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Fraunhofer ISE raises efficiency record for tandem III-V/Si solar cells

Riber delivers first MBE 8000 system • Odyssey raises $5m • US-Mac consortium formed • 5N Plus buying AZUR SPACE

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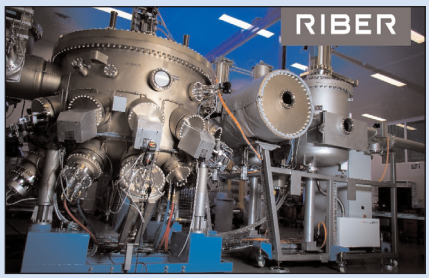
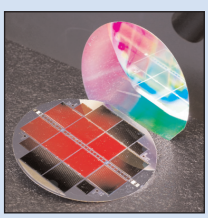
p11 II-VI Inc has expanded its SiC wafer finishing manufacturing footprint in China to serve the world's largest market for EVs and for clean energy.



p26 Riber has delivered its first MBE 8000 system to longstanding customer IntelliEPI, for manufacturing VCSEL epiwafers.

p51 Germany's Fraunhofer ISE (Institute for Solar Energy Systems) has officially inaugurated its new Center for High Efficiency Solar Cells.



Cover: Fraunhofer ISE has again set a new solar energy conversion efficiency record for a monolithic tandem cell made of III–V and Si semiconductors . The new monolithic triple-junction solar cell — specifically, a III–V//Si tandem solar cell — converts 35.9% of sunlight into electrical energy.. **p50**

editorial

Supply chain for vertical integration

Over the last month, the shortages in silicon chip supply has proliferated, as demand for consumer electronics (such as smartphones and game consoles) has been driven by coronavirus-era home working & entertainment and as automotive manufacturing revives and is now competing with other industries to re-establish its supply chain. This has highlighted how (1) chip manufacturing has been outsourced to just a few increasingly dominant foundries (mainly Taiwan's TSMC and South Korea's Samsung) and (2) industries have become geared to minimizing component inventories through just-in-time supply via rapid, barrier-free transit of goods worldwide. The vulnerabilities of this have been highlighted both by pandemic-driven supply-chain disruption and by tariffs caused by trade disputes.

There is a desire to take control of leading-edge wafer processing back in-house (particularly by Intel) and generally to expand semiconductor manufacturing both in the USA (with GlobalFoundries moving its HQ to New York State as part of its expansion there — see page 9) and in the EU (to double Europe's share of global semiconductor output to 20% by 2030).

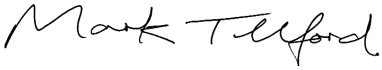
While there is a benefit to on-shoring the upstream front-end stages of the manufacturing chain, it makes sense for the back-end stages to be local to the largest end-markets, particularly where a market is rapidly developing, e.g. in wide-bandgap materials such as silicon carbide and gallium nitride for power electronics in electric vehicles (EVs), solar panel inverters, etc.

For example, II–VI Inc is complementing its 5–10-fold expansion in SiC substrate production capacity in the USA (including introducing 200mm-diameter substrates) by expanding its conductive SiC wafer-finishing capacity via a new back-end processing line at its Asia Regional HQ in China — the "world's largest market for EVs and for clean-energy applications" (page 12).

Meanwhile, the Innovate UK-funded project SOCRATES aims to establish an industrial supply chain for high-power SiC trench devices to create vertically conducting (rather than the established horizontally conducting) transistors (see page 14). Specifically, it aims to addresses gaps in the UK power electronics, machines and drives (PEMD) supply chain, i.e. the lack of (1) a trench SiC power MOSFET process and (2) a high-volume supplier of SiC transistors for the UK EV industry (since there are currently no UK-based high-volume 6–8" SiC wafer fabs). The project consortium comprises the South Wales-based CSconnected cluster, Swansea University, the Compound Semiconductor Centre, Newport Wafer Fab and epiwafer foundry IQE. It is led by SPTS Technologies, which makes the equipment needed to etch the trenches to create the vertical SiC transistors. "As we have seen with silicon in the past, SiC and GaN are moving towards vertical, trench-based structures," notes SPTS' process technology manager Huma Ashraf.

Indeed, vertically conducting GaN devices are also the focus of 2016 Cornell University spin-off Odyssey, which has just raised $5m to fund further development and production of high-voltage vertically conducting GaN power-switching devices, targeting applications such as EVs, solar inverters, industrial motors and power grids rather than the low-voltage consumer electronics applications to which horizontally conducting GaN power devices have been limited (page 16). Due to lower on-resistance (and hence lower power loss) and higher-frequency operation, GaN promises to provide more compact, less costly and higher-performing vertical power-switching transistors than even SiC.

Mark Telford, Editor



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

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

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Mini-LED iPad Pro shipments to reach 5 million in 2021

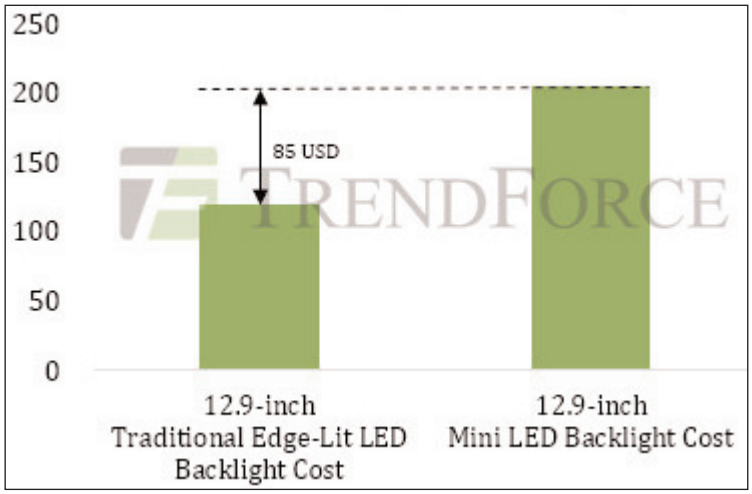
Forecasted share of tablet market raised from 2.5% to 3.1%

During its Spring Loaded event, Apple announced the upcoming release of its latest 12.9-inch iPad Pro models featuring mini-LED display technology. According to TrendForce's latest investigations, demand for the 12.9-inch iPad Pro has already been relatively high in niche markets. So, given the thorough improvement in product specifications as well as the very slight price hike of merely $100 over the previous generation, TrendForce is not only revising up its shipment forecast for the 2021 version of the 12-inch iPad Pro from 4 million units to 5 million units this year but also expects this product to account for a 3.1% share of the global tablet market, compared with the previous forecast of 2.5%.

Analyst Max Chen highlights three key areas of observation with respect to Apple's latest flagship tablet: technology cost, retail price, and product spec.

First, in terms of technology cost, the mini-LED backlight used in the new 12.9-inch iPad Pro costs about $85 more than the traditional edge-lit LED backlight used in the previous generation.

Second, in terms of retail price, the entry-level 128GB model of the 12.9-inch mini-LED iPad Pro retails for $1099, which is only $100 higher than the equivalent model of the previous generation. As such, the price hike in the latest model is, for the most part, a result of the increased cost of mini-LED backlights, rather than wholly being an attempt at driving up profit margins. The modest price hike is therefore an indication of Apple's desire to become the gold standard in the tablet market by adopting mini-LED backlight technology.



Cost difference between LED backlights used in 12.9-inch iPad Pros (in millions of US$).

Finally, in terms of product spec, the latest 12.9-inch mini-LED iPad Pro is equipped with Apple's high-end Liquid Retina XDR technology, which gives the tablet a maximum full-screen brightness of 1000 nits, peak brightness of 1600 nits, and contrast ratio of 1,000,000:1, with the peak brightness and contrast ratio both being firsts in the tablet industry. Furthermore, the latest tablet is equipped with 10,384 mini-LED chips, divided into 2596 dimming zones, giving it additional high contrast and high color saturation performance that is superior to the 31.5-inch iMac, which features 512 backlight dimming zones and is the first product to feature Apples' XDR display technology.

Regarding Apple's plans for second-half 2021, the 14-inch and 16-inch MacBook models will likewise feature mini-LED backlight technology, which will become the hardware benchmark for high-end tablets and notebook computers.

The release of Apple's mini-LED-equipped tablets is expected to galvanize growth against market headwinds for upstream and downstream companies in the mini-LED supply chain, including mini-LED chip suppliers (e.g. Ennostar), testing and sorting service suppliers (e.g. FitTech, Saultech, and YTEC), SMT suppliers (e.g. TSMT and Yenrich), backplane PCB suppliers (e.g. Zhen Ding Tech and Tripod Technology), driver IC suppliers (e.g. Parade, Novatek, and Macroblock), and light source module suppliers (e.g. Radiant/ROE and GIS), concludes TrendForce.

www.trendforce.com/research/led

Smartphone revenues to rebound by 13% in 2021

Global smartphone wholesale revenues will rise by 13% year-on-year in 2021, the highest revenue growth in six years, forecasts market research firm Strategy Analytics. Despite the economic uncertainty and dented consumer confidence caused by the coronavirus, the market will be able to bounce back in 2021 on the back of the Apple iPhone 12 super cycle and the migration to 5G globally, it adds.

"Although global smartphone wholesale revenues decreased -5% year-on-year in 2020 as a result of the global coronavirus pandemic, we expect them to rebound strongly +13% in 2021 and continue to rise in the following years," says associate director Boris Metodiev. "Economic recovery following COVID-19-related lockdowns globally, overdue replacement of aging devices and higher component prices, as well as migration towards 5G, are all going to contribute to the revenue growth in 2021," he adds.

"We expect global smartphone sales volume will grow +7% year-on-year at 1.4 billion units, and global smartphone wholesale average selling price (ASP) will grow +6% to $294 in 2021, resulting in smartphone wholesale revenue exceeding $400bn," says senior director Linda Sui. "We expect the ultra-premium segment ($600 wholesale and above) to perform particularly well due to iPhone 12's super cycle, and to contribute to almost half of the overall wholesale revenues this year," she adds.

"We expect the four largest countries of China, USA, India and Japan to account for 54% of all smartphone wholesale revenues worldwide in 2021," notes senior VP David Kerr. "A downside risk remains in terms of volumes and value in India and Brazil, which are suffering through significant surges in COVID-19 currently. However, in general we remain modestly optimistic about both replacement sales and new customers."

www.strategyanalytics.com

Smartphone shipments surge 24% year-on-year in Q1

Global smartphone shipments were 340 million units in first-quarter 2021, up +24% on 275 million a year ago (the highest growth since 2015), reports market research firm Strategy Analytics. The smartphone market rebound was driven by healthy demand from consumers with aging devices and a phenomenal 5G push from Chinese vendors, it notes.

"The China smartphone market had a sensational quarter, driven by 5G product success across multiple price tiers," comments senior director Linda Sui. China smartphone shipments were up +35% year-on-year, reaching 94 million units in Q1/2021. Globally, the top five vendors combined took a 76% market share, up from 71% a year ago. "Chip shortages and supply-side constraints did not have a significant impact in Q1 among the top five brands but was and will be a concern for smaller vendors over the next few quarters in our view," she adds.

Samsung remains the largest vendor, shipping 77 million smartphones globally in Q1, up 32% year-on-year from 58 million units in Q1/2020. "Samsung's newly launched, more affordable A series 4G and 5G phones and the earlier launched Galaxy S21 series combined drove solid performance in the quarter," notes executive director Neil Mawston. Apple shipped 57 million units iPhones worldwide (up 44% from 39 million a year ago), capturing second place with a 17% volume market share. "The strong momentum behind the 5G iPhone 12 series continued across multiple markets," he adds.

Xiaomi held third place in terms of volume of smartphones shipped for the second quarter in a row, shipping 49 million globally (up 80% on 28 million a year ago) and taking a 15% market share in Q1 (up from 10% a year ago). "The vendor maintained strong momentum in both India and China, and the expansion in Europe, Latin America and Africa region also started to bear fruit," comments senior analyst Yiwen Wu.

OPPO (not including Realme and OnePlus) won 11% market share and remained the fourth largest smartphone vendor in Q1. It was followed by vivo, which grew an impressive 85% year-on-year.

www.strategyanalytics.com/

Global Smartphone Shipments (Million of Units)	Q1 2020	Q1 2021	Q1 2021 Market Share %	Q1 2021 YoY %
Samsung	58	77	23%	32%
Apple	39	57	17%	44%
Xiaomi	28	49	15%	80%
OPPO	23	38	11%	68%
vivo	20	37	11%	85%
Others	107	82	24%	-23%
Total	275	340	100%	24%

STRATEGY ANALYTICS

Skyworks acquiring Silicon Labs' Infrastructure & Automotive business for $2.75bn

Combined market opportunity approaching $20bn annually

Skyworks Solutions Inc of Woburn, MA, USA (which manufactures analog and mixed-signal semiconductors) has agreed to acquire the Infrastructure & Automotive business of Silicon Laboratories Inc of Austin, TX, USA, a provider of silicon, software and solutions, in an all-cash asset transaction valued at $2.75bn.

Over the past two decades, the Infrastructure & Automotive business has provided solutions to a highly diversified customer base. The acquisition encompasses the technology portfolios and related assets of Silicon Labs' power/isolation, timing and broadcast product lines, which are highly complementary to Skyworks' connectivity portfolio.

The acquisition is expected to accelerate Skyworks' expansion into the industry's most important growth segments, including electric and hybrid vehicles (EV/HEV), industrial and motor control, power supplies, 5G wireless infrastructure, optical data communication, data center, automotive, smart home and several other applications. Skyworks reckons that it will be uniquely positioned to address a combined market opportunity approaching $20bn annually.

Mark Thompson, senior VP of Silicon Labs and general manager of the Infrastructure & Automotive business, will join Skyworks, reporting directly to Skyworks' president & CEO Liam K. Griffin. In addition, about 350 staff, including the senior management team of the business, are expected to join Skyworks upon completion of the transaction.

"This acquisition will broadly expand our capabilities across high-growth end markets including automotive, communications and industrial, creating new and highly compelling opportunities for Skyworks," says Griffin. "By leveraging our global sales channels, operational scale and deep customer relationships, Skyworks is well positioned to drive above-market growth, while diversifying revenues, expanding margins and delivering strong returns in earnings and cash generation," he believes.

The acquisition is expected to accelerate Skyworks' expansion into the industry's most important growth segments, including EV/HEV, industrial and motor control, power supplies, 5G wireless infrastructure, optical data communication, data center, automotive, smart home

"With our companies' shared cultures of design excellence and customer collaboration, I am confident that the Infrastructure & Automotive team will continue their decades-long history of delivering industry-leading innovations," says Silicon Labs' CEO Tyson Tuttle. "Silicon Labs and Skyworks will partner to ensure a seamless transition for customers, suppliers and employees."

Skyworks expects the transaction to be immediately accretive and to accelerate the path to it achieving its target financial model. The transaction, which is expected to close during third-quarter 2021, has been approved by the boards of directors of both firms and is subject to customary closing conditions, including regulatory approvals.

Skyworks expects to fund the transaction with a combination of cash on hand and committed debt financing arranged by J.P. Morgan.

www.silabs.com
www.skyworksinc.com

Skyworks launches high-gain LNA for small-cell, cellular 5G NR and base-station applications

SKY67181-396LF joins SKY67183-396LF and SKY67189-396LF launched last August

Skyworks Solutions Inc of Woburn, MA, USA (which manufactures analog and mixed-signal semiconductors) has introduced the SKY67181-396LF high-gain, low-noise amplifier (LNA).

Designed to meet the challenging requirements of cellular LTE and 5G NR infrastructure applications, the new LNA features ultra-low noise figure, high gain and operates over a wide range of frequencies.

Featuring an ultra-compact 2mm x 2mm plastic surface-mount package to reduce PCB board space, SKY67181-396LF is pin-to-pin compatible with the SKY67183-396LF and SKY67189-396LF (launched last August).

These LNAs are suitable for 2G/3G/4G/5G TDD and FDD infrastructure applications, including small-cell, massive MIMO, and macro base-stations.

GlobalFoundries moving HQ to New York State as it expands fab capacity

Firm to maintain substantial presence in Silicon Valley's Santa Clara

At an onsite event with Senate Majority Leader Chuck Schumer, GlobalFoundries (GF) of Santa Clara, CA, USA (which has operations in Singapore, Germany and the USA) announced that it will relocate its headquarters to Malta, New York, the site of Fab 8, the firm's most advanced semiconductor manufacturing facility — as it positions itself for growth, strengthens partnerships with customers and recruits new talent.

GF has invested more than $15bn in its Fab 8 facility over the last decade to support innovation and manufacturing capacity. In 2021, the firm is doubling its planned investment to expand global capacity, with $500m targeted for Malta, NY alone.

The firm says that its move from its previous headquarters to its fab in New York is part of its commitment to address the soaring global chip demand, with a focus on semiconductor manufacturing innovation. GF will maintain a substantial presence in Santa Clara, California, in the heart of Silicon Valley, where many of GF's leading US customers and ecosystem partners are based.

"GF's Fab 8 in New York is a $15bn advanced semiconductor manufacturing facility and one that is playing a key role in the transformation of our industry to meet rapidly accelerating demand," said CEO Tom Caulfield. "Our amazing 3000-person workforce, in partnership with our local, state and federal leaders, will together build on GF's success, solidifying the Empire State's place as one of a few world-class semiconductor manufacturing hubs at a time when our national and economic security depends more and more on what we can make here at home."

"I would like to thank Senator Schumer for his steadfast support for GF over the years and his tireless leadership in forging a bipartisan coalition in Congress that, together with the Administration, fully appreciates the need for a secure and resilient domestic semiconductor supply chain," Caulfield added. "The time for the Endless Frontier Act is now and, once approved by Congress and signed into law by President Biden, GF stands ready to do our part by expanding in upstate New York and creating many more high-paying American jobs. Our ambitious goal is to double our capacity at this site in the years to come in partnership with our customers, local, state and federal governments."

The chips that GlobalFoundries manufactures here in Malta are critical to our national security and to our economic competitiveness across key industries

"GlobalFoundries' transition of its headquarters to Fab 8 in Malta is further indication of the company's commitment to growth in New York and to the Empire State's leadership in the semiconductor industry," said Senate Majority Leader Chuck Schumer, who successfully passed into law new federal semiconductor manufacturing and R&D incentives in last year's National Defense Authorization Act (NDAA). "The chips that GlobalFoundries manufactures here in Malta are critical to our national security and to our economic competitiveness across key industries. I have worked closely with GlobalFoundries over the years to look for opportunities to expand their presence in New York and I am now pushing to secure the federal funds necessary to implement programs we passed into law last year to support further expansion of domestic chip production by companies like GlobalFoundries, accelerating even more growth in the semiconductor industry across Upstate New York."

GF employs more than 15,000 globally, with 7000 people across the USA including nearly 3000 at Fab 8. In 2020, GF announced a land purchase option to provide additional flexibility to expand Fab 8's footprint to support growing demand from the US government and industry customers.

www.globalfoundries.com

Purchaser of MACOM notes executes option for extra $50m

Total of $450m to be used to repay outstanding term loans

MACOM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog RF, microwave, millimeter-wave and photonic applications) says that the initial purchaser in its offering of $400m convertible senior notes (announced on 22 March) has exercised its option to purchase an additional $50m of the notes.

The 'Greenshoe' clause provided the initial purchaser the option to purchase up to $60m additional notes under the same terms. No additional notes will be issued, resulting in a total of $450m convertible senior notes being issued.

MACOM intends to use the incremental net proceeds for further repayment of outstanding term loans.

www.macom.com

MixComm joins OpenRF Association

First mmW-focused firm to join 5G RFFE industry consortium

Fabless semiconductor company MixComm Inc of Chatham, NJ, USA has joined the Open RF Association, an open industry consortium dedicated to creating a 5G ecosystem of functionally interoperable hardware and software across RFFE (RF front-end) and chipset platforms. As the organization's newest associate member, MixComm will work with founding members Qorvo, Samsung Electronics, MediaTek and others to drive adoption of 5G technology.

"As a 5G mmWave RF front-end IC and subsystem provider, we see the need and importance of an open and interoperable ecosystem," says MixComm's CEO Mike Noonen. "Our 'Antennas to Algorithm' product strategy fits perfectly with OpenRF. We're thrilled to join this association and support its mission to improve time to market, performance and cost while allowing for product differentiation," he adds.

"MixComm is the first company with a focus on mmW technology to join OpenRF," notes OpenRF's president Kevin Schoenrock. "Leveraging their sub-system and unique software expertise, we look forward to the contributions MixComm will bring to the organization," he adds. "As use cases for mmW technology expand in conjunction with 5G cellular applications, evolving the capabilities of an open and interoperable eco-system is important for the industry."

"We see the need and importance of an open and interoperable ecosystem," says Noonen

With a background in mmWave and RF-SOI (silicon-on-insulator) innovations, MixComm brings unique expertise to OpenRF. The firm's products, such as the SUMMIT 2629 5G 28GHz beam-forming front-end IC, address fundamental challenges that come with 5G mmWave links. MixComm believes that, by working with other association members, best-in-class mmWave configurable solutions can be driven to market faster.

https://openrf.com
www.mixcomm.com

Altum RF gains GLOBES Elektronik as sales rep

Expanded sales coverage supports Germany, Austria and Switzerland

Altum RF of Eindhoven, The Netherlands (a supplier of high-performance RF to millimeter-wave solutions for next-generation markets and applications) has announced a sales representative agreement with GLOBES Elektronik GmbH & Co KG of Heilbronn, Germany, covering customers in Germany, Austria and Switzerland.

Founded in 1995, sales and distribution company GLOBES specializes in high-frequency, microwave and RF technologies, and has expertise and relationships in communications, military, ISM and satellite markets.

"With knowledgeable sales engineers in the RF and microwave industry, we are confident GLOBES will provide excellent technical expertise to customers, enabling them to be successful on design projects," comments Altum RF's CEO Greg Baker.

"The addition of Altum RF's innovative products to our catalog bolsters our ability to supply technical solutions," says GLOBES Elektronik's chief operating officer, partner and co-founder Ulrich Blievernicht.

www.globes.de

Altum RF announces ISO 9001:2015 surveillance audit

Evaluation of quality management system reported no deviations

Altum RF has achieved a successful ISO 9001: 2015 surveillance audit of its quality management system. The audit reported no deviations, demonstrating the continual focus on the quality, reliability and performance of its design and development of semiconductor products, the firm says.

"We are pleased to announce another important milestone for our quality management system, proving our effectiveness to comply with the requirements of the ISO 9001 standard," says CEO Greg Baker. "We stay committed to achieving and maintaining high quality standards and certifications to become a trusted supplier in the RF and microwave industry."

The ISO 9001:2015 audit was conducted by TÜV Nederland (part of the international TÜV NORD GROUP, a global company located in 70 countries that has more than 100 years of experience with quality systems certification).

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

www.altumrf.com

II-VI expands conductive silicon carbide wafer finishing capacity in China

Backend processing complements a 5–10-fold SiC substrate capacity expansion in the USA

Engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA has expanded its silicon carbide (SiC) wafer finishing manufacturing footprint in China to serve the world's largest market for electric vehicles (EVs) and for clean energy applications.

Spurred by increasing regulatory requirements for lower emissions of greenhouse gases and the decreasing cost of lithium-ion batteries, the market for EVs is growing rapidly and driving demand for power electronics based on silicon carbide which, as a wide-bandgap semiconducting material, can boost the driving range of EVs by about 10% on a single charge, compared with power electronics based on silicon. To meet the market demand in Asia, II-VI has established a backend processing line for conductive SiC substrates, in over 50,000ft^2 of new cleanroom space, at II-VI's Asia Regional Headquarters in Fuzhou, China.

"According to recent industry reports, China is expected to continue to be the world's largest electric car market, at over 40% of global sales," says Sohail Khan, executive VP of II-VI's New Ventures & Wide-Bandgap Electronics Technologies business unit. "We are planning to substantially increase

our global production capacity for SiC boules and substrates in the USA over the next 5–10 years to address the accelerating power electronics market, including for electric vehicles and clean-energy applications," he adds. "These investments will be supported by our global sales force and a SiC platform built by our innovations of the last 20 years, including the world's first 200mm conductive substrates in 2015."

In addition to EVs, power electronics based on SiC enable high efficiency in inverters for solar and wind energy generation, as well as in smart-grid power switching, due to reduced switching losses, high power density, better heat dissipation and increased bandwidth capability compared with existing devices based on silicon.

The backend SiC wafer processing performed at II-VI's new SiC facility in Fuzhou includes edge grinding, chemical-mechanical polishing (CMP), cleaning and inspection, all performed in Class 100 and Class 1000 cleanrooms. The facility is part of II-VI's already announced plan to ramp its SiC substrate manufacturing capacity by 5–10 times over five years, including with 200mm diameter substrates. II-VI maintains a large manufacturing operations and product development presence in China in the cities of Fuzhou, Guangzhou, Shanghai, Shenzhen, Suzhou, and Wuxi.

www.ii-vi.com

NoMIS Power Group to provide silicon carbide power semiconductor devices and modules

SUNY Poly and Indium Corp evaluating packaging materials and compatibility with silicon carbide devices

NoMIS Power Group LLC, a spin-off of State University of New York Polytechnic Institute (SUNY Poly), began from a research effort begun in September 2019, when postdoc Dr Adam Morgan connected with associate professor of Nano-engineering Dr Woongje Sung and his students to help them further evaluate their silicon carbide (SiC) power semiconductor devices beyond on-wafer measurements.

Spearheading a project proposal to the New York State Center for Advanced Technology in Nano-materials and Nanoelectronics (CATN2) matching investment program, and in partnership with Indium Corp, the group received funding in 2020. As a result, SUNY Poly and Indium have been evaluating advanced packaging materials (die attachments and thermal interface materials) and their compatibility with the SiC devices.

"The performance of the SiC devices produced were on par, if not better, in some key aspects than what is commercially available," says Morgan, based on the successful outcomes of Sung's projects. "At the same time, the rising interest globally in clean tech was making it clear that a growing market exists for the SiC device technologies we are working on," he adds.

Because Morgan's expertise revolves around making the SiC bare chips usable by applications engineers by means of packaging the SiC chips using supporting material systems with high-power terminations (allowing them to be usable in power electronic circuits), the research team felt they had the necessary technical background to turn the technology into a product. They hence formed NoMIS (Novel Materials and Innovative Semiconductors Power Group).

NoMIS' CEO Adam Morgan.

The near-term goal of NoMIS is to design, manufacture and sell SiC power semiconductor devices, modules and associated services that are currently unavailable on the market in order to provide enabling 21st century technology that supports power management product developers (i.e. power electronics engineers who are operating in the electric vehicle (EV) fast-charger, heavy-duty EV, traction locomotive, marine electrification, and industrial motor drive markets) as they work on next-generation, efficient and reliable clean tech products/solutions.

Along with co-founder, technical & business advisor Dr Anant Agarwal (a professor at The Ohio State University), the following SUNY Poly experts are the driving force behind the company:

- Dr Adam Morgan: co-founder, CEO and technical lead of power packaging efforts;
- Dr Woongje Sung: co-founder, technical lead of SiC device design; and
- Dr Shadi Shahedipour-Sandvik: co-founder, technical lead of wide-bandgap material and GaN device design, SUNY provost-in-charge and SUNY Poly interim VP of Research and Graduate Studies.

"The rising interest globally in clean tech was making it clear that a growing market exists for the SiC device technologies we are working on," says CEO Adam Morgan

"SUNY Poly is well connected to the rapidly growing technology ecosystem of New York State (NYS) and is strongly supported by government, industry and research institutions," notes Morgan. "This puts its students at an advantage of getting to be a part of it all."

Currently, NoMIS is focused on scaling the production of larger SiC chips and multi-chip modules in the form of available prototypes, as well as customer discovery efforts. Within five years, it aims to have established a diversified, reliable supply chain capable of mass producing its SiC technology and, in parallel, partner with several customers and researchers to perform rigorous field demonstration testing that shows off the technology's performance in order to attract additional customers.

It is anticipated that NoMIS' products could lead to the deployment of more clean technologies, from large-scale residential and commercial photovoltaic (PV) solar and wind generation coupled with energy storage to electrified transportation, or high-speed industrial motors, for example.

Already, NoMIS is a semi-finalist for the American-Made Solar Prize competition; a competition funded by the US Department of Energy (DoE) that would award the firm $3m to help develop the technology for its potential use to integrate solar technology on the grid.

www.nomispower.com
www.sunypoly.edu

Pre-Switch reports 99.3% efficiency for 200kW inverter

Use of three discrete 35mΩ SiC MOSFETs per switch location aids electric vehicle and renewable energy designs

Pre-Switch Inc of Campbell, CA, USA, a start-up that has developed the first AI-based DC/AC, AC/DC soft-switching controller, has published performance data that shows that its 200kW (space vector modulated) CleanWave200 evaluation inverter exceeds 99.3% efficiency at 100kHz using only three discrete, low-cost 35mΩ silicon carbide (SiC) MOSFETs per switch location. This is expected to revolutionize electric vehicle (EV) and renewable energy designs.

"We are shipping the CleanWave200 evaluation systems to initial customers around the world, and the efficiency data we are making public today more than justifies our design goals," says CEO Bruce Renouard. "Customers could use the Pre-Switch technology with even better MOSFETs and expect to get incremental performance gains, but there is no other approach that even comes close to 99.3% efficiency at 100kHz with such few, low-cost SIC MOSFETs."

The Pre-Switch AI enables users to migrate from lossy, expensive hard-switching implementations to high-efficiency, soft-switching designs with a 10x higher switching frequency which produces an almost pure sine-wave output, says the firm. The Pre-Switch controller analyzes multiple inputs on a cycle-by-cycle basis, making adjustments in real time to small, forced-resonant transistors enabling what is said to be perfect soft-switching in harsh changing environments. Variations in system temperature, device degradation, changing input voltages and abrupt current swings are all accounted for and optimized within the Pre-Switch AI algorithm.

The published data plots system efficiency for 50–100kHz switching speeds, input voltages, power output and current output, enabling system designers to compare the Pre-Switch results to their own requirements. "Switching losses using our Pre-Switch technology are effectively zero," says Renouard. "If we put that into perspective, an EV with Pre-Switch technology improves inverter efficiencies, producing a pure sine-wave output that dramatically improves motor efficiency at low torques where people drive. This will result in an increase its range by up to 12%," he reckons.

The Cleanwave200 evaluation system, reference design and design files can be ordered now from Pre-Switch.

www.pre-switch.com

UK's SOCRATES project aims to establish supply chain for high-power SiC and GaN trench devices

Consortium includes SPTS, Newport Wafer Fab, Swansea University, Compound Semiconductor Centre and CSconnected

The UK compound semiconductor sector is taking steps to establish an industrial supply chain for high-power silicon carbide (SiC) and gallium nitride (GaN) trench devices.

SOCRATES (SilicOn Carbide tRAnsistor Trench procEsS) is a 9-month project (from January–September) that is part funded by £137,423 from the Catalysing Green Innovation challenge of government agency Innovate UK via UK Research and Innovation (UKRI). The objective of the project is to address opportunities in the UK power electronics, machines and drives (PEMD) supply chain.

PEMD supply chains play a critical role in the global decarbonization effort and in achieving net zero targets. Applications require robust devices that can operate at high voltages, temperatures and frequencies, as well as the ability to handle high current densities. Wide-bandgap (WBG) semiconductor materials are suited to such applications and allow for an increase in system efficiencies and reduction in weight and volume.

The compound semiconductor materials silicon carbide (SiC) and gallium nitride on silicon carbide (GaN-on-SiC) are frontrunners in the field of high-power devices and are identified as optimal WBG materials for trench-based vertical devices to increase device performance.

