"With the anticipation of a rebound in deliveries of our laser systems during the fourth quarter of 2023, we have adjusted our full-year 2023 outlook accordingly and are eagerly awaiting the positive impact of our technological improvements," says Knaley.

NUBURU has revised its 2023 outlook to revenue of $2.1m (rather than over $3m), EBITDA of –$18m to –$21m (cut from –$21m to –$23m), and free cash flow of –$17m to –$20m (cut from –$24m to –$26m). The firm believes that it has access to sufficient sources of capital to fund this business plan.

www.nuburu.net

NUBURU names CFO Brian Knaley as new CEO

NUBURU has appointed Brian Knaley as chief executive officer, replacing Dr Mark Zediker, who has left the firm to pursue other opportunities. Knaley has also joined the board.

Knaley, was chief financial officer from February 2022, has over 25 years of experience in finance and operations. He served as the CFO of controlled environmental solutions provider CEA Industries Inc and as CFO of medical device start-up Proximo Medical LLC. He was also senior VP & interim CFO of ViewRay, a manufacturer of MRI-guided radiation therapy systems.

"Brian is an accomplished and respected leader with profound expertise in scaling and operating public companies," comments executive chairman Ron Nicol. "I also want to thank Mark for his tireless work in setting the foundation for NUBURU."

NUBURU announces $5.5m bridge financing

Bridge loan secured by patent portfolio valued at $100m

NUBURU Inc of Centennial, CO, USA — which was founded in 2015 and develops and manufactures high-power industrial blue lasers — has agreed a secured bridge loan worth $5.5m with existing investors and a new institutional investor in order to finance the firm until it secures long-term credit financing, which is anticipated in the near term.

"The bridge financing is an important step on our way to a longer-term credit facility intended to support the commercialization of our blue lasers," says CEO Brian Knaley.

The bridge loan consists of zero-interest promissory notes issued with a 10% original issue discount, which will mature when NUBURU closes the anticipated credit facility (or 12 months after issuance at the latest). The notes are secured by NUBURU's patent portfolio, which was independently and preliminarily valued to be worth $100m. Following acceptance by the NYSE of the firm's supplemental listing application, NUBURU will also issue to the holders of notes warrants exercisable for common stock equal to 100% of the note principal, which will be exercisable for $0.25 per share, have a five-year term, and may be repurchased by the company when the trading price exceeds $1.50 for 20 out of 30 trading days. If the notes have not been repaid within six or nine months after issuance, the notes will begin to bear interest (at the SOFR rate plus 9% and at the SOFR rate plus 12%, respectively) and additional 25% warrant coverage will be provided at each such date. Pursuant to a registration rights agreement between the firm and the holders of warrants, NUBURU intends to register the common stock underlying the warrants no later than 1 February 2024.

The parties to the bridge financing also entered into an inter-creditor and subordination agreement with the holders of senior secured convertible notes, whose convertible notes will now be secured and rank senior in priority to the Notes.

Northland Capital Markets acted as sole placement agent on the institutional investor portion of the bridge financing.

www.nuburu.net

BlueScan order for coil and motor winding production

NUBURU has received a purchase order for its BlueScan solution from a "worldwide leader in coil and motor winding and assembly systems to produce electric motors". BlueScan includes a BL-250 laser, scanner and optics that will be supplied to the customer's R&D lab where the automotive solenoid manufacturing production process will be validated.

Historically, arc welding is used for this application, but is limited by production speed as well as frequently required post-welding processing. By comparison, the BlueScan solution enables wire to post welding without porosity or the spatter associated with arc welding or infrared fiber lasers. NUBURU's solution is faster and enables the high yield needed for mass production.

"While we continue expanding our product offering to more high-growth industries and applications, I'm excited about the extension of our BL-250 laser system within the E-mobility market, as it represents one of the largest and fastest-growing serviceable addressable market for NUBURU," says CEO Brian Knaley.

The firm says that the order is a natural extension of its advancement into next-generation computers, consumer electronics and communication (3C) device manufacturing and marks a significant expansion in offering to the growing electric vehicle (EV) automotive industry.

NYSE American begins delisting of NUBURU's warrants

NYSE American LLC says that the staff of NYSE Regulation has decided to commence proceedings to delist the redeemable warrants of NUBURU, each whole warrant exercisable for one share of common stock at an exercise price of $11.50 (ticker symbol BURU WS) from the NYSE American small-cap equity market. Trading in the warrants has subsequently been suspended immediately. Trading in the NUBURU's common stock (ticker symbol BURU) continues on the NYSE American.

NYSE Regulation has determined that the warrants are no longer suitable for listing pursuant to Section 1001 of the NYSE American Company Guide due to the low trading price of such warrants.

NUBURU has a right to a review of the delisting of its warrants by the Listings Qualifications Panel of the Committee for Review of the board of directors of the exchange. The NYSE American will apply to the US Securities and Exchange Commission to delist NUBURU's warrants upon completion of all applicable procedures, including any appeal by the company of the NYSE Regulation staff's decision.

www.nyse.com/markets/nyse-american

Europe's integrated photonics firms call on EU to support building resilient supply chain for PICs

CEOs present eight-year, €4.25bn plan to support growth of self-reliant industry

CEOs from eight of Europe's largest integrated photonics companies have presented Thomas Skordas (deputy director-general of DG Connect), Lucilla Sioli (director for artificial intelligence & digital industry at DG Connect) and Werner Steinhögl (head of sector, Unit for Microelectronics & Photonics for the European Commission) with a plan to build a resilient European supply chain for photonic integrated circuits (PICs).

The plan calls for €4.25bn in funding over eight years and a range of recommendations to enable the European integrated photonics industry to become a global leader and have the ability to supply EU customers autonomously. Enabling the creation of smaller, faster and more energy-efficient devices, photonic integrated circuits are already being used in high-speed telecoms and datacoms, data security, autonomous vehicles, quantum communication and agriculture.

The group states that the low level of EU manufacturing capacity and over-reliance on Asia threatens the EU's economic security and resilience. Currently, less than 6% of the manufacturing of indium phosphide (InP) and silicon nitride (SiN) PICs is undertaken in the European Union (EU) and less than 4% of global assembly, testing and packaging capacity resides in Europe. Furthermore, research by Dutch photonics ecosystem PhotonDelta highlights that competitor nations are making concerted efforts to acquire EU PIC technologies and assets along with seeking stakes in EU SME companies in the EU PIC supply chain.

The CEOs Rudi de Winter of XFAB (Germany/France), Johan Feenstra of SMART Photonics (The Netherlands), Felix Grawert of Aixtron (Germany), Albert Hasper of PHIX Photonics Assembly (The Netherlands), Inigo Artundo of VLC Photonics (Spain), Jean-Louis Gentner of Almae (France), Thomas Hessler of Ligentec (Switzerland/France) and Ewit Roos of PhotonDelta (The Netherlands) unveiled the plan at PIC Summit Europe in front of more than 500 members of the global photonics and semiconductor communities. The proposal makes a number of recommendations including:

PICs have the capacity to transform a huge range of industries. It is also fundamental to the advancement of some of the most exciting new technologies... The EU has a vibrant and growing integrated photonics industry. However, without volume manufacturing, testing & packaging capacity, we are incredibly vulnerable to global events and the policies of competitor countries

- providing over €2bn in incentives for industrial-scale InP and SiN PIC manufacturing capacity in Europe;
- providing EU PIC SMEs access to industrial PIC test and experimentation facilities (TEFs) that partly mirror commercial lines, with the latest commercial wafer processing equipment and tools, at the relevant industry-standard wafer sizes;
- establishing an industrial PIC 'manufacturing supply chain' resilience fund of €200m to support the investments needed to strengthen linkages and minimize vulnerabilities;
- providing a €360m fund to stimulate application development through offering design tape-outs, leading to industrial photonic design IP creation and validation based on hardware testing;
- promoting and incentivising collaboration among vertical clusters and the European PIC ecosystem.

"Over the past few years we have been repeatedly reminded that the world is becoming a more volatile and unpredictable place. Global supply chains have been shown to be fragile, and over-reliance on one country for critical components is an economic and security risk. This is particularly true of the semiconductor industry," says SMART Photonics' CEO Johan Feenstra.

"Photonic integrated circuits have the capacity to transform a huge range of industries. It is also fundamental to the advancement of some of the most exciting new technologies. Currently, the EU has a vibrant and growing integrated photonics industry. However, without volume manufacturing, testing & packaging capacity, we are incredibly vulnerable to global events and the policies of competitor countries," he adds.

"Our proposal outlines a number of practical steps that the EU can take over the next decade to ensure the continued growth and security of the integrated photonics industry. For just over €4bn we can build our supply chain and ensure the future of an industry which has the capacity to generate hundreds of billions of Euros each year for decades to come," Feenstra concludes.

www.smartphotonics.nl
www.photondelta.com

imec and SMART Photonics sign MoU to work on hybrid integration of InP on SiN/SiPh

Datacoms, automotive, agrifood and health applications targeted

Nanoelectronics research center imec of Leuven, Belgium and independent pure-play indium phosphide (InP) photonic integrated circuit (PIC) foundry SMART Photonics of Eindhoven, The Netherlands have signed a memorandum of understanding (MOU) to underpin their intention to work together in the field of hybrid integration of InP on silicon nitride/silicon photonics (SiN/SiPh).

The collaborative work will include topics such as:

- hybrid integration of InP on SiN/SiPh with flip-chip bonding and butt coupling;
- hybrid integration of InP on SiN/SiPh with micro-transfer printing;
- component design, i.e. laser design and design of interface elements for the integration of InP/SiPh along with system demonstration and prototyping.

Smart Photonics' CEO Johan Feenstra (left) and an imec representative. Courtesy: Smart Photonics.

Through the cooperation, imec and SMART Photonics aim to accelerate the adoption and market pull of hybrid integrated solutions for domains such as datacoms, automotive, agrifood and health applications.

www.smartphotonics.nl

ROHM launches 120W high-power laser diode for LiDAR

Uniform luminous intensity of 97% over entire luminous width contributes to higher-definition LiDAR

ROHM has launched the RLD90QZW8 high-power laser diode, suitable for industrial equipment and consumer applications requiring distance measurement and spatial recognition.

In recent years, light ranging & detection (LiDAR) has been increasingly adopted in a wide range of applications that require automation — including AGVs (automated guided vehicles), robot vacuums and autonomous vehicles (AVs) — where it is necessary to accurately measure distance and recognize space. In this context, there is a need to improve the performance and output of laser diodes when used as light sources to increase detection distance and accuracy.

To meet this demand, ROHM has established original patented technology to achieve a narrower emission width that contributes to longer range and higher accuracy in LiDAR applications. In 2019, the firm launched the 25W laser diode RLD90QZW5 followed by the 75W laser diode RLD90QZW3 in 2021. In response to the growing market demand for even higher output, ROHM developed the new 120W laser diode.

The RLD90QZW8 is a 120W infrared high-output laser diode developed for LiDAR used in distance measurement and spatial recognition in three-dimensional time-of-flight (3D ToF) systems. Original device development technology has allowed ROHM to reduce the temperature dependence of the laser wavelength by 66% over general products, to just Δ11.6nm (average 0.10nm/°C). This makes it possible to narrow the bandpass filter while extending the detection range of LiDAR. At the same time, a uniform light intensity of 97% is achieved over the industry's smallest class of emission width of 270μm, representing a range of 264μm that contributes to higher resolution. Additional features that include high power-to-light conversion efficiency (PCE) enable efficient optical output that contributes to lower power consumption in LiDAR applications.

Original device development technology has allowed ROHM to reduce the temperature dependence of the laser wavelength by 66% over general products, to just Δ11.6nm (average 0.10nm/°C)

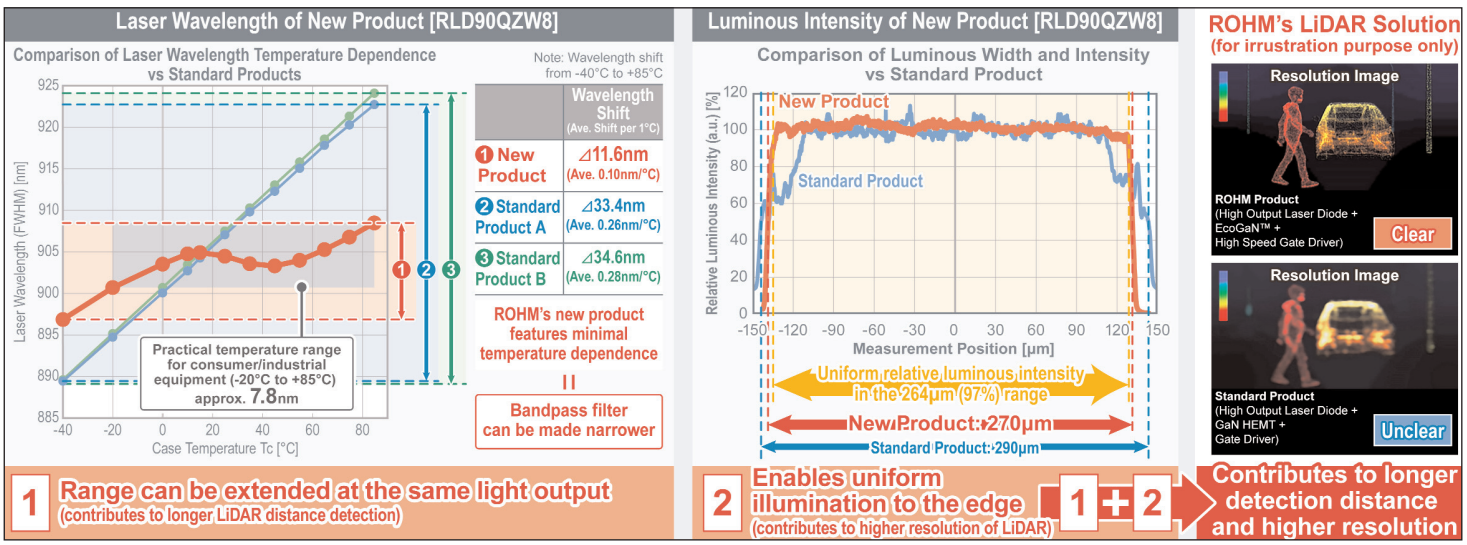
A variety of design support materials necessary for integrating and evaluating the new product is available free of charge on ROHM's website that facilitate market introduction. To drive laser diodes with the high nanosecond-order speed required for LiDAR applications, ROHM has developed a reference design available now that combines the firm's 150V EcoGaN HEMT and gate drivers.

A broad range of design data is available on ROHM's website free of charge, including simulation (SPICE) models, board development data, and application notes on drive circuit design necessary for integration and evaluation that supports quick market introduction.

ROHM has also gained certification under the IATF 16949 automotive quality management standard for both front-end and back-end processes at its manufacturing facilities. As a result, laser diode product development for automotive applications (AEC-Q102 compliant) is underway, with commercialization planned by the end of 2024.

Increasing measurement range by reducing wavelength temperature dependence by 66%

www.rohm.com/products/laser-diodes/high-power-



Sivers, LioniX and Chilas partner to develop narrow-linewidth CW tunable 1310nm lasers for optical communications and sensing

InP100-based optical amplifier to be assembled with LioniX's PIC for laser to be tested and sold by Chilas

IC and integrated module supplier Sivers Semiconductors AB of Kista, Sweden says that its subsidiary Sivers Photonics of Glasgow, Scotland, UK has commenced a new partnership with LioniX International BV (LXI) and Chilas B.V. (both of Enschede, The Netherlands) to develop and supply a narrow-linewidth integrated O-band continuous wave (CW) tunable 1310nm laser targeting high-growth applications across optical communications and optical sensing sectors.

LioniX designs and produces customized integrated microsystems, specializing in silicon nitride photonic integrated circuits (PICs) and micro-electro-mechanical systems (MEMS), with expertise spanning chip fabrication, electro-optical system architecture, and module assembly and packaging. Lionix has introduced the laser to meet the growing demand for O-band solutions for use by OEMs, advanced laboratories, and industrial sensor manufacturers innovating in the communications (passive optical networks, fiber-optic communications), LiDAR, and molecular analysis markets.

Sivers Photonics has developed a customized optical amplifier component on its InP100 product platform to efficiently power this integrated laser solution and will supply this part as standard to the LioniX platform. The end-user Chilas will provide testing services for the assembled photonic integrated circuit, and offer this latest product worldwide as part of its diverse laser portfolio.

"This partnership with LioniX and Chilas further demonstrates Sivers Photonics' RSOA gain blocks being deployed into high-precision laser sources," says Sivers Photonics' managing director Andy McKee. "The narrow linewidth and wide tunability afforded by these external-cavity lasers make them ideal sources for a broad range of applications including datacoms and optical sensing markets," he adds.

"The two technology platforms of LioniX International and Sivers complement each other, creating ultra-narrow-linewidth lasers with unprecedented performance," says LioniX's CEO Arne Leinse. "This collaboration between Sivers, LioniX and the end-user Chilas is a great example of how the ecosystem can work together to create new applications in this wavelength domain," he adds.

"Chilas acknowledges Sivers on their tailored semiconductor manufacturing capabilities, making them perfectly suitable for hybrid integration," comments Chilas' chief technology officer Dimitri Geskus. "This greatly benefits the development of wavelength-agile laser sources such as the demonstrated O-band tunable laser," he adds. "Chilas is actively supporting the joint efforts of Sivers and LioniX International with great enthusiasm, and we are looking forward in turning the tunable O-band laser into a product."

www.chilasbv.com
www.lionix-international.com

Sivers Photonics receives $1m in orders

Sivers Photonics has received new orders worth $1m (about SEK10m) for advanced optical sensing products from three customers across light detection & ranging (LiDAR), medical and industrial sectors.

