semiconductorTODAY

COMPOUNDS & ADVANCED SILICON

www.semiconductor-today.com

Join our LinkedIn group: Semiconductor Today

Follow us on Twitter: Semiconductor_T

Choose *Semiconductor Today* for . . .

MAGAZINE

Accurate and timely coverage of the compound semiconductor and advanced silicon industries

Targeted 82,000+ international circulation

Published 10 times a year and delivered by e-mail and RSS feeds

WEB SITE

Average of over 26,000 unique visitors to the site each month

Daily news updates and regular feature articles

Google-listed news source

E-BRIEF

Weekly round-up of key business and technical news

E-mail delivery to entire circulation

Banner and text marketing opportunities available

ISSN 1752-2935 (online)

semiconductorTODAY

COMPOUNDS & ADVANCED SILICON

Vol. 17 • Issue 1 • February 2022

www.semiconductor-today.com

Integration of lasers with silicon

Intel buying Tower • IVWorks buys Saint-Gobain's GaN wafer unit
Infineon investing €2bn in SiC & GaN power semiconductor fab

IQE

THE GLOBAL LEADER IN EPIWAFER SUPPLY

Enabling the Best RF, Photonics & Power Semiconductors

- 'One-stop-shop' for III-V & Silicon epiwafer products
- 2" to 6" epitaxy ready substrates & polycrystalline materials
- Multiple manufacturing sites; Europe, Asia & America
- Leveraging 30+ years of compound semiconductor IP
- Custom engineered structures; R&D to production volumes

RF

GaN HEMT
5G Infrastructure
Radar, EW/ECM, & SATCOM

GaAs HBT / pHEMT / BiHEMT
5G Smartphones & Infrastructure
WiFi6 Hotspots, GPS & IoT

SiGe HBT
5G Smartphones
WiFi6, Bluetooth, GPS & IoT

PHOTONICS

InP Laser & Detector
Optical Comms & Data Centres
SW IR Imaging

GaSb Laser & Detector
MW-LW IR imaging
Biometrics

GaAs VCSEL
3D Sensing & LiDAR
Datacoms

POWER

GaN on Si HEMT
GaN on GaN
Electric Vehicle Systems
Power Conversion & Storage

GaAs Multi-Junction Solar
High Efficiency Terrestrial CPV & Space PV

GaN LED & Laser
MicroLED Display & AR/VR
UV Sterilisation

EUROPE: +44 2920 839 400
AMERICAS: +1 508 824 6696
APAC: +886 3 579 8181
ALL INQUIRIES: sales@iqep.com

www.iqep.com

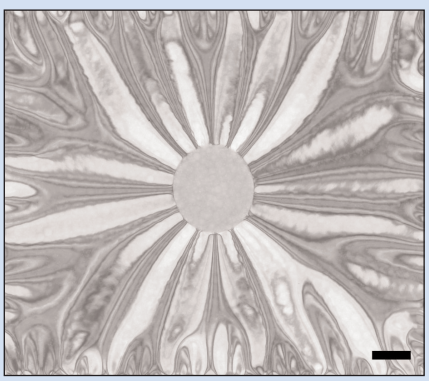
contents

semiconductorTODAY
COMPOUNDS & ADVANCED SILICON

Vol. 17 • Issue 1 • February 2022

p18 Infineon is investing €2bn in SiC and GaN power semiconductor manufacturing at its Kulim, Malaysia fab.

p53 Porotech has secured $20m Series A funding to accelerate global expansion and mass production of its micro-LED product.



p68 Strain engineering by Surrey University could lead to direct-bandgap group-IV lasers integrated on silicon.

Cover: At Photonics West 2022, TRUMPF Photonic Components presented a live showcase on VCSELs with controlled polarization for illumination applications in smartphones, such as face recognition, 3D mapping and camera autofocus. **p59**

editorial

WBG power electronics ramping up

In December, after years of development, Germany-based Bosch began volume production of silicon carbide power semiconductors, supplying automotive manufacturers. The development was indicative of the transition of power semiconductor manufacturers from incumbent silicon to silicon carbide, especially for burgeoning high-voltage sectors such as electric vehicles, power-trains in rail-cars, and industrial applications.

For example, Wolfspeed (formerly the LED-focused company Cree) — after refocusing on wide-bandgap silicon carbide (SiC) and gallium nitride (GaN) power & RF electronic devices — is starting to qualify the world's first 200mm-wafer SiC chip fabrication plant (the $1bn Mohawk Valley Fab, in Marcy, NY), while it continues to expand SiC substrate manufacturing capacity at its HQ in Durham, NC. The firm also reports that its device design-ins for fiscal first-half 2021 were up a more than targeted 70% year-on-year (mostly automotive-related — see page 23).

In addition, US-based SiC substrate maker II-VI Inc — which in mid-2020 licensed SiC power electronics device manufacturing technology from General Electric — has just qualified its 1200V SiC MOSFET platform to automotive standards and has signed a three-year agreement with GE Research to gain access to its SiC module technology and expertise to accelerate customer design-in engagement activities (see page 20).

Meanwhile, Japan's Toshiba has launched its first SiC MOSFET modules with voltage ratings of 1200V and 1700V, targeting industrial equipment such as converters and inverters for railway vehicles and renewable energy power generation systems (page 19). Also, Germany's Infineon is launching SiC MOSFET-based power modules tailored to applications in rail vehicles.

Now, Infineon says that it is investing over €2bn into wide-bandgap power semiconductor manufacturing capacity by building a third module at its site in Kulim, Malaysia, which should generate €2bn in additional annual revenue from SiC- and GaN-based products (see page 18).

According to Atlantic Market Research, the global GaN power devices market is rising at a compound annual growth rate of 57.4% through to 2030, driven primarily by the adoption of wireless charging (particularly in smartphones and EVs) and a reduction in GaN device pricing (page 7).

After three-fold growth in revenue (and raising $150m in growth capital funding last November), GaN Systems of Ottawa, Canada is now expanding its Taiwan-based Asia HQ three-fold, to enable further growth in the consumer electronics, EV, data-center and industrial markets (page 28).

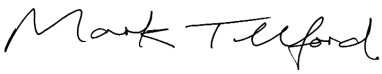
Meanwhile, doubling revenue in 2021 was California-based GaN power IC firm Navitas (page 26), which began trading on the Nasdaq Global Market last October while raising $325m in funds through a SPAC.

Also doubling its revenue year-on-year (after an eighth consecutive quarter of growth) was University of California Santa Barbara (UCSB) spin-off Transphorm — which makes GaN FETs for high-voltage power conversion —and is now uplisting from OTCQX to the Nasdaq Capital Market (page 32).

Whereas commercially available high-power GaN transistors are generally 600–650V, Transphorm claims to offer the only 900V qualified GaN devices. At May's International Symposium on Power Semiconductor Devices and ICs (ISPSD), the firm is demonstrating R&D results from its 1200V GaN device.

With fast-growing demand and extending capabilities, the prospect is that all applications of power devices can be served by not just SiC but also GaN wide-bandgap semiconductors.

Mark Telford, Editor



semiconductorTODAY
COMPOUNDS & ADVANCED SILICON

Editor
Mark Telford
Tel: +44 (0)1869 811 577
Cell: +44 (0)7944 455 602
Fax:+44 (0)1242 291 482
E-mail: mark@semiconductor-today.com

Commercial Director/Assistant Editor
Darren Cummings
Tel: +44 (0)121 288 0779
Cell:+44 (0)7990 623 395
Fax:+44 (0)1242 291 482
E-mail: darren@semiconductor-today.com

Advertisement Sales
Darren Cummings
Tel: +44 (0)121 288 0779
Cell:+44 (0)7990 623 395
Fax:+44 (0)1242 291 482
E-mail: darren@semiconductor-today.com

Original design Paul Johnson
www.higgs-boson.com

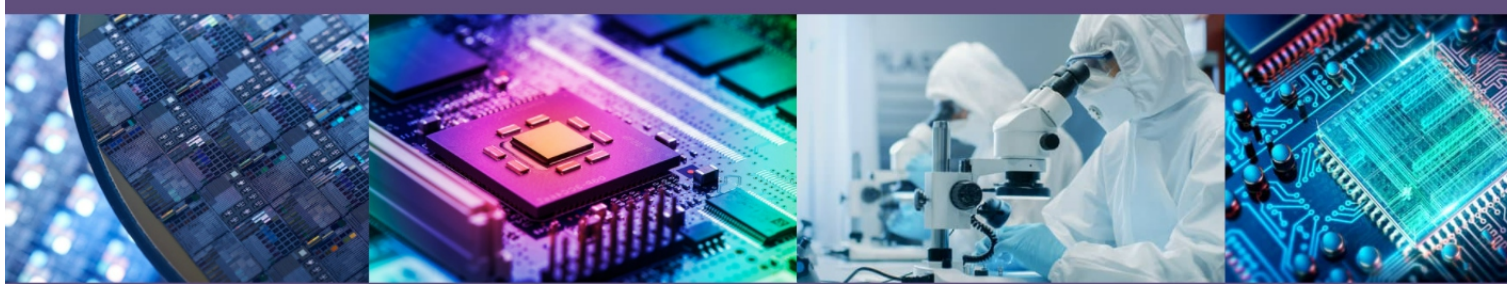
***Semiconductor Today* covers the R&D and manufacturing of compound semiconductor and advanced silicon materials and devices** (e.g. GaAs, InP and SiGe wafers, chips and modules for microelectronic and optoelectronic devices such as RFICs, lasers and LEDs in wireless and optical communications, etc).

Regular issues contain:
- news (funding, personnel, facilities, technology, applications and markets);
- feature articles (technology, markets, regional profiles);
- conference reports;
- event calendar and event previews;
- suppliers' directory.

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

csconnected

THE WORLD'S FIRST COMPOUND SEMICONDUCTOR CLUSTER



CSconnected is home to the world's first regional ecosystem based on the manufacture of compound semiconductor enabled hardware, located in south Wales

Driving tomorrow's technologies

csconnected.com I info@csconnected.com

InP market to grow at 11.9% CAGR to $13.4bn by 2030

Asia-Pacific held nearly half of market in 2020

The global indium phosphide (InP) compound semiconductor industry was $4.5bn in 2020, and will rise at a compound annual growth rate (CAGR) of 11.9% from 2021 to $13.4bn in 2030, forecasts the report 'Indium Phosphide Compound Semiconductor Market, 2021–2030' from the company Allied Market Research.

Drivers, restraints and opportunities

Growth is being driven by an increase in the need for high-speed Internet connectivity in telecom and datacom applications, the benefits of indium phosphide, and the emerging trend towards the use of compound semiconductors in the automotive industry. However, high cost and disadvantages associated with compound semiconductor materials and components hinder market growth, notes the report. In contrast, the advent of compound semiconductors in smart technologies is expected to open up new opportunities for market players in the future, it adds.

Impact of COVID-19

The COVID-19 pandemic led to falling business confidence, uncertainty in stocks, and an immense slowing in supply chain operations. Moreover, it affected production processes in the semiconductor and electronics industries, notes the report.

Also, the restrictions on international trade placed constraints on the outlook for demand and supply. In addition, the prolonged lockdown negatively affected the market.

Power semiconductor segment held largest market share

By product, the power semiconductor segment comprised the largest share of the market in 2020 (over a quarter), due to a rise in demand for efficient energy management in high-voltage power electronics such as solar inverters and hybrid vehicles. However, the transistors segment of the InP market is expected to register the highest CAGR of 14.4% during the forecast period, due to their advantages over traditional transistors that make them suitable for commercial applications.

Sensing segment to grow fastest

By application, the sensing segment will exhibit the highest CAGR of 15% from 2021 to 2030, the report forecasts. However, the power electronics segment held the largest share in 2020, comprising nearly a third of the global indium phosphide compound semiconductor market, as InP compound semiconductor enhance electron velocity.

Asia-Pacific held the largest share

By region, the Asia-Pacific comprised the largest share in 2020, accounting for nearly half of the market (followed by North America and Europe). Moreover, the Asia-Pacific region is expected to exhibit the highest CAGR of 13.7% during the forecast period. On the other hand, the global indium phosphide compound semiconductor market in North America is expected to register a CAGR of 8.7%, concludes the report.

www.alliedmarketresearch.com/indium-phosphide-compound-semiconductor-market-A14526

GaN power devices market to grow at over 57.4% CAGR to 2030

Top companies include EPC, On Semiconductor, Infineon, GaN Systems and Panasonic

The global gallium nitride (GaN) power devices market is expected to grow at a compound annual growth rate (CAGR) of 57.4% during 2022–2030, driven primarily by demand for GaN in commercial radio-frequency applications, the adoption of GaN in electric vehicles (EVs), escalating demand for wireless charging, and a reduction in the price of GaN devices, according to a report from Atlantic Market Research. Wireless charging in particular has been widely adopted in smartphones and electric vehicles (EVs), with various initiatives across the globe, and has proven to be the major market driver, paving the way for GaN power devices.

By device type, discrete GaN power devices (transistors, field-effect transistors, MOSFETs, etc) comprised more than 50% of the market in 2021, and will grow at a CAGR of 22.4% during the forecast period. The primary reason for their dominance is their ease of fabrication compared with integrated circuits (ICs) and modules. Further, discrete power devices also offer more design flexibility in power systems.

The presence of a large number of companies manufacturing discrete devices (compared with companies involved in IC and module manufacturing) has also aided their market growth. GaN power discrete devices have negligible charge storage, low on-resistance and allow switching efficiencies in excess of existing silicon devices. Further, companies are also engaged in developing new discrete devices, creating further growth opportunities.

By vertical segment, automotive is expected to grow at the highest CAGR of 23.4% during the forecast period. The primary reason for the widespread adoption of GaN power devices in the automotive sector is the ability of wide-bandgap materials such as GaN to cut electricity losses by up to 66% during vehicle battery recharging (according to the Institute of Electrical and Electronics Engineers). Further, GaN based power devices offer high efficiency in terms of converting AC to DC power and also help in improving vehicular operating in the electric traction drive. Due to the growing electric vehicle market and the large amounts of funding going to the startups manufacturing GaN-based power devices, the automotive-based GaN power device market is expected to grow substantially over the forecast period.

By geographic area, North America leads the global GaN power device market after capturing the largest share of over 37% in 2021, and is expected to grow at a 23% CAGR in 2022–2030. The North America market is driven primarily by a large amount of investments in the development of GaN power devices. In 2014, the US Department of Energy (DOE) launched the Power America program, with the goal that, by 2030, 80% of all US electricity will flow through power electronics. To achieve this, Power America is working to make wide-bandgap semiconductors such as gallium nitride and silicon carbide (SiC) cost competitive with silicon-based power devices, aiding the adoption of GaN power devices in the energy sector in the USA.

Due to the growing electric vehicle market and the large amounts of funding going to the startups manufacturing GaN-based power devices, the automotive-based GaN power device market is expected to grow substantially

The market is also driven by the large pool of GaN power device makers in North America that are committed to innovating new products related to GaN power devices and have captured a large share of the global GaN power device market. Key players in the North America region include Efficient Power Conversion (USA), GaN Systems (Canada), Texas Instruments (USA) and Cree Inc (USA).

The Asia Pacific GaN power device market is expected to rise at the highest CAGR of 24.3% during 2022–2030, driven primarily by funding for the development of GaN-based power devices. Also driving growth is the surge in the number of electric vehicles in Asia Pacific, as it is expected that GaN-based inverters will replace silicon-based power semiconductor devices in electric vehicles due to their efficient AC-to-DC power conversion. The Asia-Pacific GaN power device market is also influenced by the presence of key players in the region such as Taiwan Semiconductor Manufacturing Company (Taiwan), Panasonic Corp (Japan), Fujitsu (Japan), Toshiba Corp (Japan), Mitsubishi Chemical Corp (Japan) and others.

The primary strategy adopted by companies in the GaN power device market is product launch, notes Atlantic Market Research. New and advanced products help to improve a company's market visibility while competing effectively with key competitors already present in the market. The secondary strategy is merger and acquisition, in order to expand a product portfolio and increase market share. M&A also enables companies to extend their market reach into unexplored regions, concludes the market research firm.

www.atlanticmarketresearch.com/gan-power-devices-market

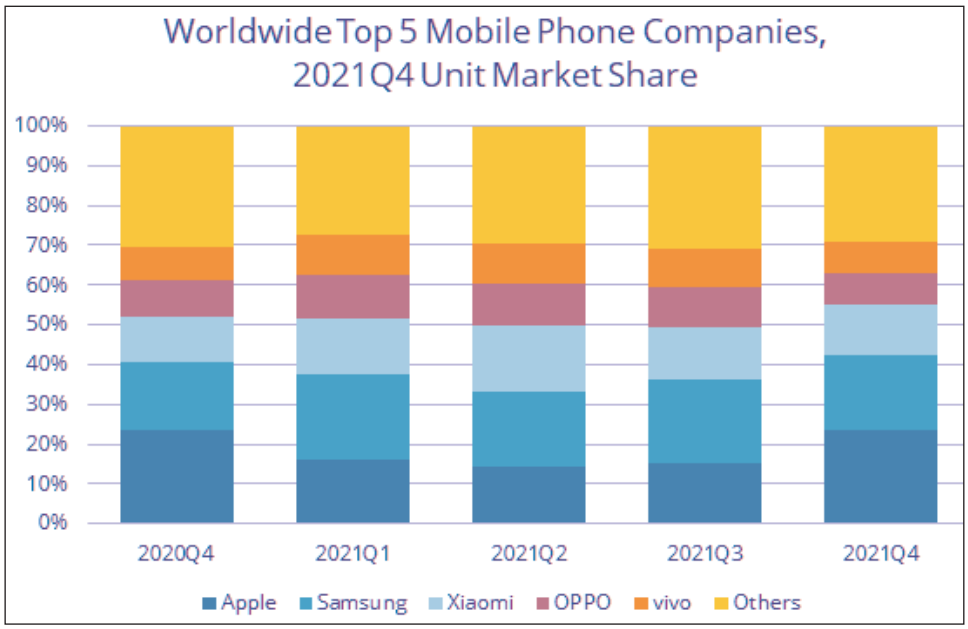
Smartphone shipments down 3.2% year-on-year in Q4, but full-year 2021 still up 5.7%

Low channel inventory plus easing of supply constraints towards mid-2022 to drive market growth

In fourth-quarter 2021, global smartphone shipments declined year-over-year for a second consecutive quarter. However, despite a challenging second half of the year, full-year shipments still grew due to a strong first half, according to the International Data Corporation (IDC) Worldwide Quarterly Mobile Phone Tracker. Smartphone vendors shipped a total of 362.4 million phones during the holiday quarter (Q4/2021), which was down 3.2% year-on-year but slightly better than IDC's forecast. On an annual basis, the market grew 5.7% in 2021, with 1.35 billion smartphones shipped.

"The second half of 2021 failed to meet expectations, with volumes declining 4.5% compared to the second half of 2020," says Ryan Reith, group vice president with IDC's Worldwide Mobile Device Trackers. "The supply chain and component shortages started to have meaningful impact on the smartphone market as we entered the second half of the year, and this continues to be the case as we've now entered 2022," he adds. "We expect to see supply and logistical challenges continue through the first half of this year, but we currently believe we'll return to growth in the second quarter and second half of 2022. There is no question that demand is still strong in many markets, and to some extent we are seeing increasing consumer interest in 5G and new form factors like foldables."

Despite a slight year-over-year decline in shipments, Apple had a good holiday quarter, once again jumping above Samsung into the top spot. Its supply chain strength was on display more than ever in fourth-quarter 2021. iPhone 13 SKUs were an impressive portion of volumes in the holiday quarter, driving strong growth in overall iPhone average selling prices (ASPs).



Samsung and Xiaomi followed with the second and third spots. These were the only vendors of the top five that grew shipments year-on-year in Q4/2021, IDC notes. OPPO and vivo rounded out the top five.

For full-year 2021, all five vendors grew shipments year-over-year, with four out of five achieving double-digit growth. While Xiaomi had the highest annual growth (reaching almost 30%), Samsung had the lowest (just 6% growth). This contrast clearly illustrates which vendor benefitted the most from the massive decline of Huawei this year.

The second half of 2021 failed to meet expectations, with volumes declining 4.5% compared to the second half of 2020. The supply chain and component shortages started to have meaningful impact on the smartphone market as we entered the second half of the year, and this continues to be the case as we've now entered 2022

Apple too had healthy annual growth of 15.9% in 2021 for reasons already mentioned as well as due to the 40% growth in China in 2021.

"The fact that 2021 would have come in drastically higher if it were not for the supply constraints adds even more positivity to the healthy 5.7% growth we saw for 2021," comments Nabila Popal, research director with IDC's Mobility and Consumer Device Trackers. "There is significant pent-up demand in almost all regions. Even in China, where there are some challenges around weakening consumer demand, the market performed much better in the fourth quarter than expected – 5% better to be exact – albeit still a year-over-year decline. With channel inventory low in almost all regions and as supply constraints ease up towards the middle of the year, IDC expects this pent-up demand to drive the market toward healthy growth in 2022."

www.idc.com

Smartphone shipment recovery to continue in 2022, growing 4% to 1.386 billion units

Penetration of 5G phones to rise from 37% in 2021 to 47% in 2022 then over 50% by 2023

Since reaching a peak of 1.457 billion units in 2017, it has been difficult for smartphones to significantly increase their penetration rate, notes market research firm TrendForce. In addition, mobile phone hardware updates have slowed, which has lengthened the consumer replacement cycle. Together with the negative effects of the COVID-19 pandemic, growth in overall smartphone shipment volume has become increasingly difficult to achieve.

However, based on the premise that the pandemic is slowing down, coupled with the strategy of certain brands actively exploring emerging markets, growth momentum in the global smartphone market gradually got back on track in 2021, with shipments reaching 1.333 billion units, or 6.4% growth year-on-year. This upward trend is expected to continue in 2022, with shipments expected to reach 1.386 billion, or 4% growth year-on-year.

However, the status of the pandemic is still the biggest concern affecting the smartphone market this year, and this applies doubly to the production capacity of semiconductors, TrendForce stresses. The current problem of material shortages has yet to be alleviated, and RF chips, organic light-emitting diode (OLED) display driver integrated circuits (DDICs) and power management integrated circuits (PMICs) continue to be in short supply. In addition, issues such as China's rolling blackouts, spiking shipping costs and rising chip costs, will cause smartphone brands to face price pressures, and it remains to be seen whether higher prices will be acceptable to consumers.

Judging from the 2022 brand market share forecast, Samsung will remain number one, followed by Apple, Xiaomi, OPPO, VIVO and Transsion, reckons TrendForce. Among these companies, Xiaomi is the brand with the fastest-growing annual shipment growth rate. In addition to stimulating sales in the Chinese market through the strategy of expanding brick-and-mortar stores, Xiaomi's sales occur mostly overseas, and it is first in market share in India and Russia. In the future, it will continue to explore the Middle East, Latin America, Southeast Asia and Africa markets.

Four keys to mobile phone trends in 2022

Folding phones, 5G, self-developed chips and a reduction in the number of rear-facing cameras are the four keys to focus on this year.

In terms of 5G mobile phones, the global penetration rate in 2021 was 37%. This is expected to rise to 47% in 2022, and may exceed 50% by 2023. Currently, China is the most active country in promoting 5G models, which comprise more than 80% of shipments. So, the key to increasing the global penetration rate of 5G mobile phones in the future is focusing on regions outside China.

In the past, only Samsung, Apple and Huawei were capable of self-developing chips. However, Google launched its self-developed Tensor processor in 2021, and Xiaomi, OPPO and VIVO have each launched professional imaging chips in succession, notes TrendForce.

www.trendforce.com

Apple iPhone tops smartphone market in Q4/2021, but Samsung remains top for full year

Shipments to grow just 3% in 2022, but constraints ease in second half

Global smartphone shipments fell by 2.7% year-on-year to 365 million units in fourth-quarter 2021, according to market research firm Strategy Analytics. "Factory constraints and component shortages continued to restrict smartphone supply in the final quarter of last year," notes senior director Linda Sui.

Despite this, full-year smartphone shipments still rose by 4.5% year-on-year to 1.36 billion units in 2021, recovering from a sharp Covid-led decline of –8% year-on-year during 2020.

Apple iPhone topped the global smartphone market with a 22% share in Q4/2021, shipping 80 million units. "Demand was strong for the new iPhone 13 series in China and other markets," notes Woody Oh, director at Strategy Analytics.

However, for full-year 2021, Apple remained in second place (with 16.8% market share), as Samsung maintained first place (with 20% market share).

Samsung shipped 69 million smartphones, up 12.4% year-on-year, for 18.9% market share in Q4/2021. "Samsung had a good quarter, led by its innovative Flip and Fold 5G models. Samsung grew faster than all its major rivals," he adds. Samsung ramped up volumes in North and South America amid the withdrawal of LG, but the competition in Asia remained fierce.

Xiaomi shipped 45 million smartphones and took third place with 12.3% global market share in Q4/2021, up slightly from 11% a year ago. "Xiaomi benefitted from the withdrawal of Huawei and LG and expanded its retail footprint into all major regions last year," says senior analyst Yiwen Wu.

OPPO (OnePlus) held fourth spot and captured 9.4% global market share in Q4/2021. Vivo stayed fifth with 7.8% market share in Q4/2021. However, OPPO (OnePlus) and Vivo both lost ground, as 5G competition from Honor and other smartphone competitors intensified sharply at home in China."

"Global competition among other major smartphone brands, beyond the top-five, was fierce during Q4/2021," notes Neil Mawston, executive director at Strategy Analytics. "Honor, Lenovo-Motorola, Realme and Transsion all outperformed the overall market and posted double-digit growth rates. Honor continued to soar in China. Lenovo-Motorola gained share from LG in the Americas. Realme had a very strong quarter in India, China and elsewhere. Transsion held firm across the Africa region," he adds.

"We forecast global smartphone shipments to grow a mild +3% year-on-year in full-year 2022," says senior director Linda Sui. "This year will be a tale of two halves. Component shortages, price inflation and Covid uncertainty will continue to weigh on the smartphone market during the first half of 2022, before the situation eases in the second half due to Covid vaccines, interest rate rises by central banks, and less supply disruption at factories."

www.strategyanalytics.com

Q4 2021 and 2021: Global Top 5 Vendors Smartphone Shipments (M), Market Share (M/S) and Y-o-Y Growth (%)

	Q4 2021 Shipments (M)	Q4 2021 M/S (%)	Q4 2021 YoY(%)
Apple	80.1	22.0%	-2.0%
Samsung	69.0	18.9%	+12.4%
Xiaomi	45.0	12.3%	+4.7%
OPPO	34.2	9.4%	-11.4%
Vivo	28.3	7.8%	-17.3%
Others	108.3	29.6%	-6.7%
Total	364.9	100.0%	-2.7%

	2021 Shipments (M)	2021 M/S (%)	2021 YoY(%)
Samsung	272.0	20.0%	+7.0%
Apple	228.4	16.8%	+11.1%
Xiaomi	190.3	14.0%	+30.6%
OPPO	150.6	11.1%	+22.7%
Vivo	130.3	9.6%	+17.0%
Others	386.8	28.5%	-16.0%
Total	1358.4	100.0%	+4.5%

Source: Strategy Analytics, Wireless Smartphone Strategies Service

Note: OPPO includes both OPPO and OnePlus. All numbers are rounded

Intel to acquire analog foundry Tower for $5.4bn

Acquisition diversifies Intel's global, end-to-end foundry business

Intel Corp of Santa Clara, CA, USA has agreed to acquire specialty analog foundry Tower Semiconductor Ltd of Migdal Haemek, Israel for $53 per share in cash, representing a total enterprise value of about $5.4bn. The acquisition advances Intel's IDM 2.0 strategy as it further expands its manufacturing capacity, global footprint and technology portfolio to address unprecedented industry demand.

The transaction has been unanimously approved by the boards of directors of both Intel and Tower and (subject to certain regulatory approvals and customary closing conditions, including the approval of Tower's stockholders) is expected to close in about 12 months and be immediately accretive to Intel's non-GAAP EPS. Intel intends to fund the acquisition with cash from the balance sheet.

To provide multi-fab sourcing and extended capacity for its customers, Tower has two fabrication plants in Migdal Haemek (150mm & 200mm), and two at its US subsidiaries in Newport Beach, CA and San Antonio, TX (both 200mm), and three at TowerJazz Japan Ltd (two 200mm and one 300mm) which it owns through its 51% holdings in TPSCo. Also, Tower is sharing a 300mm manufacturing facility being established in Italy with ST.

"Tower's specialty technology portfolio, geographic reach, deep customer relationships and services-first operations will help scale Intel's foundry services and advance our goal of becoming a major provider of foundry capacity globally," says Intel's CEO Pat Gelsinger. "This deal will enable Intel to offer a compelling breadth of leading-edge nodes and differentiated specialty technologies on mature nodes — unlocking new opportunities for existing and future customers in an era of unprecedented demand for semiconductors."

As a key part of its IDM 2.0 strategy, Intel established Intel Foundry Services (IFS) in March 2021 to help meet the growing global demand for semiconductor manufacturing capacity and to become a major provider of US- and Europe-based foundry capacity to serve customers globally. IFS currently offers leading-edge process and packaging technology, committed capacity in the USA and Europe and other geographies in the future, and a broad intellectual property (IP) portfolio.

Tower's expertise in specialty technologies, such as radio frequency (RF), power, silicon germanium (SiGe) and industrial sensors, extensive IP and electronic design automation (EDA) partnerships, and established foundry footprint will provide broad coverage to both Intel and Tower's customers globally. Tower serves high-growth markets such as mobile, automotive and power. Operating a geographically complementary foundry presence with facilities in the USA and Asia serving fabless companies as well as IDMs, it offers more than 2 million wafer starts per year of capacity — including growth opportunities in Texas, Israel, Italy and Japan. Tower also has what is described as a foundry-first customer approach with a customer support portal and IP storefront, as well as design services and capabilities.

"Tower's specialty technology portfolio, geographic reach, deep customer relationships and services-first operations will help scale Intel's foundry services and advance our goal of becoming a major provider of foundry capacity globally," says Intel's chief executive officer Pat Gelsinger

"Tower has built an incredible range of specialty analog foundry solutions based upon deep customer partnerships, with worldwide manufacturing capabilities," says Tower's CEO Russell Ellwanger. "Together with Intel, we will drive new and meaningful growth opportunities and offer even greater value to our customers through a full suite of technology solutions and nodes and a greatly expanded global manufacturing footprint," he reckons.

"Their decades of foundry experience, deep customer relationships and technology offerings will accelerate the growth of Intel Foundry Services," comments IFS' president Dr Randhir Thakur. "We are building Intel Foundry Services to be a customer-first technology innovator with the broadest range of IP, services and capacity," he adds. "Tower and IFS together will provide a broad portfolio of foundry solutions at global scale."

Intel claims to be the only leading-edge player with both R&D and manufacturing in the USA, including recently announced capacity expansions in Arizona and New Mexico, as well as plans to build a new mega-site in Ohio. Tower's technology and manufacturing footprint is complementary to Intel's IFS capabilities in leading-edge processes, allowing the combined company to provide broader offerings to customers at scale. With the addition of Tower, Intel reckons that it is positioned to bring more value to customers across the nearly $100bn addressable foundry market.

Until the deal's closure, IFS and Tower will run independently; IFS will continue to be led by Thakur, and Tower will continue to be led by Ellwanger. Intel's intent is then for the two organizations to become a fully integrated foundry business.

www.towersemi.com
www.intel.com

Qorvo's December quarter exceeds the mid-point of guidance for revenue, gross margin and EPS

For its fiscal third-quarter 2022 (ended 1 January), Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has reported revenue of $1114m, down 11.2% on last quarter's record of $1255.2m but up 1.7% on $1094.8m a year ago, and $9m above the midpoint of $1090–1120m guidance.

"Supply chain effects did moderate in the quarter," notes chief financial officer Mark Murphy.

"Sustained year-over-year revenue growth was supported by multi-year secular growth drivers in 5G, IoT connectivity, defense and power," says president & CEO Bob Bruggeworth. "Demand was broad-based across markets, and included multiple new product categories, including 5G transmit diversity, ultra-wideband Wi-Fi 6E and 7 and power management and other power solutions."

Mobile Products revenue was $848m, down from $996m last quarter but up from $826m a year ago, and above the expected $830m, due to the continued growth of inherently higher-content 5G smartphones, plus gaining content in both flagship and mass-market 5G devices. "The multi-year migration of 5G continues to drive RF content and integration trends," said Bruggeworth last quarter. "The RF content increase in mass-market phones is now greater on a percent basis than in flagship devices."

Infrastructure & Defense Products (IDP) revenue was $266m, down on $269m a year ago (and below the expected $275m) but up from $260m last quarter. Sequential growth is broad-based across markets, except for Wi-Fi (still impacted by the ongoing shortages of chipsets). Infrastructure and programmable power management grew not only sequentially but also year-on-year. "In the defense supply chain, there is still some COVID-related disruption," notes Murphy, "but it did improve, as we expected."

On a non-GAAP basis, gross margin was 52.6%, down on 54.4% a year ago. But despite the more challenging supply/demand environment than expected, this was the fifth consecutive quarter above 52%, up from 52.4% last quarter and above the midpoint of the 52–52.5% guidance range, due to a better-than-expected product mix and yields.

Operating expenses were $214.2m (19.2% of revenue), down from $222.1m last quarter (and below the expected $224m) due to lower incentive compensation and the timing of development programs. However, this is up on $194.2m a year ago, due to new product and technology investments (spending on core technologies and expanding capabilities in new businesses). This includes OpEx from power device maker United Silicon Carbide of Princeton, NJ, USA (acquired in early November), partially offset by lower incentive compensation.

Operating income was $372m (33.4% of revenue, a fifth consecutive quarter of operating margin over 33%), down on $435.4m (34.7% margin) last quarter and $401.4m (36.7% margin) a year ago.

Net income was $330.4m ($2.98 per diluted share), down from the record $384.5m ($3.42 per diluted share) last quarter and $356.7m ($3.08 per diluted share) a year ago, but exceeding the $2.75 earnings per share guidance.

Operating cash flow was $117m, halving from last quarter's $244.8m, but this reflects a sizeable payment for a long-term supply agreement. "Supply agreements allow us to advance our differentiated technology position and simplify our long-term planning," says Murphy. "Qorvo is building longer-term and more collaborative partnerships to provide our customers supply assurance and to address their product and technology needs."

Also, Qorvo's inventory rose above $700m (115 days of inventory), in line with the forecast, due to (1) needing to support expected growth (i.e. content gains in both flagship and mass-tier smartphones, plus increases in IDP) and (2) a realignment of demand among OEMs in China. "Given our focus on cash flow and capital returns and risk management, it's certainly higher than we want it to be and higher than it's run over the past 1.5 years or so," says Murphy. "But we're working through those. We have a plan that rolls off over the next few quarters, and we expect more normal turns as we move through the year."

Capital expenditure (CapEx) was $50.5m (below the projected $70m). "It remains concentrated in core areas such as BAW [bulk acoustic wave] and gallium arsenide (GaAs), where we enjoyed a differentiated position and see continued growth," says Murphy.

Free cash flow was hence $66.5m, down from $197.5m last quarter.

During the quarter, Qorvo repurchased $302m of shares. "We continue to repurchase shares based on our long-term outlook, low leverage, and other factors," says Murphy.

In December, Qorvo issued its first investment grade note. Proceeds from this $500m three-year note were used in part to retire the firm's $195m term loan.

As of the end-December, Qorvo had $2047m of debt and $988.5m of cash and cash equivalents. Net debt to EBITDA rose to more than 0.5 turns.

"Qorvo is operating well and expanding the markets we serve while investing to extend product and technology leadership across our portfolio," says Bruggeworth.

Strategic highlights

In Mobile, Qorvo ramped shipments during the quarter to a Korea-based smartphone OEM in support of flagship and mass-market smartphone launches. It also expanded customer sampling of highly integrated

main path and secondary transmit solutions for Android 5G smartphones (increasing content as these architectures are adopted more broadly).

In ultra-wideband, Qorvo achieved a key strategic milestone, supplying its first complete ultra-wideband solution for an Android smartphone (including a UWB transceiver and a software stack compatible with other Android devices). "This speaks to the strength of our core technology and highlights the opportunity across the Android ecosystem," says Bruggeworth. For industrial and enterprise applications, Qorvo launched a fully integrated module combining its ultra-wideband chip-set with Nordic's Bluetooth Low Energy solution to address a wide range of applications.

In Wi-Fi, design activity continues to be robust. Qorvo secured new Wi-Fi 7 chip-on-board reference design engagements for mobile applications and began customer sampling of Wi-Fi 7 front-end modules (FEMs). For home and enterprise applications, the firm ramped Wi-Fi 6E FEMs for mesh networks and released 5GHz iFEMs with BAW filtering for tri-band Wi-Fi mesh networks.

In cellular infrastructure, Qorvo was selected by a base-station OEM to supply 3.4–3.8GHz 8W GaN power amplifier modules for massive MIMO 5G deployments in Europe. "We see infrastructure market strengthening in 2022 worldwide, with significant growth in the rest of the world, excluding China," notes Bruggeworth.

In automotive, Qorvo was selected to provide a cellular FEM for V2X connectivity for a leading Europe-based automotive OEM.

In power, Qorvo secured design wins to supply silicon carbide for on-board chargers (OBCs) and DC-to-DC converters in support of leading automotive OEMs in Europe and Asia. Also, sales of power management integrated circuits (PMICs) for video processors and solid-state drives were strong, as were sales of motor control solutions for battery-powered tools.

"To expand our power franchise, we are combining our power management and silicon carbide technologies to deliver superior levels of power efficiency and high-power applications," notes Bruggeworth. "Our first products are for the defense industry, and we are broadening the portfolio to serve additional markets, including infrastructure and automotive," he adds. "The integration of United SiC is proceeding well and enhancing our opportunities in higher-voltage applications that demand maximum power efficiency. These include electric vehicles, charging stations and renewable energy systems."

"In both mobile and IDP, Qorvo is capturing diverse opportunities supported by multi-year secular growth drivers in 5G, IoT connectivity, defense and power," summarizes Bruggeworth.

We expect the supply environment to continue to improve through this quarter

Outlook

Reflecting reduced disruption in the supply chain, the timing of high-volume smartphone launches, content gains and stronger IDP volumes, for fiscal fourth-quarter 2022 (to end-March) Qorvo expects revenue to grow more strongly than usual to $1.135–1.165bn, up 3% sequentially and 7% year-on-year. Mobile Products should be flat sequentially but up about 5% year-on-year due to flagship and mass-tier phone launches and content gains and a more stable supply–demand situation. IDP should return to year-on-year growth, with broad-based demand supporting revenues over $300m. "In our IDP business, some of the silicon supply in our connectivity business there, along with some of our power management systems business, we still see tightness," notes Bruggeworth. "We do expect things to improve through the quarter and throughout the year."

Gross margin should be about 52%. Operating expenses are expected to rise to about $232m due to increased investment in core technologies and new capabilities as well as early-calendar-year payroll effects. Diluted earnings per share should fall slightly to $2.94.

For full-year fiscal 2022, year-on-year revenue growth should exceed 15%. Gross margin is expected to about 30 basis points higher than fiscal 2021 (which had exceeded 52%). With OpEx cut from nearly 20% of revenue to just over 19%, operating margin is expected to rise to over 33% and earnings per share should grow by 25% to $12.18. Murphy expects full-year free cash flow to still end up near $900m (and to grow next year).

"We expect the supply environment to continue to improve through this quarter and the calendar year," says Murphy.

CapEx is projected to be about $55m in the March quarter, "as we manage spend to intersect demand and support long-term supply agreements with multiple customers," says Murphy. "We are still supply constrained in some areas and forecast to remain so beyond our fiscal year-end. We continue to expand BAW and GaAs capacity along with some assembly and test to support growth."

"Looking beyond this fiscal year, Qorvo is well-positioned to serve secular growth trends in connectivity and power and to deliver growth in earnings and free cash flow," reckons Murphy. "We expect solid growth in our advanced cellular products for smartphones as 5G mix grows, RF complexity increases and content expands. In broader connectivity solutions, we expect strong double-digit growth as connected devices increase and use-cases proliferate [while WiFi business should pick up in fiscal 2023]. Finally, we expect infrastructure, defense and power markets to support double-digit growth as 5G build-outs pick up outside of China, defense spend mixes to higher-performance electronics, and requirements increase for power semis to support electrification trends," he concludes.

www.qorvo.com

Skyworks' revenue grows 15% sequentially to record $1.51bn

Growth fueled by 5G, IoT, automotive and wireless infrastructure

For fiscal first-quarter 2022 (to end-December 2021), Skyworks Solutions Inc of Irvine, CA, USA (which manufactures analog and mixed-signal semiconductors) has reported record revenue of $1.51bn, up fractionally year-on-year and up 15% on $1.311bn last quarter, driven by continued strong demand across the firm's entire portfolio. "The growth trajectory we established in fiscal 2021 is extending into fiscal 2022," notes CEO, president & chairman Liam Griffin. "This demonstrates the strength of our broadening product portfolio. Growth was well diversified across Mobile and Broad Markets."

Mobile business (comprising 68% of total revenue) was up 12% sequentially, driven by increasingly complex architectures in 5G phones at the firm's largest customer and momentum across the Android ecosystem. Mobile revenue was down 13% year-on-year, but: "You have to take into account the timing of the ramp of flagships, especially last year, where the large customer had a condensed ramp with a late launch in the late October/early November time frame," comments senior VP & chief financial officer Kris Sennesael. "This year, the launch was spread over the September and December quarters," he adds. "Our large customer left some revenue on the table in the December quarter [due to their capacity constraints], and they're still trying to catch up - they see improvements going into the March quarter."

