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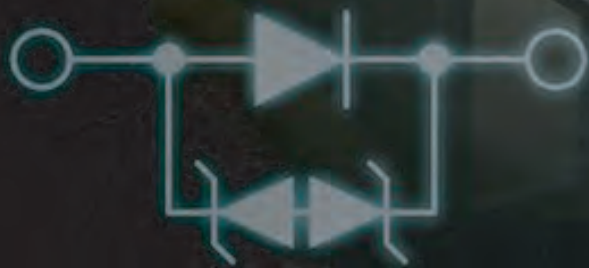
COMPOUNDS & ADVANCED SILICON

Vol. 8 • Issue 8 • October 2013

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Bridging the amber-green gap

1



GaN-on-Si

News from SCTE Cable-Tec • Shimadzu unveils 10W blue laser
II-VI buys Oclaro's amplifier and micro-optics unit

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p28 SDK has launched 6" SiC epiwafers for use in power devices.



p62 Finisar has opened its new plant in Wuxi, China (an hour from its Shanghai plant) for making tunable and parallel transceivers, WSS modules, ROADM line-cards, passives & subassemblies for VCSELs and detectors.



p67 Semprius supplied specially designed lightweight versions of its record-breaking solar module to Delft University's Nuon Solar Team to help its Nuna7 win the World Solar Challenge.



p40 Cover: Toshiba has launched the first devices in its second generation of LETERAS white LEDs, which are fabricated using a gallium nitride-on-silicon process. Scheduled for mass production in November, the 1Watt TL1F2 LEDs offer a more cost-effective alternative to current LED packages, says the firm.

Diversifying and refocusing

In the feature article on pages 82–88 of this issue, as well as the accompanying articles on pages 90–91 and 92–93, we cover the topic of how researchers are using various techniques to extend the emission wavelength of LEDs into the ‘amber-green gap’. This range of colors is of particular interest for the prospect of having the constituent mix of different-colored LEDs to produce white light directly, rather than the existing method of using a phosphor coating to convert some of the light from a blue LED, yielding a white-light color mix (albeit with compromises in terms of color balance and stability over time).

Research is being driven by the demand for more efficient (and hence less expensive) white-light LEDs for general lighting applications. According to market research firm IHS, revenue for packaged LEDs for lighting applications should nearly double in the next three years, as the unit shipments almost quintuple (see page 7), bringing down the price per unit, due to economies of scale.

Anticipation of such a market has been driving firms such as San’an in China — aided by government subsidies — to purchase hundreds of GaN LED MOCVD systems over the last few years, such that San’an’s GaN LED wafer processing capacity is due to surpass that of current leader Epistar (of Taiwan) in fourth-quarter 2014 (see page 8). However, this is only in terms of installed capacity, rather than revenue, not considering the proportion of capacity that is utilized and product pricing.

Combined with lesser prospects of some other Chinese start-ups, there is still continuing overcapacity in MOCVD processing of GaN LEDs. Such a feast and then famine of orders for MOCVD systems over the last few years has driven suppliers Aixtron and Veeco to diversify their customer bases and application sectors. For example, Aixtron’s ‘5-Point’ recovery program involves not only near-term efficiencies but also longer-term investment in ‘future business opportunities’ such as silicon applications, organic LEDs and power electronics (see page 34).

Also diversifying their technology portfolios and customer bases are the firms which are traditionally focused on gallium arsenide RFICs, but which have increasingly been extending their activities to gallium nitride (for power semiconductor devices), silicon-on-insulators (for switches), RF CMOS etc (for low-end wireless handsets). RF Micro Devices’ Q3 revenue is up 48% year-on-year. In addition to expanding its dollar content in leading 4G LTE smartphones and ramping production of new average power tracking (APT) and envelope tracking (ET) power amplifiers etc, RFMD cites “very strong adoption of ultra-low-cost CMOS PAs and next-generation handset platforms targeting emerging markets. Over time, we intend to migrate all of our customers for 2G PAs to this product family” (see page 10). TriQuint’s Q3 revenue is up 32% on Q2 (page 12), also citing demand for new LTE products. However, it is reducing GaAs capacity to “better align with projected demand for this process technology”. While the GaAs device market is forecast by Strategy Analytics to see above-average growth in 2013–2014, thereafter competitive technologies and new architectures (silicon-based technologies, particularly CMOS, and the trend toward multi-band PAs) combine to capture market share and slow growth (page 6). While this won’t hurt diversifying GaAs RFIC makers, it may impact demand for GaAs wafers.

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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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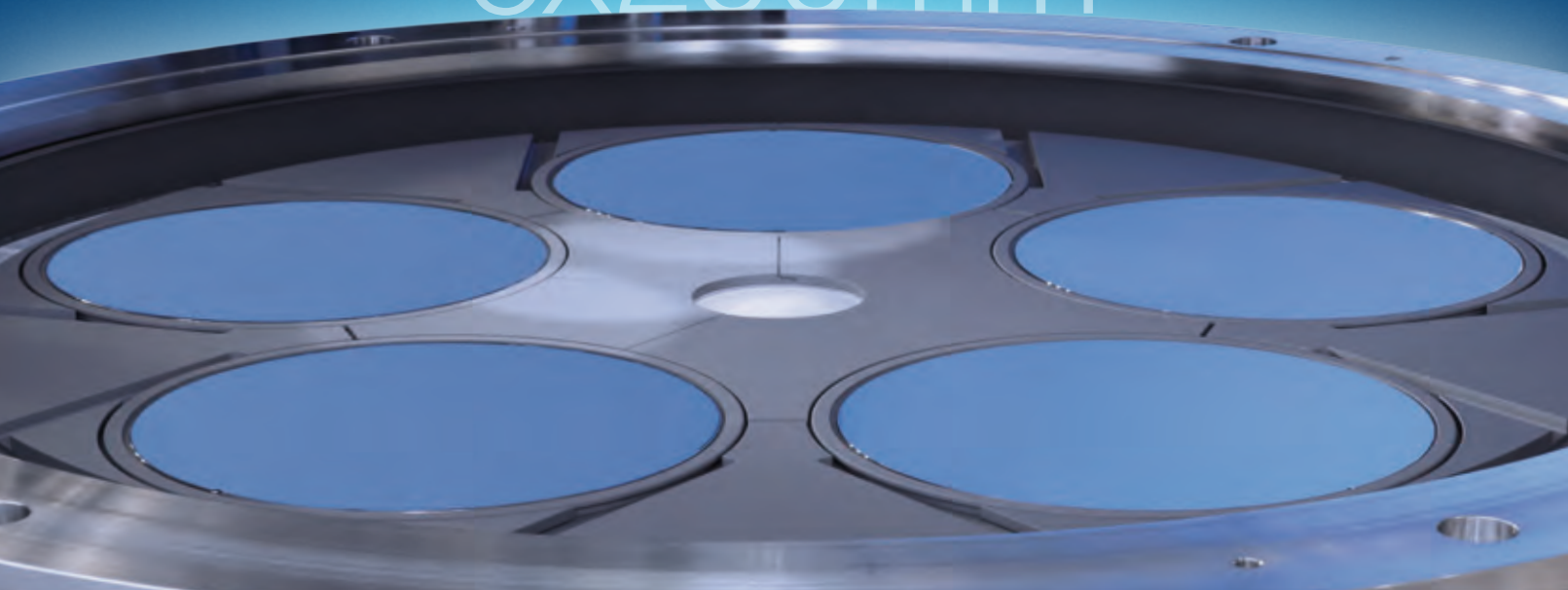
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Gallium arsenide device revenue to grow from \$5.3bn in 2012 to \$6.1bn in 2017

Cellular to drive above-average growth in 2013–2014, before slowdown due to CMOS and multi-band PAs

A strong close to 2012 allowed the gallium arsenide device market to grow by about 2% to record revenue of slightly more than \$5.3bn for the year, due mainly to the cellular segment, as most other segments for GaAs devices were flat or declined, according to Strategy Analytics' report 'GaAs Industry Forecast: 2012-2017'.

The report also forecasts above-average growth for the GaAs device market in the next two years, followed by slowing cellular demand that will pull the growth rate below historical averages. The result of these trends will be revenues slightly less than \$6.1bn in 2017.

"The GaAs market closed 2012 with strong growth and we have seen a continuation of that trend so far in 2013," notes Eric Higham,

director of the Strategy Analytics GaAs and Compound Semiconductor Technologies Service (GaAs).

"We anticipate 2013 and 2014 will see growth above historical averages as demand for cellular applications, particularly power amplifiers, picks up. Unfortunately, we believe this will be short-lived as competitive technologies and new architectures combine to

2013 and 2014 will see growth above historical averages... This will be short-lived as competitive technologies and new architectures combine to capture market share and slow the growth of GaAs devices

capture market share and slow the growth of GaAs devices," he adds.

"Silicon-based technologies, particularly CMOS, and the trend toward multi-band power amplifiers, will put a damper on the growth of GaAs device revenue," says Asif Anwar, director in the Strategy Analytics Strategic Technologies Practice (STP).

The Strategy Analytics forecast segments the GaAs device market by application, device type, process, geography and frequency. The report also addresses results, trends and forecasts for the semi-insulating GaAs bulk substrate and semi-insulating GaAs epitaxial substrate markets that make up starting point for the GaAs device supply chain.

www.strategyanalytics.com

Gallium arsenide epiwafer production to grow from 29,000 ksi to 31,600 ksi over 2012–2017

Epi substrate production fell by 7% for MOCVD & 1% for MBE in 2012

Due to the slow growth in the GaAs device market and increasing use of multi-band GaAs power amplifiers in cellular applications, total demand for semi-insulating (SI) GaAs epitaxial substrates (from manufacturers such as IQE, VPEC, Kopin, RFMD, Hitachi Cable, Intelliepi and Sumitomo) fell by nearly 5% from 2011 to about 29,000 kilo square inches (ksi) in 2012, estimates market research firm Strategy Analytics in its Forecast and Outlook report 'Markets for Semi-Insulating GaAs Epitaxial Substrates: 2012–2017'. The report forecasts that slowing demand from the GaAs device market will translate to slow growth in GaAs

epitaxial substrate demand, with production reaching slightly more than 31,600 ksi by 2017.

"The decline in GaAs epitaxial substrate production hit both MBE and MOCVD structures in 2012, but not equally," notes Eric Higham, director of the Strategy Analytics GaAs and Compound Semiconductor Technologies Service. "After a sharp increase in 2011, MOCVD material production fell by nearly 7% in 2012. Our results showed that MBE production, hit hard the previous two years, was more stable and fell by slightly less than 1%," he adds.

"The decline in MOCVD production indicates the growing trend toward

multi-band power amplifiers in handset applications," says Asif Anwar, director in the Strategy Analytics Strategic Technologies Practice (STP). "The small drop in MBE production indicates the bulk of the handset switch conversion to other technologies is complete, with the MBE capability now being used for other applications."

The Strategy Analytics forecast segments the SI GaAs epitaxial substrate market by diameter, geography, epitaxial processing technique, application and supplier. The report also addresses trends and recent developments in these segments.

www.strategyanalytics.com

Revenue for packaged LEDs for lighting to nearly double in three years

Shipments to rise from 520 million units in 2013 to 2.4 billion in 2016

Amid falling prices and rising consumer acceptance, light-emitting diode technology is taking over the lighting business, spurring a 96% increase for global revenue for packaged LEDs used in lighting applications, from \$3.6bn in 2013 to \$7.1bn in 2016, according to the report 'Packaged LEDs – World – 2013' from market research firm IHS Inc.

"As retail prices for LED lamps have fallen, it has become more obvious that they are an attractive alternative to conventional light bulbs, providing long-term savings in energy and replacement costs," says Stewart Shinkwin, market analyst, lighting and LEDs, for IHS. "Because of this, shipments of LED lamps for lighting are set to increase dramatically in the coming years, rising to 2.4 billion units in 2016, up from 520 million in 2013," he adds. "The rapid expansion of the lighting market will come as a major boon to suppliers of packaged LEDs, which are seeking the next growth opportunity following the slowdown of the backlighting business."

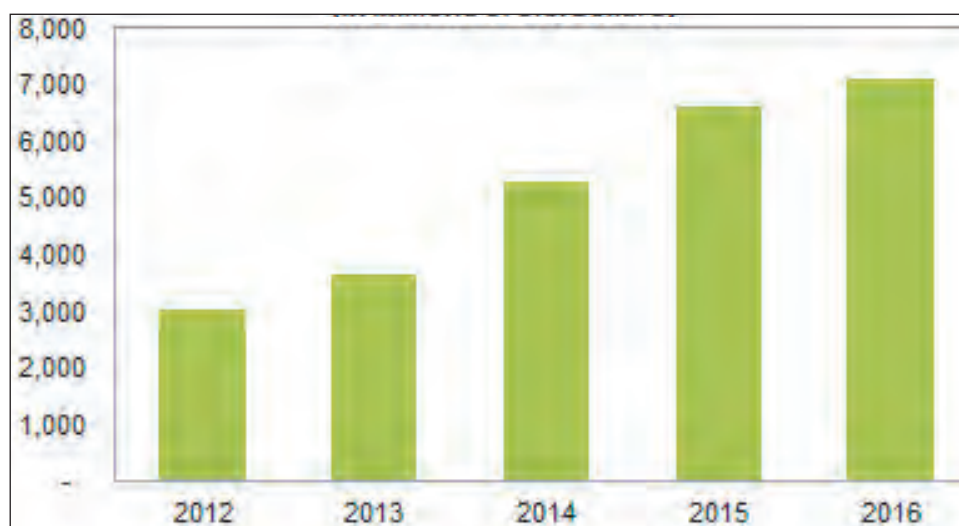
Looking back at backlighting

In the past, rapid growth in the packaged LED market was driven by LCD display backlighting in applications such as mobile phones, notebooks and TVs. Most of these applications have completed their transition to LED technology. Therefore, while LED demand for these products remains stable, annual unit growth is largely limited to single-digit percentages.

The lighting market, however, is predicted to provide the next wave of explosive growth for packaged LEDs.

Let there be lighting

In 2012, the lighting sector became the largest end-application for packaged LEDs, having finally overtaken TV backlighting. Market



Forecast market revenue for packaged LEDs in lighting applications (US\$m).

saturation for LED backlighting has resulted in a number of leading suppliers shifting their focus and development resources toward the lighting industry.

With LED lamp retail prices decreasing and more consumers realizing the cost savings that LED lamps can provide over long periods of time, penetration of LEDs into the lighting market is set to increase significantly, reckons IHS.

The projected growth in LED lamps will result in intensified competition among suppliers vying to capture market share, reckons the market research firm. This competition will continue to further drive down prices. IHS forecasts that average selling prices for packaged LEDs in lighting will fall from \$0.41 in 2013 and \$0.25 in 2016 to \$0.19 in 2018

Light fight

Along with great opportunity, the projected growth in LED lamps will result in intensified competition among suppliers vying to capture market share, reckons the market research firm. This competition will continue to further drive down prices. IHS forecasts that average selling prices for packaged LEDs in lighting will fall from \$0.41 in 2013 and \$0.25 in 2016 to \$0.19 in 2018.

The price erosion, in turn, will reduce the consumer payback period for LEDs, helping to increase adoption. However, declining profit margins will be undesirable for suppliers.

LED lamp penetration is already significant in a number of lighting applications such as the retail and hospitality sectors. However, it is the residential sector that IHS forecasts will provide the largest opportunity for packaged LEDs. Packaged LED revenue in the residential sector is forecast to grow from an estimated \$850m in 2013 to nearly \$2.7bn in 2016. Manufacturers that carve out share early on in this market could garner significant returns as the market booms, IHS concludes.

www.ihs.com

San'an to overtake Epistar in GaN LED wafers by end 2014 China to account for 80% of MOCVD shipments in 2013, 85% in 2014

China-based chip maker San'an Optoelectronics Co Ltd is projected to take the lead in gallium nitride LED wafer capacity by the end of 2014, overtaking current leader Epistar Corp of Taiwan, according to market research firm IHS Inc.

While Epistar is forecast to continue its spot at the pinnacle in 2013 and through most of 2014, its run at the top will end sometime in fourth-quarter 2014 when San'an takes over, forecasts IHS.

Wafer capacities are calculated based on tracked installations of metal-organic chemical vapor deposition (MOCVD) systems, and San'an's potential lead is dependent on a planned installation of new machines in 2014. "The second-phase fab of San'an in Wuhu, China is ready for another 100 GaN LED MOCVD tools in addition to the 100 that had been installed in 2011," says Alice Tao, senior analyst for LEDs and lighting at IHS.

Altogether, San'an could reach 10.8% of wafer capacity by fourth-quarter 2014 in 2"-equivalent wafer capacity, followed by Epistar with a forecast 10.1%, LG Innotek with 6.8%, and Samsung LED with 6.1%.

However, the rankings could change depending on what is being measured, notes IHS. For instance, Epistar remains the top manufac-

Top 10 Suppliers of GaN LED Wafers, by 2"-Equivalent Wafer Capacity

Company	Percentage Share of Market by Wafer Capacity in Q4 2014
San'an	10.8%
Epistar	10.1%
LG Innotek	6.8%
Samsung LED	6.1%
Elec-Tech	5.0%
Forepi	4.5%
Seoul Opto	4.3%
Lextar	4.0%
Tongfang Opto	3.7%
Genesis Photonics	3.2%

turer for yielded die and binned die, even by the end of 2014. Also, companies such as Nichia of Japan, Osram of Germany, North Carolina-based Cree and California-based Philips Lumileds rank high in terms of actual revenue when utilization rates and pricing are considered, even though the four makers are not in the top-five when it comes to unprocessed wafer capacity.

While San'an's capacity is double that of any other China-based manufacturer, others in China, such as HC Semitek, Elec Tech and Focus Lightings, are also expanding capacity. This is true despite continued overcapacity in the industry and even if some China manufacturers have been less than successful, says IHS.

China was the primary destination in 2012 for most MOCVD system shipments. The country's prominence in the market appears uncontested

for the short term, accounting for 80% of shipments in 2013 and 85% in 2014. In comparison, shipments and orders will be low in other regions. As a result of both these factors, China-based firms are predicted to increase their overall share of the market.

Many China manufacturers had jumped into the market or had expanded their capacities in 2011 when subsidies from local governments were available. However, most top suppliers continue to be based in other areas, including the western hemisphere South Korea, Taiwan and Japan — with many of these holding the strongest intellectual property (IP) portfolios, notes IHS.

Outside Asia, Chinese firms are not particularly strong. For example, no Chinese manufacturers appear in the top-10 for packaged LEDs. This makes the anticipated rise of San'an to the top in wafer die capacity by the end of 2014 even more striking, IHS concludes.

www.sanan-e.com/en

www.ledmarketresearch.com

External optical modulator market to reach \$229m

Consumption of external modulators in optical fiber communication networks is projected to reach \$229m in 2013, according to ElectroniCast Consultants in a new forecast.

There are essentially two ways to modulate laser diodes: directly and indirectly (externally). In the new research study, ElectroniCast provides a market forecast of the use of electro-optic (E-O) and electro-absorption (EA) modulators.

Consumption (use) of electro-optical (E-O) modulators is set to maintain market leadership over

electro-absorption (EA) modulators throughout the forecast period (2013–2018), reckons ElectroniCast.

The report details optical modulator use for the following transfer rate categories: less than 10Gbps; 10Gbps to less than 40Gbps; 40Gbps and higher.

According to the study, the use of modulators with optical communication transmitters at rates of 10Gbps and higher (but under 40Gbps) is forecast to maintain the lead in relative market share throughout 2013–2018. However,

the 40Gbps (and higher) category is forecast to increase at a faster annual pace and set to nearly catch-up in market share. "The dramatic push for faster bit-rates and extended connectivity of data centers, residential, mobile smart-phones, and smart network communications will eventually drive networks to incorporate optical interfaces beyond 100G," notes Stephen Montgomery, director of the Fiber Optics Component Group at ElectroniCast.

www.electronicast.com

Thermal management materials for LEDs and power electronics to grow from \$1.8bn in 2013 to \$4.8bn in 2020

Thermally conductive polymer market share to rise from 16% to 40%

The market for thermal management materials for light-emitting diodes (LEDs) and power electronics will more than double from \$1.8bn in 2013 to \$4.8bn in 2020, according to new report 'Cooling Heats Up: Sizing the Opportunity for Conductive Polymers in Thermal Management' (part of the Lux Research Energy Electronics Intelligence service). In particular, as manufacturers look for more cost-effective ways to improve heat dissipation, thermally conductive polymers will dramatically increase their market share, from 16% in 2013 to 40% (\$1.9bn) in 2020, adds Lux Research.

"Miniaturization and performance are creating a need for improved thermal management, driving sig-

nificant market growth and technology shifts," says analyst Pallavi Madakasira, lead author of the report. "Thermally conductive polymers offer a cost-effective and efficient alternative to incumbents like aluminium, making them an increasing critical material in this market."

Lux Research analysts sized up the market opportunity for thermal management in LEDs and power electronics, and identified top technology developers. Their findings include the following:

- LED lighting will be the main driver. Thermal management for LED lighting will more than double to \$3.8bn in 2020, led by aggressive growth in the residential and commercial markets, as well as

automotive LED lighting, which will reach \$730m in 2020.

- Thermal interface materials take off in smart-phones and tablets. The smart-phone and tablet thermal materials market will triple to more than \$300m in 2020. Given the sensitivity to weight and cost, these two end-markets will rely on special thermal interface materials (TIMs), rather than secondary heat-sinks.

- Solar and electric vehicles grow most rapidly, but use few polymers. Thermal materials for solar inverters and power modules in hybrid and electric vehicles will boom to \$170m in 2020. However, performance demands will limit the use of polymers in these applications to just a few million dollars.

www.luxresearchinc.com

Solid-state lighting to grow at 18.7% to \$56.79bn in 2018

Asia-Pacific exceeds 50% market share, growing at CAGR of over 25%

The global solid-state lighting (SSL) market is expected to rise at a compound annual growth rate (CAGR) of 18.7% from 2013 to \$56.79bn in 2018, according to a new market research report 'Solid State Lighting Market by Types (LED, OLED, and PLED), Application (General Lighting, Backlighting, Automotive, Medical), Verticals (Industrial, Residential, Consumer Electronics), Materials & Geography — Analysis & Forecast (2013–2018)' published by MarketsandMarkets.

The report segments the solid-state lighting market by types of SSL, applications and verticals. Types includes light-emitting diodes (LED), organic light-emitting diodes (OLED) and polymer-based light-emitting diodes (PLED). The SSL-based LEDs are further segmented by materials used at different stages of the manufacturing process (i.e. die level, package level, module level and luminaire

level). LED-based SSL is utilized primarily in general lighting and backlighting-based applications. In addition, as well as automotive lighting, the energy-efficient characteristics of SSL lighting technologies are being integrated with light-based medical applications, says the report. For example, surgical lighting has incorporated low-heat-dissipating LEDs, enabling comfortable working environment for surgeons and patients. Vertical markets for solid-state lighting include the automotive & transportation industry, residential & offices, consumer electronics, and the industrial sector.

OLEDs have a large market share in backlighting applications. Demand for OLED displays has been accelerating as they have diverse applications and better display features, says the market research firm. Going forward, with decreasing production costs, prices

of OLED panels will decline and OLEDs will further penetrate the display market, displacing LCD and LED display technologies, it is forecast. Many Asian companies have geared up to emerge as dominant players in the OLED equipment and materials market. OLED-based solid-state lighting is set to be one of the major SSL technologies in future, with a CAGR projected to exceed 25% in major applications such as general lighting, backlighting, automotive lighting and medical lighting.

In 2012, the Asia-Pacific (APAC) was the leading region in the overall solid-state lighting market (with 50% market share), followed by North America and Europe (with 23.9% and 19.9%, respectively). In the rest of the world (ROW), Russia, Brazil and the Middle East are the largest contributors (with a total share of 6.3%).

www.marketsandmarkets.com

RFMD's sales grow 48% year-on-year to record \$310.7m

For its fiscal second-quarter 2014 (ended 28 September 2013), RF Micro Devices Inc of Greensboro, NC, USA has reported record revenue of \$310.7m, up 6% on \$293m last quarter and 48.2% on \$209.7m a year ago. Growth is attributed mainly to generation-over-generation increases of RFMD's RF solutions in the industry's marquee smartphones.

Cellular Products Group (CPG) revenue was \$255.4m, up 7% on \$237.7m last quarter and 59% on \$160.4m a year ago. CPG benefited in the entry-level segment, with leading market share on major reference designs and expanded customer engagements with Xiaomi, Coolpad, Lenovo, Huawei and others. It also expanded its dollar content in the leading 4G LTE smartphones. CPG ramped production of new average power tracking (APT) and envelope tracking (ET) power amplifiers (PAs), PA duplexers, antenna control solutions, antenna switch modules, and diversity switches. It also saw favorable design activity for the carrier aggregation switch portfolio.

Multi-Market Products Group (MPG) revenue was \$55.2m, flat on \$55.3m last quarter but up 12% on \$49.2m a year ago. Growth spanned multiple markets, demonstrating stability in MPG's industrial and communications end-markets. In particular, high-performance Wi-Fi grew by 49% (across a range of mobile and CPE applications, including routers, access points and set-top boxes) and broadband cable TV and hi-rel applications both grew more than 20%. MPG also experienced strong design activity for its Wi-Fi front-ends for both mobile devices and consumer premises equipment.

RFMD's markets continue to grow with the expanding demand for high-performance, broadband connectivity. "The shift taking place in the entry-level from voice-centric 2G devices to 3G entry smartphones is doubling and even tripling our content opportunity, with an even greater jump anticipated with the

deployment of TD-LTE," says president & CEO Bob Bruggeworth. This is enabling RFMD to expand its dollar content generation-over-generation in the highest-tier smartphones as well as in the highest-volume entry-level phones and reference designs.

Solid financial performance is highlighted by "continued diversification, margin expansion and operating leverage," says Bruggeworth. On a non-GAAP basis, gross margin was 36.2%, up from 35.1% last quarter and 35.2% a year ago. Net income has risen from \$7.8m (\$0.03 per diluted share) a year ago and \$25.6m (\$0.09 per diluted share) last quarter to \$33.9m (\$0.12 per diluted share, exceeding guidance of \$0.10–0.11). During the quarter, the firm repurchased 2.4 million shares at an average price of \$5.03 (for \$12.1m in total). Operating cash flow was \$21.5m. Including investments in assembly capacity and equipment to reduce gold usage, capital expenditures were \$16.7m, with depreciation of \$11.3m and intangible amortization of \$6.7m. During the quarter, cash, cash equivalents and short-term investments fell from \$159.4m to \$149.5m.

"In the December quarter, RFMD anticipates another quarter of significantly improved financial performance, given our expectations for continued dollar content growth, expansion into new categories, and the benefit of ongoing new product ramps," says Bruggeworth. "We are increasing our participation on the industry's most critical reference designs and highest-volume devices, across all tiers, and we are executing on multiple opportunities to further expand our dollar content next year."

RFMD believes the demand environment in its end-markets supports expectations for sequential revenue growth in CPG (despite Tier 2 customer BlackBerry falling by perhaps \$10m). This should be partially offset by a sequential decline in MPG of 5–6% (about \$3m). Hence, total revenue should be

roughly flat to up 5% sequentially. RFMD expects gross margin to expand sequentially by 120 basis points, and earnings per share (EPS) to be \$0.13–0.14.

"RFMD is delivering diversified revenue growth and executing on our margin expansion initiatives," notes chief financial officer & VP of administration Dean Priddy.

"In April, we outlined our intent to expand RFMD's gross margins by 300–400 basis points by the March 2014 quarter. Now we expect to deliver on that goal this quarter," says Priddy. "RFMD has delivered 180 basis points of gross margin improvement since March, and we intend to deliver another 120 basis points this quarter. This is a result of an intense focus on cost reductions and our ongoing efforts in support of three key margin initiatives," he adds.

"First, RFMD has transitioned to a flexible GaAs sourcing strategy. As part of this, we have sold our UK fab [in Newton Aycliffe]. We consistently stated that this will support approximately half of our gross margin expansion goal, and we now expect to achieve the full benefit of that goal this quarter," continues Priddy.

"Second, RFMD is seeing very strong adoption of our ultra-low-cost CMOS PAs and next-generation handset platforms targeting emerging markets. Over time, we intend to migrate all of our customers for 2G PAs to this product family.

"Third, we have installed and qualified additional assembly capacity in our Beijing facility. And we've begun capturing the benefit of this investment in the December quarter," Priddy notes.

"Beyond December, our confidence in margin expansion allows us to project margin improvement in a seasonally down March quarter [typically down 10–15%]," he adds. "For the first time in recent history, we can look into the next calendar year [2014] and project achieving our quarterly non-GAAP gross margin model of 40%."

www.rfmd.com

RFMD begins high-volume production of envelope tracking power amplifiers and power management ICs

RF Micro Devices Inc of Greensboro, NC, USA has begun high-volume production of multiple new power amplifiers (PAs) and power management integrated circuits (ICs) that incorporate the firm's envelope tracking (ET) technology. RFMD says that its unique ET technology enhances power efficiency in new LTE platforms, resulting in longer battery life across all modes and bands, increased network coverage, and higher-data-rate throughput.

Unlike traditional PAs that operate with a constant supply voltage, the supply voltage applied to RFMD's

ET-enabled PAs is continuously adjusted so that the amplifier operates at maximum power efficiency. The result is much lower battery power consumption, particularly in LTE platforms.

RFMD says that its expanding ET product portfolio is tailored for leading LTE chipsets and provides full ET-compatible coverage of all FD-LTE and TD-LTE bands (1–14, 17–21, 25–28, 38, 40, 41 and 44). The portfolio includes the RF7389 and RF8085 multi-mode, multi-band PAs, the RF80xx(i) family of 10 single-band satellite PAs, and the

RF8081 ET power management IC.

The firm's technology is well suited for the power demands of new LTE platforms now being rolled out worldwide, reckons Eric Creviston, president of RFMD's Cellular Products Group. "RFMD is very well positioned with power management technologies such as envelope tracking and average power tracking to expand our RF content in the newest generation of smartphones, tablets, ultrabooks and machine-to-machine (M2M) applications."

www.rfmd.com

TriQuint introduces 2.5W 2100MHz integrated small-cell power amplifier module, halving board space

RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has introduced its first integrated power amplifier solution for small-cell and active antenna base-stations, dramatically reducing board space while delivering high efficiency, the firm says. Small-cell solutions are key components in 3G/4G mobile networks including LTE.

TriQuint's TGA2450-SM integrated small-cell power amplifier is the first in a family serving all key mobile infrastructure frequency bands. The new power amplifier and other integrated solutions for base-station, networks and defense applications were exhibited at European Microwave Week (EuMW 2013) in Nuremberg, Germany (8–10 October).

Small-cell radio systems have deliberately defined coverage areas that can improve connectivity where it is most needed. The radio transceivers in these systems are smaller by design to support indoor or outdoor deployment, as required. By significantly reducing board space, network infrastructure OEMs can reduce the size of radio

systems and their bills of materials.

"The market trend is towards more densely packed, smaller radio links - small cells," notes James L. Klein, TriQuint's Infrastructure and Defense Products VP & general manager. "TriQuint's highly integrated solution offers the flexibility to support our customers' emerging designs," he adds. "Our product family uses only half the space of traditional discrete parts."

Infrastructure researcher Earl J. Lum reports that small-cell and active antenna solutions will be a growing part of infrastructure and future heterogeneous networks supporting faster 3G/4G data rates. "Highly integrated power amplifier solutions such as the TGA2450-SM and filtering technology offered by TriQuint support additional network capacity, higher-efficiency systems and reduced system bill of materials (BOMs)," says Lum, president of ETL Wireless Research. "The overall LTE outdoor microcell market is expected to begin high-volume shipments in 2014 and reach \$1.8bn by 2017," he adds.

The TGA2450-SM is a fully integrated surface-mount 3-stage power

amplifier module suited to 3G and 4G small-cell base-station applications with 1W RMS power at the antenna. The module is 50 ohm input and output and requires minimal external components. It is also compact (supplied in a 20mm x 20mm SMP package) and offers a much smaller footprint than traditional discrete component solutions, TriQuint says.

The TGA2450-SM incorporates a Doherty final stage delivering high power-added efficiency of 35% for the entire module at 2.5W average power. Three-stage gain is 35dB. Peak power is 18W. Operating at 2.11–2.17GHz and supporting multi-mode and multi-carrier signals (for W-CDMA and LTE bands 1, 4 and 10), the module includes InGaP/GaAs heterojunction bipolar transistor (HBT) device technology to provide a combination of high efficiency and DPD (Data Processing Design) friendliness. Typical applications include 3G/4G wireless infrastructure, BTS transceivers/repeaters, heterogeneous networks, and MIMO.

Samples and evaluation fixtures of the TGA2450-SM are available now.

www.triquint.com

TriQuint's Q3 revenue grows 32% on Q2, driven by demand for LTE products and product ramp

Charge of \$20–25m expected in Q4 on reduction of GaAs capacity to align with projected demand for the process technology

For third-quarter 2013, RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has reported record revenue of \$250.8m, up 25% on \$200.8m a year ago and up 32% on \$190.1m last quarter.

Subcontract assembly firms Foxconn Technology Group and ProTech Corp accounted for 35% and 13% of total revenue, respectively.

End-market revenue split was:

- 72% Mobile Devices (up strongly from 62% last quarter);
- 16% Network Infrastructure (down from 24%); and
- 12% Defense & Aerospace (down slightly from 14%).

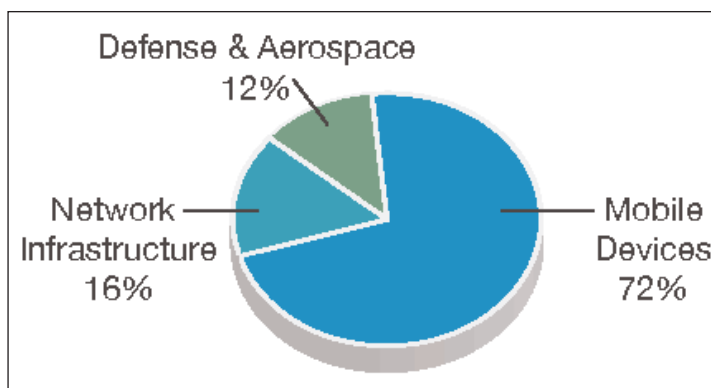
Mobile Devices revenue grew 53% sequentially and 42% year-on-year, driven by demand for new LTE products and a significant product ramp.

Defense & Aerospace revenue grew 11% sequentially and 28% year-on-year, due primarily to airborne radar (up 50% year-to-date, driven by program timing, increased content in radar systems, and more radar products are the revenue increase).

Network Infrastructure revenue was up 4% year-on-year but down 11% sequentially, due largely to a reduction in non-strategic foundry business.

"Strong mobile demand drove improved factory utilization while expenses were managed closely," notes president & CEO Ralph Quinsey. On a non-GAAP basis, gross margin was 38%, up from 31.3% last quarter due to higher revenue and the improved factory utilization, as well as better product mix and efficient management of production ramp.

Operating expenses were \$68.6m, down by \$1m on \$69.6m last quarter.



Breakdown of TriQuint's Q3/2013 revenue by end-market.

Net income was \$26.3m (\$0.16 per diluted share, exceeding guidance by \$0.06), an improvement on a net loss of \$10.9m (\$0.07 per share) last quarter.

Capital expenditures of \$20.8m were well below quarterly depreciation and primarily for TriQuint's premium filter products.

During the quarter, cash and investments fell by \$62.4m, from \$89.3m to \$26.9m, due mainly to a \$75m increase in accounts receivable (due to growth in revenue and the poor linearity in timing of shipments within the quarter) and repayment of the \$20m balance on TriQuint's revolving line of credit.