The orders, from several US-based customers, were received during the first part of fourth-quarter 2023 and will result in the manufacturing of advanced laser and optical amplifier products for critical applications, with the majority of the delivery expected throughout 2024.

With a production facility in Glasgow and over 20 years' experience in the design and fabrication of customized III-V compound semiconductor devices, Sivers Photonics is a supplier of laser light sources to the silicon photonics industry, working across a range of customers from Fortune 100 businesses to highly funded, high growth start-ups.

The latest orders are the result of an increase in demand for Sivers' lasers as companies engineer next-generation products for autonomous vehicles (AV) and smart factories, innovative medical devices and equipment, and multiple new applications across a range of industries.

"These production orders demonstrate the continued strong organic growth across established and emerging optical sensing markets and further validate the technical capability of Sivers Photonics' UK wafer fabrication facility," says Sivers Photonics' managing director Andy McKee.

"We have put up a medium-term goal of increasing product sales from currently 30% of our revenue to over 80% by 2026," says Sivers Semiconductors' CEO Anders Storm. "This is one of many product orders we therefore expect to see, to secure our continued growth that will be fueled by an increased share of product revenue in the coming years."

www.sivers-semiconductors.com

Coherent unveils first 800G ZR/ZR+ transceiver in QSFP-DD pluggable form factor

New transceiver leverages 140GBaud IC-TROSA launched at ECOC

Materials, networking and laser technology firm Coherent Corp of Saxonburg, PA, USA has launched its 800G ZR/ZR+ transceiver in ultra-compact QSFP-DD and OSFP form factors for optical communications networks, claimed to be the first digital coherent optics (DCO) that can plug directly into QSFP-DD and OSFP transceiver slots on IP routers.

Artificial intelligence and machine learning (AI/ML) applications are accelerating the exponential growth of data-center traffic in cloud networks, driving the demand for efficient bandwidth upgrades in data-center interconnects and optical transport networks. Leveraging their high output power of 0dBm, the transceivers can connect routers directly to access, metro and regional DWDM transport networks without additional intermediary interfaces, eliminating an entire layer of optical equipment and significantly reducing both capital and operational expenditures.

"This 800G ZR/ZR+ pluggable transceiver is built on the 140GBaud IC-TROSA [transmitter-receiver optical subassembly] that we introduced at ECOC [the European Conference on Optical Communications] in September 2023, which was also an industry first," says Matthias Berger, vice president, Coherent Technology. "We continue to advance the state of the art of optical transmission in core networks by leveraging the inherent capabilities of our indium phosphide technology platform. Indium phosphide photonic integrated circuits are differentiated by their high output power in combination with high performance, which enables disruptive use cases such as IP-over-DWDM in metro networks," he adds.

"We demonstrated the new transceiver with 800G 16QAM for metro/regional transmission and with 400G 8QAM for long-haul transmission," says Dr Beck Mason, executive VP, Telecommunications. "The module is designed to support multiple modulation formats including QPSK, 8QAM and 16QAM, and multiple data rates between 200Gbps and 800Gbps. This 800G transceiver features a high-efficiency indium phosphide modulator and receiver combined with a built-in tunable laser that delivers best-in-class transmission performance and high optical output power."

Alpha samples of the 800G QSFP-DD DCO ZR/ZR+ transceivers will be available in first-quarter 2024.

www.ecocexhibition.com
www.Coherent.com

Infinera awarded $14m, five-year CalCompetes grant

CHIPS funding to expand and modernize US production of InP & PICs

Infinera Corp of San Jose, CA, USA — a vertically integrated manufacturer of digital optical network systems — has been awarded a California Competes (CalCompetes) grant worth up to $14m over five years by the California Governor's Office of Business and Economic Development (GO-Biz). This is a first step to expanding and modernizing Infinera's US-based domestic production of compound semiconductors and continuing to support innovation and economic development in the USA in future years.

The grant will enable Infinera — which has in-house fab operations and test & packaging capabilities in multiple states — to build upon its 20+ year history in the USA and continue to drive innovation in indium phosphide (InP)-based compound semiconductor and monolithic photonic integrated circuit (PIC) technologies. It is expected that fostering domestic production of these critical technologies will help to increase the USA's economic and national security in semiconductor innovation, manufacturing and supply chain resilience.

The CalCompetes Grant Program is one of California's main incentive programs to leverage tens of billions of dollars of federal funds available under the Creating Helpful Incentives to Produce Semiconductors (CHIPS) Act, which is designed to encourage growth and expansion of semiconductor manufacturing and R&D in the USA.

The grant is "an important step in helping to boost America's domestic production of semiconductor technologies," reckons Infinera's CEO David Heard. "Since our founding, we chose to keep our optical compound semiconductor fab and advanced packaging operations in the United States," he adds. "We remain committed to leveraging our unique expertise, talent and capabilities to support the goals of US federal and state initiatives focused on economic development and national security."

www.infinera.com

Ayar Labs names co-founder & CTO Mark Wade as CEO

Wade to drive next phase of Ayar Labs' growth, accelerate industry adoption of optical I/O

Silicon photonics-based chip-to-chip optical connectivity firm Ayar Labs of Santa Clara, CA, USA has appointed co-founder & chief technology officer Mark Wade to serve as its new chief executive officer. He succeeds Charles Wuischpard, who will continue to serve in an advisory capacity over the coming weeks before he transitions out of the company in mid-January.

"My focus since I joined Ayar Labs was to put the company on the path to long-term growth," says Wuischpard. "With the incredible progress we have made over the past two years in particular, this feels like the right inflection point to make this transition."

"There is a growing sense of momentum across the industry as it becomes increasingly clear that optical I/O enables large-scale AI compute and other data-intensive workloads to operate at bandwidths, energy efficiencies and latencies that are unachievable through electrical-based interconnect technology," Wade says. "I look forward to guiding our incredible team to capitalize on this opportunity, enabling our customers to realize the full potential of in-package optical I/O, and helping the company accelerate into our next growth phase," he adds.

"Mark's deep understanding of Ayar Labs' technology and its application is shaped by a breadth of industry and customer engagements that make him the ideal leader to carry the company forward to its next stage of growth," believes Matt Hershenson, partner & co-founder of Playground Global. "I would like to thank Charlie for his tremendous leadership and contributions to the company over the past five years, and for his ongoing guidance to ensure a seamless leadership transition in the coming weeks," he adds.

Mark Wade, now Ayar Labs' CEO.

Wade is recognized as a pioneer in photonics technologies and, prior to founding Ayar Labs, led the team that designed the optics in the world's first processor to communicate using light. He and his co-founders invented breakthrough technology at MIT and UC Berkeley from 2010-2015, which led to the formation of Ayar Labs.

"With strategic investments from NVIDIA, Hewlett Packard Pathfinder, Intel Capital and several others, Ayar Labs is deeply partnered with the commercial ecosystem and well positioned to scale to meet the high-volume opportunity we see with in-package optical I/O," comments Will Graves, chief investment officer at Boardman Bay Capital Management, which led Ayar Labs' Series C funding. "2023 has been an impressive year of progress for the company and I look forward to Mark and the team building on this in 2024 and beyond," he adds.

Earlier this year, Ayar Labs showcased the industry's first 4 terabit-per-second (Tbps) optical solution, moving data from one TeraPHY optical I/O chiplet to another at 2Tbps in each direction powered by Ayar Labs' SuperNova light source. The firm is able to achieve this data transfer at very low latency (5ns per chiplet + TOF) and using less than 5pJ/bit (10W), a high level of energy efficiency that provides the power density and performance per watt needed for data-intensive workloads such as generative AI, machine learning and more while also supporting novel disaggregated compute and memory architectures.

Ayar Labs recently demonstrated its in-package optical I/O solution integrated with Intel's Agilex FPGA technology. This new optically enabled FPGA promises 5x the existing industry bandwidth at 5x lower power and 20x lower latency, all packaged in a common PCIe card form factor.

www.ayarlabs.com

Lumentum's quarterly revenue falls due to inventory correction at networking customers

Cloud applications to drive over 30% of Cloud & Networking revenue in 2024 after Cloud Light acquisition

For its fiscal first-quarter 2024 (to end-September 2023), Lumentum Holdings Inc of San Jose, CA, USA has reported revenue of $317.6m, down 14.3% on $370.8m last quarter and 37.3% on $506.8m a year ago, but above the midpoint of the $300–325m guidance range.

During the quarter, to better align with trends in its markets and its customer and product mix, Lumentum changed its organizational structure, from the two reportable segments 'Optical Communications' (OpComms) and 'Commercial Lasers' to 'Cloud & Networking' (Telecom and Datacom product lines from OpComms) and 'Industrial Tech' (the former Commercial Lasers segment plus the Industrial & Consumer product lines from OpComms).

Cloud & Networking segment revenue was $229.7m (72.3% of total revenue), down 19.8% on $286.5m last quarter and 36.2% on $360.1m a year ago. This was as expected, given the inventory correction underway at networking customers, with broad-based softness across most networking product lines, partially offset by sequential growth in intra-data-center lasers and tunable access module.

Industrial Tech segment revenue was $87.9m (27.7% of total revenue), down 40.1% on $146.7m a year ago (due mainly to more intense competition for market share on a certain 3D sensing socket, end-market demand and pricing) but up 4.3% on $84.3m last quarter (driven by the expected uptick in 3D sensing business with a new smartphone product ramp, partially offset by softness in fiber lasers as the firm's leading fiber-laser customer works to bring down inventory).

"While we continue to see very strong growth in the demand for our data-center chips as well as our newly acquired intra-data-center transceivers, this strength is being offset by the telecom and industrial inventory drawdown activities," says president & CEO Alan Lowe. "Due to this inventory correction, we believe we continue to ship below end-market demand."

During fiscal Q1, there were again three greater-than-10% customers (two in the Networking segment and one in the Industrial Tech segment).

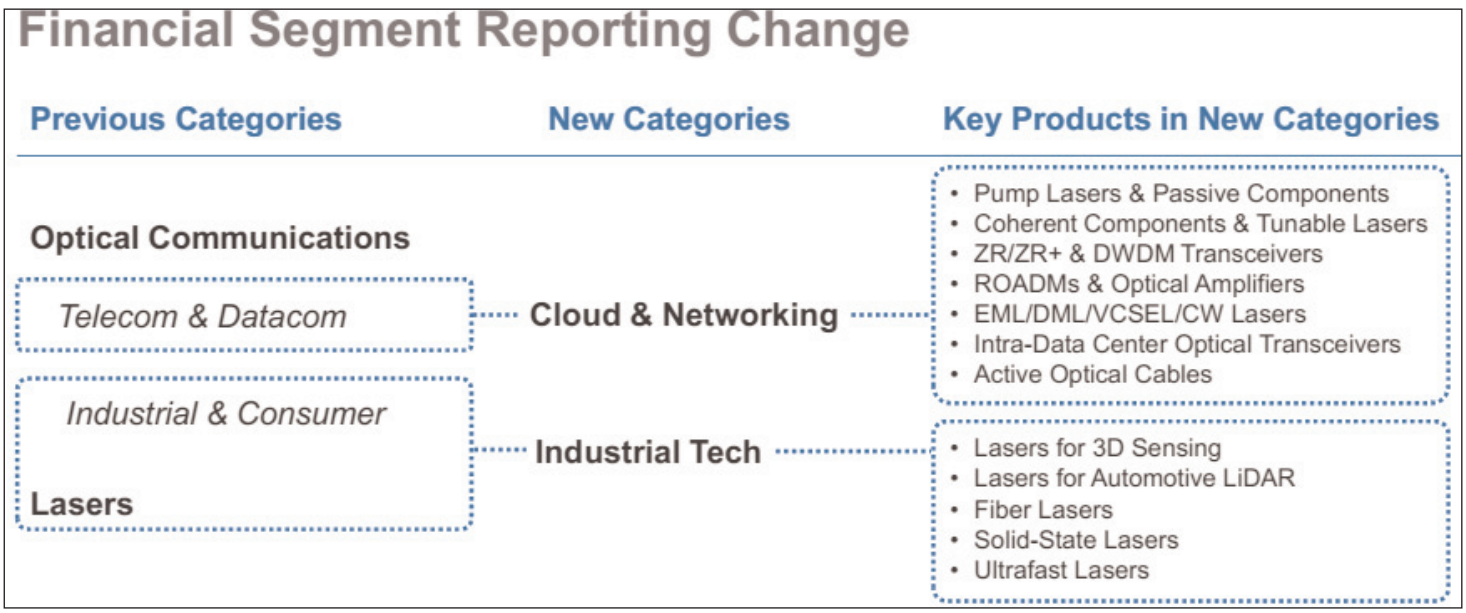
"As we navigate this transition period, we are delivering as planned on our product roadmaps and synergy attainment with respect to our NeoPhotonics acquisition [acquired in August 2022]," says Lowe.

On a non-GAAP basis, gross margin has fallen further, from 48.2% a year ago and 36.7% last quarter to 34.9%, due mainly to the lower revenue, factory under-utilization and product mix.

Operating expenses have been cut further, from $106.7m a year ago and $102.4m last quarter to $100.1m (31.5% of revenue), due to tight expense controls. SG&A expense was $39.1m. R&D expense was $61m.

Operating income has fallen further, from $137.4m a year ago (operating margin of 27.1%) and $33.7m (9.1% margin) last quarter to $10.6m (3.3% margin).

Likewise, net income has fallen further, from $119.2m ($1.69 per diluted share) a year ago and $40.2m ($0.59 per diluted share) last quarter to $23.4m ($0.35 per diluted share, but at the top of the



$0.20–0.35 guidance range).

"First-quarter revenue and EPS results were above the midpoints of our guidance, and we are maintaining tight cost controls," says Lowe.

However, during the quarter, cash, cash equivalents and short-term investments fell by $69.3m from $2013.6m to $1944.3m. The firm used $30m in cash to purchase its wafer fab and campus in the UK. "This purchase reflects our confidence in the longevity of indium phosphide technology to address the ever-growing need for higher and higher-performance telecom transmission components," says chief financial officer Wajid Ali. To capture COGS synergies from the NeoPhotonics acquisition, Lumentum is pre-building nearly $30m of inventory to help facilitate the factory consolidation happening over the next few months. Also, the firm had an annual Japan tax payment of about $17m, as well as expenses related to the Cloud Light acquisition.

On 7 November, Lumentum completed its acquisition (announced at the end of October) of Cloud Light Technology Ltd of Hong Kong (which designs and makes optical transceiver modules for automotive sensors and data-center interconnect applications).

Hence, including the projected financial results of Cloud Light after the acquisition date, for fiscal second-quarter 2024 (to end-December 2023) Lumentum expects revenue to rise to $350–380m, with Industrial Tech down sequentially but Cloud & Networking up sequentially.

Operating margin is expected to be 2–4%, while diluted earnings per share should be $0.25–0.35.

To streamline operations and achieve synergies, Lumentum will be consolidating NeoPhotonics back-end manufacturing facilities, and hence expects under-absorption of capacity relating to these moves during fiscal Q2 and Q3/2024. "By the end of Q4, as we ramp up production of NeoPhotonics' products within Lumentum's manufacturing footprint, we expect to shift buffer inventory, enabling these manufacturing costs to align with the rest of our production," says Ali. "In addition, as we continue to focus on cash generation, we expect our internal inventories to decline throughout the balance of the fiscal year."

While we continue to see very strong growth in the demand for our data-center chips as well as our newly acquired intra-data-center transceivers, this strength is being offset by the telecom and industrial inventory drawdown activities. Due to this inventory correction, we believe we continue to ship below end-market demand

"The addition of Cloud Light's products to our portfolio positions Lumentum as a leader in providing photonics to cloud operators at a time when artificial intelligence is rapidly accelerating growth in the data-center market. Lumentum's served opportunity within data centers has expanded more than five-fold as a result of the Cloud Light acquisition," says Lowe.

"For years, Cloud Light has been supplying differentiated high-speed products to leading hyperscale customers, both custom products to address unique customer needs, as well as standard products to address a broad range of hyperscale customer requirements. In the last 12 months, over 90% of Cloud Light's revenue was derived from 400G-and-higher-speed products. In the most recent quarter, over half of Cloud Light's optical transceiver revenue was derived from 800G transceivers," he adds.

"In calendar 2024, we expect cloud applications will drive over 30% of our Cloud & Networking revenue, both within data centers and for data-center interconnect. We anticipate year-over-year Cloud & Networking growth in calendar 2024, driven by accelerating AI compute requirements, and as customer inventory levels are reduced and our shipment rate is more in sync with end-market demand."

www.lumentum.com

Lumentum acquires Cloud Light for $750m to accelerate data-center speed and scalability

Cloud intra-data center infrastructure revenue to more than double

Lumentum Holdings Inc of San Jose, CA, USA (which designs and makes optical and photonic products for optical networks and lasers for industrial and consumer markets) has acquired Cloud Light Technology Ltd of Hong Kong (which designs and makes optical modules for automotive sensors and data-center interconnect applications) for about $750m (before certain adjustments), paid in cash from Lumentum's balance sheet and the assumption and substitution of outstanding unvested Cloud Light options.

Lumentum expects the acquisition to accelerate its push into the fastest growing segments of the multi-billion-dollar opportunity for optical modules used in cloud computing data-center infrastructure. Cloud Light has a track record of developing and manufacturing the highest-speed connectivity solutions at the leading edge of new and rapidly growing technology

transitions. Nearly all of Cloud Light's more than $200m revenue in the last 12 months was derived from 400G or higher-speed transceiver sales. In the most recent quarter, over half of Cloud Light's optical transceiver revenue was derived from 800G modules.