The SOCRATES project addresses gaps in the UK's PEMD supply chain, i.e. the lack of (1) a trench SiC power MOSFET process and (2) a high-volume supplier of SiC transistors for the UK EV industry, (there are no existing UK-based high-volume 6–8" SiC wafer fabs). In contrast, international competitors are establishing key strategic PEMD links in order to supply SiC devices to the future EV market, e.g. Infineon with Hyundai, STMicroelectronics (already producing 4000 wafers per month) with Tesla, and XFab with General Motors and Ford. Thus, the UK is in danger of losing its security of supply of this crucial technology to the UK automotive sector, it is reckoned.

Led by SPTS Technologies Ltd of Newport, Wales, UK — a KLA company that manufactures etch, deposition and thermal wafer processing solutions — the consortium also includes Newport Wafer Fab (NWF, the UK's 200mm compound semiconductor wafer foundry), Swansea University, Compound Semiconductor Centre Ltd (CSC, a joint venture founded in 2015 between Cardiff University and epiwafer foundry and substrate maker IQE plc of Cardiff, Wales) and CSconnected (the compound semiconductor cluster, based in South Wales). The consortium aims to deliver industrial processes for SiC and GaN-on-SiC trench etching, as well as in-line fabrication processes for integration of the etch into high-volume manufacturing.

"Whilst the UK has strong industrial expertise in PEMD systems development, there has been a lack of a coordinated PEMD supply chain in the UK until now, with high-volume supply of vertical SiC transistors being identified as an opportunity gap, particularly for the growing electric vehicle (EV) industry," comments Rob Harper, program manager Power & RF at CSC.

"As a UK-based global company in the semiconductor industry we have a strong customer base overseas and we look forward to supporting the UK activity in the decarbonization effort through regional collaboration," states Huma Ashraf, process technology manager at SPTS. "As we have seen with silicon in the past, SiC and GaN are moving towards vertical, trench-based structures and SPTS's wafer processing solutions and extensive experience in compound semiconductors are well-suited to deliver this at an industrial scale," he believes.

In addition to the capabilities at SPTS in etch technologies, the project also benefits from years of know-how in power device fabrication at Newport Wafer Fab (the UK's largest semiconductor fabrication facility). "The power semiconductor device market is going from strength to strength, with EVs, renewables and wider electrification efforts paving the way for rapid growth in demand for SiC devices," comments Sam Evans, NWF's director of quality & external affairs.

"Here at Swansea University, we have invested heavily in 6"and 8" fabrication facilities and expertise to support the semiconductor industry with prototyping activities," notes Swansea University associate professor Mike Jennings. "These industry-focused projects are invaluable in training future talent for the growing compound semiconductor industry," he adds.

"PEMD is a perfect example of the many applications in which compound semiconductors are set to become ubiquitous with the increasing demand for high-performance devices, from power and energy through to communications and quantum technologies," states CSconnected director Chris Meadows. "The CSconnected cluster has a long history in collaborative R&D in compound semiconductor technologies and is positioned strongly to deliver on future cutting-edge, high-volume opportunities."

https://gtr.ukri.org/projects?ref=76399
http://csconnected.com
www.compoundsemiconductorcentre.com

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- Lock Out Tag Out (LOTO) safety devices (fixed and removal types) are available as option.

Fuji Electric Corp. of America Distribution & Control Department

For sales, product & distributor information, please visit https://americas.fujielectric.com/products/distribution-control/

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

Wolfspeed launches multi-stage GaN-on-SiC MMICs for X-band phased-array radar

Four new devices enable improved RF system size, weight and power

Cree|Wolfspeed of Durham, NC, USA has introduced four new multi-stage gallium nitride on silicon carbide (GaN-on-SiC) monolithic microwave integrated circuit (MMIC) devices, extending its range of RF solutions for a diverse array of pulsed and continuous-wave X-band phased-array applications, including marine, weather surveillance and emerging unmanned aerial system radars.

Using Wolfspeed GaN-on-SiC technology, the new devices deliver high power-added efficiency (PAE) in small, industry-standard packages that allow designers to achieve maximum performance with smaller systems that consume less power, says the firm.

"Cree|Wolfspeed's new X-band offerings provide today's design engineers with a wide breadth of options for systems requiring high-efficiency transmit solutions in challenging form factors such as those needed for active phased-array radar applications," says Jim Milligan, senior director foundry, aerospace & defense at Cree|Wolfspeed. "Using Wolfspeed GaN-on-SiC solutions enables them to meet the critical RF system requirements related to smaller size, lighter weight and higher power (SWaP) while reaching new levels of performance," he adds.

The firm's X-band portfolio offers solutions that support multiple stages of gain, reducing the number of devices that are needed in a transmit chain. They come in a variety of power levels to optimize system performance and are offered in multiple platforms to optimize system architecture.

www.wolfspeed.com/RF
www.wolfspeed.com/xband

SKU	Frequency	Saturated Output Power	Gain	Efficiency	Operating Voltage	Device Type	Package Type
CMPA901A020S	9 - 10 GHz	20 W	31 dB	45%	28 V	MMIC	Surface Mount
CMPA9396025S	9.3 - 9.6 GHz	35 W	27 dB	45%	40 V	MMIC	Surface Mount
CMPA801B030F1	8 - 11 GHz	37 W	20.8 dB	44%	28 V	MMIC	Flange
CMPA801B030S	7.9 - 11 GHz	40 W	20 dB	40%	28 V	MMIC	Surface Mount

Odyssey raises $5m to produce vertical GaN devices

High-voltage power-switching devices targeted at EVs and solar energy

Odyssey Semiconductor Technologies Inc of Ithaca, NY, USA has raised $5m in a common stock private placement of 1.25 million shares (at $4 per share) to further fund the development and production of high-voltage vertically conducting gallium nitride power-switching devices.

"We welcome the new shareholders to Odyssey Semiconductor and their support in enabling more efficient and compact power conversion for applications such as electric vehicles," says chairman & CEO Alex Behfar. "With the entire world focused on the adoption of clean energy and electric power, we're excited about the advancements our technology can bring to the industry."

Vertically conducting GaN-based power devices are said to outperform other devices fabricated using silicon and silicon carbide (SiC), but they have proven difficult to fabricate using standard methods. As a result, GaN power devices have been limited to horizontal-conducting low-voltage consumer electronics.

Odyssey has developed a proprietary GaN processing technology to produce high-voltage power-switching devices that can break down long-standing performance barriers

Odyssey has developed a proprietary GaN processing technology to produce high-voltage power-switching devices that, it is claimed, can break down long-standing performance barriers for applications such as electric vehicles, solar inverters, industrial motors, and power grids.

The firm aims to provide engineering samples of the vertically conducting GaN product and start qualifications under the Joint Electron Device Engineering Council (JEDEC) standard by the end of 2021.

Odyssey has also recently expanded its customer base using its foundry fabrication services. The team has experience supporting diverse semiconductor applications, including power devices, integrated optoelectronics, chemical sensing, and spectroscopy. The company provides support to customers from prototype production to full foundry capabilities.

www.odysseysemi.com

STMicroelectronics launches MasterGaN4 family of devices for high-efficiency power conversion up to 200W

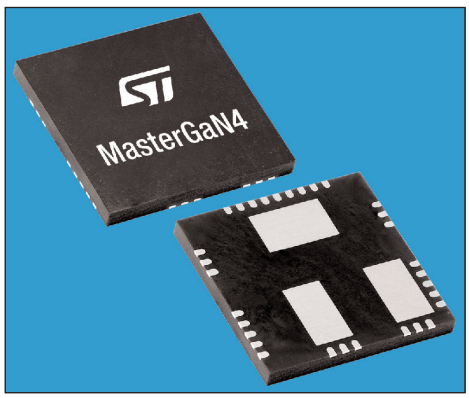
Power packages integrate symmetrical 225mΩ, 650V GaN power transistors with optimized gate drivers and circuit protection

STMicroelectronics of Geneva, Switzerland has added to its MasterGaN family of devices by launching MasterGaN4 power packages, which integrate two symmetrical 650V gallium nitride (GaN) power transistors with on-resistance ($R_{DS(on)}$) of 225mΩ alongside optimized gate drivers and circuit protection to simplify the design of high-efficiency power-conversion applications up to 200W.

MasterGaN4 is said to simplify design using wide-bandgap GaN power semiconductors by taking away the complex gate-control and circuit-layout challenges. With inputs tolerant of voltages from 3.3V to 15V, MasterGaN4 can be controlled by connecting the packages directly to Hall-effect sensors or a CMOS device such as a microcontroller, digital signal processor (DSP) or field-programmable gate array (FPGA).

Leveraging the higher operating frequencies enabled by the switching performance of GaN transistors, as well as their increased efficiency that reduces thermal dissipation, designers can choose small magnetic components and heatsinks to build more compact and lightweight power supplies, chargers and adapters, says ST. MasterGaN4 is suited to use in symmetrical half-bridge topologies as well as soft-switching topologies such as active clamp flyback and active clamp forward, adds the firm.

The wide supply-voltage range, from 4.75V to 9.5V, allows convenient connection to an existing power rail. Built-in protection further simplifies design, including gate-driver interlocks, low-side and high-side under-voltage lockout (UVLO), and over-temperature protection. There is also a dedicated shutdown pin.



ST's MasterGaN4 power packages,

As part of the launch, ST is also introducing a dedicated prototype board (EVALMASTERGAN4) that provides a complete set of features to drive MasterGaN4 with a single or complementary driving signal. An adjustable deadtime generator is also provided. The board gives users the flexibility to apply a separate input signal or PWM signal, insert an external bootstrap diode, separate the logic and gate-driver supply rails, and to use a low-side shunt resistor for peak-current-mode topologies.

MasterGaN4 is in production now, in a 9mm x 9mm x 1mm GQFN package that has more than 2mm creepage distance for safe use in high-voltage applications. Pricing starts at $5.99 for orders of 1000 pieces. The EVALMASTERGAN4 board is $87.

www.st.com/en/power-

Navitas driving Spigen's ArcStation Pro 45W GaN-based fast charger

Fast charger for Samsung S21 Ultra just 47mm x 47mm x 27mm

Navitas Semiconductor Inc of El Segundo, CA, USA says that smartphone accessory maker Spigen Inc of Irvine, CA, USA has extended its range of ArcStation Pro GaN-based fast chargers, now including what is reckoned to be world's smallest 45W model for Samsung's flagship smartphone S21 Ultra.

GaN is reckoned to run up to 100x faster than silicon, and enables up to 3x more power or 3x faster charging in half the size and weight. Founded in 2014, Navitas introduced what it claimed to be the first commercial GaN power ICs, which monolithically integrate GaN power field-effect transistors (FETs) with drive, control and protection circuits, enabling faster charging, higher power density and greater energy savings for mobile, consumer, enterprise, eMobility and new energy markets.

The Samsung S21 Ultra smartphone has a large 5000mAhr battery and uses an advanced version of the universal serial bus (USB) power delivery protocol called 'programmable power supply' (PPS). PPS can monitor the phone's battery status in finer detail and adjust the delivered power more accurately to ensure the fastest — and safest — charging speed.

Measuring only 47mm x 47mm x 27mm (60cc) including folding pins, the Spigen 45W (model PE2015) is said to be the world's smallest 45W PPS charger, and ~30% smaller and lighter than Samsung's own 45W model.

"The original GaNFast 20W ArcStation Pro charger for the iPhone 12 was our most successful launch," says Spigen's product and marketing manager Sean Lee. "By expanding the ArcStation Pro range with increased power, we can extend that success to the Samsung S21 and S21 Ultra, which can fast-charge using a full 45W. The 40W version has dual USB-C outputs, so you can charge two devices at the same time," he adds.

"Spigen's ArcStation Pro delivers the fastest charging rates for the new Samsung S21 range — and is differentiated by superb 'soft-touch' industrial design, affordable price points and commitment to quality," comments Stephen Oliver, Navitas' VP corporate marketing and investor relations.

www.navitassemi.com
www.ganfast.com/products

Navitas' GaN power ICs debut in industrial applications at Electronica China 2021

Navitas debuted its GaNFast power ICs in a wide range of industrial applications at the Electronica China 2021 show in Shanghai (14–16 April), which was attended by almost 50,000 participants and more than 1100 electronics companies (including Xiaomi, TE Connectivity, Honeywell and other tier-1 manufacturers). The Navitas booth had over 1200 visitors, says the firm.

Navitas says that more than 75 customer projects are in mass production with its GaN, including Xiaomi, Lenovo, Dell, OPPO and Amazon, and over 150 customer projects in development.

The industrial examples span a broad range, from a 50W fast-acting smart circuit breaker, to a 1200W server power supply. A 500W portable power station (DC–AC inverter) was shown with over 98% efficiency, and the world's highest-power 1kW 400V-input 'quarter brick' DC–DC converter from Density Power was displayed at the booth and featured in a technical talk.

At the International Power Electronics Innovation Forum, senior application director Lin Dong presented 'The Future of Power: High-Frequency Systems Enabled by GaN' to more than 500 attendees, plus others via live-stream. Lin Dong discussed how advanced engineers had been frustrated by old silicon technology, and were now introducing new, high-frequency topologies using GaN to deliver up to 6x more power in industrial applications.

"From our strong position in the mobile fast-charger market, Electronica China was the perfect venue for Navitas to demonstrate expansion into the industrial market, with a variety of AC–DC, DC–DC and DC–AC applications over a broad power range," comments Stephen Oliver, VP of corporate marketing & investor relations. "When you add renewables, data-center and electric vehicle (EV)/eMobility markets, GaN is projected to address markets valued at over $13bn by 2026 and, looking ahead with an eye on the health of our world, GaN can impact up to 2.6Gtons of CO_2 reduction in 2050."

www.electronica-china.com/en

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EPC showcasing high-power-density eGaN FETs and ICs in volume customer applications

PCIM Europe highlighting automotive, computing and robotics

At the PCIM (Power Conversion and Intelligent Motion) Europe 2021 Digital Days event (3–7 May), 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 — is delivering two technical presentations, an educational tutorial, an exhibitor webinar, and participating in panel discussions on GaN technology and applications. The firm is also participating in the event's virtual exhibition, showing its latest enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) and integrated circuits in customers' end products that are rapidly adopting eGaN technology.

In the virtual exhibition, EPC experts will be available to discuss eGaN devices in several applications including: high-performance 48V DC–DC power conversion for automotive and advanced computing and applications; high-power nanosecond pulsed laser drivers for light ranging & detection (LiDAR) systems used in robotics, drones and autonomous vehicles (AVs); and precision motor drives for robotics and drones.

Technical presentations and panels featuring EPC's eGaN FETs and ICs include:

- Bi-Directional 1/16th Brick 48 V – 12 V Converter using Monolithic GaN ePower Stage', 4 May (9:50am CET);
- 'A 1 kW eGaN FET-Based LLC Resonant Converter in the 1/8th Power Brick Size for 48V Server Applications', 4 May (3:45pm CET);
- Exhibitor Webinar: 'How GaN is Driving Changes in Autonomy, Automotive, and eMobility', 4 May (4:30–5pm CET);
- Panel Session hosted by Bodo's Power Systems, 'GaN-based 3 kW Bi-directional Converter for 48 V Automotive Power', 5 May (3:55–4:25pm CET);
- Educational Tutorial: 'Maximizing GaN FET and IC Performance', 12 May (3–6pm CET).

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

EPC adds automotive-qualified 65V eGaN FET for higher-resolution LiDAR

3.3Ω EPC2219 integrates reverse gate clamp diode

EPC has expanded its AEC Q101-qualified product family with the addition of the EPC2219 65V GaN transistor with integrated reverse gate clamp diode optimized for high-resolution light detection & ranging (LiDAR) systems in the automotive industry and other harsh environments.

eGaN technology has been in mass production for more than a decade, accumulating billions of hours of successful field experience in automotive applications, such as LiDAR and radar for autonomous vehicles (AVs), 48V–12V DC–DC converters for mild hybrid power, ultra-high-fidelity infotainment systems, and high-intensity headlamps for trucks.

The EPC2219 has completed rigorous automotive AEC Q101 qualification testing including humidity testing with bias (H3TRB), high-temperature reverse bias (HTRB), high-temperature gate bias (HTGB), temperature cycling (TC), as well as several other tests. The new GaN device will be followed with several more discrete transistors and integrated circuits designed for the harsh automotive environment.

In addition to LiDAR in demanding automotive applications, the EPC2219 — a 65V, 3.3Ω, eGaN FET with integrated reverse gate clamp diode and tiny 0.81mm^2 footprint — is suitable for driving GaN FETs in radar and ultrasonic sensors, satellite reaction wheels, high-frequency DC–DC conversion, wireless power, and class-D audio.

To complete AEC Q101 testing, EPC's eGaN FETs undergo rigorous environmental and bias-stress testing. EPC notes that its wafer-level chip-scale (WLCS) packaging passes all the testing standards created for conventional packaged parts, demonstrating that the superior performance of chip-scale packaging does not compromise ruggedness or reliability. eGaN devices passing AEC Q101 testing are produced in facilities certified to the Automotive Quality Management System Standard IATF 16949.

"This new automotive product is the latest addition to a growing family of EPC transistors and integrated circuits designed to enable autonomous driving and improve fuel economy and safety," says CEO & co-founder Alex Lidow.

The EPC2219 eGaN FET is priced at $0.54 each for 2.5Ku/reel and is available for immediate delivery from distributor Digi-Key.

www.epc-co.com/epc/Products/eGaNFETsandICs/EPC2219.aspx

EPC adds eToF laser driver IC optimized for AR

40V, 10A FET integrated with gate driver and LVDS logic level input

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 expanded its new family of GaN ICs offering higher performance and smaller solution size for time-of-flight (ToF) light detection & ranging (LiDAR) applications (including robotics, drones, 3D sensing, gaming and autonomous vehicles) by introducing a laser driver that integrates a 40V, 10A FET with a gate driver and low-voltage differential signaling (LVDS) logic level input in a single chip.

The EPC21603 laser driver is controlled using LVDS logic and is capable of very high frequencies exceeding 100MHz and super short pulses (<2ns) to modulate laser driving currents up to 10A. The EPC21603 is a single-chip driver plus eGaN FET using EPC's proprietary GaN IC technology in a chip-scale BGA form factor that measures only 1.5mm x 1.0mm. The LVDS logic control allows the eToF laser driver IC to be controlled from a field-programmable gate array (FPGA) for applications where noise immunity is critical, such as augmented reality (AR).

Integrated devices in a single chip make it easier to design, easier to layout, easier to assemble, save space on the PCB, increase efficiency, and reduce cost, says EPC. The new family of products should enable faster adoption and increased ubiquity of ToF solutions across a more comprehensive array of end-user applications, the firm reckons.

"The EPC21603 joins the recently announced EPC21601 as the initial products in our new family of GaN ICs that dramatically improve the performance while reducing size and cost for time-of-flight LiDAR systems," says CEO & co-founder Alex Lidow. "This new family of GaN integrated circuits will continue to expand to higher currents, higher voltages, as well as furthering integration of additional control and logic features on a single chip."

The EPC9156 development board features the EPC21603 eToF laser driver IC and is primarily intended to drive laser diodes with short, high-current pulses. Capabilities include minimum pulse widths of <2ns, 10A peak currents, and bus voltage rating of 30V.

The EPC21603 eToF laser drive IC is priced at less than $1 at 500ku. The EPC9156 development board is $465.23. Both are available for immediate delivery from distributor Digi-Key Corp.

www.epc-co.com/epc/Products/eGaNFETsandICs/EPC21603.aspx

Keysight's power device testing solution selected by China's Semipower

Xi'an Power Device Testing Application Center targeting wide-bandgap semiconductors

Keysight Technologies Inc of Santa Rosa, CA, USA says that its power device testing solutions have been selected by China-based power device maker Xi'an Semipower Electronic Technology Co Ltd to accelerate and promote the development of next-generation semiconductors.

Semipower's Power Device Testing Application Center, a comprehensive testing center for power device testing capabilities, has been recognized by the China National Accreditation Service for Conformity Assessment (CNAS) and International Laboratory Accreditation Cooperation (ILAC). Offering third-party testing qualification, the center is said to be critical to promoting the development of the 'third-generation semiconductor' industry (i.e. wide-bandgap semiconductors such as gallium nitride and silicon carbide). Leveraging Keysight's power device testing solution, the center offers a test platform for such devices to ensure performance and reliably speed market introduction.

Specifically, Semipower chose Keysight's PD1500A dynamic power device analyzer/double pulse tester to deliver repeatable, reliable measurements of wide-bandgap semiconductors. The off-the-shelf measurement solution is said to enable faster time-to-market by providing quick and reliable results, while ensuring a safe test environment.

"Keysight is committed to innovation in the field of power semiconductor test, and for we work closely with key partners to provide powerful test tools in conjunction with advances of industry-critical technology waves," says Thomas Goetzl, VP & general manager of Keysight's Automotive and Energy solutions.

"Since the establishment of Xi'an Power Device Testing Application Center, Keysight has provided us with effective and continuous technical support for 10 years," says Semipower's president Luo Yi. "From the initial test system to the latest dynamic test system, Keysight helps us improve and enhance the third generation of semiconductor testing research by continuously optimizing the system," he adds. "Joining forces with Keysight has enabled Semipower to promote our understanding and research of third-generation semiconductor devices and create a better platform for applications including new energy vehicles."

www.samwinsemi.com
www.keysight.com/gb/en/

SEL and Silvaco co-develop SPICE model of oxide semiconductor FETs

Semiconductor Energy Laboratory Co Ltd (SEL) of Atsugi, Japan and Silvaco Inc of Santa Clara, CA, USA (which provides electronic design automation and IP software tools for process and device development) have jointly developed a SPICE model of oxide semiconductor field-effect transistor (FETs) for use in applications including artificial intelligence (AI).

The crystalline oxide semiconductor CAAC-IGZO FET (c-axis aligned crystalline indium-gallium-zinc oxide FET) developed by SEL has extremely low off-leakage current, which enables ultra-low power consumption for integrated circuits including memory. The new device is expected to be key in helping to reduce power consumption in the coming AI era. Until now a compact model for SPICE simulation, essential for circuit design, has not been available and it has been difficult to reproduce detailed circuit characteristics through simulation.

The jointly developed compact, charge-based model extends the material characteristics and operation mode of CAAC-IGZO FET and is based on BSIM-CMG (the industry-standard model for multi-gate FinFETs). The new model can faithfully reproduce the characteristics of oxide semiconductor FET.

Advantage of the model include:

- modeling of operation in the oxide semiconductor's accumulation mode;
- modeling of L/W scalability and temperature dependence;
- support of multi-gate structure with Fin shape;
- modeling of threshold voltage control by bottom gate;
- modeling of interface trapped charge and sub-gap localized charge;
- implemented in industry-standard Verilog-A language.

The new SPICE model card has been generated by Silvaco's SPICE model extraction tool Utmost IV with the measured data from SEL and has been verified with Silvaco's high-performance circuit simulator SmartSpice. This model will be used by partners who use SEL's CAAC-IGZO FET technology.

"The CAAC-IGZO FET has a back gate, and the current can be controlled independently of the top gate," says Takayuki Ikeda, general manager of SEL's CD Division. "However, the design has been limited by the lack of a suitable model for circuit simulation. To eliminate this limitation, we partnered with Silvaco to develop a model for CAAC-IGZO FET," he adds. "We hope that the new model will be adopted by the industry and enable wide adoption of CAAC-IGZO FET."

SEL and Silvaco presented a paper on the compact model for CAAC-IGZO FET at the 5th IEEE Electron Devices Technology and Manufacturing Conference (EDTM2021) in Chengdu, China (8–11 April).

www.ewh.ieee.org/conf/edtm/2021
www.sel.co.jp/en

Silvaco appoints new chairman

Silvaco has appointed Pierre-Yves Lesaicherre as chairman of its board. He succeeds Iliya Pesic, who continues t on the board of directors.

"Silvaco is experiencing significant growth with an expanding product portfolio and growing customer base," says Pesic. "Dr Lesaicherre's long history of leadership in corporate governance and technology companies will be invaluable to Silvaco as we grow our footprint in the semiconductor design market domestically and internationally. We look forward to working with Dr Lesaicherre and benefit from his extensive experience in corporate strategy and governance."

Lesaicherre was president, CEO and board member at Nanometrics (a provider of process control metrology and inspection systems used primarily in the fabrication of integrated circuits, sensors, discrete components, high-brightness LEDs, and data storage devices) from November 2017 until it merged with Rudolph Technologies in October 2019 to form Onto Innovation. From January 2012 to February 2017, he was CEO of Lumileds, a supplier of LED components to the lighting and consumer industries as well as the automotive industry (with revenues of over $2bn). Prior to that, Lesaicherre was senior VP & general manager of the Microcontrollers & Logic business lines in the High-Performance Mixed Signal business unit at NXP. Prior to NXP, Lesaicherre was a research engineer and then process technology development manager at Japan's NEC Corp.

Lesaicherre holds an MBA with a focus on International Business and Strategy from INSEAD, and has an MS and PhD degree in Material Science from the Grenoble Institute of Technology. He is a Governance Fellow for NACD (National Association of Corporate Directors) and an active member of SVDX (Silicon Valley Director's Exchange).

"I feel very privileged to take on this role at such an exciting time for Silvaco," says Lesaicherre. "The semiconductor industry is experiencing tremendous growth, driven by automotive, AI, IoT, 5G and high-performance computing applications ,and Silvaco is well positioned to benefit from these trends and grow its business. I look forward to working with Silvaco's talented team to accelerate its growth."

www.silvaco.com

IQE's revenue grows 27% to a record £178m in 2020

Beginning of 5G mega-cycle drives return to cash-positive position

For full-year 2020, epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has reported record revenue of £178m (exceeding both September's initial guidance of "at least £165m" and November's revised guidance of "at least £170m"). Compared with 2019's £140m, this is up 27.1% (or 27.5% on a constant-currency basis, taking into account a US$/£ foreign exchange headwind of £0.5m). Growth was driven by the start of the 5G mega-cycle, says the firm.

Business continuity was maintained at all global sites during the COVID-19 pandemic, with no interruptions to production. "Despite the global uncertainty that we encountered, the strength and diversification of our business enabled us to deliver record revenues," notes CEO Dr Drew Nelson. There was strong growth in each of the firm's primary business segments.

Wireless wafer revenue rose by 38% from 2019's £68.2m to £94.2m (up from 48.7% to 52.9% of total revenue). Growth was driven by: 5G infrastructure deployments in Asia, in particular gallium nitride on silicon carbide (GaN-on-SiC) for mMIMO (massive multiple-input, multiple-output) base stations; and increased demand for gallium arsenide (GaAs) wafers for 5G handset power amplifiers (PAs) fuelled by growing end-market demand for '5G ready' smartphones (in which there is increased GaAs content versus 4G phones). Of Wireless revenue, GaAs comprised 63% and GaN 37%.

Photonics wafer revenue rose by 17% from 2019's £69.8m to £81.6m (going from 49.8% to 45.8% of total revenue). Growth was driven by: consistently high demand for GaAs vertical-cavity surface-emitting laser (VCSEL) wafers for 3D sensing applications throughout the year; and continuing strong demand for high-performance gallium antimonide (GaSb) wafers for advanced infrared sensing applications, in particular epiwafers for direct time-of-flight (DToF) camera modules that are enabling augmented reality (AR). Of the Photonics revenue, VCSELs comprised 56%, infrared 29%, and indium phosphide (InP) 15%.

CMOS++ segment revenue rose from £2.09m to £2.2m (though falling from 1.5% to 1.2% of total revenue).

Adjusted gross margin rebounded from 14.9% in 2019 to 18.7% in 2020, as IQE has benefited from greater tool capacity utilization (spreading foundry overheads over a larger volume of wafers).

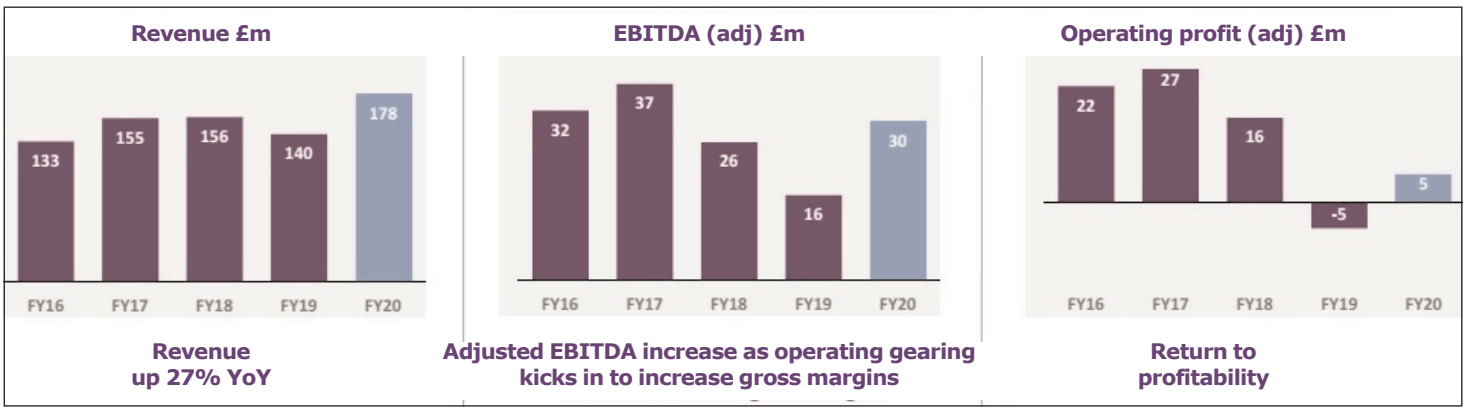
Adjusted selling, general & administrative (SG&A) expenses rose from £25.8m to £27.8m, primarily reflecting an increase in investment in corporate functions and employee headcount as IQE continues to grow. By end-2020, the firm had 650 staff across nine manufacturing locations in the UK, USA, Taiwan and Singapore.

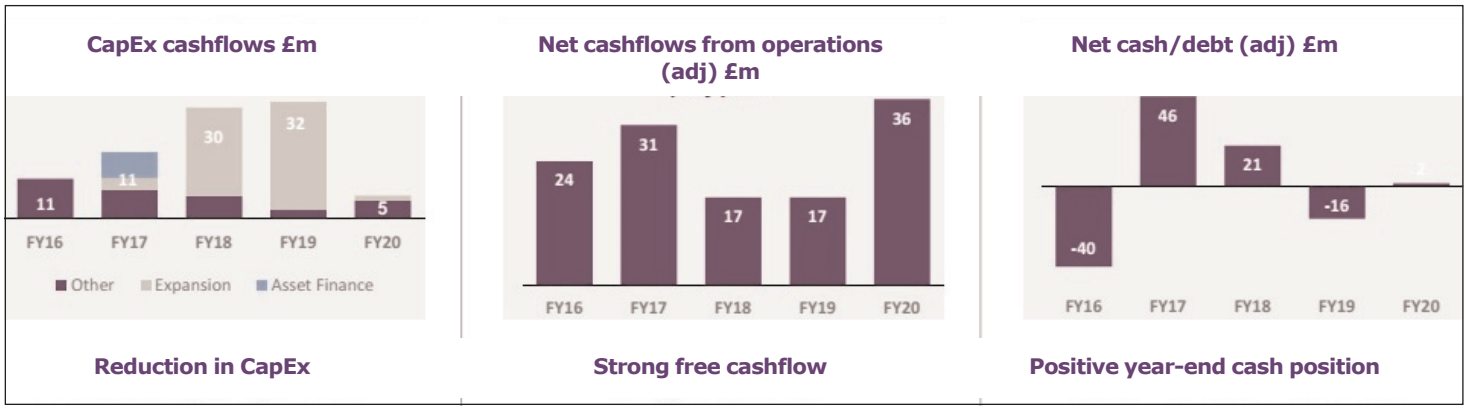
Restructuring costs were cut further, from £0.813m in 2019 (comprising £226,000 of final costs from closure of IQE's manufacturing facility in New Jersey plus £587,000 in site-specific employee severance costs) to £0.16m in 2020 (related to employee retention bonuses associated with the announced closure of the firm's manufacturing facility in Pennsylvania, as IQE is consolidating US molecular beam epitaxy manufacturing at its North Carolina site by 2024).