Broad Markets business was a record $477m, up 23% sequentially and 46% year-on-year (rising from 22% of total revenue a year ago through 29% last quarter to 32% now).

"Growth was fueled by both the continued adoption of our solutions across 5G, IoT [Internet of Things], automotive and wireless infrastructure, and an expanding set of new customers and markets from our recently acquired I&A business [Infrastructure & Automotive, acquired last July from Silicon Laboratories Inc of Austin, TX, USA for $2.75bn]," says Griffin. "We've done really well in the last couple of months of introducing the I&A products and technologies to customers that we already have — proven customers that we do a lot of business with — which is a great synergy for us," he adds. "The majority of the portfolio and the I&A business had been more of a fabless play. Over time, we're going to bring that technology under our own roof here at Skyworks and leverage the great [manufacturing] scale that we have."

On a non-GAAP basis, gross margin was 51.2%, up slightly from 51.1% a year ago and 51% last quarter.

Operating expenses were $187m (12.4% of revenue), at the top end of the forecasted $184–187m range but cut further from 13.8% of revenue last quarter, "demonstrating leverage in our operating model while continuing our strategic investments in support of future growth," says Griffin.

"Skyworks delivered strong first quarter results, with double-digit sequential growth in both revenue and earnings per share," notes Griffin.

Net income was $523m ($3.14 per diluted share, up 20% sequentially and exceeding the targeted $3.10). This is up from $438.8m ($2.62 per diluted share) last quarter.

Operating cash flow was a record $581.7m (up from $398m last quarter and $485.1m a year ago). Capital expenditure (CapEx) was "somewhat light" at $96m (compared with $263m last quarter). Free cash flow was hence a record $486m (free cash flow margin of 32%), driven by strong profitability and working capital management. In fact, inventory was cut by 22 days to 103, and receivables were reduced by 5 days to 47.

In terms of capital allocation during the quarter, Skyworks paid $93m in dividends, and repaid $50m of its term loan. The firm also repurchased 1.7 million shares of common stock for a total of $269m. "Given where the stock is trading today and what it was trading over the last 3 months, we have switched on the buybacks again," says Sennesael. "We have still $2.2bn of debt on the balance sheet in addition to $1bn of cash. Gross debt is less than a turn of EBITDA," he notes.

"Despite macro challenges in supply-chain-specific headwinds, Skyworks delivered excellent first-quarter results, underscoring the increasingly diverse composition of our customer base and extending our track record of strong profitability and robust free cash flow generation," says Griffin. "This strong performance and outlook reflect our critical position within the wireless ecosystem and how complexity favors Skyworks with its vast IP, deep customer relationships, differentiated manufacturing capabilities and market-leading solutions."

Quarterly business highlights

"The rapid adoption of new wireless technologies enables a proliferating set of use cases, with design wins spanning Mobile and Broad Markets, further bolstered by contributions from our recently completed acquisition [I&A]," says Griffin.

In Mobile, Skyworks shipped Sky5 platforms across leading 5G smartphone OEMs including Samsung, Oppo, Vivo and Xiaomi.

In enterprise and IoT, Skyworks supported the launch of Wi-Fi access points at Siemens, powered NETGEAR's latest Wi-Fi 6E mesh system, partnered with British Telecom to launch their 5G home routers, ramped Wi-Fi 6 and 6E modules at Juniper Networks and Telus, and provided digital isolation products for GE consumer appliances.

In automotive, Skyworks leveraged Sky5 technology to enable 5G telematics, security, driver-assist

and other advanced services at leading automotive OEMs. The firm also scaled volume production of timing and isolation products, enabling the leading electric vehicle (EV) manufacturers.

In the infrastructure and industrial space, Skyworks captured design wins at Quectel for their enterprise machine-to-machine (M2M) platforms, and delivered industrial IoT solutions to Itron, Honeywell and Thales (supporting smart energy and factory automation).

Skyworks also expanded its position in timing applications at the top five data-centers server providers.

"As markets evolve, we expect to deploy billions of wireless devices, capitalizing on a strong multi-year growth trend," notes Griffin.

Outlook

"Looking forward, demand for connectivity is rapidly expanding across multiple essential wireless protocols, including 5G, advanced Wi-Fi and precision GPS," says Griffin. "Skyworks is uniquely positioned to outperform in all of these technologies through an expanding blue-chip customer base, differentiated manufacturing capabilities and market-leading solutions, all underpinned by strong cash generation," he reckons.

"Based on new product ramps across our increasingly diversified product portfolio, we expect double-digit year-over-year revenue and earnings growth in the March quarter," says Sennesael.

For fiscal second-quarter 2022 (to end-March), Skyworks expects revenue of $1.3–1.36bn. This is down 12% sequentially, but slightly better than normal seasonality compared with the last five years of March quarters. Year-on-year it is up 13.5%, with both segments growing by double-digits (more strongly in Broad Markets than in Mobile). Gross margin is expected to be 50.75–51.25%. With operating expenses steady at $186–188m, diluted earnings per share should be $2.62 (up 11% year-on-year).

"We do expect normal seasonality for the June quarter [just a transition quarter – typically down 3–4% sequentially, driven mostly by Mobile]," notes Sennesael. "Based on our technology roadmap, the products, the design-win momentum and the design wins that we have on the book right now, we feel very strong for further sequential growth into the September and December quarters, typically as you see, with strong performance in the second half of the year," he adds.

"This is still early stages in a multi-year 5G upgrade cycle. There's a lot of growth opportunities and growth markets. So we will continue to further invest in our manufacturing, adding more size and scale, but at the same time also supporting the technology roadmaps," says Sennesael.

We expect double-digit year-over-year revenue and earnings growth in the March quarter

"As you start to see 5G really accelerate, to really get the performance that's been promised and that's been desired, you've got to put in more filtering," notes Griffin. "You need to raise the performance of your gallium arsenide (GaAs) technologies. You got to look at your packaging & test, and the coexistence issues that happen when you have more and more of these technologies in a single application, whether the application is a phone or something else," he adds.

"We have major success with bulk acoustic wave (BAW), and so the revenue of integrated devices that have BAW filters inside is growing very strong, and we're supporting that," says Sennesael.

"We have an outstanding position in WiFi today. But there have been improvements in technology and demand for higher speeds and higher performance. In those cases, bulk acoustic wave is a critical element within the WiFi system," says Griffin. "We have ramped our bulk acoustic wave technology in smartphones with a lot of work, a lot of investment. Now we're seeing that move into WiFi. We have design wins now that capture bulk acoustic wave within a WiFi system, multiple customers. A lot of that is in the Broad Markets side. When you get into the connectivity nodes around WiFi and other cases, you have a broadening there. So we're in a great position also now to start to lever up bulk acoustic wave beyond the mobile phone," he adds. "A key element in our strategy in Broad Markets is to do more and raise the bar there on overall WiFi performance… It plays into core technologies that we have in-house… We have our own gallium arsenide technology. We have our own TC-SAW [thermally compensated surface acoustic wave filters], standard SAW, bulk acoustic wave, assembly & test."

"We're also making the necessary investments in Mexicali, in our back-end operation, supporting advanced packaging and test," says Sennesael. "So, again, we have a lot of growth opportunity for us. We will support that, and we will continue to expand the capacity and pay CapEx."

"The strength of our balance sheet and consistent outperformance demonstrates the significant value of our vertically integrated model and the compelling advantages it delivers… We are committed to supporting the strategic investments in technology, product development and world-class manufacturing scale to further extend our market leadership," concludes Griffin.

Dividend payment

"Given our strong cash flow and confidence in the business model, we will continue to focus on investing in our business, while returning cash to the shareholders through both share repurchases and dividends," notes Sennesael. Skyworks' board of directors has hence declared a cash dividend of $0.56 per share of common stock, payable on 15 March to stockholders of record at the close of business on 22 February.

www.skyworksinc.com

pSemi introduces complete 5G mmWave RF front-end solution

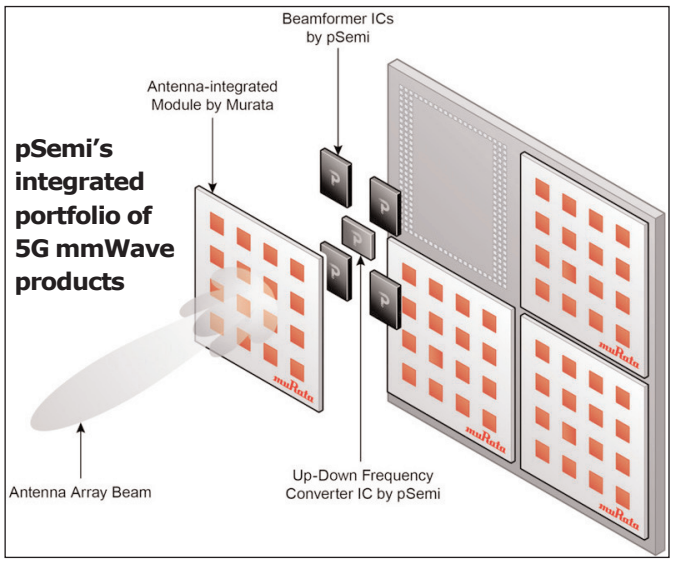
Covering 24–40GHz, portfolio showcases integrated module and discrete beam-forming and up-down converter RFICs

Murata company pSemi Corp of San Diego, CA, USA — a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-insulator (SOI) — has announced the expansion of its millimeter-wave (mmWave) RF front-end (RFFE) portfolio for 5G wireless infrastructure applications.

The new pin-to-pin compatible products, including three beam-forming ICs and two up–down converters, offer flexibility to interchange ICs for full IF-to-RF coverage across the n257, n258 and n260 bands. This modular approach, combined with on-chip calibration and digital correction, allows system teams to simplify their design cycles and quickly adapt to different active antenna design configurations. Available as discrete RFICs or as part of the Murata 28GHz antenna-integrated module, this diverse portfolio delivers performance, integration and reliability in the smallest IC form factor, it is claimed.

mmWave will reach mainstream deployments first in dense urban areas that benefit from short-range coverage supported by smart repeaters, indoor base stations and other small-cell applications. This increased demand for network capacity, along with the proliferation of beam-forming and active antenna systems, has opened new doors for SOI-CMOS technology as the preferred mmWave platform for advanced 5G systems, says pSemi.

"pSemi has offered mmWave products since 2015, deepening our expertise and patent portfolio in high-frequency RF SOI design," says Vikas Choudhary, VP of sales & marketing. "This history — combined with the advanced packaging and global manufacturing strength of our parent company, Murata — enables us to support higher levels of integration to simplify 5G mmWave development and deployment," he adds.



pSemi's integrated portfolio of 5G mmWave products

8-channel beam-former RFIC features and benefits

Each PE188100, PE188200 and PE189100 RFIC integrates power amplifiers (PA), low-noise amplifiers (LNA), phase shifters and switches into a single die that provides optimal signal strength for up to 1024-element antenna arrays.

- Full spectrum coverage — n257 (PE188200), n258 (PE188100) and n260 (PE189100) band support and pin-to-pin compatibility.
- Flexible antenna design — Eight independently controllable RF channels with support for four dual-polarized or eight single-polarity antenna elements.
- Beam-forming accuracy — Linear POUT at the desired EVM with low RMS phase and amplitude error for increased array gain and antenna directivity.

Dual-channel up-down converter RFIC features and benefits

Each PE128300 and PE129100 RFIC integrates frequency multipliers, quadrature mixers, amplifiers and switches into a single die that can be paired with up to 16 pSemi beam-forming RFICs, or 128 total beam-former channels, to support massive MIMO, hybrid-beam-forming and other active antenna configurations.

- Wideband coverage — n257/n258 (PE128300) and n260 (PE129100) band support and pin-to-pin compatibility.
- Low-noise system design — Optimal I/Q balance adjustment and minimal LO leakage, resulting in improved EVM performance.
- Low power consumption — Industry-leading low power consumption enabling more efficient system thermal management.

5G antenna-integrated module features and benefits

pSemi and Murata have co-designed an easy-to-use 5G mmWave antenna-integrated module (Type 1QT) that supports the 28GHz band. In a 4x4 antenna array, each module integrates high-performance antennas and pass-band filters with pSemi beam-forming ICs and an up–down converter. Multiple modules can be combined, allowing designers to quickly scale and build antenna arrays of any size.

- Precise LTCC substrate packaging — Excellent heat and moisture resistance for stable performance and thermal management including in harsh environments.
- Advanced pass-band filter technology — Low insertion loss and high attenuation, reducing interference to maximize signal integrity.
- Manufacturing over-the-air (OTA) tested — Validated performance with OTA manufacturing test, simplifying the development process.

www.psemi.com

Construction contract awarded for CSL-MIF at MIT Lincoln Laboratory

Compound Semiconductor Laboratory – Microsystem Integration Facility to research and prototype heterogeneously integrated microelectronic components

The US Army Corps of Engineers (USACE) has awarded a contract to Gilbane–Exyte Joint Venture to build the Compound Semiconductor Laboratory — Microsystem Integration Facility (CSL-MIF) at Massachusetts Institute of Technology (MIT) Lincoln Laboratory.

The CSL-MIF will be a research and advanced prototyping facility yielding complex, integrated microelectronic components for ground, air and space demonstrations enabling scientific discovery and solving key national security challenges.

A design rendering of the Compound Semiconductor Laboratory – Microsystem Integration Facility at MIT Lincoln Laboratory. Construction should begin this spring.

Scheduled to begin this spring, the $279m building project is funded by the US Air Force military construction (MILCON) program, under the direction of USACE, who will manage the building of the 160,000ft^2, three-story facility (of which 35,000ft^2 will be high-end cleanroom space). Lincoln Laboratory will install and calibrate the facility's microelectronics fabrication equipment.

"The CSL-MIF will enable the most advanced microelectronics research and prototyping in critically important national security areas for decades to come," says Lincoln Laboratory director Eric Evans.

When fully constructed and integrated, the CSL-MIF will enable scientists and engineers to grow, fabricate and characterize compound semiconductors and package specialized heterogeneously integrated electronic prototypes. The capability to integrate different semiconductor material systems and device technologies allows for the creation of customizable microsystems targeting a wide range of applications. Technologies of focus will include 3D-integrated focal-plane arrays (FPAs) for scientific imaging and surveillance, integrated electro-optical systems for space-based optical communication, superconducting microsystems for integrating quantum information bits (qubits), and advanced 3D-ladar imaging systems. The capabilities of the CSL-MIF will be complementary to those of the Lincoln Lab's existing Microelectronics Laboratory (ML), the US government's most advanced silicon-based research and advanced prototyping fabrication facility.

"The combination of the new CSL-MIF with our existing ML infrastructure will be a powerful and differentiating resource for the Laboratory in the advanced microelectronics area," says Craig Keast, associate head of the Advanced Technology Division and technical lead on the CSL-MIF project. "The two facilities together will allow us to explore and demonstrate complex heterogeneously integrated microsystems that could not be realized without access to the capabilities provided by these two specialized facilities," he adds.

The CSL-MIF building project has been over a decade in the making. In 2014, the Department of Defense acknowledged a critical need for Lincoln Laboratory facility modernization, and the CSL-MIF was one of two MILCON-funded building projects. The second is a new Engineering Prototyping Facility (EPF) for establishing advanced fabrication and integration laboratories for large system prototypes. Together, the CSL-MIF and EPF make up a larger facility modernization effort called the West Laboratory Project.

"The CSL-MIF is a major step forward for Lincoln Laboratory and its sponsors," comments Laboratory assistant director for operations Scott Anderson. "We appreciate the strong partnerships with the US Air Force, USACE, and our primary sponsor, the Under Secretary of Defense for Research and Engineering, that made this possible."

www.ll.mit.edu

Infineon investing €2bn in third module at Malaysia front-end fab for wide-bandgap power semiconductors

6" and 8" silicon lines to be converted to SiC and GaN manufacturing

Infineon Technologies AG of Munich, Germany is investing over €2bn to add manufacturing capacity in wide-bandgap power semiconductors by building a third module at its site in Kulim, Malaysia. Once fully equipped, the new Kulim 3 module should generate €2bn in additional annual revenue from products based on silicon carbide (SiC) and gallium nitride (GaN).

Following the firm's long-term manufacturing strategy, the expansion will benefit from the economies of scale already achieved for 200mm manufacturing in Kulim, complementing Infineon's position in silicon, based on 300mm manufacturing in Villach and Dresden.

"Renewable energies and electromobility are major drivers for a strong and sustainable rise in power semiconductor demand," says chief operations officer Jochen Hanebeck. "The expansion of our SiC and GaN capacity is readying Infineon for the acceleration of wide-bandgap markets," he adds. "We are creating a winning combination of our development competence center in Villach and cost-effective production in Kulim for wide-bandgap power semiconductors."

Aerial view of Infineon's front-end fab in Kulim, Malaysia.

Two wide-bandgap sites for supply chain resilience

Infineon already provides over 3000 customers with SiC-based products, offering better system performance in efficiency, size and cost compared with silicon. Target applications are industrial power supply, photovoltaic, transportation, drives, automotive and electric vehicle (EV) charging.

Infineon targets revenue of $1bn with SiC-based power semiconductors by the middle of the decade. The GaN market is predicted to rise at a compound annual growth rate of 76% from $47m in 2020 to $801m in 2025 (according to Yole Développement's 'Compound Semiconductor Quarterly Market Monitor Q3 2021').

Construction of Kulim 3 will begin in June and the fab will be ready for equipment in summer 2024. The first wafers will leave the fab in second-half 2024. Fully loaded, Kulim 3 will create 900 jobs. The investment will comprise significant value-added steps, in particular epitaxial processes and wafer singulation.

"Malaysia is one of Infineon's main regional hubs and this further investment truly attests to our conducive ecosystem and the capability of our local talent to support long-term growth," says Malaysia's Senior Minister and Minister of International Trade and Industry Dato' Seri Mohamed Azmin Ali.

Villach to be global wide-bandgap competence center

The Villach site will continue to serve as the innovation base and global competence center for wide-bandgap technology by converting existing silicon facilities over the next few years. 6" and 8" silicon lines will be converted to SiC and GaN manufacturing by repurposing non-specific silicon equipment.

Infineon names Wijburg as chief operations officer

Infineon says that Rutger Wijburg will join its management board as chief operations officer on 1 April. He succeeds Jochen Hanebeck, who will replace Dr Reinhard Ploss as CEO.

An "internationally experienced industry expert with intimate knowledge of both semiconductor manufacturing and the silicon foundry world", Wijburg will bring "valuable additional perspectives," says Dr Wolfgang Eder, chairman of the supervisory board.

"Based on our structural growth drivers, Infineon is ready to invest in its manufacturing capacity and to extend partnerships," says Wijburg.

Wijburg joined Infineon in 2018. As managing director of Infineon Dresden, he was responsible for the ramp-up of highly automated 300mm production. After taking over as head of Frontend at the beginning of 2021, Wijburg has focused on expanding wide-bandgap capacities and was instrumental in establishing the concept of the 300mm 'One Virtual Fab' cluster.

www.infineon.com

Infineon launches CoolSiC power module for streetcars

Infineon Technologies AG of Munich, Germany is launching power semiconductors with CoolSiC MOSFET and .XT technology in the XHP 2 package, tailored specifically to the requirements of rail services.

The XHP 2 power module from Infineon has already been proven in a joint field test conducted by Siemens Mobility and Stadtwerke München (SWM). An Avenio streetcar in Munich was equipped with these power modules and tested in passenger service for a year, covering around 65,000km. Siemens Mobility concluded that this use of power semiconductors based on silicon carbide (SiC) had made it possible to reduce the energy consumption of streetcars by 10%. At the same time, it was also possible to significantly reduce engine noise during operation.

"Innovative semiconductor solutions for rail technology are an important driver for green mobility. The successful field test with streetcars in Munich demonstrates the benefits of SiC technology for manufacturers, rail operators and residents," says Dr Peter Wawer, president of Infineon's Industrial Power Control Division. The tests were carried out under the European development and research project PINTA and are part of the extensive European research and innovation initiative Shift2Rail (a joint undertaking under grant agreement no. 826054 that has received support from the European Union's Horizon 2020 research and innovation program), which aims to create a sustainable European rail system through targeted investments.

Implementing SiC in power modules for traction propulsion systems can also pose major challenges: In addition to an efficient and very robust SiC chip, packages that allow high switching speeds are required, as well as interconnection technologies that enable a long service life. These are precisely the features offered by Infineon's power module, it is claimed: Since trains accelerate and decelerate frequently, the power cycles for semiconductors in rail applications are very demanding. The constant temperature fluctuations stress the interconnection technology. Infineon's .XT technology provides a solution to this challenge. The technology significantly improves the lifetime during power cycles and has been used for years in similarly challenging applications such as wind turbines.

In Infineon's XHP 2 power module, CoolSiC MOSFET chips enable low conversion losses while maintaining high reliability. They are the basis for increased energy efficiency and are already used today in many applications like photovoltaic systems. The XHP 2 package features low stray inductance, a symmetrical and scalable design, and high current capacity. As a result, the package is suitable for silicon carbide.

Thus, in addition to the established application areas of photovoltaics and charging infrastructure for electric vehicles (EVs), silicon carbide MOSFETs now also provide significantly more energy efficiency in the area of rail-bound vehicles.

On 31 March, Infineon is hosting the 'Industrial Wide-Bandgap Developer Forum' for design and development engineers as a livestream. During the event, Stefan Schönewolf of Siemens Mobility GmbH will talk about SiC in rail vehicles.

www.infineon.com/coolsic

Toshiba launches 1200V and 1700V SiC MOSFET modules

First Toshiba products with these voltage ratings to contribute to smaller, more efficient industrial equipment

Tokyo-based Toshiba Electronic Devices & Storage Corp (TDSC) — spun off from Toshiba Corp in 2017 — has launched two silicon carbide (SiC) MOSFET dual modules: MG600Q2YMS3 with a voltage rating of 1200V and drain current rating of 600A, and MG400V2YMS3 with a voltage rating of 1700V and drain current rating of 400A. The first Toshiba products with these voltage ratings, they join the previously released MG800FXF2YMS3 in a lineup of 1200V, 1700V and 3300V devices.

The new modules (provided in a 2-153A1A package) have mounting compatibility with widely used silicon insulated-gate bipolar transistor (IGBT) modules. Their low-energy-loss characteristics are said to meet needs for higher efficiency and size reductions in industrial equipment.

Applications include: inverters and converters for railway vehicles; and renewable energy power generation systems; motor control equipment; and high-frequency DC–DC converters.

https://toshiba.semicon-storage.com

II-VI qualifies 1200V SiC MOSFET platform to automotive standards and expands relationship with GE

Three-year technology access agreement with GE Research to give access to SiC module technology

Engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA has qualified its 1200V silicon carbide (SiC) MOSFET platform, on its SiC substrates, to stringent automotive standard requirements and is expanding its relationship with GE by signing a three-year technology access agreement (TAA) with GE Research to gain access to the Lab's SiC module technology and team of experts to accelerate customer design-in engagement activities.

A growing number of applications, such as in electric vehicles (EVs), renewable energy, data centers, industrial motors and power supplies, are driving the strong demand for SiC-based power electronics, due to their high efficiency, lower total system-level cost of ownership, higher reliability, and ability to achieve more compact system designs compared with state-of-the-art silicon-based devices. Leveraging its 150mm SiC substrates, II-VI completed the qualification of its 1200V SiC MOSFET platform to the Automotive Electronics Council AEC-Q101 standard, exceeding it to 200°C.

"This qualification represents an important milestone that allows us to begin ramping up our commercial activities for devices in the industrial motor and renewable-energy markets, while in parallel initiating longer-term design-in activities in the electric vehicle market," says Sohail Khan, executive VP, New Ventures & Wide-Bandgap Electronics Technologies. "The licensing of GE's technology in [June] 2020 allowed us to achieve our qualification milestone ahead of schedule. The technology access agreement will strengthen our relationship with GE and further accelerate our time to market as we continue to execute on our previously announced plan to grow by investing $1bn in capacity and innovation for our SiC platform over the next ten years."

The TAA with GE Research expands the relationship with GE by building on an earlier agreement in which II-VI licensed GE's technology to manufacture SiC devices and modules for power electronics. The TAA will involve about a dozen of GE Research's SiC device and systems experts and test facilities, which will be dedicated to the next phase of the commercialization of II-VI's SiC devices and modules.

The new agreement "will enable II-VI to capitalize on billions of dollars of new market opportunities for power electronics in the automotive, industrial and other sectors," says Vic Abate, GE's chief technology officer. "As we work with II-VI to expand its market base, we will also leverage new advancements in SiC power devices and modules to improve GE's position with its SiC products in the aviation market and support other GE products in the energy and healthcare spaces that will benefit from these more capable power electronics devices," he adds.

GE Aviation offers a portfolio of SiC-based electrical power products for aerospace, industrial and military applications. Also, GE's other businesses, which include renewable-energy assets, grid infrastructure and medical imaging scanners, should all see improved performance and efficiency through the integration of SiC-based power electronics platforms.

Sample dies are available now and packaged samples are scheduled to be available by mid-2022.

www.ii-vi.com

Fuji Electric
Innovating Energy Technology

Fuji Electric G-Twin UL Plug-In Series

New High Quality Product with improved safety features, easy installation and compact

TÜV Rheinland IEC JIS EN c UL us LISTED CE

Global Standard

The New Generation of Molded Case Circuit Breakers and Earth Leakage Circuit Breakers.

- ★ Built-In Compact Ground Fault for Space Saving Designs
- ★ Same Footprint! MCCBs and ELCBs interchangeable without Panel Modifications
- ★ All frame sizes (50AF-250AF) can be mounted with the same mounting pitch of 70mm
- ★ Lock Out Tag Out (LOTO) safety devices (fixed and removable types) are available as an option
- ★ Improves safety measures and easy & quick installation
- ★ UL489 and CSA C22.2 No.5 approved and certified

Fuji Electric Corp. of America **Distribution & Control Department**

For sales, product & distributor information, please visit americas.fujielectric.com/UL-Plug-In

or contact us: x-fea-fuji-dc@fujielectric.com

Wolfspeed revenue grew 11% in December quarter despite supply constraints

Design-ins up 70% year-on-year, driven by silicon carbide power devices

For its fiscal second-quarter 2022 (ended 26 December 2021), Wolfspeed Inc (formerly Cree Inc) of Durham, NC, USA has reported a sixth consecutive quarter of revenue growth (for continuing operations) to $173.1m (near the high end of the $165–175m guidance range). This is up 11% on $156.6m last quarter and 36% on $127m a year ago.

After divesting its Lighting Products business in May 2019 and its LED Products business in March 2021, on 4 October Cree changed its name to that of its Wolfspeed business unit, focused on manufacturing silicon carbide materials as well as both silicon carbide (SiC) and gallium nitride (GaN) power-switching & RF semiconductor devices.

"Last November, we held an Investor Day at the New York Stock Exchange, where we outlined how the team is focused on driving the industry transition from silicon to silicon carbide by expanding our leading market position with innovative new solutions, building additional capacity in New York and North Carolina to support what we see as a steepening demand for silicon carbide solutions, growing our opportunity pipeline and converting to design-ins at a very robust pace," says CEO Gregg Lowe.

"Our power business continues to see increasingly robust demand from the automotive markets, and we're also encouraged by rising demand across a number of industrial and energy customers," says Lowe.

Power device revenue was up 37% quarter-on-quarter and more than 100% year-on-year. "We saw significant growth in both direct and distribution channel customers," notes chief financial officer Neill Reynolds. "Since we converted the Durham fab over to primarily a power device factory, we just saw record output in that factory," he adds.

"On the RF device front, we continue to see solid demand from a 5G and aerospace & defense perspective, which increased over the prior year, but was relatively flat over the prior quarter.

Last quarter, Wolfspeed saw some supply constraints and some lower productivity as its Malaysian contract manufacturer continued to ramp activities back up following a COVID-19 outbreak (which led to a seven-day closure). "We continue to increase capacity," says Reynolds. "We're seeing some benefits from the output in Malaysia."

"From a materials perspective, demand for our 150mm silicon carbide substrates remains very strong. This resulted in year-over-year growth, though roughly flat versus the prior quarter as we continue to increase capacity and better match supply with demand," says Reynolds.

In May 2019, Cree began a multi-year factory optimization plan. In Durham, the firm has converted an old lighting and office space into industrial space for a significant expansion of its crystal growth and epi capability (part of a plan to increase silicon carbide materials capacity by 30x). "Our expansion enabled us to increase the number of growers, and take advantage of our continued crystal growth technology improvements, which increased production yield," the firm said last quarter.

Also, in September 2019 Cree announced that the plan was being anchored by a new automated 200mm SiC device fabrication facility at Marcy in Mohawk Valley, New York State (expanding from the firm's existing 150mm-wafer SiC device fab in Durham).

On a non-GAAP basis, gross margin was 35.4%, up from 33.5% last quarter (and towards the high end of the 33.7–35.7% guidance range), driven by improved output cost and yields from the Durham fab and the Malaysia subcontractor, as well as $8.5m lower depreciation expense resulting from a 2–5 year extension in the useful lives of certain machinery and equipment assets following the divestiture of the LED Products business and the continued investment in 200mm technology. This was partially offset by device products comprising a greater proportion of the revenue mix (since they have a higher cost base and hence lower profitability than materials). "The profitability of the device business [which has had a sub-optimal production footprint in North Carolina] improved significantly versus last quarter with the better factory performance [as the firm works through factory transitions and improves yields]," says Lowe. "So, over time, we would expect that mix impact to dissipate."

Operating expenses were $86.6m (below the expected $88m). This was up slightly from last quarter, due largely to R&D, including investment in 200mm efforts (supporting the ramp-up of the new Mohawk Valley fab), plus hiring staff to support sales & marketing activities. In addition, during the quarter Wolfspeed incurred start-up costs (primarily related to Mohawk Valley) totaling about $11m (up from $8.6m last quarter).

Net loss has been cut further, from $26.6m ($0.24 per diluted share) a year ago and $23.8m ($0.21 per diluted share) last quarter to $18.6m ($0.16 per diluted share, almost bettering the guidance range of $0.16–0.20).

Cash outflow from operations was –$32.5m (almost halved from –$62.5m last quarter). Capital expenditure (CapEx) was $144m (down from $208.5m last quarter).

Free cash outflow was hence –$176m (cut from $272m last quarter). Cash, cash equivalents and short-term investments has hence fallen from $857.8m at the beginning of the quarter, but Wolfspeed still has about $700m of cash and liquidity on hand to support current plans.

Additionally, in December, Wolfspeed incurred a loss of $24.8m on completing the redemption of its 0.875%-convertible senior notes due 2023 (issued in August 2018) in exchange for about 7.1 million shares of common stock, leaving the firm with convertible debt with a face value of $575m. "This transaction better positions us to capitalize on increasing demand by strengthening the balance sheet, increasing optionality and preserving cash during our peak investment period," believes Reynolds. "We will continue to be opportunistic from a capital market standpoint to ensure we have the flexibility to invest as we see fit to capitalize on a market-leading position and support continued growth."

During the quarter, Wolfspeed secured a record $1.6bn of design-ins. "Our device opportunity pipeline continues to grow and is now well above $20bn, underscoring the enormous demand we're seeing across all end-markets. The pipeline also reflects more than 8700 projects [up from 8200 last quarter], and our team continues to identify new opportunities at a rapid pace," notes Lowe. "More importantly, the sales team continues to convert design-ins at a high rate across a wide range of applications. This includes things like personal watercraft and snowmobiles, defense applications, trains, electric vehicle (EV) charging, a plasma generator and an electric vertical takeoff and landing (VTOL) aircraft." The design-in total for fiscal first-half 2022 is $2.1bn (mostly automotive-related, but industrial and RF as well). This is up 70% year-on-year and well above the original plan. "At this pace, we are on a trajectory to significantly exceed our design-in total from fiscal 2021 [of $2.9bn]," notes Lowe.

"This positive momentum is a direct result of customers adopting silicon carbide at a faster rate than we originally anticipated and is creating a stronger tailwind for our long-term revenue outlook than we showed at our Investor Day back in November... We were projecting $2.1bn of total revenue at the company level and roughly $1.4bn of device revenue. It's that device revenue where we're seeing the momentum. There's three things that are really kind of driving all of this. The adoption rate of electric vehicles is well ahead of plan. The adoption of silicon carbide inside both EVs and the industrial markets is well above any expectation we had. Finally, our win rate in this business is actually ahead of our plan as well."

"To support our rapid growth, it's critical that we continue to invest in people. We have attracted senior talent from a variety of exceptional companies and have demonstrated a tremendous ability to bring in people from the outside with substantial amounts of automotive experience or semiconductor wafer fab experience. The opportunity to join Wolfspeed as we drive the industry transition to silicon carbide is exciting, and we're taking advantage of this excitement to attract some of the industry's finest leaders and innovators," says Lowe.

"Adding to our management team with proven semiconductor leadership is a critical factor to our future success, and the Durham fab team — now led by Missy Stigall — has made solid progress in a relatively short amount of time, already contributing to positive results," comments Lowe. "In addition, we recently added Joe Robel — who has over 20 years of semiconductor manufacturing experience — to lead our global back-end operations, including oversight of our subcontractor in Malaysia," he adds. "We expect continued operational improvements in our Durham fab, and our Malaysia subcontractor will have a positive impact on gross margin and capacity for the remainder of the year."

For fiscal third-quarter 2022 (to end-March), Wolfspeed targets double-digit sequential revenue growth for a second consecutive quarter, to $185–195m, driven by all areas of the business but led by power devices (doubling year-on-year for a second consecutive quarter) and improved output from RF and materials. "We're going to see more productivity, more power device ramp-up as we work into Q3," says Reynolds. "Revenue here in the shorter term is really more of a function of supply than it is demand. Revenue is going to be just a function of the how well we can drive productivity through the current footprint that we have. Growth and capacity that we're seeing now really is a direct result of the new operations leadership just making an impact."

Gross margin should be 35–37%. "We anticipate seeing better performance in the fab and the back-end, offset by some of that product mix," says Lowe. "Even as you move out into Q4, we should see the margins flattish, maybe even moving up from 36%, he adds. "The key to our gross margin transition for the mid-30s to 50% in 2024 is largely based on three elements, including optimizing Durham, transitioning from 150mm to 200mm wafers, and driving revenue through Mohawk Valley," says Reynolds. "We are on track with all three elements and anticipate modest continued improvement in gross margin over time."

Operating expenses are expected to rise to $88–89m for fiscal Q3. "We anticipate operating expenses will continue to slowly increase over time as we continue to invest in R&D and sales & marketing resources, but expect that it will become a smaller percentage of revenue as we enter the middle of the decade," says Reynolds. "We are also continuing to identify areas across the business to reduce costs and improve productivity, as we scale our global operations to better support

our customers. For example, we will be opening a global capability center in Belfast, Northern Ireland, in partnership with the Northern Ireland government. This facility will operate as a shared services hub for Wolfspeed's IT organization, helping drive critical IT innovation and expansion of global digital capabilities."

Net loss is targeted to be $15–20m ($0.12–0.16 per diluted share) in fiscal Q3.

"We expect a total of $80m of start-up costs in fiscal 2022, with the majority of these costs incurred in the second half of the fiscal year as we qualify and ramp the Mohawk Valley fab," says Reynolds.

"We are continuing to experience a much steeper demand curve from our customers for SiC products than we had initially anticipated," says Reynolds. "This has led to supply constraints where some customer orders [more than $100m worth] will not be fulfilled this fiscal year and channel inventory levels will remain low until we ramp production in our Mohawk Valley fab. We are confident that we will be able to meet this demand once Mohawk Valley is up and running. But in the meantime, we continue to accelerate CapEx capacity investments and improve output in our Durham facilities," he adds.

"We are anticipating net capital expenditures of about $475m this year, stepping down in the back half of 2022, as we receive more reimbursements [of the pending $500m, from the state of New York] for the Mohawk Valley construction. At Mohawk Valley, we have more than 60 tools in place, are currently testing equipment, and we expect to begin running wafers later this quarter," says Reynolds. "We'll start the qualification in this quarter, and then we'll quickly transition from internal to customer qualifications shortly after that," he adds. "We don't expect to realize any meaningful revenue from the facility until the second half of fiscal 2023."

"We have invested heavily not only in our products but in expanding our capacity and the talent needed to run it," says Lowe. "The expected return on these investments is compelling and we will continue to invest in both capacity and talent to ensure we meet the steepening demand from our customers."

www.wolfspeed.com

Wolfspeed prices private offering of $650m of convertible senior notes

Offering upsized from previously announced $500m

Wolfspeed has priced $650m of its 0.25% convertible senior notes due 2028 in a private offering to qualified institutional buyers. The offering size was increased from the previously announced $500m.

In addition, Wolfspeed granted the initial purchasers of the notes an option to purchase up to an additional $100m of notes (again, upsized from the previously announced $75m).

The sale of the notes to the initial purchasers was expected to settle on 3 February, yielding $634.6m in net proceeds (or $732.3m, including the additional notes) after deducting the initial purchasers' discount and estimated offering expenses payable by Wolfspeed.

The notes are unsecured, senior obligations of Wolfspeed, bearing interest at a rate of 0.25% per year, payable semi-annually in arrears on 15 February and 15 August each year, beginning on 15 August 2022. The notes mature on 15 February 2028, unless earlier repurchased, redeemed or converted.

Wolfspeed intends to use about $93.7m of the net proceeds to fund the cost of entering into capped call transactions. The firm intends to use the remainder for general corporate purposes. If the initial purchasers exercise their option to purchase additional notes, then Wolfspeed intends to use a portion of those proceeds to fund the cost of entering into additional capped call transactions.

The initial conversion rate for the notes is 7.8602 shares of Wolfspeed's common stock per $1000 of notes (equivalent to an initial conversion price of about $127.22 per share of Wolfspeed's common stock). Conversions of the notes will be settled in cash, shares of Wolfspeed's common stock or a combination thereof, at Wolfspeed's election. The initial conversion price represents a conversion premium of about 35% over the last reported sale price of $94.24 per share of Wolfspeed's common stock on the New York Stock Exchange on 31 January.

In connection with the pricing of the notes, Wolfspeed entered into privately negotiated capped call transactions with one or more of the initial purchasers of the notes or their affiliates. The capped call transactions cover (subject to anti-dilution adjustments substantially similar to those applicable to the notes) the number of shares of Wolfspeed's common stock that will initially underlie the notes. If the initial purchasers exercise their option to purchase additional notes, Wolfspeed expects to enter into additional capped call transactions with the option counterparties.

The cap price of the capped call transactions will initially be $212.04 per share, which represents a premium of 125% over the last reported sale price of $94.24 per share of Wolfspeed's common stock on the New York Stock Exchange on 31 January, and is subject to certain adjustments under the terms of the capped call transactions.

Wolfspeed's chief technology officer John Palmour elected to US National Academy of Engineering

Wolfspeed Inc (formerly Cree 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 — says that the US National Academy of Engineering has elected its co-founder & chief technology officer Dr John Palmour into its 2022 class for the development of SiC-based advanced electronic devices.

Membership in the National Academy of Engineering honors those who have made outstanding contributions to engineering research and practice, including pioneering of new and developing fields of technology and making major advancements in engineering.

This year, 111 new members and 22 international members were elected. Their formal induction will take place on 2 October at the National Academy of Engineering's Annual Meeting.

CTO John Palmour.

Palmour was one of the graduate students from North Carolina State University who founded the company (then Cree) in 1987. Now, over 30 years later, the business has grown into the pure-play power semiconductor firm Wolfspeed, focused on the industry transition from silicon to silicon carbide.

"His passion and expertise with this transformational technology has led our team to groundbreaking innovation over the years and today is enabling us to help our customers reach new levels of energy efficiency," comments CEO Gregg Lowe.

Silicon carbide is currently utilized in technologies from electric vehicles (EVs) to gaming systems to industrial motors, renewable energy and energy storage. Palmour has championed and innovated silicon carbide for power and GaN-on-SiC for RF for over 30 years, enabling faster, more energy-efficient technologies that are said to be foundational for many industries as they prepare and adapt for a more sustainable future.

Palmour has authored a total of 386 scientific publications and holds 81 US patents in the areas of processing and device designs for silicon carbide and gallium nitride electronic devices.

www.nae.edu
www.wolfspeed.com

GaN power IC firm Navitas doubles revenue in 2021

Expenses and losses rise, but revenue expected to double again in 2022

For fourth-quarter 2021, the gallium nitride (GaN) power integrated circuit firm Navitas Semiconductor Corp of El Segundo, CA, USA and Dublin, Ireland has reported revenue of $7.3m, up 30% on $5.6m last quarter and 55% on $4.7m a year ago. Full-year revenue doubled from $11.8m in 2020 to $23.7m in 2021.

Founded in 2014, Navitas introduced what it claimed to be the first commercial GaN power integrated circuits. Its proprietary GaNFast power ICs monolithically integrate GaN power field-effect transistors (FETs) and GaN drive plus control and protection circuits in a single SMT package to enable faster charging, higher power density and greater energy savings for mobile, consumer, enterprise, eMobility and new energy markets.

"2021 was a pivotal year for Navitas as we doubled revenue and became a public company," says co-founder & CEO Gene Sheridan. "We have strengthened our leadership position in the mobile market, with all of the top mobile players shipping or developing their next-generation chargers with Navitas," he adds.