With the acquisition, Lumentum reckons that it will be well positioned to serve the growing needs of cloud and networking customers, particularly those focused on optimizing their data-center infrastructure for the demands of artificial intelligence and machine learning (AI/ML). Lumentum expects its more comprehensive product and technology portfolio to enable customers to more effectively manage the escalating compute and interconnect requirements of AI workloads. The combination also brings what are reckoned to be best-in-class design and assembly, test and packaging capabilities together with Lumentum's global scale and customer reach.

"With Cloud Light, we are making a strategic investment to significantly expand our opportunities in the cloud data-center and networking infrastructure space," says Lumentum's president & CEO Alan Lowe. "Cloud Light provides us with the highest-speed transceiver solutions at scale and complements our advanced component capabilities. This results in a broad product and technology portfolio that addresses a wide range of cloud operator needs," he adds. "This transaction will deliver substantial, long-term value to our stockholders, with immediate earnings accretion and accelerated revenue growth," he believes.

"We founded the company with a vision that our deep expertise in high-volume precision manufacturing would result in a superior value proposition for cloud data-center customers," says Cloud Light founder & CEO Dr Dennis Tong. "Having worked closely with the technology teams within leading cloud operators, we believe we can build upon our success to date and further accelerate cloud data-center growth by combining Lumentum's advanced photonic integration and transmission technologies with our highly automated packaging and manufacturing processes," he concludes.

www.lumentum.com

Strategic and financial benefits of Cloud Light acquisition

The acquisition of Cloud Light Technology is expected to enable Lumentum to:

- **Capture AI inflection with expanded intra-data-center opportunity**:
The complementary combination is reckoned to position Lumentum as a leader in providing photonics to cloud operators, enabling a more than a five-fold expansion in the firm's served opportunity within data centers. With the advent of generative AI, cloud network needs for 400G and higher-speed optical transceivers have accelerated rapidly, with the opportunity for these intra-data-center products expected to grow at a compound annual growth rate (CAGR) of 30% and exceed $10bn by 2028. Cloud Light provides the highest-speed optical transceiver products to leading hyperscale cloud customers, with even higher-speed solutions well along in their development, complementing Lumentum's existing portfolio of laser transmitters and other integrated components for data-center transceivers.
- **Better address future customer roadmaps**:
AI models are driving an exponential increase in compute requirements, where performance is now doubling every 3–4 months, compared with the historical doubling every two years according to Moore's Law. Scaling workloads even higher is limited by existing network and interconnect bottlenecks. With the addition of Cloud Light, Lumentum reckons that it better addresses these challenges — both now and into the future — by combining advanced optical interconnect technologies based on chip-scale photonic integration, together with highly automated packaging and manufacturing technologies.
- **Become a more strategic partner to cloud and AI infrastructure customers**:
With Cloud Light, Lumentum can more effectively address the growing and diverse needs of cloud operator and AI infrastructure providers. This includes providing next-generation optical connectivity and optical switching within data centers, as well as coherent pluggable modules and optical line system components for data-center interconnect applications. Lumentum expects that, with its vertical integration capabilities in components and diversity in its global manufacturing footprint, customers can benefit from improved security of supply and superior technology and cost roadmaps.
- **Amplify edge and metro networking opportunities**:
Cloud Light's proven capabilities in low-cost product development and high-volume manufacturing are relevant not only for cloud data-center and data-center interconnect solutions but also for network edge applications, including those served by direct detect and coherent tunable DWDM transceivers. A broader set of networking customers should benefit from the added advanced packaging technologies and manufacturing capabilities offered by the combination.

The transaction should be immediately accretive to Lumentum's non-GAAP earnings per share and more than double cloud data-center infrastructure revenue in the 12-months after the transaction close.

www.cloudlight.com.hk

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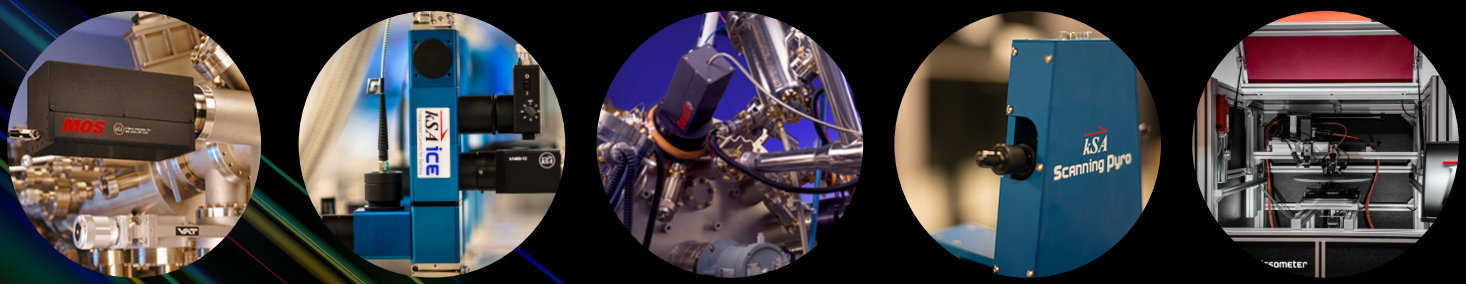

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Ascent CIGS efficiency rises from 15.5% to 17.55%

Addition of rubidium fluoride plus manufacturing process improvements achieve minimum efficiency for satellite applications

Ascent Solar Technologies Inc of Thornton, CO, USA says that the latest test results of its proprietary flexible copper indium gallium diselenide (CIGS) thin-film photovoltaic (PV) technology show an increase in efficiency from 15.5% to 17.55%.

In August, Ascent began optimizing both the manufacturing processes and chemistry of its CIGS technology. This has resulted in a steady increase in efficiency that began with a jump from 10.8% to 15.2% on 5 September; an additional increase to 15.5% on 12 September; and now to 17.55% just six weeks later.

The latest efficiency increase can be attributed to the addition of rubidium fluoride to the chemistry, combined with improvements to Ascent's manufacturing process. The improvements will result in an increase in specific power in the space environment from 1900W/kg to 2100W/kg at AM0. This enables the solar energy system to provide additional power with the same flexible, resilient and lightweight footprint, says the firm.

Ascent plans to further improve its CIGS technology efficiency through the incorporation of Zn(O,S), a thin film that is considered to be a most promising candidate for a cadmium-free buffer layer, as well as broader chemistry optimization. Utilizing Zn(O,S) increases efficiency and specific power as it expands interactions with light in the blue spectrum, as well as helps counter degradation through improvements after light soak.

"We have now reached the minimum efficiency (17%) that many satellite companies require, a milestone achievement for our team and a critical step toward commercialization for our space product development program," says CEO Paul Warley. "We are well positioned for adoption as one of the most flexible, light and suitable solar solution to reduce waste in space," he reckons.

Backed by 40 years of R&D, 15 years of manufacturing experience, and a comprehensive IP and patent portfolio, Ascent provides flexible thin-film solar panels for use in environments where mass, performance, reliability and resilience matter. Its PV modules have been deployed on space missions, multiple airborne vehicles, agrivoltaic installations, in industrial/commercial construction as well as a range of consumer goods.

www.AscentSolar.com

Ascent achieves specific power of 1900W/kg at AM0

Latest advance surpasses 100–400W/kg of deployed crystalline solar

Ascent's latest CIGS technology has achieved a measured specific power (power-to-weight ratio) of 1900W/kg at AM0 (air mass 0, the standard solar spectrum that represents solar radiation outside Earth's atmosphere, in the vacuum of space). The existing range of specific power for crystalline solar technologies deployed in space is 100–400W/kg.

The specific power rate is the most important factor for solar applications where overall array mass is crucial, including those in the aerospace sector, where the cost per kilogram is $2000–25,000 to launch payloads into low earth orbit (LEO). Higher-energy orbits such as geosynchronous equatorial orbit (GEO) or cislunar space typically run an order of magnitude more per kg, with payloads intended for moon landing having been booked for over $1m/kg.

Ascent says that its thin-film solar is suitable for use in a space environment due to its radiation resistance, resilience to physical damage, self-annealing, as well as ultralight weight and flexibility. With recent advances in power density, Ascent reckons it can provide meaningful power for space customers without the increased cost of mass. There is a fixed amount of mass and volume available for current mission launches and, by increasing power density, Ascent can increase the system power available, with no increases to mass and volume. As a result, there is no impact to launch cost, enabling space missions to get even more out of the existing and growing number of orbital launch providers.

"Ascent streamlines the otherwise onerous process of assembly, integration and testing for solar arrays for satellites and other spacecraft," says CEO Paul Warley. "Our Plug & Fly array solutions eliminate the scheduling impacts needed to pick, place, wire, solder and test individual cells while simultaneously reducing the cleanroom space bottleneck that the process typically requires. Ascent technology can prevent space vehicle and system integrators from having to deal with thousands of credit-card-sized components and delicate interconnects between them by instead providing them a single thin-film solar array with pre-integrated and tested PV modules," he adds.

"Our most recent performance improvements now make Ascent space products viable drop-in replacement power generation solutions that can also produce more power over the course of a mission," Warley continues. "This translates to saving multiple kilograms for mission managers and spacecraft engineers balancing spacecraft power and mass budgets."

www.AscentSolar.com

Swift Current Energy extends First Solar relationship with 500MW order

Series 7 modules to be delivered in 2027–2028, builds on existing 3.3GW relationship

First Solar Inc of Tempe, AZ, USA has agreed to supply Boston-based utility-scale clean energy developer, owner and operator Swift Current Energy with 500MW of Series 7 cadmium telluride (CdTe) thin-film photovoltaic (PV) modules. Swift Current Energy previously placed orders for 3.3GW of First Solar modules in 2022. This latest order, which was booked prior to the release of First Solar's third-quarter 2023 results on 31 October, will see modules delivered between 2027 and 2028.

Swift Current Energy has commercialized more than 2.5GW of renewable energy projects, has a project pipeline of more than 10GW of solar, wind and energy storage, and owns 1.4GW of renewable energy projects currently in operation or in advanced construction.

"As we continue to progress our US development pipeline, certainty of pricing and supply is essential to ensuring that we deliver capacity as planned," says Swift Current Energy's co-founder & CEO Eric Lammers. "This latest agreement with First Solar supports our effort to build a resilient, competitive value chain, while supporting investments in domestic manufacturing, along with the jobs and economic benefits that come with it."

First Solar's modules are claimed to set industry benchmarks for quality, durability, reliability, design and environmental performance, with the Series 7 modules having the lowest carbon and water footprint of any commercially available PV module. The firm is reckoned to be the first PV manufacturer to have its product included in the Electronic Product Environmental Assessment Tool (EPEAT) global registry for sustainable electronics.

"Swift Current Energy has chosen to extend its partnership with First Solar to 2028, entrusting a significant portion of its development pipeline to our technology," notes First Solar chief commercial officer Georges Antoun. "Their decision speaks volumes to the competitive value that we are able to deliver in terms of energy, certainty of pricing and supply, and an advanced PV module that is responsibly produced in America, for America."

First Solar is the largest solar manufacturer in the Western Hemisphere, with about 6GW of operational, fully vertically integrated nameplate capacity in the USA. The firm has embarked on an expansion strategy that is forecast to grow its footprint to 14GW of nameplate capacity in the USA and 25GW globally by 2026. In addition to its third Ohio factory, commissioned earlier this year, First Solar expects to further expand its footprint in the state by 0.9GW while building new manufacturing facilities in Alabama and Louisiana, each with an expected annual nameplate capacity of 3.5GW.

The Alabama and Louisiana facilities, which are expected to represent over $2bn in investment and are forecast to begin commercial shipments in 2024 and 2026 respectively, are designed to produce the Series 7 modules ordered by Swift Current and expected to be made with 100% US-made components identified in the current domestic content guidance issued by the US Department of the Treasury. First Solar anticipates that, once its Louisiana factory is completed and ramped, Series 7 modules will account for over two-thirds of its annual domestic nameplate capacity. Series 7 modules currently produced at the firm's Ohio facility are already manufactured with US-made glass and steel.

www.firstsolar.com

Ascent meets compliance requirements, maintains Nasdaq listing

In mid-October, Ascent Solar Technologies Inc of Thornton, CO, USA — which makes lightweight, flexible copper indium gallium diselenide (CIGS) thin-film photovoltaic (PV) modules that can be integrated into consumer products, off-grid applications and aerospace applications — announced a positive resolution with Nasdaq, maintaining its senior exchange listing.

After completing its public offering on 2 October, the firm believed that it had regained compliance with the Nasdaq continued listing requirements for (i) $1 minimum bid price, (ii) $2.5m minimum stockholders' equity, and (iii) 500,000 minimum publicly held shares.

On 11 October, Nasdaq confirmed it had evidenced compliance with all applicable criteria for continued listing on Nasdaq. The securities will continue to be listed and traded on The Nasdaq Capital Market.

The previously scheduled hearing before the Nasdaq Hearing Panel was cancelled.

"This positive resolution with Nasdaq is an important step in Ascent's continuing growth strategy," says CEO Paul Warley.

www.AscentSolar.com

Fully in-situ roughening for ultrathin III–V solar cells

Increased light trapping boosts short-circuit current by 5%.

Colorado School of Mines and the National Renewable Energy Laboratory (NREL) in the USA report on fully in-situ fabrication of light-trapping structures to improve III–V solar cell performance [Allison N. Perna et al, J. Appl. Phys., v134, p135307, 2023].

The structures were generated by texturing the final growth surface through vapor phase etching and re-deposition in the solar cell material growth chamber. The resulting roughened surfaces have high broadband scattering, trapping light for longer in the cell.

The team was particularly interested in developing III–V cells with ultrathin absorber layers (under 400nm). For space applications, this enables higher radiation tolerance and specific power (W/kg), and reduced material content, growth time, and (hence) cost.

The team comments: "Lower manufacturing cost may help expand the market for III–V solar cells to include terrestrial applications where high efficiency and high specific power are paramount."

Another advantage of thin cells is higher open-circuit voltage due to reduced diffusion recombination. Unfortunately, currents tend to be reduced by increased optical transmission loss. To overcome this, light-trapping schemes need to be implemented. Such schemes are often implemented ex-situ, but as such increase processing times and cost, not least in terms of needing extra capital equipment.

The materials for the Colorado/NREL solar cells were grown using atmospheric-pressure 650°C dynamic hydride vapor phase epitaxy (D-HVPE) on n-type (100)-oriented gallium arsenide (GaAs:Si) substrates with a 6° offcut toward (111) A. The cells consisted of a single junction grown in an inverted sequence, enabling flip-chip fabrication (Figure 1).

The researchers comment: "Inverted cell growth enables in-situ texturing of the rear surface immediately following growth without removal of the sample from the reactor and without requiring subsequent growth on a roughened surface."

The team also points out that D-HVPE is a high-throughput and potentially lower-cost epitaxial growth technique, and that combining D-HVPE with a fully in-situ texturing method further supports III–V industrial throughput.

The last-grown zinc-doped gallium indium phosphide ($Ga_{0.5}In_{0.5}P$:Zn) layer was grown with a thickness that maintained a 100nm emitter/contact layer after texturing with in-situ etching/re-deposition in the reaction chamber.

The researchers used a dual-growth reactor, where the process conditions for the next layer are prepared in one chamber, while the growth proceeds in the other. The last etch/texturing step involved hydrogen chloride (HCl), phosphine (PH_3), or both gases in hydrogen carrier gas. These gases were also used in the growth of GaInP.

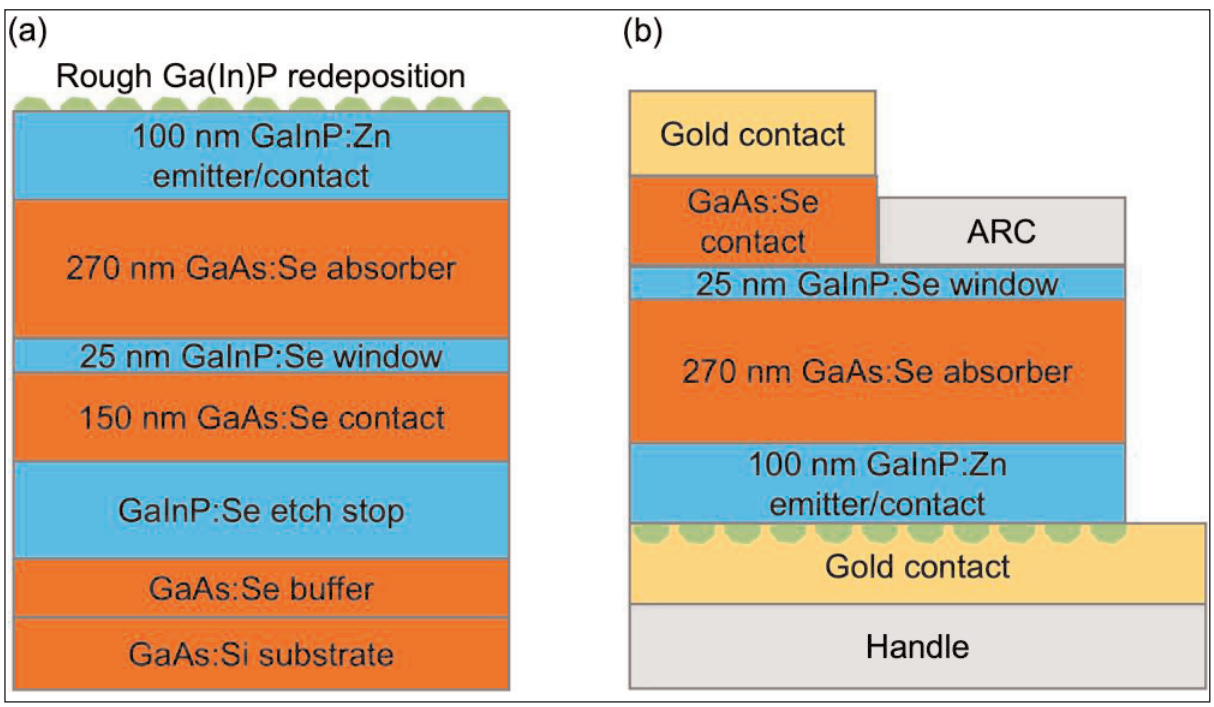

Figure 1. Cell schematics of (a) as-grown inverted cell structure and (b) processed cell structure with nominal layer thicknesses.