Compared with 2019's patent dispute legal cost of £4.3m, 2020 yielded patent dispute income of £1.7m related to a settlement with the plaintiff of a multi-faceted intellectual property (IP) legal dispute, following an arbitration panel ruling on 17 January 2020 in favour of IQE that resulted in £1.825m (US$2.5m) cash being received in February. Patent dispute income also includes insurance income of £410,000 received from IQE's insurers in relation to relevant costs incurred as part of the dispute, offset by £546,000 of legal costs.

Compared with the adjusted operating loss of £4.7m in 2019, there was a return to profitability in 2020, which yielded an adjusted operating profit of £5.4m.

By segment, adjusted operating profit (and operating margin) improved for Wireless from £6.6m (9.7% margin) in 2019 to £11.4m





(12.1% margin) in 2020 and for Photonics from just £1.3m (1.9% margin) in 2019 to £9.1m (11.1% margin) in 2020, primarily reflecting increases in volume and increased utilization of manufacturing capacity. For CMOS++, adjusted operating loss was cut from £1.3m to £0.714m.

As a result of the strong trading performance, capital spending controls and careful working capital management, adjusted net cash flow from operations has more than doubled from £16.5m in 2019 to £36.3m in 2020, representing 120% adjusted EBITDA to adjusted operating cash conversion.

Capital expenditure was slashed from 2019's £31.9m to £5m following completion of the infrastructure phase of IQE's capacity expansions during 2018–2019 in Massachusetts USA (for wireless GaN), Hsinchu Taiwan (for wireless GaAs) and at its Newport Foundry in South Wales, UK (focused on 3D sensing applications). Future CapEx spending will be more linear with revenue opportunities, notes IQE.

Free cash flow was £23.6m, compared with free cash outflow of –£25.4m in 2019.

During 2020, cash and cash equivalents rose by £15.9m, from £8.8m to £24.7m (compared with 2019's decline of £12m).

Due to the strong free cash flow, net cash (excluding lease liabilities) turned positive, at £1.9m at the end of 2020, compared with net debt of £16m at end-2019. Including bank loans of £22.74m (repayable over a period to 29 August 2024), net funds are hence £24.66m.

"We have made positive progress against our strategy and recorded strong growth across our Wireless and Photonics divisions, despite the external pressures," says Nelson. "This progress, combined with the return to a cash positive position and the range of unique materials solutions for high-performance devices in our development pipeline, ensures we are well placed to maintain our leadership position as the 5G mega-cycle gathers pace in the coming years," he adds.

In particular, strong progress has been made in new product development, including IQepiMo template technology for RF filters, IQGeVCSEL 150 technology for 6" VCSELs on germanium (a critical step in the pathway to 8" VCSEL technology), and (post year-end) IQDN-VCSEL technology for advanced sensing applications at longer wavelengths on 150mm GaAs substrates.

Current trading and first-half 2021 outlook

After a consistently strong year in 2020 across IQE's broad portfolio of products, trading has continued positively in 2021. In particular, revenues for Wireless GaAs epiwafers are strong as a result of continued 5G handset market penetration and increased GaAs content. In addition, demand for 3D sensing, advanced sensing applications and communications products continues to remain positive.

IQE reckons that it is well positioned for further 5G-related GaN-on-SiC growth over the multi-year replacement cycle. In first-half 2021, GaN-on-SiC revenue is expected to be lower than in first-half 2020 amid lower market estimates for mMIMO deployment in Asia. But, beyond the near term, the opportunities for this and other GaN-on-Si technologies are very strong as global roll outs of 5G gather pace.

IQE notes that it is experiencing a foreign exchange headwind in 2021 on a reported basis, as the firm's revenues are predominantly earned in USD but are reported in GBP.

Nevertheless, IQE expects revenue and adjusted EBITDA in first-half 2021 to be similar to first-half 2020 on a constant-currency basis.

Capital expenditure for 2021 is expected to be £20–30m as IQE resumes investment in capacity for specific growth platforms. This includes three new Aixtron G4 metal-organic chemical vapor deposition (MOCVD) systems ordered in Q1/2021 to support volume growth for Wireless GaAs in Taiwan (in order to underpin further growth in 2022). On 5 October 2020, IQE acquired the remaining 9.82% minority stake in Taiwanese subsidiary IQE Taiwan ROC (raising its equity ownership from 90.18% to 100%) for £1.4m, subject to an ongoing statutory court process regarding valuation.

Capitalization of development costs are expected to be £7–10m for full-year 2021, as IQE continues to invest in future products to meet anticipated growing demand for compound semiconductors driven by the macro trends of 5G and connected devices.

www.iqep.com

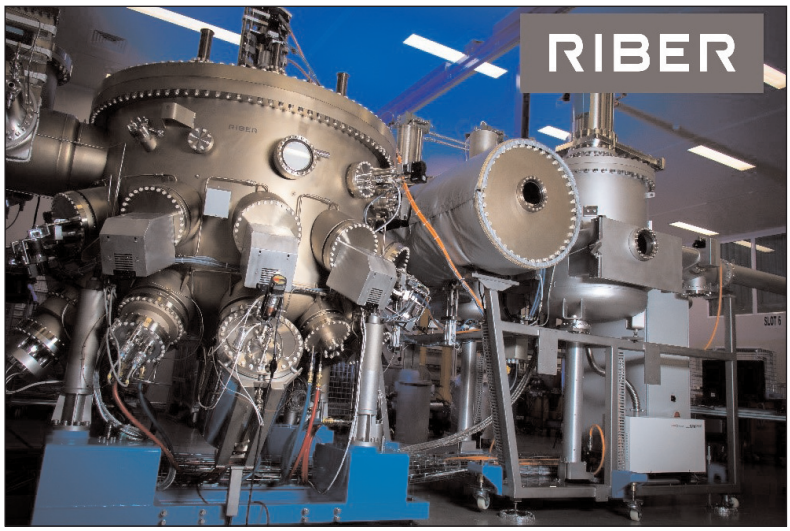
Riber delivers first MBE 8000 system

IntelliEPI to manufacture VCSEL epiwafers

Riber S.A. of Bezons, France — which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells — has delivered the first MBE 8000 system (said to be the world's largest MBE machine) to longstanding customer Intelligent Epitaxy Technology Inc (IntelliEPI) of Richardson, TX, USA — which was founded in 1999 and manufactures MBE-grown epitaxial wafers. The delivery is part of a sales agreement for the equipment to be used for manufacturing epiwafers for ultra-high-performance vertical-cavity surface-emitting laser (VCSEL) applications.

Because VCSEL-based devices emit via the substrate surface, they can be fabricated into devices with a high-density array of emitters. These components are gradually replacing traditional lasers as the benchmark technology for a growing range of applications, e.g. 3D sensing (facial recognition on smartphones) or movement control, across diverse sectors ranging from consumer electronics to healthcare, automotive and telecoms, says Riber.

The firm claims that, compared with other technologies, its MBE technology offers a range of benefits. Specifically, the ability to create very abrupt interfaces — combined with very precise dosage control — results in improved quality of deposited semiconductor films, enhanced conductivity properties and stronger performance for lasers, Riber adds. To address the need for a higher-production-throughput MBE platform for high-performance epiwafer manufacturing with excellent wafer uniformity, Riber has developed the new MBE 8000 production system.



Using ultra-high-vacuum deposition, the fully automated MBE 8000 is a multi-wafer reactor with the capacity to grow up to eight 150mm wafers simultaneously and offers the possibility of transitioning to 200mm wafers. The system makes it possible to produce VCSELs and other device structures with precise control down to atomic monolayer precision and with film thickness uniformity well below the 1% level.

For IntelliEPI, the MBE 8000 system will further strengthen its epitaxy capabilities. Alongside its existing fleet of three MBE 49s, eight MBE 6000s, two MBE 7000s, one V90 and one VG100, the new MBE 8000 production platform will enable it to meet the expected increase in demand for its growing VCSEL and other markets, particularly for 6-inch gallium arsenide epiwafer products.

The MBE 8000 multi-wafer system offers production volumes aligned with market demands, Philippe Ley, chairman of Riber's executive board. "This machine shows that the MBE technology is perfectly optimized and provides additional value-added compared with alternative technologies, especially in terms of operations and output for manufacturing complex semiconductor structures. In addition, the MBE 8000 system presents strong prospects for business development in the future," he adds.

"This state-of-the-art MBE 8000 technology platform, with increased throughput and enhanced performance, will enable IntelliEPI to better address the emerging high-performance markets, such as VCSELs for automotive LiDAR as well as HEMT or HBT for 5G RF applications," comments IntelliEPI's president & CEO Yung-Chung Kao. "One key improvement is the increase in material uniformity across a much larger reactor platform," he adds. "With future deployment of these MBE 8000 reactors at our expanded manufacturing facilities located in Texas, USA, IntelliEPI will be able to provide even better value products and services to all of its customers," he concludes.

www.intelliepi.com

Riber wins Asian orders for MBE 6000 production systems

Riber has received an order from an Asian industrial client for a fifth MBE 6000 production system, worth several million euros.

Intended to produce electronic and optoelectronic devices, the new system will be delivered during 2021.

Riber has also received a separate order worth several million euros from another Asian customer for its second MBE 6000 production reactor (a very high-performance multi-wafer production system), also for delivery in 2021.

www.riber.com

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NeuroSys funded by BMBF initiative Clusters4Future

Aixtron partnering in RWTH Aachen University-led cluster on energy-efficient neuromorphic artificial intelligence chips based on two-dimensional materials

Germany's Federal Ministry of Education and Research (BMBF) has announced the winners of the Clusters4Future ideas competition. The clusters being funded include the future clusters 'Hydrogen' and 'NeuroSys — Neuromorphic Hardware for Autonomous Artificial Intelligence Systems' involving RWTH Aachen University as well as partners from the Aachen region.

As a supplier of deposition equipment, Aixtron SE of Herzogenrath, near Aachen, Germany is a partner in NeuroSys, developing, building and optimizing the necessary metal-organic chemical vapor deposition (MOCVD) tool for the new application. Work on NeuroSys is expected to run for several years.

NeuroSys researches adaptive and energy-efficient neuromorphic AI chips, with the aim of allowing intelligent and resource-saving on-site data processing and thus creating an essential prerequisite for artificial intelligence (AI) applications. However, the use of AI poses challenges such as high CO_2 emissions, further exacerbating climate issues. They arise when training large neural networks based on modern graphics processing units (GPUs) using deep learning methods. GPU-based neural networks are therefore ecologically unsustainable.

Neuromorphic systems for resource-efficient on-site data processing

Resource-efficient neuromorphic hardware that makes neural networks more efficient and provides for data security as a design component is therefore becoming key to the widespread use of AI. This is especially true for application areas in autonomous vehicles, medical technology, and sensor networks for intelligent production or urban regions.

Neuromorphic systems are modeled on the two basic building blocks of the human brain: neurons and synapses. By integrating new materials with specific properties, they can ideally perform on-site processing of data in a way that conserves resources. This is summarized under the keyword memristive (from 'memory' and 'resistor' for electrical resistance).

RWTH Aachen University and Research Center Jülich have already been able to demonstrate the functionality of neuromorphic devices made of memristive materials. However, there are no pilot lines or production capacities worldwide for the manufacture or integration of neuromorphic chips on an industrial scale.

Chips based on novel 2D materials

Also, the system of hardware, design, algorithms and application-driven software must work together to take advantage of the great benefits of neuromorphic hardware. What is required, therefore, is a paradigm shift with the opportunity to take a leading position in this new technology, says Aixtron. NeuroSys aims to work out the crucial prerequisites.

Aixtron is at the beginning of the value chain in the project. Very thin layers of novel 2D materials, just a few atomic layers thick, are required as the material base for the neuromorphic chips. The production of these materials on the largest possible wafers is Aixtron's core competence.

"Creating GPU-based neural networks that are environmentally sustainable is a major challenge. We are pleased to be able to make our contribution in the area of development and provision of the material base," says Dr Michael Heuken, VP corporate research & development at Aixtron and professor at RWTH Aachen University. "As part of this and other projects, we will develop the world's most powerful technology platform for the industrial production of these materials and operate it in our laboratory in Herzogenrath."

Important element also for structural change in Rheinischen Revier

"The Future Cluster is a great opportunity for the Aachen–Jülich region, especially in connection with the structural change in the 'Rheinischen Revier'," says research work coordinator professor Max Lemme, chair of Electronic Components at the RWTH Aachen University and managing director of AMO GmbH. "We are stepping up to transfer excellent science to companies and startups in the region. Our vision is to set up a production line in the Aachen region. There, the co-integration of neuromorphic functions using new materials into conventional silicon technology will then take place."

As well as RWTH Aachen University, the Research Center Jülich, AMO GmbH, IHK Aachen, the firms AixACCT Systems GmbH, Aixtron SE, AppTek GmbH, ELMOS Semiconductor SE, RWTH Innovation GmbH and STAR Healthcare Management are involved in NeuroSys. The start-ups AiXscale Photonics UG, Black Semiconductor GmbH, Clinomic GmbH and Gremse-IT GmbH are also involved.

Clusters4Future is part of the German government's High-Tech Strategy 2025. The open-topic competition focuses on regional innovation networks that combine the strengths of the players, tap into emerging fields of innovation and develop solutions for the challenges of the future.

www.aixtron.com
www.bmbf.de

Aixtron's AIX G5+ C MOCVD system selected for micro-LED production

Aixtron SE of Herzogenrath, Germany has supplied a tier-1 US LED maker with an AIX G5+ C metal-organic chemical vapor deposition (MOCVD) system, developed and qualified for meeting the tighter requirements of micro-LED manufacturing.

The next generation of LED displays requires millions of micron-size LEDs to be transferred onto a single display, which has compelled LED suppliers to develop new mass transfer technologies, notes Aixtron. To enable this, large arrays of LEDs are taken directly from the processed LED wafers, preventing any upfront wafer binning or sorting of defective chips. As a consequence, 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 innovative and new MOCVD approaches, adds the firm.

Aixtron's AIX G5+ C system hence uses wafer-level control (based on Auto-Feed Forward) of the film surface temperature during the epitaxial process in combination with ultraviolet (UV) pyrometry. This allows very accurate control of indium incorporation into the multi-quantum wells (MQW), which ultimately defines the wavelength consistency among the wafers produced. A cassette-to-cassette transfer module, coupled with in-situ cleaning, then helps to ensure that no particles contaminate the films during handling or the epitaxy process.

"We are looking forward to further accelerate the roll out of micro-LEDs for displays," says president Dr Bernd Schulte. "Micro-LED technology is disrupting the existing LED eco-system, embracing methods and approaches seen to date only in the LCD or semiconductor industry, and our AIX G5+ C platform perfectly backs these stringent epitaxial requirements," he adds.

"Micro-LED technology is a game changer for the display industry, outperforming existing liquid-crystal displays (LCD) and organic light-emitting diode (OLED) technologies on power consumption while exhibiting superior pixel density, contrast ratio and brightness," comments senior product marketing manager Arthur Beckers. "It will open new horizons for consumer mobile products as well as premium television displays."

www.aixtron.com

OIPT and LayTec collaborate on high-volume front-end processing

Joint development and exclusive supply agreement to span entire range of plasma etch and deposition systems

Plasma etch and deposition processing system maker Oxford Instruments Plasma Technology (OIPT) of Yatton, Bristol, UK and in-situ metrology system maker LayTec AG of Berlin, Germany have announced an exclusive collaboration agreement to enable the requirements of advanced semiconductor devices in the high-volume manufacturing (HVM) environment. The partnership aims to develop and integrate LayTec's accuracy and control with Oxford Instruments' wafer processing expertise.

Together, they aim to combine plasma process solutions with proven in-situ metrology to achieve next generation device performance and enable a repeatable HVM process to shorten customers' yield ramp. LayTec will develop the in-situ metrology while Oxford Instruments will integrate LayTec's control with its wafer processing solutions.

Driven by market demand for efficient power conversion, the Internet of Things (IoT) and datacoms compound semiconductor devices based on materials such as gallium arsenide/indium phosphide (GaAs/InP), silicon carbide (SiC) or gallium nitride (GaN) are becoming increasingly used due to their superior performance. However, challenges remain to move the technology from small prototypes to wafer-scale HVM. While device dimensions are relatively large, the often complex layer structure means that acute accuracy of processing within these layers is required to realise the required process stability and yield to drive down the cost per wafer and accelerate adoption into the target application.

"This technology partnership allows us to expand further along the process chain in one of our traditional core markets by applying our key knowledge of data analysis and integration of customized high-precision optical metrology systems," says LayTec's CEO Volker Blank. "After serving our customers in the compound semiconductor industry for more than two decades, we look forward to this new opportunity to support our customers in further processes and device optimization," he adds.

"This is a crucial next step in the implementation of our product development strategy, and the accelerated timing reflects the recent momentum we've seen in the markets we serve," says Frazer Anderson, Innovations & Solutions director at Oxford Instruments. "It also underlines our commitment to deliver continuous productivity improvements to our customers," he adds. "As we enter a very exciting period of innovation and growth, it is our firm intention to meet the requirement of improved performance and reduced cost of ownership objectives necessary to support needs of the emerging GaN power and RF market. This collaboration with LayTec will further increase our ability to be able to deliver both requirements," Anderson believes.

Combining Oxford Instruments' stable plasma processing platform with LayTec's precise end-point technology in plasma etching applications allows the control and repeatability needed to increase wafer-to-wafer yield, it is reckoned. The synergy of joint development and exclusive supply agreement will allow the expertise in both companies to develop and supply unique HVM-ready solutions for the evolving needs of the compound semiconductor industry, the firms add. The long-term agreement will cover developments on the entire range of Oxford Instruments' plasma etch and deposition systems with shared rights to the intellectual property (IP) produced and co-ordinated marketing activities. The delivery of the first joint customer solution is targeted for second-half 2021.

www.laytec.de
https://plasma.oxinst.com

Camtek receives orders of over $20m for advanced packaging and compound semiconductor applications

Inspection and metrology systems to be delivered in Q2–Q3/2021

Camtek Ltd of Migdal Haemek, Israel says that in recent weeks it has received orders for inspection and metrology systems totaling over $20m for delivery during the second and third quarters of 2021 to several customers that manufacture products in the field of advanced packaging and compound semiconductors.

"We continue to see strong momentum in our business, and these new orders make us increasingly confident in our expectations for 2021, all of which point to another record year for Camtek," says CEO Rafi Amit.

www.camtek.com

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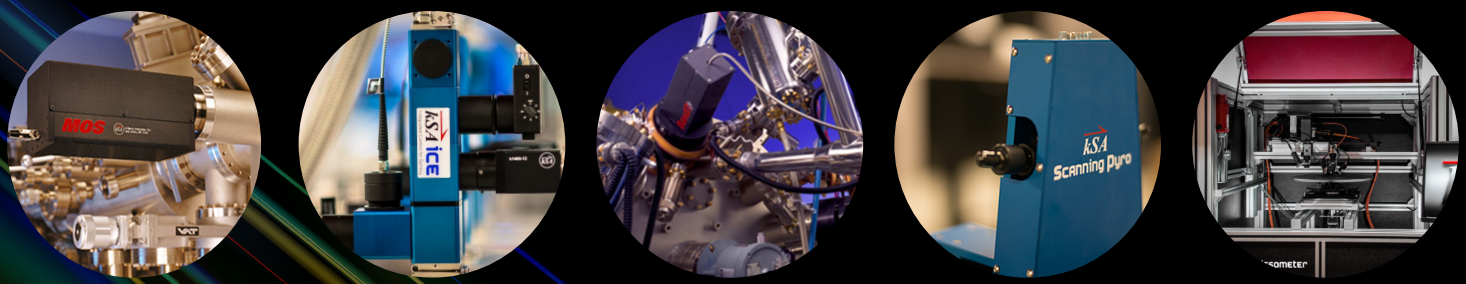

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Cardiff University report highlights resilience of compound semiconductor cluster during pandemic

A new report published by the Welsh Economy Research Unit at Cardiff University examines economic activity in Wales and the impact of the CSconnected compound semiconductor cluster (formed in South Wales in 2017), focusing on the contribution to the economy by the CSconnected consortia during 2020.

The report finds that, in the final quarter of 2020, CSconnected firms and organizations accounted for an estimated 1407 jobs, with private sector partners accounting for about £440m of sales, much of which (over 90%) related to overseas exports, mostly destined for markets outside the European Union (EU).

Employment within the compound semiconductor cluster has been stable in the challenging economic conditions during the global pandemic, with output largely maintained at a time when there has been a 9.9% contraction in UK economic activity in 2020 (the largest annual contraction on record).

Prospects in the cluster for 2021–22 are good, with increased vacancies and positive sentiment prevailing on business conditions, says the report. To meet growth expectations, CSconnected — in partnership with Cardiff University — has launched a co-ordinated mid-term skills development activity that will scale in line with cluster growth from 2021 to 2025.

The Welsh economy benefited from a contribution to gross value added (GVA) from CSconnected firms and organizations of an estimated £121.3m during 2020. Productivity in the cluster is one of its strongest points, it is reckoned. It is estimated that average GVA per employee in the cluster was about £86,000 in 2020 (more than double the Welsh average).

The report suggests that, after accounting for the role of the cluster in supporting local suppliers and household incomes, the economic contribution of the cluster to Wales grows to about £172m, with around 2100 full-time-equivalent jobs supported.

The report concludes that the resilience of the CSconnected community activity through the 2019–2020 period was very marked, with the cluster already showing excellent prospects for further employment and GVA growth in 2021–22.

"UKRI's Strength in Places program has provided the CSconnected community in South Wales with a unique opportunity to align world-class academic research and core supply elements such as capital equipment and device packaging based in the region," says CSconnected's director Chris Meadows. "The project will accelerate Wales' unique capability to be center stage at the forefront of new and emerging technologies. CSconnected aims to bring high-value-add manufacturing back to the UK and create significant jobs growth over the coming years," he adds.

"The development of the compound semiconductor cluster is important for long-term economic prospects for the regional economy," comments Max Munday, one of the report's authors. "Critically, there is an evolving industry ecosystem in Wales that embraces the private sector firms, institutions and higher/further education colleges. The UKRI Strength in Places support is going to provide new opportunities to better embed cluster activity in the regional economy."

The report was written by professor Max Munday, Dr Annette Roberts and professor Robert Huggins of Cardiff University and builds on their previous work developed to support the Strength in Places (SIP) Fund application process in 2019.

https://csconnected.com

Picosun increases LED and OLED production efficiency

Atomic layer deposition (ALD) thin-film coating technology provider Picosun Group of Espoo, Finland says that its PICOSUN P-300BV ALD system has been proven to significantly increase production efficiency for its LED and OLED manufacturing customers.

Recent tests have shown that a reduced ALD process cycle time and an increased number of wafers deposited with the same film thickness resulted in almost 100% better throughput. A throughput of over 20,000 wafers per month can be reached with a batch of 100 4" wafers. At the same time, process quality in terms of film thickness uniformity has remained <1% (1σ) within wafer, wafer-to-wafer as well as batch-to-batch (120nm TMA + H_2O @ 200ºC).

LED and OLED makers use ALD in production to achieve better device performance and longer product lifetimes, says Picosun. This is a result of thin, conformal, uniform and pinhole-free material layers deposited by ALD for passivation and moisture protection as well as for creating buffer and interface layers, adds the firm.

"Picosun ALD solutions have become the standard in high-volume ALD manufacturing," says Juhana Kostamo, VP, Industrial business area of Picosun Group. "The PICOSUN P-300BV ALD system is designed especially for production of LEDs and OLEDs," he adds. "With our experience and deep know-how in ALD we are continuously striving to minimize the total cost of ownership and ensure future-proofness."

www.picosun.com/product/p-300bv

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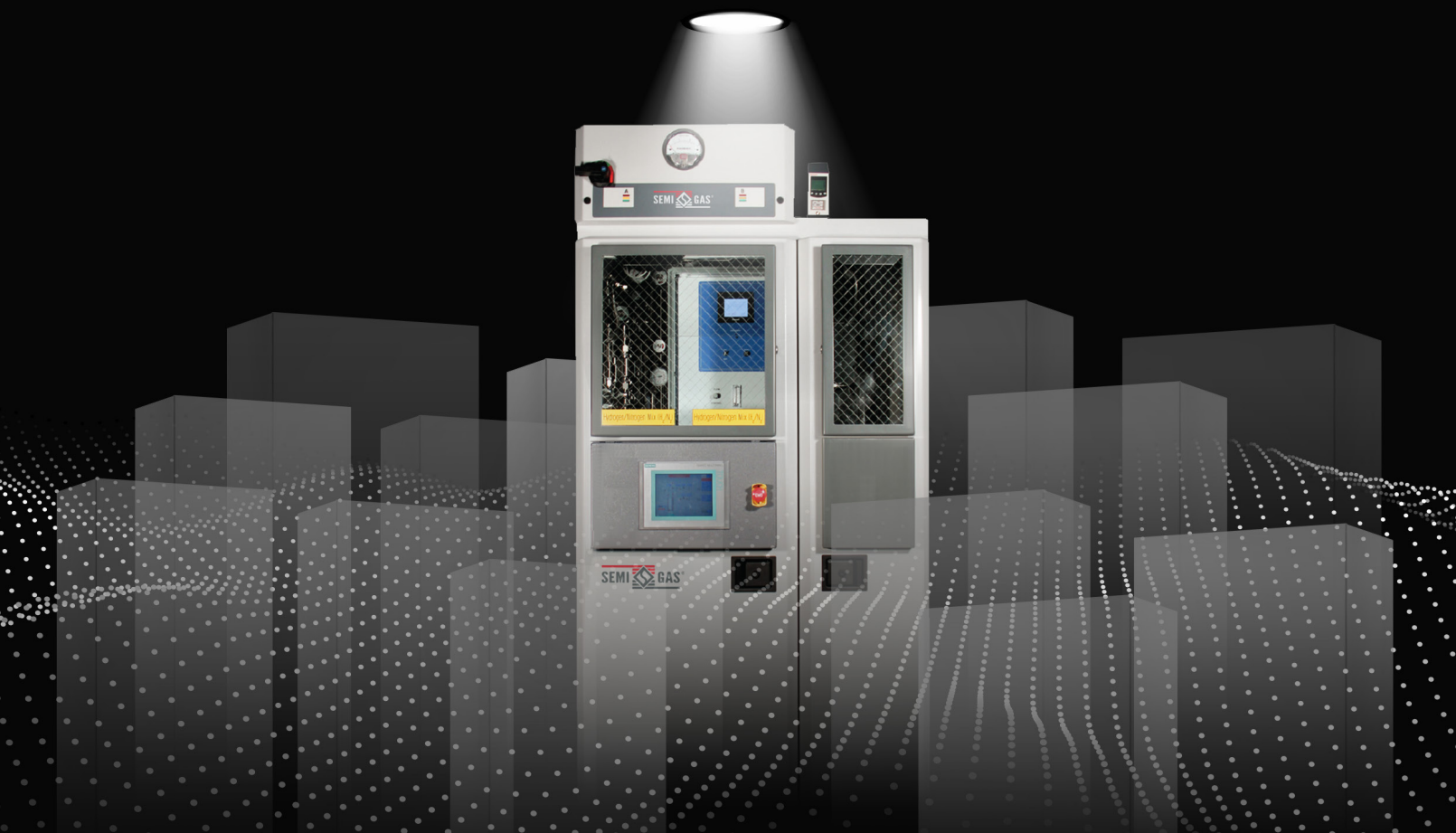

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FBH presents UV LED developments at ICULTA

Reliability of UVB and UVC LEDs improved

Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH) of Berlin, Germany presented current developments and results at the 'International Conference on UV LED Technologies & Applications (ICULTA 2021, held virtually on 19–20 April).

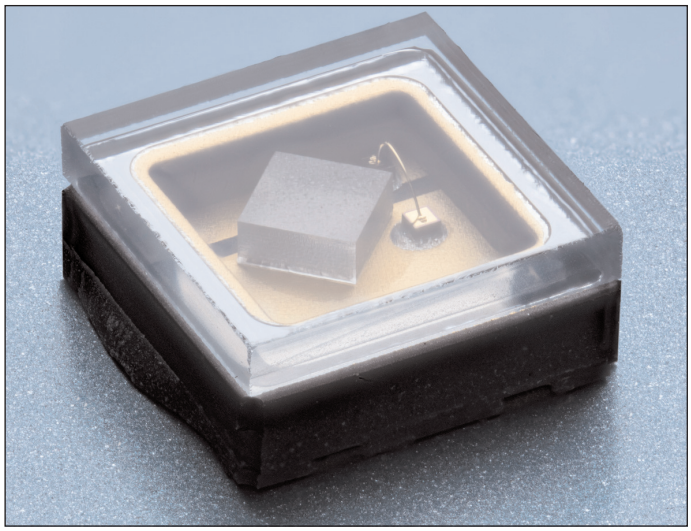
FBH participated with an invited talk 'Understanding the degradation mechanisms of UVB and UVC LEDs to improve their reliability' by Johannes Glaab, plus showcases presenting its portfolio at the accompanying exhibition.

The range extends from customized LEDs to ready-to-use prototypes that can be used for applications like surface disinfection. In particular, FBH reported important progress in the reliability of UVB and UVC LEDs.

Improved reliability of UVB and UVC LEDs

Up to now, the lifetime of state-of-the-art UVB and UVC LEDs has been limited to several thousand hours. At ICULTA, FBH presented a new understanding of the degradation processes of UV LEDs. The degradation behavior was analyzed under various operating conditions, for different LED designs and material compositions. Based on the knowledge gained, FBH has derived a model for the physical degradation processes of UV LEDs.

In collaboration with TU Berlin, FBH has increased the lifetime of UVB LEDs and certain UVC LEDs to more than 10,000 hours — a key milestone for ensuring that the devices can be used in future commercial products. Together with its partner, FBH offers customized UV LEDs with specific wavelengths in the UVB and UVC spectral range. The portfolio also comprises customized packages that, for example, have monolithically integrated ESD protection or are equipped with micro-optics to adjust the emission angle.



1mm x 1mm UV LED chip in a hermetically sealed package of 3.5mm x 3.5mm.

Prototype UVC LED irradiation system to fight multi-drug-resistant pathogens using 120 LEDs - suitable for application to the skin.

Prototype using 265 nm LEDs for disinfecting everyday objects: 128 LEDs irradiate the object on a UV-transparent pane from above and below.

UV LED emitters to fight pathogens — from surfaces to human skin

Since UVC light inactivates viruses, bacteria and fungi, FBH is developing the required LEDs jointly with TU Berlin, covering the entire value chain from semiconductor technology to ready-to-use prototypes. With its LEDs emitting in the far-UVC spectral range at 233nm, the partners are world leaders, it is reckoned. Light of this wavelength offers the advantage that it barely penetrates the living layers of the skin, and is therefore suitable for human exposure.

FBH has meanwhile developed and manufactured several UV LED irradiation systems using 233nm LEDs. These are being tested in medical studies at the Charité – Universitätsmedizin Berlin and the Universitätsmedizin Greifswald. An array of 120 LEDs is integrated into each of the systems on an area of 8cm x 8cm. This achieves a maximum irradiance of 0.17mW/cm^2 with more than 90% uniformity over an area of 6cm x 6cm.