In mobile fast chargers, the number of customer designs released to production increased by 75% to over 170 by the end of 2021, with an increase of over 100% in the number of customer designs in development, now at over 240 projects. Tier-1 'in-box' wins have doubled, which include Dell, Lenovo, Xiaomi, Vivo, Motorola and LG among others. At year end, over 35 million GaN ICs had shipped with zero reported GaN field failures.

GaNFast power ICs with new GaNSense technology are in production with Lenovo, Xiaomi and Vivo, and Navitas now has 145 patents issued or pending.

On a non-GAAP basis, gross margin was 44.3% in Q4/2021, up on 37.7% a year earlier. Full-year gross margin rose from 33.2% to 45.4%.

However, operating expenses have risen from $8.1m a year ago to $10.1m, and full-year operating expenses from $21.6m in 2020 to $35.3m for 2021.

Quarterly net loss has risen further, from $6.37m ($0.39 per share) a year ago to $6.95m ($0.07 per share). The full-year net loss has hence risen from $17.8m ($1.10 per share) in 2020 to $24.8m ($0.63 per share) in 2021.

"Our expansion plans into data-center, solar and EV are well underway with sampling of our high-power GaN ICs and the opening of our new design centers dedicated to data-centers and EV applications," says Sheridan.

Navitas expects revenue to fall back slightly to $6–7m in first-quarter 2022, but full-year 2022 revenue should still double to about $48m. Gross margin should be 44% for both the quarter and the full year. Operating expenses are expected to be rise to $13m for Q1 and $58m for full-year 2022 (which includes a full year of expenses associated with being a public company).

www.navitassemi.com

Navitas GaN ICs to be highlighted at APEC

GaN advances beyond mobile fast chargers to data center, solar & EV

At the Applied Power Electronics Conference (APEC 2022) in Houston, TX, USA (20–24 March), gallium nitride (GaN) power integrated circuit firm Navitas Semiconductor of El Segundo, CA, USA and Dublin, Ireland will highlight technology for mobile fast chargers, plus expansion into higher-power markets including data-center, solar and electric vehicles (EVs).

GaN runs up to 20x faster than silicon and enables up to 3x more power, 40% energy savings and 3x faster charging in half the size and weight, says Navitas. GaNFast power ICs integrate GaN power and drive plus protection and control circuitry to deliver simple, small, fast and efficient performance. Over 145 Navitas patents are issued or pending, and over 35 million GaNFast power ICs have shipped with zero reported field failures since the firm was founded in 2014.

In exhibition booth #1616, Navitas features the latest GaNFast power IC technology, including the CES Innovation Award-winning GaNSense technology. Mobile fast and ultra-fast chargers from Dell, Lenovo, Xiaomi, LG, vivo and many others will be displayed from the more than 160 in production today, plus new names to be revealed. Beyond chargers, new hardware will show advances in higher-power applications such as high-efficiency data-center power and fast-charging EVs. Next-generation prototype hardware and roadmap technology will be shared with customer partners under NDA in an adjacent private suite (Marriot Marquis).

Throughout the event visitors can experience ultra-fast charging at the GaNFast Giveaway, with a chance to win GaNFast chargers from sponsors Spigen, Baseus, UGREEN, Angry Miao and UIBI, and enter the Navitas 2022 competition to win a Tesla Model 3 Performance, worth over $60,000.

Navitas presentations during APEC 2022 are as follows:

22 March

1:45pm, Exhibitor Seminar, room 361 DEF: 'GaNFast Power ICs: Electrify Our World' — Dan Kinzer, Navitas COO/CTO & co-founder.

23 March

9:45am, IS06.4: 'GaN Adoption, Market-by-Market' — Stephen Oliver, VP corporate marketing & investor relations;

4:45pm, IS13.6: 'Advancement on GaN Power IC System Integration' — Victor Sinow, senior principal design engineer, and Marco Giandalia, VP IC design;

4:45pm, IS14.6: 'GaN Half-Bridge ICs Enable Next Gen Mid-Power, Multi-Port, High-Density Charger Topologies' — Tom Ribarich, senior director strategic marketing.

24 March

1:45pm, IS21.x: 'SiC and GaN Product and Technology reliability, Robustness and Qualification' — session co-chair Anthony Schiro, VP quality & sustainability.

www.navitassemi.com

Consumer electronics & accessory specialist UGREEN announces GaNFast Global Marketing Program

Navitas has announced a GaNFast Global Marketing Program with consumer electronics and accessory specialist UGREEN. The program builds on the companies' technology partnership to create awareness of GaN and education for global consumers. In-person and on-line events emphasize the capability of GaN technology to set all-new standards in fast charging, with miniaturized form factors, and significant sustainability benefits to reduce energy consumption and carbon emissions.

UGREEN invited Navitas to participate in the live broadcast launch of the new 100W four-port GaN charger, during which Navitas' Dr Xiucheng Haung provided insight into the benefits of GaN, its impact on charger performance and relevance to the consumer industry.

Additional cooperation to increase global consumer awareness of GaN and associated charger products includes enhanced product promotion via the companies' official websites, social media channels, conference/trade show booths including the Consumer Electronics Show (CES 2022), and video displays on the Nasdaq building in Times Square, New York.

"We have already established a highly successful relationship with UGREEN at the product technology level," says Charles Zha, VP & general manager of Navitas China. "This new program builds on that success and takes it to a new level by strengthening the depth of cooperative marketing. Together, we will offer more in-depth knowledge for the market and consumers and also strengthen the link between the power semiconductor industry and the 3C digital product industry."

"This partnership is a natural next step for our two companies to raise awareness about GaN technology. UGREEN, as a world-renowned 3C digital manufacturer, always has a keen sense for innovative technologies and is willing to invest time in developing them," says Evan Li, VP at UGREEN. "This collaboration will turn UGREEN's products into game-changers that benefit users around the world and contribute to carbon-neutral initiatives."

www.ugreen.com

GaN Systems expands Taiwan-based Asia operation by 3x

New office campus in Hsinchu driven by three-fold revenue growth

GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) has expanded its Asia presence with a 3x increase in its operation in Taiwan. Due to a 3x growth in revenue from consumer electronics, electric vehicles (EVs), and data-center and industrial power supply producers embracing GaN Systems' power transistors, more people and space were necessary, says the firm.

The new office campus is in Hsinchu Science Park, which is also headquarters to GaN Systems' foundry partner Taiwan Semiconductor Manufacturing Company (TSMC), the world's largest dedicated independent (pure-play) semiconductor foundry.

GaN System's Asia headquarters, which opened with a few employees in 2015, has grown by more than 10x and will exceed 100 staff in the coming year. The space features a research and design center with dedicated subject matter experts in the design and system validation of solutions for customers in several markets, including mobile phones, laptop PCs, data-center power supplies, and automotive EV powertrain electronics. The enlarged R&D team will expand GaN Systems' line-up of high-performance transistors and high-power modules and build on its extensive range of reference designs for 65W, 100W and 250W phone and computer chargers, PFC, DC–DC, and inverter designs for higher-power markets.

"GaN Systems has grown tremendously, driven by the rapid adoption of GaN in consumer, industrial and automotive electronics," says Stephen Coates, VP, global operations & general manager, Asia. "Our campus in Taiwan scales up our manufacturing, product and module design, and innovation footprint, and expands support for our global customers and business partners. This 3x expansion demonstrates our commitment to Asia and to supporting the continued growth of Taiwan's semiconductor ecosystem."

Acceleration of the growth in Asia continues with the addition of Andy Chuang, GaN Systems' VP of business development. Based in the new Taiwan office, Chuang has decades of wide-bandgap experience. Incremental to the expansion in Taiwan, GaN Systems says that its presence in Asia is also growing with success in India in e-mobility, with applications in the two-, three- and four-wheeler EV segments.

GaN Systems' says that growth in the Asia region and internationally are affirmation of its US$150m growth capital funding round (announced in mid-November) to accelerate innovation and adoption of GaN technology across its automotive, consumer, industrial and enterprise markets (with global companies such as Dell, HARMAN, Siemens, Signify and Philips already relying on its transistors).

www.gansystems.com

Greenworks chooses GaN Systems for charging station

GaN power transistors featured in 24V Cordless Stick Vacuum super charging station

GaN Systems says that its power transistors are featured in the 24V Cordless Stick Vacuum super charging station of Greenworks, a provider of battery-operated power equipment that aims to make sustainable, eco-friendly products designed to deliver high performance with the lowest environmental impact.

The collaboration is said to underscore the trend towards USB charging becoming the ubiquitous solution for charging consumer, household and industrial products. Greenworks says that incorporating a multi-port USB charger into its charging station improves the convenience of charging everyday products and helps to reduce the need for additional chargers.

GaN Systems says that it is delivers the fast charging and small form factors needed for Greenworks' charging station. Specifically, the super charging station offers fast-charging of multiple devices in a single charge location:

- It charges up to six items simultaneously, including the onboard 24V battery, a second 24V auxiliary battery, and four portable electronic devices.
- It features three USB-C charging ports and one USB-A charging port. The 24,000mAh USB-C power bank is detachable and can charge three portable electronic devices at once, including computers, phones and tablets.
- It allows users to quickly recharge in 30 minutes or less.

GaN Systems says that its transistors and reference designs meet consumer and industrial market charger requirements. GaN chargers are reckoned to be up to 4x smaller than conventional chargers and meet the fast-charging needs of today's devices. "GaN is becoming the universal choice for chargers and adapters beyond smartphone and computing products," says CEO Jim Witham. "It's great to see USB charging expand into more and more adjacent markets."

semiconductorTODAY

COMPOUNDS & ADVANCED SILICON

www.semiconductor-today.com

Join our LinkedIn group: Semiconductor Today

Follow us on Twitter: Semiconductor_T

Choose *Semiconductor Today* for . . .

MAGAZINE

Accurate and timely coverage of the compound semiconductor and advanced silicon industries

Targeted 82,000+ international circulation

Published 10 times a year and delivered by e-mail and RSS feeds

WEB SITE

Average of over 26,000 unique visitors to the site each month

Daily news updates and regular feature articles

Google-listed news source

E-BRIEF

Weekly round-up of key business and technical news

E-mail delivery to entire circulation

Banner and text marketing opportunities available

EPC releases Phase 14 report on GaN reliability

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA — which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) and integrated circuits for power management applications — has announced its Phase-14 Reliability Report, documenting the strategy used to achieve a its field reliability record. The rapid adoption of GaN devices in many diverse applications calls for the continued accumulation of reliability statistics and research into the fundamental physics of failure in GaN devices, the firm says. The Phase-14 Reliability Report presents the strategy used to measure and predict lifetime based on tests that force devices to fail under a variety of conditions. This information can be used to create stronger and higher-performance products for applications such as light detection & ranging (LiDAR) for autonomous cars, robotics, security and drones, high-power-density computing, and satellites.

The report presents the results of testing eGaN devices to the point of failure, providing the information to identify intrinsic failure mechanisms of the devices. By identifying these, deep knowledge of the behavior of a device over time, temperature, electrical or mechanical stress can be developed and used to create physics-based models that accurately project the safe operating life of a product over a more general set of operating conditions.

The report is divided into eight sections, each dealing with a different failure mechanism:
Section 1: Intrinsic failure mechanisms impacting the gate electrode of eGaN devices;
Section 2: Intrinsic mechanisms underlying dynamic $R_{DS(on)}$;
Section 3: Applying the physics-based model to common real-world use cases;
Section 4: Safe operating area (SOA);
Section 5: Testing devices to destruction under short-circuit conditions;
Section 6: Custom test to assess reliability over long-term LiDAR pulse stress conditions;
Section 7: Mechanical force stress testing;
Section 8: Thermo-mechanical stress.

"The release of EPC's Phase-14 Reliability Report represents the cumulative experience of millions of devices and five generations of technology to lead to a deeper understanding of the behavior of GaN devices over a wide range of stress conditions," notes CEO & co-founder Dr Alex Lidow.

www.epc-co.com

Digi-Key to distribute EPC Space's rad-hard GaN power devices for high-rel and aerospace applications

EPC Space LLC of Haverhill, MA, USA says that Digi-Key Electronics will be a global distributor for its line of radiation-hardened (rad-hard) gallium nitride-on-silicon (GaN-on-Si) transistors and ICs, packaged, tested and qualified for satellite and high-reliability applications.

Spanning a range of 40V to 300V, EPC Space offers a family of rad-hard enhancement-mode power transistors that are said to demonstrate significant performance advantages over competing silicon-based rad-hard power MOSFETs. The firm says that its technology produces GaN devices that are smaller, have lower resistance, and have many times superior switching performance compared with silicon.

Digi-Key will also distribute EPC Space's family of rad-hard enhancement-mode GaN drivers and power stages. Rad-hard GaN drivers are optimized to drive rad-hard GaN transistors in critical space-borne systems. Rad-hard power stages integrate a high-speed gate drive circuit with power switches to provide a monolithic complete power stage in a tiny footprint for smaller, lower-weight systems.

The drivers and power stages product line includes ultra-fast, low-side eGaN drivers, ultra-fast, dual low-side eGaN drivers, and half-bridge drivers with integrated eGaN power switches.

Critical space-borne applications that benefit from the performance improvements that the devices offer include power supplies for satellites and mission equipment, light detection and ranging (LiDAR) for robotics and autonomous navigation and rendezvous docking, motor drives for robotics and instrumentation, and ion thrusters for satellite orientation and positioning as well as interplanetary propulsion of low-mass robotic vehicles.

"The addition of EPC Space's rad-hard GaN-based power management products completes the entire EPC's product portfolio through Digi-Key and brings intriguing next-generation breakthrough benefits to existing silicon-based solutions," comments David Stein, VP of global supplier management for Digi-Key.

"Digi-Key has the fastest global logistics and the most efficient supply chain to service customers from early engineering through volume production," comments EPC Space's CEO Bel Lazar. "Digi-Key's world-class distribution capabilities will translate into fast and easy service to our global customers who want to access the entire line of EPC's GaN power device products to replace their less-efficient, more costly silicon solutions."

www.digikey.com
www.epc.space

Wise-integration agrees Asian channel partnership with distributor EDOM involving design collaboration

Wise-integration of Meylan, France, aims to expand business in Asian markets for its gallium nitride (GaN) power semiconductors after announcing a new channel partnership with distributor and solutions provider EDOM Technology of Taipei, Taiwan.

The strategic partnership will leverage Wise-integration's GaN power transistor and digital control capabilities, as well as EDOM's distribution network for semiconductor components and customer-support capability throughout Asia.

Customers should benefit from greater access to GaN products and resources globally, especially in Asia (one of the fastest-growing markets for GaN technology).

In addition, Wise-integration and EDOM will collaborate on GaN design using Wise-integration's WiseGan portfolio of components and WiseWare digital control AC–DC system architecture software. This should provide customers with more benefits, including reduced bill of materials (BOM), easier, faster-design-in, and higher performance due to digital control.

"Optimistic about the next-generation materials' market potential of wide-bandgap semiconductors as well as the small-size, high-efficiency GaN technology that Wise-integration provides, we are glad to have Wise-integration as EDOM's new partner on expanding our power solutions, and we will bring more options and advanced solutions to our clients," comments EDOM's chairman Wayne Tseng.

"By combining our GaN expertise with EDOM's capabilities, I am confident that we will be able to grow our business and help customers realize more benefits from GaN in their power supply applications," says Wise-integration's CEO Thierry Bouchet.

www.wise-integration.com
www.edomtech.com

EPC launches 2kW, two-phase, regulated-output-voltage 48V/14V bidirectional converter

Collaboration with MPS yields DC–DC reference design

EPC has announced the availability of the EPC9165, a 2kW, two-phase 48V–14V bidirectional converter that operates with 97% peak efficiency in a small footprint, suitable for high-density and high-power 48V battery packs such as those required for eMobility and light mobility.

The solution is scalable; two converters can be paralleled for 4kW, three converters for 6kW or only one phase can be used for 1kW. In this application, the output voltage is 14V; however, since the topology is a hard-switching buck converter, the output voltage can be easily adjusted for voltages between 12V and 36V.

The EPC9165 reference design features the EPC2302 GaN FET, which uses EPC's latest-generation 100V GaN technology. The EPC2302 delivers 101A continuous current and 390A pulsed current. The thermally enhanced QFN package with an exposed top improves the thermal dissipation to the heatsink. It delivers 0.2ºC/W thermal resistance to the heatsink, and wettable flanks simplify assembly inspection and improve robustness for thermal cycles. The EPC2302 GaN FET offers a small typical $R_{DS(on)}$, of just 1.4mΩ typical and 1.8mΩ maximum, together with very small Q_G of 23nC typical, Q_{GD} of 2.3nC typical, Q_{OSS} of 85nC typical, and zero Q_{RR} for low conduction and switching losses.

The EPC9165 reference design features the new MPS MPQ1918 100V automotive half-bridge driver developed specifically for use with GaN FETs. The MPQ1918 is available in a small 3mm x 3mm FCQFN package with wettable flanks to enable optical inspection. The device has a peak source current of 1.6A with a 0.2Ω/1.2Ω pull-down/pull-up resistance to enable usage of high-power FETs with faster switching edges to maximize efficiency and increase power density. Compared with other automotive half-bridge GaN drivers, the device provides higher efficiency, improves EMI, and is very cost effective.

"GaN FETs and ICs provide the fast switching, small size and high efficiency needed to further reduce the size and weight of 48V to 12V/14V converters," says EPC's CEO Alex Lidow. "By utilizing the MPS 100V automotive gate driver and EPC's first packaged device, the EPC2302, the EPC9165 reference design showcases a solution that increases efficiency, increases power density, and simplifies design; in space- and weight-critical designs like eMobility," he adds.

"The new MPS MPQ1918 is designed to fully utilize the high performance of GaN FETs to maximize efficiency and power density for high-power solutions," comments Maurice Sciammas, VP of sales & marketing at MPS. "As EPC is one of the key players providing power eGaN FETs, we are glad to collaborate to bring this solution to market to improve efficiency and reduce solution size in bidirectional converters."

www.epc-co.com

Transphorm's quarterly revenue up 129% year-on-year

Eighth quarter of growth driven by power adapters and fast chargers

For its fiscal third-quarter 2022 (ended 31 December 2021), Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and manufactures JEDEC- and AEC-Q101-qualified gallium nitride (GaN) field-effect transistors (FETs) for high-voltage power conversion applications — has reported revenue of $4.6m, up 129% on $2m a year ago.

This is down from $11.3m last quarter, but that included $8m of licensing revenue related to a development project with a manufacturing partner.

Excluding this licensing revenue, revenue rose by 39% from $3.3m last quarter, reflecting record product sales of $3.6m (up sequentially for an eighth consecutive quarter, and up 220% year-on-year). The growth in product sales is due to ramping shipments of GaN devices for a broad range of power conversion applications (including shipping more than 1 million SuperGaN Gen IV FETs for 45-300W power adapter and fast-charger applications in December).

"As overall demand for GaN solutions is accelerating, our sales pipeline continues to expand rapidly, driven by our products' unique, easy-to-interface GaN architecture, our world-leading GaN portfolio with a broad range of power capabilities (45W–5kW already powering our customers' systems today, scalable to 100kW plus in the future), and our products' established real-world performance and reliability," says president & co-founder Primit Parikh.

Highlights during the quarter included increasing total design-ins for power adapters and fast chargers to over 50 (with over 20 in production) and total design-ins for higher power (300W–4kW) to over 30 (with over 20 in production).

"Our emphasis going forward is to capitalize on this momentum, grow our ecosystem of solution partners, and expand our manufacturing capacity, with a strong focus on providing a total supply chain solution to customers," says Parikh.

On a non-GAAP basis, operating expenses were $4.4m, roughly level with $4.45m last quarter but up 20% on $3.7m a year ago, due primarily to an expansion in the sales and applications team to support increased revenue together with one-off compliance costs tied to a year of change.

Net loss was $4.3m ($0.09 per share), compared with net income of $3.6m ($0.09 per share) last quarter but a cut in net loss from $4.7m ($0.13 per share) a year ago.

In December, Transphorm closed a $12.9m non-brokered private placement of common stock at $7.71 per share, bringing the total amount of equity financings closed during the quarter to more than $45m. Cash and equivalents were hence boosted from $2.5m to $41m.

"Over the past two quarters we have completed multiple equity financings from a combination of strategic and institutional investors, resulting in a significant increase in both the company's cash position and stockholders' equity at quarter end," notes chief financial officer Cameron McAulay. "This additional capital provides expanded operational flexibility in support of our future anticipated growth, and we believe the company's strengthened balance sheet satisfies all of the financial qualification requirements for uplisting to the NASDAQ. As such, we expect and look forward to providing a definitive update on this important milestone in the near future," he adds.

Transphorm uplists from OTCQX to Nasdaq Capital Market

Transphorm's common stock has been approved for listing on the Nasdaq Capital Market. Trading on Nasdaq was due to commence at the market open on 22 February, with shares continuing to trade with the ticker symbol 'TGAN' after previously trading on the OTCQX.

"Our uplisting to Nasdaq is a significant milestone for Transphorm and is a testament to the dedication and hard work of the Transphorm team, as well as our strong cooperation with our valued customers and partners," says president & co-founder Primit Parikh. "This uplisting should raise the visibility of Transphorm in the capital markets and allow for increased sponsorship from worldwide institutional investors as well as increased liquidity in the trading volume of our stock," he believes.

"This achievement and recognition represents a key benchmark for both GaN and Transphorm," says chief technology officer & co-founder Umesh Mishra. "With our world-leading innovations in GaN and robust IP portfolio of more than 1000 patents, we are proud to be a world leader in GaN power conversion, which is the next large market for GaN since GaN LEDs and GaN RF transistors."

Transphorm claims its patented GaN platform differs from competing solutions in ways that are crucial to power conversion application performance requirements — from 45W fast chargers/power adapters to 4kW gaming, data-center server, crypto mining, and industrial power supplies to renewable energy to higher-power automotive converter and inverter applications through multi tens of kilowatt. The firm also claims to be one of the few high-voltage GaN manufacturers that is vertically integrated, controlling its GaN FET designs through innovation, epitaxial wafer and manufacturing processes.

www.transphormusa.com

NexGen appoints chief systems officer to lead Global Systems Engineering group

Bangalore-based former Western Digital SVP product development to aid commercialization of Vertical GaN

NexGen Power Systems Inc of Santa Clara, CA, USA (which was founded in 2017), a designer and manufacturer of proprietary power electronics and conversion systems using patented Vertical GaN (gallium nitride) technologies, have appointed 30+ year industry veteran Ganesh Guruswamy as chief systems officer.

Guruswamy will oversee NexGen's Global Systems Engineering group, with established engineering facilities in Santa Clara, CA, and Syracuse, NY, and a Center of R&D Excellence in Bangalore, India. The Bangalore R&D Center brings together experts in power electronics, mechanical design, software, testing and board layout.

Guruswamy joins NexGen from Western Digital, where he served for six years as senior VP for product development. He has more than 30 years of senior semiconductor engineering experience, with earlier roles at both AMD and Freescale.

Ganesh Guruswamy.

Guruswamy expects to accelerate NexGen's already fast growth in Bangalore, where he previously helped to expand Western Digital's significant engineering presence.

"Ganesh's extensive experience in leading engineering teams, and a proven track record of scaling and driving technology excellence, especially in India, makes him an ideal fit as chief system officer," comments NexGen's co-founder & co-CEO Dinesh Ramanathan. "We look forward to working together to scale NexGen Systems worldwide, as we move closer toward commercial availability of our revolutionary Vertical GaN products," he adds.

"NexGen Power Systems is enabling the future of power electronics by building a complete state-of-the-art system leveraging patented Vertical GaN technologies," says Guruswamy. "The NexGen R&D team in Bangalore has helped to develop the world's most efficient power systems, switching at 1+MHz, and making the systems 60% smaller and 50% lighter than comparable electronics," he adds. "This is only the beginning as we introduce game-changing innovation across multiple consumer and industrial applications."

www.nexgenpowersystems.com

MIT gains $4.5m from ARPA-E's OPEN 2021 program

Project to develop vertical GaN super-junction devices on 8" silicon

The US Department of Energy (DOE) has announced $175m for 68 R&D projects aimed at developing novel advanced energy technologies.

Led by DOE's Advanced Research Projects Agency-Energy (ARPA-E), the OPEN 2021 program prioritizes funding high-impact, high-risk technologies that support novel approaches. The selected projects — spanning 22 states and coordinated at universities, national laboratories, and private firms — will advance technologies for a wide range of areas including electric vehicles, offshore wind, storage and nuclear recycling.

Ranging from technologies such as revolutionizing fuel cells for light- and heavy-duty vehicles to generating less nuclear waste and reducing the cost of fuel, the OPEN 2021 projects include $4,521,601 for '8" GaN-on-Si Super Junction Devices for Next Generation Power Electronics' in which Massachusetts Institute of Technology (MIT) will develop a new generation of power electronics based on vertical gallium nitride super-junction diodes and transistors that can vastly exceed the performance of existing GaN power devices.

The new super-junction structure will surpass the theoretical trade-off between on-resistance and breakdown voltage observed in conventional unipolar GaN, leading to more efficient and cheaper power converters. These new GaN power devices should enable the next generation of low-cost, fast, small and reliable power electronics, which are key for efficient power conversion in data centers, solar farms, power grids and electric vehicles (EVs).

Among the first of billions of dollars for R&D opportunities that DOE announced last year to address the climate crisis, OPEN 2021 is ARPA-E's latest installment of the OPEN program. The first four iterations — 2009, 2012, 2015 and 2018 — awarded more than $600m in funding to 225 projects working to achieve breakthroughs in commercializing a variety of energy solutions, including in the development of transformative solar, geothermal, batteries, biofuels and advanced surface-coating technologies.

Since its founding in 2009, ARPA-E has provided $2.93bn in R&D funding, and ARPA-E projects have attracted more than $7.6bn in private-sector follow-on funding to commercialize clean energy technologies.

www.arpa-e.energy.gov
www.mit.edu

China's Innoscience launches international operations in USA and Europe

8-inch GaN-on-Si FET producer adds design and sales support in Santa Clara, CA, and Leuven, Belgium

Innoscience Technology of Suzhou, China, which makes 8-inch gallium nitride on silicon (GaN-on-Si) wafers for power switching applications, has officially launched its international operations in the USA and Europe, enabling it to support customers through the addition of design and sales support facilities in Santa Clara in California and Leuven in Belgium.

Founded in December 2015, Innoscience first established a mass-production 8-inch wafer line for GaN-on-Si devices in Zhuhai National Hi-Tech District in November 2017, then inaugurated a new facility in Suzhou in September 2020. With 1400+ staff and over 300 R&D specialists, the firm now claims to be the largest integrated device manufacturer (IDM) fully focused on GaN technology, with two wafer fabs including what is claimed to be the world's largest dedicated 8-inch GaN-on-Si site.

Currently, Innoscience has a capacity of 10,000 8-inch wafers per month, which will ramp up to 14,000 8-inch wafers per month later this year and 70,000 8-inch wafers per month by 2025. The company has a wide portfolio of devices with voltages ranging from 30V to 650V and has shipped more than 35 million parts for use in applications including USB PD chargers/adapters, data centers, mobile phones and LED drivers.

Innoscience produces normally-off e-mode GaN field-effect transistors (FETs). The company says that, by introducing a stress-enhancement layer, it has significantly reduced $R_{DS(on)}$ without affecting other parameters, including threshold voltage and leakage. Both epitaxy as well as device processing have been optimized to achieve high reproducibility and yield. The devices have passed quality and reliability tests in excess of JEDEC standards.

"We will surpass anyone on price for an equivalent device, and our huge manufacturing capacity means that our customers are assured of security of supply, which is often uppermost in people's minds given the shortage of chips at the moment," says Dr Denis Marcon, general manager, Innoscience Europe. "We look forward to working with any company in order to proliferate GaN throughout the global electronics industry," he adds.

"Customers can benefit from Innoscience's applications understanding and demo boards to develop their unique solutions," notes Yi Sun, general manager, Innoscience USA. "This will allow us to better support our customers in the USA, and in particular the Bay area."

It is expected that both new Innoscience offices will expand rapidly in the coming months and years, in order to strategically support the burgeoning market for GaN-on-Si power solutions in Europe and the USA.

www.innoscience.com

Cambridge GaN Devices launches project to develop reliable GaN power ICs for data centers

ICeData aims to boost efficiency of server power supplies beyond 98%

Fabless semiconductor company 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 to develop power semiconductors using gallium nitride (GaN)-on-silicon substrates — has launched ICeData, a project aiming to develop and commercialize a highly efficient GaN-based integrated circuit for use in data-center server power supplies.

The primary goal of the ICeData project is to deliver GaN power IC technology to boost the efficiency of data-center server power supplies to more than 98%. Specifically tailored for switched-mode power supplies (SMPS) for data centers and telecommunication servers, ICeData should contribute to the saving of more than 8 megatons (million metric-tons) of CO_2 emissions annually in 2030.

Data centers currently account for about 2% of the world's energy use, with an annual electricity consumption rate of 400TWh in 2018 set to double by the end of the decade. In power electronics applications (such as power supplies for consumer electronics and servers for data centers), GaN has the potential to massively reduce the energy wasted due to its structural and conductive properties.

The combination of higher efficiency and higher power density can also achieve significant savings on the capital expenditure (CapEx) and operating expenditure (OpEx) of data centers, potentially reducing investment and running costs by up to 10%, it is reckoned. Featuring the proprietary ICeGaN gate technology developed by CGD (which enables simple driving of the GaN transistor without using a specialized GaN driver), the ICeData product will be a market first, it is claimed.

It will also have smart features for sensing and protection to enhance reliability, without the need for extra components. The on-chip sensing and protection circuits can react in nanoseconds to over-current and over-temperature events, protecting the device and ultimately protecting the power system.

By the project's end, CGD should have a qualified and production-ready set of GaN power IC solutions. The overall GaN market is forecasted to grow from a few million dollars currently to more than $1.1bn by 2026, driven by demand for lighter and more efficient power supplies and more compact and powerful on-board chargers for electric vehicles (EV) and hybrid electric vehicles (HEVs). CGD's first product line featuring ICeGaN technology will be released in first-half 2022.

"Exponential growth in demand for data storage and processing, accelerated by the Covid-19 pandemic where cloud-based connectivity became an essential tool for businesses around the world, is resulting in huge increases in data-center energy usage. This is a serious concern when 2% of the world's energy usage is already consumed by data centers and this is only set to rise," comments CEO & founder Dr Giorgia Longobardi. "Cambridge GaN Device's ICeData project addresses solutions that are lighter, more compact, significantly more efficient and potentially cheaper than those based on silicon. Developing green technologies that deliver real reductions in CO_2 emissions and create greater energy efficiency is vital if we are to meet low-carbon targets on the path to net zero," she adds.

"The ICeData project is a great opportunity to complement CGD's efforts towards energy efficiency and to boost the development of highly reliable, extremely easy-to-use GaN-based solutions for key markets such as servers, telecommunications and other high-power segments," says Andrea Bricconi, VP of business development. "Innovation relies on developing great GaN material, design and on outstanding packaging solutions: ICeData is a strategic initiative that will enhance CGD's portfolio even further, always targeting sustainability and reducing our impact on the environment."

www.camgandevices.com

IVWorks acquires Saint-Gobain's GaN wafer business

IVWorks Co Ltd of Daejeon, South Korea – which was founded in 2011 and manufactures 100–200mm gallium nitride (GaN) epitaxial wafers for RF & power electronics applications — has acquired the GaN wafer business of France-based materials maker Saint-Gobain, which designs, manufactures and distributes materials and services for the construction and industrial markets.

GaN epiwafers are used in manufacturing power devices for high-speed chargers, electric vehicle (EV) power conversion, and defense radars. Silicon carbide (SiC) or silicon substrates are used to stack III–N films depending on the application field, but GaN wafers are required for high-power devices such as EV powertrains, says IVWorks.

The firm comments that Saint-Gobain in France and some Japanese material companies (such as Sumitomo and Mitsubishi) are leading in GaN wafer production technology. With the acquisition of the GaN wafer business from Saint-Gobain, IVWorks reckons that it has acquired state-of-the-art technology for the mass production of 4-inch and 6-inch diameter GaN wafers.

IVWorks' GaN epiwafer.

IVWorks says it is the sole South Korean enterprise specializing in semiconductor materials that has mass-produced GaN epiwafers of 4-, 6- and 8-inch diameters. The firm also claims in-house development of the first epiwafer production technology integrated with an artificial intelligence (AI) production system. The start-up has also recently installed a 12-inch production facility for the first time in South Korea.

"The use of GaN power devices is increasing significantly in all electronic products due to their advantages in terms of energy efficiency, and interest in GaN is high in the EV applications, a new market area," notes IVWorks' CEO Young-Kyun Noh. "Based on this acquisition, we will be able to expand our product portfolio by supplying GaN-on-GaN epiwafers in high-power application fields and compete with SiC materials in the EV market," he reckons.

www.ivwkr.com
www.saint-gobain.com

II-VI licenses E6's single-crystal diamond technology

II-VI Inc of Saxonburg, PA, USA and synthetic diamond materials firm Element Six of Oxford, UK (E6, part of the De Beers Group) have announced a strategic collaboration that will expand II-VI's diamond platform, accelerating the development of new applications by licensing Element Six's single-crystal diamond technology.

Since size, weight and power consumption are strategic value drivers, the unique characteristics of diamond materials offer what are reckoned to be breakthrough solutions for designers of future generations of products. Applications of advanced power and RF electronics, including for 6G wireless components, as well as other emerging applications in life sciences, sensing, thermal management and quantum computing, are expected to drive the adoption of single-crystal diamond, a material extremely challenging to manufacture but well known for its outstanding optical, mechanical, thermal and electrical properties.

Through the collaboration, II-VI is licensing from Element Six its intellectual property and equipment necessary to produce high-quality single-crystal diamond, thus expanding its core competency in diamond technology ahead of anticipated market opportunities.

"Element Six has invested hundreds of millions of dollars for over 70 years to become a world leader in single-crystal diamond engineering and growth. Its unique capabilities complement II-VI's proprietary polycrystalline diamond, a material we already manufacture at scale," comments Steve Rummel, senior VP, Engineered Materials and Laser Optics business unit, II-VI Inc. "This exciting collaboration is consistent with II-VI's innovation strategy of making early investments in technology platforms that are process- and capital-intensive, and that require time to evolve, mature and scale, so we can enable our customers' technology roadmaps," he adds.

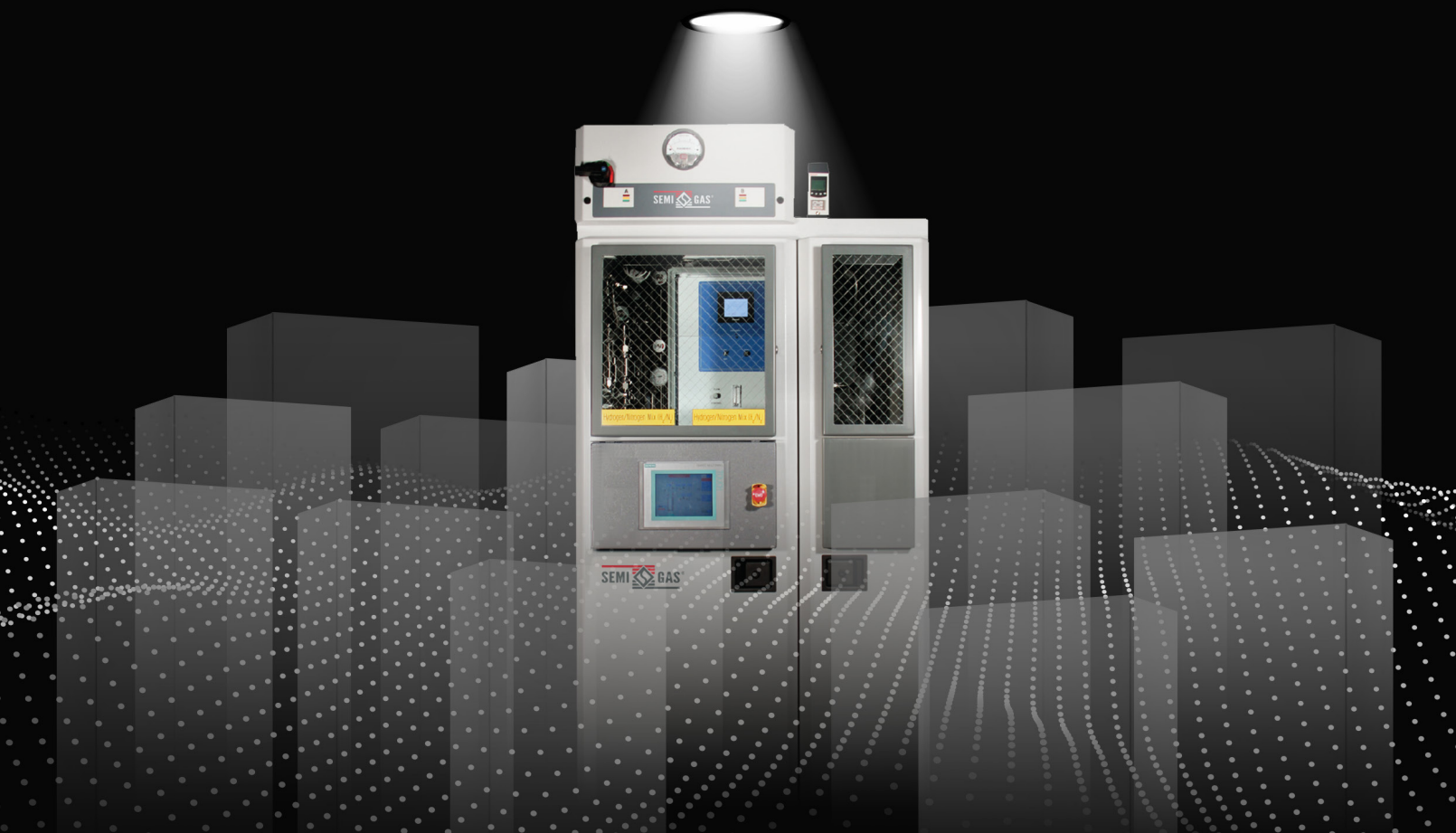
"With its diverse global manufacturing footprint, growth markets expertise and a successful vertically integrated structure, II-VI is one of the largest listed photonics and compound semiconductor companies," comments Element Six's chief technologist Dr Daniel Twitchen. "These elements make it an ideal partner to accelerate the market adoption of this remarkable material," he reckons. "Besides future opportunities for electronics, there is also a wide range of near-term applications driving the demand for accessible high-quality single-crystal diamond, including high-power optics, high-durability parts and high-performance thermal-management systems. We look forward to enabling these and many new markets through this strategic collaboration with II-VI."

www.ii-vi.com
www.e6.com

SEMI GAS®

HIGH INNOVATION HAS HIGH STAKES.

Rise to new standards with SEMI-GAS®.



Semiconductors are mission-critical to many advanced applications today. Subpar gas delivery system performance not only inhibits output quality and reliability—it can also compromise safety.

For 40 years, SEMI-GAS® ultra high purity gas delivery systems have been relied upon by fabs looking to up their innovation, addressing evolving risks with features that don't just meet but exceed codes for safety, precision & purity.

BROUGHT TO YOU BY

APPLIED ENERGY SYSTEMS

Improve yield, ensure high-performance output, and protect the processes and people that make innovation possible with SEMI-GAS®. Start today at appliedenergysystems.com/stakes.

Riber's full-year 2021 revenue up 3% to €31.2m, as Services & Accessories compensate for restricted export licenses for MBE Systems

Order book grows by 3% to €14.8m, with MBE Systems up 39%

Riber S.A. of Bezons, France — which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells — has reported full-year revenue up 3%, from €30.2m in 2020 to €31.2m for 2021. Of total revenue, 31% came from Europe, 59% from Asia, 9% from North America, and 1% from other regions.

Most recently, revenue in fourth-quarter 2021 was €15.4m, up 21% on €12.7m a year ago and more than doubling from €6.6m last quarter.

Due to the consequences of the COVID-19 pandemic, seasonality increased significantly, with a focus on the second half of the year, especially for the Systems business.

Systems revenue was down 4% on 2020's €18.2m to €17.4m for full-year 2021, due to the French authorities' refusal to grant several export licenses for orders amounting to €9m. Eight MBE systems (comprising four production units and four research units) were delivered, compared with 10 in 2020 (comprising four production units and six research units).

Revenue for Services & Accessories rose by 15% from €12m to a record €13.8m (44.2% of total revenue). Riber says that this successful strategic development is helping to further strengthen its robust positions with its R&D and production clients, while also ramping up recurring revenue across its fleet of machines.

Due to the consequences of the COVID-19 pandemic, seasonality increased significantly, with a focus on the second half of the year... Systems revenue was down 4%... due to the French authorities' refusal to grant several export licenses for orders

Earnings results for full-year 2021 will be released on 13 April, but Riber confirms its forecast of an operating income of €1.2m.

MBE System orders up by 39% in 2021

The order book rose by 3% from €14.4m at end-2000 to €14.8m at end-2021.

Specifically, orders for MBE Systems grew by 39% from €5.7m to €7.9m (including three systems to be delivered in 2022). This does not include an additional order recorded at the start of 2022 and three orders pending export licenses.

Following the major deliveries at the end of 2021, orders for Services & Accessories fell by 21% from €8.7m at the end of 2000, but remained at a good level of €6.9m at end-2021.