In August, TriQuint acquired CAP Wireless of Newbury Park, CA, USA and its patented Spatium RF power combining technology, which replaces travelling-wave tube amplifiers (TWTAs) in communications and defense systems. The acquisition "will leverage TriQuint's strong position in gallium nitride (GaN) with very high-

RF content growth is being fueled by next-generation smartphones operating in a more crowded spectrum with expanding frequency requirements

power solid-state amplifiers that deliver better reliability, efficiency, power density and bandwidth than tube-based solutions in the market today," notes Quinsey.

Also during the quarter, TriQuint won business with multiple cus-

tomers with its new bulk acoustic wave (BAW) filter products, announced 5G Wi-Fi reference designs with Broadcom, introduced the what is claimed to be the industry's most integrated small-cell power amplifier (for increasing network capacity), and released new 100–200Gb/s solutions (to support the global build-out of optical fiber networks).

"RF content growth is being fueled by next-generation smartphones operating in a more crowded spectrum with expanding frequency requirements," says Quinsey. "TriQuint is uniquely positioned to supply high-performance solutions for the most challenging and complex RF front-end requirements."

For fourth-quarter 2013, TriQuint expects revenue to rise to \$260–270m. However, gross margin should fall to 35–36%, as TriQuint's factories slow down slightly in anticipation of a seasonally weaker Q1/2014. Operating expenses are expected to rise to \$70–72m. Net income should fall to \$0.12–0.14 per diluted share. "We currently expect to take a non-cash charge of \$20–25m as we reduce our GaAs capacity to better align with projected demand for this process technology," comments chief financial officer Steven Buhaly.

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IN BRIEF

Anadigics exhibits DOCSIS 3.1 CATV RF infrastructure amplifiers at SCTE Cable-Tec

At the Society of Cable Telecommunications Engineers (SCTE) Cable-Tec Expo 2013 in Atlanta (22–24 October), broadband wireless and wireline communications component maker Anadigics Inc of Warren, NJ, USA exhibited its portfolio of cable television (CATV) RF infrastructure products, such as its new family of DOCSIS 3.1 solutions that includes what is claimed to be the industry's first 1.2GHz gallium nitride (GaN) surface-mount line amplifier (the ACA2429, launched in July).

Anadigics says that its complete portfolio of CATV infrastructure solutions combines linearity with ruggedness and reliability to ensure ultra-fast data throughput and high-quality video delivery, while minimizing downtime and service calls. The new DOCSIS 3.1 product family — which includes power doubler and push-pull line amplifiers, Edge QAM amplifiers, reverse path amplifiers, and optical receivers — is optimized to support high signal fidelity over extended frequencies up to 1.2GHz with a 'high-split' return path.

Anadigics says that the new RF amplifiers leverage proven high-linearity gallium arsenide (GaAs) process and high-reliability package technology (for long mean-time-to-failure rates) along with GaN high-electron-mobility transistor (HEMT) technology (for high output power and optimum power efficiency).

<http://expo.scte.org>

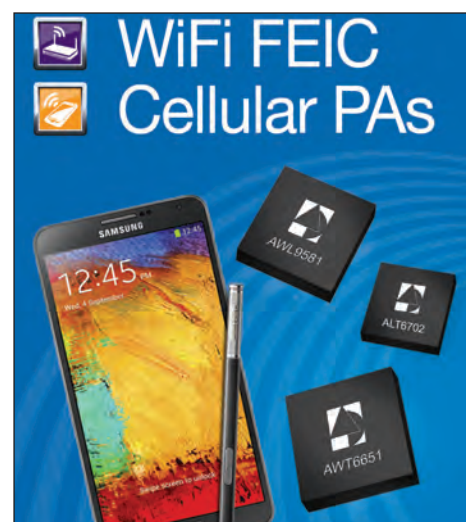
www.anadigics.com/products/catv

Anadigics' WiFi and cellular solutions powering Samsung GALAXY Note 3

Anadigics Inc of Warren, NJ, USA says that its AWL9581 802.11ac front-end integrated circuit (FEIC), AWT6651 ProEfficient power amplifier (PA), and ALT6702 HELP4 PA are enabling wireless connectivity in Samsung Electronics' new GALAXY Note 3. The GALAXY Note 3 improves upon the Note II (which is also powered by Anadigics' RF solutions) by providing a larger 5.7" HD Super AMOLED display, faster processor, slimmer size and longer battery life.

The GALAXY Note 3 is the latest in a wide range of Samsung mobile devices (including the S 4, S 4 Mini, Tab 3 and Mega) that are powered by Anadigics' RF products, says president Dave Cresci. "We look forward to continuing our collaboration with Samsung on their next generation of phones and tablets," he adds.

The AWL9581 5GHz FEIC, AWT6651 ProEfficient PA and ALT6702 HELP4 PA all leverage Anadigics' exclusive InGaP-Plus technology and patented design architectures. The firm's 802.11ac FEICs combine a power amplifier, low-noise amplifier (LNA) and RF Tx/Rx switch on a single die (in a compact 2.5mm x 2.5mm x 0.4mm QFN package) to improve manufacturability and reliability. Also incorporating a high-accuracy integrated power detector and RF ports internally matched to 50 Ohms, this level of integration also reduces PCB space requirements and simplifies RF front-end design for faster time-to-market, says Anadigics. The complete family of 802.11ac FEICs offers ultra-low error vector magnitude (EVM) and noise figure performance in the toughest 802.11ac modulation formats, enabling extremely high data throughput. Anadigics claims that its WiFi front-end integrated circuits deliver the industry's lowest current consumption, extending battery-life in mobile applications.



ProEfficient power amplifiers provide high efficiency across all power modes to extend 3G and 4G talk time and data use for longer overall battery life with or without the use of a DC–DC converter. The power amplifiers are optimized for use with average power tracking (APT) to further increase efficiency and reduce current consumption at medium and low operating powers. The compact 3mm x 3mm package incorporates internal voltage regulation and integrated DC blocks on the RF ports to reduce PCB space requirements. It also integrates high-directivity coupler for ease of system integration. RF matching is optimized for output power, efficiency and linearity in a 50Ω system.

HELP4 power amplifiers offer three mode states to optimize power-added efficiency at low-range and mid-range output power levels. HELP4 PAs allow a high level of integration in a 3mm x 3mm footprint (with DC blocks on RF ports and internal voltage regulation) to save PCB space, as well as an integrated 'daisy chainable' directional RF coupler with 20dB directivity.

ProEfficient and HELP4 power amplifiers also deliver what is claimed to be best-in-class linearity to ensure stable, high-throughput 3G/4G connections for clear voice and high-speed data usage.

www.anadigics.com



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UMS makes available enhanced PDKs using Agilent's latest ADS EDA software

United Monolithic Semiconductors (UMS), which designs and produces RF, microwave and millimeter-wave components and ICs at its facilities in Orsay, France and Ulm, Germany, has made available enhanced process design kits (PDKs) by using the latest product innovations in Agilent Technologies' Advanced Design System (ADS) electronic design automation software.

UMS offers a proven family of III-V semiconductor material based processes for low-noise and high-power monolithic microwave integrated circuits (MMICs) for the defense, automotive, space, telecom, and industrial markets.

"Our foundry customers expect an integrated tool flow that addresses their RF and microwave design challenges and enables them to achieve first-time-right designs," says Eric Leclerc, manager of UMS' foundry business department. "By

leveraging the latest ADS capabilities in our PDKs, we are providing our mutual customers a greatly enhanced front-to-back MMIC design flow with scalable devices and integrated 3D EM engines with unified stack-up that provide native air-bridge, via hole and dielectric opening descriptions. This further improves design accuracy and efficiency beyond existing capabilities like native design rule check and layout-versus-schematic check," he adds.

"We collaborated with UMS to incorporate advanced electromagnetic analysis, like native air-bridge support, and the latest ADS enhancements in their PDKs," says Juergen Hartung, foundry program manager of Agilent's EESof EDA division (which supplies EDA software for microwave, RF, high-frequency, high-speed digital, RF system, electronic system-level,

circuit, 3D electromagnetic, physical design and device-modeling applications). "With these kits, our customers can now enjoy the industry's most comprehensive multi-technology design platform using Momentum, the industry-leading 3D planar electromagnetic simulator, and our integrated full 3D Finite-Element-Method engine," he adds. "For customers, that means increased performance, consistency, and yield."

The updated PDKs work seamlessly with ADS 2012.08 and ADS 2013.06. All PDKs support a complete ADS front-to-back MMIC design flow, including schematic-driven layout creation, layout-versus-schematic, design rule check, and integrated 3D planar and finite-element method electromagnetic simulation.

www.ums-gaas.com

www.agilent.com/find/eesof-ads

Hittite's Q3 revenue and profit exceed guidance

For third-quarter 2013, Hittite Microwave Corp of Chelmsford, MA, USA (which designs and supplies analog, digital and mixed-signal RF, microwave and millimeter-wave ICs, modules and subsystems as well as instrumentation) has reported revenue of \$68.7m (slightly above the forecasted \$66.5-68.5m), up slightly on \$68.6m last quarter and up 2.3% on \$67.2m a year ago.

Of total revenue, 43.4% (\$29.8m) came from customers in the USA

(versus 44%, or \$30.2m, last quarter) and 56.6% (\$38.9m) came from customers outside the USA (versus 56%, or \$38.4m, last quarter).

Gross margin has fallen further, from 73.6% a year ago and 72.4% last quarter to 71.2%. Nevertheless, operating income has risen from \$27.6m (41% of revenue) a year ago and \$27.5m (40.1% of revenue) last quarter to \$28m (40.7% of revenue).

Likewise, net income has risen further, from \$17.7m a year ago and \$18m last quarter to \$18.7m, exceeding the \$16.7-17.7m guidance. During the quarter, total cash and marketable securities rose by \$19.2m, from \$438.2m to \$457.3m.

For fourth-quarter 2013, Hittite expects revenue to fall slightly to \$66.5-68.5m and net income to fall to \$16.7-17.7m.

www.hittite.com

Hittite elects former Microchip chairman Steve Sanghi to board

Hittite's board of directors has elected Steve Sanghi as a member of the board.

Hittite says that Sanghi brings significant industry and management expertise. He has served for more than 20 years as chairman, president & CEO of Microchip Tech-

nology Inc, which manufactures specialized semiconductor devices for control applications. He also serves on the board of directors of Xyratex Ltd, and is chairman of the board of private company FlipChip International and FIRST (a non-profit organization formed

to inspire young students in their interest in science, technology, engineering and maths).

"His experience and background is well suited to serve Hittite's needs as we implement our strategy for the future," comments chairman Franklin Weigold.

MACOM launches highly integrated plastic-packaged control MMIC for commercial radar

M/A-COM Technology Solutions Inc of Lowell, MA, USA, which makes semiconductors, components and subassemblies for RF, microwave and millimeter-wave applications, has launched what it claims is the industry's first integrated core chip for the 8–11GHz frequency range. Containing 6-bits of phase control, 6-bits of attenuation control and 26dB of gain, the core chip is an easy-to-use serial/parallel interface in a surface-mount QFN package. Suitable for commercial radar applications, the integrated MMIC enables radar systems in early detection and warning for severe impending weather.

The X-band core chip (MAMF-011015) is a highly integrated solution that the firm claims sets new standards for size, weight and performance (SWaP), enabling the next generation of radar system design. Building on a legacy of product design across the entire frequency range, the X-band core chip integrates a CMOS logic driver with a GaAs transmit/receive MMIC within a single QFN package. The

surface-mount 7mm x 7mm plastic package offers a cost-effective, easy-to-implement solution, the firm claims. The device's versatility and flexibility make it suitable for weather, wildfire and related commercial radar applications.

"The device offers a unique combination of QFN surface-mount packaging with advanced MMIC design integration to provide a simple and effective solution for next-generation X-band weather radar systems," says product manager Paul Beasley.

The X-band core chip development is a product of a joint investment between MACOM and FIRST RF Corp of Boulder, CO, USA to support new weather radar programs such as the Collaborative Adaptive Sensing of the Atmosphere (CASA) Weather Radar Program. CASA is a multi-sector partnership among academia, industry and government that is dedicated to engineering revolutionary weather-sensing networks. The networks save lives and property by detecting the region of the lower atmosphere currently below

conventional radar range - mapping storms, winds, rain, temperature, humidity, and the flow of airborne hazards.

"The X-band core chip provides us with an integrated, surface-mount solution that allows for high-yield automated assembly, smaller-footprint design and improved reliability — enhancements which empower us to quickly identify critical weather systems, to protect people and property, and mitigate damage," says FIRST RF's president Theresa Boone.

The packaged device consists of a common leg circuit that includes digital attenuators, phase shifters, a low-noise receive chain, and a transmit driver amplifier, as well as a CMOS logic driver. The integrated circuit uses MACOM's 0.25µm pHEMT process, which has been optimized for high-power and low-noise amplifiers, passive and control components, and allows for a high level of integration on a single MMIC.

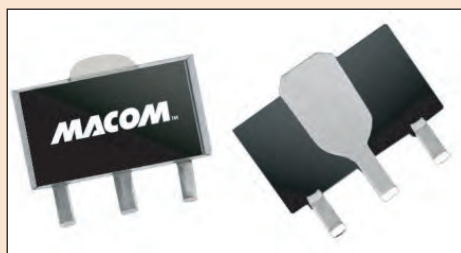
www.macomtech.com

www.firstrf.com

5W GaN power transistor in SOT-89 surface-mount plastic package

At European Microwave Week (EuMW 2013) in Nurnberg, Germany (6–11 October), M/A-COM Technology Solutions launched a gallium nitride (GaN) unmatched wideband transistor in an SOT-89 package that is suited to 50V operation in driver and power applications.

MACOM says that the MAGX-000040-00500P is an effective solution for those needing a reliable power device with wideband performance and high-voltage operation. Operating over DC-4.0GHz frequency bandwidth, the device is packaged in a lightweight 2.5mm x 4.5mm SOT-89 plastic surface-mount package that allows easy implementation and



MACOM's GaN unmatched wideband transistor in SOT-89 package.

assembly, it is claimed. The transistor delivers reliable operation at junction temperature of 158°C in CW mode, with the device being rated to a maximum junction temperature of 200°C. With small size, surface-mount assembly and reliable high-voltage operation, the device provides a high-performing

alternative to traditional flanged or metal-backed module components, says the firm.

"RF and microwave designers are continuously challenged to improve size, weight and performance (SWaP) of radar and communication systems," says product manager Paul Beasley. "The newest 5W addition to the GaN in Plastic family extends MACOM's leadership in supporting customers to meet design challenges with the key advantages of 50V bias, CW operation and small-size, surface-mount plastic packaging."

Production quantities and samples of MAGX-000040-00500P are available from stock.

www.macomtech.com/gan

IN BRIEF

Skyworks receives awards from Lenovo

Skyworks Solutions has received the Outstanding Supplier and Perfect Quality awards from China's Lenovo for "product innovation, delivering perfect quality solutions and serving as a strategic partner". Skyworks is Lenovo's leading provider of analog and RF solutions, having supported it through several major product launches and growth in market share. Lenovo leverages a variety of Skyworks' products including SkyHi front-end solutions, multi-mode multiband power amplifiers, switches, diodes and global positioning system devices.

"Over the past few years Skyworks and Lenovo have forged a strong relationship, one that has grown even stronger as Lenovo has become much more than a PC company," says David Wang, VP of procurement at Lenovo. "We are delighted with Skyworks' reliable, high-quality and turnkey solutions, and look forward to collaborating with them for years to come, particularly as Lenovo expects to grow its market share in China and abroad," he adds.

"We are delighted to be partnering with Lenovo to enable a variety of personal technology platforms including smartphones, tablets and smart television with an increasing number of our analog and connectivity solutions," says Kenneth J. Huening, VP of quality at Skyworks.

With sales growing in India, Indonesia, the Philippines, Russia and Vietnam, market research firm Gartner predicts that Lenovo will become China's top smartphone vendor in 2013. According to IDC, Lenovo already has the third highest worldwide market share for 'Smart Connected Devices' (which combines PC, smartphones and tablets).

www.lenovo.com

Skyworks partners with WNC on connected home solutions

Skyworks Solutions Inc of Woburn, MA, USA is partnering with Asia-based original device manufacturer (ODM) Wistron NeWeb Corp (WNC), which supplies connected home solutions for a number of branded original equipment manufacturers (OEMs). WNC is leveraging Skyworks' power management and ZigBee front-end modules for several of their low-power RF devices that, among other things, allow consumers to turn lights on and off, automate appliances, monitor security cameras and control other things around the home from anywhere via their smartphone.

"WNC is pleased to be collaborating with Skyworks to deliver easily integrated products for the connected home," says Fa Yu Chen, VP of automotive and digital media business at WNC. "Our ability to develop well thought out platforms from conception to volume production complements Skyworks' best-in class solutions."

"With the connected home market expanding, Skyworks is delighted to work closely with WNC, a leading global manufacturer of products for smart home applications," says Bradley C. Byk, senior VP of worldwide sales at Skyworks. "Together we are creating innovative wireless solutions for brand-name enterprises, system operators and content service providers – ultimately allowing consumers to enjoy the full power of mobile connectivity."

As cited in GSMA's Vision of Smart Home: The Role of Mobile in the Home of the Future report, combined revenue from the smart metering, home automation and home energy management segment is forecasted to generate more than \$44bn in 2016, according to market research firms ABI and Berg Insight. The overall revenue potential of the smart home is expected to be even higher as devices from the entertainment, health and home security sectors also become connected.

Partnering with WNC expands Skyworks presence in the fast-growing connected home market. In June, Skyworks also announced it is supporting SMC Networks for home security, monitoring and automation solutions.

Skyworks' connected home solutions include the following products:

- AAT4712 — a programmed, current-limited, P-channel, metal-oxide-semiconductor field-effect transistor (MOSFET) power switch designed for high-side, load-switching applications. With the programmed current limit, the integrated circuit ensures that the power ratings of the host are not exceeded and balances the system load and supercap-charging current automatically to provide enough

Revenue potential of the smart home is expected to be even higher as devices from the entertainment, health and home security sectors also become connected

system-load current in top priority. The integrated discharge-path control assures that the system load can be supported in the short term until the input power has

fully charged the supercap.

- SE2432L — a 2.4GHz fully integrated RF front-end module (FEM) designed for ZigBee and smart-energy applications. Designed for ease-of-use and maximum flexibility, the FEM contains integrated, fully matched input baluns, integrated inter-stage matching and harmonic filter, and digital controls compatible with 1.6–3.6V CMOS levels. The RF blocks operate over a wide supply voltage range of 2.0–3.6V, allowing the device to be used in battery-powered applications over a wide spectrum of the battery-discharge curve.

www.skyworksinc.com

Peregrine launches carrier-grade Wi-Fi switch delivering 50 times more isolation and 10 times better linearity for 802.11ac Wi-Fi access points

Peregrine Semiconductor Corp, of San Diego, CA, USA, a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-sapphire (SOS), has announced what it claims is the highest-performance, carrier-grade Wi-Fi switch on the market. With the highest isolation by a factor of 50, the switch (which provides support for 802.11 a/b/g/n/ac) also sets a new level for linearity, making it suitable for the fast-growing market of 802.11ac Wi-Fi access points.

"Mobile Experts' research shows the number of carrier-grade Wi-Fi access points deployed has grown 40% this year alone," says Joe Madden, founder & principal analyst at Mobile Experts. "With the Wi-Fi market shift to dual-band 802.11ac support, we predict the market for RF suppliers – such as Peregrine – will grow even faster at a rate of 50% annually through 2016," he adds.

The rising amount of cellular-data offload to Wi-Fi networks is significantly increasing the complexity of access-point radios, says Peregrine. Most Wi-Fi access points now contain multiple radios in order to address the capacity demands of cellular data. Based on Peregrine's UltraCMOS technology, the PE42423 is claimed to be the first in its class to offer 41dB of port-to-port isolation at 6GHz, enabling multi-radio access points to perform at peak levels without interference between the radios. Exceeding the stringent 802.11ac standard, the switch also offers 65dBm of linearity to achieve higher data rates. In addition, UltraCMOS technology delivers equally high performance at either 3.3V or 5V, unlike gallium arsenide (GaAs) switches that experience severe performance degradation below 5V, Peregrine says. The switch gives networking-product designers the flexibility to operate at lower power supplies and reduce energy consumption, the firm reckons.

"Peregrine is committed to meeting the Wi-Fi data-rate and capacity demands of the future, and we are already helping networking vendors achieve unprecedented performance using this switch in their Gigabit Wi-Fi access points," says Dave Shepard, VP of Peregrine's high-performance solutions business unit.

Now shipping, the PE42423 is a single-pole double-throw (SPDT) Wi-Fi RF switch covering 100MHz to

6GHz and featuring low insertion loss (0.8dB @ 2.4GHz, 0.95dB @ 5.8GHz), fast switching time (500ns) and high ESD ratings (3.0kV HBM on all RF pins). The switch supports +1.8V standard logic control, and provides stable RF performance over a wide power supply range of 2.3–5.5V. The 3mm x 3mm 16-lead QFN package is RoHS-compliant.

www.psemi.com



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Skyworks' FEMs supporting Broadcom 5G WiFi platforms

Skyworks Solutions Inc of Woburn, MA, USA says that its wireless connectivity front-end modules (FEMs) are being used by Broadcom Corp in several of its 5G WiFi solutions, enabling some of the fastest download speeds available in access points, routers, DSL/cable gateways, PCs, smartphones and tablets.

Skyworks' complete 2.4 and 5GHz 802.11a/g/n/ac solutions integrate power amplifier, filter, power detector, transmit/receive (T/R) switch, diplexer and associated matching in an ultra-compact form factor, delivering all the essential functionality from the output of the SOC to the antenna.

"With digital content consumption on the rise, particularly as consumers watch video on more devices and in more places around the home, Broadcom is closely collaborating with Skyworks to deliver solutions that offer the industry's fastest wireless speeds and enhance the overall user experience," comments Dino Bekis, VP of marketing, Wireless Connectivity at Broadcom.

"Broadcom and Skyworks have a long history of partnering to deliver market leading solutions with performance and cost advantages for both manufacturers and consumers," says Liam K. Griffin, executive VP & corporate general manager at Skyworks. "This engagement comes as market demand for 5G WiFi is accelerating across developed and emerging markets."

By next year, 802.11ac is expected to be the dominant standard and its reach is expected to go well beyond just smartphones, tablets and computers. According to a study by Strategy Analytics, sales of consumer devices compatible with 802.11ac, including routers and gateways, will grow and surpass 1 billion units by the end of 2015 and 2.8 billion in 2017. The 802.11ac deployment will initially involve smartphones and tablets, with connected televisions, media players and other devices to follow.

Designed to meet stringent linearity conditions of 802.11ac standard, Skyworks' SE5516A delivers < 2% error vector magnitude (EVM) at rated AC power. All RF ports are matched to 50Ω to simplify printed circuit board layout and the interface to the transceiver RFIC. The device also includes a transmitter power detector with 20dB of dynamic range for each transmit chain. Each power amplifier (PA) has a separate digital enable control for transmitter on/off control. The power ramp rise/fall time is less than 0.4μs. It also provides a notch filter from 3.260–3.267GHz prior to the input of each 2.4GHz and 5GHz PAs, respectively. The device is housed in a 4mm x 4mm x 1mm halogen- and lead-free, restriction of hazardous substances (RoHS)-compliant, moisture sensitivity level 3 (MSL3) land grid array package.

The SKY85302-11 is a complete 802.11ac WLAN RF FEM with a Bluetooth port. It provides all the functionality of a fully matched PA, power detector, harmonic filter, low-noise amplifier (LNA) and single-pole, triple-throw switch. It also provides a complete 2.4GHz solution from the output of the transceiver to the antenna, and from the antenna to the input of the transceiver. The LNA increases the receive sensitivity of embedded solutions to improve range or to overcome the insertion loss of cellular filters, often included for mobile applications. The device also includes a transmitter power detector with 20dB of dynamic range, and a digital-enable control for transmitter power ramp on/off control. The FEM is also provided in a compact 16-pin, 2.5mm x 2.5mm, quad-flat, no-lead (QFN) package.

The SKY85706-11 is a highly integrated 5GHz FEM incorporating a single-pole, double-throw T/R switch, an LNA with bypass, and a PA intended for mobile/portable, 802.11n/ac applications and systems. An enable/disable function is included, allowing power savings during off mode. Also, an integrated power detector with 20dB of dynamic range is included to provide closed-loop power control within the system. The FEM comes a 16-pin, 2.5mm x 2.5mm QFN package.

www.skyworksinc.com

www.broadcom.com

Hittite adds 10W, 6–18GHz PA to GaN MMIC range

Hittite Microwave Corp of Chelmsford, MA, USA has launched a gallium nitride (GaN) MMIC power amplifier (PA) that is claimed to offer significant performance, size and durability advantages for communications, test instrumentation and radar systems operating in the 6–18GHz frequency range.

The HMC7149 is a 10W GaN MMIC PA that typically provides 20dB of small-signal gain and +40dBm of

saturated output power. It draws 680mA quiescent current from a +28V_{DC} supply and features RF I/Os that are matched to 50Ω for ease of use.

The PA also offers high-output-power capability, a compact die size and simplified biasing, which make it suitable for integration into high-power-density multi-chip module (MCM) and subsystem applications.

The HMC7149 is Hittite's fifth

GaN MMIC amplifier to be launched during 2013, following the 2–6GHz, 25W HMC1086 and HMC1086F10 and the 2–20GHz, 8W HMC1087 and HMC1087F10 power amplifiers (launched in July).

All five GaN MMIC PAs complement Hittite's line of microwave power amplifiers, which provides continuous frequency coverage from 0.01GHz to 86GHz.

www.hittite.com

RFaxis demonstrates pure CMOS 802.11ac RF front-end ICs at Broadband World Forum

Fabless semiconductor firm RFaxis Inc of Irvine, CA, USA, which designs RF semiconductors and embedded antenna solutions for wireless connectivity and cellular mobility, demonstrated and showcased its pure CMOS 802.11ac RF front-end IC (RFeIC) technology at the Broadband World Forum 2013 in Amsterdam, The Netherlands (22–24 October).

"Our products being demonstrated at the Broadband World Forum are designed to support the latest generation of broadband wireless access and media/entertainment devices, including home and enterprise access point (AP)/routers, set-top boxes, HD video bridges, media servers, and handsets/tablets," says chairman & CEO Mike Neshat.

All featured RFaxis products are pin-to-pin compatible with existing solutions available on the market based on more expensive com-

pound semiconductor processes, says RFaxis. The products being showcased are as follows:

- RFX8050: A highly integrated, single-chip, single-die RFeIC that incorporates key RF functionality needed for IEEE 802.11ac WLAN systems operating in the 5.15–5.85GHz range.

- RFX8051: Provides the same key features and functionalities as the RFX8050 but in a 3mm x 3mm x 0.55mm package.

- RFX8422S: A fully integrated, single-chip, single-die RFeIC that incorporates all the RF functionality needed for dual-mode IEEE 802.11b/g/n/ac WLAN and Bluetooth operations including simultaneous WLAN and Bluetooth receive capability.

Products are pin-to-pin compatible with existing solutions on the market

- RFX240: A high-power, high-linearity power amplifier implemented in CMOS. The device is optimized to provide all functionality of transmit power amplification for IEEE 802.11g/n/ac applications in the 2.4GHz frequency range.

RFaxis' product portfolio supports a range of products and technologies serving a broad base of customers across multiple high-growth market segments besides core WLAN applications. The firm's products and technology are designed and optimized for use in broadband, high-bandwidth devices, multimedia and enterprise access point/router markets in addition to entry-level access point/routers, as well as devices and components for handset, smartphone, tablet, and laptop computing WiFi-enabled clients.

www.rfaxis.com

www.broadbandworldforum.com

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RFMD unveils 1.2GHz power doubler amplifier supporting new DOCSIS 3.1 cable specification

RF Micro Devices Inc of Greensboro, NC, USA has unveiled its first power doubler amplifier in a multi-chip module to support the demands of the new data over cable service interface specification (DOCSIS) 3.1.

RFMD says that its new gallium nitride (GaN)-based RFCM3316 allows cable operators and MSOs (multiple systems operators) to easily upgrade existing CATV infrastructure to meet the power amplifier requirements of the new DOCSIS 3.1 standard, increasing effective downstream data rates from 160Mb/s to 10Gb/s and upstream data rates from 120Mb/s to 1Gb/s compared to DOCSIS 3.0. The firm says that, due to the high output and gain benefits derived from the GaN-based RFCM3316, cable operators can upgrade their

existing equipment within current locations, saving on both installation time and cost, as well as extending the life of existing networks.

The RFCM3316 is a drop-in replacement to its predecessor, the RFCM2680, combining a small footprint with adjustable current consumption. "Early customer feedback has been positive, and we look forward to supporting them as they roll out new DOCSIS 3.1-compliant products beginning in early 2014," says Norm Hilgendorf, president of RFMD's Multi-Market Products Group.

The RFCM3316 operates from 40MHz to 1200MHz and provides a high output level of 60dBmV under a 1.2GHz channel loading with $<10^{-10}$ BER (bit error ratio) and 42dB MER (modulation error ratio) and -80dB CTB and -80dB CSO

distortion products. The modular, surface-mount device saves about 50% in board space compared to traditional SOT115J packages, while maintaining linearity and ruggedness, says RFMD. Due to the efficient nature of the GaN process, the product can also operate at 20% less current than GaAs-based products at a comparable distortion level.

The RFCM3316 is sampling with key customers, and volume production is due to begin in first-quarter 2014.

RFCM3316 is the newest addition to RFMD's differential amplifier family developed for CATV transmission, which includes power doublers and push-pull amplifiers. RFMD showcased its CATV component portfolio at the SCTE Cable-Tec Expo in Atlanta, Georgia (22–24 October).

www.rfmd.com

TriQuint expands CATV infrastructure portfolio with GaAs & GaN hybrid and MMIC power doubler amplifiers

At the SCTE Cable-Tec Expo (22–24 October), TriQuint Semiconductor Inc of Hillsboro, OR, USA has launched the first two members of its cost-effective TriAccess hybrid-packaged power doubler family. The CATV infrastructure devices are the first to utilize proprietary on-die linearization for what is claimed to be best-in-class performance including excellent gain and low distortion. TriQuint has also announced full production of two new GaN MMIC power doublers for CATV infrastructure.

TriQuint is now sampling its new GaN and GaAs hybrid power doublers as well as its MMIC power doublers.

TriQuint says that its fully released and wide-ranging CATV portfolio includes both hybrid package and surface-mount package (SMP) products that can reduce part counts and improve performance in 12–24V systems. The new hybrid products with on-die linearization complement the firm's recently

released 1200MHz, 12V GaAs and 24V GaN surface-mount devices. TriQuint is a vertically integrated CATV/FTTH solutions provider with all key technologies in-house, enabling what is claimed to be cost-effective, high-performance broadband content delivery through infrastructure, head-end and subscriber premises solutions.

TriQuint also addressed future CATV design and the new DOCSIS 3.1 specification. At a Cable-Tec Expo workshop 'HFC on Steroids: Options for Energizing the HFC Plant into the Future' senior director of engineering Chris Day presented the paper 'Rethinking Amplifier Technology for DOCSIS 3.1', focused on meeting the challenges of this demanding new specification through increased bandwidth, higher RF output power and improved power efficiency. He is demonstrating how these goals can be achieved without adding component costs.

Housed in SOT115J packages and operating over a frequency range of 50–1000GHz from a supply voltage of 24V and drain current of 440mA, the TAT8884HO and TAT8888 CATV GaAs power doubler hybrids have gains of 26dB and 24dB and noise figures of 5.0dB and 3.5dB, respectively, and CSO/CTB of -75/-78dBc (at 56dBmV) and -75/-69dBc (at 61dBmV).

Housed in 5mm x 7mm QFN packages and operating over a frequency range of 50–1200GHz from supply voltages of 24V and 12V and drain currents of 440mA and 650mA respectively, the TAT9988 GaN CATV power doubler MMIC and TAT8804D1H GaAs CATV power doubler MMIC have gains of 24dB and 21dB, respectively, both with a noise figure of 4.0dB, and CSO/CTB of -65/-65dBc (at 61dBmV) and -82/-78dBc (at 59dBmV), respectively.

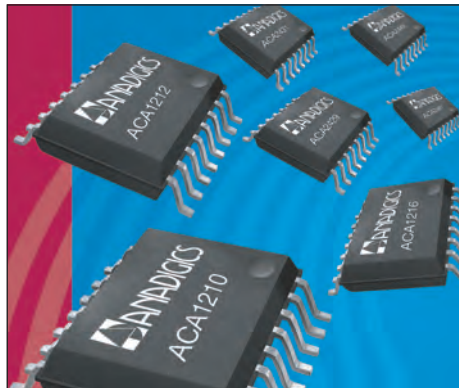
www.triquint.com

Anadigics expands surface-mount line amplifier family for 1.2GHz DOCSIS 3.1 systems

At the Society of Cable Telecommunications Engineers (SCTE) Cable-Tec Expo 2013 in Atlanta (22–24 October), broadband wireless and wireline communications component maker Anadigics Inc of Warren, NJ, USA announced that it has expanded its surface-mount line amplifier family for data over cable service interface specification (DOCSIS) system standard version 3.1.

The new 12V and 24V line amplifiers deliver what is claimed to be exceptional linearity and output power, enabling CATV service providers to increase system bandwidth in support of DOCSIS 3.1. By extending frequencies to 1.2GHz, DOCSIS 3.1 enables higher data speeds as well as additional high-definition television (HDTV) and video on demand (VOD) services.

“Our new DOCSIS 3.1 surface-mount line amplifiers deliver industry-leading linearity and output power across an expanded frequency range to support the newest generation of 1.2GHz downstream equipment,” claims



Tim Laverick, VP of Infrastructure Products. “We are helping MSOs confidently upgrade their network hardware as they roll out exciting new services made possible by DOCSIS 3.1.”

Operating over frequencies of 40–1200MHz, the new 12V ACA1210, ACA1212 and ACA1216 output amplifiers (with current consumption of 250mA, 530mA and 500mA, and typical gain of 19dB, 12dB and 27dB, respectively) run from a 12V supply. The new ACA2431 and ACA2449 power doubler amplifiers (GaN HEMT and GaAs MESFET, respectively, drawing current of 425mA and 490mA,

with gain of 28dB and 25dB) and the new ACA2461 GaAs MESFET push-pull amplifier (drawing 290mA, with gain of 25dB) run from a 24V supply.

These new line amplifiers join the ACA2429 gallium nitride (GaN) power doubler (launched in July) in providing high signal fidelity over extended frequencies up to 1.2GHz.

The surface-mount solutions offer what is claimed to be outstanding bit error rate (BER), composite triple beat (CTB), composite second order (CSO), cross-modulation and carrier-to-intermodulation noise (CIN) characteristics for optimal performance in a fully loaded spectrum.

The DOCSIS 3.1 line amplifier family leverages Anadigics’ proven high-linearity gallium arsenide (GaAs) MESFET process for reliability (to maximize up-time) along with GaN HEMT technology (for high output power and optimum power efficiency).

<http://expo.scte.org>

www.anadigics.com/products/catv

Anadigics launches DOCSIS 3.1 Edge QAM amplifier

At SCTE Cable-Tec Expo, Anadigics launched the ACA1240 CATV Edge QAM (EQAM) driver amplifier.

As part of cable modem termination systems (CMTS), EQAM is used by CATV multiple system operators (MSOs) to provide switched digital delivery, such as video-on-demand, telephone, and Internet services. By implementing EQAM modulators, MSOs can support growing demand for network services and rising concurrence rates of video services.

The ACA1240 leverages Anadigics’ GaAs technology and circuit designs to deliver what is claimed to be the industry’s highest level of linearity with high output power and gain. The performance ensures high data throughput, distortion-free

video and audio, and clear IP voice communications in DOCSIS 3.1.

“EQAM is being adopted by MSOs to reliably manage increasingly complex networks and services,” says Tim Laverick, VP of infrastructure products. “These devices require exceptionally linear amplification at high output power and gain levels to ensure quality of service and reliability.” Anadigics has hence developed an infrastructure amplifier that is optimized for more dense and compact EQAM applications using highly linear amplification and attenuation stages.