Another prototype using 265nm LEDs was specifically developed to disinfect everyday objects such as mobile phones and reusable masks. The demonstrator comprises 128 LEDs that irradiate the respective object, which lies on a UV-transparent glass pane, from both sides. The average irradiance is more than 1mW/cm^2.

www.iculta.com/program
www.fbh-berlin.com

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Giving our customers the lead through mass production of high performance TCOs, metals and DBRs with the best cost of ownership is our daily business. However, leveraging our know how to help customers develop new more demanding processes or ramp up production of next generation Optoelectronic devices like Micro LED or OLED on CMOS is where we add value too, and in this edition of LAYERS you can also read about solutions we can offer for exactly that.

Stefan Seifried, Head of BU Optoelectronics

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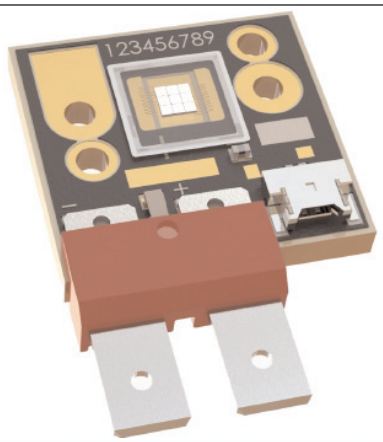
Luminus expands portfolio of ultra-high-power IR LEDs

780, 850 and 940nm wavelengths target life science & industrial use

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 ultra-high-power infrared (IR) LEDs with a new product line that addresses the rapid expansion of life sciences, medical, machine-vision and industrial applications. The CBM-90-IRD LEDs come in three peak wavelengths — 780nm, 850nm and 940nm — and deliver what is claimed to be unmatched radiometric power in a compact package platform suited to fiber-coupled applications.



Version	PeakW (typ)	Centroid W (typ)	Typ Output 13.5A	Typ Vf @ 13.5A	FWHM (typ)
IRD-780	780 nm	776 nm	8-11 W	3.5 V	30 nm
IRD-850	855nm	850 nm	13-15 W	3.7 V	35 nm
IRD-940	950 nm	940 nm	11-13 W	3.6 V	45 nm

Based on dual-junction technology, the new IR products are specifically designed to compete against laser diode and vertical-cavity surface-emitting laser (VCSEL) technologies, with the advantages of being eye-safe, less expensive and easily integrated into an optical light engine. Depending on the drive condition and peak wavelength, the LEDs can deliver over 15W of radiometric power under CW (100% duty cycle) conditions or 40W under pulsed conditions.

In addition to traditional industrial and machine-vision markets, the LEDs can also be used as light sources in medical and life-science applications. The 780nm version can be used to excite near-infrared (NIR) biomarkers such as Indocyanine Green (ICG), which are widely used in fluorescence imaging markets.

"Our CBM-90-IRD-780nm LED product delivers 10+W of radiometric power that can be efficiently coupled in 5-7mm optical fiber bundles used in endoscopy and infrared light engines," says Yves Bertic, senior director of global product marketing. "With the growing demand for light sources capable of exciting the new biomarkers that are continuously being developed, this product line is the perfect alternative to legacy laser-based light sources."

The CBM-90-IRD product line complements Luminus' extensive CBT/CFT-90 LED series that spans UV-A and visible ranges. The copper chip-on-board package includes high-precision optical alignment features, handles very high currents, and offers an extremely low thermal resistance.

The product line is available at distributors Digikey and Mouser.

www.luminus.com/products/ir

SemiLEDs' quarterly revenue rebounds, despite Chinese New Year shut-down

Profits and revenue still down on a year ago

For fiscal second-quarter 2021 (ended 28 February), LED chip and component maker SemiLEDs Corp of Hsinchu, Taiwan has reported revenue of $1.2m, rebounding from $719,000 last quarter, despite shutting down manufacturing production for two weeks (6–21 February) due to the Chinese New Year holiday. However, this is still down on $1.537m a year ago.

Gross margin was 20%, recovering from –3% last quarter but below the 36% a year ago.

Operating expenses have fallen further, from $1.077m a year ago and $950,000 last quarter to $748,000, due partly to R&D expenditure being cut from $346,000 to $288,000.

Operating margin was -42%, an improvement from -135% last quarter although still below the –26% a year ago.

Net loss was $255,000 ($0.06 per diluted share), rebounding from $697,000 ($0.17 per diluted share) last quarter but down on $348,000 ($0.08 per diluted share) a year ago.

During the quarter, cash and cash equivalents fell from $2.7m to $2.1m.

"We are unable to forecast revenue for fiscal third-quarter 2021 (to end-May) at this time given the continuing uncertain impact of COVID-19 on the economy and the company," cautions SemiLEDs.

www.semileds.com

Seoul Semiconductor achieves record Q1 revenue, up 28.3% year-on-year

Double-digit growth expected again in Q2/2021

For first-quarter 2021, South Korean LED maker Seoul Semiconductor Co Ltd has reported consolidated revenue of KRW312bn, up 28.3% year on year.

Recovering from the COVID-19 pandemic impact in first-half 2020, Seoul continued to register over KRW300bn quarterly revenue for the past three consecutive quarters, including record first-quarter revenue for the company.

Despite being a seasonally low quarter in the LED industry, Seoul Semiconductor's strong performance in the first quarter will lead to a higher expectation for full-year 2021, says the firm.

"The manufacturing transition to Vietnam, which has been started from 2017, entered the stabilization stage," notes Seoul Semiconductor. "Seoul expects further profitability for the year by delivering superior cost advantage and pricing competitiveness. We also expect exceptional revenue growth in the second half as mass production of mini-LEDs, one of the core next-generation display technologies, starts," it adds. Seoul's mini-LED products use package-less WICOP (wafer-level integrated chip on PCB) technology, reckoned to be the world's first technology that directly mounts LED chips onto a substrate.

Seoul Semiconductor is due to report full details of first-quarter earnings and sales guidance for second-quarter 2021 at the end of April.

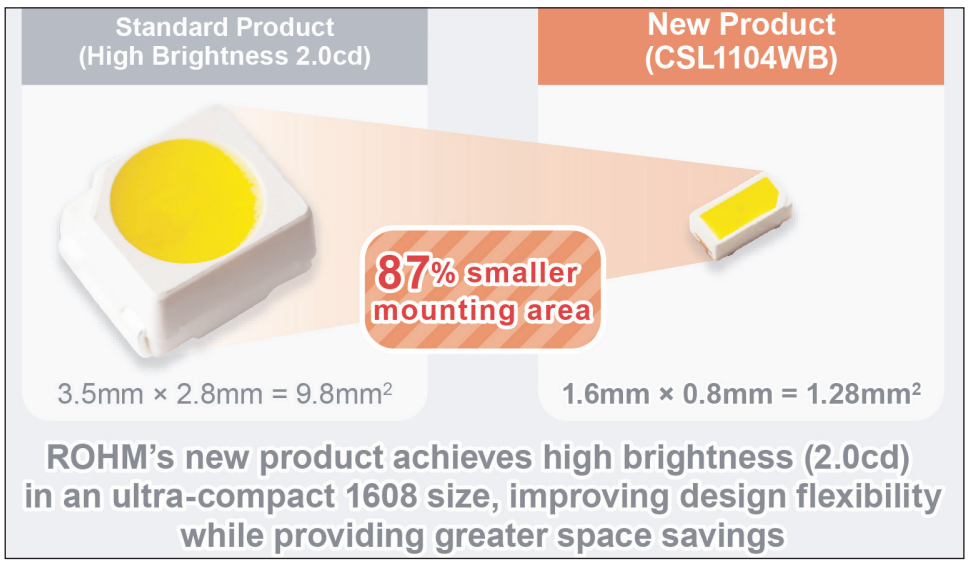
www.SeoulSemicon.com

ROHM launches 2.0cd white LEDs in compact 1608 size

Same luminosity as 3528 size but in 87% smaller form factor

Japan's ROHM has unveiled the CSL1104WB ultra-compact high-luminous-intensity white-chip LEDs, optimized for applications requiring high-brightness white-light emission such as Internet of Things (IoT) devices, drones and other battery-equipped applications.

In recent years, high-luminous-intensity (2.0cd) white LEDs have been increasingly adopted to improve visibility in a range of applications in the consumer electronics and automotive sectors. At the same time, the emergence of applications that mount multiple LEDs in a small space – such as IoT devices and drones – requires high-density mounting. This makes it difficult to achieve high brightness in a compact footprint.



ROHM's new product achieves high brightness (2.0cd) in an ultra-compact 1608 size, improving design flexibility while providing greater space savings

High brightness in an ultra-compact size improves design flexibility

The CSL1104WB series achieves a high luminous intensity of 2.0cd in an ultra-compact 1608 size (1.6mm x 0.8mm = 1.28mm^2), which was previously difficult to achieve, says Rohm. The result is the same luminosity as the existing mainstream 3528-size PLCC package (3.5mm x 2.8mm = 9.8mm^2) but in an 87% smaller form factor.

Fine-grained, accurate white color chromaticity

Moreover, color variation is significantly improved, simplifying the color adjustment process by ensuring accurate white color chromaticity. This not only contributes to greater application space savings, but also improves design flexibility along with visibility through high-density mounting of high-luminosity LEDs, reducing development load considerably, says ROHM. In addition, qualification under the AEC-Q102 automotive reliability standard specifically developed for optical devices is planned, enabling smooth application inside industrial equipment and automotive applications that are exposed to harsh environments.

ROHM says that it is committed to further expanding its lineup of 1608-size white-chip LEDs from low to high brightness — aiming to improve design flexibility while reducing development load (i.e. decreasing application height, simplifying product design).

www.rohm.com/products/led/

Lumileds upgrades performance of LUXEON 5050 Square LES light-emitting diodes

Flux boosted from 825lm to 835lm for 4000K CCT and 70CRI

Lumileds LLC of San Jose, CA, USA recently upgraded the performance of its LUXEON 5050 Square LES LEDs. For example, the variant with a correlated color temperature (CCT) of 4000K and color rendering index (CRI) of 70 has had its typical luminous flux improved from 825lm to 835lm.

Lumileds says that the LED's luminance output and corrosion resistance enables designs for outdoor and industrial lighting markets.

The LUXEON 5050 Square LES uses an industry-standard 5050 surface-mount package and comes in a complete range of CCTs and CRIs, and offers hot-color targeting to ensure that the LEDs are within color target at application conditions of 85°C.

Lumileds adds Lime to LUXEON Rubix LED family

New color provides additional mix-and-match options

Lumileds LLC of San Jose, CA, USA has added Lime to its family of LUXEON Rubix LEDs (launched last August).

The new color provides additional mix-and-match options for customers in their luminaire designs. The Lime color enables color mixing fixtures that achieves a higher color rendering index (CRI) score and higher quality of light due it its broader spectral coverage.

The LUXEON Rubix Lime also comes with a maximum driving current of 3A to maximize performance. Luminous flux is 420lm (minimum) and 510lm (typical).

www.lumileds.com

Samsung launches PixCell LED for intelligent headlights

Monolithically integration provides precise selective lighting control

South Korea's Samsung Electronics Co Ltd has announced PixCell LED, a new automotive LED module optimized for intelligent headlights, such as adaptive driving beam (ADB) systems. ADB headlamps powered by Samsung's PixCell LEDs are targeted at helping to improve driver visibility and safety to enhance driving at night and in poor weather conditions such as fog or heavy rain.

"Much more than a simple automotive lighting source, Samsung's PixCell LED is based on new lighting technology designed to improve road safety and driving convenience," says Un Soo Kim, senior VP of the LED business team. "Beginning with PixCell LED, we will introduce tailored lighting solutions well-suited for future automobiles, including electric and autonomous vehicles," he adds.

ADB is an advanced driver assistance technology designed to help secure maximum driving visibility. To prevent glare to other drivers, ADB automatically adjusts headlight beam patterns when it detects any object near a moving vehicle, preventing any unnecessary glare. Recent developments in future automotive technologies, such as autonomous and connected driving, have been raising the bar for vehicle safety standards and ultimately boosting demand for ADB systems, says Samsung.

Leveraging Samsung's expertise in semiconductor technology, the new PixCell LED can monolithically integrate more than 100 ultra-small segments into a single LED chip, while making the light-emitting area significantly smaller, at 15.4mm x 2.7mm.

These LED segments are separated by a silicon wall to prevent optical cross-talk and, in turn, offer superior contrast for much greater driver visibility, says Samsung. Each segment functions like a pixel to meticulously control light distribution, as it distinguishes on and off areas so that the beam from the headlight only illuminates the exact location where it is needed.

With the light-emitting area shrunk to 1/16 of conventional discrete LED modules for ADB systems, the PixCell LED can reduce the headlamp size by 30–50%, allowing greater freedom in designing sleeker and more elegant lamps.

The light distribution and brightness levels of the PixCell LED are designed using automotive lighting software, making them easily adjustable to meet diverse regulations and requirements for automotive lamps around the world, says Samsung. Based on a single standard headlamp design, lamp makers can customize light output to suit varying design needs and achieve reduced lead time for development, production, supply and time-to-market.

Samsung has begun shipping its PixCell LEDs to lamp manufacturers for use in next-generation electric cars and has already provided enough PixCell LEDs to light more than 300,000 electric vehicles.

www.samsung.com

Vector Photonics gains £1.6m equity investment

Vector Photonics Ltd (which was spun off from Scotland's University of Glasgow in March 2020, based on research led by professor Richard Hogg) has received £1.6m of equity investment from a consortium of three specialist funding companies: Foresight, the UK Innovation & Science Seed Fund (UKI2S) and Equity Gap.

This takes the start-up's seed funding round to more than £4m, including £2.4m from three grants that came through UK Government agency Innovate UK: 'LOCAL' ('Lasers for Communications Applications', optimizing PCSEL technology for datacoms applications); 'Bloodline' (for 3D metal printing); and 'Facilitator' (for 3D plastic printing). Vector's CEO Neil Martin describes the seed funding as "a fantastic achievement for a one-year-old, Covid-era University of Glasgow start-up".

The funding will be used to commercialize Vector's unique PCSEL-based semiconductor laser technology. PCSELs (photonic-crystal surface-emitting lasers) are claimed to have benefits over existing laser technology in data communications; additive manufacturing, including metal and plastic printing; light detection & ranging (LiDAR); and optical sensing (some of the fastest-growing technology markets in the world).

"Each investment company adds its own unique value to our business and will have board representation," comments Martin. "Foresight invests in high-growth-potential companies with innovative and transformational technologies via the Foresight Scottish Growth Fund and Foresight Williams, a joint venture with Williams Advanced Engineering. UKI2S is a specialist deep-tech seed fund focused on spin outs from the UK's research base. Equity Gap is an angel investment syndicate, investing early in new technology businesses throughout Scotland," he adds.

www.vectorphotonics.co.uk

Vector Photonics appoints PCSEL co-inventor as director of product development

Vector Photonics has appointed Dr David Childs as director of product development.

Childs co-invented all-semiconductor photonic-crystal surface-emitting lasers (PCSELs), Vector Photonics' proprietary laser technology. In his new role, he will supervise operations, developing new PCSEL designs into production-ready devices, for the company's initial target markets: datacoms, LiDAR (light detection & ranging), and 3D metal printing and plastic printing.

"David brings exceptional semiconductor laser design and optimization experience to the company, from design and simulation through to testing and reliability analysis," comments CEO Neil Martin. "His expertise extends across surface-emitting, continuous-wave, modulated, telecommunications, tunable and swept-source lasers."

David Childs, Vector Photonics' new director of product development.

Childs has come from the University of Glasgow's School of Engineering, where he was part of the Photonic Devices and Systems Group of the Electronics and Nanoscale Engineering Division. Before that, he was with the University of Sheffield's Semiconductor Device Group. He has a PhD from Imperial College, London, has published over 60 peer-reviewed journal papers, and has numerous patents to his name.

Childs' industrial experience began as a research scientist at Marconi Optical Components and Bookham Technology (since acquired by Lumentum Holdings Ltd). He has also worked extensively on university collaboration projects with industrial partners QD Laser, CST Global, BB Photonics, Denselight Semiconductors, POET Technologies, II-VI, Huawei, Compound Photonics, Filtronic, and M Squared Lasers.

Initial tests demonstrate that Vector Photonics' PCSELs will deliver faster speeds than any equivalent lasers

At the Compound Semiconductor International Virtual Conference on 12 April, Vector Photonics' director of product development Dr David Childs presented a paper on the first speed measurement of a photonic-crystal surface-emitting laser (PCSEL), demonstrating that the PCSEL's speed aligns with the firm's device modelling.

The results verify that Vector Photonics' PCSEL technology is capable of significantly faster speeds than equivalent VCSEL or edge-emitting lasers (EELs). Childs concludes that a PCSEL, with a smaller area and optimized for speed, has the potential to be over two times faster than a VCSEL equivalent and three times faster than a DFB laser equivalent.

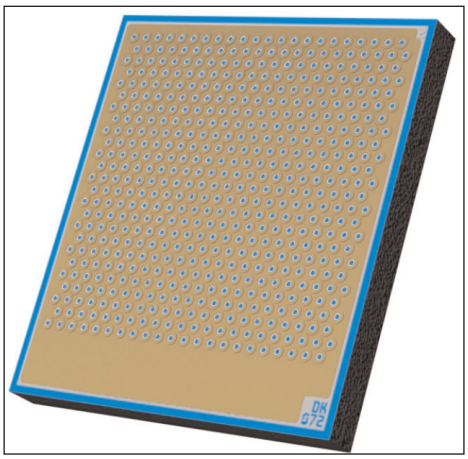
Osram unveils 550 aperture multi-junction VCSEL

Faster rise and fall times suit time-of-flight applications

At the online Photonics West show (6–11 March), Osram Opto Semiconductors GmbH of Regensburg, Germany unveiled its PowerBoost multi-junction vertical-cavity surface-emitting laser (VCSEL).

Due to its beam quality, simple design and compact size, VCSEL technology is making a huge impact in the 3D sensing market, notes the firm. The PowerBoost VCSEL is said to improve power conversion efficiency by up to 60% and enhance optical power. Its faster rise and fall times enable short pulse lengths, which are critical in time-of-flight (ToF) applications for reaching greater distances without compromising eye safety. VCSELs power many consumer applications, such as 3D cameras and facial recognition in mobile devices, as well as industrial applications like short-range light detection & ranging (LiDAR), machine vision and robotics. The 550 aperture PowerBoost VCSEL was selected as a finalist for the Prism Award for Photonics Innovation in the category of vision technology.

One year ago, Osram Opto announced the development of multi-junction VCSEL technology, providing better efficiency and speed than single-junction VCSELs. Now, the same technology drives the PowerBoost VCSEL portfolio, which includes chip products using dual-junction epitaxy (V00155) and a triple-junction epitaxy (V00156). The higher slope efficiencies of 2W/A of a dual junction and 3W/A of a triple junction significantly reduce the pulsing forward-current requirements to reach the same optical power as a single-junction VCSEL. Thermal load is reduced due to a power conversion efficiency of 60% with a single-aperture 940nm VCSEL and 53% with a power array.



Osram's 550 aperture PowerBoost VCSEL.

"The unrivaled efficiency of the multi-junction PowerBoost VCSEL is a major advantage for customers looking to reduce current and improve the modulation speed of their drivers," says Dominik Schulten, director of business development at Vixar (an Osram company). "The product's high power density dramatically reduces chip and package size, allowing customers to simplify their designs and system architecture."

The PowerBoost VCSEL family will expand later this year with the announcement of a new packaged product for flood illumination.

At Photonics West, Osram also showcased a new driver reference module for industrial ToF application designs. The module includes a VCSEL array and was developed to reduce the design time for ToF applications, simplify testing and evaluation, and provide VCSEL operating principles, measurements, module date for its customers.

www.osram.com

KAIROS delivers commercial-grade single-mode 894nm vertical-cavity surface-emitting lasers

UK-funded project focused on atomic clock applications

Running from November 2018 to September 2021 and part-funded by the UK National Quantum Technologies Challenge via UK Research and Innovation (UKRI) to develop a miniaturized atomic clock platform for precision timing, GPS-free navigation and primary time standard applications, the £4.4m KAIROS project has delivered single-mode vertical-cavity surface-emitting lasers (VCSELs) with ultra-high mode-stability operating at 894nm, the wavelength corresponding to the D1 transition line of Cs used in high accuracy (10e-13) clocks.

Led by Teledyne e2v (UK) Ltd with partners Compound Semiconductor Centre Ltd (CSC), the UK National Physical Laboratory (NPL), Leonardo, Altran, ICS, HCD Research, Optocap, University of York and Cardiff University, the KAIROS consortium was targeted at developing a pre-production prototype of a miniature atomic clock for providing precise timing to critical infrastructure services such as reliable energy supply, safe transport links, mobile communications data networks and electronic financial transactions.

Capabilities demonstrated by the project consortium's laser design, epitaxial materials and device fabrication partners includes:

- A suite of proprietary laser design and simulation models at Cardiff University and Institute for Compound Semiconductors (ICS) Ltd;
- High-uniformity epitaxial layer structures realized at CSC — a joint venture founded in 2015 between Cardiff University and epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK — with <3nm centre wavelength tolerance;
- * Polarization-insensitive, single-mode VCSEL performance with a linewidth of ~30MHz and side-mode suppression ratio (SMSR) of 28dB, fabricated by ICS Ltd;
- * Novel VCSEL characterization processes specifically developed for quantum applications at the National Physical Laboratory (NPL).

Having met stringent target performance specifications required for atomic clock applications, the supply-chain partners are preparing to service future opportunities for high-specification VCSELs through several parallel activities, one of which is the QFoundry project to upscale the manufacturability and reliability of quantum photonic components (QPCs), also part-funded by the UK National Quantum Technologies Challenge.

The recent achievement at the Institute for Compound Semiconductors at Cardiff University in establishing a multi-wafer 6" VCSEL fabrication pilot-line further supports the partners' collective capability in high-performance VCSEL design, fabrication and testing.

"Whilst high-stability, single-mode VCSEL operation is required for numerous emerging applications, the concern over reliability and cost is forcing system integrators to compromise on performance," says CSC director Wyn Meredith. "Following solid groundwork on uniformity improvements for Kairos VCSEL structures, we are confident that our collective capabilities across the VCSEL supply chain will provide a pathway towards high-end VCSEL solutions for new applications in quantum, sensing and industrial markets," he adds.

"We are extremely pleased to deliver a manufacturing capability for high-specification single-mode VCSELs to complement our existing product lines in avalanche photodiodes, Hall-effect sensors and resonant tunnelling diodes (RTDs)," states ICS chief technology officer professor Mohamed Missous.

"VCSEL technologies are a key focus area for Cardiff University and we are in a position to support industry with prototyping novel VCSEL devices to complement our device simulation and design expertise for highly specialized structures," comments ICS director professor Peter Smowton.

www.ukri.org/innovation/industrial-strategy-challenge-fund/quantum-technologies
www.compoundsemiconductorcentre.com

NUBURU wins patent for copper welding with blue light

US patent adds to 34 patents already awarded

NUBURU Inc of Centennial, CO, USA (which was founded in 2015 and develops and manufactures high-power, high-brightness industrial blue lasers) has been awarded US patent no. 10,940,562 (for blue laser applications of welding copper material and its alloys) by the US Patent Office.

NUBURU's IP portfolio previously grew in January with the addition of seven patents across 3D printing and material processing. The firm's foundational patent ('3D printing Devices and Methods', PCT/US14/35928) was awarded in 16 countries, with several other applications and continuations pending around the world, including with the US Patent Office (2016/0067780).

"This new patent covers all forms of 3D printing, welding, and methods of opening up the keyhole using blue laser light," says founder & chairman Dr Mark Zediker. "It is a core addition to the broad list of 34 patents NUBURU has already been awarded," he adds. "Our IP portfolio widely covers blue laser technology, multi-mode and single-mode as well as broad applications within 3D printing and material processing, and we have an additional 79 pending patent applications, signaling the possibility for even further expansion of our portfolio."

NUBURU says that its blue lasers provide speed and quality control for metal processing operations, such as welding and additive manufacturing, particularly in growing industries like e-mobility and automotive, where copper materials, stainless steel and aluminium are increasingly critical, and existing market technologies do not have the flexibility, speed or power to produce high-quality results. The firm says that its industrial blue lasers leverage a fundamental physical advantage to produce defect-free welds up to ten times faster than the traditional approaches — all with the flexibility inherent to laser processing.

"We've taken great strides in just a few months to expand the reach of our capabilities and increase our intellectual property portfolio, further securing our market potential and ability to serve customers across industries," says CEO Guy Gilliland.

www.nuburu.net

nLIGHT raises $75m in public offering

Proceeds to be used for working capital, capital expenditure and general corporate purposes

nLIGHT Inc of Vancouver, WA, USA (which was founded in Seattle in 2000 and provides high-power semiconductor and fiber lasers for industrial, microfabrication, aerospace and defense applications) priced its underwritten public offering of 2,205,883 shares of common stock (pursuant to its shelf registration statement) at $34 per share.

The aggregate gross proceeds from the offering were expected to be about $75m, before deducting the underwriting discounts and commissions and estimated offering expenses.

In connection with the public offering, nLIGHT granted the underwriters a 30-day option to purchase up to an additional 330,882 shares of its common stock at the public offering price, minus the underwriting discounts and commissions.

nLIGHT said that it intends to use the net proceeds from the offering for working capital, capital expenditures and other general corporate purposes.

www.nlight.net

Kyoto signs supply and reseller agreement with CEL

Customer access expanded to include North America, India, Israel

Japan-based Kyoto Semiconductor Co Ltd has entered into an agreement for California Eastern Laboratories (CEL) to be a multi-national reseller of its optical device solutions.

The partnership extends Kyoto Semiconductor's sales and support network not only to North America but to countries such as India and Israel while it enhances CEL's product offering with Kyoto's photodiodes for optical communication and sensing equipment.

Established in 1959, California Eastern Laboratories has been a provider of wireless connectivity solutions and optical devices. Kyoto Semiconductor is "recognized for high performance and outstanding quality in its photodiodes," comments CEL's president & CEO Paul Minton.

"Kyoto Semiconductor is pleased to collaborate with CEL, one of the best suppliers of compound and silicon semiconductors, known for its superior customer support and technological expertise," comments Kyoto's CEO Tsuneo Takahashi. "With this partnership, we extend our customer reach worldwide, ranging from North America to India or Israel," he adds. "Our products are critical for the 5G and beyond-5G wireless network and the IoT market."

www.kyosemi.co.jp/en

Lynred to develop SWIR detector for European LSTM mission

Airbus Defence & Space to integrate detector into satellite's imager, whose land-surface temperature observations will help to improve sustainable agriculture productivity

Lynred of Palaiseau (near Paris) and Veurey-Voroize (near Grenoble), France, which designs and manufactures infrared (IR) detectors for aerospace, defense and commercial applications, says that Airbus Defence & Space (ADS), prime contractor in the European Copernicus Land Surface Temperature Monitoring (LSTM) mission, has selected it to develop a new linear shortwave-infrared (SWIR) array to meet the special requirements of the satellite's imager instrument.

The linear SWIR array will be integrated into an imager; a high-resolution radiometer that measures land-surface temperatures. LSTM's overall aim is to improve sustainable agricultural productivity at field-scale in regions experiencing increasing water scarcity and climate variability. Its objective is to improve how the agriculture sector predicts droughts and addresses other land degradation issues.

"Lynred has a long track record in developing and manufacturing SWIR detectors for space instruments," comments Vincent Chorvalli, LSTM instrument project manager at ADS. "We trust in Lynred's capacity and technological performance to tackle the challenges in this program and deliver the LSTM SWIR detector according to our expectations."

This type of IR detector, in particular its performance, is one of the major components enabling the imager instrument to achieve its overall system performance. Equally important is the requirement for the IR detector to operate at nominal performance while withstanding the rigors of space, notably high radiation levels. This makes its role and the requirement to perform reliably all the more critical.

"Our brand of IR detectors for space applications, built upon decades of the highest technological performance, reassures customers of Lynred's reliability as a supplier and its ability to help them achieve the ambitious goals of their space programs," says Lynred's space business development manager Philippe Chorier. "We see this legacy as a key driver in the design of future missions, based on this large-format SWIR detector," he adds. "We look forward to engaging with customers on other projects designed to preserve and protect the planet."

Lynred's SWIR detector will capture infrared light at three different wavelengths (0.945µm, 1.375µm and 1.61µm). Its design will meet the special needs of the mission, notably a linear array with four different lines (the line at 0.945µm being duplicated according to mission needs) of 1200 pixels each in the across-track satellite velocity direction and 12 pixels in the long-track scanning direction (scanning methods are used to acquire a multispectral image). The 12 pixels will enable the implementation of a TDI (time-delay integration) operation — a signal-to-noise ratio improvement method employed to enhance image quality — directly on the detector chip. As a consequence, the interface towards detector electronics is significantly simplified for global detection chain design optimization.

Lynred will deliver the first flight model by the end of 2023. The firm has previously contracted with ADS on other space missions, such as Sentinel 2, Sentinel 5, Microcarb and METImage.

www.lynred.com
www.esa.int

Intevac wins $1.8m directed-energy weapons contract

Intevac Inc of Santa Clara, CA, USA has received a $1.8m development contract award from the US directed-energy weapons development agency Joint Directed Energy Transition Office (DE JTO) in Albuquerque NM, representing the funding for year one of a projected three-year, $7m development effort.

Intevac Photonics will develop a gated SWIR sensor for high-energy laser (HEL) 2D fine tracking and adaptive optics system applications, building on the firm's experience in its fielded LIVAR (Laser Illuminated Viewing and Ranging) camera technology and legacy fine tracking/adaptive optics sensor technology first used on the Airborne Laser (ABL) program.

Based on its patented Electron Bombarded Active Pixel Sensor (EBAPS) technology (which incorporates a III-V photocathode in proximity-focus with a high-resolution, backside-thinned CMOS chip anode), Intevac's digital night-vision sensors provide state-of-the-art capability to the the US Department of Defense's avionic fighting platforms.

"The gated SWIR camera developed under this program represents a return of Intevac to the rapidly growing directed energy (DE) weapons systems market," says Timothy Justyn, executive VP & general manager of Intevac Photonics. "DE systems are expected to become a critical component of our military's advanced weapons systems and represent a significant future market opportunity for Intevac."

"This contract award demonstrates the US military's continued commitment to Intevac's SWIR LIVAR technology for new systems applications," says Intevac's president & CEO Wendell Blonigan.

www.intevac.com

Coherent accepts II-VI acquisition proposal

Lumentum merger agreement terminated

After consultation with its financial and legal advisors, Coherent Inc of Santa Clara, CA (which provides lasers and laser-based technology for scientific, commercial and industrial applications) determined that the acquisition proposal received on 17 March from engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA continued to be a 'Company Superior Proposal' under Coherent's 9 March merger agreement with Lumentum Holdings Inc of San Jose, CA (which designs and makes photonic products for optical networks and lasers in industrial and consumer markets) after considering the revised acquisition proposal received from Lumentum on 22 March.

Coherent said that its board of directors had evaluated the comparative benefits and risks of the II-VI and Lumentum proposals, including the near-term and long-term financial opportunities and risks presented by each proposal, the potential synergies available through a combination with each company, and the complementary businesses of each company.

Subject to approval by the stockholders of Coherent and II-VI, receipt of US and foreign regulatory approvals and other customary closing conditions, each share of Coherent common stock will be exchanged for $220 in cash and 0.91 shares of II-VI (when the transaction is expected to close in fourth-quarter 2021).