Riber says that, in a buoyant semiconductor market, the dynamics of its order intake point to growth in revenue in 2022.

www.riber.com

New university in Asia orders Riber MBE 412 system

System to be used to study magneto-transport effects in GaAs/AlGaAs QWs and to grow III-V nanostructures on silicon

Riber has received an order for a fully automatic MBE 412 system from newly established university in Asia focusing on engineering sciences.

To be delivered in 2022, the system will be used to study the magneto-transport effects in gallium arsenide/aluminium gallium arsenide (GaAs/AlGaAs) quantum wells and to grow III-V nanostructures on silicon with high crystalline perfection.

The work and the research programs carried out will be academic. The MBE 412 system will also be used to develop structures for prototype MEMS (micro-electro-mechanical systems) micro-pumps, which will be used in the medical field.

Riber receives Japan order for automated MBE 412 system

System to be used for development and production of high-speed fiber-optic communications devices

Riber says that a Japanese company has placed a multi-million euro order for an automated MBE 412 system.

For delivery in 2022, the system will be used for the development and production of optoelectronics devices for high-speed optical fiber communications.

LIQUID NITROGEN PIPING

Single phase, low pressure LN_2 to your use point for on-demand supply

- Clean, frost-free cooling to cryogenic temperatures
- Automatic LN_2 circulation for MBE cryopanels
- Variety of internal diameter piping to accommodate a range of flow rates
- Modular and re-configurable with vacuum jacketed feed-through connections

Since 1958

VACUUM BARRIER VBC CORPORATION

4 Barten Lane, Woburn, MA 01801
T 781 933 3570 | F 781 932 9428
sales@vacuumbarrier.com

vacuumbarrier.com

IQE confirms 2021 revenue guidance, down 8%

In a pre-close trading update for full-year 2021, epiwafer and substrate maker IQE plc of Cardiff, UK says that it expects revenue to be in line with its November trading update guidance of about £164m (down 8% year-on-year, at constant currency), subject to external audit review.

Cash capex spend for full-year 2021 is expected to be in line with previously issued guidance of £14–17m. This should result in a net debt position at end-2021 of about £6m.

IQE will report its full year financial results on 29 March.

www.iqep.com

Environmental, Social and Governance board committee

IQE has announced the formation of an Environmental, Social and Governance (ESG) board committee with the purpose of developing and monitoring the execution of its ESG strategy as well as overseeing the communication of ESG activities with all stakeholders.

Chairman Phil Smith will chair the committee and will be joined by non-executive directors Drew Nelson and Sir Derek Jones. Jones will also be IQE's nominated workforce engagement representative and will report to the committee on workforce engagement matters.

"This is an important step which reflects our commitment to continuous improvement and implementing best practice across the business," says CEO Americo Lemos (who joined IQE in January). "While we recognise that we are at the beginning of our sustainability journey, our consideration of ESG issues is materially important to our future strategy and will be critical to ensuring a sustainable and viable business in the long term."

www.iqep.com

CSA Catapult appoints Gawera as non-executive director

Wireless comms expertise to aid Compound Semiconductor Applications Catapult

The UK's not-for-profit Compound Semiconductor Applications (CSA) Catapult (based in South Wales) has expanded its board of directors and appointed Raj Gawera as a non-executive director.

Established by UK Government agency Innovate UK (which provides funding and support for business innovation as part of UK Research and Innovation), CSA Catapult is a not-for-profit organization (headquartered in South Wales) focused on accelerating the adoption of compound semiconductors and on bringing applications to life in four technology areas: power electronics, RF & microwave, advanced packaging and photonics. It works across the UK in a range of industry sectors from automotive to medical, and from digital communications to aerospace.

Gawera has over 25 years of experience in short-range and wireless communications technology R&D, business development and marketing. He was part of the initial IEEE 802.11 team that defined the first WLAN standard in 1996, a technology which has now shipped over 5 billion units. He also helped pioneer the first 3G data transmissions, working with Motorola and others to demonstrate one of the first video calls at the 3GSM show in 1998, many years before 3G licences were awarded.

CSA Catapult's new non-executive director Raj Gawera.

In 1999, Gawera was a founder member of start-up UbiNetics, which successfully exited in 2005 for over $120m. As part of that deal, he joined CSR and ultimately took the role of VP marketing, where (in 2009) he was part of the team that acquired SiRF Technologies for $136m to add GPS technology to CSR portfolio. In 2012, Gawera helped sell CSR's handset business to Samsung in a deal worth $310m for 310 staff. As part of that deal, he took up the role of VP marketing responsible for defining future wireless products.

In 2014, Gawera was promoted to head the SCSC subsidiary leading the silicon and software development for Samsung's connectivity solutions. He is now responsible for several European development centers delivering leading-edge technology into Samsung's semiconductor division. The technology from these development centers has now been in mass production in hundreds of millions of units across multiple global customers in mobile and Internet of Things (IoT) products.

"His wealth of experience and expertise within wireless comms technology is a fantastic addition to our non-executive team," comments CSA Catapult's CEO Martin McHugh. "We look forward to working with Raj in 2022, which is sure to be an exciting year for the Catapult," he adds.

www.csa.catapult.org.uk

Nippon Sanso and NCSU collaborating on GaN epitaxy and device technology

Three-year deal involves working with outside companies via NC State Nanofabrication Facility

Taiyo Nippon Sanso Corp (TNSC) of Tokyo, Japan and North Carolina State University (NC State) have announced a three-year agreement to collaborate on methods and equipment solutions to enable gallium nitride (GaN)-based optoelectronic, photonic and electronic devices. NC State will use a TNSC SR2000 metal-organic chemical vapor deposition (MOCVD) reactor for its R&D, with support and expertise from TNSC. The goal of the three-year collaboration is to advance the state-of-the-art in GaN-based device epitaxy and device technology with a blend of complementary equipment, process and device expertise.

"NC State has an excellent reputation for wide-bandgap device and technology development and commercialization," comments TNSC corporate officer Kunihiro Kobayashi. "Taiyo Nippon Sanso is looking forward to working with professor Fred Kish, the NC State staff and students, and outside companies that work with the NC State Nanofabrication Facility." As applications for GaN lasers and LEDs continue to expand, TNSC expects its SR and UR MOCVD platforms to be the platforms of choice for advanced GaN optoelectronics fabrication.

"With the addition of the TNSC MOCVD system, NC State is now one of the very few research institutions with this state-of-the-art materials growth capability," says Fred Kish, the M.C. Dean Distinguished Professor of Electrical and Computer Engineering and director of the NC State Nanofabrication Facility. "The collaboration with TNSC will significantly impact advances in the realization of next-generation wide-bandgap and ultrawide-bandgap materials and devices," he reckons.

www.tn-sanso.co.jp/en
www.mocvd.jp
www.ece.ncsu.edu

Report details growth in compound semiconductor jobs and exports in Wales

CS cluster contributes 15.4% of gross value added in Wales' electronic and engineering sector

A new report published by the Welsh Economy Research Unit at Cardiff University focuses on the contribution to the economy by the Wales-based compound semiconductor cluster CSconnected during 2021.

As in 2020, and despite a complex economic backdrop dominated by the COVID pandemic and Brexit, the compound semiconductor sector as a whole out-performed the wider economy in a number of key areas, including job growth and exports.

Exports from the sector bucked the overall trend that saw the value of Welsh exports tumble by about 25% over the three years to first-quarter 2021.

Employment within the sector grew by about 14% year-on-year in 2021 to around 1600 full-time employees, accounting for over 10% of Wales' total employment in electrical and electronic engineering.

The report also identified that average gross pay across the sector was about 60% higher than the overall average pay in Wales.

Expansion plans already announced across the industry provide a strong indication that growth in employment is expected to accelerate, with skills shortages in some parts of the compound semiconductor community becoming more acute.

The Welsh technology sector has out-performed the overall UK technology output over the last three years. The report suggests that that the relatively strong performance of the compound semiconductor cluster in the 2019-2021 period reinforced this trend in the Welsh economy, in spite of poor overall trading conditions in much of Welsh manufacturing.

In terms of direct value to the Welsh economy, it is estimated that the sector directly contributed about £194m of gross value added (GVA), representing around 1.7% of Welsh manufacturing GVA and 15.4% of GVA in the more tightly defined electronic and engineering sector.

Taking into account the cluster's purchasing of regional goods and services, and its payment of wage incomes, it indirectly supports a further £83m of GVA, so that the cluster overall supports directly and indirectly an estimated £277m of Welsh GVA.

"The Welsh compound semiconductor cluster is the first of its kind in the world. The region should be proud to be home to a robust and innovative technology sector that is widely recognized globally and enables a wide portfolio of applications from resilient communications to advanced healthcare technologies and energy-efficient devices that will help achieve net-zero targets," says CSconnected's director Chris Meadows. "The UKRI [UK Research and Innovation] Strength in Places program has enabled the CSconnected community to accelerate its global influence, placing Wales at the center of new and emerging technologies that will change the way we live, work and spend our leisure time over the coming decades," he adds.

"The robust growth of the compound semiconductor community continues to make a significant contribution to the Welsh economy and demonstrates resilience and sustainability that will be positive for the region's long-term economic prospects," comments professor Max Munday, one of the report authors (along with Dr Annette Roberts and professor Robert Huggins). "The growing ecosystem embraces the private sector firms, academic institutions and government agencies," he adds. "The UKRI Strength in Places support provides a great springboard for the region to be at the centre of the next technology revolution, increasing its contribution to the Welsh economy."

In 2020, CSconnected received government funding provided via UK Research and Innovation's flagship Strength in Places Fund (SIPF). The 55-month CSconnected SIPF project has a total value of £43.74m, supported by £25.44m of UKRI funds.

http://csconnected.com

CSconnected 'Strength in Places Fund' project to focus on overcoming skills barriers

Compound semiconductor cluster gains £43m over 55 months

A £43m, 55-month project part-funded by £25m through UK Research and Innovation's flagship Strength in Places Fund (SIPF) is focusing on strengthening the emerging regional compound semiconductor cluster CSconnected in South Wales around advanced semiconductor materials, research and manufacturing.

The skills element of the 'CSconnected Strength in Places Fund' project has deliverables in Continuing Professional Development (CPD) and in the coordination of education and outreach initiatives. Both are essential to help overcome the skills barriers that are currently limiting the growth of the CS cluster.

Continuing Professional Development

A new report is available that identifies the short- to mid-term CPD needs and demand from the compound semiconductor industry in South Wales. The 'Continuing Professional Development (CPD) scoping report — CSconnected Strength in Places Fund' was first made available in November by Cardiff University's CPD unit after consultations with the CSconnected industry partners to better understand how to support growth of the semiconductor cluster in South Wales.

This CPD Scoping Report forms a first-stage deliverable in the CSconnected SIPF skills work package that seeks to resource and accelerate the development of skills initiatives that will create the skilled workforce of the future for the region.

CPD aims to up-skill existing employees, re-skill professionals from related sectors (potentially those made redundant) and provide new skills in the latest research and technology developments.

It also supports outreach and engagement initiatives through activities to upskill teachers, careers advisors and youth influencers, who are all essential to feeding the pipeline of the future workforce.

The report focuses on current gaps in provision and makes a series of recommendations about which CPD activities should now be prioritized for development.

Skills development will be essential to enabling growth of the CSconnected cluster, since the number of jobs is expected to more than double over the next three years. An aim is for CPD activities to reach more than 1000 semiconductor professionals by 2025, including employees from supply chain organizations.

CPD priority topics

The CPD topics being developed in first-half 2022 are:

- Introduction to compound semiconductors (also covering semiconductors and photonics);
- Cleanroom Protocols;
- Practical Cleanroom Skills (semiconductor manufacturing technologies in etching, wafer cleaving and wire bonding).

The intention is for these priority CPD courses to be available from summer 2022. They will be offered out on a chargeable basis and will be available to both individuals (looking to re-skill into the sector) and organizations (who are already embracing/plan to embrace compound semiconductor technologies).

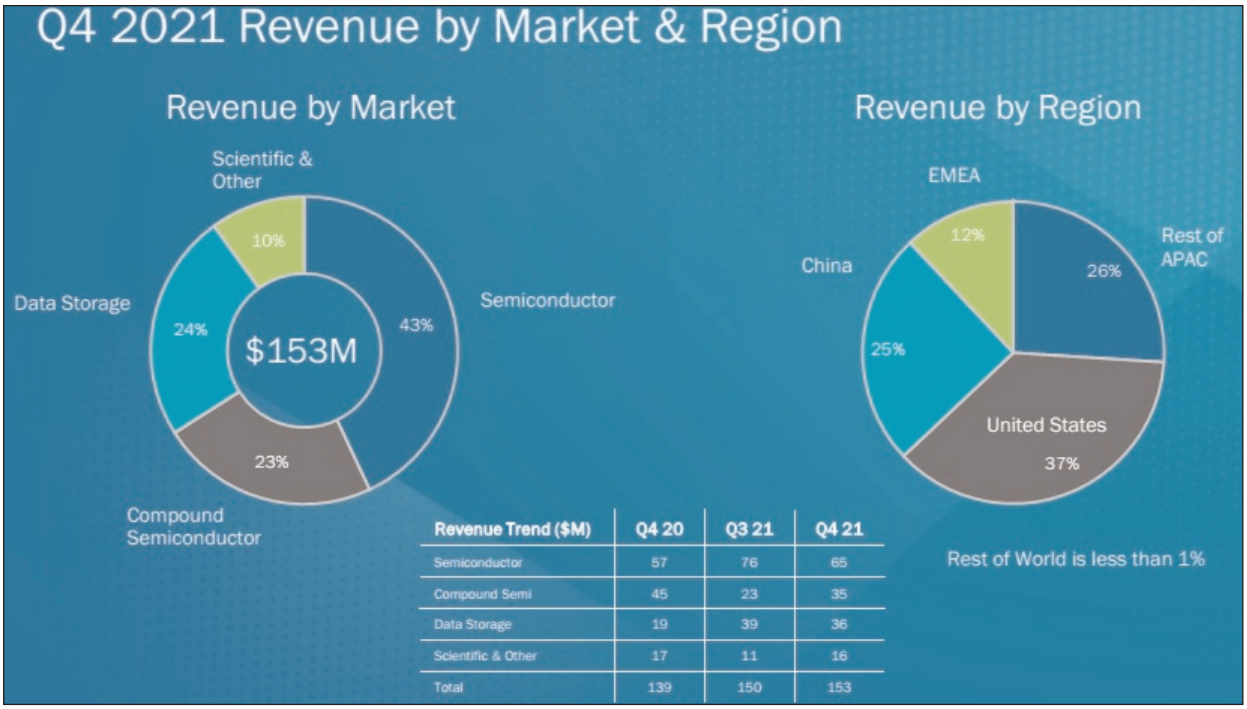
Outreach & engagement

To further support the delivery of the CSconnected SIPF skills package, Cardiff University and CSconnected are scoping the design and delivery of a range of outreach activities that will be undertaken over the next four years to increase interest in STEM related subjects and careers. CSconnected SIPF is also represented on the Cardiff Capital Region Regional Skills Partnership (CCRRSP) board that support the delivery of a shared CCR employment and skills agenda for the City Deal and Welsh Government.

http://csconnected.com

Veeco grows annual revenue 28% in 2021

Growth driven by MOCVD for power electronics and photonics, and laser annealing and ion-beam deposition for semiconductors



Revenue Trend ($M)	Q4 20	Q3 21	Q4 21
Semiconductor	57	76	65
Compound Semi	45	23	35
Data Storage	19	39	36
Scientific & Other	17	11	16
Total	139	150	153

For fourth-quarter 2021, epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has reported revenue of $153m, up 1.8% on $150.2m last quarter and 10.2% on $138.9m a year ago, driven mainly by strong performance in the semiconductor market.

Semiconductor (Front-End and Back-End, as well as EUV Mask Blank systems and Advanced Packaging) contributed $65.4m (43% of total revenue), up 13.9% on $57.4m a year ago. This is driven by (1) multiple multi-tool orders from a variety of customers for laser annealing (to add capacity for advanced nodes as well as trailing-node applications) and (2) advanced packaging lithography systems (since demand remains high for applications such as flip-chip bumping, fan-out wafer-level packaging and heterogeneous integration).

Compound Semiconductor (Power Electronics, RF Filter & Device applications, and Photonics including specialty, mini- and micro-LEDs, VCSELs, Laser Diodes) contributed $34.7m (23% of total revenue), up 48.9% on $23.3m (15% of revenue) last quarter, driven by multiple shipments of wet-processing systems to photonics customers as well as 5G RF customers adding filter and power amplifier capacity.

Data Storage (equipment for thin-film magnetic head manufacturing) contributed $36.5m (24% of total revenue), down 7.1% on $39.3m last quarter.

Scientific & Other (research institutions and other applications) contributed $16.3m (10% of total revenue), up 43% on $11.4m last quarter.

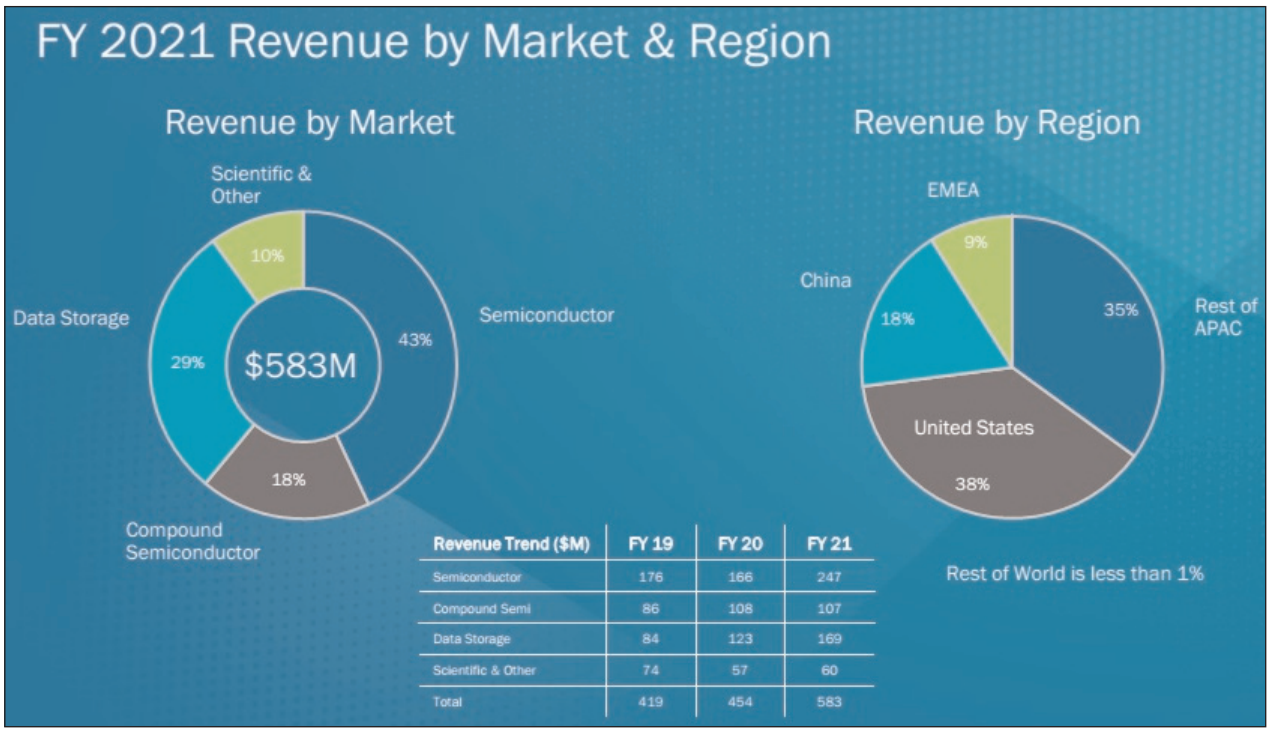
By region, the Asia–Pacific region (excluding China) comprised 26% of revenue (down on 48% a year ago) driven by semiconductor system sales, the USA 37% (up on 26%) driven by data storage customers, China 25% (up on 14%) driven primarily by semiconductor systems (with particular strength in trailing-node laser annealing) as well as compound semiconductor systems (led by wet-processing and ion-beam systems for RF power amplifiers), and Europe, Middle-East & Africa (EMEA) 12% (level year-on-year), with the rest of the world remaining less than 1%.

"I think of 2021 as an inflection point at Veeco, where we completed our transformation, and we're now squarely executing our growth strategy," says CEO Bill Miller. "We continued our focus on innovation with R&D projects supporting laser annealing, ion-beam deposition for semiconductor applications, and MOCVD [metal-organic chemical vapor deposition] for power electronics and photonics applications."

Full-year revenue grew by 28% from $454.2m in 2020 to $583.3m for 2021 (exceeding the revised guidance of $580m, and the initial guidance of just 10% growth), driven by Semiconductor and Data Storage performance.

Semiconductor contributed $247.1m (43% of total revenue), up 49% on 2020's $165.9m (36% of revenue). "We had a record year in our semiconductor market, and we had a record year with our wet-processing systems," says Miller.

Compound Semiconductor contributed $107m, roughly flat on 2020 (although shrinking from 24% to 18% of total revenue). However, normalizing for about $20m of one-time commodity LED-related MOCVD system sales of slow-moving inventory in 2020, this represents underlying growth in areas where Veeco is now focused.



Data Storage contributed $168.8m (29% of total revenue), up 37% on 2020's $123.3m (27% of revenue), as hard-disk-drive customers continued adding capacity for their thin-film magnetic head manufacturing.

Scientific & Other (research institutions and other applications) contributed $60.5m (10% of total revenue), up 6% on 2020's $57m.

By region, the Asia–Pacific (excluding China) comprised 35% of revenue (down from 39% in 2020) due mainly to semiconductor customers, the USA 38% (up from 32%) driven by data storage customers, EMEA 9% (down from 16%), and China 18% (up from 13%), with the rest of the world remaining less than 1%.

On a non-GAAP basis, full-year gross margin has fallen from 43.3% in 2020 to 42% for 2021. However, despite falling from 42.6% last quarter, Q4/2021 gross margin was 42.4%, still up on 41.3% a year ago.

"We were able to maintain this level of gross margin in spite of the challenging supply chain environment while continuing to invest in service capabilities and supporting our evaluation systems in the field," chief financial officer John Kiernan. "Throughout 2021, we saw increasing challenges as the year progressed and experienced higher logistics costs, inflationary pressures on materials and longer lead-times. Our supply chain team has done a fantastic job of mitigating most issues they encountered," he comments. "For the year, there was about a one percentage point impact to our gross margin. We expect the situation to be similar for a few more quarters, the impact of which has been incorporated in our previously provided guidance for 2022."

Operating expenses were $40m, roughly level with $39.6m last quarter and $39.7m a year ago (and below the expected $41–43m). Full-year operating expenses rose from $144m in 2020 to $158.5m for 2021, reflecting R&D investments made to drive future growth as well as higher variable SG&A expenses associated with an increase in revenue and order intake. However, OpEx as a percentage of revenue was reduced year-on-year from 32% to 27%, providing operating leverage to the company.

Net income has risen further, from $15m ($0.30 per diluted share) a year ago and $20.5m ($0.40 per diluted share) last quarter to $22.6m ($0.43 per diluted share), near the top end of the guidance of $14-23m ($0.27–0.45 per diluted share). Full-year net income has grown from $42.3m ($0.86 per diluted share) in 2020 to 2021's $73.6m ($1.43 per diluted share, up 66%, and exceeding the $1.35 guidance).

CapEx during the quarter fell back to $9.2m (including $8m used for the build-out of the new facility in San Jose), bringing full-year CapEx to $41m (including $31m used for the expansion). "We made great progress on our capacity expansion and shipped first systems from the new San Jose facility [expecting to be fully transitioned into the new space by the end of Q3/2022, providing twice the manufacturing output of the existing San Jose facility], and we enhanced both our service capability and our service offerings, focusing on our customers' needs for system uptime and spare-parts availability," says Miller.

Cash flow from operations was $17m in Q4, and $68m for full-year 2021 (up 58% year-on-year).

However, cash and short-term investments fell by $111m from $336m to $225m, due mainly to convertible notes repurchased during the quarter.

In Q4, Veeco repurchased $112m of convertible notes (due in January 2023) for $117m in cash (leaving just $20m of 2023 notes remaining, together still with $133m and $125m of convertible notes due in 2025 and 2027, respectively). With long-term debt cut by $102m to $229m (represents the carrying

value of the total $278m of convertible notes remaining), annual cash interest expense has hence been cut from $12.9m to $9.9m.

In 2021, Veeco also entered into a $150m revolving credit facility. "With our improved balance sheet, along with our credit facility, we have the flexibility and capital to focus on driving long-term growth across the business," believes Kiernan.

"We successfully advanced our product innovation and penetrated new customers, enhanced our service capabilities, increased our manufacturing capacity, improved our capital structure, solidified our governance and commitment to corporate responsibility," summarizes Miller.

"Demand in our semiconductor and compound semiconductor markets is exceptionally strong and we exited 2021 with order momentum, increased backlog and exciting opportunities that will support our growth strategy," he adds.

Order intake grew faster than revenue throughout the year, with order bookings of $661m in full-year 2021, yielding a book-to-bill ratio of 1.13.

Order backlog is hence $440m, up 20% year-on-year.

By market segment, Semiconductor backlog more than doubled and Compound Semiconductor backlog grew by 47%, while Data Storage backlog fell by 51% as customers slowed the pace of new orders for capacity additions.

"With Q4's performance, we exit 2021 on a positive note with strong order momentum, increased backlog and focus on execution," says Miller.

For first-quarter 2022, Veeco expects revenue of $145–165m, gross margin of 42–44%, operating expenses of $42–44m, and net income of $15–26m ($0.28–0.44 per diluted share).

"We're currently experiencing strong demand from laser annealing, EUV mask blank production and advanced packaging, and expect this demand to continue and drive significant semiconductor growth in 2022," says Miller.

"We expect significant growth in the compound semiconductor market in 2022, which is based on our backlog and visibility of MOCVD and other systems selling primarily into photonics applications and, secondarily, GaN power," notes Kiernan. "We're beginning to see traction in the photonics market with a recent announcement for a multi-system order for our Lumina platform," says Miller. "Longer term, we believe we're well positioned for the micro-LED and 8-inch GaN power opportunities with both our Lumina and Propel platforms."

Based on the improved backlog and current visibility (expecting slightly higher revenue in second-half 2022 than first-half 2022), Veeco is reaffirming its recently provided full-year 2022 revenue outlook of $640–680m. This would be up 13–14% year-on-year, driven mainly by 35% growth in both the Compound Semiconductor market and the Semiconductor market (including nearly 50% growth for laser annealing systems, which will be Veeco's largest business in 2022), more than offsetting a 35% drop for Data Storage. Also, Veeco continues to target diluted EPS of $1.50–1.70 per share.

"We expect to grow revenue in 2022, while improving our gross margin as we make progress toward our long-term target model [of 45%]," concludes Miller.

www.veeco.com

Multi-tool order for Veeco from opto component maker

Lumina MOCVD systems to be used for photonics applications

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA says that a leading manufacturer of optoelectronic components has ordered multiple Lumina metal-organic chemical vapor deposition (MOCVD) systems for the production of optoelectronic components for photonics applications. The customer currently operates multiple Veeco MOCVD platforms, as well as other Veeco technologies.

"Following a successful evaluation, the superior performance of the Lumina platform has now been fully validated with several follow-on orders for use in high-volume manufacturing," says Adrian Devasahayam Ph.D., Veeco's senior VP, product management. "The Lumina system is built on over 20 years of high-volume MOCVD expertise and carries on the proven performance of our core TurboDisc technology," he adds. "To enable advanced photonics devices, leading companies depend on superior film quality, exceptional uniformity, repeatability and low defectivity with unmatched cost of ownership that Lumina delivers."

At the heart of the Lumina system is Veeco's MOCVD TurboDisc technology, which features what is claimed to be excellent uniformity and low defectivity over long campaigns for exceptional yield and flexibility. In addition, Veeco's proprietary technology drives uniform injection and thermal control for thickness and compositional uniformity. Providing a seamless wafer size transition, the system is capable of depositing high-quality arsenic phosphide (As/P) epitaxial layers on wafers up to 8-inches in diameter. The Lumina system allows users to customize their systems for maximum value in delivering micro-LEDs, LEDs, edge-emitting lasers and vertical-cavity surface-emitting lasers (VCSELs) in high-volume production, says Veeco.

www.veeco.com

Aixtron ships AIX 2800G4-TM and AIX G5+ C MOCVD systems to China's HC Semitek

Chipmaker targets rising demand for RGB micro-LEDs in displays

Deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany says that in fourth-quarter 2021 it shipped AIX 2800G4-TM (IC2) and AIX G5+ C metal-organic chemical vapor deposition (MOCVD) systems (all in 8x6-inch configuration) to China-based chipmaker HC Semitek.

HC Semitek is positioning itself for micro-LED technology (a strong emerging market in the display industry) that enables what is described as unmatched pixel resolution, superior display quality and much higher current efficacy than existing display technologies. To achieve these benefits, the next generation of LED displays will require millions of micron-size LEDs to be transferred onto one single display, which has driven LED suppliers to develop new mass-transfer technologies.

To enable this, large arrays of LEDs are taken directly from the processed LED wafers, making any upfront wafer binning or sorting of defective chips obsolete. Consequently, says Aixtron, it is essential that all epitaxial wafers produced have a very tight wavelength distribution and a very low level of defects on their surfaces, calling for new MOCVD approaches.

Aixtron says that its Planetary system features wafer-level control of the film surface temperature during the epitaxial process. This enables very accurate control of the indium incorporation into the multi-quantum wells (MQW), which will ultimately define the wavelength consistency among all wafers. Cassette-to-cassette automation — coupled with in-situ cleaning — ensure that no particle will contaminate the films during handling or the epitaxy processing, says the firm.

"Aixtron has been our trustable and reliable partner for MOCVD solutions over the past 15 years. We are delighted to now strengthen our cooperation in the area of micro-LED products," says HC Semitek's CEO Dr Jianhui Zhou. "Aixtron's Planetary technology has been well proven for the best uniformity and low particle performance… This is a key step for the commercialization of micro-LEDs and will reinforce HC Semitek's leading position in the display market," he reckons.

"We are looking forward to supporting the acceleration of the roll out of micro-LEDs for displays," says Aixtron's CEO & president Dr Felix Grawert. "Micro-LED technology is disrupting the existing display ecosystem, embracing methods and approaches only seen in the semiconductor industry. Our Planetary technology platform solutions perfectly fulfill these stringent epitaxial requirements," he believes.

www.hcsemitek.com
www.aixtron.com

ACM strengthens wet processing portfolio

ACM Research Inc (ACM) of Fremont, CA, USA, which makes wafer processing solutions for semiconductor and advanced wafer-level packaging (WLP) applications, has introduced its comprehensive tool set to support compound semiconductor making.

The 150–200mm bridge systems support front-end cleaning and WLP applications for compound semiconductors including gallium arsenide (GaAs), gallium nitride (GaN) and silicon carbide (SiC) processes. The wet process portfolio includes coater, developer, photoresist (PR) stripper, wet etcher, cleaner and metal plating tools that feature automated systems for flat or notched wafers.

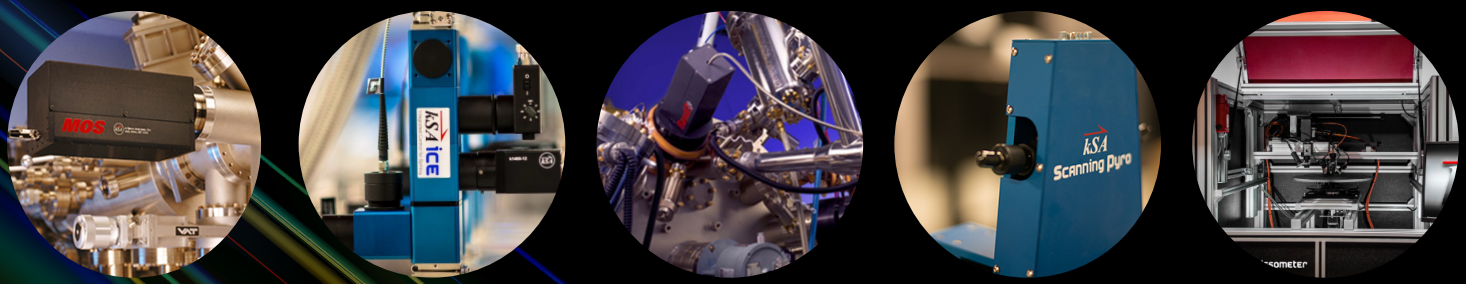
"The compound semiconductor industry is growing rapidly, with demand increasing across a variety of end markets," says president & CEO Dr David Wang. "ACM has leveraged its expertise and technology in front-end and WLP tool sets to deliver high-performance and cost-effective systems to address the specific technology requirements of compound semiconductors. We believe the market for compound semiconductor capital equipment offers significant growth opportunities to ACM, as GaAs, GaN and SiC devices are becoming an increasingly integral part of future electric vehicle (EV), 5G communication system and artificial intelligence (AI) solutions."

ACM's compound semiconductor capital equipment portfolio includes:

- Ultra C SiC cleaning tool: ACM's Ultra C SiC cleaning tool targets SiC wafer cleaning using sulfuric peroxide mix (SPM) for surface oxidation and hydrofluoric (HF) acid to remove residues. It also features ACM's SAPS and Smart Megasonix technologies to achieve a more comprehensive clean without damage to device features. The Ultra C SiC delivers advanced cleaning performance with <10@0.3μm particles per wafer and metal <1e10atoms per cm^3. The tool delivers throughput of >70 wafers per hour and should be available in second-half 2022.
- Ultra C wet etch tool: The Ultra C wet etch tool delivers uniformity of <2% for GaAs and indium gallium phosphide (InGaP) processes with repeatability of less than 2%. The Ultra C wet etch tool offers high-performance chemical temperature control and etching uniformity. The first Ultra C wet etch tool was delivered to a key customer in third-quarter 2021 and has since passed initial customer testing.
- Ultra ECP GIII 1309 tool: ACM's Ultra ECP GIII 1309 tool supports Cu pillar and solder for Cu, nickel (Ni) and tin silver (SnAg) as well as redistribution layer (RDL) and under-bump metallization (UBM) processes with integrated pre-wet and post-clean chambers. It achieves within-wafer and within-die uniformity of <3% and repeatability of <2%. The first Ultra ECP GIII 1309 tool was delivered to a key customer mid-2021 and successfully passed customer testing.
- Ultra ECP GIII 1108 tool: The Ultra ECP GIII 1108 tool provides Au bumping, thin-film and deep via processes with integrated pre-wet and post-clean chambers. It uses ACM's proven paddle technology for deep via plating to improve step coverage. It delivers within-wafer and within-die uniformity of less than 3% and repeatability of less than 2%. The chamber and tank are designed to avoid oxidation of Au electrolyte and the tank features a nitrogen gas (N_2) purge function to reduce oxidation. The first Ultra ECP GIII 1108 tool was delivered to a key customer in late 2021 and successfully passed customer testing.
- Ultra C ct coating system tool: ACM's Ultra C ct coating system enables even coating of PR chemistry using double-coat, spin-coating technology. It offers advanced benefits, including precise coating control, auto-clean functionalities, hot and cold plate modules, and independent process control functions for each chamber.
- Ultra C dv developer tool: ACM's Ultra C dv developer tool performs the crucial steps of post-exposure baking, developing and hard bake for compound semiconductor processes. It leverages ACM's superior technology to achieve ±0.03LPM of the desired flow rate and ±0.5ºC of the desired temperature.
- Ultra C s scrubber system: The Ultra C s scrubber system leverages ACM's wet cleaning technology for superior contaminant removal. It achieves high performance through N_2 spray or high pressure to realize more effective cleaning for smaller particles. It is also fully compatible with ACM's proprietary Smart Megasonix technology to ensure excellent particle removal efficiency (PRE) without damaging finer pattern structures.
- Ultra C pr wet stripping system: ACM's Ultra C pr wet stripping systems utilize both wet bench tank soaking and single-wafer processing to ensure maximum effectiveness for compound semiconductor stripping. The tool was recently ordered by a leading global integrated device manufacturer for ease of use in PR removal, further validating ACM's technology.
- Ultra SFP polishing system: The Ultra SFP provides an environmentally friendly alternative to conventional chemical mechanical planarization (CMP) through-silicon via (TSV) processes and fan-out wafer-level packaging (FOWLP). In TSV, ACM's stress-free polishing (SFP) system is used to remove bulk copper overburden down to 0.2μm by employing proprietary electro-polishing technology, further remove copper to barrier layer by employing conventional CMP, and to remove barrier by employing wet etch, which significantly reduces the cost of consumable. For FOWLP, the same process can handle wafer warpage from stress of thick copper layer, removes Cu overburden and planarizes RDLs.

www.acmrcsh.com

When Accurate Real-Time Measurement Matters



In Situ Thin-Film Metrology Solutions for Research, Development, and Production

- Film thickness and deposition rate
- Wafer and film temperature
- Thin-film stress and strain
- Wafer curvature, bow, and tilt
- Surface roughness and quality
- Wafer carrier characterization
- Analytical RHEED

Visit www.k-space.com today to discover the measurement solution that's right for you.

k-Space Associates, Inc.
Putting Light to Work
www.k-space.com

SemiLEDs to co-develop UV-C LED chips with CrayoNano

CrayoNano AS of Trondheim, Norway — which develops and makes semiconductor components based on patented and proprietary nanomaterials technology — and LED chip and component maker SemiLEDs Corp of Hsinchu, Taiwan have agreed to jointly develop next-generation UV-C LEDs for the disinfection market.

CrayoNano has validated and selected a strategic partner to accelerate the industrialization of its UV-C LED technology. SemiLEDs is a manufacturer of UV LEDs with what is described as industry-proven experience and capabilities for faster ramp-up to high-volume manufacturing of LEDs.

"Following our agile business model and the increasing market demand, we must fast-track our development. SemiLEDs has over 15 years of industry expertise in chip processing and industrialization of UV LEDs," says CrayoNano's CEO Jo Uthus. "Their experience, capabilities and resources are complementary for the engineering of CrayoNano's ground-breaking nanowire and hybrid material technology and enabling our development of new products based on it."

The collaboration aims to alleviate capacity and supply chain constraints that continue to choke global supply. The partnership will add to CrayoNano's resources and capacities in Trondheim and de-risk the supply chain dependency, aiding market entry, it is reckoned.

"Current UV-C LED products using conventional sapphire-based substrate are inefficient and high cost; the need for significant improvements in efficiency and performance is required for mass-market adoption of UV-C LED for disinfection market," says SemiLEDs' CEO, president & chairman Trung Doan.

"One-dimensional nanostructures growth on graphene has shown unique characteristics for optoelectronic devices; CrayoNano's nanowire and hybrid material technology is second to none, a real disruptor in this space. SemiLEDs will contribute with engineering support and our unique patented know-how of chip processing, to bring the evolutions of CrayoNano UV-C chip products faster to the market and verify opportunities of further products."

The firms will jointly develop products based on CrayoNano's nanowire and hybrid material technology and SemiLEDs' unique LED process technology and process know-how to accelerate CrayoNano's mid-to long-term UV-C product roadmap. CrayoNano will own the products developed under the agreement, and innovations and R&D will remain in Trondheim.

www.semileds.com

Chip supply secured for ramp-up to volume production

CrayoNano has executed the first high-volume supplier contract, with an undisclosed manufacturer, for over 1 million units of UV-C LED packaged chips targeted for the water disinfection market following its controlled market entry plan. The contract also secures long-term capacity ramp-up beyond 10 million units/year manufacturing. CrayoNano says this is a strategic partnership to develop its product roadmap according to market and customer requirements.

The supplier is a specialist in semiconductor packaging technology and will manufacture a customized, high-performing package specifically for CrayoNano's UV-C LED product series. The product specifications are co-designed with key strategic customers, targeted at water disinfection in point-of-use and point-of-entry applications. The product will be made available to selected key customers for a controlled market entry.

"The current industry bottleneck with the challenging supply of chips has been a key concern," says CEO Jo Uthus. "We have now proactively resolved the situation and continue our efforts on disrupting the UV-C LED market, where we see growing demand for our solutions."

The initial manufacturing volume will utilize commodity, industry-standard chip technology and components combined with CrayoNano's optimized custom packaging & assembly technology. This is in preparation for the integration of CrayoNano's nanowire chip architecture through testing and validating the supply-chain and driving a controlled market entry to enable a quality and reliability-focused UV-C LED product series.

After market entry and customer qualifications, CrayoNano aims to implement its proprietary nanowire and hybrid materials chip architecture into the same optimized package using the same assembly and test processes, positioning it for a leading cost-performance position in the market, it reckons.

The first order of pilot products will be delivered to customers in first-half 2022. The pilot order will be used by customers to benchmark and qualify the product prior to placing orders. The first volume shipment should be available to selected customers in Q3/2022.

Due to the substantial lack of UV-C LED products in the market, CrayoNano has obtained signed letters of intent (LOI) from what it calls industry-influencing OEMs and system integrators (tier-1 and tier-2). "With our supply-chain partners we are now in a position to execute a ramp-up and commercialization of our nanowire and UV-C LED technology according to our business plan," says Uthus. "Through this, CrayoNano will contribute to solving the lack of supply in the UV-C LED market."

http://crayonano.com

CrayoNano establishes branch in Taiwan

Commercialization of UV-C LED products for disinfection being accelerated

CrayoNano AS of Trondheim, Norway — which develops and makes semiconductor components based on patented and proprietary nanomaterials technology — has expanded its operations and established a branch in Taiwan, located in the city of Hsinchu (which has a well-established technology infrastructure and semiconductor community).