In separate experiments to tune the etch/re-deposition texturing, it was found that HCl on its own resulted in a mirror-like surface, similar to the initial GaInP layer, without generating the desired texturing.

The team reports on the effect of adding PH_3: "In contrast to the planar etching observed while using only HCl, the addition of PH_3 to the HCl vapor etch led to a rough textured surface with low broadband specular reflectance that is potentially useful as a broadband scatterer."

Changes in texturing quality were studied by varying the process duration and HCl flow rate. Studies using scanning electron microscopy, Auger electron spectroscopy (AES), cross-sectional scanning transmission electron microscopy with energy-dispersive spectroscopy (STEM-EDS), and high-resolution x-ray diffraction (HRXRD), found the texturing to result from etch and re-growth of Ga(In)P (highly Ga-rich GaInP).

The researchers comment: "The observation that the textured morphology does not form from HCl etching alone and does form with supplied PH3 suggests that re-deposition and island growth of Ga(In)P result from reactions between etch products and the supplied PH_3."

The material used for solar cells was textured using a HCl/PH_3 flow rate of 4/8 standard cubic centimeters per minute (SCCM) at 0.0008/0.0110atm partial pressures, respectively. The texturing time was 60 seconds.

Cell fabrication began with electroplating gold onto the textured surface. The device was then flipped onto a silicon handle substrate. The active area of the cell was about 0.25cm^2. The flipped cell also included a magnesium fluoride/zinc sulfide ($MgF_2/ZnS/MgF_2$) anti-reflective coating (ARC) on the window area. The performance was compared with a cell without texturing (Figure 2).

The best of four devices for each type showed a 4.9% increase in short-circuit current density (J_{SC}) for the textured structure. Averaged over the four samples the increase was 5.1%.

The external quantum efficiency (EQE) performances were similar for the two device types, apart from some oscillations for the planar type arising out of Fabry–Pérot interference effects. The textured cell efficiency was 19.6%, compared with 18.2% for the control planar device.

The researchers comment that there is no appreciable loss in open-circuit voltage V_{OC} or fill factor, "indicating similar material quality and no adverse effect on the back contact metallization, respectively."

The absorption (A) of the cells was calculated from total hemispherical reflectance (Rh) data from UV–Vis measurements in an integrating sphere (A = 1–Rh).

The researchers report: "We observe a lower EQE than absorption in both cells that, for the textured cell, is more significant at long wavelengths. This may be due to parasitic absorption in the rough gold surface,

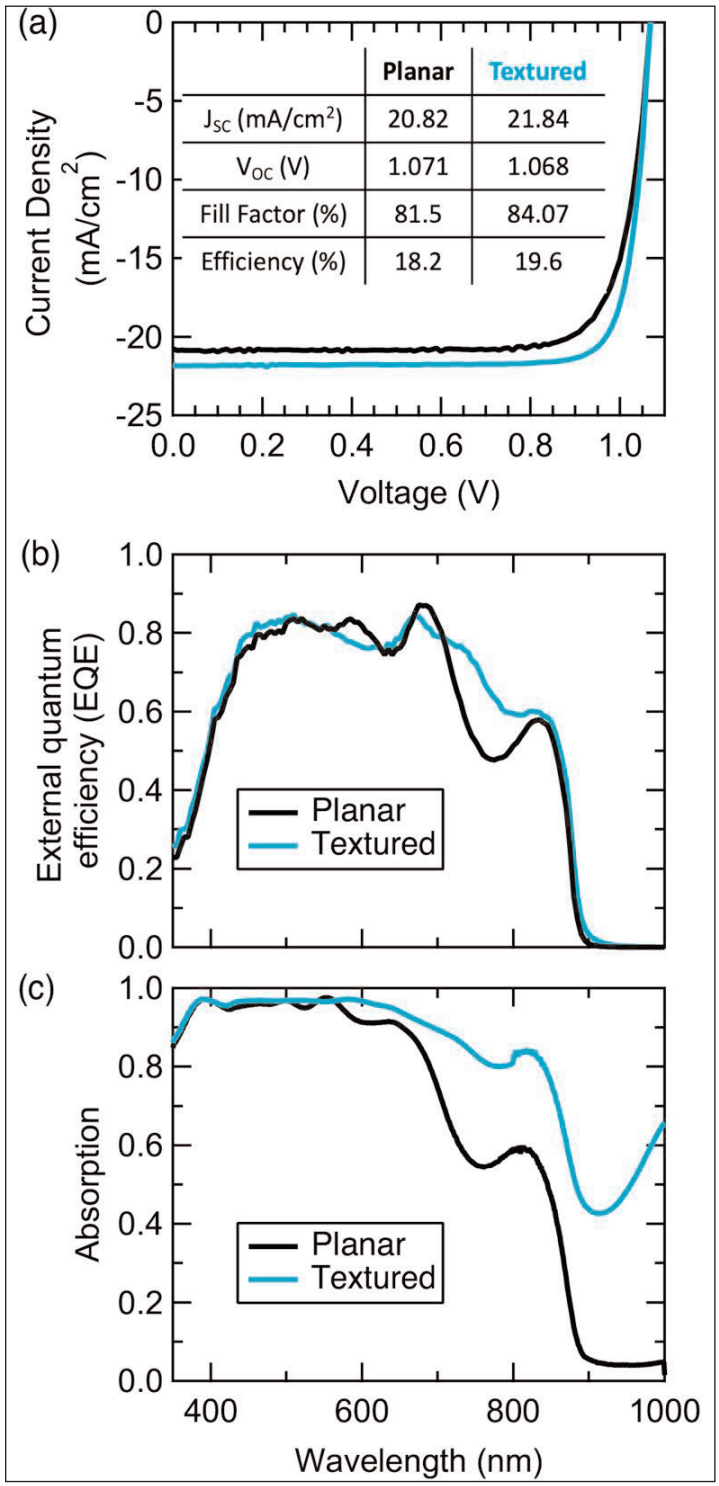

Figure 2. Cell measurements of thin solar cells without texturing (black) and textured (blue): (a) current density versus voltage; (b) external quantum efficiency; (c) absorption.

causing the metal to act as a lossy mirror."

In an ideal cell, the two quantities would be equal, suggesting losses either due to optical absorption or recombination of carriers into photons. The team suggests that improving the rear-side metallization process could result in lower losses and increased current. ■

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Author: Mike Cooke

First droplet epitaxy of InAs quantum dots on InGaAsP quaternary alloy

Light emission spans the low-loss C-band as well as other important telecom optical-fiber wavelengths.

University of Sheffield in the UK reports the first demonstration of indium arsenide quantum dot (QD) growth on indium gallium arsenide phosphide (InGaAsP, lattice matched to the InP substrate) by droplet epitaxy (DE) [Elisa M. Sala et al, Phys. Status Solidi RRL, p2300340, 2023].

The 1400–2200nm photoluminescence emissions from the resulting QDs cover the low-loss telecom C-band 1530–1565nm, along with other important telecom optical-fiber bands, such as O and L. QDs are seen as having strong potential for telecom lasers, pure single-photon and entangled photon pair emissions for quantum information technologies, and for novel nanomemory devices.

The team adds: "The investigation of InAs QD growth embedded in InGaAsP/InP is particularly important given the extensive use of this quaternary alloy as waveguide material for telecom lasers."

The researchers first studied the formation of indium droplets on a 5nm $In_{0.719}Ga_{0.281}As_{0.608}P_{0.392}$ layer and their dependence on temperature. The lattice-matched InGaAsP layers were grown by metal-organic vapor phase epitaxy (MOVPE) on InP(100) substrates.

The team found that of the temperatures used droplets only formed for the higher temperatures of 350°C and 400°C. Below these temperatures, the trimethyl-indium precursor failed to pyrolyze. At 350°C and 400°C, the droplet densities were $3x10^6/cm^2$ and $1x10^6/cm^2$, respectively. The corresponding diameters/heights were around 425/90nm and 750/105nm.

While droplet formation on InGaAsP at 400°C had a lower density than either InGaAs (c) or InP ($6x10^7/cm^2$), the size of the droplets were significantly larger (Figure 1): about 30x wider/10x higher than for InGaAs, and 10x/2x than InP.

The team comments: "We ascribe such considerable variation of droplet sizes and densities to a modification of the surface diffusion. From these observations, we can conclude that the InGaAsP surface presents the highest surface diffusion among the three surfaces, which leads to a very low droplet density with the largest size."

The researchers also point out that (100) InGaAsP features lateral composition modulation (LCM) with GaP- and InAs-rich regions. "Also, greater LCM appears to be correlated with an increased adatom surface diffusion, as this configuration will decrease the adatom incorporation rate," they add.

To form InAs QDs, the researchers raised the temperature to 520°C and exposed the droplets to arsine (AsH_3). For atomic force microscopy, the QDs were left uncapped. For other work, the QDs were capped with InP.

For InP droplets, no QDs resulted. However, for droplets on InGaAs and InGaAsP there resulted InAs QDs with a higher density than the droplets. The QD

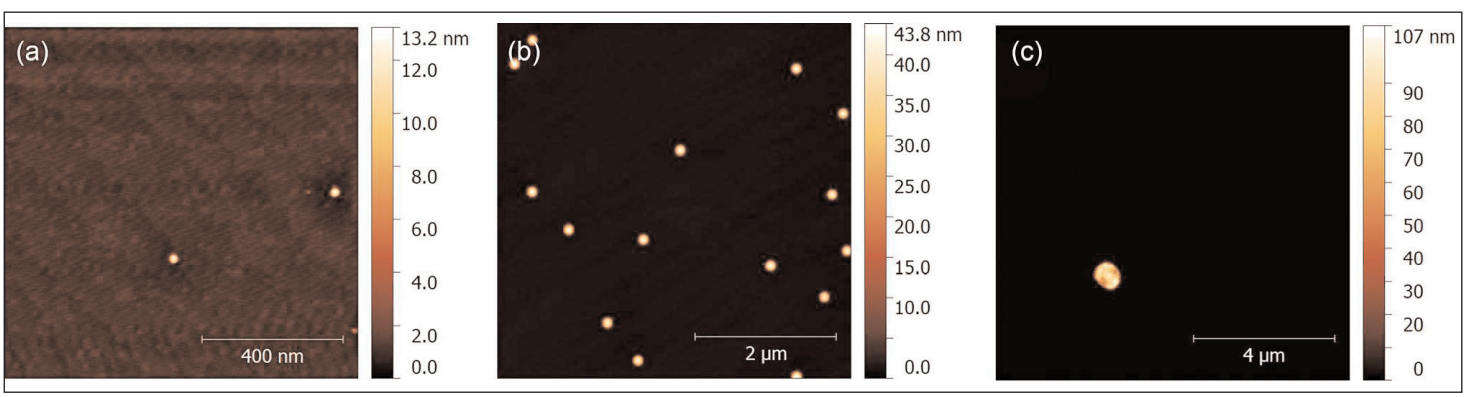

Figure 1. Atomic force micrographs of free-standing indium droplets deposited at 400°C on three different surface types: (a) InGaAs, (b) InP, and (c) InGaAsP. Note different sizes of scan areas adjusted for better visualization.

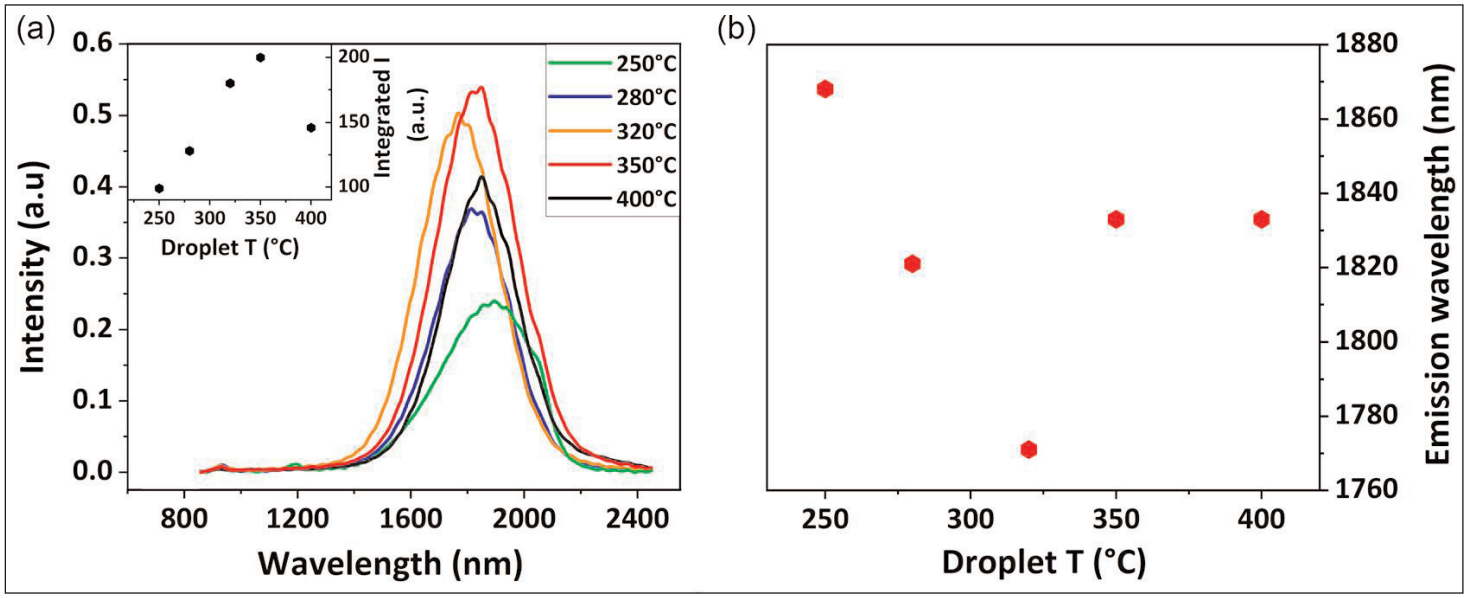

Figure 2. (a) Room-temperature photoluminescence of QDs grown with 250–400°C droplet deposition temperatures (inset: integrated intensity). (b) Peak emission wavelength versus droplet deposition temperature.

densities were $1x10^{10}/cm^2$ and $2x10^{10}/cm^2$ for the InGaAs and InGaAsP samples, respectively.

Further, the QDs on InGaAsP were much smaller than the initial indium droplets, unlike for the InGaAs-based QDs. "We attribute this to an out-diffusion of indium and redistribution on the InGaAsP surface during the thermal ramp step, which can lead to a reduction in droplet size and a 're-wetting' of the surface," the team reports.

For lower-temperature droplet deposition samples, the same process resulted in InAs QDs even below 350°C where there were no indium drops visible on the surface. The researchers explain: "For a droplet temperature of less than 320°C, the indium precursor trimethyl-indium is not pyrolyzed, i.e. broken down into methyl-indium groups. An increase in temperature during the thermal ramp will trigger a gradual decomposition of methyl-indium occurring at the surface, and providing metallic indium available for droplet formation."

At 250°C droplet deposition, the InAs QD density was $8x10^8/cm^2$, increasing rapidly to the $10^{10}/cm^2$ level at higher droplet deposition temperatures. Beyond 400°C droplet deposition, the researchers found surface degradation to result from increased defect formation.

The team also noted that the process avoided quantum dash formation, i.e. dots elongated in a particular crystal direction, unlike when InAs is deposited on InGaAsP/InP substrates without using droplet epitaxy. The team ascribes this to "the fact that the DE method does not rely on the lattice mismatch between surface and epilayer, thus allowing for a better control of QD formation, which is decoupled from the layer/epilayer mismatch."

Photoluminescence measurements (Figure 2) showed an increase in intensity up to 350°C droplet deposition, followed by a sharp decrease at 400°C. The wavelength range was 1400–2200nm.

Closer study of the dots using 4K low-temperature micro-photoluminescence showed bright single-dot emission in a narrower 1300–1600nm wavelength range. ■

https://doi.org/10.1002/pssr.202300340

www.rfwireless-world.com/Terminology/optical-fibre-wavelength-bands.html

Author: Mike Cooke

Determining droop in green InGaN LEDs

Researchers in the USA find an imbalance between radiative recombination and intrinsic Auger–Meitner recombination in green indium gallium nitride LEDs.

Researchers based in the USA report that "intrinsic Auger–Meitner recombination was found to be the primary mechanism for non-radiative recombination" in green indium gallium nitride (InGaN) light-emitting diodes (LEDs), according to their experimental studies [Xuefeng Li et al, Appl. Phys. Lett., v123, p112109, 2023].

The team from University of New Mexico, Lumileds LLC and Sandia National Laboratories in the USA comment: "The efficiency droop can be attributed to the imbalance between radiative and intrinsic Auger–Meitner recombination due to carrier localization and Coulomb enhancement in the LEDs studied. Thus, maintaining a low carrier density in thin QWs is advantageous for avoiding strong intrinsic Auger–Meitner recombination and utilizing the interplay of carrier localization and Coulomb enhancement on the radiative process."