Accordingly, Coherent decided to terminate the amended 9 March merger agreement with Lumentum by paying it the agreed $217.6m termination fee.

Lumentum notes that, using the closing share prices as of 24 March, its offer (of $230 in cash and 0.6724 shares of Lumentum stock for each Coherent share) equated to $283.12 per share, versus II–VI's offer (of $220 in cash and 0.91 shares of II-VI for each Coherent share) equating to $281.21 per share.

"We are pleased to have reached an agreement with Coherent to create a global leader in photonic solutions, compound semiconductors and laser technology and systems," says II-VI's CEO Dr Vincent D. Mattera Jr. "Together, we will have significant opportunities to accelerate our growth through complementary technology platforms, strengthen our competitiveness by using our combined scale across the value chain, benefit from deeper market intelligence and expertise, and further diversify our businesses by end market and geography. Moreover, the combination of II-VI and Coherent will increase our collective exposure to irreversible megatrends for decades to come," he adds.

Together, we will have significant opportunities to accelerate our growth through complementary technology platforms, strengthen our competitiveness by using our combined scale across the value chain, benefit from deeper market intelligence and expertise, and further diversify our businesses by end market and geography. The combination of II-VI and Coherent will increase our collective exposure to irreversible megatrends for decades to come

II-VI reckons that, together, the two firms' combined annual revenue will be about $4.1bn, leveraging technology platforms operating at scale to address a combined available market of about $25bn. Complementary laser, optics and electronics technologies at the subsystems and systems level should enable solutions to accelerate growth in aerospace & defense, life sciences and laser-additive manufacturing, while driving margin expansion and profitability, the firm adds. In addition, a highly complementary geographic presence should enable it to accelerate growth in key industrial markets in Asia.

The combined company is expected to achieve $250m in annual cost synergies within 36 months of completion of the merger, which is expected to be accretive to II-VI's non-GAAP earnings per share in the second year following close.

II-VI plans to finance the transaction with cash on hand, about $5.4bn in fully committed debt financing from J.P. Morgan Securities LLC and an equity investment from Bain Capital, which has committed $1.5bn in the combined company at a conversion price of $85 per share and has confirmed that it is willing to increase this by at least $300m of an additional $650m optional amount on the same terms, for a total commitment of at least $1.8bn. The Bain Capital investment will enable II-VI to significantly reduce leverage. Bain Capital's co-chairman Steve Pagliuca is expected to join the II-VI board. Two current Coherent directors are also expected to join the II-VI board upon closing.

II-VI's management team has "outstanding operational experience and a strong M&A track record," comments Pagliuca. "The combination of II-VI and Coherent will create a leading platform in the photonics industry."

www.Coherent.com
www.ii-vi.com
www.lumentum.com

II-VI inaugurates Technology and R&D Center in Shanghai

Firm joins National Committee on US–China Relations and US–China Business Council

Engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA has inaugurated its II-VI Technology and R&D Center in Shanghai, China at a grand opening ceremony.

With nearly 600 staff, the Center is II-VI's largest technology and R&D hub. The Center will leverage its broad base of talent (including senior scientists and engineers) in technology and product development, designing optical components, subassemblies and systems, and enabling customers worldwide to serve rapidly growing new markets. Innovations aim to unlock the further potential of the Cloud and 5G networks; integrated solutions for life sciences (including in biotechnology, medical and scientific applications); and high-power lasers for materials processing and additive manufacturing.

"The Technology and R&D Center in Shanghai will be a jewel in the crown for II-VI's worldwide

innovation initiatives, focusing on key mega market trends where II-VI will continue to have a significant impact," says CEO Dr Vincent D. Mattera Jr.

The Center's inauguration follows II-VI's announcement that it has expanded its silicon carbide (SiC) manufacturing footprint to China to serve the largest worldwide market for electric vehicles (EVs). II-VI maintains a large manufacturing operations and product development presence in China in the cities of Fuzhou, Guangzhou, Shanghai, Shenzhen, Suzhou and Wuxi, where more than half of the firm's 22,000 employees are located.

As part of its long-term commitment to customers and operations in China, II-VI has become a member of the National Committee on US–China Relations (NCUSCR) and the US–China Business Council (USCBC). The NCUSCR is a non-profit educational organization that encourages understanding of China and the USA through ongoing public education, face-to-face contact, and exchange of ideas. The USCBC's mission is to expand the US–China commercial relationship to the benefit of its membership and, more broadly, the US economy. II-VI also recently became a member of the World Economic Forum, where it will focus contributions on the advanced manufacturing and production platform (including technology adoption and workforce development), while driving the formation of resilient supply chains.

www.ii-vi.com

Marvell completes acquisition of Inphi

Inphi CEO joins Marvell's board

Bermuda-based Marvell Technology Group Ltd (which provides semiconductors for storage, processing, networking, security and connectivity infrastructure) has completed its acquisition of Inphi Corp of San Jose, CA, USA (a provider of high-speed mixed-signal ICs for communications, computing and data-center markets).

The combined company, Marvell Technology Inc, is a Delaware corporation domiciled in the USA.

"Together we will have the portfolio, capabilities and scale to expand Marvell's leadership in its key growth end-markets of 5G, cloud and automotive," reckons Marvell's president & CEO Matt Murphy. "We are now organized as a US company."

Also, Dr Ford Tamer (Inphi's president & CEO for more than nine years) has been appointed to Marvell's board of directors.

Under Tamer's stewardship, Inphi became what is said to be the market leader for electro-optics solutions for cloud and telecom operators, increasing revenue from these customers more than 20 times during his tenure, to an annual run rate of about $750m.

Prior to Inphi, Tamer was CEO of Telegent Systems. Previous to this, he was senior VP & general manager of Broadcom's Infrastructure Networking Group, which he grew five-fold to $1.2bn in revenue within five years, making that business the leader in infrastructure silicon solutions, it is claimed.

He also served as co-founder & CEO of Agere Inc, which pioneered network processors (now at Intel as the Ixia product line). After Agere was acquired by Lucent Microelectronics, Tamer became VP at Agere Systems, a spin-off from Lucent. Earlier in his career, he co-founded, operated and assisted in the growth of system management software, artificial intelligence, and renewable energy businesses.

www.inphi.com
www.marvell.com

ATLAS laser project gains SMART Expertise Welsh Government support

CSC, IQE, SPTS and Rockley partnering with Cardiff University via CSconnected cluster

A £1.8m project backed by the Welsh Government's SMART Expertise program will help what is said to be the world's first compound semiconductor cluster to solve real-world industry challenges and bring economic benefits to Wales.

Dr Samuel Shutts, a post-doctoral research fellow in Cardiff University's School of Physics and Astronomy, has been awarded a Smart Expertise Award through the Welsh Government's Business Wales support service to deliver ATLAS, a key project for the future of the compound semiconductor industry in Wales.

The total project value of £1.8m is based on 50% funding from the European Regional Development Fund (ERDF) via the Welsh Government's SMART Expertise program and 50% from the industry partners (Compound Semiconductor Centre, IQE plc, SPTS Technologies, and Rockley Photonics).

The award offers financial support to innovative collaboration projects that require a range of expertise to solve industry problems, focusing on the commercialization of new products, processes or services and growth in capacity and capability to deliver Welsh economic impact.

"ATLAS is an industry-focused project with an objective to enhance the manufacturing capability of compound semiconductor lasers, putting South Wales at the leading-edge of compound semiconductor laser production," says Shutts. "The funding aims to allow low-cost, energy-efficient manufacturing in high-volume production."

Shutts' research includes photonics; laser physics; and the design, fabrication and testing of novel compound semiconductor lasers for communications, atomic sensors (clocks and magnetometers), sensing, and biomedical applications.

Based within the UK Engineering and Physical Sciences Research Council (EPSRC) Future Compound Semiconductor Manufacturing Hub (CS Hub), Shutts will work closely with companies across South Wales specializing in the application of compound semiconductors for modern telecoms.

"The project is a fantastic opportunity to combine the expertise and problem-solving capacity of researchers within Cardiff University to address the real-world challenges faced by today's rapidly growing compound semiconductor industry in South Wales," says Shutts. "It will support South Wales to become the world's first compound semiconductor cluster, with Cardiff University and the Institute for Compound Semiconductors (ICS) facility acting as key players."

Shutts' work is closely aligned with the CSconnected project, which received £43.74m in UK government funding through UK Research and Innovation's flagship Strength in Places Fund to develop a compound semiconductor cluster.

"ATLAS will help develop key processes to be scaled up by cluster partners, enabling next-generation data communications like high-definition streaming and 5G connectivity, and sensing capabilities including the face/gesture recognition capability of digital devices or the electronic systems that assist drivers to park their cars," comments CSconnected director Chris Meadows.

www.compoundsemiconductorcentre.com
www.cardiff.ac.uk/institute-compound-semiconductors/industry/facilities
www.compoundsemiconductorhub.org
www.spts.com

Emcore expecting quarterly revenue of $38.4m, above $34–36m guidance

Improved CATV production drives greater-than-forecasted Broadband shipments

According to preliminary financial results for its fiscal second-quarter 2021 (ended 31 March), Emcore Corp of Alhambra, CA, USA — which provides mixed-signal products for the aerospace & defense and broadband communications markets — says that it expects revenue to be about $38.4m, above the guidance range of $34–36m it gave in early February.

"Our Broadband business achieved better-than-forecasted shipments due to improved CATV production output across multiple facilities during the quarter," says president & CEO Jeff Rittichier. "MSOs [multi-service operators] continue to invest in their networks to break bottlenecks caused by the bandwidth demands of businesses and their need for remote operations."

Emcore expects to provide final financial results for fiscal Q2 during the week of 3 May.

www.emcore.com

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POET's losses rise in Q4 due to increased R&D spending

Alternative sources being explored to mitigate laser supply constraints

POET Technologies Inc of Toronto, Ontario, Canada — a designer and developer of the Optical Interposer and photonic integrated circuits (PICs) for the data-center and telecom markets — has reported a net loss of $5m ($0.02 per share) for fourth-quarter 2020, up from $3.5m ($0.01 per share) in third-quarter 2020 and compared with net income (before tax recovery) of $3.2m ($0.01 per share) in fourth-quarter 2019. However, the latter included a recovery of deferred income taxes of $0.3m) plus a $8m gain on selling its Singapore-based subsidiary DenseLight Semiconductors Pte Ltd.

The Q4/2020 loss included R&D costs of $2.2m (up from $1.2m in Q3/2020 and $0.8m a year ago), reflecting a redistribution of R&D activities and costs that were previously accounted for by DenseLight and reported as discontinued operations while the organization operated as a single entity (from 1 January 2019 until the closing date of the sale transaction on 8 November 2019). These costs are now accounted for solely by POET.

During Q4/2020, POET had debt-related finance costs of $249,000, compared with $244,000 in Q3/2020 and $302,000 a year ago. Of the finance costs recognized in Q4/2020, $128,000 was non-cash compared with $141,000 in Q3 and $109,000 a year ago.

On a non-IFRS basis, cash outflow from operating activities was –$2.9m, level with Q3 but cut from –$3.7m a year ago.

"The fourth quarter was a pivotal period for our company, as we successfully achieved significant milestones on the path toward commercialization of new products based on the POET Optical Interposer platform," notes CEO Dr Suresh Venkatesan. "First, we released our first multi-product wafer (MPW) mask set for production, which was comprised of custom designs for specific applications and customers. Additionally, we completed and tested the designs of our newly launched product line LightBar, a family of high-performance laser light source products for 400G FR4, 800G and co-packaged optics (CPO) applications in cloud data centers. We are very excited about the near-term opportunity for these products to serve as a spring-board for supplying products to large cloud-based data-center customers that are aggressively seeking solutions with both higher speed and reduced cost," he adds.

"As evidence of further progress, in December we achieved an industry first with the successful test of our high-speed DML laser design flip-chipped onto POET's Optical Interposer platform, enabling the world's lowest-cost and smallest 100G CWDM4 optical engine. This accomplishment is critical to the assembly of a single-chip, fully integrated optical engine that can be produced at wafer-scale in high volume."

POET also expanded its operations team and facilities in early 2021 with the appointment of Dr Jinyu Mo as senior VP of Asia, coupled with opening a new product design and development center in Shenzhen, China.

There have been broadly reported supply chain constraints throughout the semiconductor industry. This environment has introduced challenges related to the reliable and timely sourcing of lasers, which has resulted in delayed production schedules across the industry and also for POET's alpha and beta samples

In addition, POET signed a definitive agreement with Xiamen Sanan Integrated Circuit Co Ltd (Sanan IC) in October and has recently completed official registration of the joint-venture company Super Photonics Xiamen (SPX) in order to offer a new generation of cost-effective, high-performance optical engines based on the POET Optical Interposer platform.

POET ended 2020 with cash and cash equivalents of $6.9m (up from $1.4m at the end of 2019). Subsequently, POET completed a private placement financing, resulting in gross proceeds of $11.8m. It also received $8.4m from the exercise of stock options and warrants and further reduced its debt by $1.7m through the conversion of convertible debentures into units of the company. POET hence has about $23.7m in cash available to fund operations.

"Looking at the current landscape in early 2021, there have been broadly reported supply chain constraints throughout the semiconductor industry," notes Venkatesan. "This environment has introduced challenges related to the reliable and timely sourcing of lasers, which has resulted in delayed production schedules across the industry and also for POET's alpha and beta samples. That said, we are continuing to work closely with our strategic manufacturing partners, while also exploring potential alternative sources in order to mitigate the impacts of these external supply constraints," he adds. "I want to emphasize that we have continued to meet the product development milestones that are based on variables within our control, and we've encountered no new hurdles in terms of technological barriers or device performance. Importantly, we have a solid cash position and strengthened balance sheet following the successful financing activities completed in recent months, and we remain very optimistic about our advancement of POET's product roadmap throughout 2021."

www.poet-technologies.com

POET enters telecom market with 100G LR4 optical engines

Focus initially on TX design, offering cost and performance advantages, and fast go-to-market approach

POET Technologies Inc of Toronto, Ontario, Canada — a designer and developer of the Optical Interposer and photonic integrated circuits (PICs) for the data-center and telecom markets — has completed design of a 100G LR4 (four-channel long reach) optical engine with a reach of 10km for client-side interconnects to data centers, enterprises and edge computing networks.

Of the five common types of 100G transceiver modules found within the data center, two types — CWDM4 and PSM4 — are targeted at data communications up to 2km. SR4 (500m), LR4 (10km) and ER4 (40km) are the other types typically specified for 100G datacoms. POET's focus on CWDM4 and LR4 designs is based on what it claims is a unique capability to integrate fully monolithic 4-channel multiplexing and demultiplexing functionality directly into its waveguides, avoiding the costly requirement to align and couple additional devices into a transceiver module.

POET's LR4 design converts four input channels of 25Gb/s electrical data into four LAN WDM (wavelength division multiplexing) optical signals and then multiplexes them into a single channel for 100Gb/s optical transmission along a single fiber. PSM4 and SR4 transceivers are not multiplexed and hence require four parallel fibers, which are especially costly over distances of 2–10km. Despite completing separate designs for TX (transmit), RX (receive) and combination TX–RX optical engines, POET intends to focus first on the TX design, which offers significant cost and performance advantages, and represents a fast go-to-market approach for the firm.

"A 100G LR4 transceiver sells for about 2–3x the price of a 100G CWDM4 module, due to its higher complexity and performance requirements," notes president & general manager Vivek Rajgarhia. "POET's integrated monolithic multiplexer significantly reduces the cost of the optical engine, allowing us to provide a savings to customers in the range of 25%. By flip-chipping four DML [directly modulated laser] lasers onto an Optical Interposer with inherently superior thermal management and the ability to tune the waveguides to specific center wavelengths, we are able to design an optical engine that uses 10–15% less power to deliver data at the same speed and over the same distance as comparable modules. Further, because of the small size of the optical engine, we anticipate seeing potential novel applications of this technology from customers," he adds. "Since we have had the LR4 Optical Interposer wafers in fabrication since December, we expect to be able to deliver alpha samples to customers in the third quarter of 2021. Deploying an LR4 design in a short time after the CWDM design exemplifies the power of our platform approach, as major elements of the CWDM interposer design are reused in the LR4 derivative."

As the standard for interconnects to long-haul networks, 100G LR4 transceivers are purchased in high volumes by telecom equipment providers and are not being replaced by 400G transceivers even as speeds in long-haul networks increase, notes POET. In a client webinar by LightCounting in April, shipments in 100G LR4 modules were forecasted to be essentially stable at about 4 million units annually from 2021 through 2026, with prices having stabilized as a result of there being no room left for cost reductions using the traditional manufacturing approach for these devices. This cost barrier and the high power consumption of existing transceiver designs allows POET to provide competitive designs for this segment, which represents a second large market opportunity for POET, complementing its previously announced 100G CWDM designs, says the firm.

We expect to be able to deliver alpha samples to customers in Q3. Deploying an LR4 design in a short time after the CWDM design exemplifies the power of our platform approach, as major elements of the CWDM interposer design are reused in the LR4 derivative

Powering these optical engines will be 25Gb/s DMLs from Sanan Integrated Circuits (SAIC), which has incorporated POET's interposer compatibility requirements into its line of LR4 DML lasers. These lasers have been independently tested and validated to operate to LR4 specifications and are already in their qualification phase. SAIC will also be sourcing the monitor photodiodes and high-speed photodiodes, which rounds out the bill of materials for the optical engine.

Assembly, manufacture and sales of these optical engines will be accomplished through POET's joint venture with SAIC, Super Photonics Xiamen (SPX). SPX has accepted delivery of the first-of-a-kind equipment set for the assembly of optical engines based on POET's Optical Interposer and will be actively engaged in the assembly of POET's alpha optical engine prototypes later this quarter. POET and SPX are currently working with two alpha customers, and the design-win funnel has been active with increasing demand for both standard and custom designs for LR4 optical engines.

www.poet-technologies.com

Fraunhofer ISE raises tandem PV efficiency record to 35.9% using monolithic III–V//Si solar cell

GaInAsP in middle cell boosts charge carrier lifetime and cell voltage

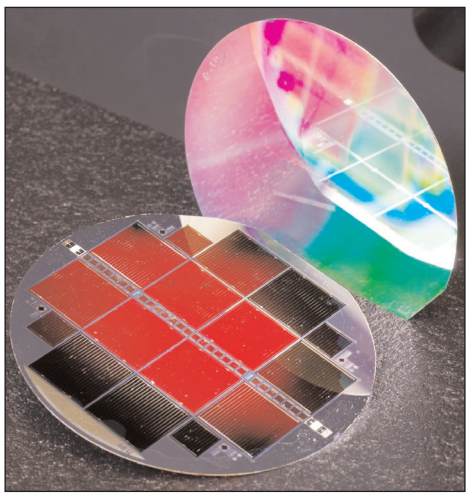
Fraunhofer Institute for Solar Energy Systems ISE of Freiburg, Germany has again set a new solar energy conversion efficiency record for a monolithic tandem cell made of III–V and silicon semiconductors.

The new monolithic triple-junction solar cell — specifically, a III–V//Si tandem solar cell — converts 35.9% of sunlight into electrical energy (measured under the terrestrial AM1.5g spectrum), demonstrating the potential of silicon-based tandem photovoltaics.

In the new record cell, the III–V semiconductor layers are connected directly to the silicon sub-cell on the atomic level. From the outside, the cell resembles a conventional two-terminal solar cell, but it achieves the same efficiency as the best four-terminal solar cells with mechanically stacked structures, as published jointly by NREL, CSEM and EPFL in 2017.

"The use of a new compound semiconductor (GaInAsP) for the middle cell was a key step in our success in achieving the improved efficiency value," notes Patrick Schygulla, doctoral student in the Department of III–V Photovoltaics and Concentrator Technology at Fraunhofer ISE. "The new material allowed us to further improve the lifetime of the charge carriers and thus achieve a higher cell voltage," he adds. "It's great to see how our material development has successfully contributed to improvements in III–V//Si triple-junction solar cells."

Initial applications for high-efficiency III–V//Si tandem cells are found where the power generation per area plays an important role, for example in electrically powered aircraft and drones. Today, the production costs of the new cells are still significantly higher than conventional single-junction crystalline silicon solar cells. This is due to the complex epitaxy step of the III–V layers and the many additional semiconductor processes required to manufacture the cells. The researchers at Fraunhofer ISE are working intensively to make the production more cost-effective in the future and thus also address the terrestrial photovoltaic market.

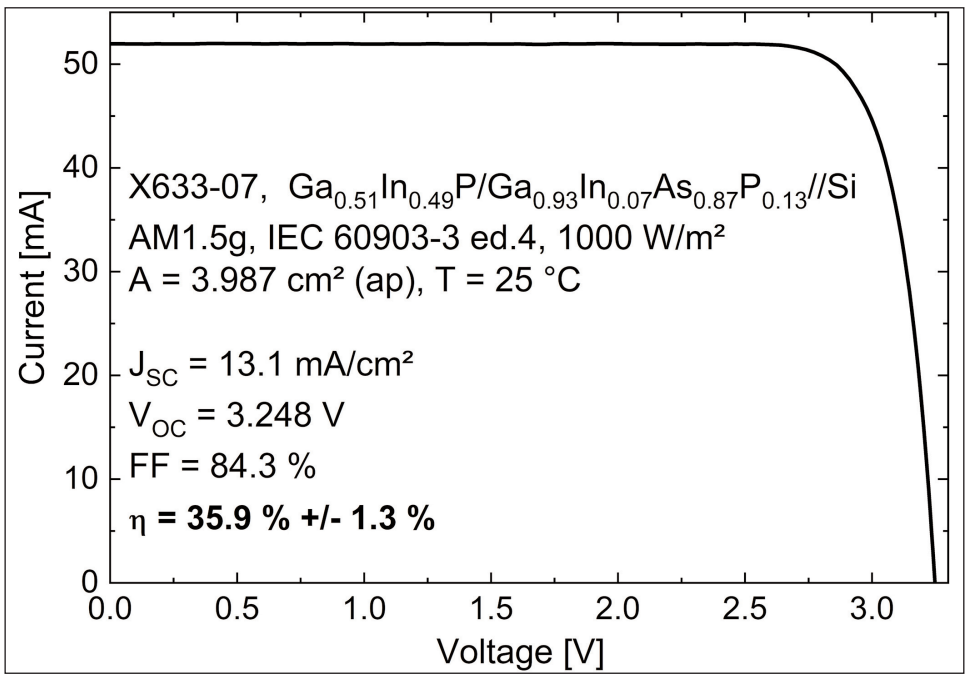


The new III–V//Si tandem solar cell. The top subcell glows red, which is a sign of outstanding material quality. The nanostructured back side of the cell shimmers in rainbow colors.

"Combining III–V semiconductor materials on silicon is one of the approaches that we are pursuing with tandem structures (i.e. the combination of different high-performance materials) in order to achieve higher solar cell efficiencies," says Fraunhofer ISE director professor Andreas Bett. "It will be a few years before any PV modules made from the type of solar cell presented here are available on the market," he adds. "However, this is an important, forward-looking path in the context of the photovoltaic expansion which is necessary for a sustainable energy supply."

Development of the III–V//Si tandem solar cells was funded by the German Federal Ministry for Economic Affairs and Energy (BMWi) in the project PoTaSi ('Demonstration of the Potential of Monolithic Tandem Solar Cells Made of III–V Semiconductors and Silicon') as well as through a doctoral stipend from the Heinrich Böll Foundation.

www.ise.fraunhofer.de/en/research-projects/potasi.html



I–V characteristic of the new III–V//Si triple-junction solar cell, measured at Fraunhofer ISE CalLab PV Cells.

Fraunhofer Institute for Solar Energy Systems inaugurates Center for High Efficiency Solar Cells

New lab building focusing on III–V/silicon tandem photovoltaics

In a virtual ceremony on 27 April, Fraunhofer Institute for Solar Energy Systems ISE of Freiburg, Germany has officially inaugurated its new Center for High Efficiency Solar Cells, which has been funded in equal parts by the German Federal Ministry of Education and Research (BMBF) and the State of Baden-Württemberg.

"In Baden-Württemberg, we have set ourselves numerous goals for climate policy, and solar energy plays a central role," noted Minister President Winfried Kretschmann in his welcoming address. "With Fraunhofer ISE, we have had one of the most important solar research institutes worldwide right here in the State of Baden-Württemberg for over 40 years. I am therefore very pleased that we are again able to give cutting-edge photovoltaic research a powerful boost with the Center for High Efficiency Solar Cells."

With an infrastructure composed of 1000m^2 of laboratory space and cleanroom equipment (including 740m^2 of cleanroom lab and 340m^2 of further labs with a customized ultra-pure media supply system), in addition to the further development of silicon and III–V technology the research focus at the Center for High Efficiency Solar Cells lies in the suitable combination of these two materials to make highly efficient tandem cells, which are reckoned to be among the most promising photovoltaic technologies for the future.

"The new laboratory building will enable us to continue developing new groundbreaking solar cell types and thus contribute to the competitiveness of the German and European photovoltaic industry, which is again on the rise with innovative processes and technologies," says Institute director professor Andreas Bett.

In recent decades, photovoltaics has undergone rapid technological development, experiencing a cost reduction of more than 90% and an increase in module efficiency, reaching 20% today. However, the potential of this technology is far from exhausted. Solar researchers in Freiburg are working to further increase the efficiency using the tandem approach. In tandem solar cells, several semiconductor materials with different absorption properties are stacked on top of each other in order to use the solar spectrum even more efficiently for energy generation. Tandem photovoltaics enables higher energy yield per unit area and thus potential savings in solar cell and module materials, making photovoltaics even more sustainable.

Fraunhofer ISE's new Center for High Efficiency Solar Cells. (© Fraunhofer ISE/photo: Guido Kirsch).

Fraunhofer ISE is the largest solar research institute in Europe, with more than 1200 staff, almost half of whom perform research in photovoltaics. The other half are dedicated to research themes involving energy systems and technologies relevant to the energy transition.

The institute holds numerous efficiency records in photovoltaics for various solar cell technologies: Most recently (in April) these include record efficiencies for both-sides-contacted silicon solar cells (26.0%) and for tandem cells on silicon (35.9%). Also, records have been achieved for a four-junction solar cell under concentrated sunlight (46%, based on a III–V multi-junction cell architecture).

"In addition to the efficiency records, we at Fraunhofer ISE are particularly proud of our developments in PV production technology," says Stefan Glunz, Photovoltaic Research division director and professor in the University of Freiburg's Faculty of Engineering. "These research developments have provided important impulses to industrial solar cell production, such as the use of lasers or the TOPCon technology," he adds. "With our new laboratory building, the new cleanroom and its cutting-edge infrastructure, we are now even better equipped to continue this success story."

www.ise.fraunhofer.de/en/rd-infrastructure/center/center-for-high-efficiency-solar-cells.html

First Solar launches Series 6 CuRe PV modules

Warranted degradation rate of 0.2% per year up to 60% lower than c-Si

Cadmium telluride (CdTe) thin-film photovoltaic (PV) module maker First Solar Inc of Tempe, AZ, USA says that its newly developed Series 6 CuRe next-generation PV technology has a warranted degradation rate of 0.2% per year, which is claimed to be the lowest rate for any commercially available PV product (based on publicly available information). This degradation rate is up to 60% lower than conventional crystalline silicon (c-Si) products, and ensures that the module will retain at least 92% of its original performance at the end of its 30-year warranty.

Combined with what is claimed to be a superior temperature coefficient, spectral response and shading behaviour, the near-zero degradation rate is reckoned to advance the Series 6 CuRe platform's competitiveness in all markets. First Solar says that the enhanced performance is enabled not only by semiconductor-level innovation but also its copper replacement (CuRe) program. Developed at the firm's Silicon Valley and Ohio R&D centers, CuRe is a proprietary semiconductor platform that replaces copper with atoms of Group V elements that enhance performance, delivering long-term stability.

"We invested in our understanding of copper's dynamics in order to turn what had been a cause of degradation into an opportunity to virtually eliminate it," says chief technology officer Markus Gloeckler. "We researched a range of alternatives and found that Group V elements could effectively replace copper, acting as a stable dopant and furthering our goal of zero degradation. CuRe is the deployment-ready result of that research."

The result of over $1.4bn in cumulative investment, First Solar's cadmium telluride technology already has one of the industry's longest proven track records in module degradation, says the firm. Its early-generation modules, predating most of the world's largest c-Si manufacturers, were installed at the National Renewable Energy Laboratory's (NREL) Outdoor Test Facility in Colorado and recently completed 25-years of continuous monitoring. The long-term study revealed a degradation rate of just 0.48% a year.

"From engineering the atoms in the semiconductor to its ability to withstand extreme weather events such as hailstorms, and from the social license that comes built-in to being able to recycle over 90% of each module, this responsibly produced technology is packed with innovation designed to address many of our customers' biggest challenges," says CEO Mark Widmar.

Series 6 CuRe builds on First Solar's Series 6 technology (claimed to be the world's only large-format thin-film module). The Series 6 CuRe module technology features a –0.28%/0C temperature coefficient (which improves upon the existing Series 6 baseline) and what is claimed to be a superior spectral response, allowing it to outperform c-Si in hot and humid environments. Unlike c-Si panels that can experience disproportionate power loss under shaded conditions, First Solar's Series 6 modules feature a superior shading response, with a linear relationship to the shaded area that minimizes shading loss, the firm says.

Series 6 CuRe technology is also immune to many issues that the firm believes continue to plague c-Si panels, including cell-cracking due to mishandling during installation or extreme weather events, such as high winds or hailstorms. It comes with the industry's first cell-cracking warranty. It is also immune to light-induced degradation (LID) and light- and elevated-temperature-induced degradation (LeTID) mechanisms that affect c-Si modules.

"Series 6 CuRe is built with our customers' needs in mind," says chief commercial officer Georges Antoun. "It delivers not just more performance, but fast installation with lower structural costs, industry-leading quality, reliability and durability, and unparalleled levels of traceability and transparency," he claims.

Manufactured under one roof at the company's manufacturing facilities in the USA, Malaysia and Vietnam, the technology's quality assurance and quality control programs offer full traceability. Series 6 CuRe also has a carbon footprint that is reckoned to be 2.5-times lower than high-efficiency monocrystalline silicon, which uses energy-intensive methods to refine and produce its polysilicon semiconductor. It also has a water footprint that is three times lower and an energy payback time that is twice as fast as monocrystalline silicon, says First Solar.

www.firstsolar.com

First Solar completes sale of North American O&M unit to NovaSource

NovaSource now world's largest PV operations & maintenance provider

Following last August's purchase agreement, First Solar has completed the sale of its North American Operations and Maintenance (O&M) unit to NovaSource Power Services (a portfolio company of Toronto-based private equity firm Clairvest Group Inc).

On closing of the transaction, about 270 First Solar O&M associates joined NovaSource.

The acquisition makes NovaSource the largest O&M provider globally.

www.novasourcepower.com

5N Plus acquiring AZUR SPACE for €73–79m

Strategic transformation targets synergies and access to larger markets

Engineered materials and specialty chemicals producer 5N Plus Inc of Montreal, Québec, Canada has agreed to acquire AZUR SPACE Solar Power GmbH of Heilbronn, Germany, whose workforce of 240 develops and makes III–V (GaAs-based) multi-junction solar cells for both satellites and terrestrial concentrated photovoltaic (PV) solar systems.