The first application of CrayoNano's nanomaterials technology targets the fast-growing disinfection market with high-quality and performance-driven UV-C ultraviolet short-wavelength light-emitting diodes. "CrayoNano is entering a global market with our UV-C LED technology," says CEO Jo Uthus. "Securing access to the world's largest market for manufacturing of semiconductor components is essential for our success. Our Asian operations in Taiwan will be key going forward."

CrayoNano says that it has learnt from the past 9–12 months of COVID restrictions and global semiconductor supply-chain constraints that control of the supply chain and partnering is an opportunity to leverage the acceleration and commercialization of its UV-C LED products for disinfection. Seeing the continuation of restrictions at the start of 2022 validates the acceleration strategy to take stronger control of the supply chain, reckons CrayoNano.

"By establishing in Taiwan, CrayoNano gets access to the talent and equipment in the region to execute the acceleration of our go-to-market plan," says Uthus. "The proximity to supply-chain and R&D partners is crucial for releasing CrayoNano's disruptive nanotechnology-based UV-C LED products and will give us the agility to respond quickly to market changes," he reckons.

By establishing in Taiwan, CrayoNano gets access to the talent and equipment in the region to execute the acceleration of our go-to-market plan. The proximity to supply-chain and R&D partners is crucial for releasing CrayoNano's disruptive nanotechnology-based UV-C LED products and will give us the agility to respond quickly to market changes

The CrayoNano Taiwan branch will be established as 'CrayoNano fab2' with a dedicated cleanroom for full nanowire chip development, processing and packaging capabilities, allowing quick-turn technology transfers to high-volume UV LED foundries. These additional resources will fast-track the industrialization and customization of products based on customer and local market requirements. CrayoNano will leverage existing facilities and manufacturing equipment from its development partners to shorten the time to become operational and reduce the capital expenditure (CapEx) requirements.

"We are setting aggressive milestones for the CrayoNano fab2 to become fully operational during this year with quality assurance and testing, order fulfillment and technology development," says Uthus. "As we are also extending our 'Fab 1' operations in Trondheim, Norway with staff and equipment, we are positioning for massive scalability and growth in the next years to come."

CrayoNano's key Asia-Pacific operations will also include sales, marketing and technology development.

http://crayonano.com

CrayoNano licensing deal gives access to 180+ extra patents

Portfolio enlarged to over 300 UV-C and LED technology patents

CrayoNano has signed a licensing agreement with what it describes as a "renowned LED industry player". CrayoNano will have access to and use of more than 180 patents, particularly in LED chip processing, fabrication, packaging and manufacturing — supplementing CrayoNano's patent portfolio covering nanowire and graphene-based technologies in general and UV-C LED products specifically.

The license agreement triples CrayoNano's patent portfolio to more than 300 patents covering UV-C and LED technology. Under this IP license agreement, the firm is expanding its intellectual property with complementary technology required for the industrialization of its nanowire and hybrid material technology in mass-market, high-volume disinfecting UV-C LED products.

"The additional patents and technology enables strong protection in the market for UV-C LED products, and the access to high-volume manufacturing know-how and technology," says CrayoNano's CEO Jo Uthus. "This will fast track the industrialization of our technology into the planned multi-million unit manufacturing capability in-line with CrayoNano's fab-lite business model."

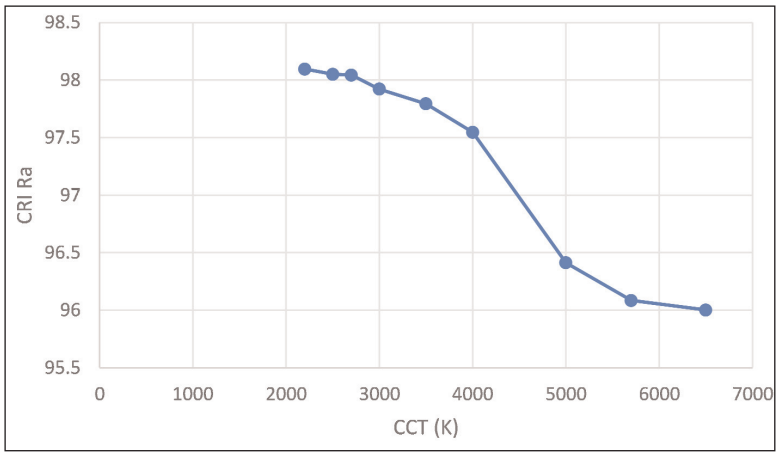
Lumileds adds cyan to LUXEON Rubix LED family

Eight color enables 96–98CRI across CCT range in color-driven solutions for entertainment, stage and studio

Lumileds has added cyan, its eighth color, to the LUXEON Rubix high-power LED family, enabling multi-color driven systems to produce very high-CRI (color rendering index) white light (important for entertainment lighting). Adding the cyan LED fills a significant wavelength gap between blue and green in a system and accounts for the significant increase in CRI.

"We love the finesse cyan contributes to skin tone rendering and the increased gamut and spectral tunability in the blue-green area," comments Wendy Luedtke, ETC Product Technology Specialist — Color.

"Cyan delivers the exact wavelength range necessary to take white light to the next level in entertainment lighting," says senior product marketing manager LP Liew. "Size, power and color options drive new designs and ideas in entertainment lighting. With cyan in the LUXEON Rubix portfolio, we have the small size, power and colors to ensure that there's no need to settle for good enough white light."



LUXEON Rubix is a 3A, 1.4mm x 1.4mm high-power LED: Cyan, Blue, Royal Blue, Red, PC Amber, Lime, Green, and 5700K White in a 3A, 1414 package. The entire LUXEON Rubix portfolio is available through Lumileds distribution partners.

www.lumileds.com/products/color-leds/luxeon-rubix

Lumileds boosts luminous efficacy for retail lighting by 3–5% lumens per Watt for 90 and 95CRI LUXEON CoBs with CrispWhite technology

Two CRI versions offer output within 1–2% and efficacy within 1–2lm/W of each other

LED maker Lumileds LLC of San Jose, CA, USA has announced substantial performance improvements for its 90 and 95 CRI LUXEON CoBs with CrispWhite technology. Now, the two color rendering index (CRI) versions offer light output within 1–2% of each other and efficacy within 1–2 lumens per Watt. Lumileds says that its patented CrispWhite technology brings a vivid and bright look to retail settings. Its ability to highlight bright whites while also revealing the richest colors found in clothing, paints and other goods results in more inviting and attractive displays, it is claimed.

Lumileds says that CrispWhite Technology has proven to be stable and reliable. The firm adds that it developed the technology so that it would improve color rendering without sacrificing efficacy, and it continues to improve this technology in its CoB (chip-on-board) products.

With CrispWhite Technology, whites appear brighter and sharper – like they do in outdoor lighting conditions – than is possible with standard LEDs. Also, with 95CRI, color fidelity is as good as it gets, the firm claims. LUXEON CoBs with CrispWhite Technology are available with light-emitting surfaces (LES) of 6–19mm at a correlated color temperature of (CCT) of 3000K and with CRI of 90 or 95.

"We've seen widespread adoption of CrispWhite Technology and now, with 95CRI performance breaking the 100 lumens per Watt level, we're seeing a majority of new designs adopt the higher-CRI option," says Keen Oun Yap, senior product manager. "We expect this product to increasingly be the standard for retail environments in which specifiers and merchandisers do not want to compromise on fidelity or accuracy of colors and whites."

LUXEON CrispWhite Technology was developed specifically for retail applications utilizing downlights and spotlights where store owners and retail customers desire the most accurate color representation. This is achieved with the LUXEON CoBs, says Lumileds.

www.lumileds.com/products/cob-leds/luxeon-cob-with-crispwhite

Porotech secures $20m Series A investment

Funding to accelerate global expansion and mass production of micro-LED products

Porotech (which was spun off in 2020 from the Cambridge Centre for Gallium Nitride at the UK's University of Cambridge) has secured $20m Series A investment to accelerate global expansion and mass production of its micro-LED products. The funding is designed to ensure that the company keeps pace with growing demand from its customers and partners in the $140bn display market.

A "multi-national electronics giant" is among the participants in the Series A funding round, which has been led by Ameba Capital and includes prior investor Speedinvest.

Porotech says that its PoroGaN porous gallium nitride (GaN) material enables the firm's micro-LED products to deliver monochrome and full-color displays on a single indium gallium nitride (InGaN) material system, with the brightness, efficiency and resolution required for high-quality image projection against bright backgrounds — even outdoors in daylight. The red micro-LED product is already achieving best-in-class performance, it is claimed.

Micro-LED displays will play a vital role in the next generation of TVs, wearables and smartphones, and GaN-based material technology is widely seen as the only technology that can deliver displays that are bright and efficient enough to meet the requirements of extended reality (XR) displays involving virtual reality (VR), augmented reality (AR) and/or mixed reality (MR), says Porotech.

Until now, the requirement to mix multiple material systems has complicated the manufacturing of full-color micro-LED displays, making the final products prohibitively expensive for mass-market applications, the firm says, adding that its use of a single material system opens the door to mass manufacturing of micro-LED displays.

"We have delivered the world's first InGaN-based red micro-LEDs and displays and have set up production of our first products — shipping to some of the biggest global names in display technology," says CEO & co-founder Dr Tongtong Zhu.

"This latest funding will accelerate our work to ensure that PoroGaN drives the commercialization of XR glasses and the new wave of user-interface innovation. It will help us to continue our expansion plans to meet demand and to continue to provide world-class service and products to our rapidly expanding customer and partner base," he adds.

"The fact that it already has industry leaders among its clients and partners is a testament to the game-changing potential of Porotech's breakthrough," comments Arthur Chen, a partner at Ameba Capital.

www.porotech.co.uk

Luminus adds 5000K technology to CCT-tunable modules

Two independent channels enable tuning between 5000K and 2200K

Luminus Devices Inc of Sunnyvale, CA, USA — which designs and makes LEDs and solid-state technology (SST) light sources for illumination markets — has expanded its human-centric lighting portfolio with the introduction of the Salud CCT-tunable modules.

The 5000K Salud technology has now been incorporated into Luminus' CCT-tunable modules (CTM) to provide lighting designers with high melanopic lux without using 6500K correlated color temperature, avoiding light with too much blue tint. The 5000K Salud channel has a melanopic ratio of 0.97 to keep people energized and alert during the day, while the 2200K channel has a melanopic ratio of 0.33 to provide a relaxing environment and allow the body to prepare for sleep. With two independent channels, the user can also tune the light to any CCT in between 5000K and 2200K to enable a smooth transition from daytime to evening.

As many public spaces open back up with health and wellness as a key consideration, the Salud technology incorporated into these modules enables the 5000K channel to meet the WELL Building requirements for high melanopic lux in the vertical plane without having to over-light the environment, says Luminus. Salud technology helps to create a healthy, productive and comfortable environment and is suitable for offices, schools, factories, shops and public spaces, adds the firm.

"Lighting specifiers are delighted that our 90 CRI [color rendering index] CCT-tunable product offering is now enhanced with Salud 5000K technology, enabling easy compliance with WELL, while the ideal warm 2200K CCT provides evening relaxation," says Tom Jory, vice president of illumination marketing.

The new CTM CCT-tunable modules are exact drop-in replacements, with same footprint and electrical characteristics as the 9mm, 14mm, 18mm and 22mm CCT-tunable modules from Luminus.

All Luminus two-channel CCT-tunable modules are now available through the firm's authorized distributors.

www.luminus.com

Cepton using OSRAM's 905nm IR edge-emitting lasers for LiDAR series production

Detroit-based automotive OEM awards Cepton large-scale contract for ADAS and autonomous vehicles

ams OSRAM of Premstaetten, Austria is expanding its partnership with Cepton Technologies of San Jose, CA, USA to provide light detection & ranging (LiDAR) solutions for advanced driver assistance systems (ADAS), autonomous vehicles (AVs), smart infrastructure and robotic vehicles.

After partnering with ams OSRAM since its founding in 2016, Cepton recently secured an order from a global, top-five automotive OEM (based in Detroit) for large-scale LiDAR series production for ADAS. LiDAR calculates how long it takes for a laser beam to hit an object and reflect back. These measurements help to create a 3D map of the vehicle's surroundings to help guide the vehicle safely. Infrared illumination allows the vehicle to 'see' its environment and is a key part of any LiDAR system. ams OSRAM has a portfolio of lasers that power many LiDAR systems.

After its recent production win, Cepton expects to be the first LiDAR company to provide mass-market LiDAR solutions that feature ams OSRAM's 905nm infrared lasers in ADAS across multiple vehicle models (not just luxury vehicles) by 2023.

ams OSRAM says that its compact laser diodes feature multi-junction

laser technology with three epitaxially grown emitters stacked on top of each other. The laser can operate at temperatures up to 125°C.

"As we looked for a laser source partner for our mass-market LiDAR solution, ams OSRAM's high-performance, compact size and automotive-grade edge-emitting laser provided a prime opportunity," comments Cepton's CEO & co-founder Dr Jun Pei. "Combined with the eye-safe operation at 905nm wavelength enabled by ams OSRAM, our proprietary MMT (Micro Motion Technology) imaging platform strikes the right balance between performance, cost and reliability, enabling the mainstream adoption of LiDAR in everyday consumer vehicles."

ams OSRAM's automotive-grade laser

ams OSRAM has been providing both edge-emitting lasers (EELs) and vertical-cavity surface-emitting lasers (VCSELs) for over a decade. The firm introduced the first 905nm edge-emitting laser, which today is the most commonly used wavelength in LiDAR because of its low cost and reliability. ams OSRAM says that it continues to invest in advancing 905nm laser technology, making it more efficient and easier to integrate.

"Our 905nm lasers are some of the most efficient in the market, delivering the long-range measurements needed by autonomous vehicles to operate in any weather condition from rain and snow to fog," says Joerg Strauss, senior VP & general manager of Visualization & Laser at ams OSRAM. "We are thrilled to continue our long relationship with Cepton by providing laser technology for its mass-market, scalable, automotive-grade LiDAR sensors. Cepton's end-to-end LiDAR solutions are making our roadways safer by reducing accidents and enabling ADAS."

www.ams-osram.com

Luminus launches Smooth White chip-on-board LED arrays

Luminus Devices Inc of Sunnyvale, CA, USA – which designs and makes LEDs and solid-state technology (SST) light sources for illumination markets – has expanded its portfolio of chip-on-board (COB) arrays with the launch and immediate availability of a new 95CRI-minimum Smooth White COB series designed for spotlights, downlights, museum, hospitality and architectural lighting applications. The new LED arrays offer what is claimed to be excellent uniformity and color over angle consistency, as well as exceptional long-term color stability.

"Luminus continues to lead the COB industry with a stunning new quality-of-light solution for low blue, broad-spectrum, directional light sources," claims David Davito, COB product line director, Illumination, at Luminus. "Building on our innovative Perfect White technology, Luminus engineers created an even more natural spectral response curve to mirror conventional halogen light sources while optimizing lumen output, vivid color rendering and human-centric characteristics," he adds. "Smooth White comes without the UV found in competitors' solutions while establishing a higher bar for efficacy."

www.luminus.com

ams OSRAM's Belago 1.1 Dot Projector featured in Luxonis' new 3D vision spatial AI cameras

Infrared VCSEL combined with advanced optics to enable 3D sensing

ams OSRAM of Premstaetten, Austria has announced a new partnership with Luxonis, a developer of embedded artificial intelligence (AI) and computer vision technology. Luxonis provides 3D solutions for automatic guided vehicles (AGVs), robots, drones and more that help to create high-quality 3D maps for applications such as object detection and obstacle avoidance. A key component are infrared light sources, such as ams OSRAM's Belago 1.1 Dot Projector, which combines an infrared vertical-cavity surface-emitting laser (VCSEL) chip with special optics and a robust package that is suited to active stereo vision (ASV).

With ASV, two infrared cameras read the pattern that Belago 1.1 projects on a defined field-of-view. By comparing the images of both cameras, depth is calculated, and a 3D map is created. Obstacles are detected on the 3D map, prompting the robot to take action, such as stopping or going around the obstacle.

Luxonis chose ams OSRAM's Belago 1.1 for its recent OAK-D Pro spatial AI camera, which provides fast and accurate object detection through AI. Its open-source software allows for fast and flexible integration into a wide variety of application environments. Stereo cameras featuring the Belago 1.1 Dot Projector are said to offer accurate depth perception for any scene and lighting condition for object tracking in real-time.

"Active stereo is incredibly powerful and useful in robotics — but it was a missing piece in the OAK ecosystem until now — primarily because we wanted a solution with rock-solid eye safety. Given the open nature of our ecosystem, it was pivotal that we be eye safe," says Luxonis' CEO Brandon Gilles. "We were ecstatic when we found Belago 1.1 because its architecture allows simple and robust eye safety, which enables Luxonis and our customers to autonomously integrate active stereo depth safely and confidently, unlocking untold applicability," he adds.

The Belago 1.1 Dot Projector features an infrared pattern projector for increased depth performance. The product includes 5000 individual light dots, which are generated by combining a VCSEL with a micro-lens array (MLA) optical system.

"The Belago 1.1 provides very stable, focus-free dot projection for increased texture on the scene and ASV depth performance," says Joerg Wertli, senior marketing manager at ams OSRAM. "Applied in Luxonis' latest ASV camera, customers have access to a turnkey 3D solution for quick adoption in a wide range of applications," he adds.

The compact dimensions of 4.2mm x 3.6mm x 3.3mm allow customers to develop space-saving system designs, says ams OSRAM. The Belago 1.1 emits light with a wavelength of 940nm for operation independent of ambient light conditions. The robot's path is reliably detected at a distance of 1–3m for collision avoidance. The Luxonis OAK-D Pro also uses ams OSRAM's SFH 4725AS A01 infrared LED for flood illumination for no-light compute vision and perception.

www.ams-osram.com

EPISTAR develops record-output SWIR LEDs

25mW 1300nm product targeted at wearable health detection devices

EPISTAR of Hsinchu, Taiwan (a subsidiary of Ennostar Inc) says that, after investing resources in recent years on developing short-wavelength-infrared LED chips (SWIR, wavelength >1100nm) — which have since been certified under related regulations and introduced in various customers' wearable health detection devices — the optical power of its 1300nm product has now reached 25mW (28% higher than others, making it the highest-output SWIR LED in the world, it is claimed).

With the rising awareness of public health, the application sector is more diverse and the demand for physiological data detection (bio-sensing) has increased sharply, notes the firm.

Besides common applications such as the detection of heart rate and blood oxygen, more applications with non-intrusive detection are being developed, such as skin moisture detection, blood glucose and blood lipids. Short-wavelength infrared LED chips with wavelengths above 1100nm are required for the detection of these specific physiological applications.

The efficiency and reliability of LED chips are key to the success of health or medical products, so EPISTAR Lab uses indium phosphide (InP) as the substrate to develop the highest-output short-wavelength-infrared LED chips with highly efficient emitting power and high reliability under low voltage. Due to the development of short-wavelength-infrared LED technology, a variety of applications with non-invasive health detection beneficial to various users will be launched on the market in the near future, says the firm.

www.epistar.com.tw

Lextar supplies first high-volume AEC-Q102-qualified VCSELs to automakers

PV88Q passed vehicle regulation certification and delivered to EU, USA

For expanding time-of-flight (ToF) three-dimensional (3D) applications, Lextar Electronics of Hsinchu, Taiwan (a subsidiary of Ennostar group) passed the strict AEC-Q102 standard and went into mass production before other companies (it is claimed) in 2020, and started to supply high-quality vertical-cavity surface-emitting lasers (VCSELs) to automakers in the European Union and USA in 2021.

Lextar says that its high-efficiency PV88Q-series VCSELs have extremely high environmental resistance (from –40°C to 125°C), can be operated without active cooling, and meet strict automotive environmental standards.

The special optical design provides a field of view (FoV) of 45–120° to meet the differing product design needs of customers. In particular, the VCSELs are especially suitable for in-cabin driving monitoring systems (DMS), advanced driver assistance systems (ADAS) and 3D gesture recognition applications in the car center control, helping drivers by improving driving safety.

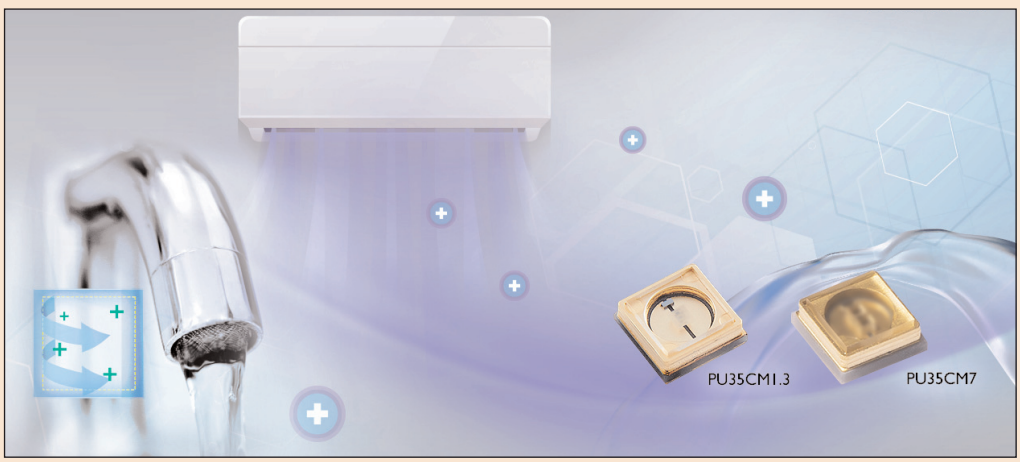
"The PV88Q VCSEL product has passed the vehicle regulation certification and has been mass produced; now, we have successfully delivered to EU and USA automakers, which symbolizes that Lextar's product design and manufacturing technology in high-end laser packaging has entered a new milestone, also proving Lextar's capability to provide efficient and reliable sensing components for the intelligent driving monitoring system in the car," says Mitch Lee, deputy general manager of the Lextar Electronics business group.

Lextar reckons that, in the future, its high-end laser sensing products will play a key role in the supply chain of new-generation vehicles.

Lextar launches UVC LED sterilization solutions

Wavelengths of 255–285nm span sterilization applications

Vertically integrated LED product maker Lextar Electronics Corp of Hsinchu, Taiwan (a subsidiary of Ennostar Inc) has launched comprehensive UVC LED sterilization integrated solutions with over 99.9% sterilization efficiency, noting that – since the outbreak of the COVID-19 pandemic – the demand for sterilization has surged, and the application of UVC LEDs has become more diverse.



Lextar can offer full-band UVC products with wavelengths ranging from 255nm to 285nm with different emitting angles to satisfy various sterilization demands, and these products have been used on home appliances. For air sterilization, Lextar provides the sterilization modules in air conditioning which – in combination with the air outlet system – have been accepted by the top three Japanese air conditioning/purifier brands and major home appliance manufacturers in EU and USA. The surface sterilization solution is used by robot vacuum, kitchen and sanitaryware manufacturers in Europe. For water sterilization, start-up brands in the European Union (EU) and the USA have used Lextar's UVC module in static sterilization and in faucets in dynamic sterilization to provide a safer water supply.

In addition to being used in consumer electronic products, Lextar says that its high-power UVC products are also suitable for crowded places that require long-term bacteriostatic suppression such as medical or research institutes and public places.

The high-power UVC air-conditioning sterilization module — co-developed with Future Taiwan Advanced Electronics Pte Ltd — has now been applied to the negative-pressure wards of Taiwan medical institutions. The advantages of concentrated light and non-diffusion are beneficial for increasing sterilization efficiency, which can meet the requirement for a zero count of colonies detected and clean air while reducing the risk of infection and improving the quality of hospitalization for patients.

www.lextar.com

Ushio ships samples of 1.2W 675nm and 690nm red multi-mode laser diodes

Uptake expected in life science fields such as skin treatment and photo-immunotherapy

Ushio Inc has begun shipping samples of its new HL67203HD and HL69203HD multi-mode laser diodes (LDs), which present improvements to output power (1.2W cw) and efficiency (40% and 41%, respectively) over the conventional 675nm and 690nm red laser light sources commonly used in medical, healthcare and life science fields.

Designed by Ushio's engineers in Japan, the new 9mm CAN-packaged red laser diodes can induce highly efficient and short-lived photochemical reactions with substances and reagents, found in the human body, which absorb light in the 670–690nm wavelength range. These absorption characteristics enable red laser diodes to function in many medical and healthcare applications, such as photodynamic therapy for cancer treatment, as well as acne or blemish treatment.

Furthermore, operating over a temperature range of –10°C to +75°C, the HL67203HD and HL69203HD are promising for practical life science analytics, such as Raman spectroscopy and confocal microscopy. In particular, high-power, high-efficiency 690nm red laser diodes, coupled with fiber, have been the subject of increasing interest for photo-immunotherapy, which has been attracting attention in recent years as a 'fifth cancer treatment'.

Ushio has been offering the HL67001DG (675nm, 200mW) and HL69001DG (690nm, 200mW) single-mode laser diodes to these markets but, to meet their evolving demands, Ushio's solid-state lighting (SSL) division set to work extending the lasing wavelength range. This was achieved by applying the same high-power, high-efficiency and high-reliability technologies that were developed for laser products in the 640nm and 660nm bands.

With the new HL67203HD and HL69203HD products, Ushio says that it aims to meet customers' needs in a wider range of applications, such as the realization of quality of life (QOL) in the life science field.

www.ushio.eu

ICS launches its first VCSEL for quantum applications

Integrated Compound Semiconductors Ltd (a spin off from the UK's University of Manchester that designs, manufactures and tests RF and optical devices for 5G wireless, 10G/25G/100G telecom and datacom markets) has launched its VCS894.6-DP vertical-cavity surface-emitting laser (VCSEL), designed specifically for atomic clock and quantum magnetometer applications.

VCS894.6-DP is a planar device, with single-longitudinal-mode emission at 894.6nm (the wavelength corresponding to the D1 transition line of Cs atoms). The device offers high mode stability, with side-mode suppression ratio (SMSR) of 25dB and narrow spectral linewidth of 40MHz, as tested at 80°C and 2mA. The device is suitable for portable applications enabled by a low temperature tuning coefficient of 0.07nm/°C and has undergone successful preliminary testing in an atomic clock configuration.

The VCS894.6-DP is the first commercial release in a portfolio of single-mode VCSELs for customers requiring narrow-linewidth, highly mode-stable devices for applications such as quantum. Enabled by the latest testing methodologies, the fabricated VCSELs are guaranteed to have single-mode emission at the point of packaging.

The VCSEL portfolio is built on scalable manufacturing processes through a partnership with Compound Semiconductor Centre (CSC, a joint venture between Cardiff University and IQE plc), which has developed the high-uniformity epitaxy process using MOCVD platforms.

"We are pleased to introduce the first product of our VCSEL portfolio for quantum applications. The specifications for such VCSELs are especially challenging and we are ready to support system integrators with VCSEL technologies that allow a pathway to market for commercial applications of quantum technologies," says ICS's VCSEL technical lead Dr Ioannis Kostakis. "Our combined capabilities and partnership with CSC allow us to develop highly customized VCSELs on volume platforms, and we are looking forward to supporting customers with narrow-linewidth VCSEL technologies beyond quantum applications," he adds.

"Together with ICS, we are making high-performance VCSEL technologies more accessible," says Dr Denise Powell, programme manager Quantum Technologies at CSC. "We have seen considerable advancement in quantum technologies over the last five years and we are excited to support ICS with the VCS894.6-DP product through high-uniformity GaAs-based epitaxy solutions. The techniques developed can be applied to other applications requiring stringent wavelength control."

www.icsld.com

www.compoundsemiconductorcentre.com

NUBURU secures new funding and appoints chief operating officer and VP of global sales

Executive appointments to accelerate commercialization of blue laser technology

High-power blue laser technology firm NUBURU Inc of Centennial, CO, USA (which was founded in 2015) says that it has raised additional growth capital, bringing the total valuation to about $350m. Existing investors Anzu Partners, GRAPHA Holdings and Thomas Wilson participated in the funding round.

The new funds will be utilized to expand NUBURU's presence across its target markets, including automotive, aerospace, consumer electronics, and defense. The firm's industrial blue laser technology is said to bring speed and quality improvements to welding and metal 3D printing of copper, aluminum and other reflective metals to increase productivity for manufacturers globally.

To boost commercialization efforts, NUBURU has also brought in experienced technology executive Brian Faircloth as chief operating officer and promoted Andrew Dodd to VP of global sales.

Faircloth brings over 20 years of operations, engineering and marketing experience, scaling high-tech companies in the laser and energy industries. Prior to joining NUBURU, he spent nearly 13 years as a technical leader at high-power laser company ForoEnergy, where he served as VP of engineering and as chief technology officer. During his tenure, he managed R&D and engineering of high-power laser and optics development for oil, gas and geothermal applications. Earlier in his career, he held executive and director roles at laser technology companies Nuvonyx and Coherent. Faircloth has master's degrees in electrical engineering and applied physics from Washington University in St. Louis and six sigma from Villanova, as well as master certificates in business management and marketing from Tulane.

"NUBURU's blue laser technology brings improvements in metal processing, unlocking critical advantages to manufacturers across industries," comments Faircloth.

Dodd, who is a 30-year veteran of the laser development and material processing industries, joined NUBURU in 2019 as the North American market development manager and has recently been promoted to VP of global sales as the firm enters this new growth phase. NUBURU says that, since joining it, Dodd has been instrumental to laying the foundations for commercial expansion, and that he brings global sales leadership and a strong track record from his tenures at GSI Lumonics, Amada WeldTech, and BLM Group North America.

"As electrification and advances in manufacturing drive growth in our target markets, this capital infusion, appointment of Mr Faircloth as COO and Mr Dodd's promotion to VP of global sales ensures continued momentum for NUBURU," says CEO, co-founder & chairman Dr Mark Zediker. "Looking ahead, we are focused on growing our customer base, expanding our distribution channels, accelerating development of our ultra-high-brightness product family, and scaling our manufacturing operations to meet demand globally."

www.nuburu.net

NUBURU names Ron Nicol as executive chairman

NUBURU has appointed Ron Nicol as executive chairman. Nicol also sits on NUBURU's board of directors and brings over 40 years of management experience to the firm. He held numerous management positions in the Boston Consulting Group (BCG), where he led its North, Central and South American business, as well as the global technology practice. During his time at BCG, Nicol managed major business transformations with a number of Fortune 50 companies. He specializes in strategy development, organization transformation, merger and acquisition advice, and the development of major cost-reduction programs.

Executive chairman Ron Nicol.

Prior to joining BCG, Nicol was an executive with Babcock and Wilcox. He is a former naval nuclear submarine officer and graduate of the US Naval Academy with a degree in Physics. He also holds an MBA from Duke University's Fuqua School of Business. Later in his career he served as chairman of Fuqua's board of visitors and was named Chairman Emeritus.

"NUBURU's high-power, high-brightness blue laser technology will revolutionize the world of laser welding and 3D printing," believes Nicol. "I am excited to continue working with the NUBURU team in a deeper capacity to further enhance the company's market approach and strategic direction."

TRUMPF and Metalenz demonstrate VCSELs with stable polarization for smartphone illumination

Consumer electronic devices need less than half components

At the Photonics West 2022 event in San Francisco (22–27 January), TRUMPF Photonic Components GmbH of Ulm, Germany (part of the TRUMPF Group) — which manufactures vertical-cavity surface-emitting lasers (VCSELs) and photodiodes for the consumer electronics, datacoms, industrial sensing, heating and automotive markets — presented a live showcase on VCSELs with controlled polarization for illumination applications.

TRUMPF says that it is building on more than 15 years of experience in the production of polarization-stabilizing gratings. Together with Metalenz, a Boston-based pioneer in designing and commercializing meta-optics, TRUMPF has demonstrated how next-generation consumer electronic devices benefit from smaller and smarter components.

Both companies demonstrated that, with their new components, in future only half or even less optical components are needed to support bright, 3D scene illumination of smartphone cameras. Not only the amount of components but also the space between components can be reduced. Smartphone makers can hence gain a competitive advantage from these compact components, it is reckoned.

Multiple functions integrated on one VCSEL chip

The showcase at Photonics West demonstrated how to easily switch between two illumination patterns using a limited number of optical components. By using a VCSEL with stable and advanced linear polarization and putting meta-optics on top of the VCSEL, only two smart components are required to create both the function of flood illumination as well as the structured light illumination.

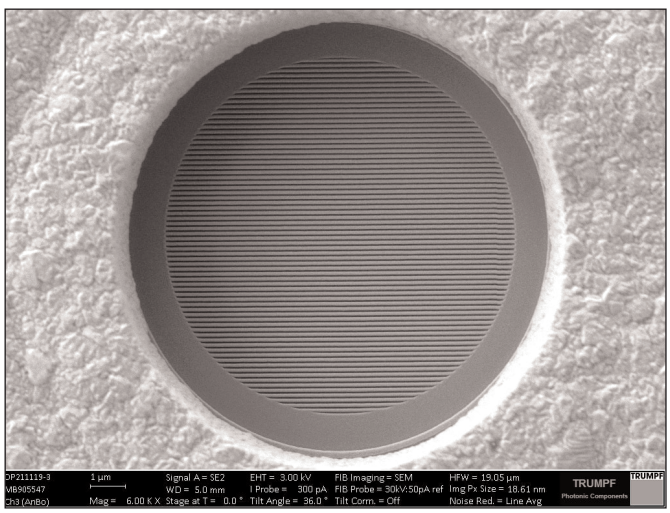
Next generation of polarized VCSEL

TRUMPF has developed the patented technology of VCSELs with stable polarization, which is locked by a surface grating that is directly etched into the gallium arsenide (GaAs). Polarized VCSELs achieve almost 100% of the efficiency compared to standard VCSELs, regarding a slope efficiency of 1W/A. The high quality is based on TRUMPF's own designs and processes to realize extremely low losses.

The design of the VCSEL can come with a single mesa or as an array. "With our development of polarized VCSELs we are addressing demanding 3D illumination applications not only in smartphones but also in OLED screens or in virtual reality (VR) and augmented reality (AR) applications. Market release of our next-generation, advanced polarized VCSEL is intended to be in 2023", says TRUMPF Photonic Components' CEO Berthold Schmidt.

"Working together with Metalenz enables us to visualize the promising solution for illumination within smartphone devices," he adds. Not only the form factor and the optical system complexity can be reduced by the next generation of VCSEL in combination with the right optics, but also the illumination quality is improved by the controlled light. The laser light is only projected to where it is needed, so the resolution is increased, even for longer distances, and overall power savings can be reached. The laser components in a smartphone can be used for illumination applications such as face recognition, 3D mapping or camera autofocus.

"Together with the VCSEL from TRUMPF we show how two leading-edge technologies can revolutionize the technical standards in smartphones for light illumination," says Carlos Calvo, VP of product at Metalenz. "We are happy to demonstrate the high quality in illumination together with TRUMPF. The laser diodes and our meta-optic technology are a perfect complement."



www.trumpf.com

PCSEL firm Vector Photonics appoints process engineer

Joao Valente to help develop high-yield processes and high-performance devices

Vector Photonics has appointed Dr Joao Valente as process engineer, bringing extensive knowledge of the micro- and nano-fabrication of optoelectronic devices to the firm.

"Dr Valente is both a material scientist and engineer, with outstanding experience and expertise in semiconductor device fabrication and characterization," comments Dr David Childs, director of product development. "This unique skill set has led to his involvement in the development of many innovative, epitaxial growth and silicon substrate nanofabrication concepts, at the cutting edge of semiconductor device manufacture. He will help Vector Photonics develop high-yield processes and high-performance devices, as we continue to commercialize our PCSEL technology during 2022."

New process engineer Dr Joao Valente.

Joao most recently held research assistant roles at the University of Glasgow, James Watt Nanofabrication Center; University College London, Electronic and Electric Department; and the University of Southampton, Optoelectronics Research Centre; advancing photonic nano-fabrication and characterization performance.

Joao's PhD, from the University of Southampton, titled 'Controlling Light with Plasmonic Metasurfaces', led to several breakthroughs in the coherent control of light and demonstrated a new magneto-electro-optical effect in reconfigurable plasmonic metamaterials. His European Masters in Material Science and Engineering, improved understanding of production techniques in high-dielectric thin films, and his degree from the Universidade Nova de Lisboa, focused on the optimization of TCO films for microelectronic devices.

www.vectorphotonics.co.uk

Nominated for 'Early-Stage Deal of the Year' award

Photonic-crystal surface-emitting laser (PCSEL) firm Vector Photonics Ltd of Glasgow, Scotland, UK was a finalist at the Scottish Business Insider 'Deals & Dealmakers Awards' in Glasgow.

The Deals & Dealmakers Awards 2020/21 acknowledge and reward excellence in corporate finance transactions. They recognize the bankers, venture capitalists, lawyers and accountants who initiate, structure and negotiate investments essential to business growth success. Judging of the awards is conducted by an independent panel of experts.

"We are honoured that Foresight Williams, an investor in Vector Photonics, nominated us for the 'Early-Stage Deal of the Year' award," says CEO Neil Martin. "We are one of only two companies shortlisted for the award, which recognizes the quality of the investment capital; the level and quality of the syndication; the scale of the market opportunity; the potential return for investors; and the role of the management team in successfully realizing the investment," he adds.

www.vectorphotonics.co.uk

Vector Photonics appoints design engineer

PCSEL device simulation to accelerate entry into datacoms, additive manufacturing and 3D printing markets

Vector Photonics has appointed Anna O'Dowd as design engineer, responsible for the simulation development for its all-semiconductor PCSEL devices. O'Dowd has a first-class degree in Physics with Particle Physics and Cosmology from Lancaster University, where she was the course representative and physics ambassador. She recently graduated from the University of Glasgow with an MSc in Nanoscience and Nanotechnology.

"Anna's impressive mathematical, analytical, problem-solving and computational skills were apparent whilst she worked at Vector Photonics on her University of Glasgow MSc research project 'Simulation of the Band Structure of PCSELs'," comments chief technology officer Dr Richard Taylor. "Now, as a staff member, we will continue to develop her research expertise, RSoft CAD modeling experience and nanofabrication lab skills. We also hope her particle physics background will help us develop new levels of granularity in the simulation of our PCSELs, accelerating our entry into next-generation datacoms, additive manufacturing and 3D printing markets."

O'Dowd was previously implementation lead at Enable International, configuring and implementing DealTrack rebate management software worldwide, including running the new San Francisco office.

POET named to 2022 OTCQX Best 50

Firm joins ranking of top 50 US and international companies traded on OTCQX market

POET Technologies Inc of Toronto, Ontario, Canada — a designer and developer of the POET Optical Interposer and photonic integrated circuits (PICs) for the data-center and telecom markets — has been named to the 2022 OTCQX Best 50, a ranking of top-performing companies traded over-the-counter on the OTCQX Best Market last year.

The OTCQX Best Market offers trading of established, investor-focused US and global companies. To qualify for the OTCQX market, companies must meet certain financial standards, follow best-practice corporate governance, and demonstrate compliance with applicable securities laws.

The OTCQX Best 50 is an annual ranking of the top 50 US and international companies traded on the OTCQX market. The ranking is calculated based on an equal weighting of one-year total return and average daily dollar volume growth in the previous calendar year. Companies in the 2022 OTCQX Best 50 were ranked based on their performance in 2021.

"During the past year, the company made significant commercial progress and achieved a number of milestones, including the introduction and demonstrations of multiple new products based on POET's Optical Interposer platform, the shipment of samples to customers as well as the securing of initial design wins and purchase orders," notes POET's executive VP & chief financial officer Thomas Mika. "Additionally, we successfully established collaborative development and supply agreements with key industry partners, and the company meaningfully improved its cash position," he adds. "We look forward to extending the company's growing momentum in 2022 as we continue to execute on the commercial ramp of POET's technology."

The company made significant commercial progress and achieved a number of milestones, including the introduction and demonstrations of multiple new products based on POET's Optical Interposer

www.poet-technologies.com

POET to supply Celestial AI with Optical Interposer-based integrated light engine modules

Deal includes contract for continued platform development, plus purchase order for initial quantities

POET Technologies has entered into an agreement with Celestial AI of Santa Clara, CA, USA to provide multi-laser integrated external light source (ELS) modules using its advanced packaging platform based on the POET Optical Interposer. The agreement includes a contract for continued platform development, along with a purchase order for initial quantities of the modules.

Celestial AI is an artificial intelligence accelerator company that has a proprietary technology platform that enables the next generation of high-performance computing solutions. Celestial AI's mission is to transform computing efficiency with its Photonic Fabric technology platform, which uses light for data movement both within chip and between chips.

"The customized Optical Interposer platform that we have co-developed with POET is among the most advanced of its kind in high-speed computing," reckons David Lazovsky, founder & CEO of Celestial AI. "POET's light engines provide us with precision optical power sources in a highly integrated form factor that meet the requirements for our Orion AI accelerator products." Celestial AI's Orion AI accelerator products serve the AI chipset market that is projected by Omdia to exceed $70bn in 2025.

"We are truly excited to take the next step with Celestial AI, one of the leading technology companies in this burgeoning field, to create a highly differentiated means to co-package electronics and photonics and help overcome the fundamental challenges of speed and power faced in high-performance computing," says POET's chairman & CEO Dr Suresh Venkatesan. "The challenges in this application are precisely those that the POET Optical Interposer was designed to overcome. They are the same as those faced by datacom and telecom companies as they seek to co-package electronics and optics and to achieve data transmission speeds of 3.2 and 6.4Tbs across a number of channels with multiple wavelengths, with lower energy consumption and higher stability," he adds. "The multi-laser integrated external light source developed for this application has direct applicability to other products in data communications and sensing."