The ACA1240 gain-integrated infrastructure amplifier features a pre-amplifier, continuously adjustable 25dB linear attenuator

and output driver in a compact 7mm by 7mm 48-pin QFN package. Separate supply and enable pins are provided for each stage, with the ability to externally set the bias current of each stage independently (for low-power operation). The DOCSIS 3.1 Edge QAM amplifier provides 37dB gain at 1.2GHz with high linearity. With full spectrum support per RF port, the ACA1240 is optimized for consolidated head-end systems, including equipment targeting the new converged cable access platform (CCAP) specifications. The ACA1240 also exceeds the Downstream Radio Frequency Interface (DRFI) +8 ACP specification.

www.anadigics.com

TriQuint launches GaN solutions, optical and base-station amplifiers for commercial and defense systems

TriQuint Semiconductor Inc has announced the release of new gallium nitride (GaN) transistors that offer what is claimed to be superior gain, thermal management and efficiency for commercial and defense RF amplifier designs.

TriQuint exhibited the new GaN products, processes and service solutions, as well as small-cell power amplifiers, optical drivers, and Spatium (TriQuint's TWTAs replacement technology) at European Microwave Week (EuMW 2013) in Nuremburg, Germany (8–10 October). "Products span from new industry-leading optical modulator drivers, to a new family of small-cell amplifiers, to Spatium PAs that replace TWTAs, and our ever-growing portfolio of GaN based products and processes," says James L. Klein, VP & general manager for Infrastructure and Defense Products.

New GaN solutions

TriQuint announced two new high-power GaN packaged transistors: the 200W T1G4020036-FS/FL (covering DC–3.3GHz) and the 285W T1G2028536-FS/FL (covering DC–2GHz). Both devices offer excellent gain, enabling smaller RF amplifiers and reduced part-counts in many applications. Both devices are widely exportable, and suit commercial and defense applications

including professional communications, commercial and defense radars, avionics and RF test systems.

TriQuint's new GaN transistors are joined by new GaN amplifiers and low-noise amplifiers (LNAs) that also deliver high efficiency and improved performance compared to competing products for wide-ranging commercial and defense applications. New GaN products include wideband LNAs covering 2–6GHz and 6–12GHz with what is claimed to be excellent gain. New amplifiers include a family of solutions that focus on the needs of S-band radar and other key frequencies with what is claimed to be excellent gain and efficiency.

Small-cell power amplifiers

TriQuint is introducing the first in a new family of small-cell integrated power amplifiers that also serve active antenna base-stations. The new TGA2450-SM amplifier reduces board space while delivering high efficiency as a key component in 3G/4G mobile networks including LTE. Sampling and now available, the TGA2450-SM meets Band 1 requirements while reducing PCB area by 50%. TriQuint also has integrated amplifier solutions in development for additional global cellular bands.

SMT optical solutions

TriQuint also recently added four new surface-mount technology

(SMT) optical network modulator drivers to its portfolio, expand the firm's line-up with devices that include miniaturized and integrated modules. TriQuint says that its optical components reduce overall system costs, simplify RF design and shrink board space for existing 100Gb/s optical fiber networks and future 200/400G systems.

Spatium replaces TWTAs

TriQuint recently acquired CAP Wireless and its Spatium RF power combining technology, which replaces traveling wave tube amplifiers (TWTAs) in communications and defense systems. The technology leverages the firm's GaN technology and expands its expertise in high-power RF solid-state amplifier systems. Spatium technology adds to the exceptional efficiency, bandwidth and ruggedness of TriQuint's product portfolio. In high-power RF applications, Spatium delivers what is claimed to be superior broadband RF power efficiency through the use of patented coaxial spatial combining techniques. Spatium also provides other performance advantages including solid-state reliability, smaller form factors, higher power densities and reduced weight compared to either TWTA-based systems or conventional planar power combining products.

www.triquint.com

GaN Systems appoints applications development partner

GaN Systems Inc of Ottawa, Canada, a fabless provider of gallium nitride-based power switching semiconductors for power conversion and control applications, has appointed US engineering consultancy Vqdot as Applications Development Partner.

Michigan-based Vqdot specializes in the development and testing of high-performance power supplies and will partner to advise firms on using GaN power semiconductors across a broad range of applications.

"We have appointed Vqdot due to its expertise across numerous application areas, including RF power, switching power supplies, and advanced power conversion applications," says CEO Girvan Patterson. "Its team is experienced in exploring novel applications for new power technologies and brings a wealth of advice and expertise to manufacturers looking to gain competitive advantage through the early adoption of GaN power semiconductors."

"GaN devices promise significant advantages over traditional silicon semiconductors, including higher electric breakdown characteristics, many times the bandgap and exceptional carrier mobility," says Vqdot's CEO Luke Raymond. "GaN devices are projected to secure a significant portion of the silicon-based market within the next 3–5 years and will enable power electronics to become smaller, lighter and more efficient."

www.gansystems.com

EPC addresses demand for GaN power management products; leverages Digi-Key for global distribution

Global electronic components distributor Digi-Key Corp of Thief River Falls, MN, USA has announced new inventory of gallium nitride (GaN) power management products, available for immediate shipment as part of an exclusive global distribution agreement with Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA.

EPC was the first firm to introduce eGaN (enhancement-mode gallium nitride-on-silicon field-effect transistors (FETs) as power MOSFET replacements in applications such as point-of-load converters, Power over Ethernet (PoE), server and computer DC–DC converters, LED lighting, cell phones, RF transmission, solar micro-inverters, and class-D audio amplifiers with device performance many times greater than the best

silicon power MOSFETs.

"Gallium nitride shows tremendous promise within the semiconductor space, as the power density benefits over silicon provide a unique opportunity for designers," says Mark Zack, VP, global semiconductor product at Digi-Key. "For the past three years, Digi-Key has partnered with EPC as the exclusive distributor of their GaN power management products," he adds.

"Through this joint venture, both companies are well positioned to continue to provide innovative GaN power management solutions."

New eGaN products are being released frequently, from the EPC2016 and EPC2018 power transistors, to the EPC9017 development board. EPC has also released the EPC800x family of high-speed, high-performance products that are

blurring the line between power and RF transistors. For designers interested in evaluating the new EPC800x family of devices, EPC has released the EPC9027 development board, which features the EPC8007 device and the LM5113 gate driver IC in a half-bridge configuration.

"Digi-Key makes it easy for engineers to develop state-of-the-art power conversion systems with our enhancement-mode GaN transistors as replacements for their less efficient silicon transistors," says EPC's co-founder & CEO Alex Lidow. "Their ability to support our customers from prototype to production has been invaluable as the adoption rate of our pioneering technology continues to grow," he adds.

"Digi-Key's innovative marketing capabilities reinforce our efforts."

www.digikey.com

EPC introduces development board showcasing 100V eGaN FETs in parallel for high-current applications

EPC has introduced the EPC9017 half-bridge development board for high-current, high-stepdown-voltage, buck intermediate bus converter (IBC) applications using enhancement-mode gallium nitride field-effect transistors (eGaN FETs).

In this application two low-side (synchronous rectifier) FETs are connected in parallel, since they will be conducting for a much longer period compared to the single high-side (control) FET. eGaN FETs have superior current-sharing

capability compared to silicon MOSFETs, making them more attractive for parallel operation, says EPC. The development board expands on EPC's work on optimal layout based on ultra-low-inductance packages.

The EPC9017 development board is a 100V maximum device voltage, 20A maximum output current, half-bridge with onboard gate drives, featuring the EPC2001 eGaN FET. The half-bridge configuration contains a single top-side device and two parallel bottom

devices and is recommended for high-current, lower-duty-cycle applications.

The development board is 2" x 1.5" and contains all critical components and layout for optimal switching performance. There are also various probe points to facilitate simple waveform measurement and efficiency calculation.

EPC9017 development boards are priced at \$130 each and are available from Digi-Key. A Quick Start Guide is included for reference and ease of use.

EPC launches family of commercial high-lead eGaN FETs

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA has introduced devices with a high-lead solder termination for applications requiring higher-temperature solder. The EPC2801, EPC2815 and EPC2818 feature high-lead content (95% lead, 5% tin) solder terminations.

- EPC2801 is a 100V_{DS} device with a maximum $R_{DS(ON)}$ of 7m Ω with 5V applied to the gate.
- EPC2815 is a 40V_{DS} device with a maximum $R_{DS(ON)}$ of 4m Ω .
- EPC2818 is a 150V_{DS} device with a maximum $R_{DS(ON)}$ of 25m Ω .

In 1k piece quantities, the

EPC2801 is priced at \$7.51, the EPC2815 is priced at \$6.35, and the EPC2818 is priced at \$16.25.

All products are available through Digi-Key Corp.

www.digikey.com/Suppliers/us/Efficient-Power-Conversion
www.epc-co.com

ARPA-E awards \$27m funding to 14 SWITCHES projects **Projects to develop GaN, SiC and diamond wide-bandgap power conversion devices and GaN substrates**

ARPA-E deputy director Cheryl Martin has announced \$27m in funding from the US Department of Energy's Advanced Research Projects Agency-Energy (ARPA-E) for 14 projects aimed at developing next-generation power conversion devices that could transform how power is controlled and converted throughout the grid. Selected under ARPA-E's SWITCHES program ('Strategies for Wide-Bandgap, Inexpensive Transistors for Controlling High-Efficiency Systems'), the projects aim to find innovative ways to lower the cost and improve the efficiency of power electronics.

In modern energy infrastructure, existing power electronics are based on decades-old technology and rely on expensive, bulky and failure-prone components. To address these inefficiencies, SWITCHES seeks to lower the cost and improve the energy efficiency of power switching devices (e.g. to control or convert electricity from high voltage to low voltage in laptops and electric motors, and — on a large scale — to connect solar panels and wind turbines to the grid, to operate industrial equipment such as eleva-

tors and HV/AC systems, and to run electric and hybrid-electric vehicles).

"To transform America's energy infrastructure, we will need innovative technology options that can radically improve how we convert and use electricity," says Martin. "The low-cost power electronic projects ARPA-E announced today could result in some of the critical components needed to update our aging infrastructure and reduce power losses from the grid."

ARPA-E says that its SWITCHES projects are creating new wide-bandgap semiconductor materials, device architectures and fabrication processes to enable increased energy density and switching frequencies, enhanced temperature control and reduced power losses in a range of power electronics applications for electric motor drives and power switching devices for the grid.

The 14 projects selected for the SWITCHES program are performing their research at a combination of universities, businesses, and national labs. For example, the University of California at Santa Barbara (UCSB) will receive \$3m to develop several new vertical gal-

lium nitride (GaN) technologies that will enhance the performance and reduce the cost of high-power electronics. UCSB's devices could reduce power losses to enable high-power conversion at low cost in motor drives, electric vehicles, and power grid applications.

Eight of the 14 SWITCHES projects are small businesses being funded through ARPA-E's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) program. For example, MicroLink Devices of Niles, IL will receive \$1.7m to engineer affordable, high-performance transistors needed for power conversion. Currently, high-performance power transistors are prohibitively expensive because they are grown on expensive GaN wafers. In conventional manufacturing processes, the wafer is permanently attached to the transistor, so the wafer can only be used once. MicroLink will develop an innovative method to remove the transistor structure from the wafer without damaging any components, enabling wafer reuse while significantly reducing costs.

The eight SBIR/STTR SWITCHES project awards are as follows:

- \$1,725,000 to Avogy Inc for 'Vertical GaN Transistors on Bulk GaN Substrates';
- \$1,425,000 to Fairfield Crystal Technology for 'High Quality, Low-Cost GaN Single Crystal Substrates for High Power Devices';
- \$793,477 to iBeam Materials Inc for 'Epitaxial GaN on Flexible Metal Tapes for Low-Cost Transistor Devices';
- \$3,224,993 to Kyma Technologies Inc for 'High Quality, Low Cost GaN Substrate Technology';
- \$1,725,000 to MicroLink Devices for 'Vertical-Junction Field-Effect Transistors Fabricated on

Low-Dislocation-Density GaN by Epitaxial Lift-Off';

- \$3,224,845 to Monolith Semiconductor Inc for 'Advanced Manufacturing and Performance Enhancements for Reduced Cost Silicon Carbide MOSFETs';
- \$1,725,000 to SixPoint Materials Inc for 'GaN Homoepitaxial Wafers by Vapor Phase Epitaxy on Low-Cost, High-Quality Ammonothermal GaN Substrates'; and
- \$225,000 to Soraa Inc for 'Large Area, Low-Cost Bulk GaN Substrates for Power Electronics'.

The six non-SBIR SWITCHES project awards are as follows:

- \$420,434 to Arizona State University for 'Diamond Power Tran-

sistors Enabled by Phosphorus Doped Diamond';

- \$3,000,000 to Columbia University for 'Vertical GaN Power Transistors Using Controlled Spalling for Substrate Heterogeneity';
- \$2,900,000 to HRL Laboratories for 'Low-Cost Gallium Nitride Vertical Transistor';
- \$558,914 to Michigan State University for 'Diamond Diode and Transistor Devices';
- \$3,172,205 to University of California, Santa Barbara for 'Current Aperture Vertical Electron Transistor Device Architectures for Efficient Power Switching'; and
- \$2,496,428 to University of Notre Dame for 'PolarJFET Novel

Toshiba adds 6, 8 and 10A devices to 650V SiC Schottky family

With analysts predicting significant growth in the silicon carbide (SiC) power device market, in order to meet an anticipated spike in demand Japan's Toshiba is expanding its family of 650V SiC Schottky barrier diodes (SBD). The TRS6E65C, TRS8E65C and TRS10E65C are 6, 8 and 10A devices, respectively, joining Toshiba's 12A TRS12E65C device, which entered volume production in second-quarter 2013.

Low forward voltage drop and a very fast switching action make the SBDs suit applications including power conditioners for photovoltaic power generation systems, solar inverters, uninterruptible power supplies (UPS) and DC-DC converters. SBDs can also act as replacements for silicon diodes in switching power supplies, where they are much more efficient.

SiC power devices offer more stable operation than current silicon devices — even at high voltages and currents — as they significantly reduce heat dissipation during operation, says Toshiba. They meet diverse industry needs for smaller, more effective communications devices and suit industrial applications ranging from servers to inverters and trains to automotive systems.

Toshiba's Schottky barrier diode range features a maximum reverse recovery current (IRRM) of 90 microamperes at 650V. All devices are housed in 2-pin TO-220 packages, with additional packages scheduled to be added in future.

Toshiba's new 650V SBDs are available now. Budgetary pricing begins at \$3.00 (for a 6A device), with volume discounts available.

www.toshiba.co.jp/index.htm

Microsemi adds 650V SiC Schottkys

Microsemi Corp of Aliso Viejo, CA, USA (which designs and makes analog and RF devices, mixed-signal integrated circuits and subsystems) has expanded its silicon carbide (SiC) Schottky diode product family with a new line of 650V solutions, targeted at high-power industrial applications including solar inverters.

Microsemi notes that, since SiC offers benefits compared to silicon (including a higher breakdown field strength and higher thermal conductivity), designers can create products with better performance characteristics encompassing zero reverse recovery, temperature-independent behavior, higher-voltage capability and higher-temperature operation to achieve new levels of performance, efficiency and reliability.

"Microsemi's SiC power semiconductors are ideal for power electronic designers looking to improve system efficiency," reckons James Kerr, senior product marketing manager

for Microsemi's Power Products Group. "Silicon carbide is a game-changing technology for many of our customers," he adds. "With in-house fabrication capabilities, a comprehensive portfolio of SiC solutions and a roadmap that includes several new SiC products, Microsemi is positioned to capitalize on this growing market opportunity."

The new 650V SiC Schottky diode product portfolio (in production now) includes:

- APT10SCD65K (650V, 10A, TO-220 package);
- APT10SCD65KCT (650V, 10A, common cathode TO-220 package);
- APT20SCD65K (650V, 20A, TO-220 package); and
- APT30SCD65B (650V, 30A, TO-247 package).

The new devices are also used in Microsemi's power modules, which are used in aerospace, welding, battery charging and other high-power industrial applications.

www.microsemi.com

IN BRIEF

High-power 600V, 10A and 1200V, 5A SiC diodes in surface-mount packages

IXYS Corp, which makes power semiconductors, mixed-signal and digital ICs for power conversion and motion control applications, has launched the SS150 and SS275 Series high-power silicon carbide diodes via its IXYS Colorado division in Fort Collins.

Supplied in the low-inductance, surface-mount DE Series package, the SS150 and SS275 are both available in 600V, 10A and 1200V, 5A ratings. Also, three standard internal diode configurations provide flexible connection and layout options:

- TI – Triple Independent (no common connections);
- TA – Triple Anode (anodes are tied together);
- TC – Triple Cathode (cathodes are tied together).

The modules suit applications such as: MHz switch mode power supplies; high-frequency converters; resonant converters; and rectifier circuits.

The use of SiC allows extremely fast switching, high-frequency operation, with zero recovery and temperature-independent behavior. Coupled with the low-inductance RF package, the diodes can be used in fast-switching diode circuits or high-frequency converter applications.

Features include: zero reverse recovery; zero forward recovery; high-frequency operation; temperature-independent behaviour; low inductance; and a positive temperature coefficient for V_f .

"The SS150 and SS275 high-power SiC diode modules allow designers more flexible design options with high-frequency applications," says IXYS Colorado's general manager Stephen Krausse.

www.ixyscolorado.com

Showa Denko launches 6" SiC epiwafers for inverter power devices

Lower-defect, higher-uniformity 4" epi also introduced

Showa Denko (SDK) has launched silicon carbide (SiC) epitaxial wafers with a diameter of 6 inches (150mm) — the largest size currently available, it is claimed — for use in power devices. The firm is also selling a new grade of 4-inch (100mm) SiC epiwafers with fewer defects and higher uniformity.

Up to now, SDK has been producing and selling 3-inch (76.2mm) and 4-inch SiC epiwafers. In addition, SDK has worked to develop the next-generation 6-inch SiC epiwafers (which should lead to increased productivity), providing samples since the beginning of this year. As the volume production technology has now been established and product specifications have been prepared, the firm has decided to begin commercial shipments as from October.

Compared with mainstream silicon-based semiconductors, SiC



SDK's new 6" SiC epiwafers.

power devices using SiC epiwafers can operate under high-temperature, high-voltage and heavy-current conditions while substantially reducing energy loss, enabling the production of smaller, lighter and more efficient power control modules. SiC power devices are therefore expected to be in high demand for use in inverters (converting direct current into alternating current) for automobiles, railcars and industrial/home electric appliances.

Inverters based on SiC power devices are already used in applications such as power sources of servers for data centers, distributed power supply systems for new energy sources, and subway railcars. The new 6" SiC epiwafers can help to reduce power-device production costs and to promote volume production of SiC power devices with current-carrying capacity of as much as 100A, reckons SDK. SiC-power-device-based inverters are hence expected to be increasingly used in electric vehicles and hybrid cars.

Following the expansion of its product lines, SDK says that it will continue to improve product quality and increase production capacity. SDK is planning to increase its SiC epiwafer production capacity from 1500 units per month (in terms of 4-inch wafers) currently to 2500 units per month by mid-2014.

www.sdk.co.jp/english

SAMCO launches production etch tool for SiC processing

At the International Conference on Silicon Carbide and Related Materials (ICSCRM 2013) in Miyazaki, Japan (29 September to 4 October), SAMCO Inc of Kyoto, Japan, a supplier of etch, chemical vapor deposition (CVD) and surface treatment systems, launched the model RIE-600iPC cassette-to-cassette production etch system for silicon carbide (SiC) processing (based on the proven RIE-600iP platform used for R&D and semi-production). The main applications are planar processing for SiC power devices, fine trench etching for SiC MOS structures, SiC through-wafer etching for via hole formation, and SiO₂ mask etching.

SAMCO says that, as a wide-bandgap semiconductor with a high dielectric voltage and capable of high temperature device operation, SiC presents processing challenges



such as preserving sidewall smoothness and etching profile at high etch rates while maintaining high sufficient etch mask selectivity.

The RIE-600iPC employs a patented Tornado ICP coil capable of high-power, high-density RF plasma (at up to 3kW) under high-vacuum conditions. With a height-adjustable lower electrode and high-capacity vacuum pump (1300 liters/sec), the system enables high-speed SiC etching with what is claimed to be excellent uniformity, and can provide a wide process window.

The system holds up to 25 six-inch wafers at a time in a vacuum cassette chamber, and automatically delivers wafers to the process chamber via a transfer/load-lock chamber, providing greater processing and production efficiency.

SAMCO says that it has set its sights on becoming the leading provider of process equipment for next-generation power devices.

www.samcointl.com

Cascade Microtech acquires ATT Systems

Cascade Microtech Inc of Beaverton, OR, USA, which provides equipment enabling precision contact, electrical measurement and test of wafers, ICs, IC packages, circuit boards and modules as well as MEMS, 3D TSV and LED devices, has acquired ATT Advanced Temperature Test Systems GmbH of Munich Germany. ATT Systems provides enhanced thermal solutions for wafer testing over an expanded temperature range (typically from -60°C to 300°C). Cascade believes that the acquisition strategically positions the combined companies for future system development and access to larger markets. ATT Systems' management team will remain with the firm in Munich.

The purchase price for the acquisition includes about €8.4m in cash (net of about €0.4m of acquired cash), about 1.6 million shares of Cascade Microtech common stock, and deferred payments of about €0.8m. The purchase price is sub-

ject to certain post-closing adjustments. The shares of common stock issued in the transaction are subject to a one-year lock-up agreement.

"As Cascade Microtech enters new markets and expands its portfolio to address new technology nodes, we are seeking innovations in instrumentation and sub-systems," says president & CEO Michael Burger. "This acquisition gives us access to thermal system capabilities, both in design expertise and through ATT Systems' high-performance products, which we expect will complement our development of next-generation systems for customers demanding the highest performance at thermal extremes, while addressing new applications such as 3D structures and FinFETs. ATT Systems provides a key component of our strategic plan and supports our customers' rapidly accelerating test requirements," he adds.

"This acquisition strengthens Cascade Microtech's financial position," says chief financial officer Jeff Killian. "The acquisition provides a basis for revenue growth, market expansion and vertical integration, and we expect that it will have an immediate and positive contribution toward our success model," he adds. "Based upon the unaudited, trailing 12-months' performance of ATT Systems, the purchase price for the company approximates six times EBITDA," he Killian continues. "Before the effects of purchase accounting, we expect this transaction to be accretive to earnings beginning in the fourth quarter of 2013, and will provide additional support to achieve our success model which includes EBITDAs of greater than 20% of revenue." Going forward, ATT Systems will be reported with Cascade Microtech's Systems segment.

www.att-systems.com

www.cascademicrotech.com

PVA TePla launches modular, highly automated PVT system for SiC crystal mass production

PVA TePla of Wettenberg, Germany has launched the baSiC-T physical vapor transport (PVT) crystal growth system (which uses sublimation of a source powder at high temperatures) for the mass production of silicon carbide (SiC) material.

Typical applications of SiC crystal include high-performance electronics for end-markets such as hybrid and electric cars and air-conditioning systems, as well as optoelectronics applications such as LEDs and DC/AC converters for photovoltaics. The major advantage of silicon carbide material lies in the energy-saving potential of over 40% compared with conventional silicon components, says the firm. In addition, SiC can also be used at high temperatures and high voltages in excess of 10,000V, dramatically exceeding the potential of silicon.



PVA TePla's new baSiC-T system.

PVA TePla says that the design of the baSiC-T system is based on a modular concept and allows the use of substrates (seeds) with a diameter ranging from 100mm to 150mm. Low operating costs and a high degree of automation facilitate inexpensive mass production of silicon carbide, the firm claims.

Systems for manufacturing SiC crystal have already been delivered

to several customers in Europe and Asia, and successfully accepted, providing proof of the systems' performance, the firm claims.

In addition to the baSiC-T, a series of other PVA TePla systems are already being used in the field of power electronics. The SiCube is an industrially tested system for SiC crystal mass production by means of physical vapor transport (PVT) and high-temperature chemical vapor deposition (HTCVD). The Floatzone (FZ35) and Czochralski (EKZ) systems are used to crystallize high-purity silicon. The recycling of susceptors used in gallium nitride (GaN) epitaxy processes is performed in special PVA TePla vacuum furnaces. Also available are various metrology technologies for non-destructive quality control.

www.pvatepla.com

Albemarle acquires MO supplier Cambridge Chemical Electronic materials catalyst portfolio expanded to laser market

Specialty chemical manufacturer Albemarle Corp of Baton Rouge, LA, USA has expanded its presence in the electronic materials market by acquiring UK-based Cambridge Chemical Company Ltd, which produces high-purity metal-organic (MO) chemicals used in the laser market. Albemarle plans to continue producing these specialty products at Cambridge Chemical's existing facilities in the UK.

Albemarle established its Electronic Materials business unit in January 2012. Since then, it has launched four products within its PureGrowth portfolio, which are used in metal-organic chemical vapor deposition.

Cambridge Chemical's technology and products are intended to

strengthen Albemarle's offerings in the electronic materials market, which include the LED, semiconductor, organic LED (OLED) and now laser segments. Albemarle reckons that it will also benefit from R&D and distribution synergies resulting from the acquisition.

"By adding Cambridge Chemical's DEOX technology to our existing PureGrowth portfolio, Albemarle will now provide an even broader array of solutions to customers in the fast-growing electronics market," says Jenny S. Hebert, global business manager for Albemarle's Electronic Materials business. "The expanded portfolio not only strengthens our current offerings, it also allows us to expand into the laser segment.

The combined synergies will allow Albemarle to provide best-in-class products and services," she adds.

"Our Electronic Materials business is a critical growth platform for us, built upon our extensive expertise in organometallic chemistry, our effectiveness in backward integration of key raw materials, and our reputation for quality," says Raphael Crawford, global VP for Albemarle's Performance Catalyst and Specialty Chemicals division.

"The acquisition of Cambridge Chemical adds unique technological capabilities, distribution channels, and expertise to our list of existing assets."

www.albemarle.com

<http://camchem.co.uk/chemicals.html>

Dow Corning adds VP of Compound Semiconductors

Dow Corning Corp of Midland, MI, USA, which provides silicones and silicon-based technology, has appointed Tang Yong Ang ('TY') as vice president of Dow Corning's Compound Semiconductor Solutions business, a provider of silicon carbide (SiC) wafer and epitaxy products.

In the newly created role, TY is leading the firm's expanding Compound Semiconductor Solutions business, reporting to the general manager of the Specialty Chemicals business. The firm says that this signals a major strategic step for Dow Corning, and highlights its increased focus and support for the SiC power electronics market.

"Dow Corning is strongly committed to a leadership role in high-growth SiC technology as it enables a new generation of ever more reliable and efficient power electronic devices," says Tom Cook, general manager, Specialty Chemicals business, and chief commercial officer of Dow Corning. "TY's strong record of proven management skills and deep industry expertise make him exceptionally qualified to leverage our Compound Semiconductor

Solutions' strong foundation, and build semiconductor substrate supply capabilities that will support sustainable and unfettered growth of high-quality SiC substrates for our customers' next-generation power electronics applications," he adds.

TY joined Dow Corning from Lam Research, where he held key positions including region VP, Southeast Asia; VP, Asia Pacific Region Operations; and VP & general manager strategic account. Previously, he worked 13 years at Chartered Semiconductor Manufacturing, where he held key positions including fab operation VP, purchasing & facilities VP, and quality VP. He also spent some years running a business as president, Engineering Solutions at Ellipsiz.

Earlier, TY held positions of increasing responsibility at Texas Instruments and AT&T Consumer Products (which included a period at AT&T HQ in New Jersey), beginning his career in 1980 as a utility engineer for Hitachi Electronics. He holds a master's in Business Administration from the State Uni-

versity of New York/Singapore Institute of Management.

SiC offers inherently superior performance compared to silicon, making them well suited for high-temperature, high-frequency power electronics applications in transportation, industrial and energy.

Through its Compound Semiconductor business, Dow Corning has been developing high-crystal-quality SiC wafers and epitaxy with steadily increasing diameters, and is now positioned for high-volume production of large-area SiC substrates.

Dow Corning created its Compound Semiconductor business — formerly Power Electronics — in 2003 with an initial investment of \$70m. Until now, it was a key part of Dow Corning's Electronics Solutions group. The Compound Semiconductor business has commercial operations in Auburn, MI, USA; Seneffe, Belgium; Tokyo, Japan; Seoul, Korea; and Taipei, Taiwan.

www.dowcorning.com/content/compsemi

Air Liquide finalizes Voltaix purchase

Gas supplier Air Liquide of Paris, France has finalized its acquisition (announced on 12 June) of Voltaix Inc of Branchburg, NJ, USA, a manufacturer of materials used in the production of semiconductor devices and advanced solar cells.

Founded in 1986, Voltaix has expertise in silicon, germanium, and boron chemistries. It operates manufacturing facilities in the USA in Branchburg (New Jersey), High Springs (Florida) and Portland (Pennsylvania) and in South Korea in Sejong-si (South Chungcheong Province), and employs 185 staff.

The acquisition complements Air Liquide's ALOHA product line of precursors, and brings synergies in molecule discovery and scale up. Air Liquide reckons that this should help to accelerate the introduction of a broader portfolio of new materials to semiconductor manufacturers and hence enable increases in computing power and connectivity.

"This acquisition combines the resources and expertise of our two companies and creates synergies and growth opportunities to expand our markets and product offerings for semiconductor manufacturers around the world and to meet the growing consumer demand for increasingly powerful flat screens, tablets and smart phones," comments Michael J. Graff, senior vice president Americas and a member of Air Liquide's executive committee.

"The legacy of what we have built at Voltaix, as a result of the contributions of so many talented and dedicated individuals, will now continue under the stewardship of Air Liquide," comment Voltaix's Peter de Neufville and John de Neufville, who is founder and chairman of Voltaix's executive committee.

www.voltaix.com

www.airliquide.com

IN BRIEF

AXT's CFO resigns

AXT Inc of Fremont, CA, USA, which makes gallium arsenide, indium phosphide and germanium substrate and raw materials, says that Raymond A. Low, VP & chief financial officer, has resigned in order to pursue another executive opportunity. For a transition period, Low will continue to support the firm as a consultant while it completes a search to fill the CFO position.

"Raymond has been a valuable contributor to AXT and a valued member of our management team," comments CEO Morris Young. "I appreciate his leadership, dedication and expertise over the past nine years," he adds.

"AXT's solid financial foundation positions the company well for continued improvement," believes Low.

www.axt.com

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Veeco to ship first GENxplor R&D MBE system to University of Oklahoma

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA says that the University of Oklahoma will receive the first shipment of Veeco's new GENxplor R&D molecular beam epitaxy (MBE) system early in fourth-quarter 2013.

The GENxplor is a fully integrated deposition system that creates high-quality epitaxial layers on substrates up to 3" in diameter and is suitable for research on a wide variety of materials including gallium arsenide, nitrides and oxides.

The University of Oklahoma is the first university in the world that will have the new GENxplor, says Dr Michael Santos, professor in Engineering Physics. "The proven growth chamber and enhanced fea-

tures of the GENxplor, including robust process flexibility and convenient access to effusion cells, are ideal for the materials research we are conducting for technologies such as lasers, photodetectors, and solar cells," he comments. "We have two other Veeco MBE systems in our lab that have performed very well."

In addition to receiving the first tool, Santos discussed his latest MBE research at the 30th North America Molecular Beam Epitaxy Conference (NAMBE 2013) in Banff, Canada (5–11 October).

"The University of Oklahoma is at the forefront of compound semiconductor materials research, so it is quite fitting that they are receiving the first GENxplor," comments

Jim Northup, VP, general manager of Veeco's MBE Operations. "It has been designed specifically for the R&D community, combining an easy-to-use platform with our world-class MBE performance."

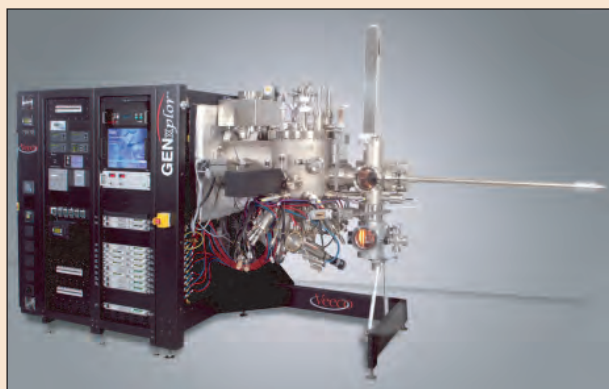
The GENxplor's efficient single-frame design combines all vacuum hardware with on-board electronics to make it up to 40% smaller than other MBE systems, it is reckoned, saving valuable lab space. Because the manual system is integrated on a single frame, installation time is reduced, Veeco adds. The open-architecture design also improves ease-of-use, provides convenient access to effusion cells, and allows easier serviceability compared to other MBE systems, says the firm.

<http://mbsantos.weebly.com>

University of Nottingham buys GENxplor R&D MBE systems for optoelectronic research

Veeco Instruments says that the UK's University of Nottingham has purchased two GENxplor R&D molecular beam epitaxy (MBE) systems for its School of Physics and Astronomy, adding to its installed base of Veeco MBE reactors. The new systems will enable the growth of large-area layers of graphene and boron nitride for electronic and optoelectronic applications.

"Compared to other technologies, MBE better enables the high-temperature and high uniformity deposition required to meet our stringent research demands," says Dr Sergei Novikov, principal research fellow in the Faculty of Science at the University of Nottingham. "The GENxplor's high-temperature substrate heater, open architecture and multi-system integration will allow us to grow materials in novel ways," he adds. "It is our goal to develop electronic and optoelectronic devices, such as diodes and



Veeco's new GENxplor R&D MBE system.

transistors, with improved performance by incorporating graphene and boron nitride materials."

Graphene is a single-molecule-thick sheet of carbon atoms. High-quality graphene is very strong, light, nearly transparent, and an excellent conductor of heat and electricity. Boron nitride has an atomically smooth surface that is comparatively free of dangling bonds and charge traps.

"Nottingham's purchase supports our belief that the GENxplor —

the industry's first fully integrated MBE system designed to deposit high-quality epitaxial layers on substrates up to 3" in diameter — is a revolutionary approach for the research community," says Jim Northup, VP, general manager of Veeco's MBE Operations.

The GENxplor's efficient, single-frame design integrates

Veeco's proven vertical chamber technology, with an easy-to-use transfer system and on-board electronics, making it up to 40% smaller than other MBE systems, it is reckoned, saving lab space. Its open-architecture design also improves ease-of-use by providing convenient access to effusion cells and electron-beam sources, improving serviceability compared to other MBE systems, adds Veeco.

www.nottingham.ac.uk/physics
www.veeco.com/genxplor

Riber adds Compact 21 DZ to its range of research MBE systems 3"-wafer system integrates 12 geometrically equivalent cell-source ports

Buoyed by the success of its Compact 21 range of research systems, at the recent North American Molecular Beam Epitaxy Conference (NAMBE 2013) in Banff, Canada (5–11 October) Riber S.A. of Bezons, France has launched the Compact 21 DZ 3"-wafer MBE research system.

Reckoned to be the first system of this size to integrate 12 geometrically equivalent cell-source ports, the new model combines flexibility and what are claimed to be outstanding performance capabilities with reduced operating costs. Particularly compact, it is designed to meet the needs of users looking to minimize their fixed costs.

The Compact 21 DZ system is especially designed for fundamental

research on new compound semiconductors for the microelectronics or optoelectronics industries, particularly for structures based on III-V, II-VI, GaN materials, graphene, oxides, etc. In particular, it is recommended for the development of emerging technologies, such as ultraviolet (UV) LEDs or high-performance solar cells.

The Compact 21 is the industry's top-selling range of MBE systems, with more than 100 installed worldwide. Riber says that the launch of the Compact 21 DZ illustrates its strategy to develop and promote its range of MBE systems, supporting the firm's development of new markets and buoyant geographical segments.

www.riber.com

IN BRIEF

Riber sells 4"-wafer R&D MBE system to Chinese material research institute

Riber has sold a 4"-wafer-capacity R&D MBE system to what is described as a leading material research institute in China.