5N Plus provides purified metals like bismuth, gallium, germanium, indium, selenium and tellurium, and also produces related II–VI semiconducting compounds such as cadmium telluride (CdTe), cadmium sulphide (CdS) and indium antimonide (InSb) as precursors for growing crystals for solar, LED and eco-friendly materials applications. Operating R&D, manufacturing and commercial centers in North America, Asia and Europe (including three in Germany and one in Belgium), the firm supplies to the thin-film PV industry and is a supplier within the US satellite supply chain. The firm reckons the integration of AZUR will not only expand its position in renewable energy but also, through Canada's status as a Cooperating State within the European Space Agency (ESA), will establish 5N Plus as a supplier to both the European and US space programs.

The transaction is subject to the customary closing conditions, including regulatory approvals. 5N Plus will fully integrate AZUR's workforce and will appoint the firm's managing director Jürgen Heizmann as a member of 5N Plus' executive committee.

"This acquisition is the foundation of a strategic transformation that will unlock notable market potential," reckons 5N Plus' president & CEO Arjang Roshan. "AZUR and 5N Plus complement each other, and our integration will culminate in a sustainable supply chain which will ensure the competitiveness and security of supply for our customers and government agencies. Moreover, the combined value chain will serve as a gateway to new businesses with significantly larger total addressable market," he adds. "We deem AZUR's activities in Heilbronn, Germany, along with those of 5N Plus in St George, Utah, and Montreal, Québec, as essential to this plan."

Subject to prevailing closing adjustments, 5N Plus will acquire all of the issued and outstanding shares of AZUR for an expected €73–79m, This includes 6.5 million shares of 5N Plus (subject to the TSX approval) to be issued from treasury at closing and cash payment (amounting to about €53m, subject to the volume-weighted average closing share price of 5N Plus prior to closing). Furthermore, 5N Plus expects to finance working capital of €20–26m with provision not to exceed €27m. The cash portion of the transaction is expected to be funded through a senior debt facility.

AZUR's most recent annual revenue was in excess of €50m with average three-year annual EBITDA of about €6m. Notwithstanding the realization of expected cost and revenue synergies, and without consideration of integration expenses and transaction costs, management estimates that the EV/adjusted EBITDA multiple for the transaction to be well aligned with 5N Plus. Post-transaction, pro forma net debt to adjusted EBITDA is expected to be 2.8 times multiple, with a projected target of about 2.2 times multiple within 18–24 months post-closing.

www.azurspace.com
www.5nplus.com

First Solar completes sale of US development platform

Over 50 members of First Solar project development team join Leeward

Following an agreement in January, cadmium telluride (CdTe) thin-film photovoltaic (PV) module maker First Solar Inc of Tempe, AZ, USA has completed its sale of a utility-scale solar project platform of about 10GW$_{AC}$ to Leeward Renewable Energy Development LLC of Dallas, TX, USA (which owns and operates a portfolio of 22 renewable energy facilities across nine states totaling about 2000MW of generating capacity).

The project development platform includes 773MW$_{AC}$ of projects that are expected to commence construction in the next two years, as well as the 30MW$_{AC}$ Barilla Solar Project, which is operational.

Leeward is a portfolio company of OMERS Infrastructure (an investment arm of OMERS, one of Canada's largest defined benefit pension plans, with CDN$105bn in net assets, as at end-December 2020). Leeward is actively developing new wind, solar and energy storage projects in energy markets across the USA.

The acquisition significantly expands Leeward's solar development portfolio, which now reaches 14GW, as well as its geographic footprint across the Southeast and Southwest USA. Each GW generates enough clean energy to power the equivalent of 230,000 homes.

As part of Leeward's acquisition of the US project platform, more than 50 members of the First Solar project development team have joined Leeward, expanding its staffing to nearly 200 (factoring in projected new hires by the end of 2021).

www.leewardenergy.com
www.firstsolar.com

US Manufacturing of Advanced Cadmium Telluride consortium formed

UToledo, Colorado State and NREL plus 10 industry members join together in US-MAC to boost CdTe photovoltaics

As part of an effort to help address America's and the world's needs for clean energy, the Wright Center for Photovoltaics at The University of Toledo (UToledo), Colorado State University and the US Department of Energy's National Renewable Energy Laboratory (NREL) have teamed with US-based companies to form the US Manufacturing of Advanced Cadmium Telluride (US-MAC) photovoltaics consortium.

Cadmium telluride (CdTe) PV technology has the potential for continued improvements in cost and performance. Made from mining byproducts, CdTe powers high-efficiency, energy-advantaged and commercially competitive solar modules that offer the lowest carbon footprint of any commercially available PV solar technology, it is reckoned.

Over the past 15 years costs for solar electricity have fallen more than ten-fold, due in part to technology and manufacturing advances that have led to the scaling of CdTe PV. CdTe PV technology was invented and developed in the USA, and the intellectual property associated with the semiconductor's use in PV remains primarily in the USA.

US-MAC says that it will work with its members to advance foundational science and engineering, stimulate innovation and capitalize on shared resources and expertise. It aims to support increased production volume, optimize performance and to diversify, integrate and support the success of domestic firms.

CdTe solar modules currently meet about 40% of the domestic utility-scale PV market demand, have excellent durability and have been shown to be immune to cell cracking as a result of extreme weather events, such as hail. They perform better than silicon at elevated temperatures or in high humidity environments and are believed to have the lowest all-in cost structure and smallest environmental footprint of any currently available PV technology.

"While already enjoying great success in the marketplace, recent scientific developments make it clear that CdTe PV has significantly more potential for dramatically higher module efficiency, lower cost, increased lifetime energy and more rapid production," says NREL laboratory director Martin Keller. "This is all achievable with the concerted cooperation and investment that will be pursued by US-MAC."

CdTe solar modules already exhibit a 19% commercial module efficiency. US-MAC aims to push the efficiency closer to the maximum theoretical efficiency of about 30%, develop advanced tandem and bifacial concepts for even higher performance, and extend lifetime even further.

CdTe annual production can be increased at least by a factor of 10 through focused and coordinated R&D, it is reckoned, and CdTe PV has the potential to meet all of the USA's new electricity demands over the next 20 years while creating new jobs and reducing the cost of clean electricity. The US-MAC consortium is bringing together US leaders to pursue this national goal.

US-MAC consists of an executive board that includes Colorado State University, NREL and UToledo, and has 10 industry members that comprise its industrial advisory board: 5N Plus Inc, Consolidated Research Systems Inc, Direct Solar Inc, First Solar Inc, Lucintech Inc, Nious Technologies Inc, Pilkington North America Inc, Sivananthan Laboratories, Toledo Solar Inc and Uriel Solar Energy.

"The membership believes that CdTe is only at the beginning of its technology maturation curve, with much work still to do," says Dr Michael Heben, director of the Wright Center for Photovoltaics at UToledo, professor of physics and McMaster endowed chair. "The Secretary of Energy's recent announcement of a new CdTe Accelerator Program reinforces this belief."

"I applaud the US-MAC cadmium telluride consortium for developing a network focused on advanced and domestic manufacturing," says US Representative Marcy Kaptur. "This partnership brings together key leaders in academia, industry and government to help our country prepare for a new tomorrow. Our nation must not only develop new technologies to confront the challenges posed by climate change, but also ensure that the manufacturing capabilities of these technologies are built in the United States," he adds. "The consortium will work to keep the American pipeline of good-paying cadmium telluride production jobs a continued American success story."

Efforts to establish US-MAC began over a year ago and a memorandum of understanding (MoU) was fully executed on 11 March. First Solar was selected by the industrial advisory board to be its representative to the executive board for a first three-year term. The executive board will work with the industrial advisory board and other key points of contact in other organizations to advance the goals of US-MAC.

The organizers and members of US-MAC intend for the consortium to be inclusive as it pursues the mission to strengthen US-based CdTe PV manufacturing. Discussions are underway with Arizona State University, the University of Delaware and the University of Utah, as well as with other companies, to join an expanding US-MAC network.

www.usa-cdte.org

Midsummer's solar panel orders grow by 550% year-on-year in Q1/2021

Shift in focus over past year to marketing building-integrated solar panels to end consumers

Midsummer AB of Järfälla, near Stockholm, Sweden — a provider of turnkey production lines as well as flexible, lightweight copper indium gallium diselenide (CIGS) thin-film solar panels for building-integrated photovoltaics (BIPV) — says that order intake for its SLIM, WAVE and BOLD thin, light and flexible solar panels in first-quarter 2021 were SEK9,870,000, up 551% year-on-year.

Midsummer also develops and markets production equipment for solar cells in the form of the DUO system (claimed to be the world's most widespread production system for flexible CIGS solar cells).

"We have shifted our business focus over the past year and are investing heavily in marketing our building-integrated solar panels to the end consumer market as we see enormous potential for beautiful and easily installed sunroofs that basically look like ordinary roofs," says CEO Sven Lindström.

"The big increase in sales in this period is validation that we are on the right track. Our attractive roofs have been received very well by customers and demand is increasing strongly from both private and commercial property owners," he adds.

"We are supported by more conscious customers, both in terms of environmental impact and design. Our hyper-efficient production process means that our panels have a carbon footprint that is only one tenth of most other panels," concludes Lindström.

Midsummer is announcing its full quarterly report on 17 May.

www.midsummer.se

Midsummer appoints new Solar Panels sales manager

Four other sales staff also hired

Midsummer AB of Järfälla, near Stockholm, Sweden — a provider of turnkey production lines as well as flexible, lightweight copper indium gallium diselenide (CIGS) thin-film solar panels for building-integrated photovoltaics (BIPV) — has strengthened its fast-growing Solar Panels business area with John Mathisen as new sales manager.

Mathisen is described as an experienced sales manager who has previously worked with sales of windows, roofs and houses and also with installations and roof renovations.

Four other employees — Anneli Nyman, Yin Qiang, Martin Kokko and Christer Olsson — join him in the solar panels sales department.

"Our end-customer solar panel business is growing so fast that it is hard to keep up with demand," says CEO Sven Lindström. "We feel strongly that attractive building-integrated solar panels are the future for our company and are pleased to have these new people on board to help us reach our potential," he adds.

John Mathisen, Midsummer's new Solar Panels sales manager.

KAUST contributes to development of perovskite-based MQWs for opto devices

Thermal evaporation has been used to deposit $CsPbBr_3$ wells and TPBi barriers.

Providing expertise for technologies in electron microscopy, secondary-ion mass spectrometry (SIMS), nuclear magnetic resonance (NMR), surface characterization and optical microscopy, members of the Surface Science Lab at Saudi Arabia's King Abdullah University of Science and Technology (KAUST) Imaging and Characterization Core Lab (IAC) have collaborated with the research teams of KAUST professors Osman Bakr, Omar Mohammed and Boon Ooi and scientists in South Korea on a project to develop a new approach for fabricating a perovskite-based artificial multiple quantum well (MQW) architecture.

The new semiconductor MQW structure can be used for manufacturing cheaper, high-performance optoelectronic devices (Kwang Jae Lee et al, 'Perovskite-Based Artificial Multiple Quantum Wells', Nano Lett. 2019, 19, 6, 3535–3542). IAC's Surface Science Lab team members utilized their expertise to characterize and confirm the proposed architecture of the new device.

Advances in perovskite semiconductors

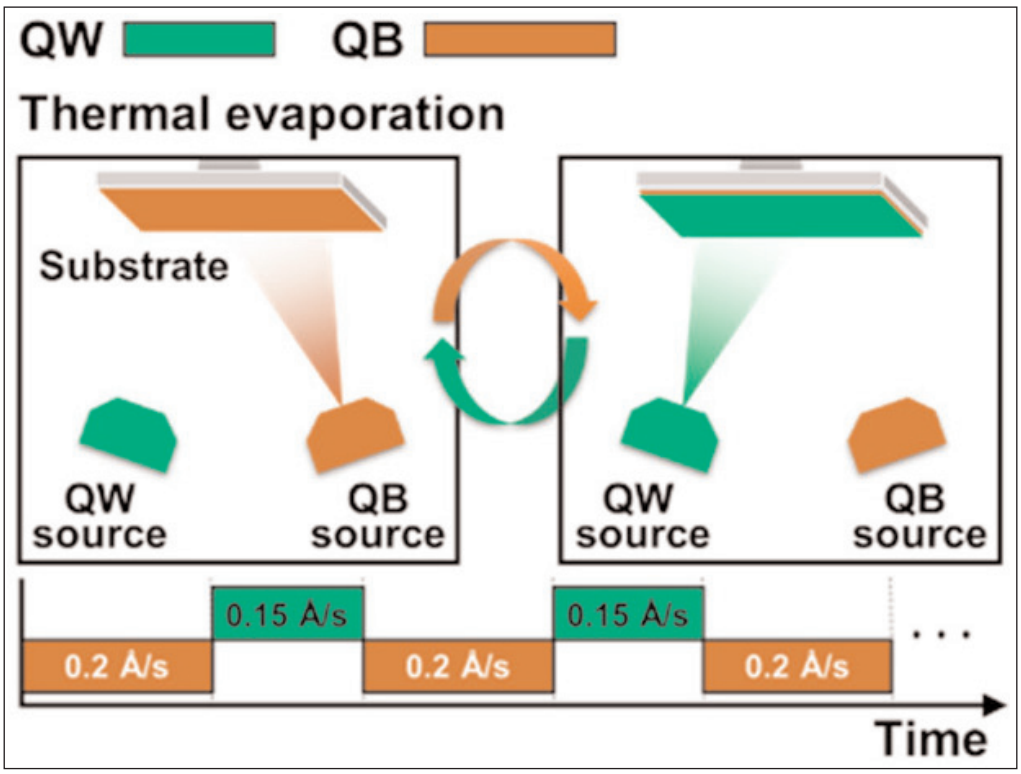
Since the nanoscale engineering of silicon through deposition processes to control its properties — for example, to produce solar cells — is time consuming and expensive, scientists have searched for alternative semiconductor materials. Perovskites comprise an emerging family of semiconductors that are low-cost, promising and efficient energy materials used in optoelectronics and photonic devices in place of silicon. Unlike silicon, the optical and electronic behaviors of perovskites can be easily tuned using different compositions and simple deposition techniques.

The materials have the same crystallographic structure as calcium titanium oxide, the first perovskite crystal discovered, and perovskite compounds generally have the chemical formula ABX_3.

"[Perovskites'] tremendous variety of structures, phases and dimensionalities makes [them] an excellent candidate for a broad array of applications, such as solar cells, photodetectors, light-emitting diodes (LEDs), and x-ray imaging (scintillators)," the researchers say.

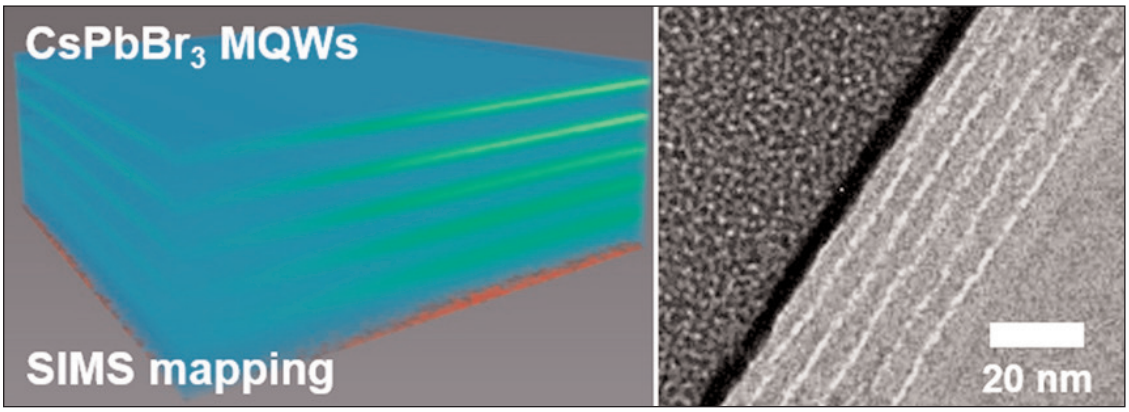
Building quantum wells

As heterostructures comprising a thin layer of one type of semiconductor between two layers of another type of semiconductor with a different energy gap (so that electrons in the middle layer have a lower energy than electrons in the outer layers), quantum wells constrain electrons in the middle layer, limiting motion to two dimensions. The well material's properties are also altered, and the effect can be increased by combining several quantum wells into a single stack, creating MQWs.



Schematic diagram of MQW structuring method using thermal evaporation.

"MQWs have technologically revolutionized traditional LEDs, laser diodes, optical modulators, and switching sensors," says the research team. "They have also facilitated conceptually new iterations of device applications... and have led to groundbreaking studies of peculiar quantum phenomena."



(left) Three-dimensional mapping of Br and Si signals by SIMS acquired from each pixel as a function of depth by scanning the ion beam over a surface area divided into 100x100 pixels, and (right) cross-sectional TEM image of 5-stacked $CsPbBr_3$(3nm)/TPBi(7nm) MQWs.

To construct MQW stacks, scientists often use epitaxial methods (depositing crystalline film onto a crystalline substrate) with gallium arsenide or gallium nitride involving expensive processes. However, the KAUST research team reckoned that a different method was needed to use the MQW structure in perovskite devices.

"Existing MQWs have been mostly restricted to conventional semiconductor materials," the researchers note. "[These materials] demand time-consuming and capital-intensive processes such as metal-organic chemical vapor deposition (MOCVD) and molecular-beam epitaxy (MBE)… The requirements have inhibited the scope of MQWs to niche and high-end applications and prevented them from becoming a ubiquitous part of energy, lighting and sensing applications," they add. "Perovskites offer immense potential for realizing MQWs that could overcome the limitations of conventionally fabricated semiconductor heterostructures."

The research team created the artificial MQWs using the simple laboratory technique of thermal evaporation. Using powder of $CsPbBr_3$ for the chosen perovskite well material and the barrier material TPBi (2,2 ,2(1,3,5-benzenetriyl)tris-(1-phenyl-1Hbenzimidazole)), the team found that the powders evaporated when heated in a vacuum chamber. The vapor particles then traveled to the glass substrate, where they formed a film. Alternating between heating the TPBi and the $CsPbBr_3$ created the quantum wells.

An improved method

"Compared to the standard epitaxial methods for growing semiconductor films, the new method is cheaper since it can be performed using a simple thermal evaporator, an instrument available in most research labs," note the KAUST researchers from Bakr and Mohammed's teams. "The evaporation method can also be used with any substrate. Moreover, the new approach leads to improved optical properties and energy conversion efficiency," they add.

"The first major step was to create and to characterize successfully a sample made of two semiconductor materials stacked in form of multilayers, where each layer should have a well-defined thickness," explains Nimer Wehbe, IAC staff scientist, surface science, who took part in the work.

The sample fabrication step — upon which the success of the developed approach was based — was characterized and studied by Wehbe and Mohamed Nejib Hedhili, IAC team lead, surface science. By employing the resources available in IAC's Surface Science Lab, they assisted the researchers with analyzing the MQW structure.

"Using a secondary-ion mass spectrometry technique (SIMS), we were able to provide an elemental 3D mapping confirming that the required architecture of perovskite-based artificial MQWs was successful," Wehbe says.

"Through the use of an x-ray photoelectron spectroscopy (XPS) technique combined with Kraut's method, we were able to determine the type of band alignment between the barrier material (TPBi) and the well material ($CsPbBr_3$ perovskite). A type-I band alignment between $CsPbBr_3$ and TPBi was obtained, allowing for a high-performance optoelectronic device," states Hedhili.

"The new perovskite-based artificial MQWs pave the way toward widely available semiconductor heterostructures for light-conversion applications that are not restricted by periodicity or a narrow set of dimensions," the research team notes in their paper.

"Our IAC staff scientists are working very hard to provide the KAUST research community with first-class technical expertise to match the cutting-edge instrumentation in the lab," says Kun Li, acting facilities director overseeing IAC. "In the research work published in Nano Letters, our scientists not only provided the 3D elemental distribution information to confirm the quantum well structure, but they also shed light on its band alignment, which would not have been possible without solid theoretical background in the field." ■

www.kaust.edu.sa

https://doi.org/10.1021/acs.nanolett.9b00384

On-chip integration of III–N LED/photodetector

Researchers show that incorporating a photodetector into a light-emitting structure boosts its response and uniformity.

Researchers in China have been studying the on-chip integration of indium gallium nitride (InGaN) light-emitting diodes (LEDs) and photodetectors (PDs) [Jing Li et al, Journal of Lightwave Technology, vol39 (2021), issue 8 (15 April), p2603].

The team from Southern University of Science and Technology, Huazhong University of Science and Technology, Shenzhen University, and Guangdong Deli Opto Co Ltd found that centrally placed photodetectors were optimal in terms of response and light-emission uniformity.

Co-integration of LEDs and photodetectors could be useful for real-time monitoring of light output in many lighting applications. Previous attempts at such on-chip integration have used devices placed at some distance from each other, of the order tens or hundreds of microns apart.

The device material used by Li et al was 6μm InGaN/GaN with an active region consisting of multiple quantum wells (MQWs), grown on 4-inch sapphire by metal-organic chemical vapor deposition (MOCVD). The material was fabricated into four types of 1000μmx1000μm LED, incorporating electrically isolated 280μmx280μm photodetector regions in different positions (Figure 1). The gap between LED and photodetector was 10μm.

Fabrication involved inductively coupled plasma (ICP) etching to the n-contact layer, indium tin oxide (ITO) current-spreading layer deposition, mesa isolation etch to the sapphire substrate, metal electrode deposition, silicon dioxide (SiO_2) passivation, 23-pair silicon/titanium dioxide dielectric distributed Bragg reflector (DBR) deposition, metal pad deposition, rapid thermal annealing (RTA), substrate thinning, and dicing into separate chips. The chips were flipped onto printed-circuit boards for testing.

The LED output power reached 103.5–106.6mW at 100mA current injection, increasing linearly over the 0–100mA range. The forward voltage at 20mA was 2.73–2.75V. With increasing current in the range 10–100mA, the peak wavelength shortened from 443nm down to 441nm, while the spectral width increased from less than 18nm to more than 20nm. The response peak of the photodetector section was less than 410nm, but the peak was broad enough for there to be some response to the LED.

The researchers comment: "With the increase of wavelength, the response curve exhibits a gradually reducing

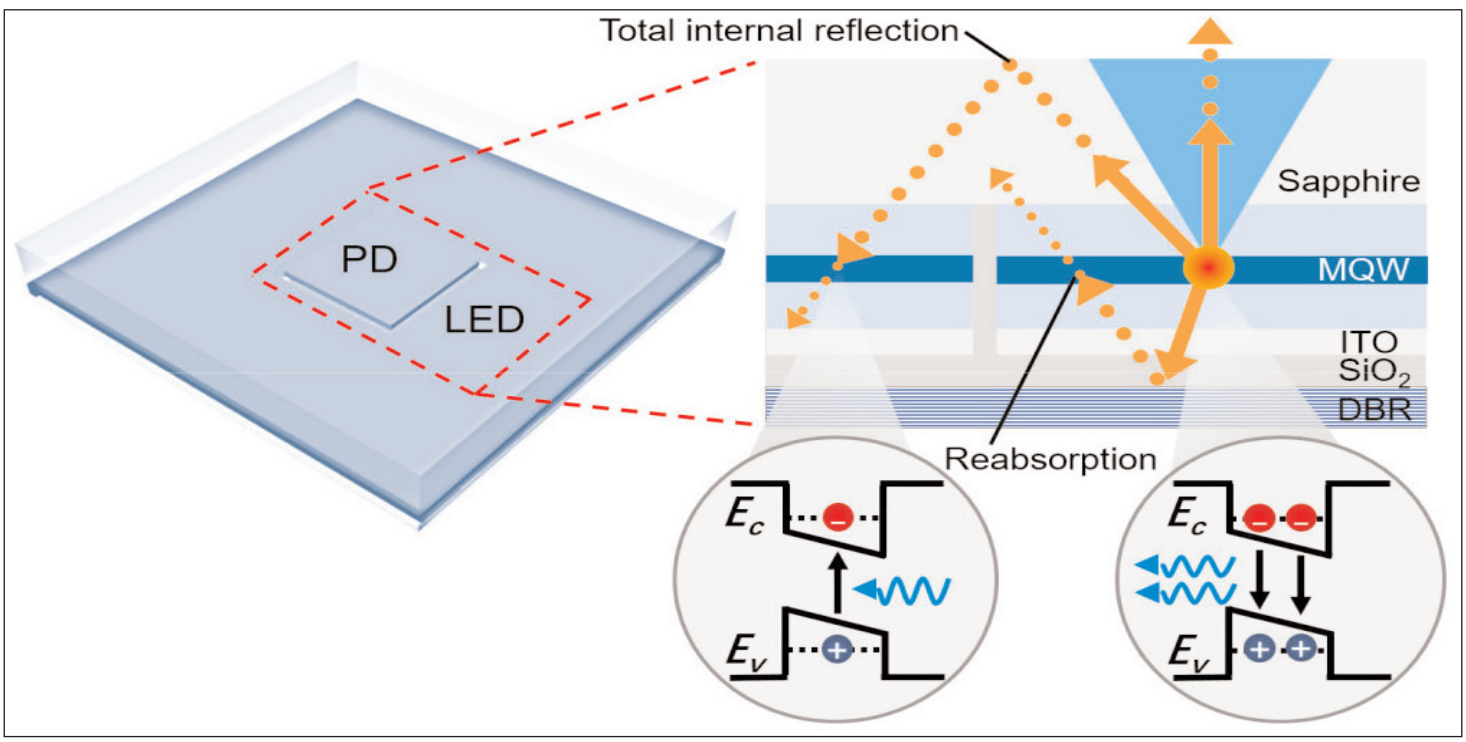


Figure 1. Working principle of LED-PD device.

trend rather than a sharp decline, which is mainly due to the band-tailing effects caused by a combination of the QCSE [quantum-confined Stark effect] and indium content fluctuations in the InGaN/GaN MQWs. The responsivity can be extended to ~442nm, which overlaps the emission spectrum by ~30nm."

The photodetector section showed little response to ambient light, showing a current-voltage behavior almost identical to dark conditions (Figure 2). The researchers explain this partly by pointing to the InGaN/GaN LED material being optimized for LED fabrication and not for broadband visible light detection. There are also differences between the ability to couple in external light, compared with the strong total internal reflection of the LED-generated light from the GaN/sapphire refractive index contrast.

The position of the photodetector was significant for detecting light from the LED with centrally placed photodetectors having 33% greater photocurrent response than corner ones at 100mA injection. The central position was also best for ensuring LED emission uniformity.

The researchers also applied yellow phosphor to the sapphire emission side of the device to get 'white' light with (0.32,0.33) CIE color coordinates. The response of the on-chip photodetector compared with a silicon-based photodetector at 3mm above the LED was 1.41x at high current injection, and 1.25x at lower current injection. The researchers point out that at high current the peak LED wavelength is shorter, and shifted towards that of the photodetector response, giving greater spectral overlap and hence photocurrent. ■

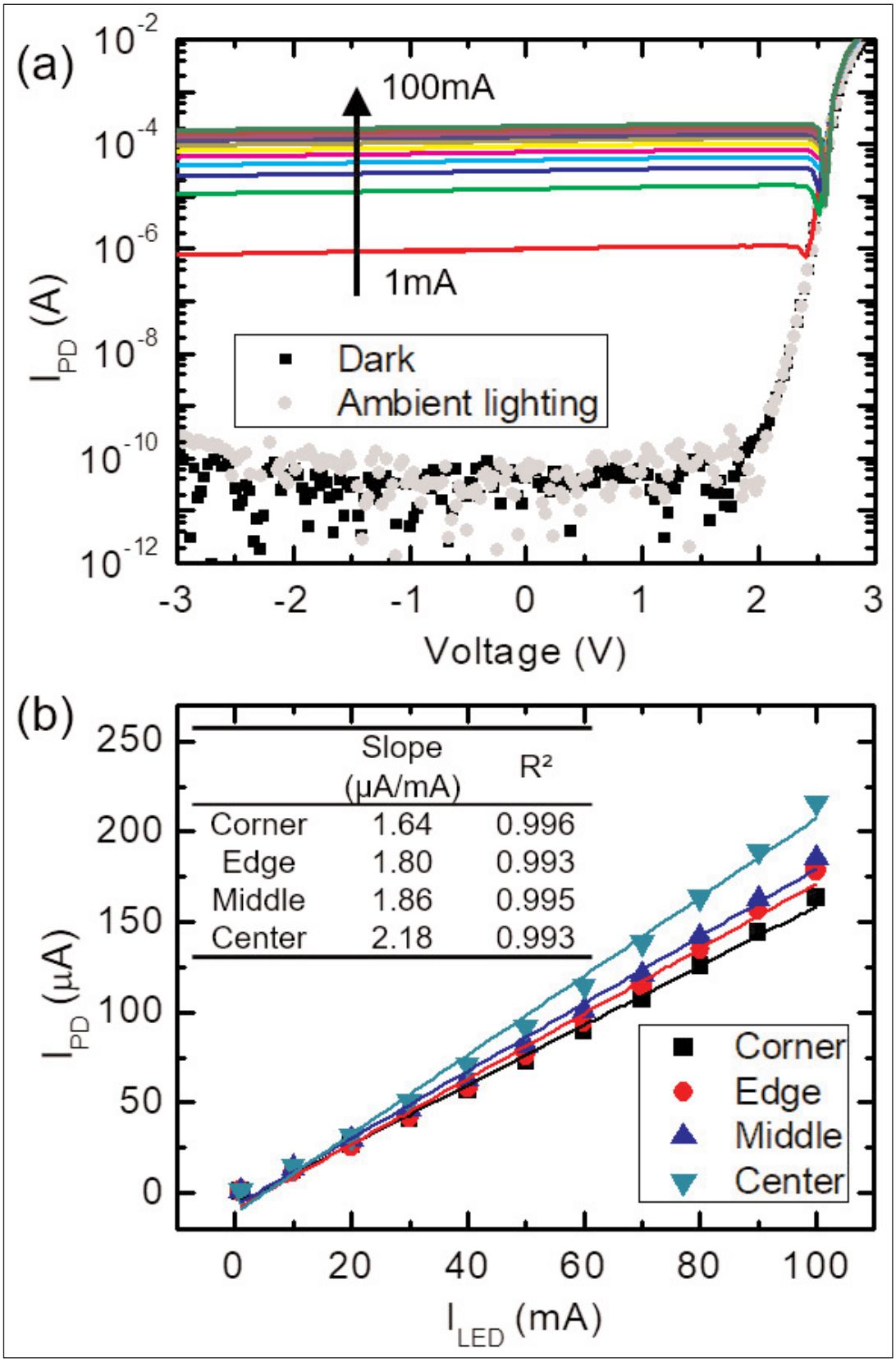


Figure 2. (a) Photodetector current (IPD) versus voltage with varying LED current injection. (b) IPD versus LED current (ILED). Solid lines represent fits to scattered data points. Inset summarizes slope and R2 correlation of fitting lines.

https://doi.org/10.1109/JLT.2020.3048986

Author: Mike Cooke

Micro-LEDs to challenge OLED displays?

Prospects depend on application, notes IDTechEx.

With the launch of micro- and mini-LED displays by various OEMs and display vendors, self-emissive LED-based displays have attracted tremendous attention from both investors and end-users, according to market research firm IDTechEx in its report 'Micro-LED Displays 2021-2031: Technology, Commercialization, Opportunity, Market and Players'.

Believed by many to represent the next-generation display technology, micro-LEDs have been pursued by players in the LED, display, OEM, materials sectors etc. It is also widely believed by many that micro-LED displays are the replacement for organic light-emitting diode (OLED) displays, especially in TV applications.

In the liquid-crystal display regime, LCD manufacturing is shifting to mainland China due to cost, the production efficiency new lines, and industry supply-chain support. Other regions have begun to shift away from the LCD business. For instance, Samsung has announced it is exiting the LCD business and will focus on its QD LCD and OLED technology. LG Display has halted its domestic production of LCD panels. Panasonic and JDI are getting out of the LCD business. Meanwhile, AUO, Innolux and a few other Taiwanese companies are slowing down investment in LCD or OLED technology.