The Auger–Meitner mechanism is also often referred

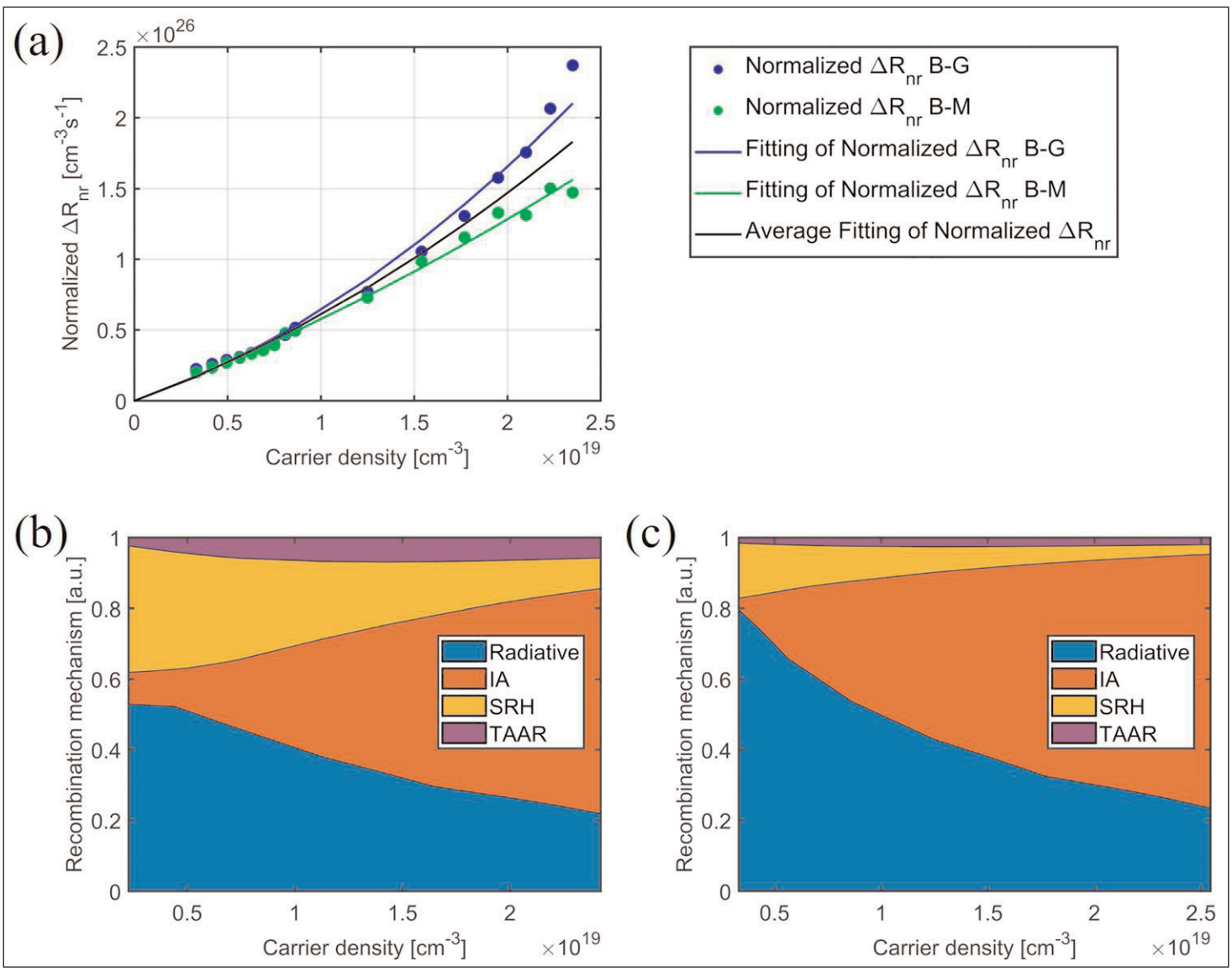

Figure 1. (a) Normalized ΔR_{nr} data and fitting versus carrier density for bad to good (B–G) and bad to middle (B–M) growth: solid dots experimental data, solid lines fits to data. (b, c) Percentages of recombination mechanisms versus carrier density in bad and good growth wafer, respectively.

to as just Auger recombination. Although Lise Meitner reported the effect in 1922 as a by-product of other research, Pierre Victor Auger independently discovered and studied the mechanism more deeply, documenting his work in 1923.

The New Mexico/Lumileds/Sandia researchers studied samples with identical active regions but different deep-level defect densities. The active regions consisted of three 3nm InGaN quantum wells (QWs) with 19% indium content, targeting green emissions, separated by 18nm GaN barriers. The samples were grown using c-plane metal-organic chemical vapor deposition. The measured defect densities were $0.45x10^{15}/cm^3$, $0.78x10^{15}/cm^3$ and $1.5x10^{15}/cm^3$, according to deep-level optical spectroscopy (DLOS) and lighted capacitance–voltage (LCV) measurements.

The team describes DLOS as "a photo-capacitance technique that measures the optical absorption spectrum of a deep level from the time-dependence of change in space-charge in a depletion region when the defect changes charge state upon photo-emission." The researchers also explain: "LCV compares C–V measurements taken in the dark with the deep level occupied and under 2.1eV illumination with the deep level optically depopulated."

From the defect density values the rates of Shockley–Read–Hall (SRH) and trap-assisted Auger–Meitner (TAAR) recombination could be estimated.

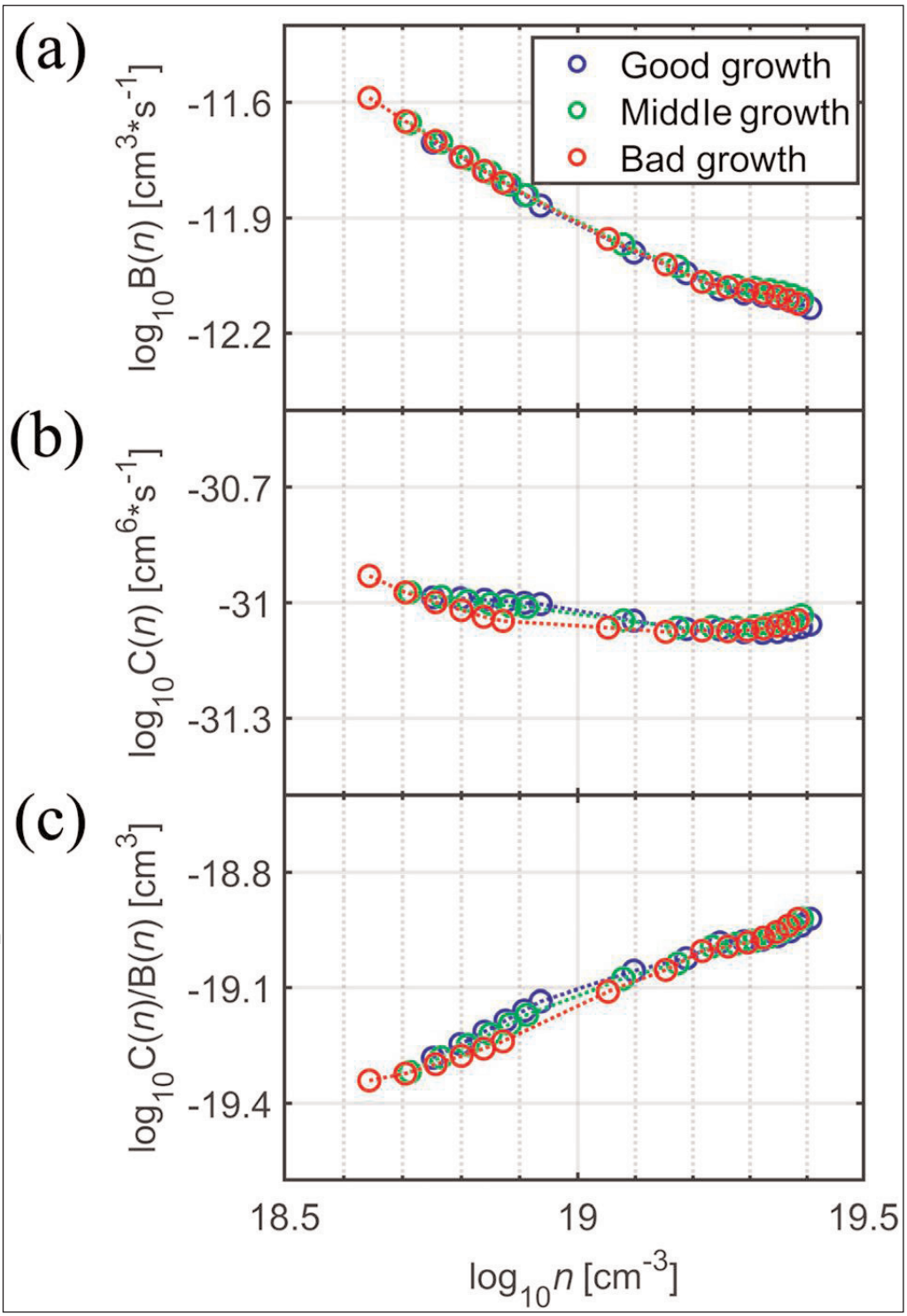

Figure 2. (a)–(c) B(n) and C(n) coefficients and the ratios of C(n)/B(n) versus carrier density for good, middle and bad growth.

Small-signal electroluminescence (SSEL) was used in combination with internal quantum efficiency (IQE) measurements to separate the radiative and non-radiative recombination rates. The IQE was determined at Lumileds' facility using external quantum efficiency (EQE) measurements from LEDs fabricated from the three materials. The LEDs had a known light extraction efficiency, allowing the IQE to be calculated.

The researchers explain: "In SSEL, the total recombination lifetime can be calculated from the integration of the differential recombination lifetime, which is directly acquired from the simultaneous fitting of the impedance and modulation responses of the LED."

The non-radiative recombination was assumed to consist of SRH, TAAR and intrinsic Auger (IA) recombinations. The SRH was assumed to be linear in carrier concentration (n), the TAAR to be quadratic (n^2) and the IA to be the remainder ($C(n)n^3$). Further, the SRH and TAAR were assumed to have linear dependence on defect density.

The differences between the non-radiative recombination rates (ΔRnr) were normalized to a difference of $1x10^{15}/cm^3$ in defect density and compared (Figure 1). The experimental data show good overlap between the good- (low defect density) and middle-quality samples relative to the bad sample at low carrier density.

The SRH and TAAR components of the non-radiative recombination coefficients were determined using quadratic fitting to the data and using the relevant defect density. The researchers point out that, while experimental and theoretical studies tend to assume a purely quadratic dependence of TAAR, "we still cannot completely exclude the possibility of an n3 dependency."

The TAAR percentages remained below 7% and 3% for the bad and good materials, respectively. "In the samples studied, intrinsic Auger–Meitner recombination still dominates the non-radiative recombination and TAAR is not found to be a significant contributor to droop or the green gap," the team comments.

Having separated out the non-radiative components, the researchers could determine (Figure 2) the coefficients for bimolecular (electron–hole) recombination into photons (B(n)) and for the intrinsic Auger rate (C(n)) as functions of carrier concentration. The B(n) values match closely for the different quality samples. Also, the C(n) trends are fairly comparable.

The researchers comment: "The fact that all the B(n) coefficients are the same confirms the accuracy of using SSEL to measure the carrier dynamics since the three samples all have different IQEs and lifetimes. In thin quantum wells, B(n) and C(n) are influenced by several mechanisms, including the quantum-confined Stark effect (QCSE), phase-space filling effect (PSF), carrier localization, and Coulomb enhancement. QCSE and PSF have a similar effect on both radiative and non-radiative recombination rates. Carrier localization increases both radiative and intrinsic Auger–Meitner recombination rates but has more of an impact on intrinsic Auger–Meitner recombination."

As a reminder, the total recombination is decomposed as:

$An + B(n)n^2 + C(n)n^3 + Dn^2$.

The A and D coefficients represent, respectively, the SRH and TAAR processes.

While the C(n) coefficient is relatively constant in the team's determinations, the B(n) coefficient is higher at low n. The researchers comment: "The decrease in radiative efficiency is partially due to intrinsic Auger recombination but is also associated with reduced carrier localization and Coulomb enhancement of B(n) at higher n as carriers become more delocalized." ■

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Author: Mike Cooke

Extracting efficiency contributions for sub-10μm LEDs

Opposing trends in LEE and IQE affect the optimum size for maximum EQE.

Universtité Grenoble Alpes, CEA-LETI in France has used cathodoluminescence (CL) to disentangle the size-dependence of the various sub-10μm indium gallium nitride (InGaN) light-emitting diode (LED) efficiencies [Palmerina González-Izquierdo et al, ACS Photonics, published online, 16 October 2023].

The team reports: "Our results show that, for small μLEDs (between 2.5μm and 10μm width), there is an optimal intermediate LED size for which the light emission is maximized, which we attribute to a competition between the light extraction efficiency (LEE) (which decreases with LED size) and the internal quantum efficiency (IQE) (which increases with LED size). In contrast to most prior studies that typically examine either the IQE or LEE with respect to size for larger LEDs, our work stands out by examining the interplay between IQE and LEE for μLEDs below 10μm."

Researchers have recently been developing μLEDs particularly for display applications in competition with liquid-crystal and organic LED products for micro-displays for augmented reality and virtual reality. Other potential applications include visible light communication, and optogenetics where cell activity can be controlled by light.

By separating the LEE and IQE contributions to the external quantum efficiency (EQE) and finding their respective dependence with size and geometry, the Grenoble Alpes, CEA-LETI team hopes to pave the way toward the efficient miniaturization of μLEDs.

The team grew InGaN-based LED heterostructures on 200mm-diameter silicon (Si) (111)-oriented substrates by metal-organic vapor phase epitaxy (MOVPE). The active light-emitting region consisted of multiple quantum wells (MQWs) with 5 layer pairs of 2nm/8nm InGaN/GaN wells/barriers.

The structure included n- and p-type GaN layers, an aluminium gallium nitride (AlGaN) electron-blocking layer, and a top layer of transparent indium tin oxide (ITO) conductor, as usual for epitaxial material aimed at LED production.

The researchers etched the material into square and circular μLED mesa structures by inductively coupled plasma (ICP). To enable cathodoluminescence (CL) analysis, the ITO layer was removed in a wet process involving hydrofluoric and hydrochloric acids.

The CL excitation used a focused 10keV electron beam with a 12nm current. A light microscope embedded within the electron objective lens collected data over a 200μm area. Monte Carlo simulations were used to find the best electron-beam energy to probe the MQW structure.

An advantage of using a silicon substrate for the CL study was that it absorbed the emitted light, virtually eliminating cross-talk between the excitation responses from the different regions of the mesas, unlike for transparent substrates like sapphire where reflections occur at the interfaces between materials with different refractive indexes.

The researchers first looked at the CL response at room temperature (RT) across the various square or circular mesas (Figure 1). The data were normalized to the highest value for each shape, and averaged over a strip about a path through the mesa center. The path for the square mesas was parallel to one side. The diameters/sides of the mesas were 2.5μm, 5.0μm, 7.5μm and 10.0μm.

One observation made was that the maximum CL intensity was reached within about 3.5μm of the edges of the largest mesas. The team points out that this is greater than the minority carrier diffusion length in GaN (0.1–1μm) or InGaN. Since the smaller mesas were less than 7μm, "the whole volume is affected by non-radiative recombination through sidewall defects," the researchers comment.

The optimal light emission for the intermediate-sized 7.5μm mesa structures at room temperature can be explained by an interplay between the LEE and the IQE for both geometries: the LEE decreases with the size of the mesa, while the IQE is governed by non-radiative recombination through sidewall defects, which affects the mesas with a higher perimeter-to-surface ratio the most

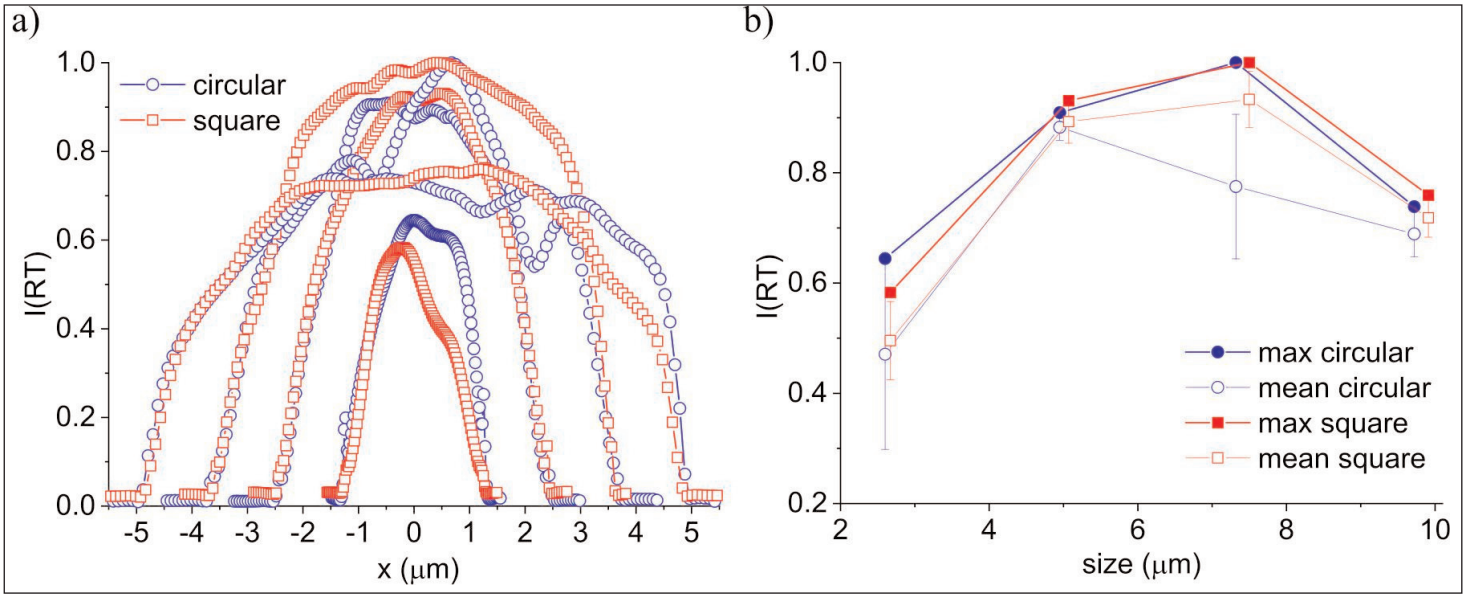

Figure 1. (a) Integrated MQW CL profile at RT for four different sized square/circular mesas. (b) Maximum (filled markers) and mean (empty markers) intensity over the central area of the mesas obtained from graph a.