II-VI grows revenue, despite supply-line and COVID-related constraints

Bookings up 21% year-on-year to record $1.1bn

For its fiscal second-quarter 2022 (ended 31 December 2021), engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA has reported revenue of $806.8m, up 1.5% on $795.1m last quarter and 2.6% on $786.6m a year ago.

"But for increased supply-line and COVID-related constraints that accelerated throughout the quarter, we would have cleared the high end of our revenue guidance [$790–840m]," says chair & CEO Dr Chuck Mattera Jr.

By business segment, Photonic Solutions revenue fell from $536m last quarter to $525m, whereas Compound Semiconductors grew from $259.1m to $281.8m.

Products for the industrial and communications markets led growth year-on-year. "The two largest drivers of the revenue gaps were from ROADMs and transceivers," notes Mattera.

Revenue in the industrial market was up 6% sequentially and 47% on a year ago. "In Industrial, again we experienced sustained increases in orders and demand for our laser components, including for CO_2 lasers and fiber lasers," says Mattera. The firm shipped a 100MW of pump laser power for fiber lasers (a new quarterly output and utilization record for its 6-inch wafer platform).

"We experienced explosive increases in orders from the semiconductor capital equipment ecosystem [for which revenue was up 34% year-on-year], including from equipment OEMs and their tier-1 suppliers," says Mattera. "The industry relies strongly on our highly differentiated materials, including polycrystalline diamond, reaction-bonded ceramics and metal matrix composite for extreme UV and deep UV lithography, as well as wafer stages and chucks for front-end fab equipment and specialty thermal management components, enabling advanced packaging and testing capabilities," notes Dr Giovanni Barbarossa, chief strategy officer & president of the Compound Semiconductor segment. "Our differentiated position met accelerated demand from the OEMs in the semi cap equipment front-end and back-end wafer fab and laser-based inspection platforms. These expansions have spurred further increases in our already large manufacturing capacity investments, and these will accelerate throughout calendar year 2022," Mattera says. "We maintain intimate partnerships with leading companies up and down this ecosystem, where we are providing unique and vital components, which are sourced solely from II-VI, including and especially for the EUV lithography tool supply chain. This is helping the leading IC producers have confidence in the returns on their investments, as they expand the much needed capacity in order to eventually clear the current IC supply-chain shortages," continues Mattera. "Demand for our products is strengthening as we expected, because of the massive investments underway in new semiconductor wafer fabs worldwide," says Barbarossa.

Silicon carbide (SiC) revenue grew 11%, both year-on-year and sequentially. "We saw very strong demand for power electronics applications, with revenue doubling sequentially and increasing by an order of magnitude compared to the same quarter in fiscal-year 2021," notes Barbarossa.

Communications revenue grew 6% year-on-year, with most of the growth from datacoms (particularly high-data-rate transceivers).

Datacom business saw "exceptional" growth, up 9% sequentially. "We experienced increased demand for datacom transceivers and open-line systems driven by the cloud and large enterprise customers," says Mattera. "The strong demand for transceivers in hyperscale data centers and artificial intelligence (AI) superclusters continues unabated… with exceptional progress on 200G and 400G output and our early ramps for 800G for a very large and growing strategic customer," he adds. "200, 400 and 800Gb/s transceivers grew 25% sequentially (reaching a third of datacom revenue — ahead of schedule — up from just 2% a year ago), a "clear sign of share gain across all high-data-rate transceivers," says Barbarossa. "We are very excited to be able to best support our customers with higher data rates, particularly hyperscalers in their build-out of AI superclusters in a market which industry analysts are projecting to grow by 20% in calendar 2022, and will continue to experience double-digit growth for at least another 3–5 years," he adds.

II-VI also reported its first design win and revenue from its clock & data recovery (CDR) IC, a "clear sign of the competitiveness of our captive IC platform, which we made available to the merchant market as part of our integration of Finisar [acquired in September 2019]," notes Barbarossa.

"We also saw a strong increase in demand from the telecom equipment customers and a clear sign of the start of a ROADM demand ramp that we expect will accelerate during calendar year 2022 as the increased availability of ICs materializes from legacy supply lines and new ones that we are collaborating with closely along with our customers to accelerate qualification," says Mattera. "The beginning of a multi-year upgrade of the US cable TV infrastructure provided for a large and long-term contract, and

is also among our exciting growth drivers, based on major fiber-deep initiatives to improve rural broadband access in the USA," he adds.

"With regard to transport networks, last quarter we announced our engagement with Windstream Wholesale," says Barbarossa. "We are pleased to report the initial shipments of our 400G-ZR+ digital coherent optics (DCO) in the QSFP-DD form factor, the first of its kind to enable IP-over-DWDM, thanks to its 0dBm out power performed by our indium phosphide component technology," he adds.

"Our Consumer business led our sequential growth [up 23%] and represented 9% of our sales this quarter, our third largest revenue by market," notes Mattera. "The competitiveness of our VCSEL [vertical-cavity surface-emitting laser] platform continues to be a winning factor in the market, and we are pleased to report the third consecutive quarter of zero-defect parts per million shipped, a world-class quality performance achieved by our team in Sherman, Texas," says Barbarossa. "On the sensing technology front, we've always emphasized the advantages of indium phosphide (InP) over gallium arsenide (GaAs) for some application-specific optoelectronics products. We are leading the consumer electronics and automotive market development with significant customer commitments and investment to date in our indium phosphide fabs," he adds. "In the emerging metaverse or virtual- and augmented-reality applications, customer engagements are gaining momentum, opening up exciting opportunities for our broad spectrum of technology platforms. Specifically, a new customer for AR/VR applications has committed to fund us with about $50m for the development and production of a broad range of new products, including lasers, diffractive optics and advanced materials. Several strategic customers are beginning to realize the unique value of the one-stop-shop offering we provide with the depth and breadth of our portfolio and the promise of our long-range roadmaps."

On a non-GAAP basis for fiscal Q2/2022, gross margin was 40.3%, down on 42% a year ago but up from 39.8% last quarter.

Operating expenses (OpEx) were $166m (21% of revenue). Cost synergies for the Finisar acquisition, originally targeted at $150m, have now reached nearly the $200m stretch target six months early. Savings in both the cost of sales and OpEx contributed to the over-delivery and have contributed to the rise in margins this year so far.

"This cost control in turn required a continuous optimization of the supply chain, including building inventories at strategic points along our vertically integrated supply chain," says Mattera. "This resulted in our inventory levels increasing again in the quarter, as we continued our focus on serving our customers in the face of COVID and to mitigate the impact of the extended lead times and other related disruptions from the supply chain." There was hence a strategic inventory build of $50m in the quarter ($100m for the first half of the fiscal year) to support growth beginning in fiscal second-half 2022.

Operating margin was 19.7%, down on 22% a year ago but up from 18.9% last quarter. By business segment, Photonic Solutions operating margin has fallen further, from 17.4% a year ago and 15.7% last quarter to 14.6%, whereas Compound Semiconductors rose from 25.6% last quarter to 29.2% (almost level with 29.3% a year ago).

Net income was $124.1m ($0.92 per diluted share), down on $131.2m ($1.08 per diluted share) a year ago but up from $117.7m ($0.87 per diluted share) last quarter — and near the top end of the guidance of $104–128m ($0.75–0.95 per diluted share) — enabled by a strong focus on controlling cost increases and on ratcheting of factory utilization and output. Return on sales was up from 1 4.8% of revenue to 15.4%.

Operating cash flow was $188m. Capital expenditure (CapEx) was $55m. Free cash flow was hence $133m.

During the quarter, II-VI paid down $30m of debt, and retired the remainder of the Finisar 2036 notes. The net cash position is now $329m. Liquidity at end-December 2021 was $3.1bn.

"We continue to see greater opportunities with a broader set of products in an expanding range of depth sensing applications, in consumer electronics, industrial and automotive markets," says Mattera.

For the first time, order bookings exceeded $1.1bn. Order backlog has hence risen to a record $1.7bn (consisting of $1.22bn for Photonics Solutions and $484m for Compound Semiconductors) — up by more than 20% ($300m) from about $1.4bn last quarter and by 58% ($600m) from $1.08bn a year ago — due to rising demand, particularly from the industrial end-market and across the communications end-market.

For fiscal third-quarter 2022 (to end-March 31), II-VI expects revenue of $785–825m and earnings per share of $0.75–0.95.

"Backlog is supported by our capacity additions, along with the planned launches of new products from both segments," says Mattera. "This gives us confidence in our double-digit growth projections beyond this fiscal year."

For fiscal 2022, II-VI now expects CapEx to be $325–375m, driven largely by its expansion of silicon carbide and indium phosphide to address the growth in power devices, communications and consumer applications. "Our capital allocation of R&D and CapEx this year is more heavily weighted to the compound semiconductor segment, given our growth aspirations for fiscal-years 2023 and 2024," says Mattera. "We expect the totality of the company's investments to contribute to the sustained growth in fiscal-year 2022, and we expect to significantly drive our target of

double-digit organic growth in both 2023 and in 2024 by a combination of continued market growth and share gains across our Photonics Solutions and Compound Semiconductors customers," he adds.

"We expect to see our substrate business continue to grow," says Barbarossa. "We have started pre-production of gallium nitride on silicon carbide (GaN-on-SiC) amplifiers on our 6-inch substrates in our Warren, New Jersey fab, with full production planned by the end of March," he adds.

Also, II-VI recently qualified its own 1200V silicon carbide MOSFET product platform to automotive standards using 150mm SiC substrates and the device technology that it licensed from General Electric [in June 2020]. "I am excited about this important milestone that we met ahead of an aggressive schedule. We expanded our relationship with GE to accelerate the next phase of commercialization in industrial, renewable energy, and automotive," says Mattera. "We will continue to focus on shortening our time to market and underpinning this platform with capacity and diameter expansions to help position our company as a market leader," he adds. "Our investments in silicon carbide are underway and encompass a variety of applications and vertical end-markets," says Barbarossa.

Also: "We are pleased to have recently kicked off an exciting partnership with Element Six to complement our world-leading polycrystalline diamond platform with a single-crystal capability that will considerably broaden the range of advanced applications we will be able to sell," adds Barbarossa.

Finally: "We were excited to receive the 2021 Supplier Award from Han's Laser in recognition of our world-class products for fiber laser applications, which will continue to drive our growth, particularly after the merger with Coherent."

The pending acquisition of Coherent of Santa Clara, CA, USA (which provides lasers and laser-based technology for scientific, commercial and industrial applications) has received the approval (or indication of imminent approval) from three out of four global anti-trust regulatory authorities, which are conditions to the closing of the transaction. "In China (the remaining jurisdiction) II-VI and Coherent are continuing to work constructively with the State Administration for Market Regulation (SAMR), and now anticipate closing the acquisition by the middle of the second calendar quarter of 2022," concludes Mattera.

400G ZR+ QSFP-DD-DCO transceivers for Windstream

II-VI has shipped its 400G ZR+ QSFP-DD-DCO transceivers — claimed to be the first with 0dBm output power — to Windstream Wholesale for field qualification.

In October, II-VI and Windstream announced their partnership to fast-track the development of high-output-power 400G transceiver technology that enables Windstream to deploy greatly simplified network architectures. II-VI's 400G transceivers are claimed to be the first digital coherent optics with the highest optical output power of 0dBm that can plug directly into QSFP-DD transceiver slots on IP routers. Windstream can leverage this technology to optically connect routers directly to access, metro and regional DWDM transport networks without additional intermediary interfaces, eliminating an entire layer of optical equipment and thereby significantly reducing both capital and operational expenditures.

"We're excited to begin qualification with Windstream ahead of our original schedule," says Matthias Berger, VP, coherent technology, II-VI Inc. "This 400G transceiver is based on our advanced and proprietary indium phosphide (InP) technology, which is uniquely suited to achieve high output power levels of 0dBm while remaining within the power consumption requirements of QSFP-DD," he adds.

"This 400G transceiver is truly a game-changing technology that will make IP-over-DWDM a reality on Windstream's ICON network," comments Windstream's chief network officer Buddy Bayer. "II-VI moved at an accelerated pace to deliver these transceivers, putting us on track to expand 400G wavelength services to large wholesale and hyperscale customers as early as the second half of calendar 2022. Our 'fast and flexible' approach is demonstrated once again through the right strategic partners."

Windstream's Intelligent Converged Optical Network (ICON) provides open and disaggregated networking infrastructure, enabling wholesale and enterprise technology customers to select unique custom routes, maintain operational insights with Windstream's Network Intelligence functions, and place their networks closer to the edge to better serve end-users.

II-VI's 400G ZR+ QSFP-DD-DCO transceiver was honored as a Lightwave Innovation Reviews High Score Recipient in the category 'Optical Transceivers and Transponders'. This 400G transceiver is built on II-VI's IC-TROSA 64Gbaud coherent optical subassembly, which features a high-efficiency InP modulator and receiver combined with a built-in tunable laser that delivers what is claimed to be best-in-class transmission performance and high optical output power and achieves the transmitter in-band and out-of-band optical signal-to-noise ratio (OSNR) requirements established by the OpenROADM standard.

www.windstreamwholesale.com

II-VI unveils pluggable optical line subsystem in QSFP form factor

QSFP-LS targeted at eight-channel 400ZR/ZR+ transport in data-center interconnects

II-VI Inc of Saxonburg, PA, USA, which provides optical communications solutions for datacom and telecom networks, has launched its pluggable optical line subsystem (POLS) in the small QSFP form factor for eight-channel 400ZR/ZR+ transport in data-center interconnects (DCIs).

The aggressive buildout of mega-datacenters is driving an exponential increase in DCIs and fueling the demand for optical transport systems that are more compact and power-efficient, as well as easier to install, configure and operate, notes the firm. The new POLS product, the QSFP-LS, is designed in the very compact QSFP form factor that plugs directly into a switch or router QSFP port, transparent to the port speed, and enables full-duplex multi-channel 400ZR/ZR+ transport, including multiplexing, demultiplexing, and variable-gain amplification. The QSFP-LS supports up to eight DWDM wavelengths at 400Gbps, or 3.2Tbps per fiber pair.

"In the last several years, we've led the industry in offering breakthrough solutions at scale of our miniature optical amplifier components, including our flagship 3-pin uncooled micro-pump," claims chief marketing officer Dr Sanjai Parthasarathi. "These components are now the building blocks that differentiate our POLS platform," he adds. "The QSFP-LS is one of our most advanced integrated products and the tiniest open line system on the market. It's about one-fifth the size of similar amplifier module technology ten years ago and consumes one-third the power, enabling it to remain within the maximum power-dissipation requirements for any QSFP socket. Compared to similar functionality in a dedicated rack-mounted line system, the QSFP-LS consumes about half the amount of power, is about a fifth of the cost, and occupies orders of magnitude less space," says Parthasarathi.

II-VI expanded its POLS platform by adding the QSFP-LS to the OSFP-LS, which was introduced in March 2020. The availability of POLS in both the QSFP and OSFP form factors provides a universal optical amplifier building block that is compatible with some of the most widely available plug-in sockets in switches and routers.

"With the original OSFP-LS and now the QSFP-LS available, we have a greatly simplified transport solution that eliminates the need for dedicated rack-mounted line systems, which will significantly reduce the number of network elements to be installed, powered up, configured, and monitored," says Martin Hull, VP of platform products at Arista Networks. "POLS technology represents a paradigm shift in data-center interconnects that is complementary to and on par with the advent of 400ZR/ZR+ pluggable transceivers, in terms of greater equipment density, lower power consumption, and pay-as-you-grow flexibility that now extends to QSFP ports."

The QSFP-LS extends II-VI's family of pluggable modules for coherent transmission, including the 400G ZR+ QSFP-DD-DCO transceiver, which was recently honored by Lightwave Innovation Reviews. II-VI is highlighting the applications and benefits of both products on a panel at a webinar 'Deploying IP over DWDM with 400 ZR+' hosted by Cignal AI on 24 February.

www.ii-vi.com

II-VI wins Excellent Supplier Award from Han's Laser

Performance and reliability of high-power laser diode pump chips and seed modules recognized

II-VI Inc has received the Excellent Supplier Award 2021 from Shenzhen Han's Laser Diodes Technology.

The award was presented to II-VI on 24 December by Han's Laser Diodes Technology general manager Jian Li in recognition of the excellent performance and reliability of the supply of II-VI's high-power laser diode pump chips and seed modules.

"Global customers like Han's Laser are leveraging our competitiveness and ability to scale to a vertically integrated 6-inch platform over the last few years," says Dr Karlheinz Gulden, senior VP, Laser Devices and Systems business unit.

II-VI's pump laser diodes are offered as bare dies and mounted chips, and seeds as fiber-coupled 10-pin or 3-pin modules. The firm's broad portfolio of components for industrial lasers includes acousto-optic modulators, fiber Bragg gratings, kilowatt pump and signal combiners, as well as IBS-coated laser optics and micro-optics for high-power isolators.

www.ii-vi.com

Lumentum's revenue falls 6.7% year-on-year to $447m

COVID-boosted supply shortages lead to $50m of unfulfilled demand

For its fiscal second-quarter 2022 (ended 1 January), Lumentum Holdings Inc of San Jose, CA, USA (which designs and makes photonics products for optical networks and lasers for industrial and consumer markets) has reported revenue of $446.7m, down by 6.7% $478.8m a year ago and by 0.4% on $448.4m last quarter.

Demand was strong across all major product lines, but Lumentum was supply constrained across many of them. "Accelerating telecom and datacom market demand is coming at a time when the supply environment is very dynamic and challenging," says president & CEO Alan Lowe. "Supply had been improving heading into and throughout the bulk of the second quarter. However, late in the quarter, the latest pandemic surge once again negatively impacted supply. This contributed to a $50m gap between the supply of material and customer demand," he adds.

Despite this, results were still above the midpoint of guidance on all metrics (e.g. $435–455m for revenue).

Commercial Lasers segment revenue was $49.3m (11% of total revenue), up 16.3% on $42.4m last quarter and 66% on $29.7m a year ago. Strength in lasers for manufacturing of semiconductor and consumer electronics as well as life science applications complemented the strength in fiber lasers for macro material processing. "Demand for our commercial lasers has never been stronger as industrial factories and semiconductor fabs expand and upgrade their capability," says Lowe.

Optical Communications segment revenue was $397.4m (89% of total revenue), down 2.1% on $406m last quarter and 11.5% on $449.1m a year ago.

The sequential drop was due to the expected 3D sensing seasonality in Industrial & Consumer business (down from $190m to $130.3m).

This was partially offset by Telecom & Datacom revenue, which was still down on $286.2m a year ago but rebounded sharply from $216m last quarter to $267.1m due to strong growth in both Telecoms (with exceptional strength in nearly every product line) and Datacoms (with record revenue from externally modulated lasers (EMLs) — up 45% year-on-year by — serving high-speed cloud data-center applications).

"Revenue from high-speed 400G-and-above coherent components and modules nearly doubled quarter on quarter. As 5G, 4K streaming, and network access requirements increase, the speed at the edge of the network must also increase and the core of the network must upgrade to higher speeds as well," says Lowe. Transceivers serving edge applications were up more than 60% quarter on quarter and more than 130% year on year. Pump laser sales grew more than 30% sequentially to a new all-time high.

"Next-generation customer systems are just hitting an inflection point as new multi-year network deployments are just starting to ramp," says Lowe. "Our cloud and networking customers are entering a multi-year hardware upgrade cycle and rely on our leading-edge photonics as their fundamental enabling technology," he adds. "We are broadening the applications of our 3D sensing lasers beyond mobile handsets into automotive driver-assistance designs, and AR/VR [augmented reality/virtual reality] applications."

We are broadening the applications of our 3D sensing lasers beyond mobile handsets into automotive driver-assistance designs, and AR/VR applications

On a non-GAAP basis, gross margin was 51%, down from 55% last quarter and 53.4% a year ago. In particular, Optical Communications segment gross margin was 50.8%, down on 55.6% last quarter and 53.8% a year ago, due primarily to the change in product mix. Commercial Laser segment gross margin has risen further, from 47.5% a year ago and 49.1% last quarter to 53.1%, due to higher volumes.

Operating expenses were $86.4m (19.3% of revenue), cut slightly from $87.8m (19.6% of revenue) last quarter.

Operating income has fallen further, from $169.9m (operating margin of 35.5% of revenue) a year ago and $158.9m (35.4% margin) last quarter to $141.6m (31.7% margin, although this is towards the top end of the 30–32% guidance range).

Likewise, net income has fallen further, from $145.4m ($1.85 per diluted share) a year ago and $135.1m ($1.79 per diluted share) last quarter to $120.2m ($1.60 per diluted share, towards the top end of the $1.47–1.64 guidance range).

Cash generated from operations was $206.5m. During the quarter, Lumentum used $29.9m to repurchase 330,000 shares of its common stock. (Since the two-year, $700m share buyback program was approved by the board of directors in May 2021, the firm has repurchased 4.5 million shares for a total $362.6m.)

Overall, total cash, cash equivalents and short-term investments rose by $137.8m during the quarter, from $1884.6m to $2022.4m.

"Industry-wide supply shortages [of semiconductors and other materials] have worsened with the recent surge in COVID-19 [in January]," says Lowe. "We expect shipments of products that rely on third-party supplied semiconductors will be the primary driver of supply constraints. The demand from our

customers has also recently accelerated… This will increase the gap between supply and demand, resulting in more than a $65m impact to our projected revenue in Q3. We expect telecom and datacom revenue to be modestly down quarter on quarter".

Industrial & Consumer revenue will also be down sequentially, due primarily to normal consumer product seasonality.

Hence, for fiscal third-quarter 2022 (to end-March), Lumentum's revenue should fall to $375–405m. This is despite Commercial Lasers growing again sequentially (driven by growth in new products and the overall market). Operating margin is expected to fall to 24–26%, and diluted earnings per share should drop to $1.01–1.19.

"Shortages come at a time when customer demand is accelerating for our differentiated communications products, which are essential to multi-year expansions in next-generation optical network capacity that are just beginning to be deployed," says Lowe. "Book-to-bill for telecom products exceeded one for the quarter, and we have more than two quarters of datacom backlog already booked," he adds.

"We continue to work diligently with our suppliers and on alternative sources of supply to alleviate shortages, and expect [fiscal] fourth-quarter revenue to be up from that of the third quarter and supply shortages to improve by the second half of this calendar year," says Lowe. "Looking beyond these near-term supply challenges, I am highly optimistic about our outlook," he adds.

"Elevated pump [laser] shipments frequently have been a leading indicator of future telecom demand. Another leading indicator of telecom demand is optical fiber deployments for networks. Significant investments in fiber infrastructure are underway as operators expand capacity, capability, and access."

"We expect to bring additional EML manufacturing capacity online in March, which will help us ramp our datacom shipments through this calendar year to fulfill strong customer demand of our differentiated products," says Lowe. EML revenue should rise by 10% in the March quarter, then grow more significantly in the June quarter.

Industry-wide supply shortages have worsened with the recent surge in COVID-19. We expect shipments of products that rely on third-party supplied semiconductors will be the primary driver of supply constraints. The demand from our customers has also recently accelerated… This will increase the gap between supply and demand, resulting in more than a $65m impact to our projected revenue in Q3

"These points, along with our design wins and long-term share and supply agreements with market-leading customers, gives us confidence that we have a strong long-term outlook in Telecom & Datacom," says Lowe.

"An important element of Lumentum's 3D sensing and LiDAR product strategy is to deploy our platforms into new markets and applications. We recently announced two new automotive customer wins," notes Lowe. "The first was a partnership with Hesai, who is making all solid-state LiDAR modules for ADAS applications, leveraging our differentiated high-power multi-junction VCSEL arrays. Also, we have begun mass production of a VCSEL solution with Stanley Electric used for in-cabin driver and occupant monitoring," he adds. "These announcements complement other design wins and opportunities in our funnel. A broad range of customers are increasingly relying on our enabling technology for their critical LiDAR and in-cabin monitoring systems. We have strong customer traction in augmented- and virtual-reality opportunities that we expect will come to market in the next few years. Most AR/VR applications will employ multiple lasers. The use-cases for these lasers include eye tracking, hand tracking or gesture recognition, and world-facing imaging applications. Customers in this space value our differentiated products as well as our unparalleled experience, quality and reliability track record, and scale in the industry as targeting high-volume and high-performance applications."

Also, Lumentum expects its Commercial Lasers quarterly revenue to surpass its previous record as the business grows over the coming year.

"Market inflections beneficial to us in all of our addressable markets will drive double-digit revenue growth in fiscal 2023 and beyond, not including the pending acquisition of NeoPhotonics [announced in November]" believes Lowe.

"The combination gives us a more complete product and technology portfolio. This enables our customers to address their next-generation cloud and networking speeds and scalability requirements," says Lowe regarding NeoPhotonics. "We have made excellent progress with our integration planning and are on track with the previously announced closed time line," he adds. "Two key closing conditions are now satisfied. On 21 January, we announced that we have received US antitrust clearance. Just two days ago, NeoPhotonics shareholders approved the transaction in a special meeting of their stockholders. We are working diligently with anti-trust authorities in China and our expectations of closing the transaction in the second half of calendar 2022 remain unchanged."

www.lumentum.com

University of Surrey produces record strain in single-crystal silicon

A single-step ion implant procedure is next to be transferred to germanium, targeting CMOS-compatible lasers.

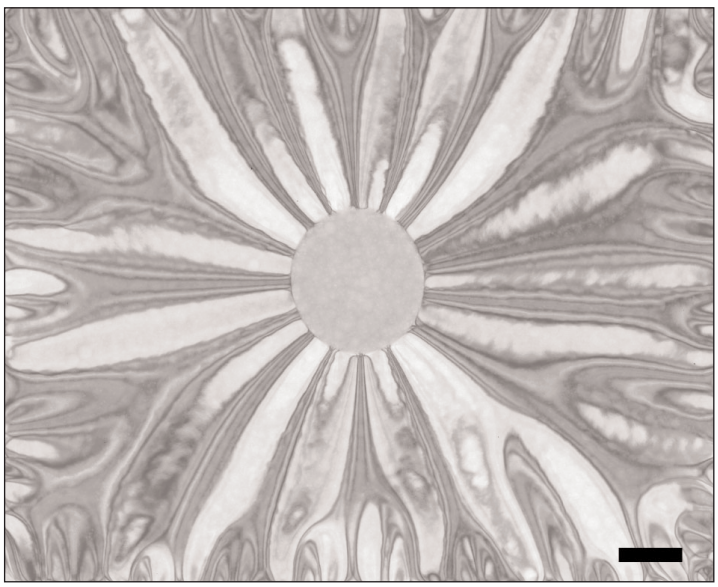
University of Surrey researchers have developed a single-step procedure to put single-crystal silicon under more strain than has been achieved before (Mateus G. Masteghin et al, 'Stress-strain engineering of single-crystalline silicon membranes by ion implantation: Towards direct-gap group-IV semiconductors', Phys. Rev. Materials 5, 124603, 21 December 2021). The discovery (which has a patent pending) could be crucial to the future development of silicon photonics, it is reckoned, which is currently constrained by the lack of cheap, efficient and easily integrated optical emitters.

Now, the Surrey-based researchers are transferring the same procedure to germanium. If successful, they could open the door to creating germanium lasers, which are compatible with silicon-based computers, and could yield new optoelectronic devices for communications systems. This would address the problem of overheating, which is becoming a threat to development in silicon-based computer systems, and would eliminate the need to develop expensive and difficult-to-integrate III–V devices (a popular area of research to try to overcome overheating).

Moving photonics fully onto silicon has been a long-held goal. While there have been many successes in developing passive silicon photonic devices, a laser that is CMOS-industry compatible, using elements from the same group of the periodic table, has remained elusive until now. The team was recently awarded a New Horizons project grant by the UK Engineering and Physical Sciences Research Council (EPSRC) to exploit their innovation and progress their work.

The new approach is also an important step towards creating near-infrared sensors that could pave the way to developing more sophisticated smartphones — e.g. fitting them with fire alarms and carbon monoxide sensors.

The new paper in Physical Review Materials describes how the team generated strain via ion implantation in suspended membranes in a similar manner to tightening a drum skin. The effect is created by a downward bowing of the implanted region because of a still crystalline layer beneath the implanted, amorphized top region in a mechanism analogous to a bi-metallic strip submitted to a temperature change.



This experiment helped to understand the effect of ion beam implantation on thin single-crystal membranes by creating an analogy with a liquid droplet placed on a thin elastic membrane in which its weight creates a downward bending (bowing) of the film beneath the droplet, followed by the appearance of radial wrinkles. The scale bar corresponds to 10μm. (Image: University of Surrey).

The team from the University of Surrey's Advanced Technology Institute and Department of Physics demonstrated (using micro-Raman spectroscopy) that up to 3.1% biaxial tensile strain and up to 8.5% uniaxial strain can be generated, but they point the way to even larger strains, achievable by varying the implant species and by exploiting the underlying crystal direction.

The method far exceeds previous records using more complex approaches. In the group-IV semiconductor germanium, an indirect-to-direct transition in the electronic bandgap occurs at much lower strains than silicon, where this new method can offer huge potential.

Although the procedure is relatively simple and points the way to a versatile, fast, generally applicable and widely available technique for strain control, its development required the use of two national facilities: the

Surrey Ion Beam Centre (which allows users to undertake a wide variety of research using ion implantation, ion irradiation and ion beam analysis, and which also has extensive processing and characterization facilities) and the National Physical Laboratory (the UK's National Metrology Institute, which develops and maintains national primary measurement standards and which ensures that cutting-edge measurement science has a positive impact in the real world).

"What excites me about this is the simplicity of the method and that it can easily be transferred to production methods," says Dr David Cox, senior research fellow at the Advanced Technology Institute at the University of Surrey. "It will be exciting to see if this can have as significant an impact on group-IV semiconductor photonics as Alf Adam's long-standing legacy on the development of the strained-layer III–V-based quantum-well lasers. Photonics will be to the 21st Century what electronics was to the 20th Century: revolutionary," he reckons.

"Seeing the wrinkles annihilation and the flattening of the membranes in real time was astonishing," says Ph.D. student Mateus Masteghin, lead author of the study. "This new technique promises to be highly disruptive to the field of photonics, and I am looking forward to continuing developing new devices based on this proposed technique." ■

https://journals.aps.org/prmaterials/abstract/10.1103/PhysRevMaterials.5.124603

www.surrey.ac.uk/advanced-technology-institute

GeSn-on-insulator platform for lasers combined with passives

Germanium tin on insulator laser structures provide prospects for integration with silicon plus higher performance than suspended microdisks.

Université Paris-Saclay and Université Côte d'Azur in France have reported work on germanium tin on insulator (GeSnOI) laser structures [Binbin Wang et al, Light: Science & Applications, vol10, p232, 2021].

The team comments: "The key advantage of this GeSnOI platform is its ability to combine active laser structures with passive SiN circuitry from the near-infrared to the mid-infrared. It represents a new paradigm for infrared Group-IV photonics that eliminates the need for III–V laser integration."

Being a group-IV compound/alloy, GeSn is easier to integrate with the mainstream (group-IV) silicon (Si) complementary metal-oxide-semiconductor (CMOS) manufacturing infrastructure that powers the modern world. Band and strain engineering of GeSn has led to hopes of efficient light emission through direct-bandgap transitions, as opposed to the generally non-radiative indirect bandgaps of Si and pure Ge.

Although the reported devices with 10.5% Sn content only operated at cryogenic temperatures below 140K, the researchers believe that, with higher Sn content, lasing around room temperature could be achieved. GeSn with 16% Sn has been used to demonstrate lasing in suspended structures at 270K, just below 0°C. The higher tin content improves the directness of the bandgap.

The GeSn bandgap is relatively narrow, coming in the mid-infrared range where applications in biochemical detection, gas monitoring and thermal imaging suggest potential. The team also believes that its GeSnOI platform could support electrically pumped devices: "Bonding GeSn diodes is completely feasible and the electrical injection can be made with such GeSnOI active layers."

The team fabricated microdisk (MD) lasers using material with a 500nm GeSn layer. The layer was prepared on 2.5μm Ge strain-relaxed buffer (Ge SRB) on 200mm-diameter (001) Si by reduced-pressure chemical vapor deposition (RPCVD). The Ge SRB source was germane/germanium hydride (GeH_4). The GeSn precursors were di-germane (Ge_2H_6) and tin tetrachloride ($SnCl_4$). GeSn is quite difficult to grow directly on silicon, since the thermal equilibrium solubility of Sn in Ge is around 1%, meaning that higher Sn content requires metastable growth.

Three different microdisk structures were studied: a traditional suspended mushroom-shaped disk on a pedestal from under-etching, and two devices using wafer bonding to silicon nitride/aluminium (SiN/Al) layers on silicon (Figure 1). These structures improved the optical confinement to enable lasing.

The mushroom microdisks use the refractive index contrast with air to give 95% confinement of the transverse electric (TE) mode and 78% for the transverse magnetic (TM) mode of the whispering-gallery mode excitations of the circular structure.

The microdisk on SiN/Al obtained through wafer bonding gave a GeSn-on-insulator (GeSnOI) profile. The aluminium provided thermal management through its heatsink properties. The optical confinement was provided by the SiN. The growth Ge/Si substrate was removed by selective etching. Further etching removed the defects that arose at the GeSn/Ge interface during growth. The defect removal and further thinning resulted in a 400nm GeSn layer. The optical confinements for TE and TM modes were 93% and 77%, respectively.

The key advantage of this GeSnOI platform is its ability to combine active laser structures with passive SiN circuitry from the near-infrared to the mid-infrared. It represents a new paradigm for infrared Group-IV photonics that eliminates the need for III–V laser integration Although the reported devices with 10.5% Sn content only operated at cryogenic temperatures of <140K, the researchers believe that, with higher Sn content, lasing around room temperature could be achieved. GeSn with 16% Sn has been used to demonstrate lasing in suspended structures at 270K, just below 0°C

The GeSn on SiN was slightly tensile strained, which could be enhanced and made more homogeneous throughout the layer by adding a top SiN layer. Raman spectroscopy suggested that the injected equivalent biaxial

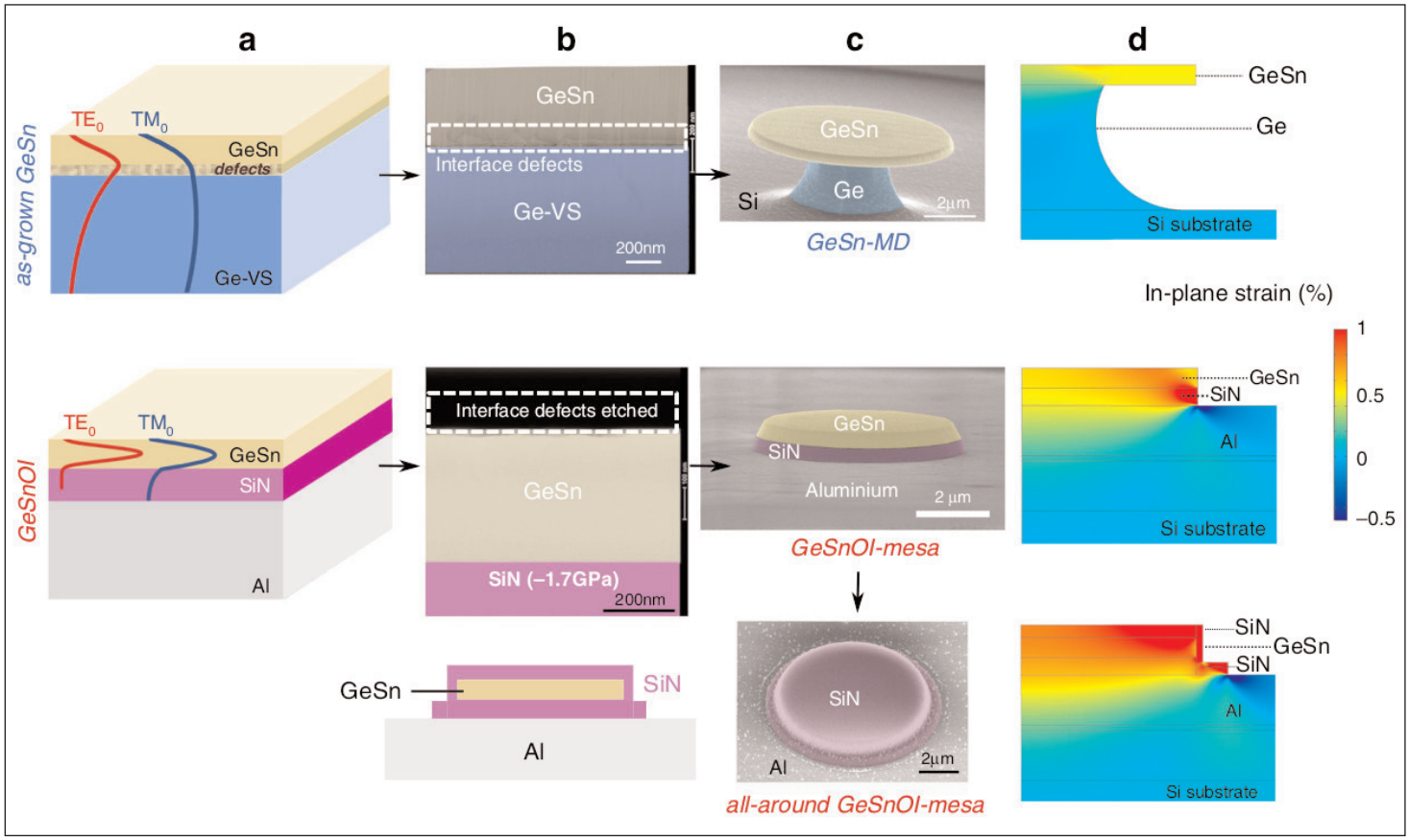


Figure 1. a Schematics of as-grown GeSn on Ge SRB and GeSnOI stacks together with TE and TM mode profiles of a confined optical wave at a 2.4μm wavelength. b Transmission electron microscope images of as-grown GeSn on Ge SRB and of GeSnOI stacks. c Scanning electron microscopy (SEM) images of GeSn and GeSnOI and all-around strained microdisk cavities. (d) In-plane strain variation, analyzed by finite-element modeling (FEM), of GeSn and GeSnOI microdisks.

tensile strain in the structure with SiN top stressor was 0.55%, compared with 0.1% without the added layer.

The researchers comment: "The SiN stressor thus enabled us to modify the strain state of our GeSn 10.5% alloy, from a _0.5% compressive state to a 0.55% tensile state, e.g. a shift by ~+1% of the strain. Band-structure engineering was thus feasible without changing the Sn content."

Devices with a 7μm-diameter mushroom or mesa microdisk were subjected to pulsed optical pumping of 1550nm wavelength at 77K. The threshold for the mushroom lasing was 45kW/cm^2. This was more than halved to 20kW/cm^2 for the GeSnOI structures. The GeSnOI mesa output intensity was around 60x that for the mushroom microdisk above laser threshold, and around 4x below.

A number of factors led the team to believe that the GeSnOI mesa absorbed less of the pump beam than the mushroom MD. The researchers comment: "We can thus assume that the improved PL [photoluminescence] signal below the threshold, despite the given above consideration, goes to the sense that carrier losses from non-radiative recombination process are partly reduced with the GeSnOI mesa, which could also partly explain such dynamic gain and threshold improvements." They believe that improvements in design, such as increasing the SiN layer thickness, could enhance absorption of the pump beam.

Increasing the temperature resulted in the laser action stopping at 80K for the mushroom microdisk, but at 135K for the GeSnOI mesa structure. The characteristic temperature for the threshold increase of the GeSnOI mesa was 40K.

Varying the GeSnOI mesa diameter gave a range of thresholds at 75K of 20–45kW/cm^2 for the respective diameters of 3–9μm. The mushroom microdisks only lased with diameters above 6μm with thresholds in the range 35–75kW/cm^2 up to 9μm diameter. While the maximum lasing temperature increased to 80K for the larger diameter mushroom microdisks, the GeSnOI mesa had reduced lasing 140–120K in the diameter range 3–9μm. The higher lasing temperatures for GeSnOI mesas was attributed to higher crystal quality.

The team was disappointed in its expectations of improved performance from adding the SiN stressor on top. The threshold for a 3μm-diameter disk was 15.5kW/cm^2, compared with 12kW/cm^2 for the disk without stressor. Also, the maximum operating temperature was 130K rather than the 140K achieved without the stressor layer.