The laboratory is a long-standing customer of Riber, and the repeat order consolidates an existing relationship, the firm says.

The new system will enable the laboratory to increase its fundamental research capabilities on what are said to be cutting-edge epitaxial layer/substrate combinations.

Riber believes that the order strengthens its key position in the Chinese market (one of the fastest-growing regions in semiconductor industry).

Riber's 2013 revenue to end-September down 39% year-on-year to €10.2m ...but full-year target of €24–26m reaffirmed, as production plan

Riber S.A. of Bezons, France, which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells, has reported revenue of €10.2m for the first nine months of 2013 (37% from Asia, 34% from Europe, 29% from North America), down 39% on €16.7m for the first nine months of 2012. This includes third-quarter revenue of €2.4m, down by two-thirds on €7.3m for Q3/2012.

Systems revenue was €6m, down 47% on €11.2m for the first nine months of 2012. However, this reflects the change in seasonal trends for the firm's production plan, which in 2013 is focused on the end of the year. During the first nine months, seven MBE machines were invoiced, compared with 10 (including two production

machines) for the same period in 2012.

Services & Accessories revenue was €3.3m, down 12% on €3.8m a year ago, factoring in the contraction in demand for services among industrial customers.

Revenue for Evaporation sources & Cells has fallen 44% from €1.7m to €1m, as it is still dependent on decisions regarding investments in the production of organic light-emitting diode (OLED) flat screens or thin-film solar cells. Nevertheless, Riber is maintaining a major research drive with a view to developing new ranges of cells for these high-potential markets. The incorporation of Riber Korea during Q3/2013 is a key enabler to this plan.

During Q3/2013, boosted by a research system order for a laboratory in Japan, Riber's order backlog

grew from €11.7m to €12m. Although down 33% on €18m a year ago, it does not include the order received in October for a system to be delivered in China (as announced on 21 October). Of the €12m order backlog, €9.7m is for Systems (down 39% on €15.8m a year ago), €2.1m is for Services & Accessories (up 9% on €1.9m) and €0.3m is for Evaporation sources & Cells (up 20% on €0.2m).

Riber has also unveiled a new DZ model in its best-selling Compact 21 range, with a view to harnessing future growth in the MBE market.

In view of industrial product planning for fourth-quarter 2013 and the short-term business outlook, Riber can confirm its target for revenue of €24–26m in full-year 2013, allowing a profit over the full year.

www.riber.com

Aixtron's recovery program improves earnings, despite revenue growth remaining subdued

Capital increase to fund technology development for power electronics, OLEDs and silicon

For third-quarter 2013, deposition equipment maker Aixtron SE of Aachen, Germany has reported revenue of €46.2m, down 26% on €62.2m a year ago but up slightly on €45.3m last quarter.

In spite of the lower percentage of final acceptances (which usually have a positive earnings effect) relative to Q2/2013 revenue, earnings before interest and taxes (EBIT) was +€2.9m (or –€9.2m, excluding provision revisions and re-categorization of insurance), an improvement on –€9.8m last quarter and –€78.3m a year ago. This is attributed particularly to the positive cost effects and efficiency gains from the 5-Point-Program initiated in Q1/2013. Thus, the firm is on track to cut its annual operating expenses by about 20%.

Net profit was +€1.6m (or –€10.6m, excluding provision revisions and re-categorization of insurance), an improvement on –€11.8m last quarter and –€78.3m a year ago.

Although free cash flow was negative at –€6.5m (due in particular to severance payments), this is an improvement on –€26m a year ago. Also, cash outflow for the first nine months of 2013 amounted to only –€0.9m (due to free cash flow of +€5.6m in first-half 2013). The free cash flow that was generated

until the end of September demonstrates the specific focus on liquidity management, says Aixtron.

Despite continuously high capacity utilization rates at many LED chip makers, there were still no significant new investments in respective production equipment during Q3. Equipment order intake was €35.7m, up only slightly on €34.5m a year ago but up 17% on €30.5m in Q2. Total equipment order backlog at the end of September 2013 was €72.8m, down 34% on €109.8m a year previously but up slightly on €71.7m at the end of June.

5-Point-Program

As part of its ongoing 5-Point-Program (presented in May), in Q3 Aixtron started its 'supply chain process', an individual project related to point 3 ('processes'). Aims of the project include an integrated planning process, in order to involve suppliers more closely in procurement and product development processes, allowing Aixtron to reduce inventory risk and improve lead times as well as allowing better management of a more defined supply chain.

Aixtron says that a thorough analysis of the firm's technology fields has fundamentally confirmed the management's view on targeted future business opportunities, such as silicon applications, OLEDs and

power electronics. Management has also identified other technology fields with attractive market potential. Consequently, R&D expenses and investments are being made in defined growth areas.

"Though the order situation is still subdued, we are using the time to adapt to the new market conditions," says CEO Martin Goetzeler. "Our customers are currently in the course of optimizing their processes for the production of more powerful and cost-efficient devices. We are actively supporting the industry in this development with our newly implemented technical key account structure and our product roadmap," he adds. "Moreover, we want to reduce both our lead times and the timeframe from the conception of a product to its volume production."

Aixtron says that high capacity utilization rates at leading LED makers give reasons to believe that the overcapacity of MOCVD deposition equipment is further diminishing. However, there has still been no significant pick-up in demand for new Aixtron equipment, even in Q3/2013. As a result, it remains difficult to give a precise forecast of revenue and EBIT margin, says the firm. However, management thinks that Q4 revenue will be higher than in Q3.

www.aixtron.com

Aixtron raises €101m from capital increase

Aixtron is increasing its share capital by about 10% through the use of authorized capital and excluding shareholders' subscription rights.

The 10,223,133 new registered shares (shares without par value) were subscribed by investors at a placement price of €9.90 per share via an accelerated book building process. The placement was considerably oversubscribed, says Aixtron.

Gross proceeds of about €101m will be used to further strengthen Aixtron's technology by selectively investing in additional growth areas, including projects related to the manufacturing of power electronics, OLEDs and silicon semiconductor applications. The capital increase should also strengthen Aixtron's financial flexibility by reinforcing its balance sheet and cash position.

The new shares are admitted for trading in the regulated market of the Frankfurt Stock Exchange, with a simultaneous listing in the Prime Standard segment of the Frankfurt Stock Exchange (which has enhanced disclosure obligations). The shares qualify for a dividend from 1 January 2013. Delivery of the new shares was expected on 29 October.

Epistar qualifies LayTec's Pyro 400 in-situ metrology system for gallium nitride LED production

LayTec AG of Berlin, Germany, which makes in-situ metrology systems for thin-film processes focusing on compound semiconductor and photovoltaic applications, says that Epistar Corp (Taiwan's largest LED chipmaker) has qualified the Pyro 400 in-situ metrology system for its gallium nitride LED production. Epistar will now use high-accuracy GaN surface temperature sensing with Pyro 400.

"We are satisfied with GaN surface temperature measurement provided by Pyro 400," comments the head of its Epitaxy Engineering Division. "The tool helps us further improve MOCVD controllability and LED production yield," he adds.

"We thank the team at Epistar for working together with LayTec's application engineers so closely,"

comments Tom Thieme, LayTec's director marketing & sales. "Through collaboration with this important and innovative customer, we have established our UV pyrometry tool in Epistar's daily LED production application," he adds. "We successfully demonstrated that precise wafer surface temperature control gives room for even further LED yield improvement and cost reduction."

The Pyro 400 controls the real GaN surface temperature during epitaxial growth on infrared transparent substrates such as sapphire or silicon carbide (SiC). The tool applies ultraviolet pyrometry and provides information on the final emission wavelength of the LED already during epitaxial growth.

www.laytec.de/pyro400

www.epistar.com.tw

IN BRIEF

IQE's acquisition of Kopin Wireless wins Business Insider Deal of the Year

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has received the Deal of the Year prize at the Business Insider Wales Business Awards.

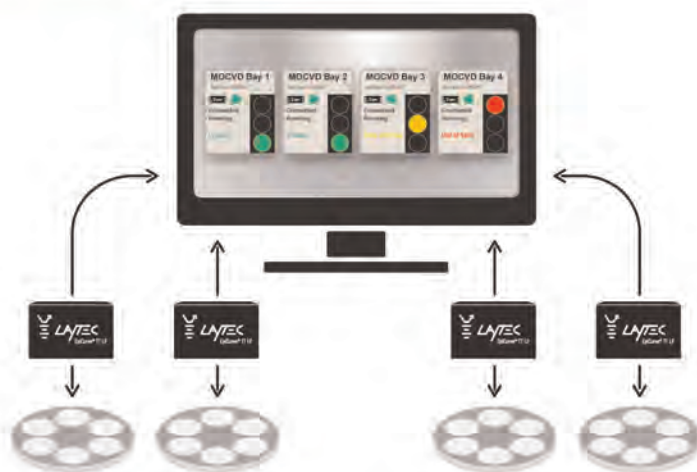
"Acquisition of US-based Kopin's wireless division earlier this year was one of three transformational deals undertaken since the beginning of 2012," said IQE chief executive Dr Drew Nelson.

"This award acknowledges the hard work by all involved in completing these major international transactions as well as the subsequent successful integration of the businesses into the IQE Group."

www.iqep.com

www.insidermedia.com

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Lincoln Lab's George Turner wins MBE Innovator Award

The 2013 MBE Innovator Award, which is co-sponsored by co-sponsored by epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA and the North American Molecular Beam Epitaxy (NAMBE) organization, has been awarded to George W. Turner Ph.D., group leader of the Lincoln Laboratory at the Massachusetts Institute of Technology (MIT). Dr Turner was presented with the award on 8 October at the NAMBE Conference in Banff, Canada by Charles Tu Ph.D., an Associate Dean and Distinguished Professor of Electrical and Computer Engineering (ECE) at the UCSD Jacobs School of Engineering.

The NAMBE organization selected Turner for his pioneering and sustained contributions in antimonide materials research and mid-wave-length infrared laser development. Most of this work has involved MBE growth in specially configured

growth systems, designed for precise and reproducible lower-temperature growth of a multitude of various lattice-matched bulk alloys and strain-compensated quantum well structures. Multiple presentations, publications and patents, as well as a chapter in 'MBE: From Research to Mass Production', document Turner's contributions to the MBE community. He has received the Johns Hopkins Applied Physics Fellowship Award and the IEE J.J. Thomson Premium Award.

"The MBE Innovator Award was established to recognize researchers who have made the most seminal contributions to the art and science of MBE," commented Dr James A. Gupta of the National Research Council of Canada and general chair of this year's NAMBE, adding that Turner's pioneering developments in antimonide material and device research have enabled an entire field of mid-infrared optoelectron-

ics.

"We proudly support this award as a key driver in the expansion of MBE technology into new frontiers of research and production applications," said Jim Northup, Veeco's VP & general manager.

Initiated 11 years ago, the MBE Innovator Award (consisting of a \$3000 honorarium and plaque) recognizes individuals whose innovations have significantly advanced the field of MBE in the following categories: (1) materials research, (2) device development, (3) device commercialization, or (4) equipment development. Members of the NAMBE organization help advance MBE technology by sharing research discoveries on new materials and devices based upon MBE, as well as by supporting MBE as a high-volume manufacturing technology.

www.ll.mit.edu

www2.avs.org/conferences/nambe/2013/awards.htm

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The Business of Science®

Praxair China opens global technology center in Shanghai

Praxair China Investment Company, a subsidiary of Praxair Inc, has opened its global technology center in Shanghai, supporting the firm's development and implementation of innovative applications technologies. The Praxair China Technology Center is located in the Jinqiao Development Zone of Pudong New Area.

The center houses laboratories, including pilot and demonstration facilities, to support a growing team of Praxair engineers and scientists working with customers in China in the steel, combustion, metal fabrication, metals and materials processing, pharmaceuticals, water treatment and electronics segments.

"The new Praxair China Technology Center is a state-of-the-art facility for our applications engineers and R&D organization," said Praxair China's president Dr Minda Ho. "These laboratories enable us to

work closely with our business partners and customers to develop innovative products that meet their unique needs. In addition, Chinese regulations for emissions reduction are becoming more stringent and are world-class in several areas. Praxair's experience will allow us to quickly replicate our applications technologies to contribute to our customers' needs for cleaner air and water. We look forward to delivering novel gas applications from this center to our customers across China."

"The inauguration of the Praxair China Technology Center builds on our rich tradition of innovation," said Dr Amitabh Gupta, executive director of Praxair Asia R&D and Applications. "Praxair technical teams are developing applications to help customers increase productivity, achieve energy savings and improve environmental performance through emissions

reductions. The development and application of these innovative products and services enables sustainable development, while truly making our planet more productive."

"China is our largest and fastest-growing market in Asia and this center is developing technology that will not only be used in China but also in Praxair's businesses around the world," said Ray Roberge, Praxair's senior vice president and chief technology officer. "In addition, we are collaborating with several respected universities across China on important areas of research, which is a strategic advantage for Praxair. The innovation stemming from these projects and our ability to attract and recruit top talent from these and other educational institutions are key reasons we chose to open our facility here."

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Picodeon unveils first automated cold ablation pulsed laser deposition production system

Multi-layer deposition on 4" wafers targets oxides, metals, composites; project partners sought

In cooperation with PVD Products of Wilmington, MA, USA, Finland-based nanotech firm Picodeon Ltd Oy, which specializes in thin-film coatings and surface treatments, has developed the ColdAb Series 4 thin-film deposition system, which is claimed to be the world's first production equipment for the use of pulsed laser deposition (PLD) in volume manufacturing.

The ColdAb Series 4 system delivers industrial-scale PLD coating production of 4-inch wafer sizes, including the fully automated delivery of substrates to the pre-clean chamber and to the main Coldab coating chamber. The deposition chamber includes many of the unique features that have been developed by Picodeon, and uses the patented ColdAb ultra-short pulsed laser deposition (USPLD) process, which enables large-area thin-film coating deposition using a high-frequency picosecond laser. The firm says that this has not been possible before at this scale,

as conventional PLD has a lower growth rate compared to the ColdAb process. The benefits of the cold ablation process are a smooth and particle-free surface, and that the target material's stoichiometry may be fully transferred to the thin film on the substrate (an important issue for oxides and composites, for example).

The new ColdAb Series 4 tool includes a 10-wafer Loadlock chamber. Also, instead of having many costly laser sources, ColdAb Series4 is equipped with one 200W @ 40MHz laser source. "This makes the system less expensive and easier to use," says CEO Dr Jari Liimatainen. "Picodeon has used earlier versions of this equipment for R&D for many years, and now it is time to ramp up that process technology to industrial scale with Series 4."

Just in August, Picodeon completed a €5m round of funding by private investment and project management firm Enso Ventures Ltd.

The firm said that the investment would fund further research into thin-film applications and the development of new thin-film materials, as well as the production of a market-ready range of laser deposition equipment.

The new system provides multi-layer deposition capability for a wide variety of materials including oxides, metals and several composites, and also enables temperature-sensitive polymers to be coated. Picodeon will use the system to commercialize new applications based on a wide range of coating materials including its patented Nicanite graphitic carbon nitride. Precious metals such as gold (Au) and oxides for the semiconductor and sensor industries are in the development roadmap, and the firm is seeking industrial partners to join these projects.

The first ColdAb Series4 system will be available from Picodeon in January.

www.picodeon.com

OEM Group adds Sales and Service facility to Taiwan re-manufacturing site

Semiconductor capital equipment provider OEM Group of Phoenix, AZ, USA has opened its new Sales and Service office in Hsinchu, Taiwan, complementing its existing re-manufacturing facility in Taiwan (which opened in 2010).

The new office will provide for the continued improvement of sales and service support across Asia for both existing customers and fast-growing applications.

OEM Group continues to expand its LEGENDS portfolio, now with 15 exclusive product lines; providing new and re-manufactured systems, specialized upgrades, genuine parts,

certified service, software licensing, and process application development. The LEGENDS portfolio is based on exclusive intellectual property acquired from semiconductor brands, including: P5000, Tegal Etch, Sputtered Films Endeavor, AMS, MRC Eclipse, AGHeatpulse, Varian Sunset, Lam AutoEtch and Chemical Process Technologies (CPT) acquired from Applied Materials—Semitool. The installed base includes more than 35,000 supported systems worldwide.

"The opening of our second office in Taiwan continues the expansion of our capabilities in Asia and is key

to serving customers quickly and efficiently," says CEO Wayne Jeveli. "Through continuous investment and expansion, OEM Group has secured our position as the leading supplier of legacy equipment solutions," he adds. "As a significant portion of our LEGENDS install base shifts from North America and Europe to new fabs throughout Asia, we are working with many new customers to help them utilize these great technologies, and giving them the complete solutions for long-term equipment usage that only an OEM can provide."

www.oemgroupinc.com

SEMI-GAS unveils low-vapor-pressure liquefied gas system

SEMI-GAS Systems, a division of Applied Energy Systems Inc of Malvern, PA, USA and a manufacturer of ultra-high-purity gas source and distribution systems, has launched an Xturion custom gas source system that safely and continuously delivers low-vapor-pressure liquefied process gases in vapor phase. VaporX is suitable for both hazardous and non-hazardous gas applications and is designed to accommodate many of the low-vapor-pressure gases used in semiconductor, LED and solar cell production as well as in R&D and other high-purity markets.

Xturion VaporX systems are available in one and two process cylinder models, each featuring a GigaGuard PLC controller and an ergonomically positioned 8" touch-screen. SEMI-GAS says that the unit's intuitive display schematics enable easy control over all the system's operations, including gas delivery, system alarms, automatic cylinder switchover and auto-purge capabilities.

The GigaGuard controller automatically interrupts gas flow and initiates

shutdown in the event of a sensor alarm trip, while an Emergency Shutoff (EMO) button offers instant manual operator shutdown. LEDs display system status, while an audible alarm accompanies flashing lights alerting the operator should a hazardous condition occur.

Each system is CE certified and is manufactured with ultra-high-purity components to guarantee long-term, reliable and consistent service, says SEMI-GAS. The system features pneumatically operated valves, Magnehelic and pressure switch exhaust monitoring as well as an optional point-of-use mass flow controller (MFC) box with heated low-vapor-pressure mass flow controllers.

To guard against undesirable process gas liquefaction and to help sustain the system's cylinder temperatures and flowrates, VaporX is designed with an integrated fully automatic multi-zone heat control package that includes process gas cylinder heating blankets, gas manifold heat tracing, and process gas line heat tracing. All heat zones are

independently controlled and employ redundant temperature measurement with over-temperature protection.

The standard two-cylinder (2CE) model is 86" tall, 33" wide and 23" deep, including the external side-mounted heater controller enclosure. Various safety features come standard, such as a UL-approved fire sprinkler, a 1/4"-thick safety glass window, a self-closing, self-latching door, and a stainless-steel cylinder scale. Heavy cast aluminum cylinder brackets and adjustable cylinder shelves ensure safe and secure gas cylinder fit-up.

"Customers work in a variety of industries with various gas requirements, so we've created VaporX specifically for our customers who require delivery of low-vapor-pressure process gases," says engineering director Todd Bell (VaporX's system designer).

"VaporX is engineered to be flexible, offering many additional mechanical, electrical and enclosure features to meet each customer's exact needs."

www.semi-gas.com

Plasma-Therm launches die-singulation system

At IMAPS (the 46th International Symposium on Microelectronics) in Orlando, Florida in September, plasma process equipment maker Plasma-Therm LLC of St Petersburg, FL, USA introduced new MicroDieSingulator (MDS) systems. The systems deliver plasma-based singulation of semiconductor dies from 4", 6" and 8" wafers mounted on industry-standard tape frames.

By utilizing energized plasma, rather than mechanical saws or lasers to cut between dies, the MDS system allows singulation (dicing) of individual dies with separation lines (streets) of 20µm or less (far smaller than most existing equipment can achieve, says the firm).

In addition to allowing maximum utilization of valuable silicon-wafer real estate by reducing street size,

Plasma-Therm's exclusive MicroDieSingulator technology separates dies without causing lateral damage from stress-induced cracking, overheating, or re-deposition of ablated material. Scanning-electron microscope images show that Plasma-Therm's MDS process produces separated dies with smooth, vertical sidewalls.

MDS systems allow integrated device manufacturers to produce more wafers per hour, as well as more individual dies per wafer, says the firm. The MDS plasma process also results in dies that are less likely to be chipped during separation and are less prone to fracture during packaging.

"MDS outperforms mechanical saws and laser cutting tools," says executive VP of marketing Ed Ostan.

"In addition, IC designers gain the freedom to utilize thinner wafers, design smaller streets, and even create non-rectangular streets and dies," he adds.

"MDS-100 systems are fully equipped for high-volume production, with automated, tape-frame cassette transfer stations," says director of technical marketing Thierry Lazerand. "By providing unmatched cut speed — equivalent to 1500mm per second on 50µm-thick wafers — and eliminating the damage inherent in laser and saw-based die separation, MDS-100 is changing the game for semiconductor manufacturing," he adds.

MDS technology is backed by Plasma-Therm's customer care and technical support services.

www.plasmatherm.com

Toshiba launches 2nd-generation GaN-on-Si white LEDs

Tokyo-based semiconductor manufacturer Toshiba Corp has announced the first devices in its second generation of LETERAS white LEDs fabricated using a gallium nitride-on-silicon (GaN-on-Si) process. Scheduled for mass production in November, the 1W TL1F2 LEDs offer a cost-competitive alternative to current LED packages, says the firm, allowing manufacturers of general purpose and industrial LED lighting to drive down costs.

High-performance white LEDs have typically been fabricated on expensive sapphire substrates in relatively small 100mm or 150mm wafer sizes. In contrast, Toshiba has developed a process that enables GaN LEDs to be produced using more cost-effective 200mm silicon wafers, helping to reduce costs while making use of existing silicon fabrication facilities.

Luminous efficacy of the TL1F2 white LEDs has been improved



Toshiba's second generation of 1W GaN-on-Si LEDs.

compared with the TL1F1 series by optimizing the package and increasing the optical output power of the GaN-on-Si LED chips. The TL1F2 series offers a full correlated colour temperature (CCT) range from 2700K to 6500K, with minimum colour rendering index (CRI) values of 80 and 70,

respectively. Typical luminous flux of the 1W LEDs ranges from 104 lumen to 135 lumen, depending on colour temperature and CRI.

The new devices are supplied in a standard 6450 package measuring just 6.4mm by 5.0mm by 1.35mm. Typical driving current (I_F) is 350mA, with a typical forward voltage (V_F) of

just 2.85V, helping designers to reduce system power consumption. An operating temperature range of -40°C to 100°C makes the TL1F2 series suitable for both indoor and outdoor use in applications such as lamps, ceiling lighting, street lights and floodlights.

www.toshiba-components.com/LEDs

Nitride Solutions achieves first commercial sales AlN template shipped to large Asian LED maker

Nitride Solutions Inc of Wichita, KS, USA, which manufactures bulk and template nitride materials for LEDs, lasers and power electronics, has achieved the first commercial sales of its new AT-50 aluminium nitride (AlN) template product to a large Asian LED maker. Founded in 2009 and with key staff and advisors stemming from Kansas State University as well as University of California Santa Barbara, Nitride is producing the 2-inch templates in quantity at its manufacturing facility in Wichita, using its proprietary hydride vapor-phase epitaxy (HVPE) process.

At the 10th International Conference on Nitride Semiconductors (ICNS 2013) in Washington DC, USA (26-28 August), R&D director Troy Baker Ph.D. presented data showing commercial template properties that are claimed to be far superior to any presented

before. The data accelerated requests for sampling by major manufacturers of LEDs and power-switching devices, the firm adds.

"Our manufacturing processes are designed for volume production and tight statistical process control," says CEO Jeremy Jones. "We offer customers the best commercially available XRD specs (average (002): 135 arc sec and (102): 513 arc sec), low defect densities and high wafer uniformity," he claims. "Our recent sales and growing sample requests validate the quality and value of our products and technology," he believes.

"Customers make decisions on substrates based on performance, quality, consistency, value delivered and supply assurance," continues Jones, citing the firm's growing global distribution and technical support channel. "The planned introduction of 4-inch aluminium

nitride templates and the expansion of our template product line to gallium nitride will bring additional value to device markets."

"The aluminium nitride on sapphire templates offered by Nitride Solutions are a much lower-cost alternative of high-quality material compared to bulk aluminium nitride substrates," comments James H. Edgar, department head of chemical engineering and distinguished professor at Kansas State University.

"That these substrates are available in 2-inch diameter size greatly facilitates their use by standard device fabrication tools," he adds. "The availability of these aluminium nitride templates creates exciting new opportunities for improved short-wavelength optoelectronic and high-power electronic devices," Edgar concludes.

www.nitridesolutions.com

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Soraa launches first high-color-rendering MR16 GU10 120V line voltage LED lamps

Soraa Inc of Fremont, CA, USA, which develops solid-state lighting technology built on 'GaN on GaN' (gallium nitride on gallium nitride) substrates, has launched what it claims is the first line of high-color-rendering LED MR16 GU10 120V line voltage lamps.

Uniquely, the firm has released a 10° spot version (not available in halogen or from other LED makers, it is claimed) as well as a 25° version that has a center-beam candle power higher than halogen and all other LED GU10 products on the market. Transformer-free, full-visible-spectrum Soraa LED lamps are now available that render the widest range of colors in the objects that we see, without ultraviolet (UV) or infrared (IR) radiation, claims the firm.

The LEDs also offer full dimmability, long lamp life, improved energy efficiency and compatibility, says Soraa. "All these features are made possible through our proprietary GaN-on-GaN technology," notes president & chief operating officer Tom Caulfield. "With our GU10 versions, you no longer need a transformer and we have made available beam and output options that did not previously exist in the market, because of limitations with all other technologies."



Soraa's new MR16 GU10 120V line voltage LED lamp; shown here is the 25° version.

The firm's continuous full-visible-spectrum GaN-on-GaN LED MR16 lamps, with a color rendering index (CRI) of 95 and R9 of 95, render deep reds and cyans dramatically and have no spectral 'blue-peak'. Also, like natural light, Soraa's lamps contain violet light, which excites optical brightening agents present in fabrics and fibers and renders whites truly, the firm adds. The lamps exceed the color metrics of other LED lamps, without the manipulation of spectra that are commonly seen in other manufacturer's products, it is claimed.

The GaN-on-GaN LEDs emit ten times more light per unit area of

LED material than LEDs built on lower-quality foreign substrates, Soraa reckons. Its lamps hence have a single light source that casts a perfect beam and a single clear shadow, bringing out textures and contrast.

Making Soraa's light available in a GU10 base solves problems for users such as transformer compatibility, says lighting designer and author Randall Whitehead.

"It also makes it easier to install in homes, reducing overall installation and fixturing costs," he adds.

The new MR16 GU10 lamps are compatible with a wide range of dimmers, which Soraa has tested and characterized through its Works with Soraa program.

Also, the company's heatsink design and thermal management system make Soraa's lamps suitable for use in enclosed fixtures, damp locations and outdoor applications.

The new MR16 GU10 10° lamp works with Soraa's magnetic attachment SNAP System. The Premium 2 10° version of the lamp has a center-beam candle power of 7120Cd and the 25° version has a center-beam candle power of 2140Cd — twice that of halogen, it is reckoned.

www.soraa.com

DOE updates SSL Manufacturing R&D Roadmap

The US Department of Energy (DOE) has published the 2013 edition of the Solid-State Lighting Manufacturing R&D Roadmap, which complements the SSL R&D Multi-Year Program Plan that guides the Core and Product Development R&D programs.

One of the goals of the roadmap is to guide the Manufacturing R&D program and help direct funding solicitations for it. The roadmap also provides guidance for equipment and material suppliers, based on industry consensus on the expected

evolution of SSL manufacturing — reducing risk, improving quality, increasing yields, and lowering costs.

The roadmap is updated annually with the help of industry feedback that comes from a series of roundtables with invited experts and from the attendees at the DOE's SSL Manufacturing R&D Workshop (held this year in June in Boston).

The 2013 roadmap has been updated extensively over the 2012 version. It goes into greater detail about the entire SSL supply chain,

with indications of what the various manufacturers are doing as well as where that work is being done — not just domestically, but globally. Also covered is how these various pieces fit together. The focus of the roadmap has been expanded beyond machines and process steps, to encompass a broader perspective and identify opportunities for improvement as well as for expanding the US manufacturing role.

www.ssl.energy.gov



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Lumileds boosts LUXEON chip-on-board LED arrays to lumen range of 1000–7000lm and efficacy of 130lm/W

Philips Lumileds of San Jose, CA, USA says that, just months after being launched on the market, its LUXEON CoB (chip-on-board) LED arrays now provide 10% greater performance.

The result is luminous efficacy of up to 130lm/W and what is claimed to be the highest combination of lumens, package density and efficacy in the industry. For example, in warm white, the 9mm array delivers 2200lm at 100lm/W and the cool white array delivers 2500lm at 105lm/W.

Using a small light-emitting surface (LES) of 9, 13 or 15mm, designers can use less expensive optical solutions, resulting in ultra-compact luminaires that deliver outstanding



center-beam candle power, it is claimed.

In addition to optical advantages, the metal-core printed circuit board of the LUXEON CoB substrate provides four times better heat transfer than competitive solutions, it is reckoned, enabling up to 40%

smaller heat-sinks or improved reliability of the lighting system when a larger heat sink is used.

“With the recent improvements in performance, LUXEON COB is an even better option for a number of general lighting solutions, including outdoor, industrial, retrofit lamps and, of course, spotlights and downlights,” says product line director Eric Senders. “Our 90-CRI versions have a typical CRI [color rendering index] of 97, which makes them perfect for high quality of light applications,” he adds.

“Lumen packages are available with CCTs of 2700–5700K and CRIs of 70, 80 or 90.”

www.philipslumileds.com

Bridgelux launches V Series chip-on-board LED arrays for sub-1000lm commercial and residential lighting

Bridgelux Inc of Livermore, CA, USA has launched its new V Series line of chip-on-board LED array products. The cost-effective light engines extend the technology and performance of the Vero line, feature high flux density in small source size packages, and are suited to sub-1000 lumen commercial and residential lighting markets where tight beam control and high quality light matter, says the firm.

The V Series arrays were developed to bring Bridgelux light source technology to a growing segment of sub-1000 lumen applications such as PAR lamps, MR-16 lamps, small-aperture downlights, landscape spots and security lights, track lights, spots and accent lights. According to Strategies Unlimited, the global LED PAR Replacement Lamp market alone is expected to grow from 13 million units in 2011 to 47 million units in 2016.

The V Series initially consists of two light engine sizes (V6 and V8) with multiple electrical configurations, correlated color temperatures (CCT)

and color rendering index (CRI) combinations, enabling greater design-in flexibility and energy efficiencies. The light engines can be efficiently driven at twice the nominal current, which translates into enhanced system flexibility and industry-leading lumen-per-dollar performance, claims Bridgelux. Also, V Series arrays are supported by low-cost mechanical holders, optics and drivers from established ecosystem partners, reducing overall sourcing and installation costs for lower-lumen applications while getting the benefit of high-performance Bridgelux light source technology.

“We have been quick to qualify V Series arrays into several high-volume product lines, so many of our clients can immediately benefit from the light quality and energy efficiencies,” comments Jack Lam, president of Hong Kong-based luminaire manufacturer RiO Light.

V Series arrays have been optimized to enable a cost-effective design for LED lamps, commercial track and spotlights, consumer down-lights and

other general lighting applications. They feature low thermal resistance and an electrically isolated thermal path for simplified thermal management. They also support Energy Star and various rebate programs with over 7000 hours of LM80 test data and R9 values exceeding California Energy Commission requirements for luminaires and lamps. V Series arrays also include ANSI-compliant 3-step binning, reducing SKUs (stock keeping units) while bringing consistent high-quality white point light to this new segment. Like all Bridgelux arrays, the V Series comes with a 5-year limited warranty.

“We leveraged many technological advances from our industry-leading Vero LED Array Series to bring our high-quality light engine technology to the V Series for lower-power, cost-sensitive applications,” says chief sales & marketing officer Max Hong. “These small LED packages are well suited for low-lumen applications and will help accelerate the migration from traditional light sources.”

www.bridgelux.com

Everlight expands JU series of COB LED portfolio

Taiwan's Everlight Electronics Co Ltd has expanded its high performance JU series of chip-on-board (COB) LEDs to include 7, 10 and 15W types in addition to the existing 4W version. COB LEDs are suited for directional applications that require a powerful single light source for effective illumination such as GU, MR and PAR retrofits, downlights and candelabras, says the firm.

The JU series now consists of four JU1215 (12mm x 15mm x 1.6mm) and one JU2024 (20mm x 24mm x 1.6mm), with powers ranging from 4W to 15W. All types provide an efficacy of 110lm/W or more at 3000K CCT, a CRI of >80Ra and 25°C substrate temperature, and are available in versions ranging from ANSI bin 2700K to 6500 K. The JU series also offers 3 step (McAdam) options for advanced utilization.

JU COB LEDs are multi-chip solutions that are directly applied to the board without housing, for efficient thermal dissipation. Their ceramic substrate base allows for thermal resistances of below 2°C/W, with the largest-wattage COB measuring around 0.8°C/W. Low thermal resistance and superior heat dissipation ensure high reliability and increase the LEDs' service life.

Each COB has its unique features with carefully calculated chip configurations for optimal lumens per dollar of >400lm/\$ and optically compact light emission surfaces (LES) for effective pairing with secondary optics.

Additional JU COB options such as Color Choice, high voltages from 45 to 250V for different regions and applications, and high CRI (>90Ra) are available to meet customers' specific needs. All JU COBs have completed LM80 lumen maintenance testing and are offered with a complete

line of accessories such as standardized holders, appropriate reflectors and more.

The future product roadmap of the JU family provides for additional

higher-power members such as 25W/35W/50W for track light, down-light or low-bay applications by Q4/2013. Meanwhile, 4W/8W/13W/17W/26W MCPCB 120lm/W COB LEDs are being introduced for wider options.

www.everlight.com



Everlight's 12mm x 15mm JU1215 COB LEDs.



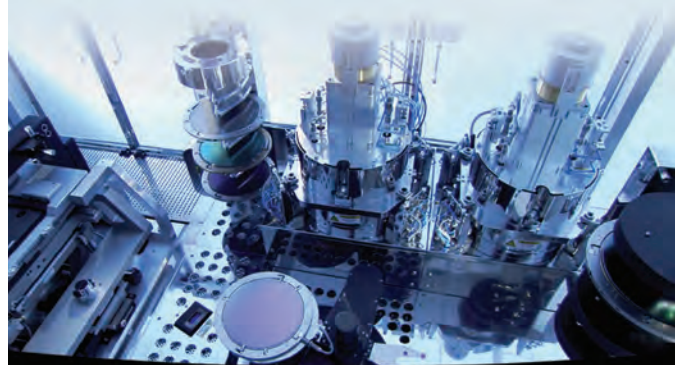
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www.EVGroup.com

Lumileds launches LUXEON TX emitters combining high flux and CRI with 'extreme' efficacy for luminaires

Philips Lumileds of San Jose, CA, USA Philips Lumileds has launched LUXEON TX LEDs, a new generation of high-power emitters delivering what is claimed to be the highest luminous flux available, with maximum efficacy, for directional and omnidirectional lighting applications. "These emitters enable customers to achieve performance metrics — such as a true 50W-equivalent MR16 lamp at [a CCT correlated color temperature of] 2700K that meets ERP/DIM2 requirements — which LEDs simply could not meet previously," claims product line director Kathleen Hartnett.

"Outdoor fixture manufacturers who need 4000K at 70 CRI [color rendering index] are taking

advantage of the LUXEON TX 360 lumen output at 1.0A and 85°C to decrease overall system cost, but have the ability to drive the same part at 350mA to deliver 155lm/W LED efficacy and enable streetlights with a system efficacy of more than 120lm/W," says Hartnett.