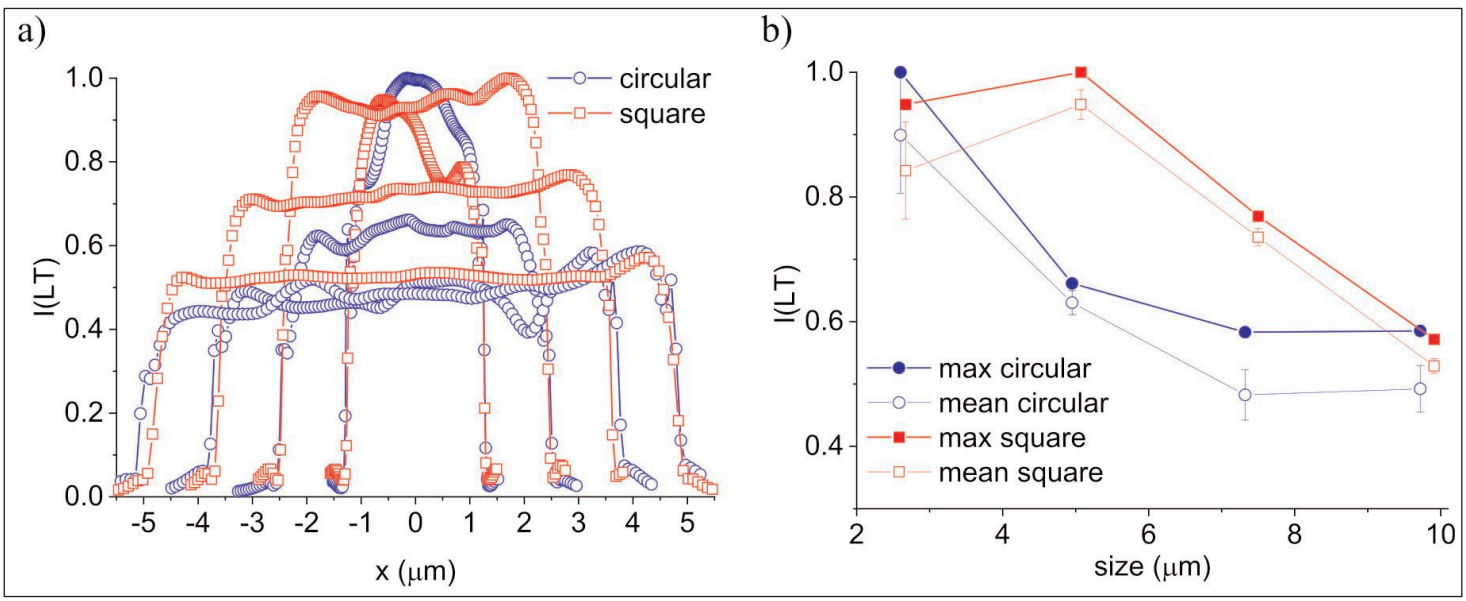

Figure 2. (a) Integrated MQW CL profiles at 10K. (b) Maximum (filled markers) and mean (empty markers) intensity over central area from graph a.

The team points out that there seemed to be a problem with their 7.5μm circular mesa structure, as indicated by the large standard deviation in mean CL intensity of the central mesa region.

The researchers then compared the RT results with those obtained at the low temperature (LT) of 10K (Figure 2). While the RT CL data are considered to be an indication of the trend of EQE, those at low temperature are seen as representing LEE, given that the LT IQE is expected to be near 100%. The idea of using LT data to represent LEE results from the theoretical expectation that non-radiative routes to electron recombination with holes are frozen out. In particular, the temperature dependence of the Shockley–Read–Hall (SRH) model for non-radiative recombination of conduction-band electrons through defect levels to holes in the valence band suggests this.

The IQE is given by EQE/LEE; and LEE is expected to be roughly independent of temperature. The ratio of the CL intensities, I(RT)/I(LT), is thus expected to be proportional to the IQE at room temperature (Figure 3).

The CL results suggest opposing trends for LEE (Figure 2) and IQE (Figure 3) with size — decreasing and increasing, respectively. For circular mesas, Figure 3 might suggest an optimum IQE near 7.5μm diameter and a sharp decline for 10μm, but the Grenoble Alpes, CEA-LETI team urges caution: "The CL intensity values measured for the 7.5μm size at room temperature exhibit a broad distribution, as seen in the mean and standard deviation presented in [Figure 2]. Consequently, caution must be exercised in drawing conclusions regarding whether this decrease repre-

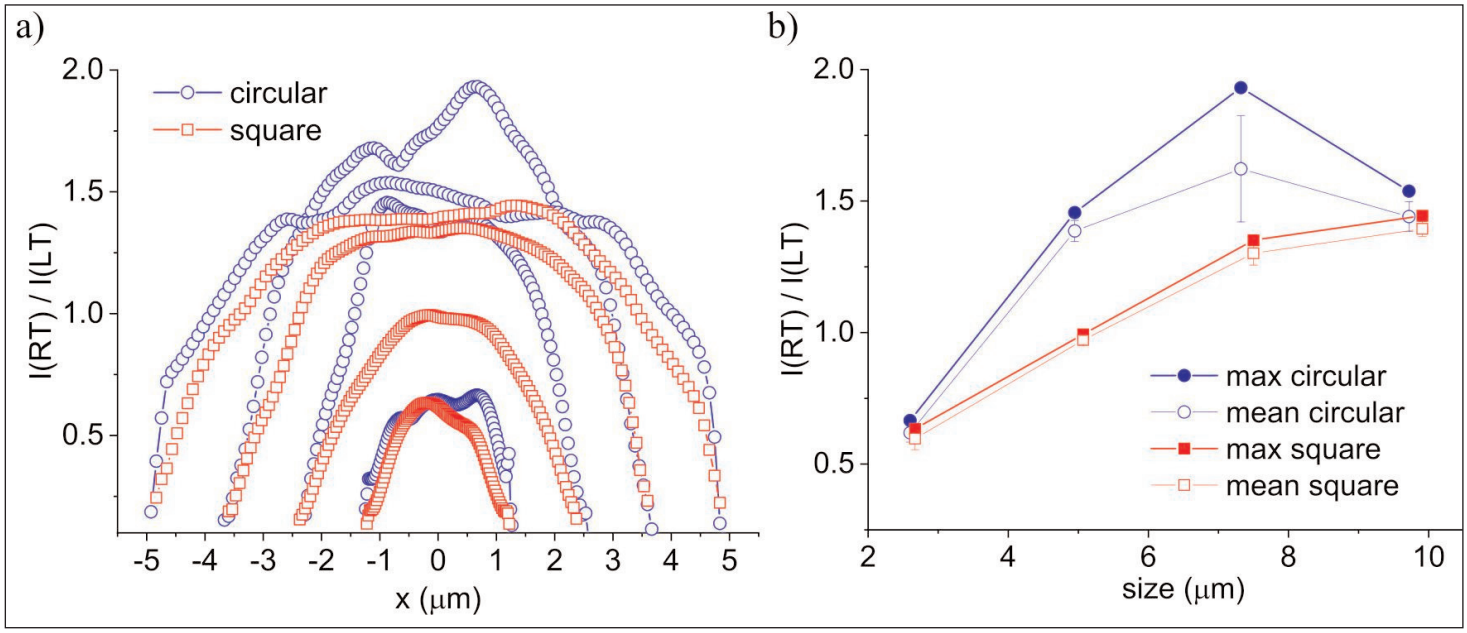

Figure 3. (a) MQW I(RT)/I(LT) profile from normalized intensities. (b) Maximum (filled markers) and mean (empty markers) value over the central area of the mesas obtained from graph a.

sents a genuine decline or a dampening effect similar to that observed in the case of square mesas."

The team concludes: "These analyses show that the optimal light emission for the intermediate-sized 7.5μm mesa structures at room temperature can be explained by an interplay between the LEE and the IQE for both geometries: the LEE decreases with the size of the mesa, while the IQE is governed by non-radiative recombination through sidewall defects, which affects the mesas with a higher perimeter-to-surface ratio the most." ■

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Author: Mike Cooke

Status of the IP competition for vertical gallium nitride power devices

China has taken over leadership from Japan in vertical GaN inventive activity, notes KnowMade.

Gallium nitride (GaN) power devices have been successfully adopted in several power applications, starting with lateral GaN devices. After the release of its new GaN electronics IP report, technology intelligence and IP strategy consulting company KnowMade discusses the status of vertical GaN device technology in the power GaN patent landscape. With the potential to overcome breakdown voltage and current capacity limitations of lateral devices, while alleviating some thermal issues, vertical GaN is seen as a promising technology for the next generation of power devices.

China takes over leadership from Japan in vertical GaN inventive activity

According to patenting activities (Figure 1), the intellectual property (IP) development of vertical GaN power devices took off in the mid-2000s, led by Japanese companies (Sumitomo Electric, ROHM, Toyota Motor). Yet the number of inventions per year remained relatively low until 2012. In 2013, the inventive activity sharply increased, driven by Sumitomo Electric, Toyoda Gosei, Seoul Semiconductor and Avogy (whose power GaN patents were transferred to NexGen Power Systems in 2017). Since 2015, the IP activities for vertical GaN power devices have reached a plateau, with new leading innovators such as Fuji Electric, Denso, Panasonic and Bosch. Notably, Chinese players — led by research organizations Xidian University and UESTC — seem to have taken the lead in inventive activity, outperforming Japanese players year after year since 2020.

Most IP newcomers in vertical GaN come from China

The main IP newcomers that have entered the patent landscape since 2019 are Chinese research organizations, such as Shandong University and Xi'an Jiaotong University, and Chinese companies. One of them is the start-up GLC Semiconductor, founded in 2018, which focuses on the development and production of GaN epiwafers, and provides GaN chip design, production, packaging and testing services. The firm disclosed several inventions in 2020 related to vertical GaN FET structures, with its chairman Yeh Shun-Min as the inventor. Interestingly, unlike most Chinese players seeking protection of their inventions in China only, GLC has successfully filed several patent applications in the US (US11411099, US10854734) and Taiwan, in addition to China.

Outside China, some notable players entered this IP space, such as imec in 2020, following a collaboration

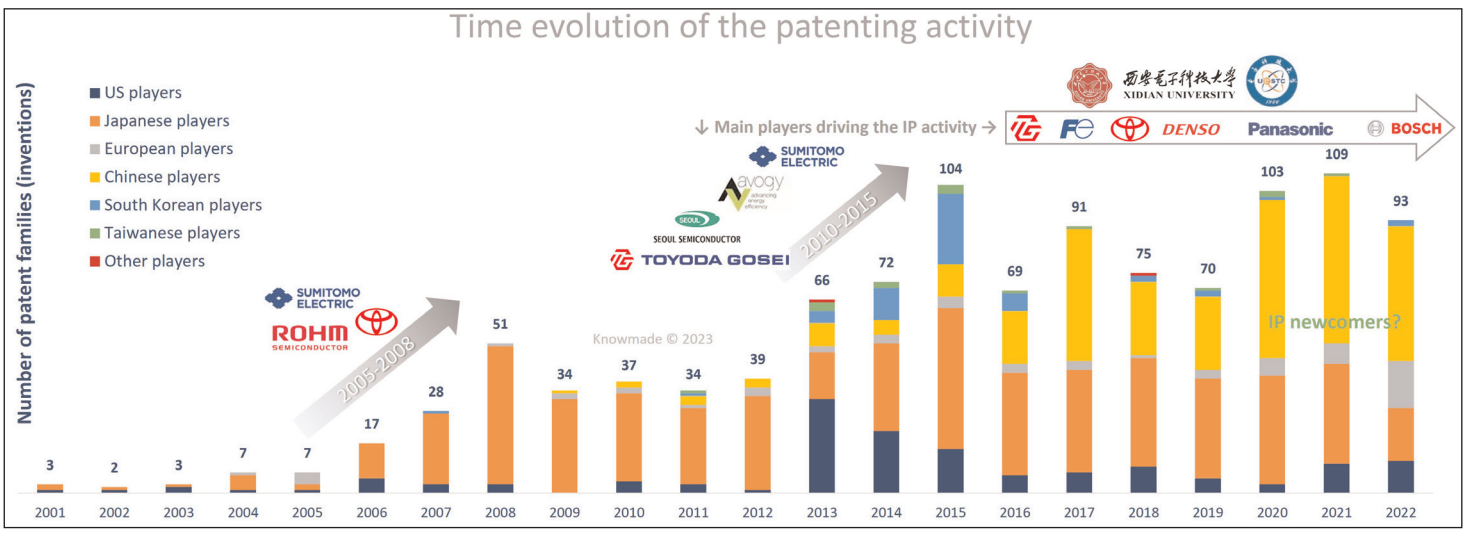

Figure 1: Time evolution of patent publications related to vertical GaN power devices since 2001.

with Ghent University, aiming to develop semi-vertical and vertical GaN power devices (US20220406926, EP3627559). Concomitantly, imec has developed an approach to co-integrate vertical GaN power diodes and transistors (US11380789). Interestingly, other major European research organizations have resumed their IP activities in this field since 2019, including CEA. The French research organization has been collaborating with CNRS for the development of new vertical GaN power devices (US20230136949) and published two additional inventions in 2022 describing vertical GaN FETs (US20220310790) and diodes (US20220037538). In the USA, Odyssey Semiconductor, a startup founded in 2019 by Cornell University researchers Rick Brown and James Shealy, entered the vertical power GaN device patent landscape in 2022, with a first patent family (invention) describing a vertical GaN FET (US11652165, US11251295).

Well-established Japanese IP players challenged by NexGen and Bosch

Following Avogy's bankruptcy in 2017, its CEO Dinesh Ramanathan founded a startup company NexGen Power Systems, which acquired Avogy's power GaN patents. In 2021, NexGen started its own patenting activity in this field. Since then, it has published more than 10 inventions, including several patent applications related to vertical GaN FinFETs (e.g. US20230260996 and US20230246027). Such vertical devices have also been developed by Bosch since 2012, as indicated by a first patent publication in 2014 (US9525056). Yet Bosch was not active in this field until 2019, and in 2021 the company accelerated its IP strategy for vertical power GaN technology with more than 15 new patent families (inventions) including patent applications US20220310836 and US20220285542.

So far, Japan's main innovators have not been challenged by Chinese companies but by Chinese research organizations, especially Xidian University and UESTC (Figure 2). These Chinese universities are focusing on China to protect their inventions, and it remains to be seen how they will leverage their patent portfolios to support the development of a domestic vertical GaN technology. By way of example, in the fast-developing power SiC industry, we have seen such organizations driving the emergence of new domestic players through partnerships and patent transfers. For GaN electronics, KnowMade has implemented several monitoring tools to detect the entry of new players in the patent landscape and in the scientific landscape.

Although Japanese players own the largest patent portfolios for vertical GaN power devices in terms of inventions (Figure 2), their impact on the IP competition is very contrasted (Figure 3). For instance, Sumitomo Electric, which has been the main innovator in this space, seems to be no longer competing for vertical GaN power devices: the company abandoned 70% of its patents protecting its vertical GaN inventions. Within Toyota Group, several companies such as Toyoda Gosei, Toyota Motor and Denso have been actively filing vertical GaN patents. As a result, Toyota group stands out as an undisputed IP leader in this space. However, these companies have followed quite different trajectories in the vertical GaN power device IP landscape over the years (Figure 3).

Starting filing patents in the 2000s, Toyota Motor is one of the main historical players in this landscape, together with Sumitomo Electric and Fuji Electric. Yet its IP leadership remained limited until Toyota initiated a partnership in 2018 with Denso, a new player in this space, to accelerate the development of power GaN technology, leading to more than 20 patent co-filings.