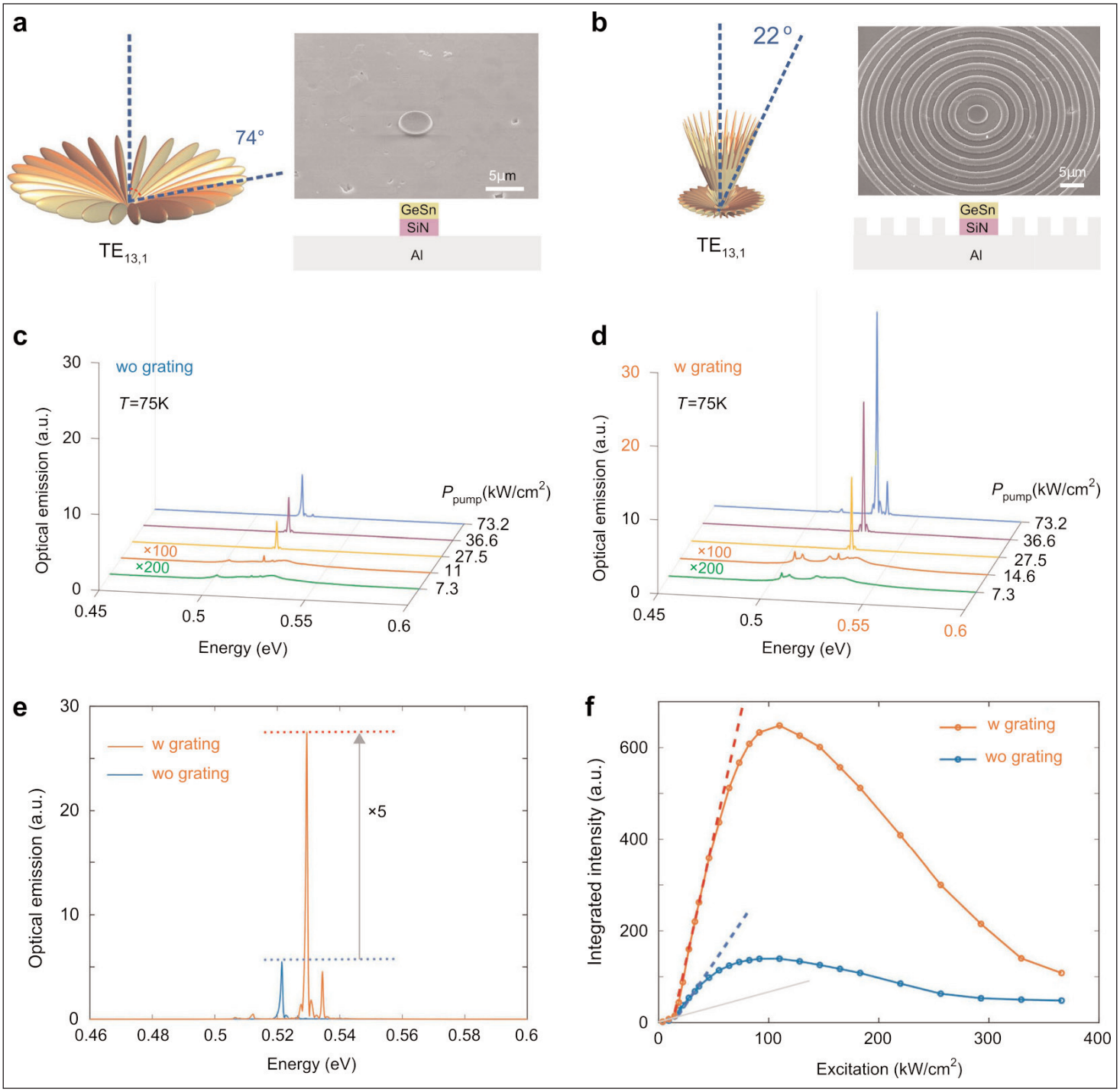


Figure 2. a, b SEM images and calculated emission patterns of 4μm-diameter GeSnOI mesas without and with Al circular grating (7 rings spaced by 3μm with a duty cycle of 50%). c, d Power-dependent spectra without and with Al circular grating. e Spectra with and without grating for 73.2kW/cm^2 excitation density. f Light-light power curves of GeSnOI lasers with and without grating.

The researchers also improved the vertical light extraction by placing a GeSnOI mesa laser within a circular grating cut into the Al heatsink layer (Figure 2). Normally light extraction from microdisk lasers is complicated by the radiation pattern being at a large angle to the vertical. Often light collected in microscope objectives is from out-of-plane leakage rather than from the laser radiation mode. Such leakage is unwanted from the perspective of reducing laser thresholds.

The GeSnOI mesa laser with grating was expected to redirect some 30% of the total flux into x50 objective with 0.65 numerical aperture. By contrast, the expectation without a grating was of the order 2.4×10^{-5}. In practice, the enhancement was around 5x above laser threshold, corresponding to a maximum collected peak power of 20–30μW. Below threshold the collected spontaneous radiation was similar with and without grating. ■

https://doi.org/10.1038/s41377-021-00675-7

Author: Mike Cooke

semiconductorTODAY

COMPOUNDS & ADVANCED SILICON

www.semiconductor-today.com

Join our LinkedIn group: Semiconductor Today

Follow us on Twitter: Semiconductor_T

Choose *Semiconductor Today* for . . .

MAGAZINE

Accurate and timely coverage of the compound semiconductor and advanced silicon industries

Targeted 82,000+ international circulation

Published 10 times a year and delivered by e-mail and RSS feeds

WEB SITE

Average of over 26,000 unique visitors to the site each month

Daily news updates and regular feature articles

Google-listed news source

E-BRIEF

Weekly round-up of key business and technical news

E-mail delivery to entire circulation

Banner and text marketing opportunities available

VCSEL micro-transfer to silicon nitride PICs

Micro-transfer printed vertical-cavity surface-emitting lasers on silicon nitride photonic integrated circuits show potential for low-cost, large-volume refractive index/biological sensing and power-efficient data communication.

Researchers based in Belgium and Sweden have used micro-transfer printing to integrate 850nm-wavelength vertical-cavity surface-emitting lasers (VCSELs) with silicon nitride (SiN_x) photonic integrated circuits (PICs) [Jeroen Goyvaerts et al, Optica, v8, p1573, 2021].

The team from Ghent University-imec in Belgium, Chalmers University of Technology in Sweden, and imec in Belgium see potential for refractive index and biological sensing and power-efficient data-communication applications. The 850nm range has a low water adsorption coefficient. Silicon nitride as a light transmission medium covers the wavelength range 400–2350nm, i.e. visible to near-infrared. By contrast, silicon PICs are restricted to infrared wavelengths longer than 1100nm.

The researchers suggest that the micro-transfer printing approach could overcome the limitations of other approaches in terms of scalable low-cost, large-volume production.

The bottom-emitting VCSELs were fabricated on the III–V epitaxial wafers (Figure 1) before transfer to the SiN_x PIC. The top titanium/platinum/gold contacts were mainly reflective disks except for a few test devices with annular contacts allowing light out of the top.

The top VCSEL mesa was formed by chlorine plasma etch. Silicon nitride was deposited to protect the device from unintentional oxidation. The VCSEL aperture was formed using wet oxidation of an aluminium gallium arsenide ($Al_{0.98}Ga_{0.02}As$) layer. The aperture diameter was set to less than 5μm with a view to achieving single-mode lasing.

The n-type contact consisted of annealed nickel/germanium/gold. The bottom mesa was created using chlorine plasma etch. The etch process stopped in the middle of a 527nm $Al_{0.12}Ga_{0.88}As$ buffer layer. After depositing more SiN_x for protection and insulation, titanium/gold contact pads were formed on the top-emitting test devices.

The VCSELs were prepared for release and transfer by opening the SiNx around the devices and etching the $Al_{0.12}Ga_{0.88}As$ with a wet etch consisting of citric acid and hydrogen peroxide. Then hydrochloric acid was used to etch an indium gallium phosphide (InGaP) release layer. The result was 50μmx90μm VCSELs suspended by photoresist anchors.

The micro-transfer printing used a polydimethylsiloxane (PDMS) stamp to pick up and deposit the VCSELs onto the SiNx PIC. The SiNx PIC platform included a 100nm plasma-enhanced chemical vapor deposition (PECVD) nitride anti-reflective coating. The adhesion of the photoresist around the VCSEL to the stamp depends on the stamp speed: fast for pick-up and slow for target deposition. Bonding of the devices was achieved by spin-coating target substrates with 40nm diluted divinyl-siloxane-benzocyclobutene (DVS-BCB)-mesitylene (1:8).

Distributed Bragg reflector	29x(p-$Al_{0.12}Ga_{0.88}As$/p
Oxidation layer	$Al_{0.98}Ga_{0.02}As$
Separate confinement heterostructure	
Multiple quantum well	5x($In_{0.10}Ga_{0.90}As/Al_{0.37}$
Distributed Bragg reflector	23x($Al_{0.12}Ga_{0.88}As/Al_{0.}$
Buffer	$Al_{0.12}Ga_{0.88}As$
Etch stop	GaAs
Sacrificial layer	$In_{0.49}Ga_{0.51}P$
Substrate	GaAs

Figure 1. Epitaxial structure for VCSEL.

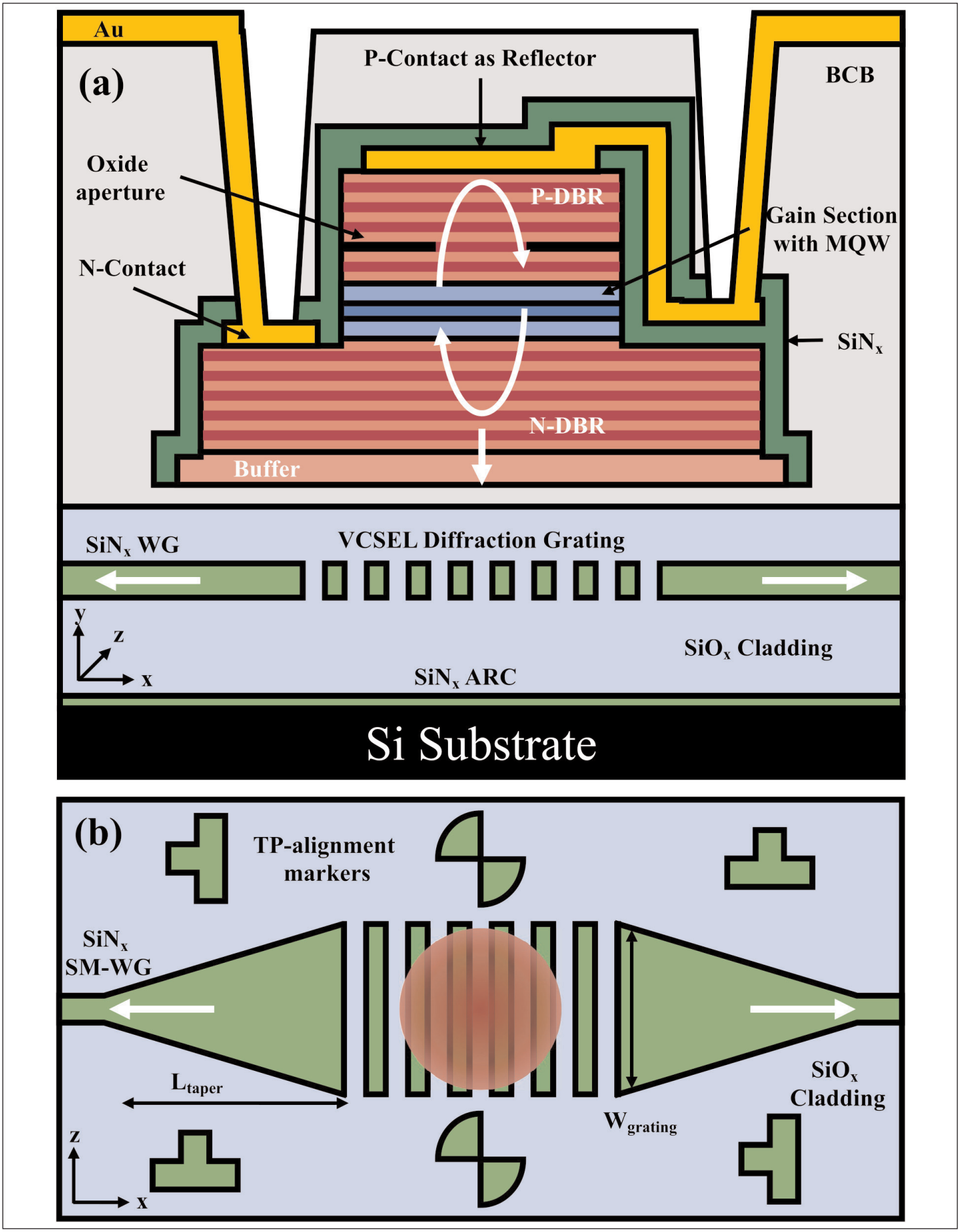


Figure 2. (a) Cross-sectional schematic of micro-transfer-printed vertical-cavity-SiNx-integrated laser (VCSIL) on SiN_x bidirectional grating coupler; (b) top-down view.

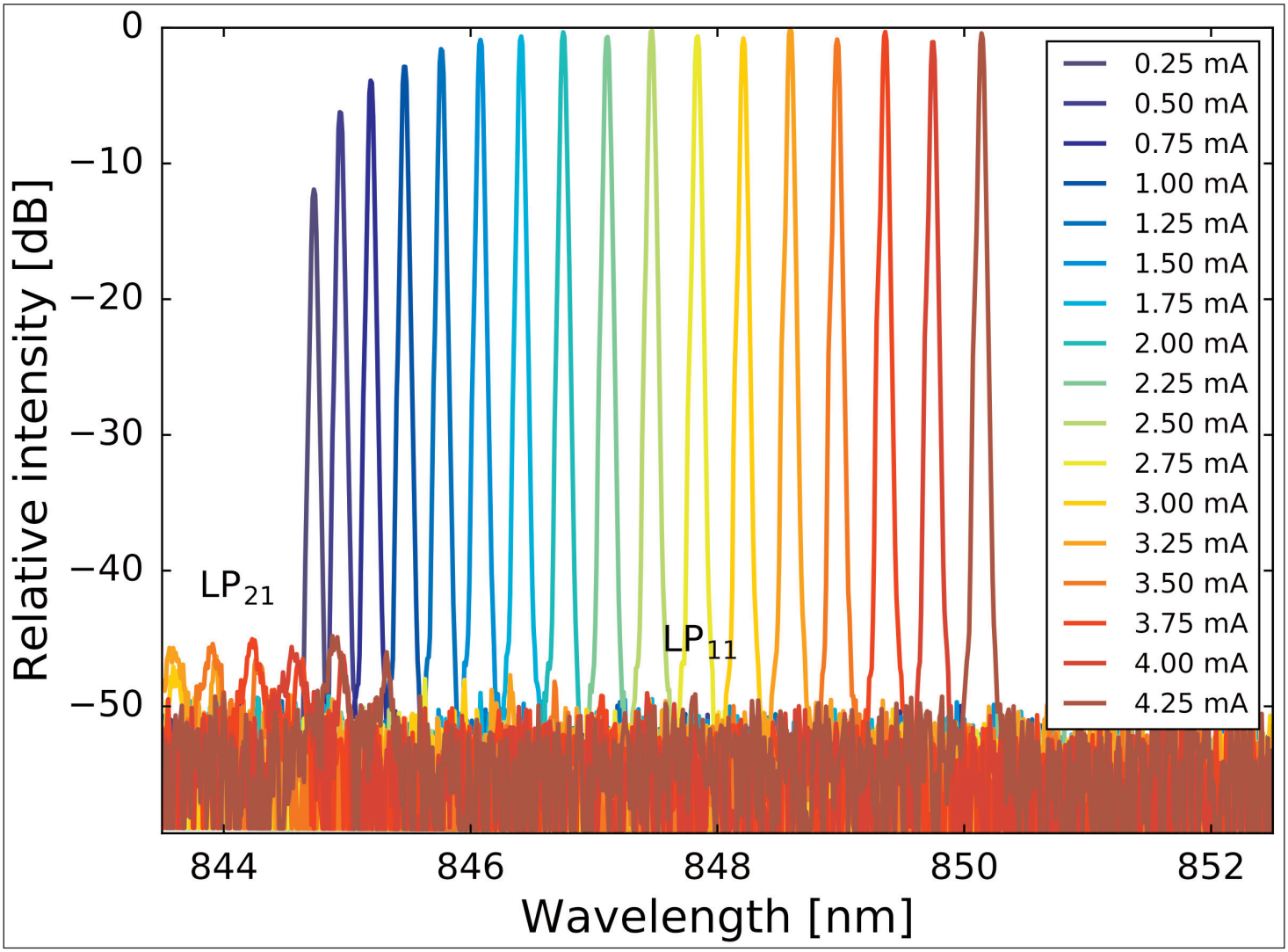


Figure 3. Output spectrum of waveguide-coupled VCSIL. Mode-selective feedback helps to suppress first higher-order LP11 mode with respect to LP21 mode.

The fabrication continued with removal of the VCSEL encapsulation, bonding-layer curing, and planarization with DVS-BCB and further curing, followed by reactive-ion etch thinning of the DVS-BCB planarization and creating slanted openings. The etch also removed unwanted SiNx to allow the final step of adding titanium/gold probe contacts.

The VCSELs on SiN_x PIC used a diffraction grating to couple the laser light laterally into 300nmx6μm waveguides that tapered down to 550nm to give single-mode transmission to a fiber grating coupler (Figure 2). The peak waveguide-coupled power was 100μmW split into a right and left waveguide. The power in the 'left' waveguide was more than 50μmW, while the power in the right was somewhat less. The different power transmission is attributed to misalignment of the printing process.

There was some interference from parasitic reflection at the fiber grating coupler, leading to small oscillation of the light power versus current behavior. Reflectionless couplers would eliminate this effect.

Although the researchers admit that the power is quite low, they see it as adequate for the needs of optical refractive index sensing, writing: "The proposed VCSEL can drive well over 100 refractive index sensors in parallel, in combination with high-responsivity, low-dark-current photodetectors." The team also sees potential for such sensors in a wearable format.

The optical output/electrical input power ratio was 2.4% with the left–right split being 1.3%–1.1%. The side-mode suppression ratio (SMSR) was 29dB over the bias range. Raising the device temperature to 85°C reduced the light output power by around 50%.

Another device was found to have a wavelength tuning range of 5nm, dependent on self-heating from the current injection (Figure 3). The power of this device in one waveguide wing was 32μmW, while the SMSR was 45dB.

A characterization 4μm aperture VCSEL on sapphire demonstrated an output power of 600μmW. The lasing threshold and slope efficiency were 0.16mA and 0.42W/A. The SMSR was 23dB. ■

https://doi.org/10.1364/OPTICA.441636

Author: Mike Cooke

semiconductorTODAY

COMPOUNDS & ADVANCED SILICON

www.semiconductor-today.com

Join our LinkedIn group: Semiconductor Today

Follow us on Twitter: Semiconductor_T

Choose *Semiconductor Today* for . . .

MAGAZINE

Accurate and timely coverage of the compound semiconductor and advanced silicon industries

Targeted 82,000+ international circulation

Published 10 times a year and delivered by e-mail and RSS feeds

WEB SITE

Average of over 26,000 unique visitors to the site each month

Daily news updates and regular feature articles

Google-listed news source

E-BRIEF

Weekly round-up of key business and technical news

E-mail delivery to entire circulation

Banner and text marketing opportunities available

Slow-light VCSEL power boost

Single-mode vertical-cavity surface-emitting laser exceeds 5W output power.

Researchers based in Japan and Egypt claim record single-mode power of more than 5W for a high-power single-mode vertical-cavity surface-emitting laser (VCSEL) with a slow light mode (SLM) surface grating [Ahmed M. A. Hassan et al, Appl. Phys. Lett., v119, p191103, 2021].

The team from Tokyo Institute of Technology in Japan, Al-Azhar University in Assuit, Egypt, Ambition Photonics Inc in Japan, the National Institute of Information and Communications Technology in Japan, and Minia University in Egypt see the potential for high-power applications including 3D sensing of objects in light detection and ranging (LIDAR) and structured light 3D scanning, which analyses the deformation of projected patterns to extract depth and surface information.

The researchers comment: "Unlike long-cavity in-plane edge-emitting lasers, an SLM-based VCSEL

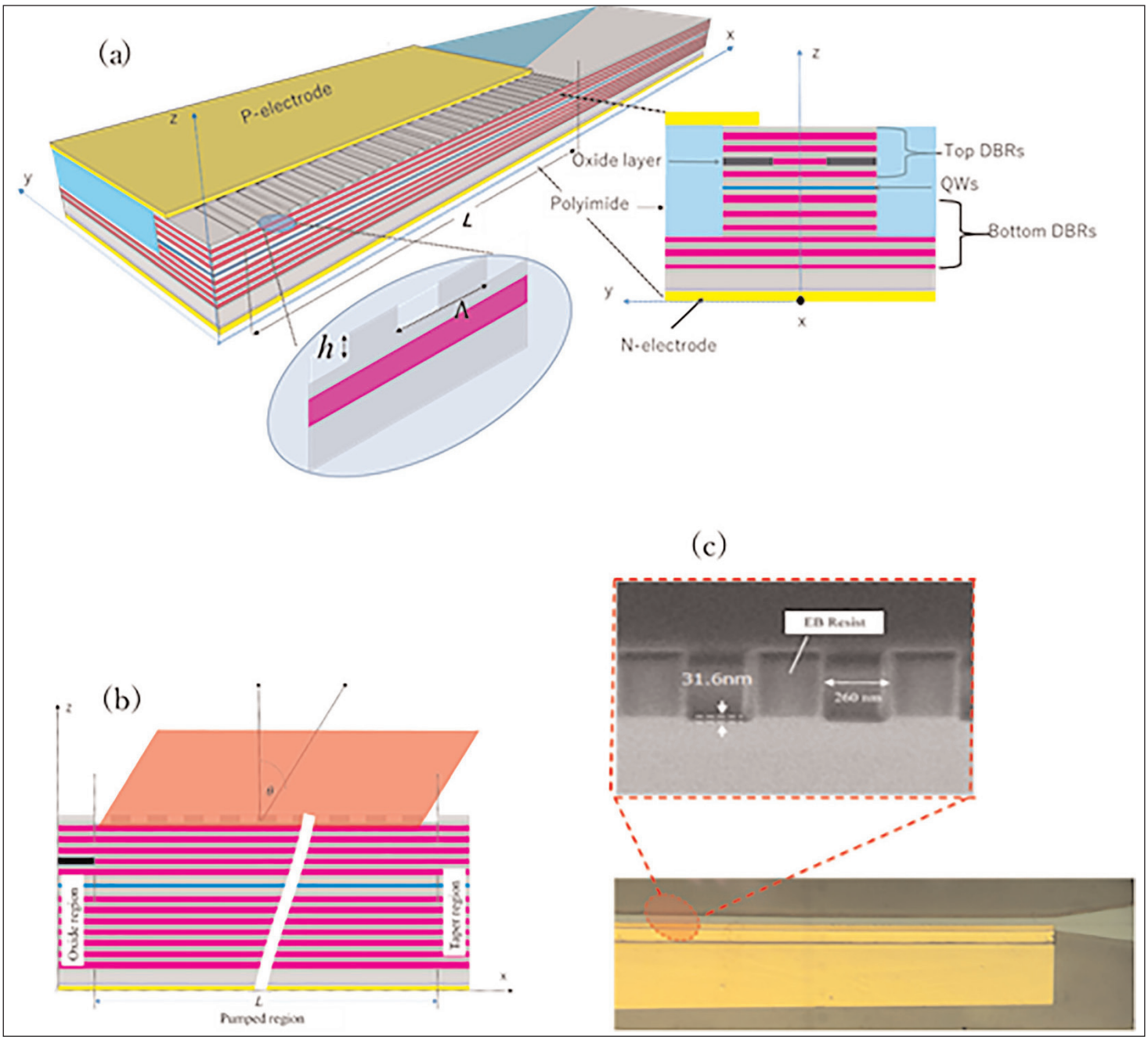


Figure 1. Structure and emission mode of device. (a) Schematic structure of surface grating VCSELs, top view and cross section. (b) Side cross section showing radiation of slow light at angle (θ). (c) Microscopic photo of real device showing surface gratings.

can provide higher output powers without limitation of catastrophic optical mirror damage."

Normal VCSELs are limited in output power to the milliWatt level due to their small volume. High output power is gained at the expense of beam quality. The SLM in the researchers' device is propagated laterally at a wavelength near the resonant/cut-off frequency where there is a large degree of dispersion between the frequency and wavelength, leading to the slow light effect in terms of the group velocity.

The VCSEL part of the device was an ~850nm wavelength gallium aluminium arsenide (GaAlAs) structure with three GaAs quantum wells and GaAs/GaAlAs distributed Bragg reflectors (DBRs) on each side (Figure 1). A surface grating was added on the top p-side 19-pair DBR of the device to give the SLM, which was detuned 20nm shorter than the vertical-cavity resonance wavelength. The researchers comment: "This detuning design gives a higher gain and, hence, lower threshold current for the SLM than a vertical lasing mode." The pitch of the grating was as large as 0.5μm, making fabrication fairly easy, using electron-beam lithography and dry etch.

The tapered rectangular device mesa was 4.5μm high and 34μm wide. Wet oxidation was used for lateral optical confinement. Oxide regions were also used to confine the injection current. Polyimide was used for planarization. The taper section was 500μm long with a taper angle of 10°, which was found to have less than 0.5% back reflection, suppressing Fabry–Perot modes. The other end of the lateral laser cavity at the semiconductor/oxide interface was highly reflective.

The device had a rectangular beam shape. "This kind of beam could be suitable for LIDAR systems and structured light sensing," the team writes. The researchers envisage devices on the scale of millimeters or even centimeters, which would increase the output power proportionally. They add: "Because the output power could be increased by increasing the device length even with keeping the surface power density and the active region is not exposed to air, catastrophic optical mirror damage can be totally avoided."

A 1mm-long device achieved lasing at 50mA injection under pulsed-mode with 50ns pulses to avoid self-heating, and a 2mm laser at 120mA. The slope efficiency for both devices was 0.59W/A. The maximum output powers were 180mW and 280mW, respectively. The devices suffered from thermal rollover, since there was no heatsink.

In continuous wave (CW) operation, the side-mode suppression ratio (SMSR) was more than 30dB. The single-mode wavelength of the 1mm device was 830.8nm at 100mA injection, close to the 830nm design target. At higher currents there was a thermal red-shift to 833.6nm at 350mA. A 845.4nm

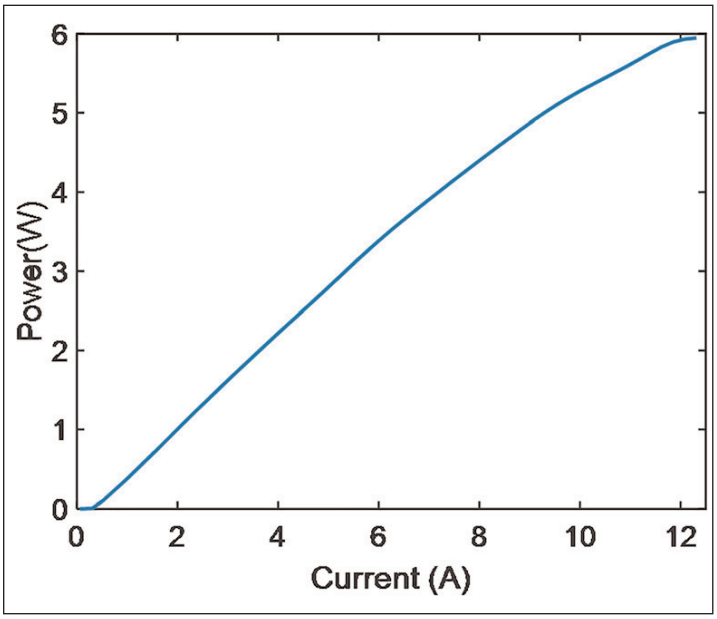


Figure 2. Light output power–current curve of 6mm device under 50ns pulsed operation.

vertical lasing mode appeared at 300mA. The team comments: "At this current, the gain aligned into vertical modes. It is important to eliminate the lasing of vertical modes to boost the output of a single slow light mode at high currents."

The researchers suggest that the ~3nm red-shift could see application in integrated beam scanners.

The far-field pattern showed a very low beam divergence of 0.084° at 100mA, around 2x the threshold for the 1mm device. The divergence increased at higher currents to 0.2° at 250mA injection, but narrowed somewhat to 0.18° by 300mA. The longer 2mm device had a narrower beam: ~0.056° at 170mA, reducing slightly to 0.053° at 300mA.

A 6mm-long device with 4μm wide oxide aperture achieved a stable single mode at 833nm with 30dB SMSR at 1A CW injection. The beam divergence was 0.19° at 1A with a minimum 0.038° at 350mA. A peak output power of 6W at 12A was achieved under pulsed operation with 50ns pulses and 1ms repetition (Figure 2). The slope efficiency was 0.6W/A. The power output saturated around 10A due to self-heating and current non-uniformity in the long device. The avoidance of self-heating in pulsed operation allowed a reduced beam divergence of 0.12° at 1A. At 12A, the divergence was 0.25°.

The researchers comment: "All of the measurements were done by using a single current probe, which causes non-uniform current distribution in particular, for long devices at high current injection. We expect significant improvements in the output power and reduction of beam divergence if wire and die bonding is carried out with better thermal management." ■

https://doi.org/10.1063/5.0066590

Author: Mike Cooke

Micro-LED chip market for large-sized displays to grow at 204% CAGR from $54m in 2022 to $4.5bn in 2026

Micro-LED large-sized displays are moving to home theater and high-end commercial display markets, says LEDinside.

With micro-LED large-sized displays moving towards the home theater and high-end commercial display markets, revenue for micro-LED large-sized display chips will be $54m in 2022 then rise at a compound annual growth rate (CAGR) of 204% to $4.5bn in 2026, forecasts market research firm TrendForce. Technical obstacles will be conquered one by one over time, it adds. The development of micro-LED large-sized displays will peak between 2026 and 2030, and annual revenue for micro-LED chips has the opportunity to reach tens of billions of dollars, reckons the firm.

In recent years, major global brands in various regions have released micro/mini-LED self-emissive large-sized display products, notes TrendForce. The world's leading TV maker Samsung released a 146-inch TV ('The Wall') in 2018 and continues to release 75-inch, 89-inch, 101-inch, 110-inch, 219-inch and 292-inch large tiled wall displays each year at the Consumer Electronics Show (CES) in Las Vegas. Due to the evolution of different application scenarios and technologies, the future development trend of micro-LED large-sized displays will be in home theaters, corporate headquarters, and boutique stores, it is reckoned. Commercial indoor and outdoor large-sized displays are mainly based on mini-LED self-emissive large-sized displays. To satisfy the requirements of close indoor viewing, micro-LED large-sized displays require a theater-level experience, seamless tiled display splicing, pursuit of zero borders, thin design, and competitive pricing. Thus, active matrix (AM) would be the first choice for display design.

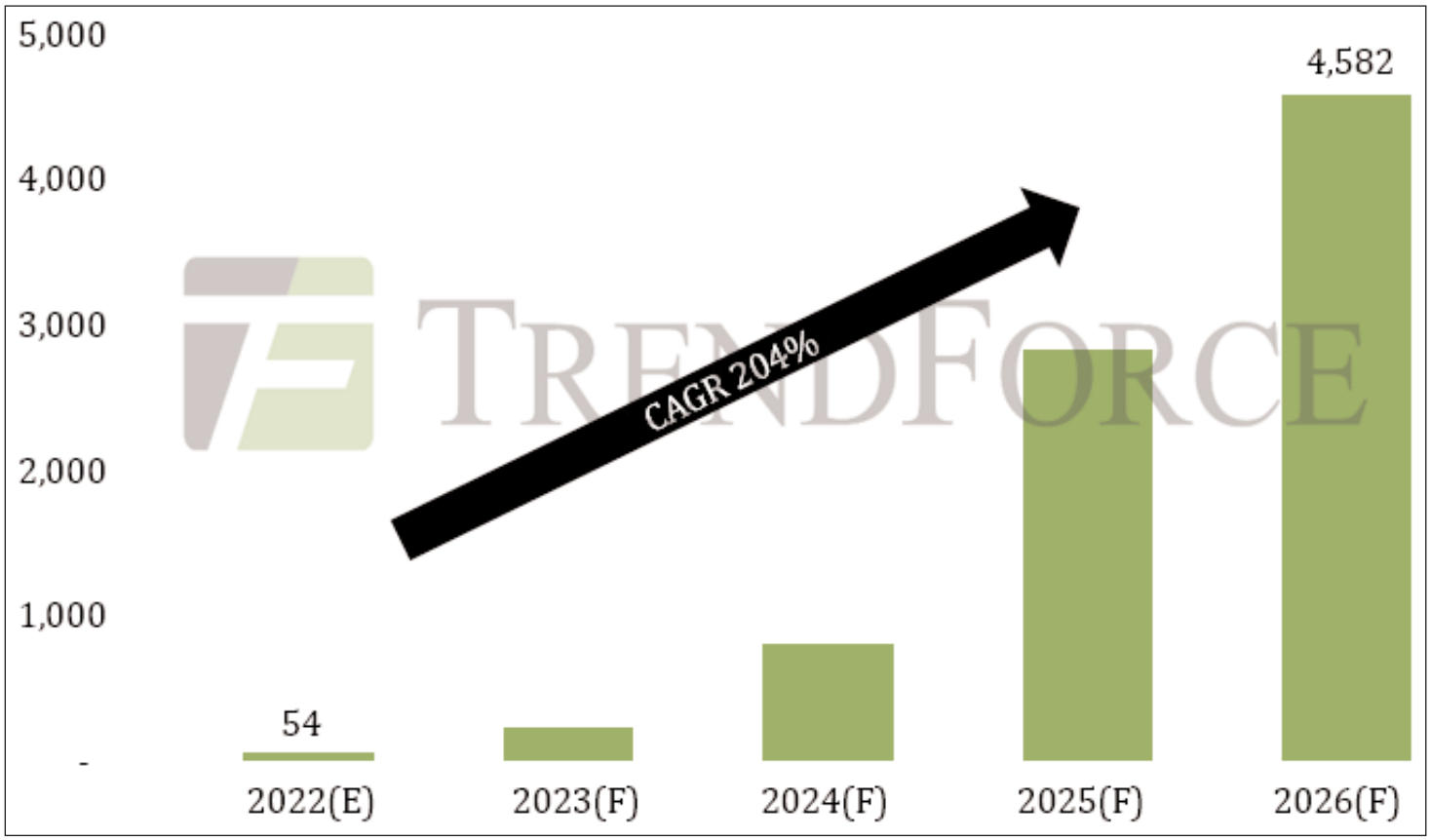
Existing micro-LED large-sized displays still face the dual challenges of technology and cost (including micro-LED chip cost) and the three key technologies of backplane technology, driving technology, and the mass transfer process, notes TrendForce.

In terms of micro-LED chip cost, due to the enormous number of chips used and the need for consistent wavelength uniformity to achieve perfect display quality, the cleanroom level requirements for epitaxial and chip processes, control of process conditions, and inspection and maintenance during processes are very strict, greatly increasing the relative process defect rate and overall cost.

In terms of mass transfer, the current mass transfer technologies used in micro-LED large-sized displays include pick-and-place technology and laser transfer technology, each with its own advantages and disadvantages. TrendForce believes that, although existing micro-LED mass transfer technology is still in the product development and adjustment stage, there have been no real quantitative achievements. However, in terms of pick-and-place mass transfer equipment capacity, using 10cm2 transfer stamps to transfer 34μm x 58μm micro-LED chips, production capacity (UPH; unit per hour) is about 7 million units. If the laser mask opening of laser mass transfer technology is 8mm2, production capacity is about 12 million units. No matter which kind of transfer technology, the mass transfer capacity of micro-LED large-sized displays needs to reach at least a 20 million unit level of efficiency and 99.999% yield in the future to meet the conditions for mass commercialization, it is reckoned.

Active-matrix design to aid development of micro-LED technology

In terms of backplane and drive technology, passive-matrix (PM) drive design is based on a PCB backplane with a passive drive circuit structure, using MOSFET as the current-switching element. Therefore, overall structure is more complex and requires a wider placement area for circuit components. In addition, when dot pitch is reduced to less than P0.625, the PCB backplane will encounter the challenges of line-width and line-space mass-production limitations and rising cost. Thus, the existing technological state of the passive-matrix drive design is more suited to large-sized display applications utilizing dot pitches greater than P0.625 and equipped with a mini-LED. However, for consumer



Estimated global revenue of micro-LED large-sized display chips, 2022–2026 (in US$ millions).

micro-LED TVs employing a dot pitch less than P0.625, active-matrix (AM) drive design will become the new direction of display design, TrendForce says. Since panel makers consider that a TFT glass backplane with LTPS (low-temperature polysilicon) switching technology is mature technology, it is necessary to adjust certain portions of the manufacturing process and parameters to precisely control and drive micro-LED current.

In addition, to achieve seamless tiled display splicing technology, glass metallization and side wire electrode glass will become further technical challenges. As resolution becomes higher and dot pitch is reduced, the front circuit of TFT glass must be guided to the back along the side or by using through-holes.

Glass metallization technology then becomes key. Since existing glass metallization technology is still afflicted with technical bottlenecks resulting in high cost due to low yield), when these bottlenecks are resolved with future technology, the launch of mass-production glass metallization will become the advantage of active-matrix backplanes. Future active-matrix drive design with micro-LED chips and seamless splicing technology have the opportunity to become the mainstream technology for micro-LED TV development and the key to unlocking a new wave of micro-LED large-sized display cost optimization, concludes TrendForce. ■

www.ledinside.com/intelligence/purchase_mi

Hot performance from InGaN red micro-LEDs

External quantum efficiency has been boosted to 3.2% at room temperature.

University of California Santa Barbara (UCSB) and Google in the USA have reported on the efficiency and high-temperature performance of indium gallium nitride (InGaN) micron-scale 'red' light-emitting diodes (μLEDs) [Panpan Li et al, Appl. Phys. Lett., v119, p231101, 2021].

The research builds on the previous work of UCSB [www.semiconductor-today.com/news_items/2021/sep/ucsb-090921.shtml]. The μLEDs demonstrate relatively high ~3% efficiencies and low 0.05nm/K red-shift with temperature. The researchers comment: "This demonstrates the robustness of InGaN red μLEDs up to high temperature, with a much-improved stability over conventional AlInGaP red μLEDs."

In fact, aluminium indium gallium phosphide (AlInGaP) devices suffer from increasing surface recombination effects sapping efficiency as devices shrink to the micron level. This is attributed to a high surface recombination velocity in the AlInGaP material system.

There has been increasing interest in μLEDs as the basis for general lighting, display and automobile headlights. In the display sector, extending the AlInGaN technology from the blue (450–485nm) sector, through green (500–565nm) and red (625–750nm) is particularly attractive. Full-color LED displays could see deployment in watches, augmented reality, virtual reality, and ultra-large televisions.

On the other hand, the high indium content required for longer-wavelength emission in the green and red sectors becomes increasingly difficult. Indium is less reactive with nitrogen than the Al, Ga components, meaning that growth temperatures need to be reduced, resulting in lower crystal quality, impacting efficiency. The lattice mismatch between high-indium-content InGaN relative to GaN also creates piezoelectric fields in LED structures, which reduce electron–hole recombination into photons (the 'quantum-confined Stark effect').

The researchers used metal-organic chemical vapor deposition (MOCVD) on patterned sapphire substrate to create the epitaxial material for the μLEDs. The light-emitting active region consisted of five InGaN quantum wells separated by AlGaN cap/GaN barrier layers.

The μLED fabrication (see link above for schematic and more details) consisted of 100nm indium tin oxide (ITO) transparent contact deposition, reactive-ion mesa etch, omnidirectional reflector formation from silicon dioxide/tantalum pentoxide layers, atomic layer deposition (ALD) of silicon dioxide mesa sidewall passivation, and evaporation of aluminium/nickel/gold for contacts/pads.

At 20A/cm^2 room-temperature injection the 40μmx40μm devices emitted light with a peak at

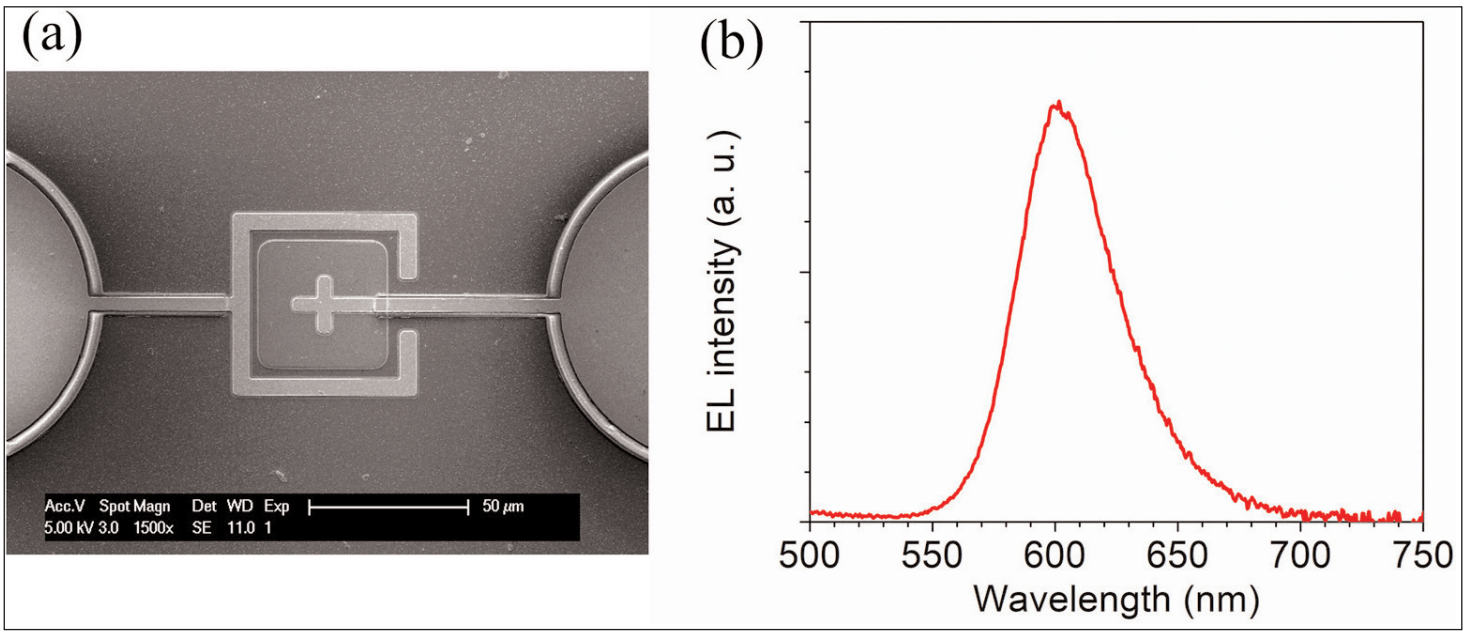


Figure 1. Scanning electron microscope image of μLED and (b) emission spectrum at 20A/cm^2.