The LUXEON TX platform is available in a range of CCTs and CRIs to satisfy the most exacting requirements of downlights, high-bay and low-bay lighting, indoor area lighting, outdoor lighting and replacement lamps. In addition, for improved design flexibility, Lumileds has added a minimum 85-CRI option so designers can further differentiate their product lines.

"Designers have typically had to choose between the lower efficacy associated with a 90 CRI LED or the poorer color rendering associated with an 80 CRI LED," says Hartnett. "Now, LUXEON TX 85 CRI emitters bridge that gap by providing high CRI with increased efficacy in a full CCT range from 2700K to 5000K."

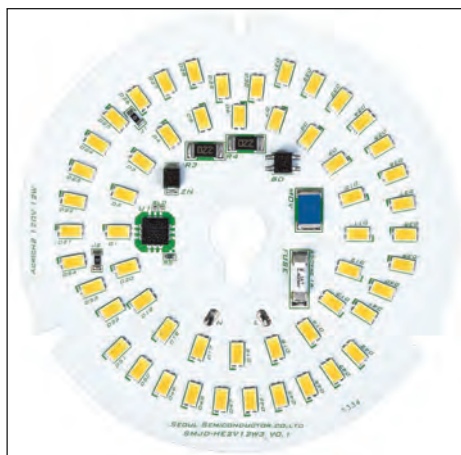
For applications that require a minimum 90 CRI, LUXEON TX delivers up to 100lm/W warm-white light (3000K CCT, 90 CRI and 700mA at 85°C). Lumileds says that this level of efficacy at 90 CRI enables superior performance for luminaires that must adhere to increasingly stringent lighting standards such as the CEC's California Quality LED Lamp Specification.

www.philipslumileds.com

Seoul Semiconductor selling Acrich2 AC LED modules in kit form for customized form factors

South Korean LED maker Seoul Semiconductor has announced the globally availability of an Acrich kit for customers trying to meet the special design requests of global lighting manufacturers. The kits consist of high-voltage Acrich Multi-Junction Technology (MJT) LEDs along with the Acrich Integrated Circuit (AIC) power controller device. Designers now have maximum flexibility in designing AC LED modules for their unique fixture needs, says the firm.

Seoul Semiconductor says that it has released the Acrich kit due to a surge in requests from customers wanting to create their own form factors. Most mid- to large-sized lighting customers have their own SMT lines and the ability to source and handle discrete parts, so they prefer to purchase a parts kit rather than a module, says Seoul Semiconductor. Acrich2 kits bring increased efficiency and convenience over traditional AC designs



Seoul Semiconductor's 10W Acrich2 module.

for those manufacturing solid-state lighting solutions, claims the firm. With high power factor, low electromagnetic interference (EMI) and low total harmonic distortion (THD), the Acrich kit can be driven directly from AC line voltages of 100-277V, and the AIC is available with a smart dimming function.

Seoul Semiconductor says that in

recent months it has dramatically improved the performance of its Acrich2 family. In September, the firm announced a 10W ceiling light module with luminous efficacy of 140lm/W, demonstrating the increase in efficiency from using Acrich 2 modules. The firm says that Acrich2 modules extend the lifetime of the fixture and extend the form factor possibilities by replacing the AC/DC converter (or ballast or driver) with the Acrich IC.

"We have seen a surge of interest in Acrich recently due to its performance improvement," says VP of marketing Marten Willemsen. "The new sales strategy to offer Acrich kits is in direct response to the requests from customers," he adds. "For broadening our targets and serving the broader global lighting market, Seoul Semiconductor is now promoting our products through Acrich kit sales at new price points."

www.seoulsemicon.com



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Cree's quarterly revenue grows 24% year-on-year to record \$391m

Profit margins rise as lighting product sales grow 37%

For its fiscal first-quarter 2014 (ended 29 September 2013), LED chip, lamp and lighting maker Cree Inc of Durham, NC, USA has reported record revenue of \$391m, up 4% on \$375m last quarter and 24% on \$315.8m a year ago.

By product sector, Power & RF product revenue was \$25.1m, up 4.6% on \$24m last quarter and 24% on \$20.1m a year ago (remaining 6% of total revenue). Power & RF product gross margin rose from 51.8% a year ago to 53.7%.

LED product revenue was \$218m, up slightly on \$217m last quarter but up 16% on \$187.6m a year ago (though falling from 60% of total revenue to 56%). LED product gross margin has risen from 40.2% to 46.6%, due primarily to higher license payments received.

Lighting product revenue was \$147.9m, up 11% on \$134m last quarter and 37% on \$108.1m a year ago (rising from 34% of total revenue to 38%), driven primarily by growth in LED fixtures. Although down on 31.6% a year ago, Lighting product gross margin has risen from 25.1% last quarter to 26.9%.

"The strong performance was primarily due to increased sales of our lighting products, higher gross margins and improved operating leverage across the business," says chairman & CEO Chuck Swoboda.

Overall gross margin (on a non-GAAP basis) has risen from 37.5% a year ago and 38.2% last quarter to 39.2%, driven primarily by improvements in lighting as Cree realizes benefits from LED bulb cost reductions and higher fixture sales, as well as LED-related license revenue.

Net income has risen from \$31.8m a year ago and \$45.6m to \$47.3m. Cash from operations was \$69.2m, up from \$61m last quarter. However, capital expenditures have risen



Cree's 60-Watt TW Series Bulb.

from \$27m last quarter to \$38.4m (again including \$5m related to patents). Hence, free cash flow fell from \$34m to \$30.8m. Depreciation and amortization was again \$39m. Altogether, cash and investments rose by \$64.9m during the quarter, from \$1.024bn to \$1.089bn.

Backlog for Q2 is similar to this point last quarter as we see good order momentum in our LED lighting product line, and LEDs are tracking in a similar range... We are targeting growth in all product segments in Q2, led by growth in LED fixtures and the Cree LED Bulb

During the quarter, Cree launched: the XLamp XQ-E LEDs (a new generation of lighting-class LEDs); the XLamp CXA 1520 LED array, the industry's first high-density (HD) LED array (delivering double the lumen density, to enable the

next generation of LED spot lights); and the TW (TrueWhite) Series LED Bulb, which emits natural LED light with a color rendering index (CRI) of 93, making Cree the first firm to meet California Energy Commission (CEC) LED bulb specifications. Cree also earned ENERGY STAR qualification for its soft-white Cree LED Bulbs.

"Order backlog for Q2 is similar to this point last quarter as we see good order momentum in our LED lighting product line, and LEDs are tracking in a similar range," says Swoboda. "Based on our backlog, current sales activity and project forecasts, we are targeting growth in all product segments in Q2, led by growth in LED fixtures and the Cree LED Bulb [and slightly higher LED product and Power & RF sales]."

For fiscal second-quarter 2014 (ending 29 December 2013), Cree expects sales to rise to \$400–420m, with gross margin of 38.5% (as LED lighting fixture and LED bulb products become a greater percentage of total sales). Operating expenses should rise by \$5.5m, due mainly to higher marketing expenditure (to promote the Cree LED Bulb) as well as taking advantage of ENERGY STAR qualification and associated utility rebates (to drive increased sales momentum) and higher sales commissions (from the higher targeted revenue). Cree also targets incremental R&D spending to support new product development and cost-reduction programs. Net income is targeted to be \$44–50m.

"Even with our success, LED lighting remains a largely untapped opportunity and we remain focused on investing in new products, new channels and building the Cree brand to grow our company and lead the market," concludes Swoboda.

www.cree.com

Cree launches XLamp XQ-E family of lighting-class LEDs

Cree has introduced the XLamp XQ-E LED family, which it says enables lighting manufacturers to significantly reduce the size and total cost of their LED luminaires without sacrificing light output, efficacy or reliability. The new LED packs the lighting-class performance of Cree's XP-E2 LED into a package that is 78% smaller. The firm claims that the XQ-E LED family opens up new design possibilities for a wide spectrum of lighting applications, such as portable, indoor directional, architectural and vehicle lighting.

The new XQ-E LEDs have a small 1.6mm x 1.6mm footprint and are available in both white and color configurations. Their combination of optical symmetry, consistent design across all configurations and



their small size enables improved color mixing and optical control compared to the larger XP-E2 LED.

"Previously, the size of LEDs dictated the form factor of the luminaire and lighting manufacturers had to design around the light source," says Paul Thieken, director of LED Components, Cree. "With its unparalleled performance and size,

the XQ-E LED redefines what's possible with lighting designs, enabling new form factors and eliminating constraints," he claims.

Built on Cree's SC3 Technology Platform and characterized at an operating temperature of 85°C, the XQ-E White LED is available in correlated color temperatures (CCTs) of 2700–6200K and offers minimum color rendering index (CRI) options of 70 and 80. The XQ-E White LED delivers up to 287 lumens at 3W, 85°C. XQ-E Color LEDs are available in red, green and blue.

XLamp XQ-E White LED samples are available now, and color LED samples will be available in late October. Production quantities are available with standard lead times.

www.cree.com/xqe

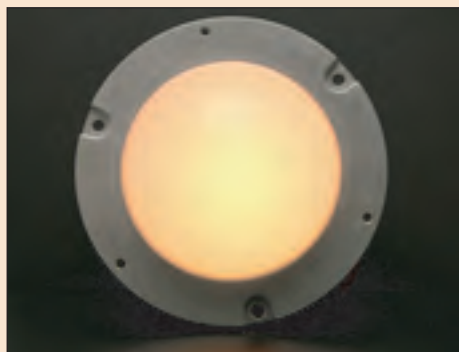
Cree launches LMH2 module with sunset dimming

Cree has introduced the LMH2 LED module with sunset dimming, enabling a natural dimming profile — similar to incandescent lighting — that was previously unachievable with any other energy-saving technology, it is claimed.

Cree's sunset dimming technology dims smoothly from 2700K to 1800K, delivering rich, warm light for applications requiring a traditional style of dimming such as hospitality and residential settings, while still achieving energy reduction of more than 80% compared to incandescents.

The robust LMH2 module family now lets lighting manufacturers address a wide range of lighting technologies with one module form factor, says Cree. The module leverages one product platform to create an entire luminaire portfolio — delivering the investment protection necessary to quickly and cost-effectively address most lighting applications, the firm claims.

"We recently launched a new product line based on the 4000 lumen LMH2 LED module," notes



Cree's LMH2LED module.

Kenny Eidsvold, president, Intense Lighting Inc. "Now, with the introduction of Cree's sunset dimming option, we can further expand our product line to offer quality LED lighting solutions for hospitality, restaurant and residential applications."

Available in a range of lumens (850 to 3000) at 2700K and multiple driver options, LMH2 modules with sunset dimming technology can plug-in seamlessly to existing LMH2 module drivers and reflectors and are also compatible with TRIAC dimmers, so it can be easily retrofitted in any room with

traditional dimming technologies or used in new installations with 0–10V or Digital Addressable Lighting Interface (DALI) dimming technologies, says Cree.

"The LMH2 module with sunset dimming opens up new markets for us and allows us to address applications that traditionally use incandescent and halogen light sources," comments Fred Farzan, president of Nora Lighting.

"The LMH2 LED module delivers rich, warm light while maintaining high CRI [color rendering index] to provide the look and feel of a traditional incandescent lamp," adds Mike Wang, vice president, lighting engineering, Edison Price Lighting.

Designed for 50,000 hours of operation and dimmable to 5%, the LMH2 module comes with Cree's five-year warranty. Samples are available now. Luminaire makers seeking ENERGY STAR qualification will have access to specification and performance data, including LM-80 reports, which can speed regulatory approvals, says Cree.

www.cree.com/lmh2

IN BRIEF

TrueWhite drives Edge High-Output luminaires outdoors

Cree has extended its Cree Edge High-Output (HO) LED luminaire series with TrueWhite Technology to bring 90-CRI quality and performance to outdoor lighting applications, delivering what is claimed to be unprecedented high-output 5000K illumination.

Designed for automotive dealership front lines, exterior retail applications and other high-lumen applications requiring high color quality, the Edge HO TrueWhite luminaire showcases inventory in vivid light while saving on energy and maintenance costs compared to the metal-halide fixtures it replaces, says the firm.

Cree says that, using its Automotive FrontlineOptic technology, the Edge HO TrueWhite luminaire precisely delivers light on the front row of a car dealership's inventory, improving the appearance of the property's highest-profile area and enabling auto dealers to use one Edge luminaire to replace up to four metal halide fixtures typically needed on each pole to properly illuminate the front line. Compared to metal halide fixtures that can lose up to 40% of their initial light output after just one year of operation, the Edge HO TrueWhite luminaire delivers both consistent light output and superior color quality while using 70% less energy, claims Cree. The new luminaire is covered by Cree's 10-year limited warranty.

"Cree engineered the Cree Edge HO TrueWhite luminaire to provide a no-compromise, high-output luminaire that offers enhanced color quality, improved illumination performance and greater reliability with a decade of virtually maintenance-free operation," says Greg Merritt, VP marketing, lighting.

www.cree.com/lighting/EdgeHO

Cree boosts XLamp CXA arrays by 68%

Cree has launched two new XLamp LED Arrays to enable high-lumen applications ranging from wallpacks to canopy lighting with one CXA LED family.

The new CXA3590 LED Array delivers up to 16,225 lumens at 85°C, which is 68% more lumens compared to Cree's previous brightest array. The CXA3590 LED Array is a suitable light source for replacing 250-watt metal halide (MH) fixtures — using 40% less power and designed to last twice as long.

"It enables us to address more applications with a single, easy-to-use platform," comments David Lin, general manager of YAH JUANG Lighting Technology. "The CXA3590 LEDs allow us to address high-lumen applications with a single LED, a feat which would have taken hundreds of other LEDs to accomplish," he adds.

Cree has also launched the CXA3070

LED Array, which delivers over 11,000 lumens at 85°C and shares the same footprint and package design as the existing CXA3050 LED.

Both the CXA3590 and CXA3070 arrays are optimized to simplify design and enable low system cost. The new high-light-output LED arrays deliver up to 134lm/W at 85°C and 70-95 CRI options, expanding what is claimed to be the industry's broadest family of LED arrays.

Characterized and binned at 85°C, the new LEDs are available in ANSI White and EasyWhite color temperatures (2700–5000K), providing what is claimed to be the industry's best color consistency for designs that use only one LED.

Samples of the XLamp CXA3590 and CXA3070 LED are available now, and production quantities are available with standard lead times.

www.cree.com/cxa

Cree's soft-white LED bulbs receive ENERGY STAR qualification for utility rebates

Cree has earned ENERGY STAR qualification for its soft-white Cree LED Bulbs, signifying that they now qualify for incentive rebates through certain local utilities. Cree says that not only do the ENERGY STAR-qualified LED bulbs look and light like traditional incandescent bulbs, use 84% less energy and last 25 times longer than typical incandescents, but they will now be more affordable in select markets with utility rebates.

"ENERGY STAR qualification can enable the Cree LED bulbs to be purchased with an instant utility rebate, delivering consumers a quality LED bulb for under \$5," says chairman & CEO Chuck Swoboda.

The bulb can pay for itself in less than a year when combined with the utility rebates (based on \$4.97 retail price — after utility rebates — on a 60W replacement at 9.5W, \$0.11 per kilowatt-hour, 25,000 hour lifetime and average usage of 6 hours per day). Incandescent and compact fluorescent lamp (CFL)

bulbs are currently installed in over 5 billion residential sockets across the USA, reckons market analyst firm IMS Research. According to ENERGY STAR, if every American home replaced just one light bulb with a light bulb that is ENERGY STAR-qualified, enough energy would be saved to light 3 million homes for a year, save about \$600m in annual energy costs, and prevent 9 billion pounds of greenhouse-gas emissions per year (equivalent to those from about 800,000 cars).

Cree says that its LED bulbs turn on instantly and are easily dimmable with most standard incandescent dimmers. In particular, the soft-white LED bulb 60-watt incandescent-replacement consumes just 9.5W, while delivering light output of 800 lumens. The firm's LED bulb 40W incandescent-replacement in soft white delivers 450 lumens and consumes just 6W.

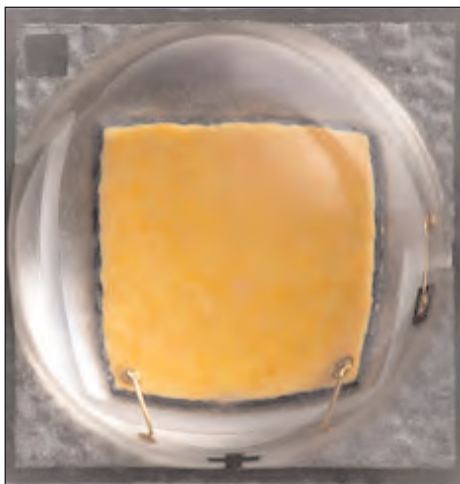
www.creebulb.com

Cree boosts brightness of XLamp XP-G2 LEDs by 7%

LED chip, lamp and lighting maker Cree Inc of Durham, NC, USA claims to have set a new industry benchmark with its higher-performance XLamp XP-G2 LEDs, boosting brightness by 7% compared to the existing XP-G2 family.

XP-G2 LEDs are used in a wide variety of applications, including street and area lighting, PAR replacement lamps and high-performance flashlights. The new XP-G2 LEDs now deliver up to 142 lumens per watt at 350mA, 85°C, or 155 lumens per watt at 350mA, 25°C, in warm white (3000K). This enables lighting manufacturers to use fewer LEDs to achieve the same brightness at a lower system cost or to increase performance levels using the same LED count and power, says Cree.

"The higher-performance XP-G2 results in fewer required LEDs, which means fewer optics, a smaller printed circuit board and less handling, all of which trans-



Cree's new XLamp XPG2 LED.

The higher-performance XP-G2 results in fewer required LEDs, which means fewer optics, a smaller printed circuit board and less handling, all of which translates to lower system cost

lates to lower system cost," says Paul Thieken, Cree's director of marketing, LED Components.

Cree is also announcing the availability of 6000 hours of LM-80 long-term testing data for the XP-G2 LED. The LM-80 data provides TM-21-reported L85 life-times of more than 36,000 hours, translating to just 15% light loss after four years, even at the maximum current of 1500mA. In addition, the XP-G2's predecessor, the XLamp XP-G LED, now has more than 12,000 hours of LM-80 data available. All XP-G data sets provide TM-21-reported L95 life-times of more than 70,000 hours (8 years), reflecting the long-term reliability of the XLamp XP package.

The higher-performance XLamp XP-G2 LED samples are available now. Production quantities are available with standard lead times, says Cree.

www.cree.com/xpg2

Cree licenses remote-phosphor patents to NNCrystal

Use of remote-phosphor optical elements by NNCrystal's customers to help shorten product time-to-market

LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA has signed a non-exclusive worldwide license agreement with China's Hangzhou Njing Technologies Ltd (NNCrystal US Corp) that provides access to Cree's remote-phosphor patent portfolio.

The licensed family of patents addresses the fundamental combination of a blue LED and a remote-phosphor element to produce white light, as well as the manufacture, design and placement of the optical element, enabling lighting manufacturers that use NNCrystal's remote-phosphor optical elements to manufacture remote-phosphor-based LED lights without taking a separate remote-phosphor patent license from Cree. Product time-to-market can be shortened by using

Cree's patented technology and by using NNCrystal's licensed remote-phosphor optical elements to access the technology, it is reckoned.

"Cree is committed to developing innovations that support our customers and help drive LED adoption," says George Brandes, Cree's director of intellectual property licensing. "Licensing of Cree's remote-phosphor patent portfolio to NNCrystal is further proof that our intellectual property strategy is working," he adds. "By providing access to Cree patents in this manner, Cree is facilitating the LED industry by providing an additional path for lighting OEMs to take in the production of high-quality, energy-efficient LED lighting," Brandes continues.

"NNCrystal and our customers respect the intellectual property of others and we recognize the value of licensing this important set of patents as the LED lighting market grows," says NNCrystal's chief technology officer Kai Su. "The Cree remote-phosphor patent portfolio includes patents that address main concepts of remote-phosphor-based light conversion and were originally filed by Cree more than ten years ago," he adds. "The license includes rights to various patent families that are issued in many countries around the world, giving NNCrystal and our customers access to this important segment of Cree's patented technology."

www.nncrystal.com

www.cree.com

Osram launches compact high-light-output, narrow-beam-angle Dragon Dome IRED for security surveillance over large distances

Osram Opto Semiconductors GmbH of Regensburg, Germany says that, with its new infrared Dragon Dome LED, security surveillance over large distances is now possible, as the focused beam of the high-power IRED achieves a range of more than 100m. The emission wavelength of 850nm makes the LED suitable as a light source for security surveillance tasks such as closed-circuit television (CCTV).

With a compact design (measuring 11mm x 6mm x 5.7mm), the SFH 4783 Dragon Dome is claimed to be the first high-power infrared LED that emits its light within a narrow angle of $\pm 12^\circ$. From a current of 1A it achieves a total radiated power of 430mW and hence a radiant intensity of 2.3 watts per steradian (W/sr), allowing a usable range of more than 100m (depending on the sensitivity and field of view of the camera). Osram Opto says that the high total radiated power of the



Osram Opto's Dragon Dome SFH 4783 infrared LED.

IRED is due to thin-film technology that enables the light to be extracted extremely efficiently from the chip.

This high radiant intensity benefits applications that need strong focused light to provide reliable illumination over large distances, says the firm. These include outdoor CCTV surveillance systems at border crossings or airports. With a wavelength of 850nm, the emitted light is well suited to camera sensors

but is barely perceptible to the human eye, so surveillance can be very discreet.

The narrow light beam is produced by the deep metallic reflector and lens of the Dragon Dome. "The integrated lens translates into less time and expense for our customers because they do not need an external lens to focus the light," says Dr Jörg Heerlein, Osram Opto's head of product marketing for Industrial Infrared Components. "This not only reduces installation time and system costs in the relevant application, but also enables the overall design to be made extremely compact," he adds. Also, the surface-mount technology (SMT) package, which is compatible with other Dragon designs, is suitable for reflow soldering processes and helps to make handling even easier and further reduces production costs, says the firm.

www.osram-os.com

Soraa appoints LED lighting executive as CEO

Soraa Inc of Fremont, CA, USA, which develops solid-state lighting technology built on 'GaN-on-GaN' (gallium nitride on gallium nitride) substrates, says that Jeff Parker has joined the firm as its new chief executive officer.

According to Soraa, as a seasoned lighting executive and innovator Parker will leverage his business acumen, acquired expertise grooming companies to financial maturity, and his reputation as an industry thought-leader to propel the firm forward. "Jeff's drive to pursue fresh ideas and ability to think outside the box will pay immediate dividends," reckons chairman Charles Giancarlo.

Before joining Soraa, Parker was a senior executive with technology



Soraa's new CEO Jeffery Parker.

CEO of LED backlighting firm Global Lighting Technologies, which Parker grew to more than \$100m in revenue before selling the R&D division to Rambus in 2009 for

licensing firm Rambus, serving as president of the Lighting and Display Technology Division (focused on producing LED lamps and fixtures).

Prior to that, he was the founder &

\$26m. He also helped to start medical lighting firm Lumitex. Parker has more than 25 years of experience in the information display, LED, medical and lighting markets. He has been granted over 100 patents covering inventions in LCD backlighting, fiber optics, LEDs, light management films, medical illuminators, and general lighting.

"Jeff is a passionate entrepreneur, successful technologist and possesses a succinct vision on how to sustain and broaden our position," comments Soraa co-founder Shuji Nakamura, professor in the Materials Department of the College of Engineering, University of California, Santa Barbara (UCSB).

www.soraa.com

Osram launches its first LED replacement headlamp

Lighting firm Osram GmbH of Munich, Germany is introducing its first fully functioning replacement LED headlamp. The new Ledriving Fog combined daytime running light/fog lamp uses LED technology to replace conventional halogen fog lamps in many car models. The number-one firm in the automotive light sector is also extending its retrofit spectrum to include the inexpensive Ledriving PX-4 daytime running light (which has a four-pixel LED) as well as colored retrofit lamps for vehicle interiors.

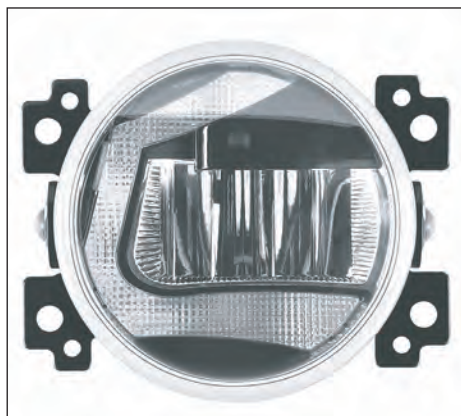
Ledriving Fog

The Ledriving Fog combined daytime running light/fog lamp with LED fiber optics is the first replacement headlamp from Osram for cars and trucks. With its rounded design and 90mm diameter, it can fully replace many conventional fog lamps with halogen technology without modifications to the car, says Osram. The new LED product not only upgrades the technical capability of the car but also provides drivers with an additional feature, since Ledriving Fog is also a daytime running light, says the firm. LEDs in OEM quality are used for both functions.

The LED light guide for the DRL function ensures uniformly bright light and a dynamic appearance, ensuring better visibility, reckons Osram. Also, due to a wider LED beam angle, the fog light enables significantly better visibility even in poor weather conditions, and the product complies completely with ECE (Economic Commission for Europe) guidelines for both functions. As well as design and functionality, there is also an economic advantage, claims Osram, since Ledriving Fog consumes up to 70% less electrical energy than conventional fog lights.

Ledriving PX-4

Osram says that those wanting to economically give their vehicle a



The Ledriving Fog, featuring a daytime running light and fog light in a single light construction.

modern design while simultaneously improving safety in road traffic can accomplish this with the retrofit Ledriving PX-4 daytime running light, which has a dotted luminous surface, a slender design, and suits most vehicle models. Contrary to many low-price products, claims the firm, the DRL complies completely with standards of the Economic Commission for Europe (ECE) and can be fitted easily in about 60 minutes.

Retrofits for interiors

Since LEDs are also popular for accent lighting in vehicle interiors, Osram's new retrofit lamps fit into conventional incandescent lamp bases of types W5W, C5W and T4W. The 12V product spectrum (available until now in cool white and warm white) has been expanded with two colored W5W variants — blue and yellow LED lamps — creating accenting for boot, instrument and glove compartment lighting. Retrofits of types W5W and T4W in cool white or warm white are now also available for buses and trucks. Due to a special optic, the LED retrofit lamps feature homogeneous light, and emit this with a high level of energy efficiency, consuming up to 80% less power than conventional lamps, says Osram.

www.osram.com

IN BRIEF

Count On Tools joins Cree Solution Provider program

Count On Tools Inc (COT) of Gainesville, GA, USA, a provider of precision components and SMT spare parts, has been invited to take part in the Cree Solution Provider program (CSP). The CSP network was created by Cree in late 2007 to help lighting manufacturers find complementary components from third-party manufacturers that work with Cree's LED products. The program aims to help lighting manufacturers by enabling a shorter design cycle to speed products to market.

Count On Tools says that, recognizing concerns with LED component handling during the pick-and-place process, it developed a new nozzle platform designed to overcome the tackiness or stickiness of the LED substrates (flashing). The firm's SMT nozzle designs for Cree LEDs avoid placing mechanical stress on the LED lens by limiting contact with the optical surface during component picking or placement processes, eliminating the possibility of degraded performance from the LED after the circuit board is assembled.

"Alliances with companies like Count On Tools are an essential part of delivering energy-efficient, high-quality Cree LED lighting solutions to the market," says David Cox, director of alliance development with Cree. "Their latest pick-and-place designs can help lighting manufacturers accurately and consistently place Cree LED components using their existing SMT equipment."

The new line of LED nozzles for Cree LEDs enables better placement with odd-form components in machines while saving money, Count On Tools claims.

www.cotinc.com

www.cree.com

Daylight wins supplemental funding from NSF

Daylight Solutions Inc of San Diego, CA, USA, which makes molecular detection and spectroscopic imaging systems based on mid-infrared quantum cascade lasers (QCLs) for scientific research, life science, industrial process control and defense applications, has been awarded supplemental funding from the National Science Foundation (NSF). Building on its existing Phase II Small Business Innovation Research (SBIR) program, the additional funding will help to accelerate the transition of the firm's mid-infrared hyperspectral imaging

platform into commercial markets.

The award was granted via the NSF Small-Business ERC Collaborative Opportunity (SECO) program, which aims to facilitate the transition of NSF's technology investments in Engineering Research Centers (ERC) and in Small Business Innovation Research (SBIR) projects into commercial markets. Daylight is an Industrial Partner with the NSF-funded ERC for Mid-InfraRed Technologies for Health and the Environment (MIRTHE). In collaboration with Dr Rebekah Drezek at Rice University, the program will

leverage the firm's imaging technology, and apply it to new methods for detecting cancer.

"This supplemental award, coupled with Daylight's own internal investments, demonstrates our commitment to working with leading researchers, so that together we enable breakthrough capabilities in life-science research," says president Paul Larson. "Daylight's mid-infrared imaging technology is an excellent platform from which to launch these capabilities," he reckons.

www.daylightsolutions.com

Shimadzu unveils 10W blue laser diode, enabling micro-machining applications

Japan's Shimadzu Corp has developed a blue direct diode laser (DDL), providing what is claimed to be industry-leading brightness levels. The 10W-type laser was exhibited at InterOpto 2013 at Pacifico Yokohama, Japan (16–18 October).

The global market for lasers for material processing applications was \$2.6bn in 2010 and is expected to surge to \$5.7bn by 2020, according to Optech Consulting's 'Fiber Laser Report 2011'. With machining lasers, in addition to conventional carbon dioxide lasers, diode-pumped solid-state lasers and fiber lasers (which use semiconductor lasers as their pumping sources) are increasingly becoming commonplace, says Shimadzu. Now, direct diode lasers (which use such semiconductor lasers directly for laser machining) have become a focus of attention as the next generation of laser machining light sources, because they are compact, feature high-efficiency electro-optic conversion, and can be mass-produced at low cost.

In this context, the development of higher-output direct diode lasers using near-infrared light is in progress, says Shimadzu. The realization of high-output semiconduc-

tor lasers that work at short wavelengths in the visible region (where the rate of absorption by metals is high) and that provide high brightness levels (from which high beam intensities can be obtained) will accommodate diversification of machining materials and enable deployment for microfabrication, where demand is increasing with the miniaturization of smartphones and other electronic devices, notes Shimadzu. The transition from carbon dioxide lasers and solid-state lasers to DDLs is hence expected to accelerate, with the commercial market expanding to about \$0.5bn by 2020, according to Optech Consulting's 'Fiber Laser Report 2011'.

Shimadzu says that it has achieved a 16-fold increase in brightness over conventional levels for fiber-coupled blue semiconductor lasers, which feature high rates of absorption by metals. This has been achieved by utilizing newly developed optical multiplexing technology in addition to high-durability coating technology and techniques for precision assembly of optical equipment, cultivated to date based on gallium nitride (GaN) semiconductor lasers used in Blu-ray Discs and projectors. Shimadzu has hence developed

what is reckoned to be the world's first blue direct diode laser that features a microscopic spot size and can be applied to microfabrication.

The blue direct diode laser features a fiber-coupling design that enables flexible laser beam delivery with high efficiency, even for kilowatt-class output. Power consumption is about half that of solid-state green lasers, expanding the possibilities for laser machining instruments and processing instruments equipped with direct diode lasers.

Shimadzu says that it has been focusing on establishing a light source industry for the next generation of advanced laser machining. In September 2012 it released the BEAM IMPACT series of external resonator-type short-pulsed semiconductor lasers, a seed light source for fiber lasers. Furthermore, this April it released a high-output laser mirror and laser window, and is subsequently targeting commercialization.

First, a 10W model will be released in January. Subsequently, 50W- and 100W-type lasers and spatial output types will be developed in order to enhance the product line, concludes Shimadzu.

www.shimadzu.com

POET appoints RapidIO Steering Committee chairman Gagnon to Special Strategic Committee advisory board

POET Technologies Inc of Toronto, Ontario, Canada — which, through subsidiary OPEL Defense Integrated Systems (ODIS Inc) of Storrs, CT, USA, has developed the proprietary planar-optoelectronic technology (POET) platform for monolithic fabrication of integrated III-V-based electronic and optical devices on a single semiconductor wafer — has appointed Stephane Gagnon to its Strategic Special Committee (SSC) Advisory Board.

Gagnon has over 20 years of experience in the semiconductor, telecom and processor industry. His most recent role was senior director of product management for Integrated Device Technology (IDT), where he drove business strategy for the RapidIO switching and IP product line (with primary responsibilities including over-all strategy and product marketing, in addition to business development and the management of international customers and partner relationships). Gagnon became involved with the RapidIO Trade Association (RTA) Technical Working Group 13 years ago and has held the position of chairman of the RTA Steering Committee for more than 3 years.

Prior to his role at IDT and Tundra Semiconductor Corp (acquired by IDT), Gagnon held positions at Motorola and Nortel Networks. He has a BSc in Computer Engineering from Laval University.

"He is current in terms of industry relationships and has demonstrated the ability to drive new technology into the marketplace, as he did in achieving 100% market share in the LTE Wireless Base station business at IDT with RapidIO," comments Peter Copetti, executive

director and chairman of the SSC.

As an advisor to the SSC, Gagnon will be granted incentive stock options to purchase up to an aggregate of 300,000 common shares, representing 0.23% of the firm's outstanding shares. The stock options are exercisable at a price

per share of CA\$0.43 (expiring on 4 October 2018), based on the closing trading price on 4 October 2013. The options will vest and be exercisable on the basis of 25% on the date of grant and 25% every six months thereafter.

www.poet-technologies.com

Gagnon has over 20 years of experience in the semiconductor, telecom and processor industry

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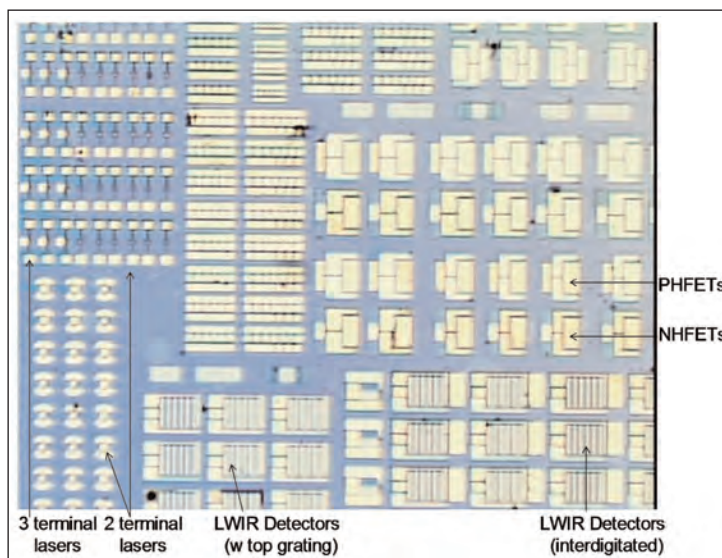
POET's Special Strategic Committee announces updates

POET Technologies Inc of Toronto, Canada — which, through subsidiary OPEL Defense Integrated Systems (ODIS Inc) of Storrs, CT, USA, has developed the proprietary planar-optoelectronic technology (POET) platform for monolithic fabrication of integrated III-V-based electronic and optical devices on a single semiconductor wafer — has announced updates regarding its near-term strategic plan and technical milestones.

The firm says it remains on track to deliver to industry (and specifically to its development partners) by mid-2014 a fully integrated monolithic optoelectronic semiconductor chip based on its POET platform. The chip will be capable of providing significant energy savings and increased performance over current silicon technology, the firm reckons.

POET Development Alliance (PDA, announced in August) — The firm says that, to date, it has met with several large-scale technology firms that have expressed interest in jointly adapting the POET process to commercial-scale implementation. Some potential alliance partners have already provided input into POET's alignment of resources, notably with respect to the firm's technical roadmap. Specific instances include the moving forward of milestone 6 in the firm's corporate presentation, achieved in second-quarter 2013; and the current 100nm initiative, which is proceeding as planned. Incubating such relationships is an ongoing task of the Special Strategic Committee (SSC), as a key aspect of finalizing licensing relationships towards a 'Powered by POET' device ecosystem.