In the OLED area, OLED panel production is dominated by Korean companies in terms of effective production capacity, technology maturity, upstream materials and equipment, downstream application, and supply chain completeness. For instance, SDC and LG Display have supported upstream material and equipment companies, building good ecosystems. For downstream applications, Samsung's small/mid-sized OLED panels are supplied first to Samsung smartphones, while LG Display's large-sized OLED panels are offered first for LG TVs. Their brands can also provide sufficient demand and feedback. Samsung and LG hence dominate small/mid- and large-sized OLED panels, respectively.

Another technology in the competitive market is quantum dot technology, mainly using its photoluminescent feature. By applying QD films in the LCD structure, the color gamut can be significantly improved. QD-based displays are catching up, says IDTechEx.

Micro-LED displays are composed of self-emissive inorganic LEDs, acting as subpixels. These LEDs are usually in the micron range, with neither package nor substrate, and therefore are transferred using a method different from traditional pick & place techniques. Micro-LED displays have value propositions including wide color gamut, high luminance, low power consumption, excellent stability and long lifetime, wide view angle, high dynamic range, high contrast, fast refresh rate, transparency, seamless connection, and sensor integration capability, notes the report.

Each technology has features to attract end-users, but some of the value propositions can be provided by alternatives such as LCD, OLED and QD technology rather than micro-LEDs alone. However, there are some value propositions unique to micro-LED displays.

However, not all the value propositions of micro-LED displays can be realized based on the existing technology maturity and cost expectations, such as low power consumption (the external quantum efficiencies of very tiny micro-LEDs are low, and final device power consumption can be much higher), extremely high resolution (similarly, very tiny micro-LEDs are not mature and therefore it is very difficult and/or costly to achieve extremely high-resolution micro-LED displays), etc. In addition, based on their current status, some value propositions may not be so significant for specific applications, considering their much higher cost. One

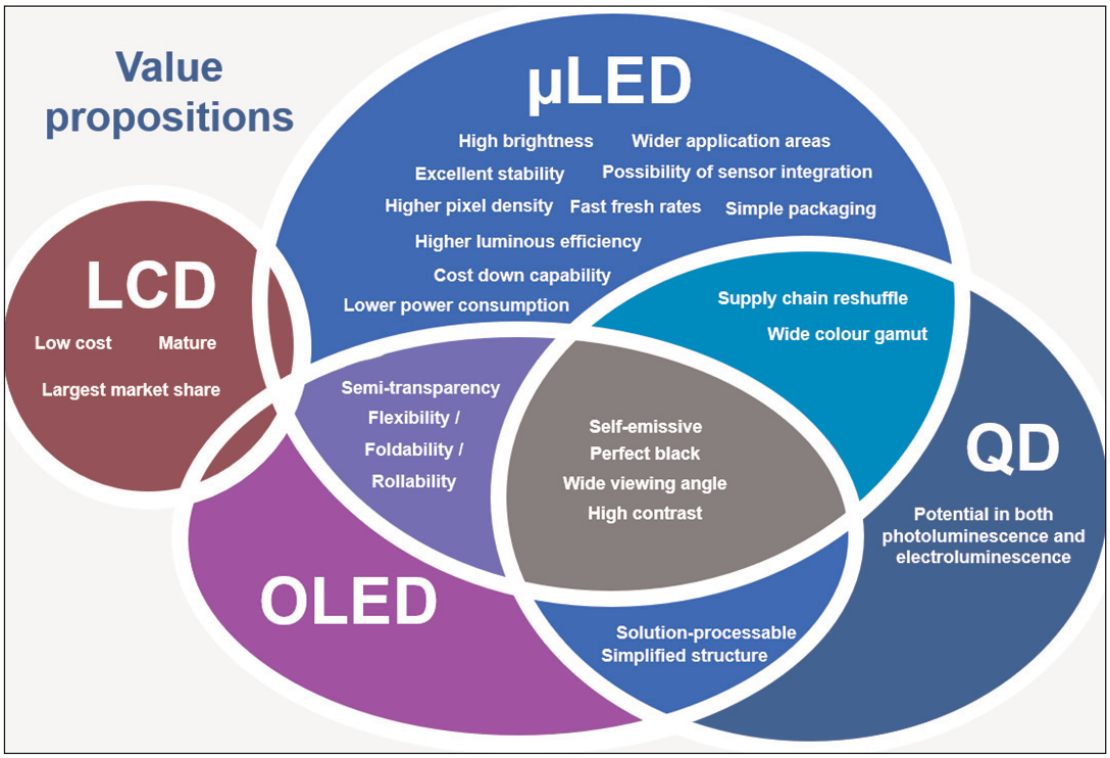
Spec.	Sony Crystal LED Display	Samsung The Window	LG Micro LED Signage	Konka Smart Wall	TCL The Cinema Wall
Size	Various	75″	175″	118″	132″
Resolution	3840x2160	3840x2160	3840x2160	3840x2160	3840x2160
PPI	20	58.7	25.2	37.3	33.4
Others	1M:1, ~140% sRGB, 1,000 nits, 120 fps	10K:1, 1,600 nits	-	10M:1, 147% DCI-P3, ≥3000, 2M:1 HDR	2.5M:1, 1,500 nits, 16 bits

example is the extremely long lifetime for mobile phone applications: Users may change their phone every 2–3 years, making the long lifetime less attractive considering the costs.

Therefore, whether micro-LED displays can replace OLEDs or not, at least in the short to medium term, is a very application-dependent question, notes IDTechEx.

The report has therefore analyzed the potential markets from two aspects:

- replacement in the existing display market,
- creating a new display market.



For the former, eight applications are addressed the most: augmented/mixed reality (AR/MR), virtual reality (VR), large video displays, TVs and monitors, automotive displays, mobile phones, smartwatches and wearables, tablets, and laptops.

For example, LCD displays (which dominate the current display market) are applied in almost all displays under 65". LCDs have their intrinsic limitation for going to larger size. OLEDs are taking an increasing market share mainly in smartphone displays. QD-LCDs are marketed as premium TVs and are accepted by an increasing number of consumers. LED displays are already used in huge public displays. To compete with them, micro-LEDs should identify their unique value proposition – or combination of value propositions — in order to offer advantages, says IDTechEx.

In terms of cost, the cost of the front plane of a typical micro-LED display is dependent on the number of LEDs, rather than area, which is different from OLED and LCD displays. This is why fabricating a smartphone with the same resolution as a TV may result in a similar cost projection, rather than orders of magnitude lower.

Therefore, it is important to understand the different technological approaches behind each application and to get a clear assessment of their possibilities and opportunities.

Creating a new display market requires features that cannot be enabled (or can hardly be enabled) by alternatives. Examples are displays with customized shapes and with integrated sensors. Emerging new displays expand our imagination beyond existing technology and help to achieve ubiquitous displays, concludes IDTechEx. ■

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Augmented/Mixed Reality


Virtual Reality


Large Video Displays


TVs and Monitors


Automotive Displays


Mobile Phones


Smart Watches and Wearables


Tablets and Laptops

Over $5bn spent on micro-LED development

Newcomers are accelerating patenting activity and challenging the heavyweights, notes Yole Développement.

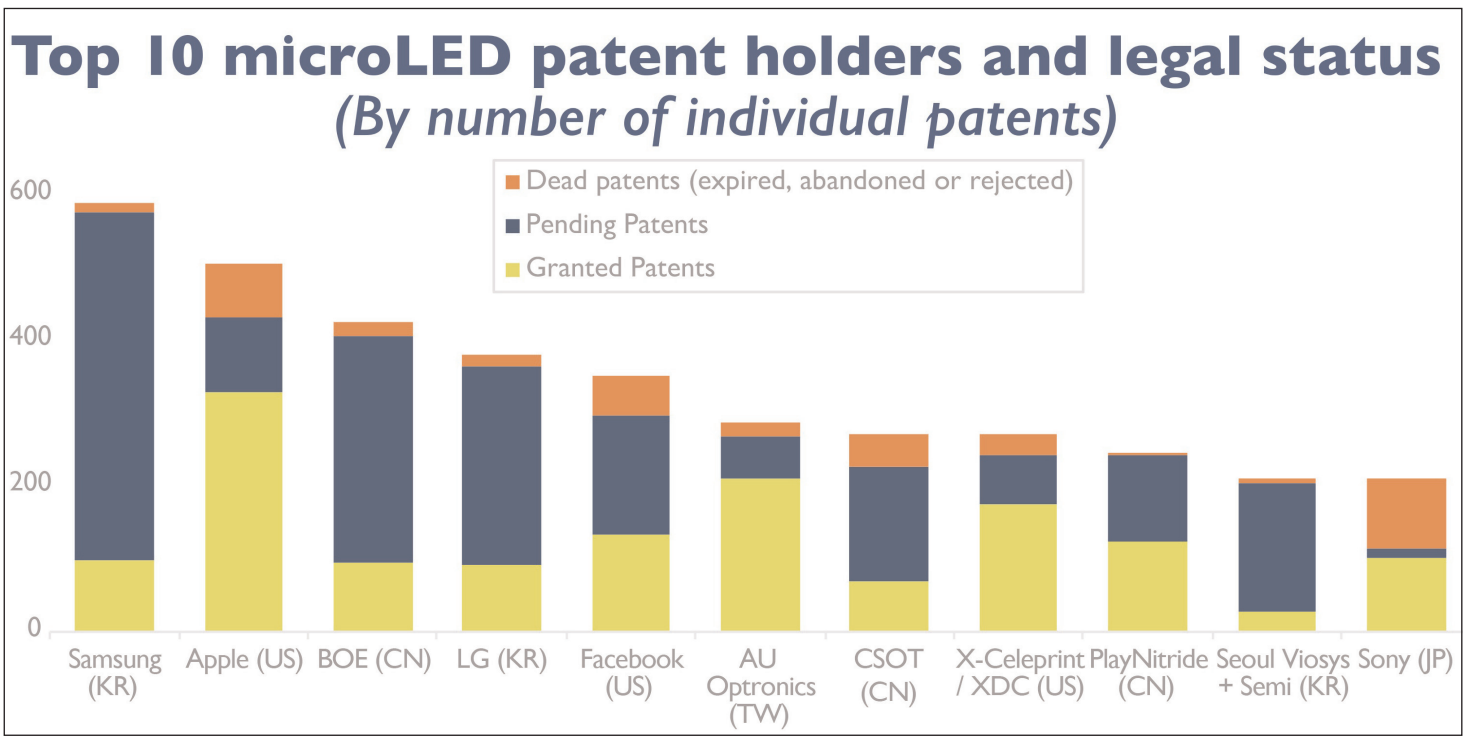
As of first-quarter 2021, more than $5bn has already been spent on micro-LED development," estimates Yole Développement in its report 'MicroLED Displays — Intellectual Property Landscape and Analysis 2021'. Of this, 26% has been spent in Apple internal R&D, 37% in other companies' internal R&D and investments, 24% in investments in startups, and 13% in acquisitions. "Activity is strongly dominated by Chinese companies, followed by Korea," Eric Virey, principal analyst, Technology & Market, Displays. "LG and Samsung made strong showings in 2019 and kept up the pace in 2020 in terms of new applications," he adds.

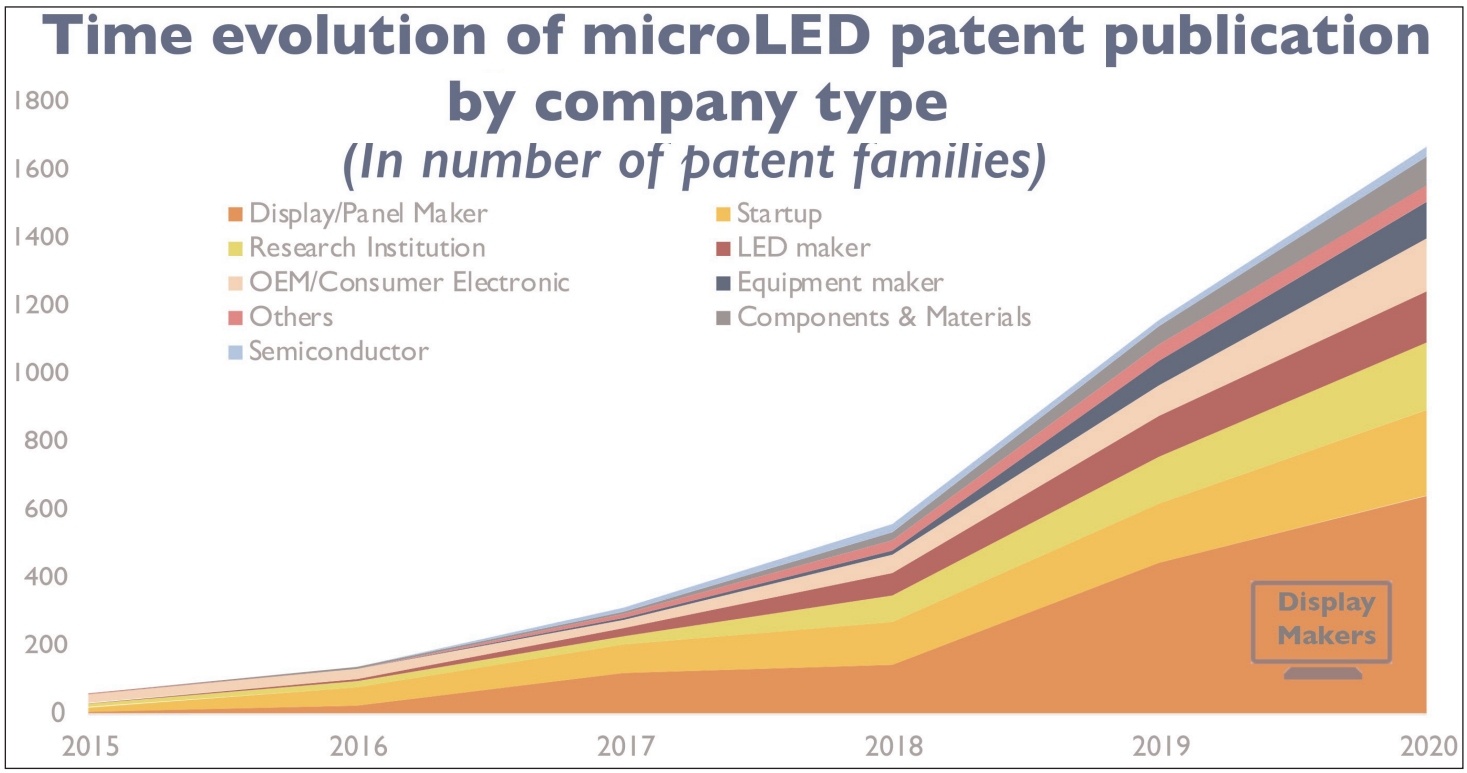
Yole says that 8900+ patents filed by nearly 480 organizations now represent a cumulated total of 4093 families selected for the corpus of patents in the study. Of these 4093 patent families, 40% (1637) were published in 2020 alone (and 81% over the last three years). As of January 2020, just 35% of the published patent applications have been granted, while 53% are still pending. In particular, BOE, LG and Samsung have vast numbers of pending applications, and CSOT is not far behind.

Samsung made a remarkable push with more than 130 new patent families, revolving for mostly around its Display division's self-assembled nanorod LED technology, often referred to as QNED (Quantum Nano-Emitting Diode). The patents show the technology maturing, and a commitment to tackle the challenges associated with moving QNED from the lab to the fab.

CSOT and BOE led patenting activity in 2019 and remained close to the top in 2020. With similar levels, startup PlayNitride (which raised another $50m in 2020 to expand capacity) is very active, challenging the leading panel makers and original equipment manufacturers (OEMs) like Facebook. Aledia, which moved into a new R&D facility in 2019 and raised nearly $95m in 2020 to build a fab, is also accelerating its IP effort, inching closer to historical leaders such as XDisplay. Panel makers that were absent (such as Japan Display, CEC Panda, HKC and Sakai Display) have now entered the patent corpus.

"The field is getting crowded, but there is still time for ambitious newcomers to build credible portfolios," says Virey. "In late 2019 and early 2020, Konka and Visionox announced plans to invest $365m and $175m



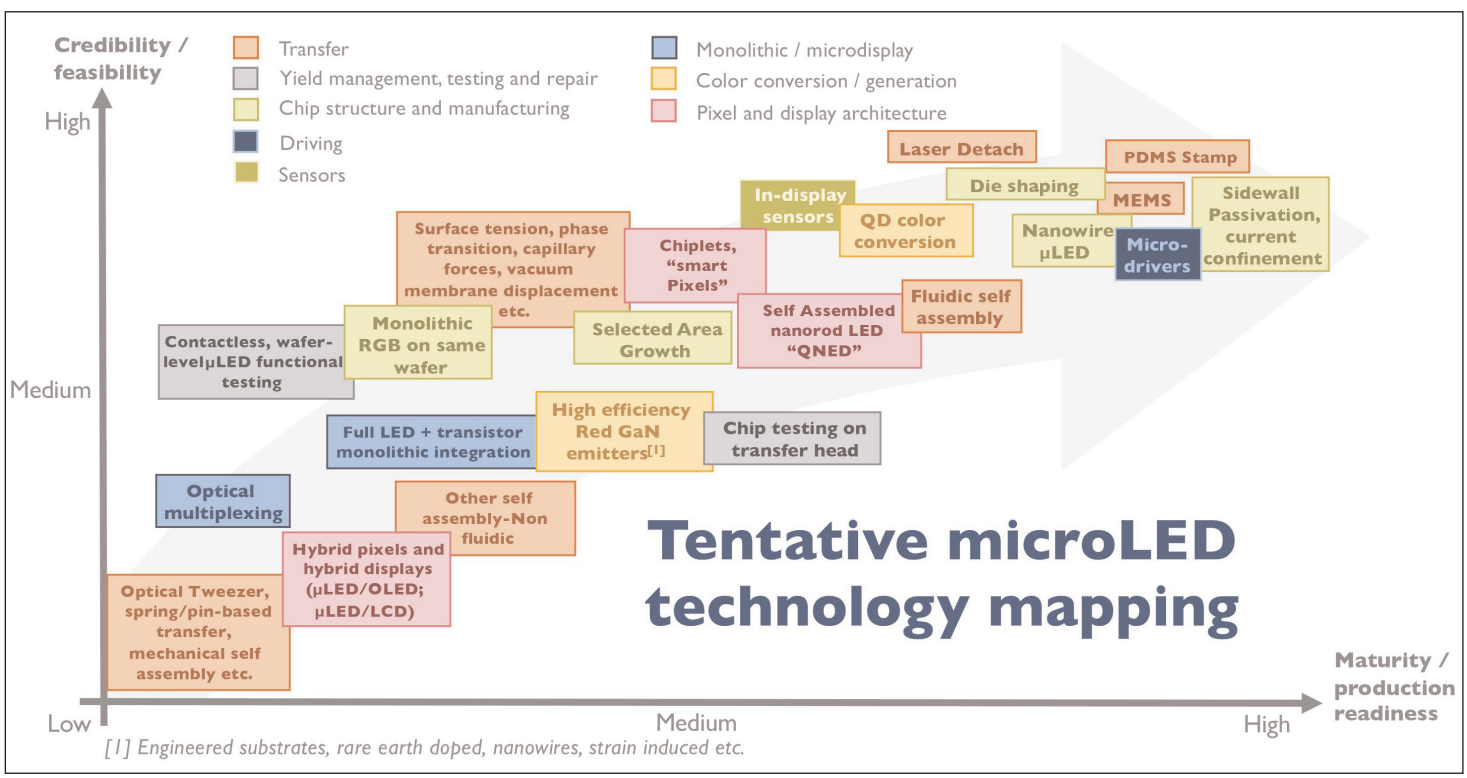


respectively in mini- and micro-LED development and production ramp ups. Konka only filed its first micro-LED patent in 2019 and Visionox in 2017, but both already have sizable portfolios of pending applications, some showing a surprising level of maturity."

Patent activity at Apple peaked in 2017. However, the quality and details of new applications shows how far the company's technology has advanced. The acquisition of Tesoro indicates a shift or expansion toward enabling volume production rather than fundamental technology development. Notable, foundry Taiwan Semiconductor Manufacturing Co (TSMC), which is expected to be one of Apple's key partners, appears for the first time in Yole's corpus.

Yole concludes that commercialization of the first micro-LED displays is just around the corner, with Vuzix's new augmented reality (AR) glasses featuring micro-LED micro-displays from JB Display, and Samsung's modular 110", 99" and 88" TVs using chips from PlayNitride. ■

www.yole.fr/MicroLED_Displays_IP_Landscpae_And_Analysis.aspx



New method observes compositional fluctuations in high-In-content InGaN LEDs

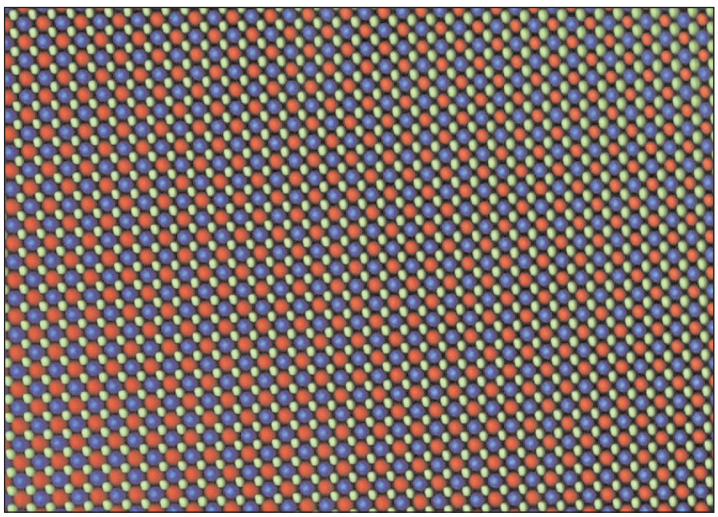
A new method paves the way for developing more efficient LEDs spanning the visible spectrum

The Low Energy Electronic Systems (LEES) Interdisciplinary Research Group (IRG) at Singapore–MIT Alliance for Research and Technology (SMART), together with Massachusetts Institute of Technology (MIT) and the National University of Singapore (NUS), have found a method to quantify the distribution of compositional fluctuations in indium gallium nitride (InGaN) quantum wells (QWs) at different indium concentrations.

InGaN light-emitting diodes have revolutionized solid-state lighting due to their high efficiencies, durability and low cost. The LED emission color can be changed by varying the indium concentration in the InGaN, giving InGaN LEDs the potential to cover the entire visible spectrum. InGaN LEDs with relatively low indium amounts compared to gallium, such as in blue, green and cyan LEDs, have enjoyed significant commercial success for communication, industry and automotive applications. However, LEDs with higher indium concentrations, such as the red and amber LEDs, suffer from a drop in efficiency with the increasing amount of indium.

Red and amber LEDs are currently made using aluminum indium gallium phosphide (AlInGaP) instead of InGaN due to InGaN's poor performance in the red and amber spectrum caused by the efficiency drop. Understanding and overcoming the efficiency drop is the first step towards developing InGaN LEDs covering the whole visible spectrum that would significantly reduce production costs.

In a paper 'Unlocking the origin of compositional fluctuations in InGaN light emitting diodes' (Mishra et al, Physical Review Materials, 5, 024605) the team employed a multi-faceted method — combining electron energy loss spectroscopy (EELS) imaging at subnanometer resolution with multi-scale computational models — to understand the origin of compositional fluctuations and their potential effect on the efficiency of InGaN LEDs. The accurate determination of compositional fluctuations is critical to understanding their role in reducing efficiency in InGaN LEDs with higher indium compositions.



Array of multi-colored LEDs periodically arranged to give off visible light as shown above; a combination of InGaN-based red, blue and green LEDs is essential to cover lighting demands efficiently in the entire visible spectrum. Photo credit: SMART.

"The [origin of the] efficiency drop experienced in higher-indium-concentration InGaN LEDs is still unknown to this date," says co-author professor Silvija Gradecak of the Department of Materials Science and Engineering at NUS and principal investigator at SMART LEES. "It is important to understand this efficiency drop to create solutions that will be able to overcome it. In order to do so, we have designed a method that is able to detect and study the compositional fluctuations in the InGaN QWs to determine its role in the efficiency drop."

The researchers developed a multi-faceted method to detect indium compositional fluctuations in the InGaN QWs using synergistic investigation that combines complementary computational methods, advanced atomic-scale characterization and autonomous algorithms for image processing.

"This method developed and used in our research is of general applicability and can be adapted to other materials science investigations where compositional fluctuations need to be investigated," says Tara Mishra,

lead author of the paper and SMART PhD fellow.

"The method that we developed can be widely applied and provide significant value and impact on other materials science studies, where atomistic compositional fluctuations play an important role in material performance," says Dr Pieremanuele Canepa, co-author and principal investigator at SMART LEES and also assistant professor in the Department of Materials Science & Engineering and Department of Chemical & Biomolecular Engineering at NUS. "The understanding of the atomic distribution of InGaN at varying indium concentrations is key to developing next-generation full-color displays using the InGaN LED platform."

The research found that the indium atoms are randomly distributed in a relatively low-indium-content InGaN. On the other hand, partial phase separation is observed in higher-indium-content InGaN, where random compositional fluctuations are concurrent with pockets of indium-rich regions.

The researchers reckon that the findings advance understanding of the atomic microstructure of the InGaN and its potential effect on LED performance, paving the way for future research to determine the role of compositional fluctuations in the new generation of InGaN LEDs and design strategies to prevent the degradation of these devices.

The research is carried out by SMART and supported by the National Research Foundation (NRF) Singapore under its Campus for Research Excellence And Technological Enterprise (CREATE) program. ■

https://doi.org/10.1103/PhysRevMaterials.5.024605

www.circuit-innovation.org

HEMTs from AlScN-barrier MOCVD

Team also investigates silicon nitride cap material for the first time.

Researchers in Germany and the Netherlands have used metal-organic chemical vapor deposition (MOCVD) to create aluminium scandium nitride (AlScN)-barrier high-electron-mobility transistors (HEMTs) [Christian Manz et al, Semicond. Sci. Technol., vol36, p034003, 2021]. The team also used silicon nitride (SiN_x) cap material as an alternative to the more usual gallium nitride (GaN), which has never been investigated before, according the best knowledge of the team.

The work with AlScN builds on previous reports on MOCVD growth from the team at Fraunhofer Institute for Applied Solid State Physics (IAF), INATECH—Albert-Ludwigs Universität Freiburg, and University of Freiburg in Germany, and Eurofins Materials Science Netherlands and Eindhoven University of Technology in the Netherlands, along with Germany's Fraunhofer Institute for Microstructure of Materials and Systems (IMWS) [www.semiconductor-today.com/news_items/2019/oct/fhg-iaf-281019.shtml].

The introduction of scandium into the barrier increases spontaneous and piezoelectric (strain-dependent) charge polarization, which enables up to 5x the sheet charge carrier density in the GaN two-dimensional electron gas (2DEG) channel on which HEMTs are based. GaN-channel HEMTs are being developed and deployed for high-power, high-voltage and high-frequency applications, ranging from electric vehicle (EV) and renewable energy power handling, to microwave wireless communications power transmission.

Although HEMTs have been fabricated before from molecular beam epitaxy (MBE)-grown AlScN material, MOCVD processes are more widely applicable for mass production. One problem with introducing scandium into MOCVD is that the vapor pressure of the potential precursors is low. The MOCVD was carried out at low pressure (40–100mbar) with hydrogen used as the carrier gas. The growth temperature ranged from 1000°C to 1200°C.

The nitrogen source was ammonia (NH_3). The group-III metals, gallium and aluminium, came from trimethyl- (TM-) organics. The scandium precursor was tris-cyclopentadienyl-scandium (Cp_3Sc). Silane (SiH_4) supplied the silicon for the SiNx cap.

The growth of the AlScN barrier layer used variously continuous and pulsed methodologies. The pulsed method consisted of alternating the metal supplies with 5s Cp_3Sc and 2s TM-Al.

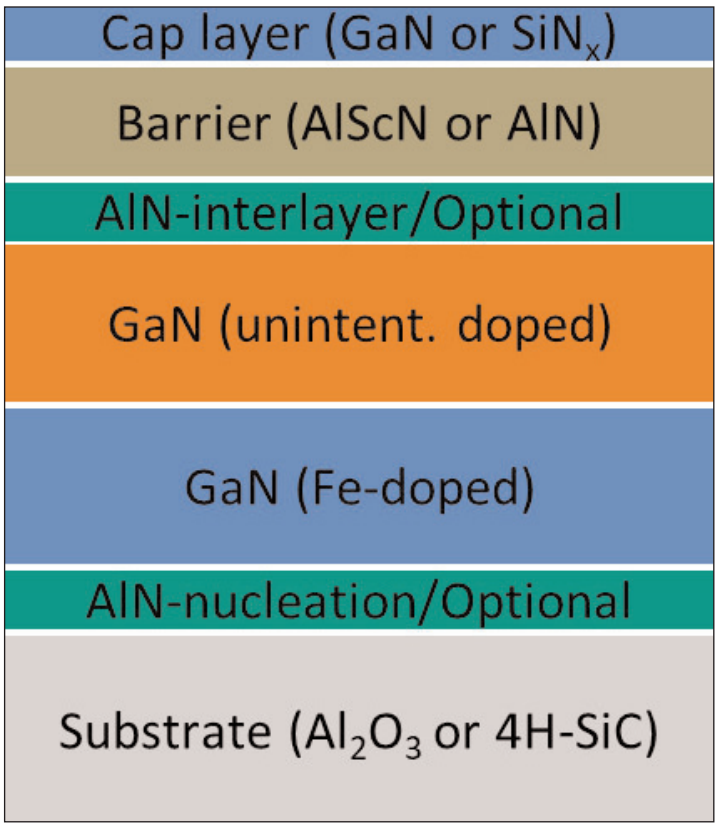


Figure 1. MOCVD scheme for AlScN barrier material.

The experiments used 100mm sapphire substrates and 4H silicon carbide (SiC) for some experiments, particularly at the transistor fabrication stage.

The HEMTs consisted of titanium/aluminium ohmic source–drain contacts with ion-implant device isolation. The SiN_x passivation enabled "low current dispersion and thermal stability", according to the researchers. The gate was designed to be low capacitance, to improve high-speed operation.

The silicon nitride was used to cap the AlScN barrier layer, to avoid oxidation of the Al containing layer. In AlGaN transistors a GaN cap is often used, but in the case of AlScN such caps have been found to be difficult to grow, resulting in '3d islands', which adversely impact its ability to protect and passivate the AlScN. GaN caps on AlScN were found to have root-mean-square roughness of 1.5nm for material grown at 1000°C, according to atomic force microscopy (AFM) measurements, compared with 0.2nm for SiN_x.

The material used for the HEMTs (Figure 1) contained around 14% Sc in the 9.5nm AlScN barrier layer.