600nm wavelength and 48nm full-width half-maximum (FWHM). The researchers say that this suggests a high crystal quality in the active region of the device. The peak is more strictly in the orange range (590–625nm).

As the temperature of the μLED was raised the wavelength red-shifted at a rate of 0.05nm/K, arriving at ~605nm at 400K. The researchers compare this very low shift with reports for InGaN on Ga_2O_3, 0.085nm//K, and for 630nm AlInGaP devices, 0.137nm/K. "InGaN-based red μLEDs are promising candidates for high-temperature wavelength-stable lighting sources," the team comments.

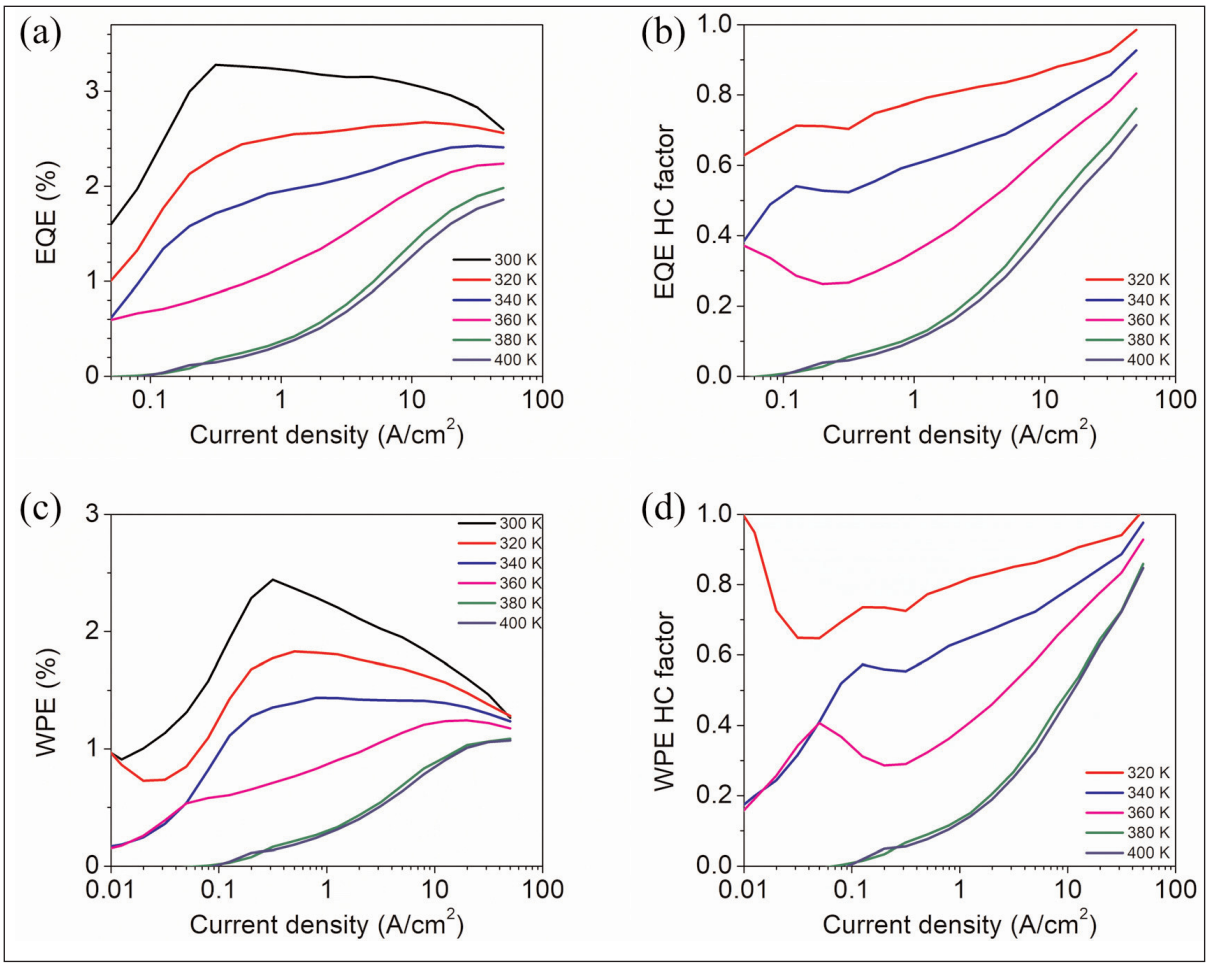


Figure 2. Temperature-dependent (300–400K) (a) EQE, (b) EQE HC factor, (c) WPE, and (d) WPE HC factor versus current density.

The forward voltage decreased at a higher rate than expected as the temperature increased (4mV/K). However, above 380K, the device became leaky at low current injection. The ideality (n) of the μLED was 6.7 at 300K, falling to 5.0 at 360K. The leaky behavior at higher temperatures pushes the ideality up again. The researchers comment: "An ideality factor larger than 2 can be caused by trap-assisted tunneling, carrier leakage, and other sources of imperfect injection. Therefore, the high ideality factors observed here indicate non-ideal transport, possibly caused by significant defect-assisted processes. The reduction in n at high temperature indicates an improvement in injection processes."

The external quantum efficiency (Figure 2) reaches 3.2% at room temperature, exceeding previous reports of 0.56% for red InGaN μLEDs. The value is also comparable with a reported 4.8% for a 32μm red μLED produced using AlInGaP materials. The relatively flat EQE behavior was attributed to the imperfect injection suggested by the high ideality. Droop sets in at ~3A/cm^2 injection.

As the current injection increases the EQE relative to that at 300K, the 'hot–cold' (HC) factor, increases. At 50A/cm^2 injection the EQE HC factor reached 0.85 at 360K. "The HC value at 360K is similar to that of commercial blue InGaN LEDs, suggesting that this high-temperature robustness is a general property of the InGaN material system," the team writes.

Combining the electrical and EQ efficiencies to give the wall-plug efficiency (WPE), the researchers found a peak value of 2.4% at ~3A/cm^2 injection. The WPE HC factor at 400K and 50A/cm^2 was 0.85. "The higher WPE HC factor (0.85) at 50A/cm^2 compared to the EQE factor (0.72) at 400K is attributed to the reduction in voltage at high temperature," the researchers explain.

The researchers compare their EQE HC factors to those for regular-size AGaInP red LEDs: 0.55 for 388/298K, and 0.4 for 400K/300K, reported by different groups. The team comments: "It is expected that the HC factor would be even lower in AlInGaP red μLEDs, since the impact of non-radiative recombination increases significantly for small sizes. Therefore, InGaN red μLEDs exhibit a smaller thermal droop compared to AlInGaP red μLEDs." ■

https://doi.org/10.1063/5.0070275

Author: Mike Cooke

Ohmic contacts on lightly doped p-GaN

Current flow has been increased by up to five orders of magnitude.

Nagoya University in Japan reports improved Ohmic behavior for contacts on p-type gallium nitride (p-GaN) through using an annealed and treated magnesium layer [Shun Lu et al, Appl. Phys. Lett., v119, p242104, 2021]. The team comments: "Compared with other conventional methods such as continuous growing or regrowth, our process requires a lower temperature and pressure and can achieve a localized contact layer easily without any etching-induced damage."

The researchers see benefits for a range of power electronics applications using components such as metal-oxide-semiconductor field-effect transistors (MOSFETs) or heterojunction bipolar transistors (HBTs), where low-resistance Ohmic contacts are essential for effective operation. GaN is favored for power electronics due to high breakdown electrical field, high saturated electron velocity, and high electron mobility. Good contacts with n-GaN are relatively easy to achieve with titanium and gold.

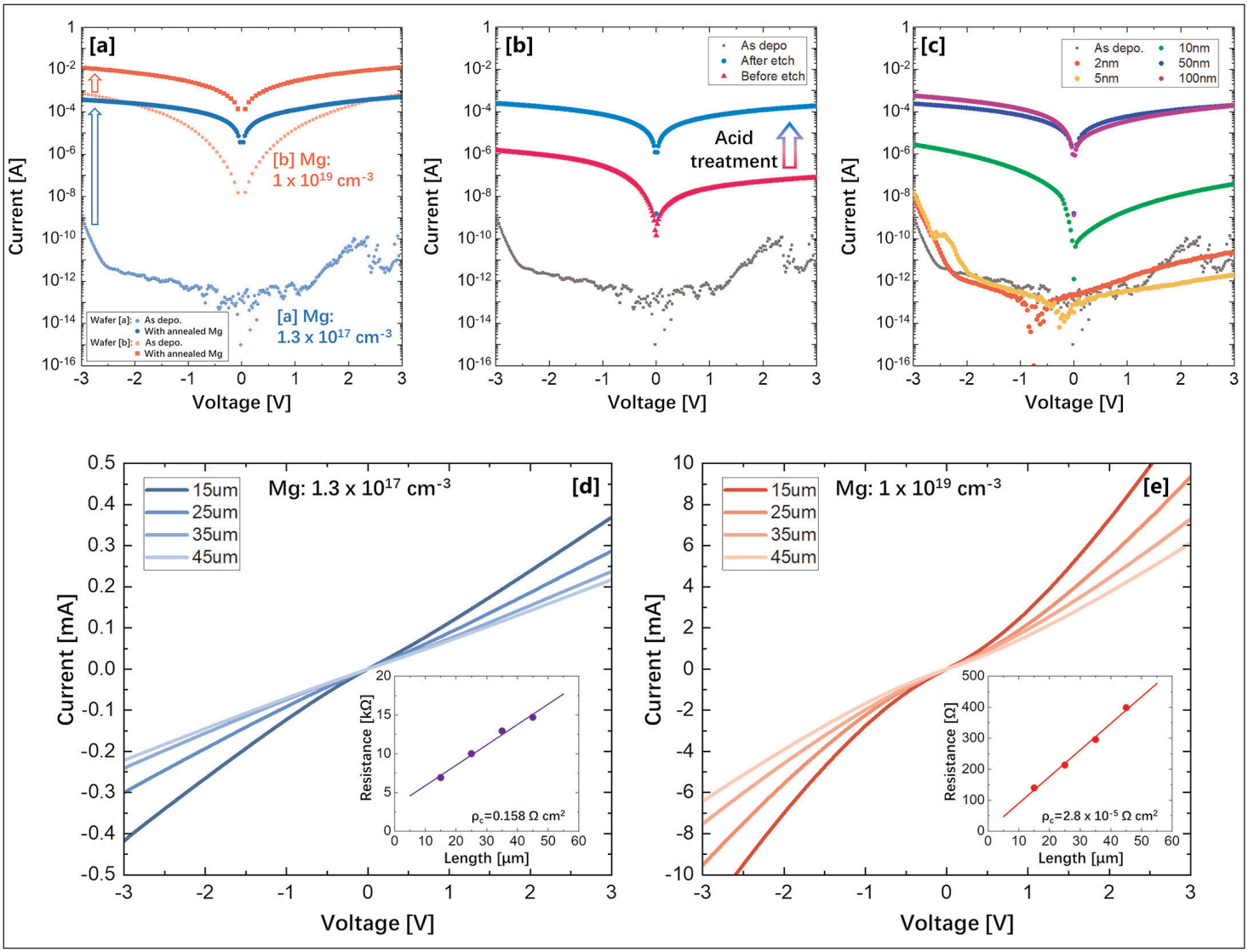


Figure 1. (a) Typical current–voltage characteristics with and without annealed Mg layer. (b) Effect of aqua regia/HF treatment after annealing. (c) Effect of deposited Mg layer thickness on current–voltage characteristics. Current–voltage and resistance-distance dependence on p-GaN with (d) low and (e) high Mg concentrations as determined by CTLM.

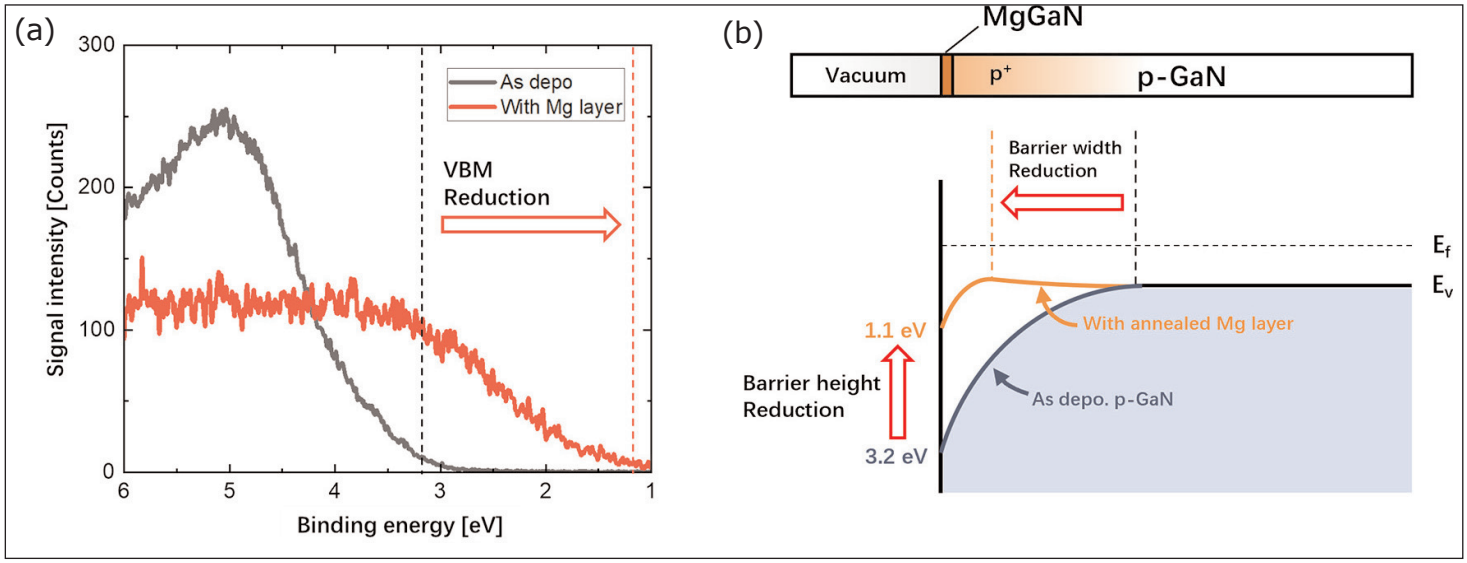


Figure 2. (a) VBM reduction determined by XPS measurement. (b) Surface band structure of as-deposited p-GaN (dark blue line) and p-GaN with annealed Mg layer (brown line).

For p-GaN, the most common metal combination for contacts is nickel/gold, which forms a p-nickel oxide layer, but there is still a thin Schottky barrier through which carriers have to tunnel, reducing Ohmic characteristics. Most device structures add a heavily doped p^+-GaN layer to improve Ohmic behavior.

In fact, the Nagoya technique allows contacts on lightly doped p-GaN to have better Ohmic behavior than the p^+-GaN samples.

The researchers used a 4-step cleaning process to prepare a p-GaN surface before application of the Mg. The cleaning removed surface oxides, metal ions, and particle contamination. This was followed by 700°C annealing in nitrogen to activate the p-GaN layer.

The Mg contact layer was deposited using radio frequency magnetron sputtering with lift-off patterning. This was followed by 800°C annealing in nitrogen and 15 minute treatments with boiling aqua regia and then hydrofluoric acid. The researchers see the annealing and acid washing as key steps towards the annealed Mg contact layer.

The annealing increased the Mg layer thickness to 80nm. The annealed layer had a rough brown surface, having lost its "surface metal luster". The acid washing reduced the layer to 20–40nm thickness. "We found that 15min is sufficient for removing the entire resistor-like layer," the team writes.

The remaining Mg contact layer was found to be non-reactive with acid. Composition studies using scanning transmission electron microscope (STEM) energy-dispersive x-ray analysis suggested the Mg contact became a $(Mg_3N_2)_{1-x}(GaN)_x$ alloy. The presence of Ga stabilized the Mg_3N_2, which on its own is very unstable in air.

The effects of the separate steps were seen in electrical characterization (Figure 1). Without the Mg contact layer, the contact of a bare p-GaN layer, doped with $1.3x10^{17}/cm^3$ Mg, on GaN/sapphire template with the electrodes was almost insulating. The annealed Mg contact increased current flow by a factor of order 10^5. The improvement with the thickness of the deposited Mg contact layer saturated at around 50nm.

A second sample on GaN substrate with $10^{19}/cm^3$ Mg concentration p-GaN showed a lesser increase in current flow, an order of magnitude at high bias, but greater at low bias, improving linearity. The acid wash also improved the linearity of the $1.3x10^{17}/cm^3$ Mg p-GaN sample, and increased the current flow from just annealing.

Circle transmission line measurement (CTLM) was carried out with annealed 20/150nm nickel/gold electrodes. The CTLM on the various contacts showed close to linear behavior with the 50nm layer on both samples, especially with low-Mg-concentration p-GaN.

The researchers estimated the specific Ohmic contact resistance at $0.158\Omega\text{-cm}^2$ for the contact on $1.3x10^{17}/cm^3$ Mg concentration p-GaN at –2.5V bias. The contact resistance on $10^{19}/cm^3$ GaN:Mg was $2.8x10^{-5}\Omega\text{-cm}^2$ (–5V bias), reduced from $1.2x10^{-2}\Omega\text{-cm}^2$ for a normal nickel/gold electrode on p-GaN without Mg layer.

One factor reducing the barrier height and therefore improving Ohmic behavior was a reduced valence band maximum (VBM), as revealed by x-ray photoelectron spectroscopy (XPS, Figure 2). The p-GaN layer without Mg contact layer had a VBM of 3.2eV, which was reduced to 1.1eV with the annealed Mg/p-GaN process.

Hall measurements gave a sheet resistance of $1.55x10^5\Omega$/square, compared with $1.73x10^5\Omega$/square without Mg contact. The Mg layer increased the sheet hole concentration ($1.79x10^{12}/cm^2$ versus $1.56x10^{12}/cm^2$), while slightly depressing the mobility ($22.5cm^2$/V-s and $23.2cm^2$/V-s, respectively). ■

https://doi.org/10.1063/5.0076764

Author: Mike Cooke

suppliers' directory

Index

To have your company listed in this directory, e-mail details (including categories) to mark@semiconductor-today.com
Note: advertisers receive a free listing. For all other companies, a charge is applicable.

1 Bulk crystal source materials

Vital Materials Co Ltd (head office)
Floor 49, International Metropolitan Plaza,
68 Huacheng Avenue,
Tianhe District,
Guangzhou, Guangdong,
China 510623
Tel: +86 020-83511906
Fax: +86 020-83511907
E-mail: Sales@vitalchem.com
www.vitalchem.com
Vital Materials is the world's leading producer of rare metals as well as the first Chinese manufacturer to deliver G11 rotary ITO target. Vital is also one of the world's three major supplier of infrared materials, a key supplier of compound semiconductor substrates, and a strategic partner of the world's largest thin film solar manufacturer.

United Mineral & Chemical Corp
1100 Valley Brook Avenue,
Lyndhurst, NJ 07071, USA
Tel: +1 201 507 3300
Fax: +1 201 507 1506
www.umccorp.com

2 Bulk crystal growth equipment

Cyberstar
109 Rue Hilaire de Chardonnet — Technisud,
38100 Grenoble,
France
Tel: +33 (0)4 76 49 65 60
E-mail: cyberstar@cyberstar.fr
www.cyberstar.fr

3 Substrates

AXT Inc
4281 Technology Drive,
Fremont,
CA 94538, USA
Tel: +1 510 438 4700
Fax: +1 510 683 5901
www.axt.com

Crystal IS Inc
70 Cohoes Avenue,
Green Island,
NY 12183,
USA
Tel: +1 518 271 7375
Fax: +1 518 271 7394
www.crystal-is.com

CS Microelectronics Co Ltd (Vital Materials subsidiary)
Gaofeng Park,
Wanzhou Economic-Technological Development Area,
Chongqing,
China 404040
Tel: +86 023-58879888
E-mail: csm_sales@vitalchem.com
www.cs-micro.com
Vital Materials is the world's leading producer of rare metals as well as the first Chinese manufacturer to deliver G11 rotary ITO target. Vital is also one of the world's three major supplier of infrared materials, a key supplier of compound semiconductor substrates, and a strategic partner of the world's largest thin film solar manufacturer.

Freiberger Compound Materials
Am Junger Loewe Schacht 5,
Freiberg, 09599,
Germany
Tel: +49 3731 280 0
Fax: +49 3731 280 106
www.fcm-germany.com

Kyma Technologies Inc
8829 Midway West Road,
Raleigh, NC, USA
Tel: +1 919 789 8880
Fax: +1 919 789 8881
www.kymatech.com

MARUWA CO LTD
3-83, Minamihonjigahara-cho,
Owariasahi, Aichi 488-0044, Japan
Tel: +81 572 52 2317
www.maruwa-g.com/e/products/ceramic

sp3 Diamond Technologies
2220 Martin Avenue,
Santa Clara, CA 95050, USA
Tel: +1 877 773 9940
Fax: +1 408 492 0633
www.sp3inc.com

Sumitomo Electric Semiconductor Materials Inc
7230 NW Evergreen Parkway,
Hillsboro, OR 97124, USA
Tel: +1 503 693 3100 x207
Fax: +1 503 693 8275
www.sesmi.com

The Fox Group Inc
200 Voyageur Drive, Montreal,
Quebec H9R 6A8, Canada
Tel: +1 925 980 5645
Fax: +1 514 630 0227
www.thefoxgroupinc.com

III/V-Reclaim
Wald 10, 84568 Pleiskirchen,
Germany
Tel: +49 8728 911 093
Fax: +49 8728 911 156
www.35reclaim.de

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
E-mail: sales@tecdia.com
www.tecdia.com

Wafer Technology Ltd
34 Maryland Road, Tongwell,
Milton Keynes, Bucks, MK15 8HJ, UK
Tel: +44 (0)1908 210444
Fax: +44 (0)1908 210443
www.wafertech.co.uk
Wafer Technology Ltd is a UK based producer of III-V materials and epitaxy-ready substrates offering the widest product range in the business.

Wafer World Inc
1100 Technology Place, Suite 104,
West Palm Beach,
FL 33407,
USA
Tel: +1-561-842-4441
Fax: +1-561-842-2677
www.waferworld.com

4 Epiwafer foundry

Albemarle Cambridge Chemical Ltd
Unit 5 Chesterton Mills,
French's Road, Cambridge CB4 3NP,
UK
Tel: +44 (0)1223 352244
Fax: +44 (0)1223 352444
www.camchem.co.uk

Intelligent Epitaxy Technology Inc
1250 E Collins Blvd,
Richardson, TX 75081-2401,
USA
Tel: +1 972 234 0068
Fax: +1 972 234 0069
www.intelliepi.com

IQE
Cypress Drive,
St Mellons,
Cardiff
CF3 0EG, UK
Tel: +44 29 2083 9400
Fax: +44 29 2083 9401
www.iqep.com
IQE is a leading global supplier of advanced epiwafers, with products covering a diverse range of applications within the wireless, optoelectronic, photovoltaic and electronic markets.

OMMIC
2, Chemin du Moulin B.P. 11,
Limeil-Brevannes, 94453,
France
Tel: +33 1 45 10 67 31
Fax: +33 1 45 10 69 53
www.ommic.fr

Soitec
Parc Technologique des Fontaines,
Chemin des Franques, 38190
Bernin, France
Tel: +33 (0)4 76 92 75 000
www.soitec.com

The Fox Group Inc
200 Voyageur Drive, Montreal,
Quebec H9R 6A8, Canada
Tel: +1 925 980 5645
Fax: +1 514 630 0227
www.thefoxgroupinc.com

VIGO SYSTEM S.A.
ul. Poznanska 129 /133, 05-850
Ozarów Mazowiecki, Poland
Tel: +48 22 733 54 10
E-mail: ent@vigo.com.pl
ent-epitaxy.com

www.vigo.com.pl www.ent-epitaxy.com

VIGO System's Epitaxy Division produces high-grade III–V compound semiconductor epitaxial structures for photonic and microelectronic devices. With more than 35 years' experience, the division offers a broad range of epi-wafers, both in large volumes and small customised batches. It focuses on innovative products for wireless, TC, sensing or printing applications.

5 Deposition materials

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

Matheson Tri-Gas
6775 Central Avenue,
Newark, CA 94560,
USA
Tel: +1 510 793 2559
Fax: +1 510 790 6241
www.mathesontrigas.com

Nouryon Functional Chemicals B.V.
Zutphenseweg 10, 7418 AJ
Deventer,
The Netherlands
Tel. +31 652 478554
https://hpmo.nouryon.com

Praxair Electronics
542 Route 303,
Orangeburg,
NY 10962,
USA
Tel: +1 845 398 8242
Fax: +1 845 398 8304
www.praxair.com/electronics

Vital Thin Film Materials (Guangdong) Co Ltd (Vital Materials subsidiary)
18G, 18th Floor, Shenzhen Free Trade Centre, No.111 Taizi Road,
Nanshan District,
Shenzhen, Guangdong, China 518067
Tel: (+86) 0755-21651348
sales@vitaltfm.com
www.vitaltfm.com
Vital Materials is the world's leading producer of rare metals as well as the first Chinese manufacturer to deliver G11 rotary ITO target. Vital is also one of the world's three major supplier of infrared materials, a key supplier of compound semiconductor substrates, and a strategic partner of the world's largest thin film solar manufacturer.

6 Deposition equipment

AIXTRON SE
Dornkaulstr. 2,
52134 Herzogenrath,
Germany
Tel: +49 2407 9030 0
Fax: +49 2407 9030 40
www.aixtron.com

ETC (LPE subsidiary)
Via Falzarego, 820021 Baranzate (Mi),
Italy
Tel: +39 02 383 41 51
Fax: +39 02 383 06 118
www.lpe-epi.com

Evatec AG
Hauptstrasse 1a,
CH-9477 Trübbach,
Switzerland
Tel: +41 81 403 8000
Fax: +41 81 403 8001
www.evatecnet.com

FHR Anlagenbau Gmbh (Vital Materials subsidiary)
Am Hügel 2, D-01458
Ottendorf-Okrilla,
Germany
Tel: +49 35205 520-0
E-mail: sales@fhr.de
E-mail: sales@vitalchem.com
www.fhr.biz
Vital Materials is the world's leading producer of rare metals as well as the first Chinese manufacturer to deliver G11 rotary ITO target. Vital is also one of the world's three major supplier of infrared materials, a key supplier of compound semiconductor substrates, and a strategic partner of the world's largest thin film solar manufacturer.

LPE S.p.A.
Via Falzarego, 8
20021 Baranzate (Mi), Italy
Tel: +39 02 383 41 51
Fax: +39 02 383 06 118
www.lpe-epi.com

PLANSEE High Performance Materials
6600 Reutte,
Austria
Tel: +43 5672 600 2422
info@plansee.com
www.plansee.com

Plasma-Therm LLC
10050 16th Street North,
St. Petersburg, FL 33716,
USA
Tel: +1 727 577 4999
Fax: +1 727 577 7035
www.plasmatherm.com

Riber
31 rue Casimir Périer, BP 70083,
95873 Bezons Cedex,
France
Tel: +33 (0) 1 39 96 65 00
Fax: +33 (0) 1 39 47 45 62
www.riber.com

SVT Associates Inc
7620 Executive Drive,
Eden Prairie, MN 55344, USA
Tel: +1 952 934 2100
Fax: +1 952 934 2737
www.svta.com

Temescal, a division of Ferrotec
4569-C Las Positas Rd,
Livermore, CA 94551, USA
Tel: +1 925 245 5817
Fax: +1 925 449-4096
www.temescal.net

Veeco Instruments Inc
100 Sunnyside Blvd.,
Woodbury, NY 11797, USA
Tel: +1 516 677 0200
Fax: +1 516 714 1231
www.veeco.com

7 Wafer processing materials

Kayaku Advanced Materials Inc
200 Flanders Road,
Westborough, MA 01581, USA
Tel: +1 617 965 5511
www.kayakuam.com

Praxair Electronics
(see section 5 for full contact details)

Versum Materials
8555 S. River Parkway,
Tempe, AZ 85284, USA
Tel: +1 602 282 1000
www.versummaterials.com

8 Wafer processing equipment

Evatec AG
Hauptstrasse 1a, CH-9477 Trübbach,
Switzerland
Tel: +41 81 403 8000
Fax: +41 81 403 8001
www.evatecnet.com

EV Group
DI Erich Thallner Strasse 1,
St. Florian/Inn, 4782,
Austria
Tel: +43 7712 5311 0
Fax: +43 7712 5311 4600
www.EVGroup.com

EV Group is a technology and market leader for wafer processing equipment. Worldwide industry standards for aligned wafer bonding, resist processing forthe MEMS, nano and semiconductor industry.

Logitech Ltd
Erskine Ferry Road,
Old Kilpatrick, near Glasgow G60 5EU,
Scotland, UK
Tel: +44 (0) 1389 875 444
Fax: +44 (0) 1389 879 042
www.logitech.uk.com

Plasma-Therm LLC
(see section 6 for full contact details)

SAMCO International Inc
532 Weddell Drive,
Sunnyvale, CA,
USA
Tel: +1 408 734 0459
Fax: +1 408 734 0961
www.samcointl.com

SPTS Technology Ltd
Ringland Way,
Newport NP18 2TA, UK
Tel: +44 (0)1633 414000
Fax: +44 (0)1633 414141
www.spts.com

SUSS MicroTec AG
Schleißheimer Strasse 90,
85748 Garching, Germany
Tel: +49 89 32007 0
Fax: +49 89 32007 162
www.suss.com

Synova SA
Ch. de la Dent d'Oche,
1024 Ecublens, Switzerland
Tel +41 21 694 35 00
Fax +41 21 694 35 01
www.synova.ch

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
Email: sales@tecdia.com
www.tecdia.com

Veeco Instruments Inc
(see section 6 for full contact details)

9 Materials & metals

Goodfellow Cambridge Ltd
Ermine Business Park, Huntingdon,
Cambridgeshire PE29 6WR, UK
Tel: +44 (0) 1480 424800
Fax: +44 (0) 1480 424900
www.goodfellow.com

PLANSEE High Performance Materials
6600 Reutte, Austria
Tel: +43 5672 600 2422
info@plansee.com
www.plansee.com

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

10 Gas and liquid handling equipment

Cambridge Fluid Systems
12 Trafalgar Way, Bar Hill,
Cambridge CB3 8SQ,
UK
Tel: +44 (0)1954 786800
Fax: +44 (0)1954 786818
www.cambridge-fluid.com

CS CLEAN SOLUTIONS AG
Fraunhoferstrasse 4,
Ismaning, 85737,
Germany
Tel: +49 89 96 24000
Fax: +49 89 96 2400122
www.csclean.com

Entegris Inc
129 Concord Road,
Billerica, MA 01821, USA
Tel: +1 978 436 6500
Fax: +1 978 436 6735
www.entegris.com

IEM Technologies Ltd
Fothergill House, Colley Lane,
Bridgwater, Somerset TA6 5JJ, UK
Tel: +44 (0)1278 420555
Fax: +44 (0)1278 420666
www.iemtec.com

Vacuum Barrier Corporation
4 Barton Lane,
Woburn, MA 01801,
USA
Tel: +1 781 933 3570
Fax: +1 781 933 9428
www.vacuumbarrier.com

VACUUM BARRIER VBC CORPORATION

Vacuum Barrier's vacuum-jacketed dynamic and sealed SEMIFLEX LN2 pipe delivers LN2 at bulk tank pressure in two-phase condition for on-demand supply. Our liquid/vapor phase separators deliver low-pressure LN2 to each use point for on-demand supply. Combine with SEMIFLEX Triax LN2 pipe eliminates two-phase flow to all use points.

Versum Materials
8555 S. River Parkway,
Tempe, AZ 85284,
USA
Tel: +1 602 282 1000
www.versummaterials.com

11 Process monitoring and control

Conax Technologies
2300 Walden Avenue,
Buffalo, NY 14225,
USA
Tel: +1 800 223 2389
Tel: +1 716 684 4500
www.conaxtechnologies.com

k-Space Associates Inc
2182 Bishop Circle
East, Dexter,
MI 48130,
USA
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
LayTec develops and manufactures optical in-situ and in-line metrology systems for thin-film processes with particular focus on compound semiconductor and photovoltaic applications. Its know-how is based on optical techniques: reflectometry, emissivity corrected pyrometry, curvature measurements and reflectance anisotropy spectroscopy.

Vacuum Barrier Corporation
4 Barton Lane, Woburn, MA 01801,
USA
Tel: +1 781 933 3570
Fax: +1 781 933 9428
www.vacuumbarrier.com
Vacuum Barrier's vacuum-jacketed dynamic and sealed SEMIFLEX LN2 pipe delivers LN_2 at bulk tank pressure in two-phase condition for on-demand supply. Our liquid/vapor phase separators deliver low-pressure LN_2 to each use point for on-demand supply. Combine with SEMIFLEX Triax LN_2 pipe eliminates two-phase flow to all use points.

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

CST Global Ltd
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
4 Barton Lane, Woburn, MA 01801,
USA
Tel: +1 781 933 3570
Fax: +1 781 933 9428
www.vacuumbarrier.com

VACUUM BARRIER VBC CORPORATION

Vacuum Barrier's vacuum-jacketed dynamic and sealed SEMIFLEX LN2 pipe delivers LN_2 at bulk tank pressure in two-phase condition for on-demand supply. Our liquid/vapor phase separators deliver low-pressure LN_2 to each use point for on-demand supply. Combine with SEMIFLEX Triax LN_2 pipe eliminates two-phase flow to all use points.

20 Facility consumables

PLANSEE High Performance Materials
6600 Reutte,
Austria
Tel: +43 5672 600 2422
info@plansee.com
www.plansee.com

W.L. Gore & Associates
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
422 North Broad Street,
Mooresville,
NC 28115,
USA
Tel: +1 704 664 9251
Email: sales@brumleysouth.com
www.brumleysouth.com

BSI

As an ISO 9001 registered global leader in the remanufacturing of wafer inspection systems, Brumley South Inc specializes in designing, installing and supporting upgrades for ADE, Nanometrics, Dryden and KLA-Tencor Surfscan tools, polysterene latex sphere calibration standards, particle deposition systems, and semiconductor parts and service.

Class One Equipment Inc
5302 Snapfinger Woods Drive,
Decatur, GA 30035,
USA
Tel: +1 770 808 8708
Fax: +1 770 808 8308
www.ClassOneEquipment.com

23 Services

Riff Company Inc
1484 Highland Avenue,
Cheshire, CT 06410,
USA
Tel: +1 203-272-4899
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

Al Shultz Advertising Marketing for Advanced Technology Companies
1346 The Alameda,
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

6–10 March 2022
Optical Fiber Communication Conference and Exhibition (OFC 2022)
San Diego Convention Center,
San Diego, CA, USA
E-mail: custserv@optica.org
www.ofcconference.org

20–24 March 2022
37th annual Applied Power Electronics Conference (APEC 2022)
George R. Brown Convention Center,
Houston, Texas, USA
E-mail: apec@apec-conf.org
http://apec-conf.org/conference/sessions/technical

27–31 March 2022
2022 IEEE International Reliability Physics Symposium (IRPS)
Hilton DFW Lakes Conference Center
near Dallas, TX, USA
E-mail: IRPSplanners@ieee.org
www.irps.org

25–27 April 2022
18th International Conference on Concentrator Photovoltaic Systems (CPV-18) and 13th World Conference on Thermophotovoltaic Generation of Electricity (TPV-13)
University of Miyazaki, Japan
E-mail: info@cpv-18.org
www.cpv-18.org

26–28 April 2022
25th Annual Components for Military & Space Electronics Conference (CMSE 2022)
Four Points by Sheraton (LAX) Los Angeles, CA, USA
E-mail: info@tjgreenllc.com
www.tjgreenllc.com/cmse

3–6 May 2022
45th WOCSDICE — Workshop on Compound Semiconductor Devices and Integrated Circuits held in Europe & 16th EXMATEC — Expert Evaluation and Control of Compound Semiconductor Materials and Technologies (WOCSDICE EXMATEC 2022)
Ponta Delgada (São Miguel island - Azores), Portugal
E-mail: WE2022@ua.pt
https://we2022.av.it.pt

9 May 2022
36th annual Reliability of Compound Semiconductors Workshop (ROCS 2022)
Monterey Marriott & Conference Center, Monterey, CA, USA
E-mail: rocs@jedec.org
www.jedec.org/events-meetings/rocs-workshop

9–12 May 2022
2022 CSMANTECH (International Conference on Compound Semiconductor Manufacturing Technology)
Monterey Marriott & Conference Center, CA, USA
E-mail: chairman@csmantech.org
www.csmantech.org

advertisers' index

10–12 May 2022
PCIM (Power Conversion and Intelligent Motion) Europe 2022
Nuremberg, Germany
E-mail: pcim@mesago.com
www.mesago.de/en/PCIM/main.htm

12–13 May 2022
Collaboration and innovation across the CS supply chain (CoInnovateCS)
Monterey Marriott & Conference Center, Monterey, CA, USA
E-mail: events@csconnected.com
www.coinnovatecs.com

15–20 May 2022
2022 Conference on Lasers & Electro-Optics (CLEO)
San Jose Convention Center, San Jose, CA, USA
E-mail: CLEO@compusystems.com
www.cleoconference.org

22–26 May 2022
International Symposium on Power Semiconductor Devices and ICs (ISPSD 2022)
Marriott Pinnacle Downtown Hotel, Vancouver, Canada
E-mail: ngwt@vrg.utoronto.ca
www.ispsd2022.com

30 May – 3 June 2022
IEEE 72nd Electronic Components and Technology Conference (ECTC 2022)
The Sheraton San Diego Hotel and Marina, San Diego, CA, USA
E-mail: reg.ectc@gmail.com
www.ectc.net

13–17 June 2022
2022 IEEE VLSI Symposium on Technology & Circuits - Technology and Circuits for the Critical Infrastructure of the Future
Hilton Hawaiian Village, Honolulu, HI, USA
E-mail: vlsi@vlsisymposium.org
www.vlsisymposium.org

10–15 July 2022
(postponed from 14-19 June 2020, then 4-9 July 2021)
20th International Conference on Metal Organic Vapor Phase Epitaxy (ICMOVPE XX)
Stuttgart, Germany
E-mail: info@icmovpexx.eu
www.icmovpexx.eu

21–25 July 2022
3rd International Congress on Advanced Materials Sciences and Engineering (AMSE-2022)
Hotel Ambasador, Opatija, Croatia
E-mail: eve4@amse-materials2021.com
www.istci.org/amse2022

21–25 August 2022
SPIE Optics + Photonics 2022
San Diego Convention Center, San Diego, CA, USA
E-mail: customerservice@spie.org
www.spie.org/opstm

31 August – 2 September 2022
PCIM (Power Conversion, Intelligent Motion) Asia 2022
Shanghai New International Expo Centre, China
E-mail: pcimasia@china.messefrankfurt.com
www.pcimasia-expo.com

7–9 September 2022
CIOE 2022 (24th China International Optoelectronic Exposition)
Shenzhen World Exhibition & Convention Center, Shenzhen, China
E-mail: cioe@cioe.cn
www.cioe.cn/en

11–16 September 2022
19th International Conference on Silicon Carbide and Related Materials (ICSCRM 2022)
Davos, Switzerland
E-mail: info@icscrm2021.org
www.icscrm2022.org

19–21 September 2022
48th European Conference on Optical Communication (ECOC 2022)
Basel, Switzerland
E-mail: info@ecoc2020.org
www.ecoco2020.org

25–30 September 2022
25th European Microwave Week (EuMW 2022)
MiCo, Milan, Italy
E-mail: eumwreg@itnint.com
www.eumweek.com

16–19 October 2022
2022 IEEE BiCMOS and Compound Semiconductor Integrated Circuits and Technology Symposium (BCICTS)
Sheraton Phoenix Downtown, Phoenix, AZ, USA
E-mail: cs@cshawevent.com
www.bcicts.org

semiconductorTODAY

COMPOUNDS & ADVANCED SILICON

www.semiconductor-today.com

Join our LinkedIn group: Semiconductor Today

Follow us on Twitter: Semiconductor_T

Choose *Semiconductor Today* for . . .

MAGAZINE

Accurate and timely coverage of the compound semiconductor and advanced silicon industries

Targeted 82,000+ international circulation

Published 10 times a year and delivered by e-mail and RSS feeds

WEB SITE

Average of over 26,000 unique visitors to the site each month

Daily news updates and regular feature articles

Google-listed news source

E-BRIEF

Weekly round-up of key business and technical news

E-mail delivery to entire circulation

Banner and text marketing opportunities available