Shareholder Rights Plan (SRP) — As announced on 16 August, the board of directors has adopted a shareholder rights plan designed to encourage the fair and equal treatment of shareholders in connection with any take-over bid for the outstanding securities of the company.



Integrated lasers, detectors, logic and transistors, all on one die.

The rights plan provides the board with additional time to assess the advantages and disadvantages to any particular offer and to seek out alternative proposals in the best interests of all shareholders. The rights plan is subject to approval of the TSX Venture Exchange and the shareholders. The firm is required to seek shareholder approval to re-approve the rights plan every three years. It notes that it has not adopted the rights plan in response to any specific proposal to acquire control of its outstanding shares.

Milestone 5 — Switching Laser Demonstration at POET's R&D Labs. Milestone 5 (nearing completion) demonstrates a fast-signal controlable laser for standard optical fiber telecommunications. While the integrated POET switchable laser transmitter is a key differentiator to silicon technology, it is considered to demand less priority on resources, because of its low-risk for achievability, over milestones in the firm's technical roadmap that have been deemed more important to potential partners.

Milestone 7 — Optical Thyristor-Based Infrared Detector Array Fabrication and Validation. Milestone 7 is proceeding with no technical issues, according to POET's third-party fab partner.

While the POET team is in continuous communication with the fab, a publicly available update may fall well into fourth-quarter reporting, as control of the fabrication and validation process remains with the firm's partner.

POET Technologies notes that the technical roadmap in its company presentation provides

best approximations based on current progress at its R&D labs and partner fabs; timing differences will arise and have arisen not only due to technical resource needs but also due to input from potential PDA partners. Due to these interactions, it has become impractical to document the numerous changes to the roadmap, but the firm has decided to keep the current presentation as indicative, rather than provide no information. Despite all this, the firm expects to complete and present its monolithic solution on time.

"This is the critical period approaching the last phases of development, towards the introduction to the semiconductor industry of a revolutionary, and validated, process to produce integrated monolithic optoelectronic chips," executive director Peter Copetti, chairman of the SSC. "The company continues to target a liquidity event for investors, which has remained a primary objective throughout our discussions," he adds. "The work of [chief scientist] Geoff Taylor's team is finally bearing fruit — securing POET Technologies as a leader in its space as the semiconductor industry works towards extending Moore's Law into the next millennium."

www.poet-technologies.com

IQE wins three-year VCSEL epi contract from Philips

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has signing an initial three-year supply contract with Philips Technologie GmbH for epitaxial wafers used for the manufacturing of vertical-cavity surface-emitting laser (VCSEL) devices.

VCSEL chips can be produced on a mass scale, in a similar process flow to LED chips, says IQE, opening the way for very cost-effective, high-performance laser devices that can be used in a wide variety of applications, including optical data communication, industrial sensing, illumination, gesture recognition and heating applications.

Together with partners like IQE, Philips aims to scale up its activities

in order to meet the increasing global demand for solid-state lasers.

IQE says that the supply contract adds significantly to its photonics business, underlines the long-term relationship between the two companies, and reflects the strengthening market for photonic devices. The contract, which provides IQE with the majority supply of epi-wafers to Philips, is renewable after the initial three-year term, and also includes a joint development agreement.

"VCSELs are expected to show rapid growth in the coming years," notes Philips Photonics' general manager Dr Joseph Pankert. "This growth is driven by a variety of applications, and Philips is commit-

ted to address the growing demand. Teaming up with IQE is an essential element of our growth strategy and enables us to meet the required volume and quality levels," he adds.

"Many of the applications that are enabled by IQE's VCSEL wafers are at an inflection point where growth is expected to significantly ramp up over the coming months and years," comments IQE's CEO Dr Drew Nelson. "IQE is able to offer many attractive USPs, including a comprehensive product range, scale of operation, multiple manufacturing locations, and long experience in laser diode epiwafer manufacturing."

www.iqep.com

Agilent launches physics-based VCSEL model to solve challenges in designing rack-to-rack opto links

Agilent Technologies Inc of Santa Clara, CA, USA has introduced a physics-based model for its opto model library that quickly and accurately solves the challenges posed by signal distortion in vertical-cavity surface-emitting lasers (VCSELs) used in rack-to-rack opto links. The new VCSEL model, available in the Advanced Design System 2013 Transient Convolution Element and SystemVue 2013 AMI Modeling Kit, is used for both modeling optoelectronic components and designing them into equipment.

Before the multi-gigabit era, rack-to-rack digital signals propagated tens or even hundreds of meters across CAT-5 twisted pair or coaxial copper cables with little distortion. However, at today's speeds, rising and falling edges degrade after travelling only a few meters, says Agilent. Laser technologies like VCSELs have pushed down the cost of optoelectronics to the point where optical fiber communication is now replacing traditional copper cabling for spans over about 10m in the multi-gigabit regime.

Up to now, simulation tools used to design these nonlinear devices required engineers to learn a whole new optical paradigm. However, with the new VCSEL model, Agilent is leveraging a technique that high-speed digital engineers are already familiar with — the Input/Output Buffer Information Specification (IBIS) AMI flow. Senior Agilent engineers contributed this model to document BIRD-156 of the IBIS Open Forum. BIRD-156 extends the AMI flow to allow both electrical and optical repeater links to be modeled and was incorporated in the recently ratified IBIS version 6.0. Agilent co-authors will present a paper 'Modeling, Extraction and Verification of VCSEL Model for Optical IBIS AMI' at the DesignCon 2014 event in Santa Clara in January.

With the VCSEL model, SystemVue 2013 now offers model builders (such as optoelectronic component vendors) a tool that supports the evolution of IBIS and can build rack-to-rack opto link models. The models run in ADS, the tool that opto component con-

sumers (data center and telecoms equipment manufacturers, for example) use to design these subsystems into their larger systems. SystemVue 2013 also now features an enhanced model for the clock/data recovery circuitry found in both optical and electrical retimers.

"With our previous opto model library release we added a simpler class of VCSEL model with frequency-independent behavior," says Colin Warwick, product manager for High-Speed Digital Design at Agilent EEsof EDA (which supplies electronic design automation software for microwave, RF, high-frequency, high-speed digital, RF system, electronic system level, circuit, 3D electromagnetic, physical design and device-modeling applications). "With this release, we are adding not only a physics-based, frequency-dependent model that uses rate equation techniques, but also a tool to fit the rate equation parameters to measured data, ensuring an accurate model."

www.agilent.com/find/eesof

IN BRIEF

VP, corporate finance replaces outgoing CFO

Oclaro's its chief financial officer Jerry Turin is resigning on 8 November to pursue other opportunities.

"Over his nearly 8 years at Oclaro, Jerry has played an instrumental role in building key relationships in the financial community, managing the Finance function, and supporting Oclaro's various mergers and acquisitions," says CEO Greg Dougherty.

Turin was first corporate controller then VP of finance before becoming CFO in 2008. "I wish the Oclaro team well as they work to execute on the restructuring and turnaround plans," says Turin.

Oclaro has named VP, corporate finance Pete Mangan as CFO (from 11 November), reporting directly to Dougherty.

"As VP of corporate finance, Pete has been an instrumental leader in helping drive our restructuring plan," says Dougherty. "His financial discipline and his wealth of experience in finance, restructuring and technology businesses are a strong complement to the executive team."

Mangan joined Oclaro in May 2012. He has since been responsible for the global operations finance team and recently the corporate accounting and tax group. He has nearly 30 years of experience in finance positions with firms including AMD, Trident Microsystems, FormFactor, Spansion, Asyst Technologies, and Sun Microsystems. Mangan was CFO at Trident Microsystems from 1996 to 1998 and again from 2008 to 2012.

"Oclaro is making progress on its plans to return the company to fiscal stability," says Mangan. "Our recently announced divestitures are an important step in restructuring the company."

II-VI buying Oclaro's amplifier and micro-optics business for \$88.6m

Unit complements Oclaro Switzerland GaAs laser diode business acquired in September

Engineering materials and optoelectronic components provider II-VI Inc of Saxonburg, PA, USA has signed an asset purchase agreement to acquire the optical amplifier and micro-optics business of Oclaro Inc of San Jose, CA, USA (which provides lasers and optical components, modules and subsystems for the optical communications, industrial, and consumer laser markets) in a transaction valued at \$88.6m.

Previously, on 12 September, II-VI paid Oclaro \$5m for an exclusive 30-day option to buy the business. II-VI will pay Oclaro \$79.6m in cash on the effective date of closing (expected on or about 1 November, dependent on the receipt of certain regulatory clearances). The remaining \$4m will be held back by II-VI until 31 December 2014, subject to traditional post-closing conditions.

Specifically, II-VI has purchased Oclaro's amplifier and related subsystems business, and its micro-optics product lines, including intellectual property, inventory and equipment. II-VI will also hire about 145 Oclaro staff, primarily located in Horseheads, NY, San Jose, CA and Shanghai, China. Revenue for the business was about \$94m for the fiscal year ended 29 June 2013.

The acquisition of the business will complement the Zurich-based Oclaro Switzerland GmbH subsidiary and associated laser diodes business acquired by II-VI on 12 September for \$115m, and is consistent with II-VI's strategy to focus on precision-engineered materials and optoelectronic component businesses. The business will be included in II-VI's Active Optical Products segment for financial reporting purposes.

"The sale of our amplifier business to II-VI is another important

milestone in Oclaro's reinvention and return to financial stability," comments Oclaro's CEO Greg Dougherty. "This transaction is another validation of the value of our technology, intellectual property and, most importantly, our people. The infusion of cash from our recent transactions with II-VI are critical catalysts to further our restructuring and turnaround plans," he adds.

"We are pleased to add a broad portfolio of world-class, fully customized solutions to provide customers with end-to-end design and manufacturing support to enable the rapid realization of customer-specific amplification and micro-optics solutions," says II-VI Inc's president & CEO Francis J. Kramer. "We will leverage the telecom laser pump product line we recently purchased from Oclaro, and the business will benefit from the complementary product portfolio and capabilities of our [near-infrared] Photop business unit," he adds. "The business and its team come to us as a recognized industry leader, and are well positioned with a broad technology and product portfolio which is underpinned by over 400 patents."

II-VI will finance the acquisition with available cash from its recently expanded credit facility. Assuming that the transaction receives regulatory approvals on or about 1 November, for the remainder of II-VI's fiscal year (to end-June 2014) the business is currently expected to generate \$60–65m in revenue and to be neutral to earnings after the impact of one-time transactions expenses is included. II-VI expects the acquisition to become accretive to earnings during the fiscal year ending 30 June 2015.

www.ii-vi.com

www.oclaro.com

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IN BRIEF

Infinera CFO resigns

Infinera Corp of Sunnyvale, CA, USA, a vertically integrated manufacturer of digital optical network systems incorporating its own indium phosphide-based photonic integrated circuits (PICs), says that chief financial officer Ita Brennan is resigning (effective 28 February 2014) to pursue another opportunity at a technology start-up. The firm is seeking a new CFO and expects to announce a succession plan on or before her resignation date.

Brennan joined Infinera in 2006 and served in various roles within the finance group, prior to her promotion to CFO in June 2010. She will continue to direct Infinera's finance activities as CFO until her departure date.

"She has built a strong financial team at the company and has been an outstanding leader both inside and outside Infinera," comments CEO Tom Fallon.

"I look forward to seeing the company continue to grow and successfully execute on the long-term strategy we have put in place," says Brennan.

● Infinera has appointed Alastair Short as senior VP, general counsel & corporate secretary.

Short was most recently general counsel & corporate secretary of Better Place Inc (a company that designed and made infrastructure for electric vehicles), which he joined in 2011. Prior to that, he was VP & general counsel for global technology firm 3PAR from 2002. He assisted in taking 3PAR public in 2007 and was a key participant when it was sold to HP in 2010. Short's experience includes senior legal positions with two start-up companies, MetaTV and Netigy, and he held senior positions at Hitachi Data Systems, including executive VP of legal affairs.

www.infinera.com

GigOptix's revenue rebounds by more-than-expected 7% in Q3 to \$7.3m Q4 to see 5% growth and return to income

For third-quarter 2013, GigOptix Inc of San Jose, CA, USA (a fabless supplier of analog semiconductor and optical communications components for fiber-optic and wireless networks) has reported revenue of \$7.3m, down 28% on \$10.1m a year ago but up 7% on \$6.8m last quarter (above August's guidance of 5%), marking an upturn after several "slow and challenging quarters".

Growth was driven by a 14% rise in High Speed Communications business, due primarily to higher demand for the fast-growing 100Gbps coherent telecom segment. "GigOptix commands a roughly 50% share of the 100Gbps coherent optical communications device market, through our dominant position in the TIA [transimpedance amplifier] and driver product areas," says chairman & CEO Dr Avi Katz. "In addition, we saw continued interest in commercialization of our products for the datacom market, where we maintain a sole merchant provider status and leadership position in optical engines for the 40Gbps QSFP+ devices for active optical cables [AOCs] and transceivers in newly installed datacenters," he adds.

On a non-GAAP basis, gross margin was 62%, up from 54% a year ago but down from last quarter's record 65%. Net loss was \$0.7m, impacted by \$0.6m in R&D wafer tape-out related expenses associated with the firm's joint development programs (JDP). This compares with net income of \$0.1m last quarter and \$0.6m a year ago. Adjusted EBITDA has fallen from \$1.3m a year ago and \$0.7m last quarter to \$0.1m, but this is only after the \$0.6m in JDP expenses.

"On 19 September, we announced a global settlement of all pending lawsuits between GigOptix and M/A-COM Technology Solutions Inc and its affiliates, including our lawsuit for alleged misappropriation of

trade secrets and breach of contract, and subsequently on 24 September received a payment of \$7.25m," says Katz. Consequently, during the quarter, cash and cash equivalents rose from \$9.5m to \$15.3m.

"We can now focus all of our efforts on continuing to build our business through new product introductions and enhancing our strategic expansion plans as we execute on our long-term business plan," says Katz. "Combined, these efforts should lead to more revenue opportunities in the next year and expansion into new, large and promising markets," he adds.

"The third quarter was an inflection point in our business," Katz believes. "After several challenging quarters for our industry, we are more confident that revenue growth will continue over the longer-term based on the current backlog for the fourth quarter of 2013 and beyond, positive comments from our customers, and other favorable indicators in the markets we serve," he adds. "In particular, we are seeing demand rebound in the 40Gbps and 100Gbps telecom and datacom markets, where we have a strong presence with several key technologies. We are also factoring into our growth forecast the expected new product introductions in 2014 for our Industrial business and new product introductions in the consumer electronics market."

In the light of the better market conditions and improving demand, for fourth-quarter 2013 GigOptix expects revenue to grow by 5%. Non-GAAP bottom-line performance and adjusted EBITDA should also improve as R&D expenses (which rose by \$0.6m in Q3 to support new JDP product tape-outs) will decline to the quarterly levels recorded in first-half 2013, expects GigOptix.

www.gigoptix.com

GigOptix launches 100/400G quad linear MZM driver with 30% power savings for coherent long-haul telecom

GigOptix Inc of San Jose, CA, USA (a fabless supplier of analog semiconductor and optical communications components over optical fiber and wireless networks) says that its GX62472 linear quad channel Mach-Zehnder modulator (MZM) driver has demonstrated more than 30% power consumption savings compared to the previous generation.

High-performance power-efficient linear devices enable 100Gbps/400 Gbps advanced modulation formats that address end-user demand for more bandwidth. GigOptix's

GX62472 is a second-generation, quad 32Gbps per channel, linear MZM driver, specifically developed and optimized for long-haul telecommunications.

GigOptix reckons that the release of a power-efficient linear driver strengthens its 50% long-haul driver market position. Enabled by advanced engineering techniques, the GX62472 now delivers what is claimed to be leading linear quad driver performance with a typical reduction of power enabling 2.1W per channel. The power reduction was achieved while demonstrating

what is claimed to be excellent total harmonic distortion performance.

"The new GX62472 device has a 30% power reduction achievement and directly enables our customers to target higher data rates via advanced modulation formats, and into smaller form factors where power consumption is of increasing concern," says chief technical officer Andrea Betti-Berutto. "Lower-power linear MZM drivers will enable faster adoption of next-generation systems working towards terabit systems."

www.gigoptix.com

GigOptix chosen as sole long-reach TIA production partner by large 40Gbps QSFP+ transceiver supplier

GigOptix says that it has become the sole long-reach (LR) transimpedance amplifier (TIA) supplier for one of the largest suppliers to the fast-growing 40Gbps QSFP+ LR transceiver market.

GigOptix has been a key supplier of TIAs for several years, having shipped hundreds of thousands of LR TIA devices to channel partners to date. GigOptix says that the

new supply partnership with one of the world's largest suppliers of optical communication components and subsystems further validates its position, as it aims to advance its place in the fast-growing QSFP+ market.

"This new supply agreement reaffirms our position as the leading industry merchant provider of TIAs to the heavily deployed 40Gbps

QSFP+ LR transceiver market," says Dr Raluca Dinu, general manager & VP of the Optics Product Line at GigOptix. "The success that GigOptix has seen in the LR market builds on our success in the short-reach (SR) datacom market," he adds. "GigOptix is becoming the leading supplier of choice to many pluggable transceiver manufacturers," he claims.

Infinera makes profit on Q3 revenue up 27% year-on-year

For third-quarter 2013, Infinera Corp of Sunnyvale, CA, USA, a vertically integrated manufacturer of digital optical network systems incorporating its own indium phosphide-based photonic integrated circuits (PICs), has reported revenue of \$142m, up 2.6% on \$138.4m last quarter and 27% on \$112.2m a year ago.

On a non-GAAP basis (excluding non-cash stock-based compensation expenses), gross margin was 49%, up on 39% both last quarter and a year ago. Net income was \$12.8m, compared with a loss of \$1.2m last quarter and \$7.8m a year ago.

"DTN-X adoption continued to drive strong financial results... We generated solid revenue growth and achieved positive cash flow from operations, with both gross margin and profitability exceeding our expectations," says Infinera's chief executive officer Tom Fallon. "During the quarter, we received purchase commitments from five additional customers, including two new to Infinera, bringing our total DTN-X customer count to 39," he adds.

"We are seeing growing global demand for Infinera's Intelligent Transport Network and the DTN-X, the only platform available

in the market today that offers super-channel scale, converged OTN switching and GMPLS network automation," Fallon claims.

"This interest is across industry segments, including domestic and international Tier 1 carriers, bandwidth wholesalers, cable, and Internet content providers," he continues.

"We remain committed to growing our market share and are increasingly confident that over the next 12 to 18 months we will add new strategic accounts while expanding our deployments with existing customers."

www.infinera.com

Finisar opens production plant in Wuxi, China

Plant to focus on tunable and parallel transceivers, WSS modules, ROADM line-cards, passives & subassemblies for VCSELs and detectors

Fiber-optic communications component and subsystem maker Finisar of Sunnyvale, CA, USA recently held a grand opening and ribbon-cutting ceremony for its new production facility in Wuxi, China, attended by government officials, executive management, and local employees.

Located in Jiangsu Province about an hour from Finisar's Shanghai plant, the land provides 550,000ft² of open space and will house two new multi-level buildings. The first is now open and the second will begin construction by the end of 2013. This facility will focus primarily on manufacturing tunable and parallel transceivers, wavelength-selective switch (WSS) modules, reconfigurable optical add-drop multiplexer (ROADM) line-cards, passive components, and high-end optical subassemblies utilized in vertical-cavity surface-emitting lasers (VCSELs) and detectors.



Finisar's new production facility in Wuxi, China.

"As the demand for high-speed optical products continues, our new Wuxi facility will add much needed manufacturing capacity in China," said executive chairman Jerry S. Rawls. "Finisar will continue to invest in the infrastructure required to give our customers critical access to products as market demands increase," he added.

"The addition of the Finisar Wuxi plant is a great example of our

worldwide manufacturing strategy, which supports continually increasing levels of high-volume production along with competitive production costs," said Joe Young, executive VP of global operations. "We are confident that the Wuxi facility will match the quality and perform-

ance of other Finisar plants around the globe."

Finisar says that it is one of just a few optics firms to operate its own manufacturing sites, allowing it to quickly ramp up volumes and shift production from one product to another as needed. Finisar Wuxi joins Finisar manufacturing sites in Ipoh, Malaysia; Shanghai, China; Fremont, California; Allen, Texas; and Jarfalla, Sweden.

Finisar demonstrates complete XFP-RF pluggable optical transmitter portfolio for cable access networks at SCTE Cable-Tec Expo

At the SCTE Cable-Tec Expo in Atlanta, Georgia (22–24 October), Finisar introduced its complete XFP-RF transmitter portfolio, including what is claimed to be the industry's first analog RF-modulated, small-form-factor optical transmitter for cable operators' access networks.

The pluggable XFP-RF transmitter transports a full lineup of analog channels plus digital QAM channels and replaces existing 1310nm broadcast transmitters. It has an expanded operating bandwidth above 1.2GHz to accommodate the DOCSIS 3.1 specification.

The new analog transmitter extends Finisar's portfolio of XFP-RF transmitters, which already includes a full QAM transmitter

with wide-band tunability up to 88 dense wavelength division multiplexing (DWDM) wavelengths. In February, the Society of Cable Telecommunications Engineers (SCTE) approved and published interface specifications for XFP-RF transmitters (SCTE 195 2013). The pluggable transmitters are being designed into existing broadband optical platforms to double the density and halve the power consumption in hybrid fiber coaxial (HFC) networks. They can also be plugged directly into next-generation Cable Modem Termination Systems and QAM modulators to move the optical ports to the network equipment, further saving space and power. With the addition of the analog

XFP-RF transmitter, cable operators have more flexibility with the type of channel loading they can carry on their networks, says Finisar.

"The analog XFP-RF transmitter saves space and power, and provides increased flexibility as cable operators continue to deploy optics to segment their networks to provide additional services to consumers," says Shawn Esser, director of product marketing for CATV products. "The XFP-RF transmitters deployed in existing optical platforms today can be re-deployed in next-generation infrastructure equipment designed with optical ports to future-proof cable operators' investment."

<http://expo.scte.org>
www.finisar.com

Finisar gives first public demo of CFP4 transceiver

Also demos 40G QSFP+ over 40km fiber and 10G tunable DWDM SFP+

At ECOC 2013 in London (23–25 September), fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA demonstrated several new technologies for high-speed optical networking applications, including what is claimed to be the first 100GE-SR4 CFP4 optical transceiver, capable of carrier-grade transmission over fiber links up to 100m. Such innovation enables higher-density links in more compact form factors while lowering system power consumption for next-generation networks, says Finisar.

The 100GE-SR4 CFP4 demonstration constituted the first public demonstration of a working module in the new CFP4 MSA form factor, reckons the firm. The versatile CFP4 almost doubles the 100G Ethernet port density of CFP2 modules, enabling up to 3.6Tb/s per host board while supporting several optical interfaces, including 100G-SR4,

100G-LR4, 100G-SR10, and 10x10GE breakout applications. The demonstration showed two 100G Ethernet CFP4 optical modules inter-operating error-free over multimode fiber with a maximum power dissipation of only 3.5W (3W typical). The module uses a 4x25G VCSEL array architecture (as defined in the emerging 100GBASE-SR4 IEEE standard) and supports OTU4 applications (i.e. 4x28G multimode) and will begin shipping to customers in the near future.

With its 40km QSFP+ module for 40GBASE-ER4 applications, Finisar also demonstrated the ability to carry 40G Ethernet in a high-density, low-cost form factor over extended reaches. The QSFP+ form factor that enables significant reductions in module size and power compared to earlier, bulky 40G CFP implementations of the same product. Based on Finisar's QSFP+ LR4 design (which incorporates the

firm's own uncooled CWDM DFB lasers), the 40G QSFP+ ER4 module is suitable for inter-connecting data centers and for high-capacity metro Ethernet applications.

The 10G tunable DWDM SFP+ module demo highlighted the ability to actively tune 50GHz-spaced DWDM channels while providing error-free operation and low power consumption across all wavelengths. This makes the module a suitable replacement for fixed-channel DWDM SFP+ modules by reducing sparing needs, creating operational efficiencies through the reduction of 100+ part numbers down to one, and providing shorter lead times for seldom used wavelengths. The module is MSA compliant (including standard length), supports SBS Suppression technology, and offers higher faceplate density and better power efficiency compared to existing products. Samples are shipping now.

www.finisar.com

JDSU showcases latest fiber-optic and 100G technology

JDSU featured its latest fiber-optic and 100G network and service enablement technology at the European Conference and Exhibition on Optical Communications (ECOC) in London, UK in late September, demonstrating solutions for next-generation networks.

Optical communications solutions demonstrated included:

● *CFP2 LR-4 and T-SFP+ update* — To address growing demand for bandwidth, JDSU previewed the first of its full suite of truly pluggable 100G modules. The CFP2 LR4 promises better performance than older CFP designs, using 60% less power and only 1/3 the space of previous designs. Also, JDSU followed the introduction of the first tunable SFP+ in 2012 by sampling a fully MSA-compliant version with 1.5W power dissipation for the most demanding, high-density appli-

cations in metropolitan networks and data-center interconnects.

● *Integrated 100G+ devices* — JDSU continues to enhance its multiple optical device platforms to enable highly integrated, high-performance components for 100G line and client applications. These technologies underpin the narrow-linewidth laser, modulator and receiver components that enable 100G coherent communication. TOSAs and ROSAs based on hybrid integration of JDSU's PLC and InP technologies enable the CFP2 LR4 transceiver and will enable future smaller form factors for client applications.

● *Trueflex portfolio adoption and Twin 1x20 ramp* — JDSU's TrueFlex product portfolio continues to ramp in production and grow in breadth. JDSU's TrueFlex Twin 1x20 and OCM products are well into their

production ramp, and JDSU continues to secure new design wins with both products. Also, JDSU is extending its product portfolio to include TrueFlex Micro 1x9 and 1x9 Twin products for release in first-half 2014.

● *Twin MxN WSS for CD* — Shipping now, this solution ushers in software-defined aspects to ROADMs. The single piece of hardware now runs two applications to save costs in a network node using the same hardware as Twin WSS.

● *Raman amplification* — Leveraging full vertical integration and more than two decades of expertise in amplification, JDSU serves the Raman market with a suite of thermally efficient solutions, ranging from robust gain control delivered modules using proprietary algorithms to full turnkey hybrid EDFA/Raman line-cards.

www.jdsu.com

Suncore acquires Israel-based ZenithSolar

Production of combined heat & power system to start in China in 2014

China-based concentrating photovoltaic (CPV) module maker Suncore Photovoltaic Technology Co Ltd, which is owned by Xiamen-based San'an Optoelectronics Co Ltd (the largest LED maker in China), has acquired the assets of Israel-based ZenithSolar Ltd, including intellectual property, inventory, and equipment, through its US subsidiary Suncore Photovoltaics Inc (SPI).

Suncore was founded in July 2010 as a joint venture owned 40% by Emcore Corp of Albuquerque, NM, USA (which makes components, subsystems and systems for the fiber-optic and solar power markets) and 60% by San'an Optoelectronics Co Ltd of Xiamen, China (which designs and manufactures products including full-wavelength-range high-brightness LED chips and wafers, solar cells, and PIN

photodiodes). Suncore is targeted at the manufacture and distribution of CPV receivers, modules and systems for terrestrial solar power applications. In June 2013, Emcore exited the JV by selling its stake to San'an.

Formed in 2006, ZenithSolar has developed a combined heat and power (CHP) product based on CPV technology, and demonstrated more than 70% combined solar energy conversion efficiency (21% electric and 49% thermal). The system provides electrical output from a photovoltaic array and concurrently generates hot water at a temperature suitable for domestic and industrial applications. However, ZenithSolar filed for bankruptcy and entered liquidation this June.

Suncore now plans to set up a production line and start mass

production of the CHP product in its facility in Huainan, China in 2014.

"The potential of this technology to provide a low-cost source of renewable energy is significant," believes Dr Charlie Wang, vice chairman of Suncore and CEO of SPI, "The CHP technology developed by ZenithSolar is an excellent complement to Suncore's CPV product portfolio," he adds.

"In addition to our existing high-efficiency CPV products targeted for mid- to large-scale utility or distributed solar power plants, we are now able to provide solar-generated electrical and thermal power to customers ranging from industrial and commercial, to residential and agricultural."

www.zenithsolar.com

www.suncorepv.com

www.Sanan-e.com

Emcore receives AURP's Innovation Award for high-efficiency multi-junction solar cells

Emcore Corp of Albuquerque, NM, USA, which makes compound semiconductor-based components and subsystems for the fiber-optic and solar power markets, has received the Association of University Research Parks' (AURP) Innovation Award for its pioneering work in the development and commercialization of high-efficiency multi-junction solar cells for space and terrestrial solar power applications. The award was presented to president & CEO Dr Hong Q. Hou on 26 September at the AURP's International Conference Awards Luncheon.

Annually, the AURP presents Awards of Excellence in several categories including the Innovation Award (presented to Emcore) and the Outstanding Research/Science Park Award (presented to Sandia Science & Technology Park in 2008).

Emcore began designing and manufacturing radiation-hardened, high-efficiency multi-junction solar cells for satellite and space power applications at Albuquerque's Sandia Science & Technology Park (SS&TP) in early 1998. The R&D team (led by Dr Hong Hou, who had come to Emcore from Sandia National Laboratories) licensed background intellectual properties related to multi-junction solar cells from Sandia, the Air Force Research Laboratory, and the National Renewable Energy Laboratory (NREL). From there, Emcore formed its Photovoltaics division in Albuquerque and built its 160,000 square foot wafer fabrication facility (now one of the world's largest multi-junction solar cell manufacturing plants).

Emcore says that its multi-junction solar cells have led the way in the transformation of the space solar

power industry over the past 15 years, advancing solar cell energy conversion efficiency from 17% (the standard for silicon-based technology prior to 1998) to 37% for its latest-generation Inverted Metamorphic Multi-Junction (IMM) solar cells (currently being introduced to volume production). With the commercialization of high-efficiency multi-junction solar cells for space power applications, Emcore relocated its corporate headquarters from New Jersey to the SS&TP in Albuquerque in 2006.

"I would also like to thank the Sandia National Laboratories and the SS&TP for their superb resources and support of our efforts from the very beginning," says Hou.

www.emcore.com

www.sstp.org

www.aurp.net

Fondation Énergies pour le Monde installs Soitec CPV system in Madagascar as part of Sunidarity initiative

As one of four winners in the first round of Sunidarity initiative awards (in December 2012), Paris-based Fondation Énergies pour le Monde (Energy for the World Foundation) has just finished installing a concentrator photovoltaic (CPV) system in southern Madagascar. The Plug&Sun system from CPV system maker Soitec of Bernin, France (founder of the Sunidarity initiative) enables independent solar-power generation in areas without access to the electricity grid.

The rural electrification project put forward by Fondation Énergies pour le Monde won over the Sunidarity jury with its original and on-target approach to bring electricity to a small community in Madagascar. To fulfill the project, Fondation Énergies pour le Monde was awarded a Plug&Sun system, as were other Sunidarity winners.

Set up in the commune of Ambondro, near Ambovombe, the Plug&Sun system comprises two trackers capable of generating 2.28kWp for a total of up to 12kWh per day. Fondation Énergies pour le Monde has coupled the Plug&Sun trackers with a small electrical network combining a set of batteries and two wind turbines installed in 2010 to supply additional power and ensure the continuity of electricity generation for the whole village. The project is the first decentralized rural electrification operation of its kind in Madagascar.

A Soitec technician assisted in assembling the CPV systems on site, connecting them to the exist-

ing power system and training local technical personnel in maintenance and servicing.

Fondation Énergies pour le Monde and Soitec says that, through this operation, they are contributing to the fight against poverty by using a technical solution that matches the social context and energy usage of the community. Access to local, renewable energy helps to improve living conditions in terms of domestic comfort, health and education for rural populations and contributes to the development of income-generating activities, eliminating the need for fossil fuels, they add.

"The installation of a hybrid wind-solar system is a first, important step," says Yves Maigne, director of Fondation Énergies pour le Monde. "Within a year, we will have sufficient feedback to be able to evaluate the system's operation. That will help us decide on the use of Plug&Sun for eight other Malagasy villages already identified by our Foundation," he adds.

"Our concentrating photovoltaic technology is especially well suited to areas that enjoy abundant sunlight, where the output from our modules is more than twice as high as that of stan-

dard photovoltaic products," notes Gaetan Borgers, executive VP of the Solar Energy Division at Soitec. "Our range of products also means we are able to supply systems for power facilities generating hundreds of megawatts as well as to respond to off-grid project requirements."

Soitec's CPV technology uses triple-junction cells mounted on a glass plate. Fresnel lenses, manufactured using silicone on glass, concentrate sunlight 500 times before it reaches the cells. A metal frame holds two glass plates to form what are described as highly robust, durable and resilient modules. By combining several modules on biaxial trackers (which use a proprietary algorithm to automatically optimize their position based on the path of the sun), Soitec says its technology maximizes energy generation throughout the day.

Designed to meet the energy needs of isolated sites, the Plug&Sun system comprises two or three trackers linked to an energy management system and a set of batteries. Each tracker consists of 12 CPV modules (with total surface area of 4.2m²) with peak power of 1.14kWp. Using an integrated battery system, the electricity produced during the day by the trackers can be stored and used to supply all kinds of electrical equipment. Plug&Sun takes only a few hours to install so it can be rolled out quickly, says Soitec.

www.soitec.com

www.sunidarity.com

www.energies-renouvelables.org

Emcore raises \$12.4m in underwritten public offering

Emcore Corp of Albuquerque, NM, USA, which makes compound semiconductor-based components and subsystems for the fiber-optic and solar power markets, priced a public offering of 2.5 million shares of common stock (announced in

mid-September) at a price to the public of \$4.30 per share.

Additionally, the firm granted the sole underwriter (investment bank B. Riley & Co LLC) an option for 30 days to purchase up to 375,000 additional shares of common stock.

After the underwriter exercised the overallotment option in full, the total sale of 2.875 million shares raised \$12.36m altogether.

Emcore plans to use the proceeds for general corporate purposes.

www.emcore.com

Semprius raises efficiency record for commercially available solar modules from 33.9% to 35.5%

R&D demo module achieves 37.1% efficiency

Semprius Inc of Durham, NC, USA, which designs and makes high-concentration photovoltaic (HCPV) solar modules, has raised its own world record for mass-produced photovoltaic module efficiency from 33.9% (announced in January 2012) to 35.5% at Concentrator Standard Test Conditions (CSTC), as confirmed by the Fraunhofer Institute for Solar Energy Systems ISE in Germany.

Made on the production line at Semprius' new manufacturing facility in Henderson, NC, the record module incorporates standard production techniques and materials, including epitaxial wafers provided by partner Solar Junction Corp of San Jose, CA, USA, which makes III-V multi-junction solar cells for CPV based on dilute-nitride materials. At over 35%, Semprius modules are the highest efficiency of any commercially available product in the PV industry — two to three

times more efficient than conventional photovoltaic modules and significantly higher than other commercially available HCPV modules, it is claimed.

"We were able to produce this new record on our pilot-production line just months after opening the facility," says CEO Joe Carr. "This is a testament not only to our R&D and manufacturing teams, but also to our production process, which is robust and scalable," he adds.

"We are now focused on continuing to ramp up production capacities to deliver increasing volumes of these high-performance, high-efficiency modules globally."

In addition to producing a 35.5% commercial module on its production line, Semprius also recently built an R&D demonstration module that achieved an efficiency of 37.1% at CSTC.

"Our R&D team continues to raise the bar for solar module efficiency as it executes against our product

roadmap," says VP of technology Scott Burroughs. "We have an extensive program of efficiency improvements and cost reductions over the next several years that will allow us to continue to improve performance and drive down the cost of solar energy."

Over the past 18 months, Semprius has deployed its modules with strategic customers in eight countries around the world.