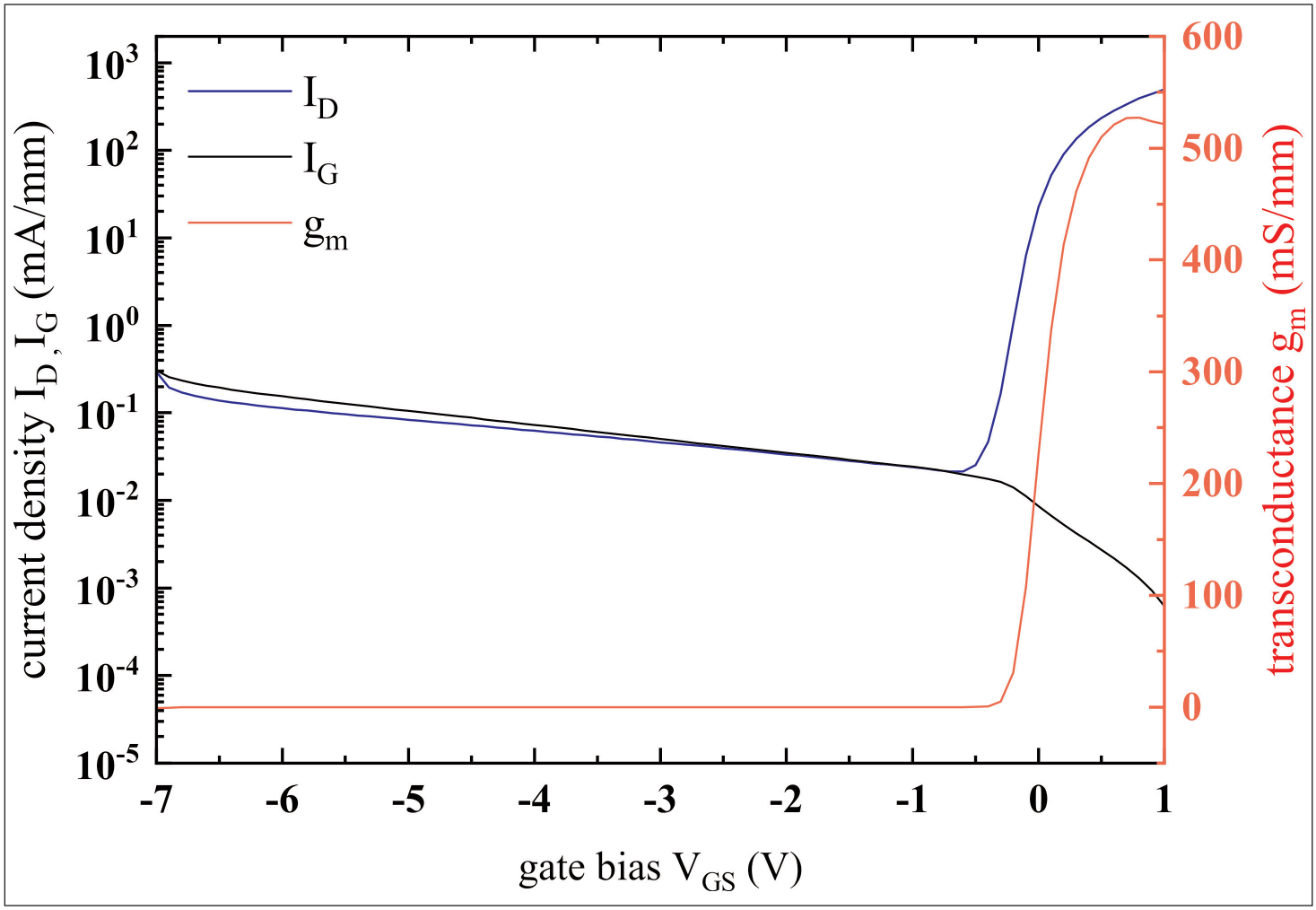


Figure 2. Transfer characteristics for AlScN-barrier HEMT with 0.25μm gate length. Drain bias 7V.

The SiN_x cap was 3.4nm. The growth temperature was 1100°C, with the AlScN deposition using continuous supply of the precursors. The substrate was 4H SiC. A comparison 5.6nm AlN barrier device with 3nm SiN_x cap was also grown and fabricated.

Table 1. Comparison of electron transport properties of AlScN-barrier and AlN-barrier HEMTs.

Barrier	AlScN	AlN
Sheet resistance	323Ω/square	325Ω/square
Mobility	729cm^2/V-s	726cm^2/V-s
Carrier concentration	2.6x10^{13}/cm^2	2.6x10^{13}/cm^2
Peak transconductance	530mS/mm	660mS/mm
Maximum drain current	1720mA/mm	1700mA/mm

The HEMT with AlScN barrier achieved performance (Figure 2) comparable with that of the device with AlN barrier (Table 1). The researchers point out that the performance of the AlScN HEMT is below theoretical expectations.

The team blames "heavy interdiffusion of the metal atoms Al, Ga and Sc in the buffer and barrier," which was detected and characterized using scanning transmission electron microscopy (STEM), energy-dispersive x-ray spectroscopy (EDX), and high-resolution x-ray diffraction analysis (HR-XRD). The barriers were therefore AlGaScN and AlGaN, respectively. Measurements suggest that the diffusion resulted in an AlGaN barrier with around 40% Ga on average.

"The primary source for the lower mobility in both samples is most likely the poor interface quality and the atoms' interdiffusion, causing alloy scattering, which is known to affect the mobility of HEMT heterostructures," the researchers write.

Even so, the team sees the results as "very promising" for high-power and high-frequency applications, adding that the AlScN HEMT is "already superior" to standard AlGaN HEMTs designed for RF applications fabricated in-house. ■

https://doi.org/10.1088/1361-6641/abd924

Author: Mike Cooke

Transistor cut-off frequency at 738GHz

Researchers report a record f_T combined with outstanding DC parameters.

A research team in Korea and Japan has reported field-effect transistors (FETs) with a cut-off frequency of 738GHz, claiming that this as "the highest f_T of any FET with any material system" [Hyeon-Bhin Jo et al, International Electron Devices Meeting, session 8.4, 2020].

The result from Kyoungpook National University (KNU), University of Ulsan and Quantum Semiconductor International Co Ltd in South Korea and NTT Device Technology Laboratories in Japan was presented online at the International Electron Devices Meeting (IEDM) at the end of 2020.

The team credits a composite indium gallium arsenide (InGaAs) quantum well (QW) channel structure with enabling the record frequency high-electron-mobility transistor (HEMT). The 738GHz figure compares with a previous InGaAs HEMT with 710GHz cut-off. However, the latter device also featured a maximum oscillation frequency (f_{max}) of more than 1THz (1000GHz), while the new device only achieved 492GHz.

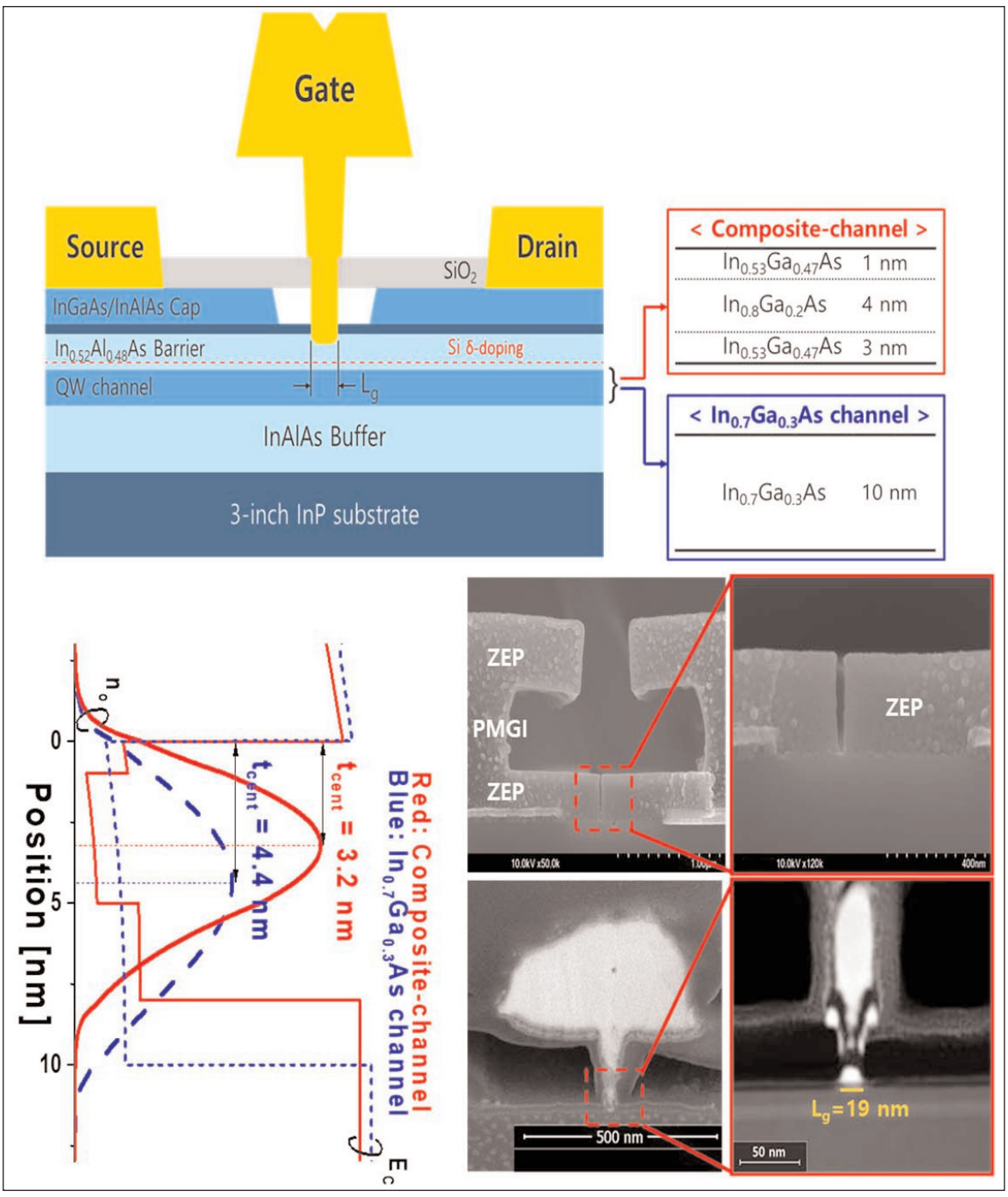


Figure 1. (a) HEMT schematic with two types of QW channel, (b) conduction-band profile in equilibrium under gate at 0.2V over threshold for both channel designs, and (c) cross-sectional scanning/transmission electron microscope (SEM/TEM) images of fabricated T-gate before and after gate metallization.

The team sees renewed interest in InGaAs devices for future electronics, such as quantum computing and beyond-5G deployment, based on the potential for lower noise performance from the combination of high f_T and low source resistance.

The researchers compared devices with a composite quantum well channel (Figure 1) with a more conventional $In_{0.7}Ga_{0.3}As$ channel. The material was grown on 3-inch indium phosphide (InP) substrate. The buffer consisted of 200nm $In_{0.52}Al_{0.48}As$. The upper layers included a 3nm InP etch stop between the barrier and the heavily doped multi-layer cap.

Hall-mobility measurements at a two-dimensional electron gas (2DEG) concentration of ~$3x10^{12}/cm^2$ showed an increase in mobility for the composite channel to 13,500cm^2/V-s, compared with 10,500cm^2/V-s for the more conventional channel. In the HEMT, the effective mobility was only slightly impacted at 13,200cm^2/V-s; the average electron velocity under the gate was $6.2x10^7$cm/s.

The fabricated HEMTs featured titanium/molybdenum/titanium/platinum/gold ohmic source/drain contacts scaled down to 0.8μm separation. Silicon dioxide (SiO_2) was used in the fabrication of the recessed platinum/titanium/platinum/gold T-gate. The gate length (L_g) was as low as 19nm.

The f_T/f_{max} values were determined from measurements between 1 and 5 at 738GHz and 492GHz, respectively. The reference conventional-channel HEMT achieved corresponding values of 540GHz and 458GHz. The drain–source bias (V_{DS}) was 0.5V.

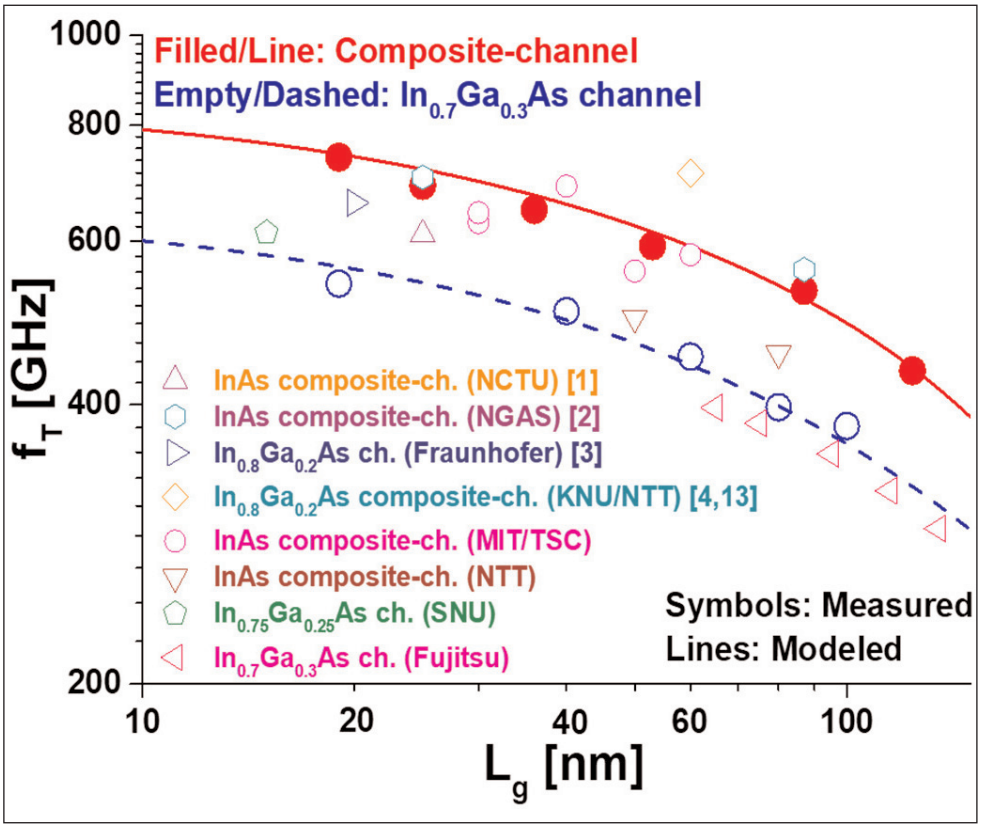


Figure 2. Benchmark of f_T versus L_g for both devices against other reports.

The researchers comment: "To the best of our knowledge, the L_g = 19nm device with the composite channel produces the highest f_T of any FET with any material system." Combined with features such as an on-resistance of 271Ω-μm and 2.5μS/μm peak transconductance, the team adds that the device demonstrates "an outstanding combination of DC and high-frequency characteristics". ■

https://ieee-iedm.org

Author: Mike Cooke

Hybrid III–V TFETs and MOSFETs on silicon

Researchers demonstrate TFETs with subthreshold swing of 42mV/decade.

IBM Research Europe and École Polytechnique Fédérale de Lausanne (EPFL), both based in Switzerland, have developed a process for hybrid III–V tunnel field-effect transistors (TFETs) and metal-oxide-semiconductor field-effect transistors (MOSFETs) on a silicon platform [Clarissa Convertino et al, Nature Electronics 4 (2021), p162]. The use of band-to-band tunneling rather than thermionic emission enabled the TFETs to achieve much lower subthreshold swings (SSs) down to 42mV/decade, compared with 62mV/decade for the MOSFETs.

Low SS enables sharper digital switching or higher gain in amplifiers. The SS value represents the change in gate potential needed for a factor-of-ten increase in drain current in the subthreshold region.

The researchers explain the attraction of hybrid TFET/MOSFET circuitry: "III–V heterostructure TFETs are promising for low-power applications, but are outperformed by MOSFETs in terms of speed and energy efficiency when high performance is required at higher drive voltages." They see particular opportunities for autonomous and wearable systems.

The team used a relatively conventional process for transistor formation as used in advanced silicon manu-

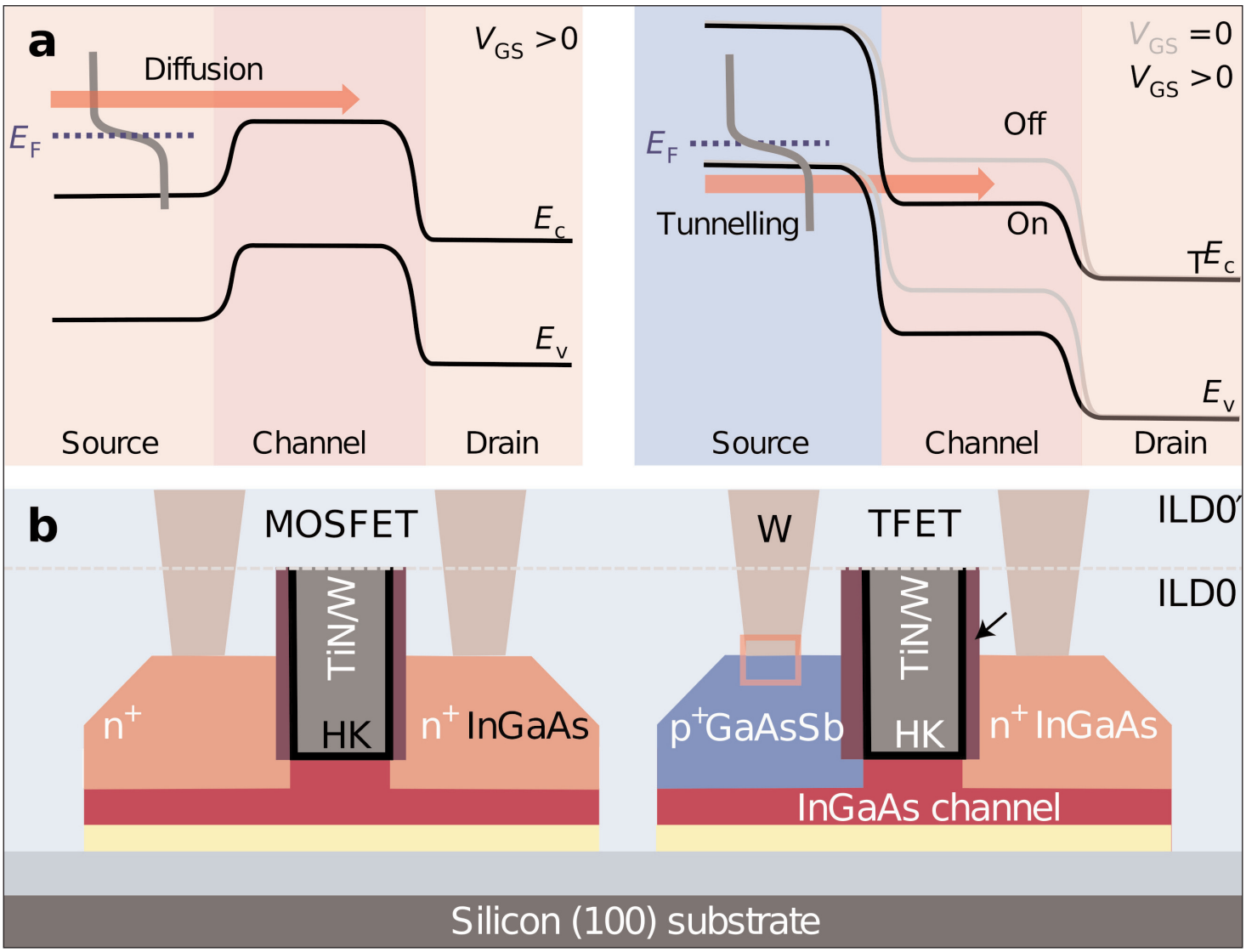


Figure 1. (a) Energy diagrams showing MOSFET (left) and TFET (right) valence and conduction bands and respective operating principles. (b) TFET and MOSFET cross sections, following last metallization.

Figure 2. Benchmarking InGaAs/GaAsSb TFET performance: (a) SS versus I_D, (b) I_{60} versus gate length (L_g), and (c) SS versus L_g.

facturing for both the MOSFET and TFET. A lateral rather than vertical structure for the TFET offers the potential for device scaling. The team comments; "None of the existing III–V-based TFET demonstrations offer a clear path for integration with MOSFETs in a hybrid, scalable platform."

The devices (Figure 1) featured indium gallium arsenide channels and source–drain regions of indium gallium arsenide (InGaAs) or gallium arsenide antimonide (GaAsSb). Doping for opposite majority carrier types in the source–drain materials enables a TFET p-i-n structure with the gate controlling the barrier width for band-to-band tunneling. In MOSFETs the gate controls the rate of thermionic emission.

The hybrid process featured replacement metal gate (RMG) and self-aligned raised source–drain (R_{SD}) contact modules. The base material consisted of 10nm/20nm InGaAs/InP layers transferred to 4-inch silicon (100) using direct wafer bonding, resulting in a buried oxide (BOX) interface with the underlying silicon. The InGaAs was lattice-matched to the InP with 53% indium content.

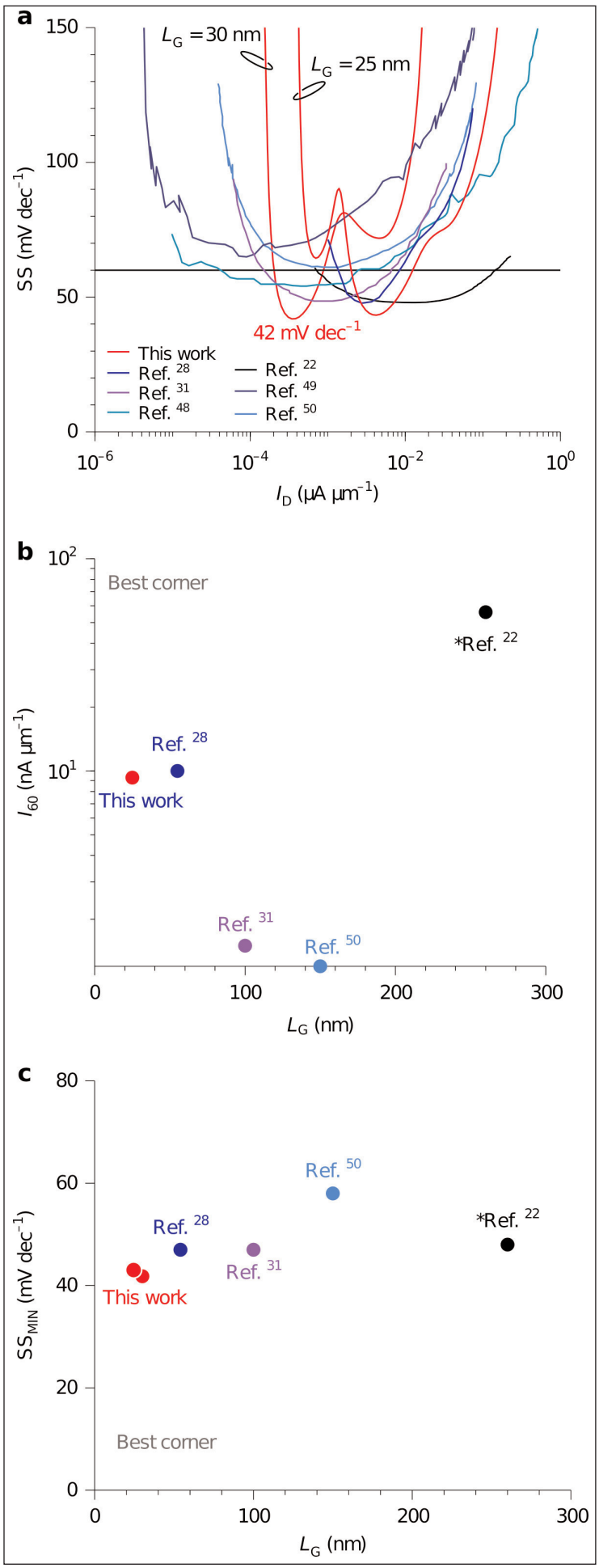
The initial fabrication step consisted of dry etching the device isolation and fins that can be as thin as 20nm wide. A selective two-step dry/wet cyclic digital etch process was used to remove the base material from the source–drain region, allowing its epitaxial regrowth with doped material for the contacts in selective growth processes.

The ohmic source–drain contacts for the MOSFET consisted of n-InGaAs. By contrast, the TFET featured an n-InGaAs drain and p-GaAsSb source. Tin (Sn) was used for the n-InGaAs doping, while zinc (Zn) provided the p-GaAsSb. The lattice-matched GaAsSb consisted of 50% As and 50% Sb.

The gate stack consisted of high-k dielectric layers of aluminium oxide and hafnium dioxide, along with titanium nitride and tungsten (W) for the metal. The dielectric had a 1nm equivalent oxide thickness (EOT).

The devices were encapsulated in interlayer dielectric (ILD) with vias etched and filled with W for the contacts. The researchers comment: "The encapsulation represents a key feature of the developed process, because Sb-based compounds are particularly sensitive to oxidizing agents and suffer from poor etching selectivity. The source contact is partially exposed only at the end of the process and, as a result, it already appears purely crystalline 2nm from the contact interface."

A TFET with 30nm gate length achieved a minimum SS of 49mV/decade with a 300mV drain bias (V_{DS}). This was pushed down to 42mV/decade with V_{DS} at 50mV. The MOSFET achieved a SS of ~62mV/decade, near the theoretical limit of 59.5mV/decade at room



temperature (300K), for both drain bias conditions.

The current in the low bias condition fell off at high gate potential. The team suggests that this could be due either to a slight gate overlap or by a lower effective doping concentration in proximity of the tunnel junction. The researchers comment: "The effect is primarily visible at low V_{DS}, where the reverse bias across the diode at the source–channel junction is smaller, thus it is probably not detrimental to device operation."

The transistors also demonstrated high peak transconductance/drain current (g_m/I_D) ratios: 50/V for the TFET, and near the 39/V 300K limit for the MOSFET. Reducing the gate to 25nm only slightly increased the SS to 43mV/decade.

Cryogenic measurements found a decreasing SS for the TFET with lower temperature, reaching 10mV/decade at 4K. The cryogenic studies also found that trap-assisted tunneling was significant at lower temperatures, which indicates that removing these traps could further improve the SS performance.

The researchers claim that their TFETs demonstrate smaller SS values compared with "competing state-of-the-art TFET technologies" (Figure 2). The team adds: "In addition to the device performance, we also underline the uniqueness of this TFET platform in terms of scalability, compatibility with standard CMOS processes and co-integration with MOSFETs."

None of the competing TFET processes considered by the team in their benchmark were CMOS-compatible. Further, only one of the competitors was produced in combination with a MOSFET. Only two of the reported TFETs were on silicon (111) or silicon-on-insulator (SOI) platforms. Four of the competitors presented used a vertical structure, with the remaining three lateral.

The device also features a short gate length and reasonable peak drain current in the region of SS less than 60mV/decade (I_{60}).

Some funding for the work came from the European Commission's 7th Framework (FP7) and Horizon 2020 programs. ■

https://doi.org/10.1038/s41928-020-00531-3
https://ec.europa.eu/research/fp7/index_en.cfm
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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
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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.

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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

3–7 May 2021
PCIM (Power Conversion and Intelligent Motion) Europe digital days 2021
— online event
E-mail: pcim@mesago.com
https://pcim.mesago.com
www.mesago.de/en/PCIM/main.htm

9–14 May 2021
2021 Conference on Lasers & Electro-Optics (CLEO)
— now a virtual, online event
E-mail: CLEO@compusystems.com
www.cleoconference.org

11–14 May 2021
10th World Congress of Nano S&T 2021
Venetian Macao Resort Hotel,
Macao, China
E-mail: esther@bitcongress.com
www.bitcongress.com/nano2021-macao

7–10 June 2021
2021 IEEE MTT-S International Microwave Symposium (IMS2021) and Microwave Week
(virtual event to follow on 20-25 June 2021)
Georgia World Congress Center,
Atlanta, GA, USA
E-mail: IMS@xpressreg.net
www.ims-ieee.org

6–10 June 2021
(postponed from 28 March –1 April 2021)
OFC 2021:
Optical Networking and Communication Conference & Exhibition
— now an online, virtual event
E-mail: OFC@csreg.zohodesk.com
www.ofcconference.org

9–13 June 2021
(postponed from 21–25 June 2020)
APEC 2021: IEEE Applied Power Electronics Conference and Exposition
Phoenix, AZ USA
E-mail: registration@apec-conf.org
www.apec-conf.org

20–24 June 2021
International Congress on Photonics in Europe
— co-located with LASER World of PHOTONICS
ICM (Internationales Congress Center München),
Munich, Germany
E-mail: info@photonics-congress.com
www.photonics-congress.com/en

21–24 June 2021
LASER World of PHOTONICS 2021
Messe München, Munich, Germany
E-mail: info@world-of-photonics.com
www.world-of-photonics.com/en

advertisers' index

~~22–24 June 2021~~ (postponed to 24–26 Aug 2021)
Strategies in Light 2021
Santa Clara Convention Center,
Santa Clara, CA, USA
E-mail: registration@endeavorb2b.com
www.strategiesinlight.com

~~4–9 July 2021~~ (postponed from 14-19 June 2020, then 4–9 July 2021, to 2022)
ICMOVPE XX:
20th International Conference on Metal Organic Vapor Phase Epitaxy
Stuttgart, Germany
E-mail: info@icmovpexx.eu
www.icmovpexx.eu

22–25 July 2021 (postponed from 22–25 July 2020 then 12–15 March 2021)
International Congress on Advanced Materials Sciences & Engineering (AMSE)
Vienna, Austria
E-mail: eve@istci.org
www.istci.org/amse2021

1–5 August 2021
SPIE Optics + Photonics 2021 — Conference and Exhibition
San Diego Convention Center,
San Diego, CA, USA
E-mail: customerservice@spie.org
www.spie.org/opstm

24–26 August 2021 (postponed from 9–11 February 2021, then 22–24 June 2021)
Strategies in Light 2021
Santa Clara Convention Center,
Santa Clara, CA, USA
E-mail: registration@endeavorb2b.com
www.strategiesinlight.com

1–3 September 2021
CIOE 2021:
23rd China International Optoelectronic Exposition
Shenzhen World Exhibition & Convention Centre, China
E-mail: cioe@cioe.cn
www.cioe.cn/en

~~12–17 September 2021~~ (postponed to 2022)
19th International Conference on Silicon Carbide and Related Materials (ICSCRM 2021-2022)
Davos, Switzerland
E-mail: info@icscrm2021.org
www.icscrm2021.org

13–15 September 2021
ECOC 2021 (47th European Conference on Optical Communication)
Bordeaux Exhibition Centre,
Bordeaux, France
E-mail: sales@ecocexhibition.com
www.ecocexhibition.com/ecoc-exhibition-2021

22–24 September 2021
LASER World of PHOTONICS INDIA 2021
Bengaluru, India
E-mail: info@world-of-photonics-india.com
www.world-of-photonics-india.com

10–14 October 2021
27th International Semiconductor Laser Conference (ISLC 2021)
Potsdam, Germany
E-mail: islc@fbh-berlin.de
www.islc2021.org

10–15 October 2021
24th European Microwave Week (EuMW 2021)
ExCel, London, UK
E-mail: eumwreg@itnint.com
www.eumweek.com

24–28 October 2021
(postponed from 13–17 September 2020)
13th European Conference on Silicon Carbide and Related Materials (ECSCRM 2020-2021)
Vinci International Convention Centre, Tours, France
E-mail: ecscrm-2020@univ-tours.fr
www.ecscrm-2020.com

7–9 November 2021
8th IEEE Workshop on Wide Bandgap Power Devices & Applications (WiPDA 2021)
Crowne Plaza Redondo Beach and Marina,
Redondo Beach, CA, USA
www.wipda.org

13–15 December 2021
67th IEEE International Electron Devices Meeting (IEDM 2021)
San Francisco, CA USA
E-mail: info@ieee-iedm.org
www.ieee-iedm.org

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

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