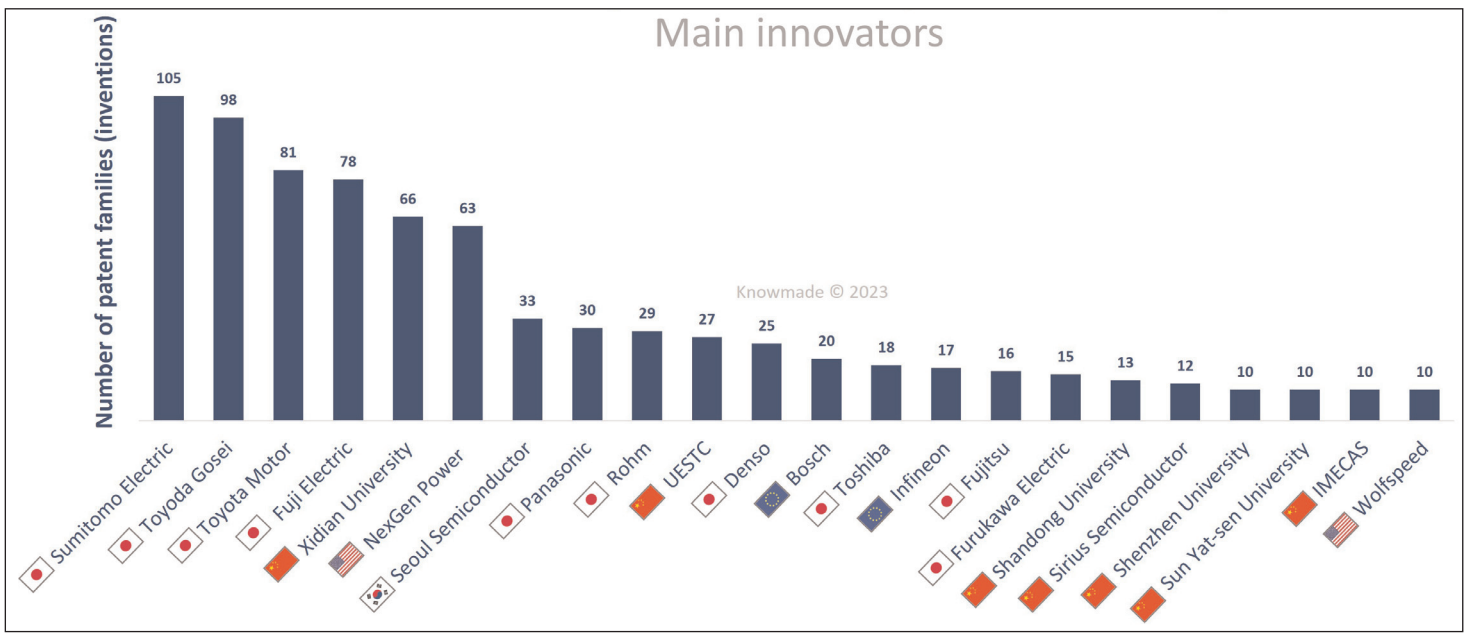

Figure 2: The main players driving the inventive activity related to vertical GaN power devices since 2000.

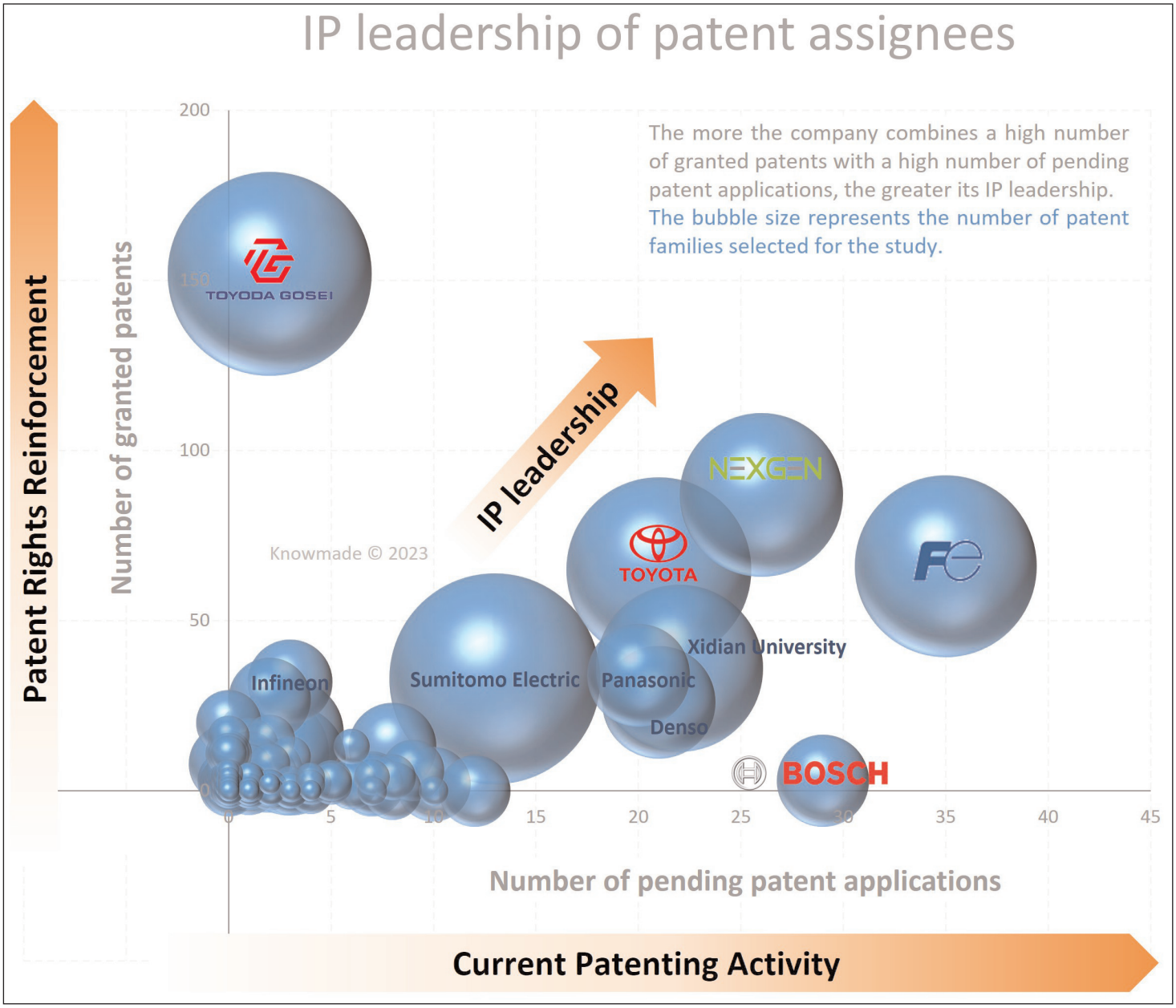

Figure 3: The global IP competition for vertical GaN power devices.

Since then, the ownership of several vertical GaN patent co-filings has been transferred to Denso, confirming that Denso took the leadership in this collaboration. In contrast, Toyoda Gosei started actively publishing vertical GaN patent applications much later than Toyota Motor, in 2014, describing the development of vertical GaN MISFET. Toyoda Gosei stopped its IP activities in 2021, after positioning itself as the best-established IP player in this space, owning the highest number of granted patents for vertical GaN power devices. Lately, Toyoda Gosei announced a successful collaboration with Osaka University to develop 6-inch diameter GaN substrates targeting power devices.

Following Toyota Group's lead, Fuji Electric and NexGen emerged as the main IP leaders for vertical GaN power devices, with Bosch as the main IP challenger. As shown in Figure 3, Xidian University is closing the gap with other leading IP players, although its IP activity has been limited to China so far.

Main IP battlefield for vertical GaN technology lies in the USA

The USA accounts for the largest number of granted patents for vertical GaN power devices, ahead of Japan. Indeed, most of the well-established IP players in this space are Japanese players that have focused their IP strategy on US territory, in addition to their headquarters country (Figure 4). Yet, according to the current IP trend, China may soon become the most crowded space in terms of vertical GaN patents.

As of 2023, Japanese players are not aiming to extend their IP leadership to other countries (China, South Korea, Taiwan, Germany). Apart from Japanese players, the main IP players are not interested in protecting their inventions in Japan. Instead, NexGen

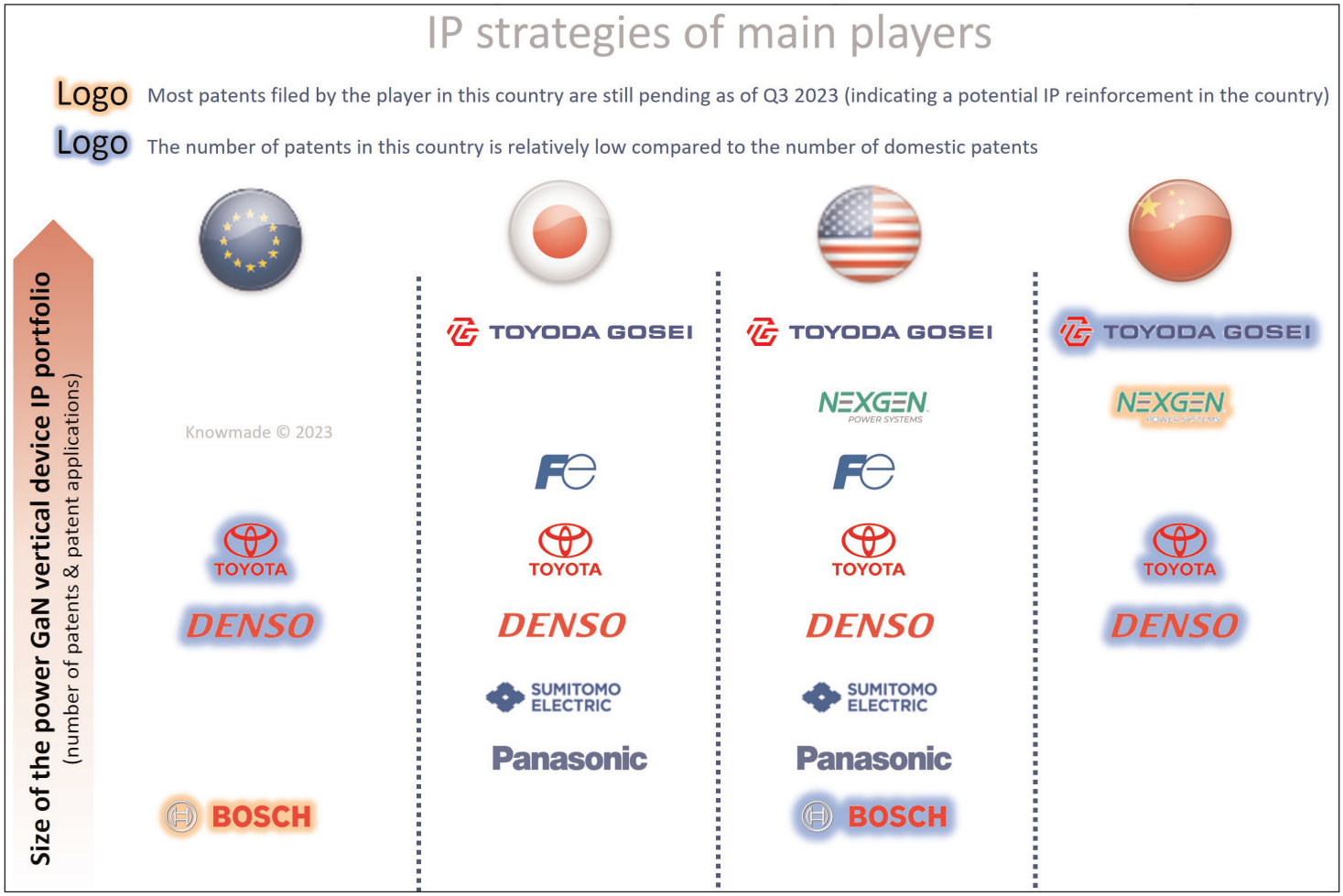

Figure 4: IP strategies of the main players competing worldwide.

is aiming to strengthen its IP position in China. Unsurprisingly, most Chinese players focus their IP activities on their national territory and have shown no significant IP activities in the other countries. Likewise, Bosch has almost limited its IP activities to Europe so far, filing only three US patents and two Chinese patents. Still, several PCT (Patent Cooperation Treaty) applications have been filed lately by Bosch, which may result in more patent applications in these countries. As vertical GaN technology increases in maturity and finds new applications, we expect IP players with a view to enter the power GaN market with vertical devices to extend the geographic coverage of their patenting activities, i.e. to protect their key inventions in the main power electronics markets.

After 20 years of innovation, the IP competition for vertical GaN technology has just started

Although more than 1000 patent families (inventions) have been filed to cover the development of vertical GaN technology since the 2000s, the IP competition has been remarkably moderate so far. This situation reflects a relatively limited investment in vertical GaN device technology. For comparison, more than 6000 inventions have been disclosed for power SiC devices so far, a technology that would be in direct competition with vertical GaN in power applications. Yet both technologies have shared similar technical issues in terms of material and device processing, which have made it particularly challenging for them to reach the maturity required in high-power and high-temperature applications.

However, several players, including incumbent automotive companies, are still investing in vertical GaN technology. Indeed, several established IP players (Fuji Electric, NexGen, Toyota Motor) and relatively new IP players (Denso, Bosch) are accelerating their patent filings. Accordingly, the vertical GaN patent landscape is expected to become increasingly competitive in the next decade. Importantly, as this technology proves itself, several well-established IP players in the field might resume their IP activities to prepare for industrialization and commercialization of the vertical GaN power devices (ROHM, Seoul Semiconductor, Sumitomo Electric). ■

www.knowmade.com/patent-analytics-services/patent-report/gan-electronics-patent-landscape-analysis-2023

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RF sputtering of gallium oxide on diamond

Researchers claim the first hetero-epitaxial growth of β-Ga_2O_3 thin films on single-crystal diamond (111) wafers using RF magnetron sputtering.

Researchers based mainly in Japan report "the first achievement in hetero-epitaxial growth of β-Ga_2O_3 thin films on single-crystalline diamond (111) wafers using RF magnetron sputtering" [Takafumi Kusaba et al, Applied Physics Express, v16, p105503, 2023]. While β-Ga_2O_3 is a promising new material for extreme-condition electronics, it suffers from a low thermal conductivity. Growing Ga_2O_3 on high-thermal-conductivity single-crystal diamond (SCD) could enable devices with self-thermal management.

The team consisted of researchers from Kyushu University, National Institute of Advanced Industrial Science and Technology (AIST), Kyushu Institute of Technology in Japan, and one from Aswan University in Egypt and the Center for Japan–Egypt Cooperation in Science and Technology (E-JUST Center) in Japan.

The researchers see their work as supporting "further research on scalable β-Ga_2O_3/diamond heterostructures for future electronic and optoelectronic applications with not only high performance but also good self-thermal management".

Among the material properties of β-Ga_2O_3 giving rise to these hopes are a wide bandgap of 4.5–4.9eV, high breakdown field (~8MV/cm), resistance to chemical damage, and an ability to withstand high levels of radiation and thermal stress. The thermal conductivity is in the range 10–30W/m-K, while that of diamond is around 2000W/m-K.

An added attractive possibility for the combination of β-Ga_2O_3/diamond hetero-structures is the easy p-type doping of diamond with boron, since at present there is no feasible method for arranging p-type Ga_2O_3, which is naturally n-type.

Techniques such as van der Waals and wafer bonding of β-Ga_2O_3 on diamond have previously been reported, but not direct-growth processes like RF sputtering. Direct growth methods tend to be preferred for scalable manufacturing and lower costs.

The radio-frequency magnetron sputtering (RFMS) was carried out using a commercial undoped Ga_2O_3 target and Ib-type (111) SCD substrate from Sumitomo Corp in Japan (Figure 1). The RFMS growth pressure was $1.5x10^{-1}$Pa. The atmosphere in the chamber was supplied by an argon flow without oxygen. The RF power was 50W, and the deposition time was 48 hours. The β-Ga_2O_3 was grown in a circular region defined by a metal mask.

While the growth rate slowed significantly at the higher substrate temperatures (315nm for the 700°C material), the Ga_2O_3 crystal quality at lower temperatures deteriorated. Indeed, at 400°C the material appeared to be amorphous, according to x-ray diffraction (XRD) analysis. The 500°C sample consisted of mixed β- and γ-phase Ga_2O_3. The 600°C and 700°C film were unmixed β-Ga_2O_3. However, the 600°C material was polycrystalline with a number of different plane orientations. The 700°C sample was mainly (–201) oriented with a significantly narrower rocking curve peak, according to the full-width at half maximum (FWHM) of 3.0°, compared with 4.1° for the 600°C material.

The researchers comment: "The higher substrate temperature promotes the β-phase crystallization of Ga_2O_3 and reduces the diamond surface energy, which stimulates the mobility of adatoms to migrate on the diamond terraces, improving the capability of the layer-by-layer growth process."

The lattice mismatch between the diamond (111) and β-Ga_2O_3 (–201) was in the range –1.6–2.2%, according to pole-figure XRD analysis, comparable to β-Ga_2O_3/sapphire (1.7–4.8%).

The team comments further on their pole-figure analyses: "Two unique planes, including (–202) and (002), of (–201) β-Ga_2O_3 texture parallel to the (111) diamond texture with six different in-plane rotation domains were found."

SEM inspection (Figure 2) of the sample surfaces showed mountain-liked crystals on the surface of the film grown at 700°C. The team explains: "These surface structures may indicate that β-Ga_2O_3 thin films were grown on SCD (111) substrates by the Stranski–Krastanov (S–K) growth mode, in which the two-dimensional (2D) mode occurs in the early stages of growth and then it changes to three-dimensional (3D) island growth when the critical thickness of the grown film is exceeded. Optimization of the film thickness is required to further flatten the surface of β-Ga_2O_3thin films grown on SCD (111)."

The researchers also used x-ray photoelectron spectroscopy (XPS) to determine the elemental ratios in the film at the different growth temperatures. The sample grown at 700°C had a O/Ga ratio of 1.31, closest of all the samples to the 1.5 of perfect Ga_2O_3.