Semprius says that its technology is suited to the world's sunniest regions, where its high-temperature performance and dual-axis tracking enable high energy production yields throughout the day. In sunny locations like the US Southwest, Saudi Arabia, Mexico and Chile, Semprius-based systems can deliver up to 30% more energy than equivalent, conventional fixed-tilt photovoltaic systems, the firm reckons.

www.semprius.com

www.sj-solar.com

Semprius supplies Aerojet Rocketdyne with HCPV modules for commercial-scale demo at Solar Technology Acceleration Center

Semprius Inc of Durham, NC, USA has delivered its high-concentration photovoltaic (HCPV) solar module technology in support of the 17.5kW_{DC} demonstration system of aerospace & defense firm Aerojet Rocketdyne of Sacramento, CA (a GenCorp company) at the Solar Technology Acceleration Center (SolarTAC) in Colorado (the largest test facility in the USA for solar technologies at the early commercial or near-commercial stages of development). The demonstration is being overseen by the Electric Power Research Institute Inc (EPRI), a non-profit organization that conducts R&D relating to the generation, delivery and use of electricity for the benefit of the public.

At its production facility in Henderson, NC, Semprius manufactures what are claimed to be the world's highest-efficiency mass-produced solar modules, announcing last week a new record of 35.5% (2–3 times more efficient than conventional photovoltaic modules). The firm says its unique design couples what are claimed to be the world's smallest commercial solar cells with established semiconductor and microelectronic manufacturing processes to deliver highly efficient, reliable, cost-competitive modules.

The SolarTAC demonstration system includes Semprius HCPV modules, a standard solar inverter and a dual-axis tracker system capable of accurately following the sun throughout the day. Connected

to the grid in August, the system is already operating at peak AC system efficiencies exceeding 30%.

"With systems installed in eight countries and four US states since 2010, we look forward to this opportunity to demonstrate the superior performance, reliability and cost-effectiveness of our technology," says Semprius' VP of business development Russell Kanjorski.

Semprius will also support Aerojet Rocketdyne's next step in HCPV commercialization by supplying modules and technical assistance under Aerojet Rocketdyne's award from the US Department of Defense for a 200kW commercial demonstration at Edwards Air Force Base in California.

www.rocket.com

Semprius supplies lightweight record-breaking solar module to power winning car at World Solar Challenge

Semprius Inc of Durham, NC, USA, which designs and makes high-concentration photovoltaic (HCPV) solar modules, supplied specially designed lightweight versions of its record-breaking solar module to the Nuon Solar Team of Delft University of Technology's in The Netherlands to help power its Nuna7 solar car in winning the World Solar Challenge.

The team has now competed in the World Solar Challenge seven times, winning in 2001, 2003, 2005 and 2007 and finishing second in 2009 and 2011 before this record fifth win.

In September, Semprius reported a record for mass-produced PV module efficiency of 35.5% (2–3 times more than conventional PV modules).

The World Solar Challenge 2013 was contested by 38 teams in three categories, covering 3000km across Australia from Darwin to Adelaide on 6–13 October (8am to 5pm daily). Only solar energy can be used.



Nuon Solar Team's Nuna7 solar car.

Earlier this year, the Nuon Solar Team approached Semprius hoping to leverage the firm's record module efficiency and compact design for the 2013 race. A key challenge was to reduce module weight to meet the race's weight limit of 160kg. Semprius modified its standard commercial modules to reduce their weight by 60%. Changes included substituting the standard front cover glass with a thinner, lightweight glass sheet and replacing its steel module enclosures with carbon fiber.

Because Semprius modules must be pointed directly at the sun to generate electricity, the modules could not be used with the car in motion. During the race, however, there are mandatory 30 minute breaks every 300km. During these breaks, the modules were deployed on manual trackers to capture extra energy for the Nuna7. Jorrit Vervordel, technical manager of the Nuon Solar Team, calculated that, by using Semprius' modules, it was possible to decrease the team's overall racing time by 1 hour.

"While we are primarily focused on commercial and utility-scale applications, this new design provides us with a lightweight, ruggedized capability for specialized military and other applications," says Semprius' VP of business development Russell Kanjorski.

www.worldsolarchallenge.org

www.nuonsolarteam.nl

Fraunhofer ISE initiates round-robin test with four leading measurement laboratories

In a round-robin test, Germany's Fraunhofer ISE CaLab PV Modules compared its results with three other leading international measurement labs for photovoltaic (PV) modules: National Renewable Energy Laboratory (NREL) in the USA, the National Institute of Advanced Industrial Science and Technology (AIST) in Japan, and the European Solar Test Installation (ESTI) of the European Commission's Joint Research Centre (JRC) in Ispra, Italy. The results showed that the measurement precision in all four laboratories was comparable, with a deviation of $\pm 1\%$ from the mean. Fraunhofer ISE says that, for investors in the growing global PV market, this has good implications for quality assurance.

Currently, the annual volume of the global PV market is over 30GW

and the trend is growing. Against this backdrop and in light of the fact that photovoltaics is still a young technology, the measures employed to increase product quality on the international level have great importance, says Fraunhofer ISE.

The round-robin test, initiated by the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg in cooperation with its long-standing international partners, tests the different measurement procedures and methods with a focus on comparability. "In spite of the different techniques and equipment, all four laboratories demonstrate measurements with a high precision with a deviation of $\pm 1\%$ from the mean," says Daniela Dirnberger, team leader at Fraunhofer ISE and initiator of the project. "We are well on our way towards being able to

provide comparable measurements worldwide."

The researchers at Fraunhofer ISE calibrate reference modules for production lines and carry out spot checks to verify the guaranteed power output in accordance with international standards. The module measurements include current-voltage curves as well as other electrical characteristics measured under standard test conditions (1000W/m^2 , 25°C and AM1.5). In addition to accurate power measurements, the researchers at Fraunhofer ISE also offer services in the development of measurement standards for new technologies as well as in the production-line qualification of solar simulators.

www.callab.de

<http://re.jrc.ec.europa.eu/esti>

University of Queensland and First Solar to build 3.275MW PV research facility

The University of Queensland (UQ) has signed a contract with First Solar (Australia) Pty Ltd, a subsidiary of cadmium telluride (CdTe) thin-film photovoltaic module maker First Solar Inc of Tempe, AZ, USA, for the construction of a solar photovoltaic research facility. The 3.275MW pilot plant — including more than 34,000 panels in a ground-mounted array — will be Queensland's largest solar power installation. First Solar will install its modules on a 12.6ha former airstrip site at UQ's Gatton campus, 90km west of Brisbane.

Under the engineering, procurement & construction (EPC) contract between UQ and First Solar, electricity is due to start flowing by the end of 2014. UQ's Property and Facilities division will manage and operate the plant.

The research facility will augment UQ's 1.22MW PV array, which was completed at the university's main campus at St Lucia in Brisbane in 2011 and remains Australia's largest rooftop solar installation.

The installation is being funded by a \$40.7m Federal Government grant, via the Education Investment Fund (EIF), which will also fund a battery-storage research station alongside the Gatton pilot plant. UQ and the University of New South Wales are partners on the overall EIF grant which will also fund new laboratories for Power Systems and Energy Economics Research at UQ's

St Lucia campus and at UNSW's Kensington campus in Sydney. The Gatton PV project is also part of the Solar Flagships Program, administered by the Australian Renewable Energy Agency (ARENA).

The Gatton plant is the pilot for two much larger solar farms that AGL Energy Ltd and First Solar are building in western New South Wales: at Nyngan (102MW) and Broken Hill (53MW). The overall 155MW, \$450m scheme will create Australia's largest solar power plants. About \$167m for the larger project is coming from ARENA; the NSW Government is contributing \$64.9m.

"Renewable energy research needs to be interdisciplinary and industry-integrated, to produce optimal results that are practical, efficient and attractive for industry and communities," says UQ president & vice-chancellor professor Peter Høj. "UQ's reputation for excellent researchers in areas including physics, engineering and sustainability helped secure the necessary buy-in from key industry leaders and government bodies. This will in turn drive outputs that can be taken up by industry, communities and governments," he adds. "Locally, the Gatton installation — like the St Lucia solar project — will yield clear benefits for campus energy supply, and for UQ research, teaching and community engagement."

The new facilities and associated research program are designed to

support the early-stage commissioning and operation of the main power plants in NSW, says professor Paul Meredith, project director at UQ's Global Change Institute and the School of Maths and Physics.

"Components of our research will focus on energy storage, plant optimization, power systems and the impact of renewable energy on the National Electricity Market. We will be able to test new technology and concepts at a meaningful scale, and our work will help build national capacity for research in solar power deployment," he adds.

"First Solar is committed to ensuring that learnings are fully leveraged to increase Australian innovation in solar power generation, to continue to facilitate a more viable and advanced utility-scale solar PV industry in Australia," says Jack Curtis, First Solar's VP of business development for Asia Pacific. "The Australian local solar industry is gaining momentum with the recent financial close of our two utility-scale projects in Nyngan and Broken Hill in NSW," he adds. "Knowledge gained through the construction and operation of large-scale, grid-connected solar power stations will help solar energy play a greater role in meeting Australia's electricity needs. The research facility will provide the opportunities for technological advancement that will ensure we can maintain this momentum for future projects across the country."

First Solar to build 250MW power plant in California for NextEra

First Solar has entered into an agreement to construct a 250MW_{AC} solar power plant in Riverside County, CA, for a subsidiary of NextEra Energy Resources LLC.

The McCoy Solar Energy Project will be located on about 2300 acres of mostly public land provided by the Bureau of Land Management (BLM) about 13 miles northwest of

Blythe, California. First Solar will provide engineering, procurement & construction (EPC) services, using its CdTe thin-film PV modules.

The project is located near the 550MW_{AC} Desert Sunlight Solar Farm (which is jointly owned by a subsidiary of NextEra, GE Energy Financial Services, and Sumitomo Corporation of America) currently

under construction by First Solar. An affiliate of NextEra Energy Resources also previously purchased two projects built by First Solar in Canada.

Construction should begin in late 2014, with completion in late 2016. The project will provide up to 400 construction jobs at peak operation.

www.firstsolar.com

First Solar completes Dubai's flagship 13MW solar power plant in under 30 weeks

Cadmium telluride thin-film photovoltaic module maker First Solar Inc of Tempe, AZ, USA has completed and handed over a 13MW_{DC} PV power plant in Dubai, United Arab Emirates (UAE). The facility, the firm's first utility-scale project in the Middle East, is the largest operating solar PV plant in the region.

Chosen by the Dubai Electricity and Water Authority (DEWA) to provide engineering, procurement & construction (EPC) services as well as its thin-film modules, First Solar connected the plant to the emirate's electricity grid just 195 days after breaking ground in March. The project had a workforce of 1280 at its peak and required more than 1.4 million man-hours to complete.

Powered by 152,880 First Solar FS Series 3 Black PV modules, the plant will generate about 24 million kilowatt hours of electricity per year. Electricity generated by the plant will, on average, displace about 15,000 metric tons of CO₂ annually (equivalent to removing about 2000 cars from the road every year).

"This plant represents an important step in the implementation of the Dubai Integrated Energy Strategy



The Mohammed bin Rashid Al Maktoum Solar Park.

2030 to diversify Dubai's energy mix, as envisioned by the Dubai Supreme Council of Energy," says His Excellency Saeed Mohammed Al Tayer, vice chairman of the Dubai Supreme Council of Energy. "For the first time, we are harnessing the sun to power growth and prosperity in the Emirate," he adds. "Through this flagship project, First Solar has been able to demonstrate many of the attributes, such as reliability, affordability, scalability and speed of deployment, that make solar power such an attractive proposition."

The 13MW plant is the first phase of the Mohammed bin Rashid Al Maktoum Solar Park, named after His Highness Sheikh Mohammed

bin Rashid Al Maktoum, vice president and prime minister of UAE and ruler of Dubai. The park is expected to eventually cover 40 square kilometers and produce 1000MW for the national grid using both

PV and solar thermal technology.

"In addition to showcasing the effectiveness of our advanced thin-film modules in hot climates, it has established a benchmark for the development of solar energy projects in the region," comments First Solar's CEO Jim Hughes.

The plant covers 59 acres (238,764m², equivalent to about 33 soccer pitches) and is designed to operate for over 25 years. First Solar completed the plant on schedule and spent as much as 50% of the facility's cost in the UAE, sourcing components such as racks, transformers, cables and switchgears from local suppliers.

www.dewa.gov.ae

First Solar acquires first large-scale solar project approved on tribal land in North America

First Solar has acquired the 250MW_{AC} Moapa Solar Project in Nevada from K Road Power Holdings LLC of New York City and San Francisco, an independent power developer focused on developing, financing, owning and operating utility-scale solar projects.

Located on the Moapa River Indian Reservation in Clark County, northeast of Las Vegas, Nevada, it is the first large-scale solar project approved to be built on tribal land in North America. The project is in an advanced stage of development, and has in place a 25-year power purchase

agreement (PPA) with the Los Angeles Department of Water and Power (LADWP).

Construction of the project, within a 2000-acre segment of the Moapa Band of Paiutes tribal land, could start as soon as fourth-quarter 2013 and be completed by the end of 2015. It is expected to create up to 400 jobs during the peak of construction, and about 10 permanent jobs when the plant is in operation. First Solar will design and build the project, using its CdTe thin-film PV modules.

In its first year of operation, the Moapa Solar Project will generate

enough energy to power about 100,000 average homes. It will displace more than 178,000 metric tons of CO₂ (equivalent to taking more than 34,000 cars off the road) and will displace more than 142,000 metric tons of water consumption annually.

The project should advance tribal economic competitiveness and job creation, serve as an example of tribal energy self-sufficiency and sustainability, and encourage further renewable energy projects on tribal land, says First Solar.

www.kroadpower.com
www.firstsolar.com

EDF Renewable Energy dedicates Catalina Solar Project as its largest operating PV project

EDF Renewable Energy of Rosamund, CA (the US subsidiary of EDF Energies Nouvelles, the renewable energy arm of electricity company EDF group) has dedicated its 143MWp (110MWac) Catalina Solar project in Kern County, California. The project represents EDF Renewable Energy's largest utility-scale solar photovoltaic project to date.

Located on 900 acres of privately owned land southwest of the Tehachapi and Piute mountains, the thin-film photovoltaic project consists of 82MWp of CIS (copper indium selenium) modules from Tokyo-based Solar Frontier (a subsidiary of Japanese energy business Showa Shell Sekiyu) and 61MWp of cadmium telluride (CdTe) modules from First Solar Inc of Tempe, AZ, USA. The project is currently the world's eighth largest photovoltaic plant (according to Bloomberg New Energy Finance) and generates electricity for 35,000 homes. EDF Renewable Services is providing the long-term operations and maintenance (O&M) services.



EDF's 143MWp Catalina Solar project.

"Catalina Solar consists of over 1.1 million solar PV panels and is estimated to offset 250,000 metric tons of greenhouse-gas emissions annually," commented Javier De La Garza, director of solar development for EDF Renewable Energy's West Region. "The project has been an important source of direct and indirect economic activity in Kern County, including over 500 workers on-site during construction," he adds. "The Catalina Solar project has played a vital role for jobs and the economy in my district," commented Senator Jean Fuller.

The project also contributes towards California's Renewable Portfolio Standard (RPS) goal of 33% renewable energy by 2020. The project's energy is provided to San Diego Gas & Electric's (SDG&E) under a 25-year power purchase agreement (PPA). EDF Renewable Energy has 343MW of renewable energy generation through three projects to meet its contract obligations to SDG&E, all of which are located in Kern County.

"Catalina Solar is an example of a renewable energy project that has overcome a number of regulatory and commercial challenges," noted Matt Burkhart, VP of electric and fuel procurement for SDG&E.

EDF Renewable Energy is one of the largest renewable energy developers in California and the USA. With Catalina Solar, it is generating a combined 835MW of energy for California.

www.solar-frontier.com

www.firstsolar.com

www.edf-re.com

Five millionth PV module installed at 550MW Topaz Solar Farms

Energy services provider MidAmerican Solar of Phoenix, AZ (a subsidiary of MidAmerican Renewables LLC) and cadmium telluride (CdTe) thin-film photovoltaic module maker First Solar Inc of Tempe, AZ, USA say that the five millionth solar module has been installed at Topaz Solar Farms in San Luis Obispo County, CA (one of the largest solar projects under construction in the world). When complete, the 550MWAC project will include more than 8 million photovoltaic modules. The first solar module was installed on 16 May 2012.

"A project of this magnitude requires extraordinary teamwork — from local communities and govern-

ment and environmental leaders to contractors and suppliers — to ensure it is successful in safely and reliably delivering renewable energy to California," comments MidAmerican Solar's president Paul Caudill.

The Topaz project is owned by MidAmerican Solar and is being constructed by First Solar, which will also provide operations & maintenance services. Construction began in late 2011 and is expected to be complete by early 2015.

"It's the first time First Solar has installed that many modules at a single solar site," notes First Solar's chief operating officer Georges Antoun.

During its three-year construction

period, the Topaz project will create an average of about 400 construction jobs. According to an economic benefits study by The Brattle Group and California Polytechnic State University, Topaz is estimated to infuse \$417m into the local economy, the majority of which will be generated during construction.

Pacific Gas and Electric Company will purchase the electricity from the Topaz project under a 25-year power purchase agreement, helping California to meet its mandate to generate 33% of its power from renewable sources by 2020.

www.midamericanrenewablesllc.com

www.firstsolar.com

Sofradir and Onera partner on IR thermal imaging

Optical integration technologies to be transferred to Sofradir

Sofradir of Chatenay-Malabry, which makes cooled infrared (IR) detectors based on mercury cadmium telluride (MCT/HgCdTe), indium antimonide (InSb), quantum-well IR photo-detector (QWIP) and indium gallium arsenide (InGaAs) technology, has agreed a new research and innovation partnership with French government aerospace & defense research and technology organization Onera of Palaiseau (both near Paris, France).

The partners have committed to a five-year project aimed at developing disruptive technologies in IR detection in order to provide OEMs with more advanced capabilities in thermal imaging. The innovations should also enable equipment makers to address future expectations in the performance of optonics systems, where IR detection is key. In addition, the project aims to accelerate the transfer of Onera's research to Sofradir, increasing the global market competitiveness of both Sofradir and its customers.

IR detectors are at the center of multiple military, space, commercial and scientific applications (thermal imagers, missile seekers, surveillance systems, targeting systems or observation satellites), and their performance and price are critical to the competitiveness of optonics systems.

Sofradir and Onera have previously collaborated on other research projects involving IR detection. The latest Partner Research Innovation (PRI) agreement (a new type of French public-private contract enabling the transfer of technology and know-how from Onera to industry) is the first that the two organizations have signed together.

Sofradir and Onera are collaborating once again to break down the technological barriers in infrared by exploring new possibilities in optical integration and other techniques," says Sofradir's chairman & CEO Philippe Bensussan. "Onera is known for its vision, vast knowledge

and expertise in aerospace and defense system design," he adds. "We have high expectations about what these advantages will bring to our customers who design optonics systems for defense, space and commercial applications."

The project involves transferring emerging technologies and know-how from Onera, making them ready for industrial processing. The team will carry out research on and develop new techniques for IR detectors, such as integrated optics, greater compactness, improved functionality and performance of thermal imaging equipment.

"This Partner Research Innovation agreement is further evidence of industry's strong interest in Onera's advanced research," reckons Onera's acting managing technical director Thierry Michal. "The long-term commitment Sofradir and Onera are giving this project will pave the way for major technological advances."

www.onera.fr

AVACO boosts CIGS PV efficiency by 30% using new atomic layer deposition process for buffer layer

Publicly traded thin-film processing equipment maker AVACO Co Ltd of Daegu, South Korea, which specializes in sputtering (PVD) vacuum deposition equipment (in-line, cluster, and roll to roll), atomic layer deposition (ALD) equipment, back-end-of-line (BEOL) equipment, and factory automation equipment (such as clean stocker, clean crane, and overhead transfer system for large-scale substrate), says that it has developed a new concept of buffer layer deposition for photovoltaic. By using its ALD process, the firm claims that energy conversion efficiency can be improved to about 30% higher than in conventional copper indium gallium diselenide (CIGS) solar cells that use cadmium sulfide (CdS) for the buffer layer.

AVACO says that its new ALD process system can provide a solution for buffer layer optimization in the dry process to effectively convert solar energy during the photovoltaic development process. The new process enhances quantum efficiency in both the short-wavelength range and the near-infrared range. The jump in short-circuit current improvement in the I-V curve contributes to higher-efficiency CIGS solar cells without affecting the open-circuit voltage (V_{oc}). The firm says that its new buffer layer deposition technique can also be applied to a wide range of CIGS absorber layers, regardless of preparation methods.

"Expansion of our core technology further strengthens and broadens

our offering of deposition process solutions," says business development director Chuck Ki. AVACO delivers mass-production manufacturing equipment for all aspects of thin-film coating, such as transparent conducting oxide (TCO), metal electrode, and dielectric layers. Target materials used in the firm's sputtering systems include Ag, AGZO, Al, Al_2O_3 , AlNd, AZO, CIGS, Cr, Cu, CuGa, CuIn, GZO, IGZO, In, ITO, IZO, Mo, MoTi, MoW, Ni, Se, SiO_2 , TiO_2 , ZnO and others, with DC, pulsed-DC, and MF using a single or dual magnetron source.

AVACO exhibited and gave a poster presentation at the Solar Power International (SPI 2013) event in Chicago (21–24 October).

www.avaco.co.kr/eng

Room-temperature indium antimonide mid-infrared photodiode

Potential applications include human body detection for power savings.

Asahi Kasei Microdevices Corporation and Kyushu University in Japan have developed room-temperature mid-infrared semiconductor detectors based on indium antimonide (InSb) [Koichiro Ueno et al, Jpn. J. Appl. Phys., vol52, p092202, 2013].

The researchers believe such devices could be used to save power in facilities where no people are present through the detection or not of human body heat.

The human body gives out detectable thermal radiation in the range 3–25 μm , peaking around 10 μm (essentially a Planck blackbody distribution for 36–37°C). The Asahi Kasei/Kyushu device covers the 2–7 μm range.

Present methods of detecting humans tend to depend on measuring temperature changes (e.g. pyroelectric devices), so if the people are stationary a false signal to turn off power could be sent. However, mid-infrared semiconductor detectors usually need cooling to operate.

To enable room-temperature operation, the researchers worked to reduce the non radiation part of the current ('the diffusion current') of the device by increasing the resistance under zero bias (R_0). The device also featured improved IR incidence efficiency by gathering radiation through the gallium arsenide (GaAs) substrate rather than through InSb layers. In addition, the GaAs surface was roughened to reduce reflection.

The indium antimonide (InSb) photodiode structure (Figure 1b) was grown on a semi-insulating (001) GaAs substrate using Riber MBE-49 molecular beam epitaxy system. The substrate temperature during growth was 410°C. The group V (Sb) to group III (In) flux ratio was 2:1. Tin (Sn) and zinc (Zn) were used to dope InSb with n- (electrons) and p-type (holes) carriers. The Zn doping was carried out at high concentration due to the element's high volatility with low sticking coefficient in InSb.

The material was fabricated into photodiodes using photolithography and chemical etch. The electrodes consisted of aluminium/titanium.

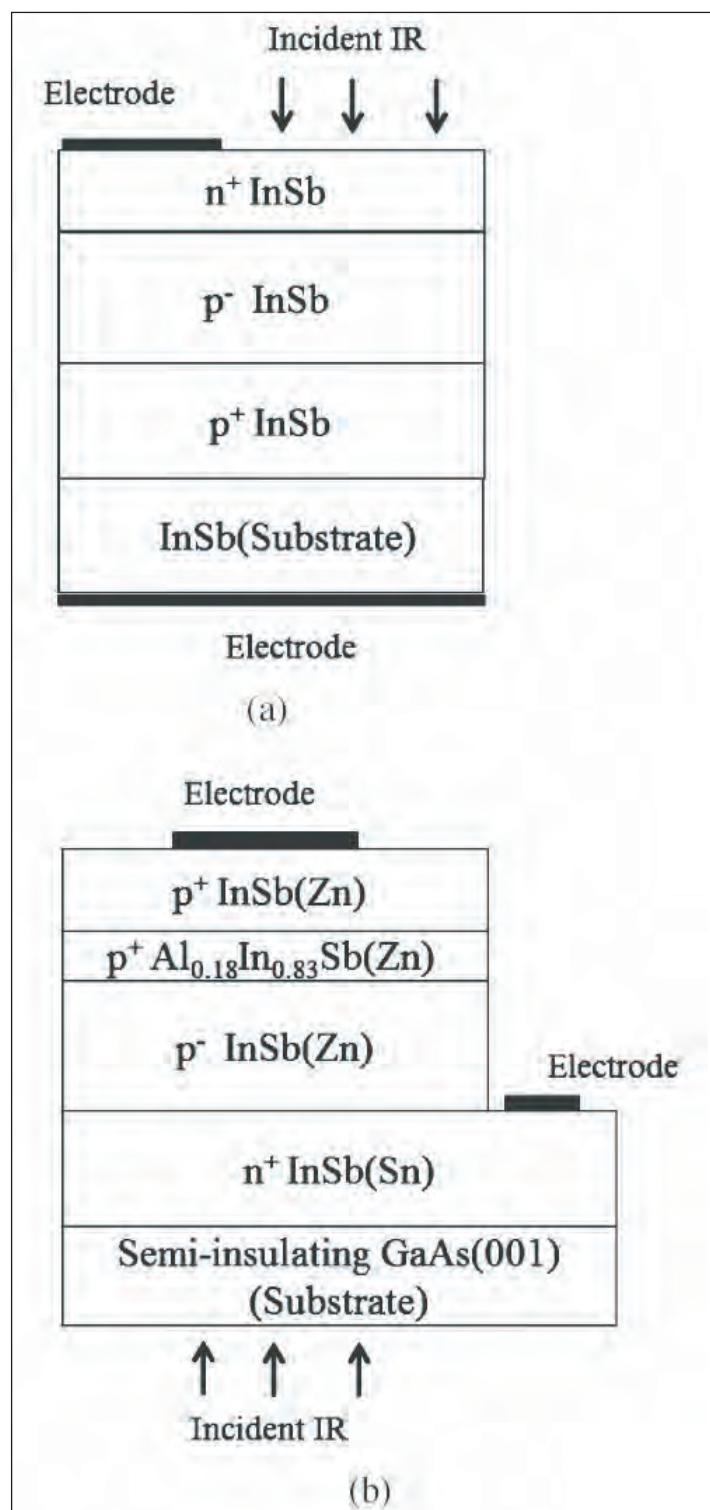


Figure 1. (a) Conventional InSb infrared sensor structure; (b) Asahi Kasei/Kyushu sensor structure.

The researchers optimized the n-type doping so that more than 80% of IR light with wavelengths longer than $3\mu\text{m}$ could penetrate the n-InSb layer. The point at which this occurred was $4.3 \times 10^{18}/\text{cm}^3$ doping concentration. At lower concentrations, the 80% value was achieved at longer wavelengths, cutting off at near $7\mu\text{m}$ with around $2 \times 10^{16}/\text{cm}^3$ doping. Although the absorption band edge did not shift much after $6 \times 10^{18}/\text{cm}^3$, the researchers decided to use $7 \times 10^{18}/\text{cm}^3$.

Another aspect that needed optimization was the heavily p-type aluminium indium antimonide (p+-AlInSb) barrier. The resistance under zero bias (R0) was maximized with an Al-fraction of 18%. Also the barrier was set at 20nm, since thicker AlInSb layers showed reduced R0. X-ray analysis suggested that this was due to degradation of crystallinity from lattice mismatch causing generation of defects. The defects in the AlInSb also caused degradation of the p-InSb layer above the barrier.

The effect of the optimized barrier is to reduce carrier leakage, as reflected by a 70% increase in R0 over photodiodes without barrier.

The GaAs substrate was also mechanically thinned in a process that also produced surface roughening to reduce reflection of the incoming IR. An increase of photocurrent of around 25% was achieved by roughening. For the complete device, an average absolute value (Ra) roughening around 200nm was chosen.

The resulting device was sensitive in the wavelength range $2\text{--}7\mu\text{m}$. The junction area was $210\mu\text{m}^2$.

To increase the open circuit voltage and R0 value of the detector, 700 photodiodes were patterned on a $600\mu\text{m} \times 600\mu\text{m}$ chip and connected in series. The

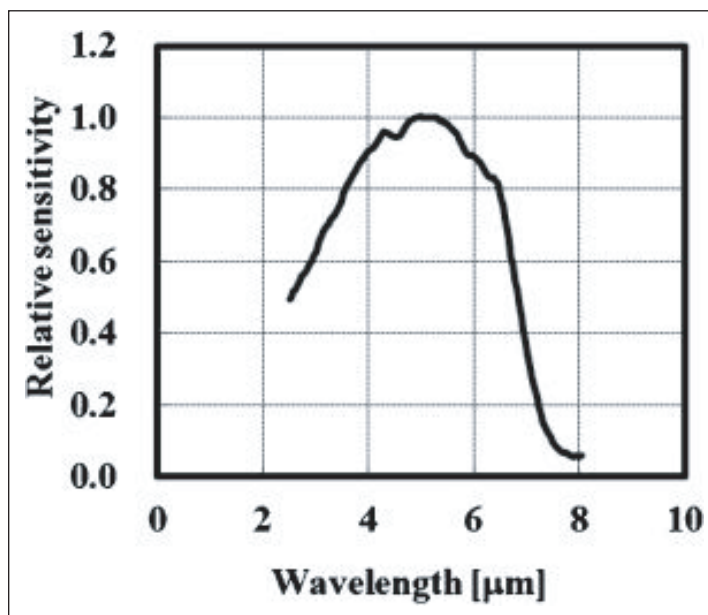


Figure 2. InSb photodiode relative spectral sensitivity characteristic.

effective junction area of each diode was $100\mu\text{m}^2$. The chip was encapsulated in a non-leaded quad flat pack with the roughened GaAs substrate uppermost in a window in the top of the package. The detector dimensions were $2.2\text{mm} \times 2.7\text{mm} \times 0.7\text{mm}$.

The packaged detector chip demonstrated a typical responsivity of 1900V/W , output noise of $0.15\mu\text{V}/\text{Hz}^{1/2}$ at 300K, and detectivity of $2.8 \times 10^8 \text{Hz}^{1/2}/\text{W}$ at 300K. The researchers conclude: "This performance is high enough for our device to be used as an uncooled mid-infrared photon detector." ■

<http://jjap.jsap.jp/link?JJAP/52/092202>

Author: Mike Cooke

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Optimizing spherical cap patterned sapphire for nitride semiconductor LEDs

Enhancement in light intensity of 15% achieved over LEDs produced on commercial substrate.

Researchers in Guangdong province, China, have been exploring the potential for improved light extraction from nitride semiconductor light-emitting diodes (LEDs) on patterned sapphire substrates with spherical cap bumps [Haiyan Wang et al, Jpn. J. Appl. Phys., vol52, p092101, 2013].

Patterned sapphire substrates (PSSs) can improve LED performance by improving the crystal quality of the light-emitting nitride semiconductor material and enhancing light extraction. Gallium nitride (GaN) semiconductor LEDs on flat sapphire suffer from total internal reflection back into the device due to larger differences in refractive index. Patterning can reduce the amount of reflection. Hemispherical and truncated cones are popular shapes for such patterning.

The team from South China University of Technology and NVC Lighting Technology Corporation first performed extensive simulations of different spherical cap geometries to find the optimum radius, height and spacing.

The simulations suggested that a 10% enhancement in light output could be achieved with flip-chip packaged LEDs where the radiation is mainly through the substrate and side-walls of the device.

The researchers then prepared two different patterned sapphire substrates: one (HPSS) with 3.45 μm -radius hemispherical bumps with 1.6 μm edge spacing, and the other an optimized 3.4 μm -radius spherical cap (SCPSS) of 2.78 μm height with 1.7 μm edge spacing (Figure 1). The bumps were arranged in hexagonal arrays to match the crystal structure of the overlying nitride semiconductor material. The patterning was performed by inductively coupled plasma etch where the etch time and plasma flux were controlled.

The researchers point out that, since the etch depth for the SCPSS is less than for HPSS, less photoresist and shorter etch times are required compared with HPSS fabrication. Hence, fabrication costs would be reduced – a very promising feature for ‘industrial mass production’.

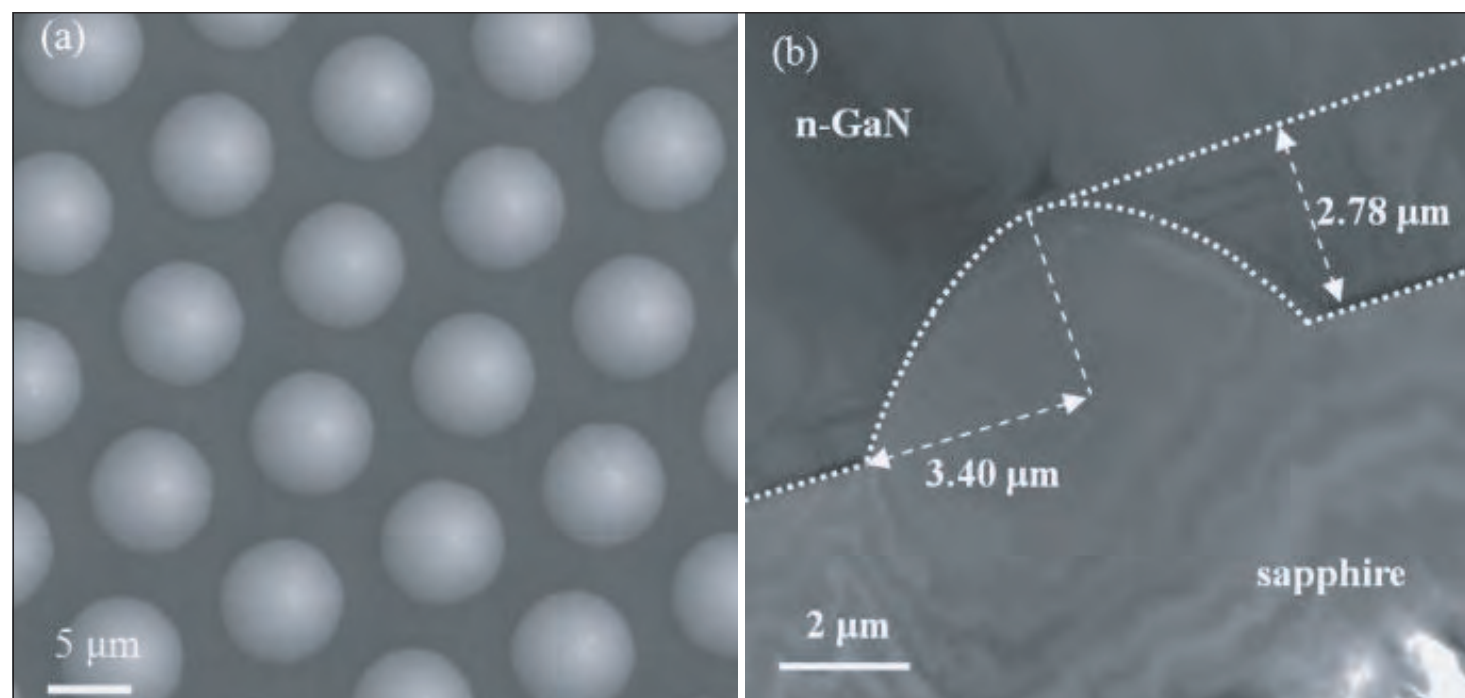


Figure 1. As-prepared spherical cap-shaped PSS. (a) In-plane scanning electron micrograph and (b) low-magnification cross-sectional transmission electron micrograph after epitaxial growth of LED structure.

Nitride semiconductor layers were applied using metal-organic chemical vapor deposition (MOCVD). X-ray analysis suggested that the quality of the crystal structures were similar on the different structures, so any difference in performance should be mostly attributed to differences in light extraction and not internal quantum efficiency.