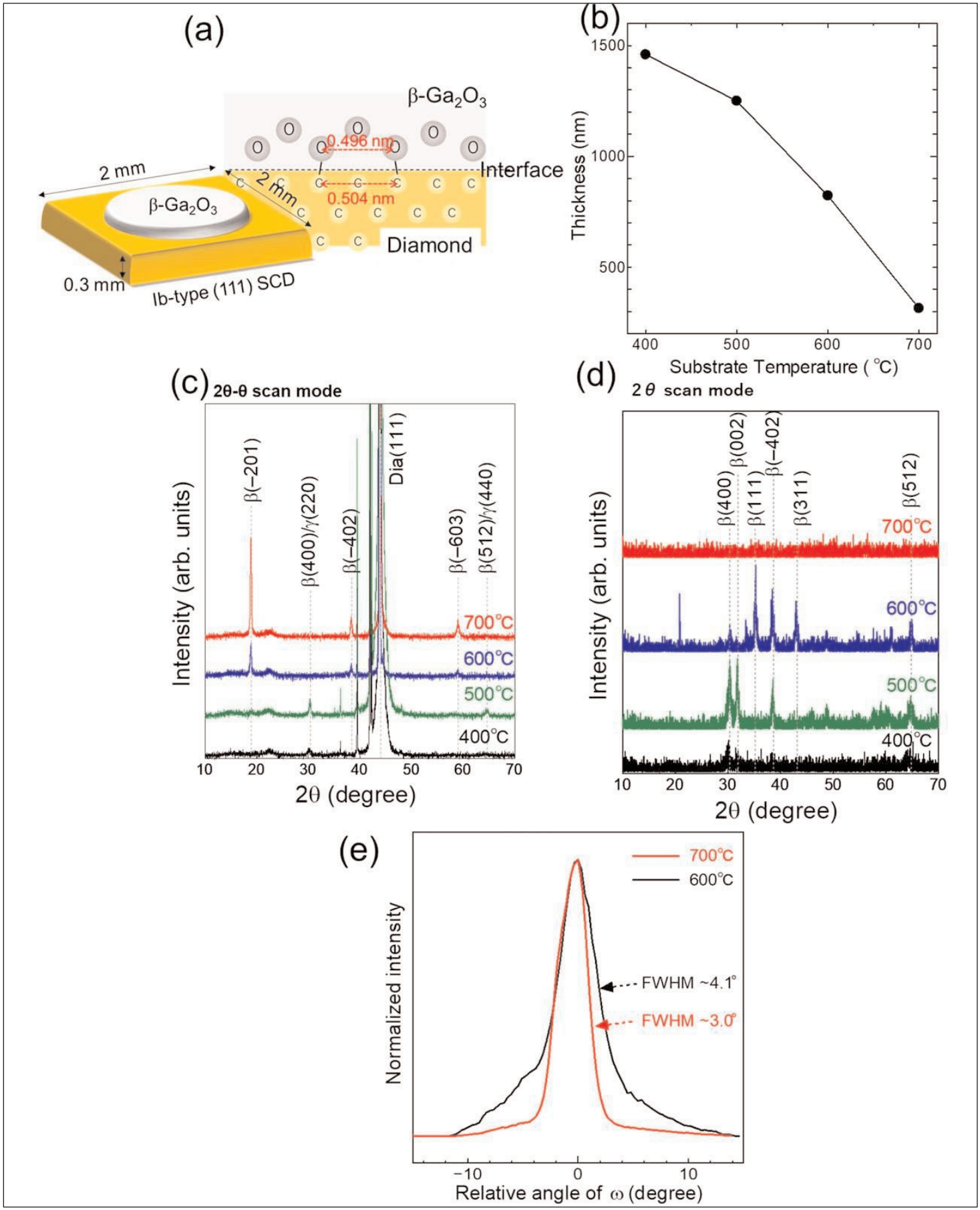

Figure 1. (a) Structural drawing of RF sputtered β-Ga_2O_3 thin film grown on SCD (111) and expected atomic bonding between oxygen and carbon atoms at Ga_2O_3/diamond interface. (b) Relationship between grown film thickness and substrate temperature. (c,d) X-ray diffraction (XRD) patterns from 2θ–θ and 2θ scan modes, respectively. (e) XRD rocking curves of (−201) peak for the samples grown at 600°C and 700°C.

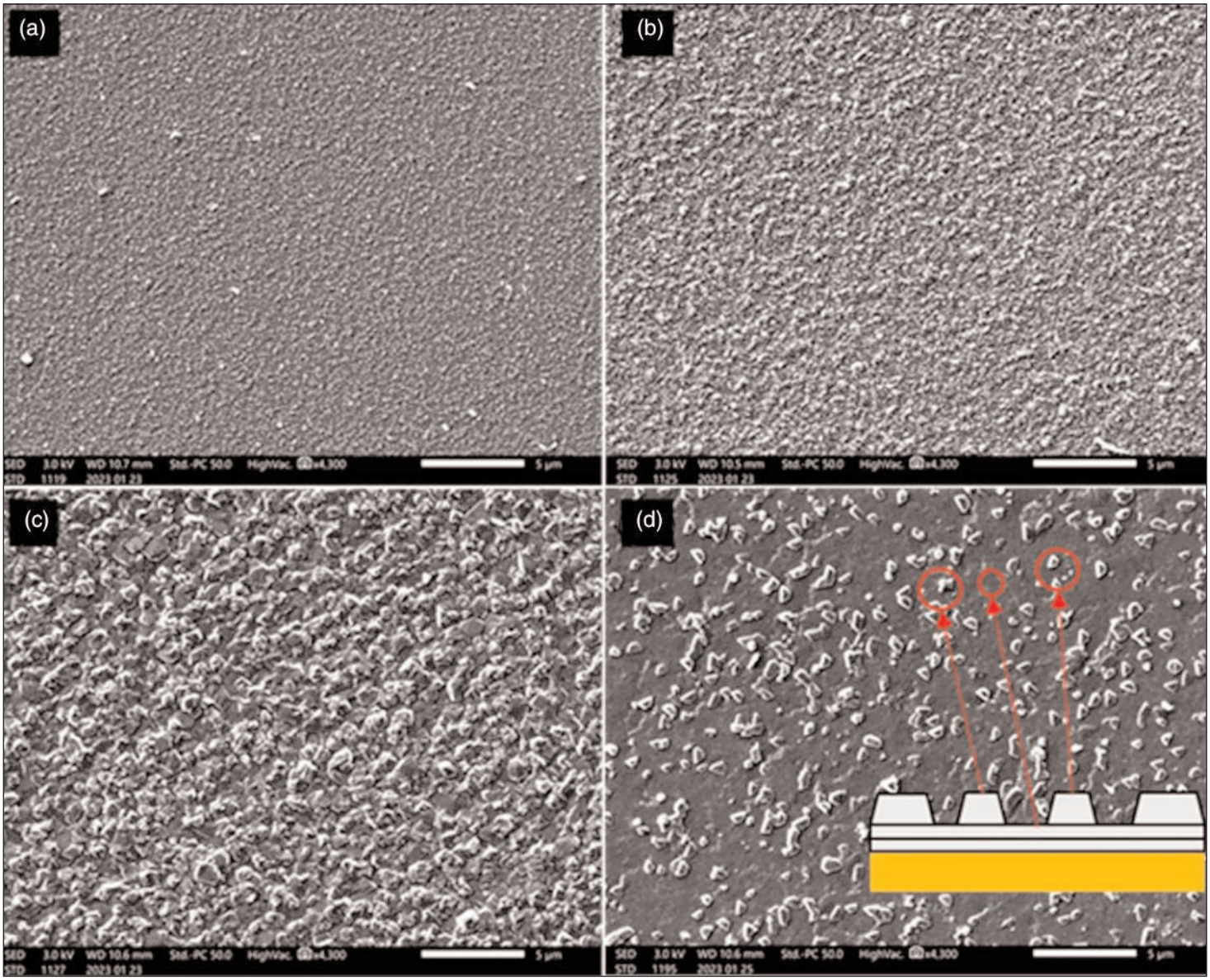

Figure 2. Top-view scanning electron microscope (SEM) images of thin films grown at different substrate temperatures: (a) 400°C, (b) 500°C, (c) 600°C and (d) 700°C. Inset: (d) film structure grown under S–K mode.

The other temperatures result in O/Ga of less than 1.16.

The team comments: "Overall, these XPS results suggested that a high-substrate-temperature deposition by sputtering is effective in suppressing the generation of oxygen defects and an acceptable atomic composition of β-Ga_2O_3 thin films grown on SCD (111) substrates could be achieved by using a substrate temperature of 700°C." ■

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Tel: +1 734 426 7977
Fax: +1 734 426 7955
www.k-space.com

KLA-Tencor
One Technology Dr,
1-2221I, Milpitas,
CA 95035, USA
Tel: +1 408 875 3000
Fax: +1 408 875 4144
www.kla-tencor.com

LayTec AG
Seesener Str. 10–13,
10709 Berlin,
Germany
Tel: +49 30 89 00 55 0
Fax: +49 30 89 00 180
www.laytec.de

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Vacuum Barrier Corporation
4 Barton Lane, Woburn, MA 01801, USA
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Fax: +1 781 933 9428
www.vacuumbarrier.com

VACUUM BARRIER VBC CORPORATION

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WEP (Ingenieurbüro Wolff für Elektronik- und Programmentwicklungen)
Bregstrasse 90,
D-78120 Furtwangen im Schwarzwald,
Germany
Tel: +49 7723 9197 0
Fax: +49 7723 9197 22
www.wepcontrol.com

12 Inspection equipment

Bruker
Oestliche Rheinbrueckenstrasse 49,
Karlsruhe, 76187, Germany
Tel: +49 (0)721 595 2888
Fax: +49 (0)721 595 4587
www.bruker.com

KLA–Tencor
160 Rio Robles, Suite 103D,
San Jose, CA 94538-7306,
USA
Tel: +1 408 875-3000
Fax: +1 510 456-2498
www.kla-tencor.com

13 Characterization equipment

J.A. Woollam Co. Inc.
645 M Street Suite 102,
Lincoln, NE 68508, USA
Tel: +1 402 477 7501
Fax: +1 402 477 8214
www.jawoollam.com

Lake Shore Cryotronics Inc
575 McCorkle Boulevard,
Westerville, OH 43082, USA
Tel: +1 614 891 2244
Fax: +1 614 818 1600
www.lakeshore.com

14 Chip test equipment

Riff Company Inc
1484 Highland Avenue, Cheshire,
CT 06410, USA
Tel: +1 203-272-4899
Fax: +1 203-250-7389
www.riff-co.com

Tektronix Inc
14150 SW Karl Braun Drive,
P.O.Box 500, OR 97077, USA
www.tek.com

15 Assembly/packaging materials

ePAK International Inc
4926 Spicewood Springs Road,
Austin, TX 78759, USA
Tel: +1 512 231 8083
Fax: +1 512 231 8183
www.epak.com

Gel-Pak
31398 Huntwood Avenue,
Hayward, CA 94544, USA
Tel: +1 510 576 2220
Fax: +1 510 576 2282
www.gelpak.com

Wafer World Inc
(see section 3 for full contact details)

Materion Advanced Materials Group
2978 Main Street,
Buffalo, NY 14214, USA
Tel: +1 716 837 1000
Fax: +1 716 833 2926
www.williams-adv.com

16 Assembly/packaging equipment

CST Global Ltd
4 Stanley Boulevard,
Hamilton International
Technology Park,
Blantyre, Glasgow G72 0BN, UK
Tel: +44 (0) 1698 722072
www.cstglobal.uk

Kulicke & Soffa Industries
1005 Virginia Drive,
Fort Washington,
PA 19034,
USA
Tel: +1 215 784 6000
Fax: +1 215 784 6001
www.kns.com

Palomar Technologies Inc
2728 Loker Avenue West,
Carlsbad, CA 92010,
USA
Tel: +1 760 931 3600
Fax: +1 760 931 5191
www.PalomarTechnologies.com

PI (Physik Instrumente) L.P.
16 Albert St . Auburn ,
MA 01501, USA
Tel: +1 508-832-3456,
Fax: +1 508-832-0506
www.pi.ws
www.pi-usa.us

TECDIA Inc
2700 Augustine Drive, Suite 110,
Santa Clara, CA 95054,
USA
Tel: +1 408 748 0100
Fax: +1 408 748 0111
www.tecdia.com

17 Assembly/packaging foundry

Quik-Pak
10987 Via Frontera,
San Diego, CA 92127, USA
Tel: +1 858 674 4676
Fax: +1 8586 74 4681
www.quikicpak.com

18 Chip foundry

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4 Stanley Boulevard, Hamilton International Technology Park,
Blantyre, Glasgow, G72 0BN,
UK
Tel: +44 (0) 1698 722072
www.cstglobal.uk

United Monolithic Semiconductors
Route departementale 128,
BP46, Orsay, 91401,
France
Tel: +33 1 69 33 04 72
Fax: +33 169 33 02 92
www.ums-gaas.com

19 Facility equipment

RENA Technologies NA
3838 Western Way NE,
Albany, OR 97321, USA
Tel: +1 541 917 3626
www.rena-na.com

Vacuum Barrier Corporation
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USA
Tel: +1 781 933 3570
Fax: +1 781 933 9428
www.vacuumbarrier.com

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20 Facility consumables

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Austria
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info@plansee.com
www.plansee.com

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401 Airport Rd, Elkton,
MD 21921-4236,
USA
Tel: +1 410 392 4440
Fax: +1 410 506 8749
www.gore.com

21 Computer hardware & software

Crosslight Software Inc
121-3989 Henning Dr.,
Burnaby, BC, V5C 6P8,
Canada
Tel: +1 604 320 1704
Fax: +1 604 320 1734
www.crosslight.com

Semiconductor Technology Research Inc
10404 Patterson Ave.,
Suite 108, Richmond,
VA 23238,
USA
Tel: +1 804 740 8314
Fax: +1 804 740 3814
www.semitech.us

22 Used equipment

Brumley South Inc
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23 Services

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Fax: +1 203-250-7389
www.riff-co.com

TECDIA Inc
2700 Augustine Drive, Suite 110,
Santa Clara,
CA 95054 ,
USA
Tel: +1-408-748-0100
Fax: +1-408-748-0111
Contact Person: Cathy W. Hung
www.tecdia.com

24 Resources

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7140 San Jose, CA 95126, USA
Tel: +1 408 289 9555
www.alshuktz.com

SEMI Global Headquarters
San Jose, CA 95134,
USA
Tel: +1 408 943 6900
www.semi.org

Yole Développement
69006 Lyon,
France
Tel: +33 472 83 01 86
www.yole.fr

event calendar

If you would like your event listed in *Semiconductor Today*'s Event Calendar, then please e-mail all details to the Editor at mark@semiconductor-today.com

27 January – 1 February 2024
SPIE Photonics West 2024
The Moscone Center, San Francisco, CA, USA
E-mail: customerservice@spie.org
www.spie.org/conferences-and-exhibitions/photonics-west

29–31 January 2024
SPIE AR/VR/MR
The Moscone Center West,
San Francisco, CA, USA
E-mail: customerservice@spie.org
www.spie.org/conferences-and-exhibitions/ar-vr-mr

31 January – 2 February 2024
SEMICON Korea 2024
COEX, Seoul, South Korea
E-mail: semiconkorea@semi.org
www.semiconkorea.org/en

18–22 February 2024
2024 IEEE International Solid- State Circuits Conference (ISSCC 2024)
San Francisco, CA USA
E-mail: Issccinfo@yesevents.com
www.isscc.org

25-29 February 2024
IEEE Applied Power Electronics Conference (APEC 2024)
Long Beach Convention & Entertainment Center,
Long Beach, CA, USA
E-mail: apec@apec-conf.org
https://apec-conf.org

11–13 March 2024
German Microwave Conference (GeMiC 2024)
Mercator Conference Center, Duisburg, Germany
E-mail: info@gemic2024.org
www.gemic2024.org

20–22 March 2024
SEMICON China 2024
Shanghai New International Expo Centre (SNIEC), China
E-mail: semichina@semi.org
www.semiconchina.org/en

20–22 March 2024
China Semiconductor Technology International Conference (CSTIC) 2024, in conjunction with SEMICON China 2024
Shanghai New International Expo Centre (SNIEC), China
E-mail: cstic@semichina.org
www.semiconchina.org/en/5

24–28 March 2024
Optical Fiber Communication Conference and Exposition (OFC 2024)
San Diego Convention Center, San Diego, CA, USA
E-mail: ofc@mcievents.com
www.ofcconference.org

7–11 April 2024
SPIE Photonics Europe 2024, co-located with SPIE Optical Systems Design 2024
Palais de la Musique et des Congrès, Strasbourg, France
E-mail: customerservice@spie.org
www.spie.org/conferences-and-exhibitions/photonics-europe

advertisers' index

14–18 April 2024
IEEE International Reliability Physics Symposium (IRPS 2024)
Hilton DFW Lakes,
Dallas, TX, USA
E-mail: IRPSreg@ieee.org
www.irps.org

16–18 April 2024
22nd European Advanced Process Control and Manufacturing (APC|M) Conference
CinemaxX, Hamburg, Germany
E-mail: isabel.dietrich@silicon-saxony.de
www.apcm-europe.eu

22–26 April 2024
2024 Materials Research Society (MRS) Spring Meeting & Exhibit
Seattle, WA, USA
www.mrs.org/meetings-events/spring-meetings-exhibits/2024-mrs-spring-meeting

30 April – 2 May 2024
27th annual Components for Military & Space Electronics conference & exhibition (CMSE 2024)
Four Points by Sheraton (LAX),
Los Angeles, CA, USA
E-mail: info@tjgreenllc.com
www.tjgreenllc.com/cmse

5–10 May 2024
2024 Conference on Lasers & Electro-Optics (CLEO)
Charlotte Convention Center,
Charlotte, NC, USA
E-mail: info@cleoconference.org
www.cleoconference.org

20–23 May 2024
2024 CS MANTECH: International Conference on Compound Semiconductor Manufacturing Technology
JW Marriott Starr Pass Resort,
Tucson, AZ, USA
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://exceleve.com/photonoptics

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
E-mail: semiconwest@semi.org
www.semiconwest.org

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
www.istci.org/amse2024

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