The electroluminescence (EL) measurements showed a 12% increase in intensity for LEDs produced on the optimized SCPSS substrate (Figure 2). The researchers also compared their devices with LEDs produced on commercial patterned sapphire with cone-shape bumps. The optimized SCPSS LEDs demonstrated a 15% increase in intensity over LEDs produced on commercial patterned sapphire. ■

<http://jjap.jsap.jp/link?JJAP/52/092101>

www.nvc-lighting.com/Index.aspx

Author: Mike Cooke

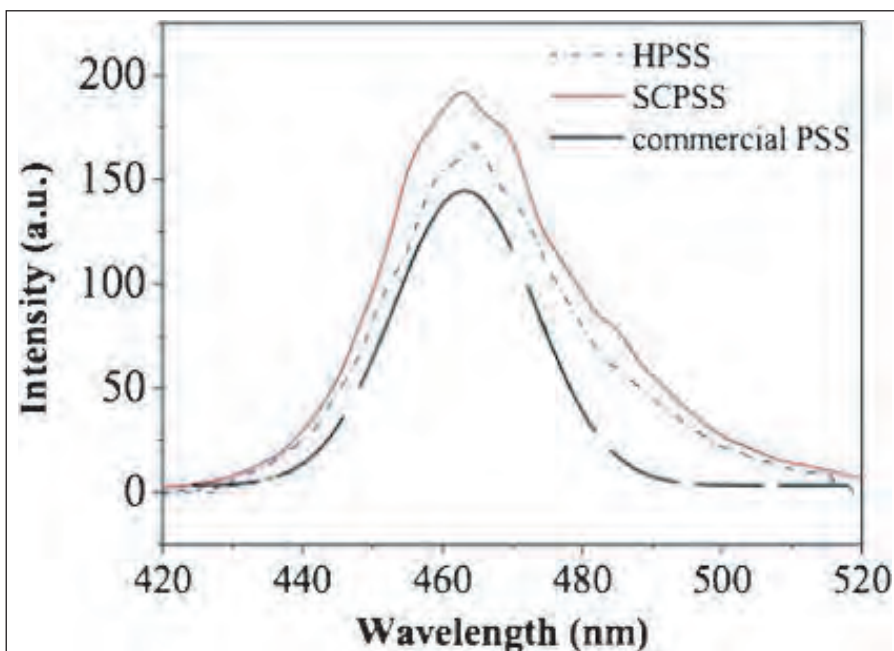


Figure 2. Comparison of EL spectra from LED chips grown on HPSS, up-to-date commercial PSS, and SCPSS.

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Increasing output power from nitride LEDs with p-InGaN contacts

China's Jimei University has increased light output power by 45% over a reference device.

Jimei University in China has used indium gallium nitride (InGaN) p-type contacts to increase light output power by 45% over a reference device [Wang Min-Shuai and Huang Xiao-Jing, Chin. Phys. B, vol. 22, p086803, 2013].

The researchers believe that the most important factor for the improved performance of the p-InGaN LED was reduced activation energy, creating an increased hole density. The team estimates that the activation energy was reduced from 180–200meV for normal p-GaN contacts to 50–100meV (or even 43meV!) for the p-InGaN, leading to a hole density around $5 \times 10^{18}/\text{cm}^3$.

A by-product of the growth process for the p-InGaN is that V-shaped pits appear on the surface. Normal flat p-GaN surfaces tend to reduce light extraction efficiency because the difference in refractive index with that of air reduces the escape cone to around 23° . The V-pits in the p-InGaN are also thought to improve the light output from the p-InGaN devices due to secondary factors such as an increased contact area and increased light extraction from the textured surface.

Other researchers have tried increasing light extraction in p-GaN by deliberately introducing V-pits by using a reduced-temperature growth process. However, these devices suffer from poor activation of the magnesium (Mg) p-type dopant, leading to reduced hole densities and thus the creation of a high-resistance contact that wastes power.

Nitride semiconductor structures for the Jimei 460nm blue LEDs (Figure 1) were grown on c-plane sapphire substrates using low-pressure metal-organic chemical vapor deposition (MOCVD). The top p-type contact layer included an aluminium gallium nitride (p-AlGaIn) electron-blocking layer before the 300nm p-GaN. The p-type magnesium doping was activated with a 10-minute 600°C anneal in air.

LED fabrication included deposition of an indium tin oxide (ITO) transparent contact/current spreading layer, and chromium/gold electrodes on the n- and p-contacts.

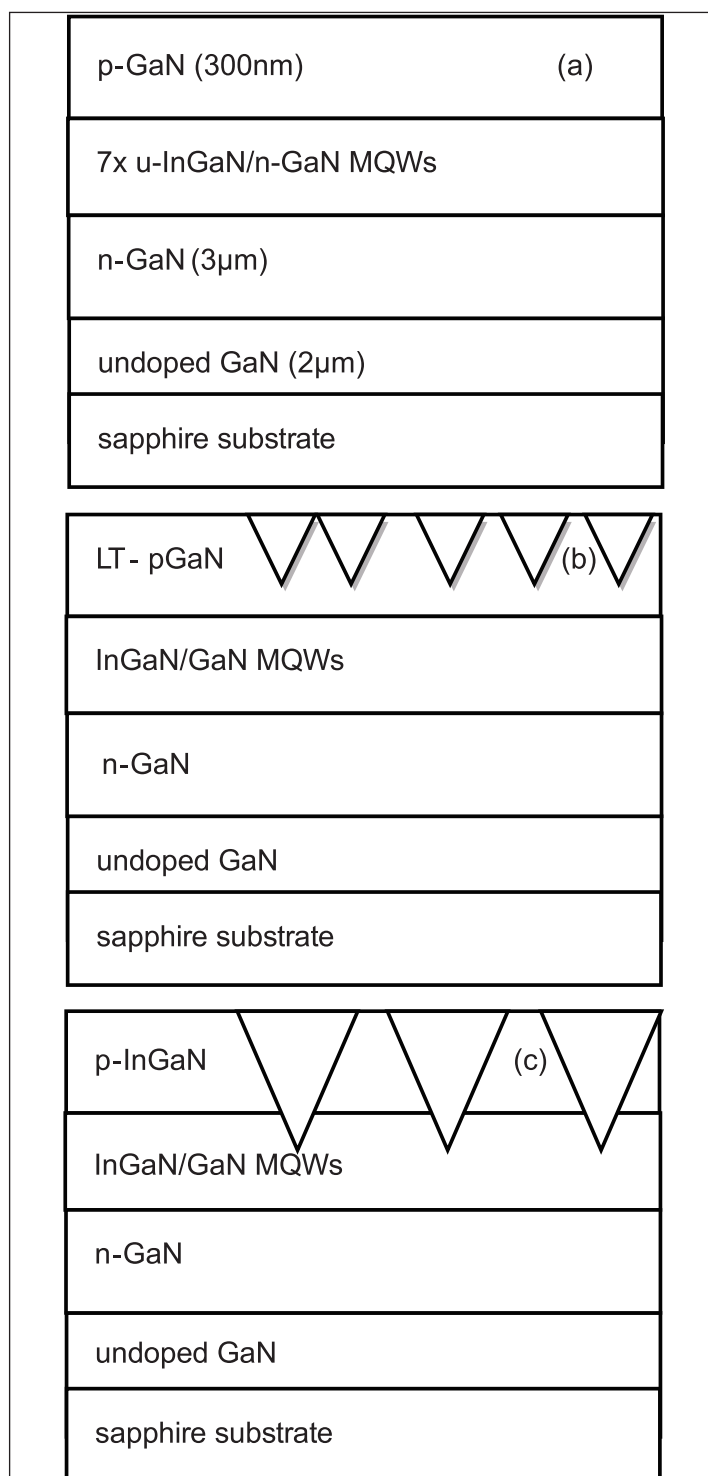


Figure 1. Schematic diagram of GaN-based LED structures with Ref-LED (a), LT p-GaN LED (b), and p-InGaN LED (c).

LEDs with V-shaped pits were formed in two different processes. First, a low-temperature (LT) 820°C process was used to deposit p-GaN (Figure 1b), rather than the 920°C used to give a planar p-GaN reference device (Figure 1a). The other V-shaped pit LED was formed by including some indium in the p-GaN layer, while maintaining the temperature at 920°C (Figure 1c). The presence of indium has the effect of reducing the activation energy of the p-type Mg doping.

The V-pits in LT p-GaN had diameters of around 300nm, those in p-InGaN around 600nm. The pit formation in LT p-GaN is thought to be related to the lower energy of the Ga atoms leading to reduced migration to proper sites in the crystal lattice or to reduced desorption. In p-InGaN the pits are believed to arise from pure or screw threading dislocations.

A further feature of the pits is their higher density (at least double) in the LT p-GaN sample to the point where some adjacent pits overlap (this rarely happens with the p-InGaN sample).

With current injection of 100mA, the p-InGaN LED outputs 45.2% more light than the reference device (Figure 2). The LT p-GaN LED only has 10.9% improved light output power compared with the reference at the same current.

The forward voltage of the p-InGaN LED at 20mA was 3.19V, a little higher than for the reference at 3.10V.

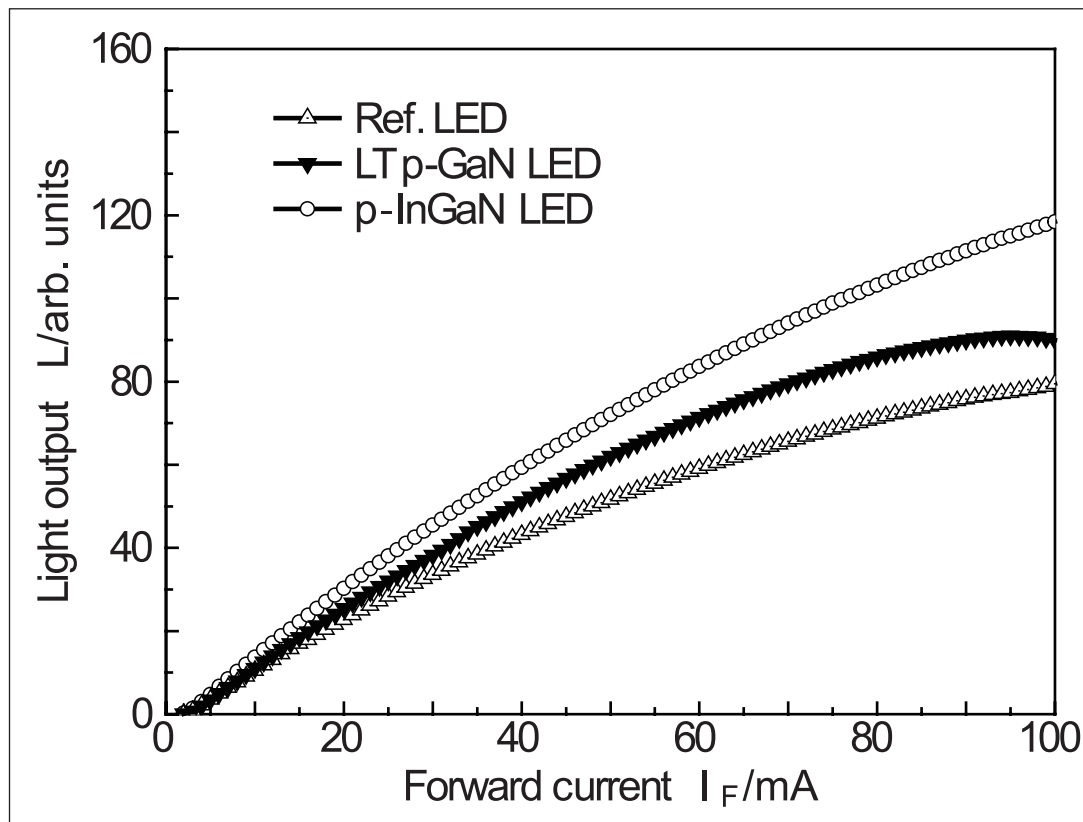


Figure 2. Light output power versus forward current for reference, LT p-GaN, and p-InGaN LEDs.

By contrast, the LT p-GaN LED had a 3.39V forward voltage at the same current. High forward currents indicate resistive power losses and hence reduced efficiency.

The researchers blame the poorer contact between the ITO layer and p-contact where V-pits are present for the increased forward voltage. These losses are somewhat compensated for in the p-InGaN LED due to its lower-resistivity contact layer due to the higher hole density.

In terms of the angular distribution of the light output, the p-InGaN LED puts out more power at all angles compared with the other devices. ■

<http://iopscience.iop.org/1674-1056/22/8/086803>

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Azzurro boosts nitride LED on silicon uniformity with strain engineering

Electroluminescence wavelength and intensity variations among the lowest reported to date.

Germany's Azzurro Semiconductors AG has reported uniformity measurements for indium gallium nitride (InGaN) light-emitting diodes on large-diameter silicon substrates up to 200mm [Andrea Pinos, et al, Appl. Phys. Express, vol6, p095502, 2013].

Although the growth of nitride semiconductor LEDs on larger substrates should provide economies of scale, there remain a number of production challenges to overcome before a commercial process can be developed. Among these challenges is the processing of high-quality, reliable material that gives uniform performance across the wafer.

An obvious roadblock is the 17% mismatch in lattice spacing between silicon and gallium nitride (GaN). This is higher than alternative but more expensive (and only available in smaller size) substrates such as sapphire (16%) or silicon carbide (3%). Further, since the GaN growth process involves a raised temperature (~1000°C is typical), the 46% mismatch in the thermal expansion coefficients raises an even more serious obstacle.

Both the lattice and thermal expansion mismatches can lead to significant wafer bowing and even cracking of the semiconductor material. It is not surprising therefore that nitride LEDs grown on silicon can show large variations in performance and yield across the wafer.

Azzurro has developed a proprietary process that results in a strain-engineered buffer layer that avoids the problems of lattice and thermal expansion mismatches. Judging from the company's previously published research [e.g. Atsushi Nishikawa et al, Jpn. J. Appl. Phys., vol52, p08JB25, 2013], the process involves bridging layers of aluminium gallium nitride (AlGaIn) and aluminium nitride (AlN).

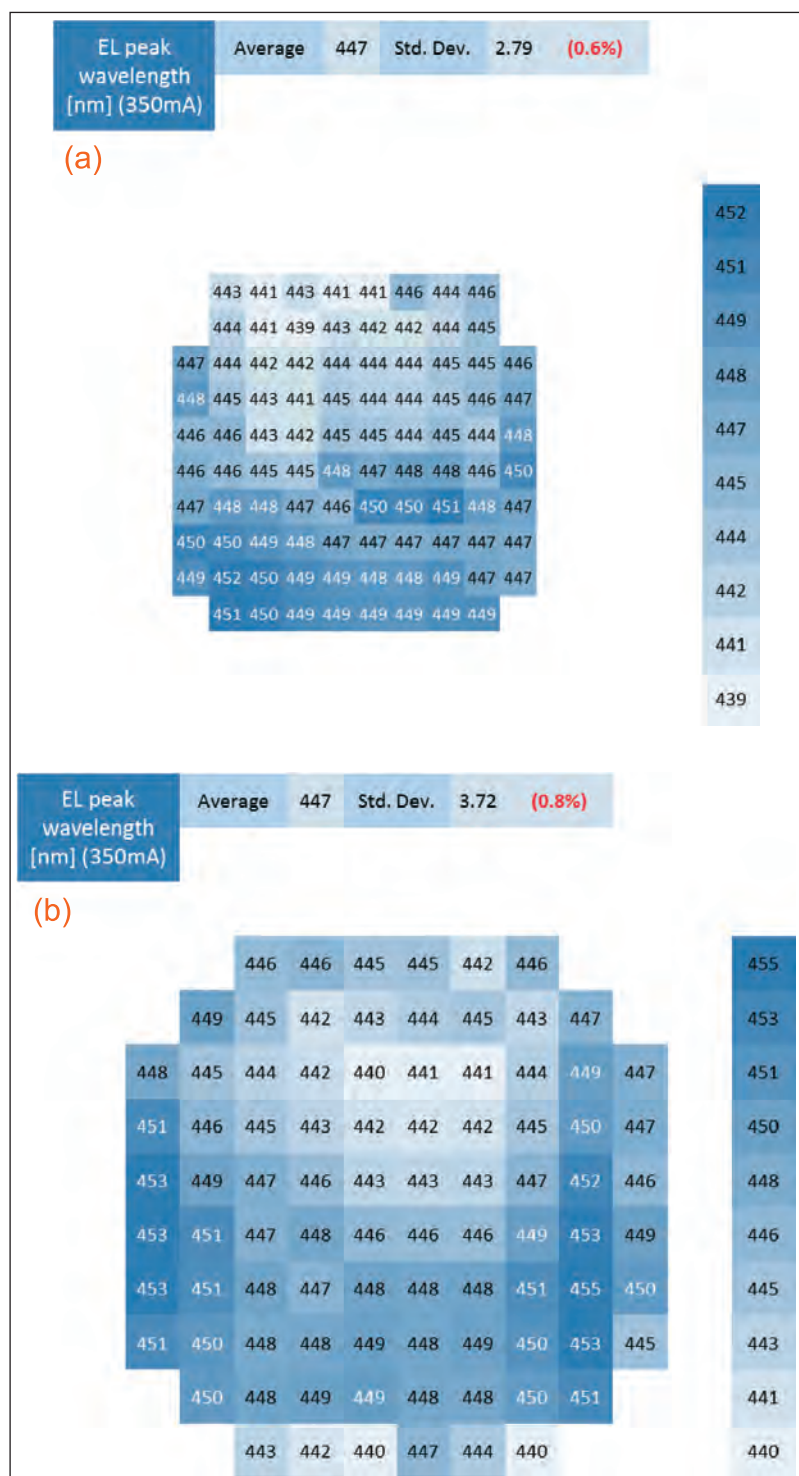


Figure 1. EL peak wavelength measured at 350mA on (a) 150mm and (b) 200mm wafers. The relative dimensions of the two maps reflect the different substrate areas.

The LED material was grown on (111) silicon substrates using multi-wafer metal-organic chemical vapor deposition (MOCVD). On top of the GaN template further layers consisted of 2µm of silicon-doped n-GaN buffer, the LED active region, and magnesium-doped p-GaN contact.

For simple testing, electrical contact with the LED structures was through 400nm annealed indium tin oxide (ITO) on the p-GaN with 150µm-diameter platinum/aluminium bond pads, and a conductive vacuum chuck on which the conductive silicon substrate was placed.

Since silicon absorbs the frequency emitted by the LED structures, one would normally remove the substrate for commercial products. Also, the devices were not etched to provide mesa isolation.

A range of uniformity measurements were carried out for 150mm-diameter wafers (Table 1). Also, the electroluminescence (EL) peak wavelength for LEDs on 200mm wafers was 447nm on average with 3.72nm standard deviation, representing 0.8% uniformity.

The standard deviation values for the EL peak wavelength on 150mm and 200mm wafers are claimed to be among the lowest reported to date (Figure 1). The researchers comment: "Achieving good wavelength uniformity on LED epitaxial wafers has been one of the main topics discussed in the US DOE SSL Manufacturing Roadmap and a key parameter to reducing manufacturing costs."

The photoluminescence (PL) spectra show a yellow band with an intensity two orders of magnitude lower than the main band-to-band emission. The EL spectra do not show such a yellow band. The researchers comment that yellow emissions are often associated with carbon-related levels from the organic precursors.

The EL intensity (Figure 2) standard deviation of 0.61 represents a relative variation of 3.9%, which is the best value reported so far for LEDs on large-diameter

The simultaneous demonstration of uniform EL intensity, wavelength and forward voltage clearly suggests that very uniform quantum wells can be achieved by MOCVD on large-area Si substrates when proper strain engineering is applied. This translates to reduced binning and a higher manufacturing yield

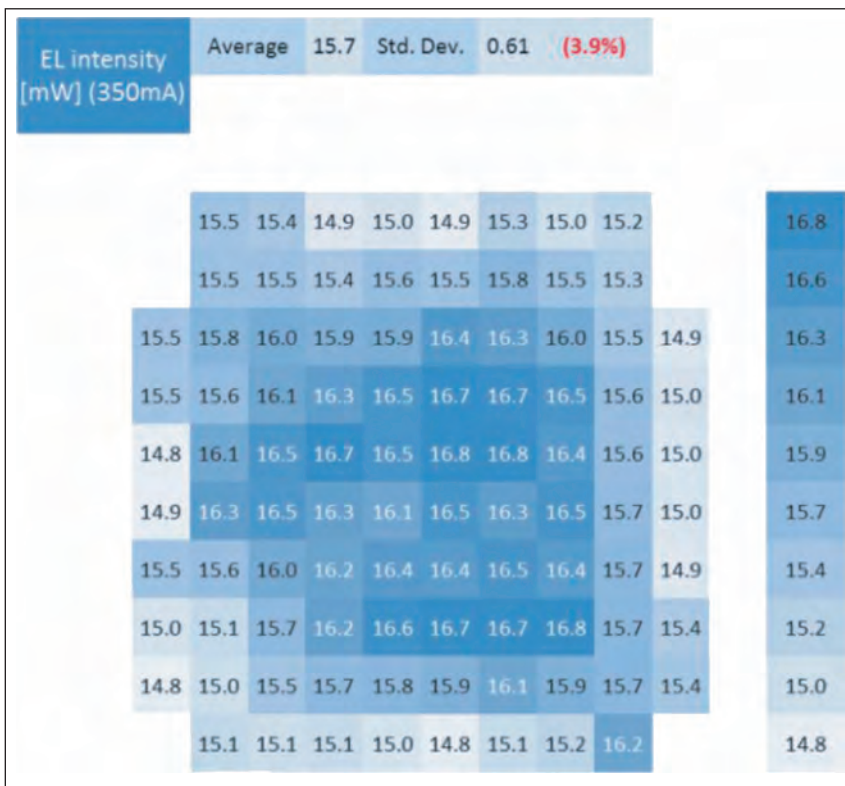


Figure 2. On-wafer EL intensity for 150mm wafer at 350mA.

substrates according to the researchers.

The relatively high value of the forward voltage at 5mA and the implied high series resistance is blamed on the AlGaIn/AlIn buffer layers between the n-Si and n-GaN. The researchers point out that these layers would be removed in a commercial process.

The researchers comment: "These results are significant, as the simultaneous demonstration of uniform EL intensity, wavelength and forward voltage clearly suggests that very uniform quantum wells can be achieved by MOCVD on large-area Si substrates when proper strain engineering is applied. This translates to a reduced binning and a higher manufacturing yield, in addition to cost savings from a reduced testing overhead from fewer bins."

The researchers also studied the reverse-bias leakage current variation with temperature and voltage. The strong temperature dependence that the researchers found suggests that "minimization of the dislocation density is critical for improving the LED brightness and reliability."

<http://apex.jsap.jp/link?APEX/6/095502/>

Author: Mike Cooke

Table 1. Uniformity performance of LEDs on 150mm silicon substrate.

350mA EL peak average \pm standard deviation (nm)	447 \pm 2.79 (0.6%)
PL peak average \pm standard deviation (nm)	455.6 \pm 3.433 (0.754%)
350mA EL intensity average \pm standard deviation (mW)	15.7 \pm 0.61 (3.9%)
PL intensity average \pm standard deviation (a.u.)	677.4 \pm 123.3 (18.2%)
5mA forward voltage (V)	3.1 \pm 0.04 (1.3%)

Tunneling to avoid efficiency droop in nitride semiconductor LEDs

Ohio State University shows how a tunnel junction with low resistivity could be used to cascade optoelectronic devices.

Ohio State University is proposing the use of a newly developed tunnel junction as a means to ameliorate the effects of efficiency droop in nitride semiconductor light-emitting diodes (LEDs) and other optoelectronic devices [Fatih Akyol et al, Appl. Phys. Lett., vol103, p081107, 2013].

The peak efficiency point of such devices can be as low as a few milliamps, with the power rating in the tens of milli-watt range. For general illumination one needs devices operating at the order of 1 Watt of power. The result is that LED bulbs need a large number of LEDs – around 100 if operating at peak efficiency.

Economic constraints lead to trade-offs between production costs and efficiency.

The Ohio proposal would be to cascade a series of LEDs in a vertically integrated monolithic structure with a number of devices coupled in series and operated at low current injection while a high voltage is applied across the whole assembly.

In such a structure, one needs to overcome the fact that the top p-type contact of one device would be under the n-type region of the next. Simply depositing the n-type contact on the p-type contact would set up a reverse-biased diode that would resist current flow.

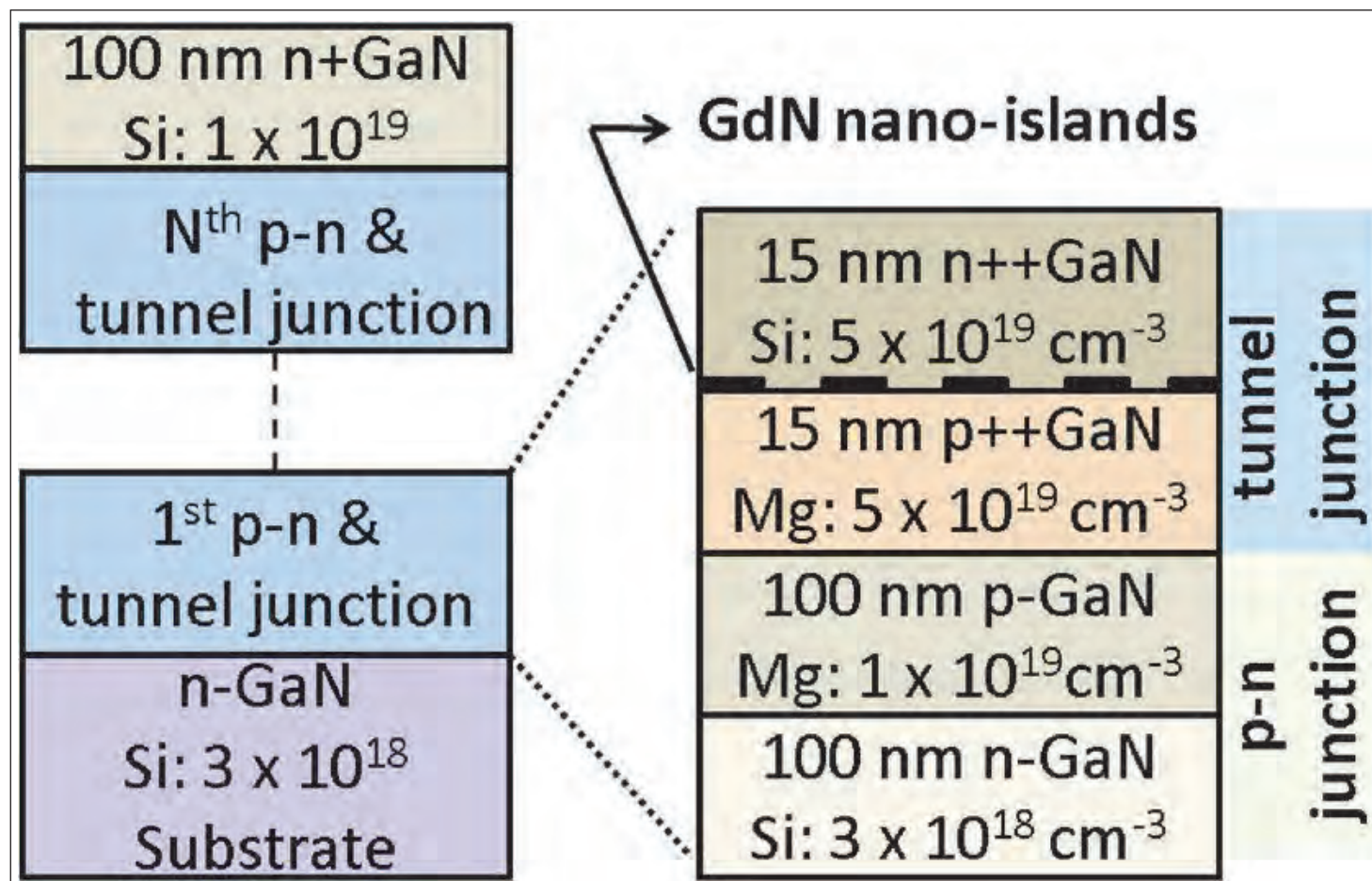


Figure 1. Epitaxial design of the cascaded p-n junctions.

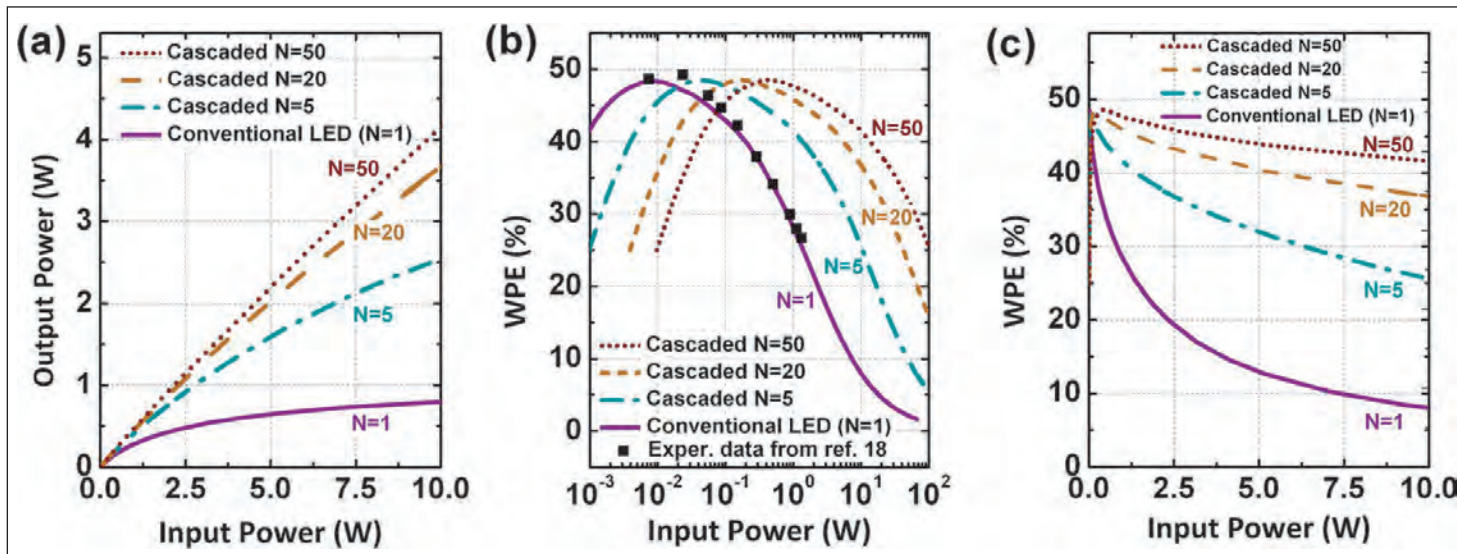


Figure 2. Change in (a) output power, (b) wall-plug efficiency (WPE) on logarithmic scale (c), and WPE on linear scale of modeled reference single-junction LED and cascaded LEDs with various cascade numbers (N). Experimental data and model fit for 470nm LED are also shown in (b).

The new tunnel junction [Sriram Krishnamoorthy, *Nano Lett.*, vol13, p2570, 2013] is proposed as an ohmic link between the devices. The junction would feed/regenerate holes into the p-type region and electrons into the n-type region. For such a tunnel junction to work effectively it has to offer as small as possible resistance to current flow in the desired direction.

The Ohio group produced a proof-of-concept where the tunnel junction is used to link a series of p–n diodes rather than LEDs (Figure 1). The structure was constructed using plasma-enhanced molecular beam epitaxy (MBE) on free-standing n-type gallium nitride (GaN) substrates. The tunnel junctions were combined with p–n junctions with up to four repeats. The tunnel junctions consisted of gadolinium nitride (GdN) nano-islands sandwiched between heavily doped p- and n-type gallium nitride.

The material stack was formed into mesa-type diodes with an area of $100\mu\text{m}^2$. The top and bottom n-GaN regions were contacted with ohmic aluminium/gold metal.

The diode cascades demonstrated rectifying behavior. The turn-on voltage increased with the number N of repeated sections. The leakage of the device with four repeats showed a high leakage current, but the researchers hope to reduce this with optimization.

Analysis of the resistance of the linear portion of the current-voltage behavior for the different diode cascades suggests a resistivity of $\sim 5.7 \times 10^{-4} \Omega\text{-cm}^2$ per tunnel junction.

The researchers comment: "This resistance would result in relatively low voltage drop of 57mV for a current density of 100A/cm^2 . This report of cascaded III–nitride p–n junctions with low series resistance could enable several devices including multi-junction

solar cells, photodetectors, and multiple active region LEDs."

To see what might be achieved, the researchers simulated stacked LEDs separated by tunnel junctions with a resistivity of $6.4 \times 10^{-4} \Omega\text{-cm}^2$, the highest/worst value from the experimental tests described above. The LED performance was modeled using an empirical fit to a commercial 470nm device. Cascades of up to 50 LEDs were simulated (Figure 2). As the number of devices increased, the maximum efficiency point was increased to higher input power.

Another benefit of cascading LEDs in this way was found to be reduced Joule heating, since the current through the layers was reduced to the level needed to avoid droop. By stacking up to 50 devices, the Joule heating effect could be reduced by more than an order magnitude, compared with single-active-region LEDs at the same output power. "This not only enhances efficiency but also can enable LED operation at elevated output power, and could eliminate thermal management issues," the researchers write.

At this point, there are several challenges to overcome before this approach can be applied to LEDs: "First, GaN-based tunnel junctions based on MBE and metal-organic chemical vapor deposition (MOCVD) growth are still relatively less efficient than the results described here and reported previously using MBE growth. Another challenge is the activation of buried Mg-atoms (p-type dopant) in MOCVD/MOVPE growth, which has been addressed previously using sidewall activation. Finally, re-absorption of photons for LEDs with a large number of active regions, and excessive heating due to unextracted photons could both reduce the efficacy of these LEDs." ■

<http://link.aip.org/link/doi/10.1063/1.4819737>

Author: Mike Cooke

Bridging the amber-green gap and white LEDs

Mike Cooke reports on recent reports of various techniques to create light-emitting diodes that could fill the chasm, possibly leading to whiter LEDs.

Presently, standard commercial white light LEDs use phosphor layers to convert short-wave-length light from indium gallium nitride (InGaN) LEDs into something that the eye will see as being an approximation to 'white'. Phosphors make the production process more complicated and costly. Lower-cost devices with phosphors have poor color rendering. Technical difficulties include reliability problems, and degraded color balance over time and due to temperature stress.

A preferable solution, if it can be made economic, would be to combine light from four LEDs with different wavelength properties. A suggested combination of wavelengths is 459nm (blue), 535nm (green), 573nm (yellow/'amber'), and 614nm (orange). The blue and orange targets are well covered by existing technology.

Production of LEDs with yellow (590–560nm) or green (560–490nm) emission is presently difficult commercially. The long- and short-wavelength ends of the visible spectrum are covered using phosphide and nitride semiconductor materials, respectively.

The nitride semiconductor approach to longer wavelengths involves problems such as enhanced efficiency droop and difficulties in growing high-quality InGaN with high indium content.

From the non-nitride III-V semiconductors, the material with widest bandgap is aluminium indium phosphide (AlInP).

However, this option has not been researched extensively due to a lack of a convenient substrate and uncertainties about the material system's characteristics, such as the region of aluminium concentration for which the gap is 'direct' and where light can be efficiently produced from electron-hole recombination.

Quantum well engineering

Chinese Academy of Sciences' Semiconductor Lighting R&D Center at the Institute of Semiconductors in Beijing has developed an electrically driven color-tunable LED based on InGaN quantum wells in gallium nitride (GaN) barriers [Hongjian Li et al, Appl. Phys. Express, vol6, p102103, 2013]. At high current injection, the devices achieve a white color rendering index of 85.6 — much higher than for conventional yellow-phosphor-converted 'white' LEDs. At the low-current end, the devices emit red light around 630nm.

The color-tunability arises from the nitride semiconductor growth process rather than from complicated device structures or fabrication methods such as

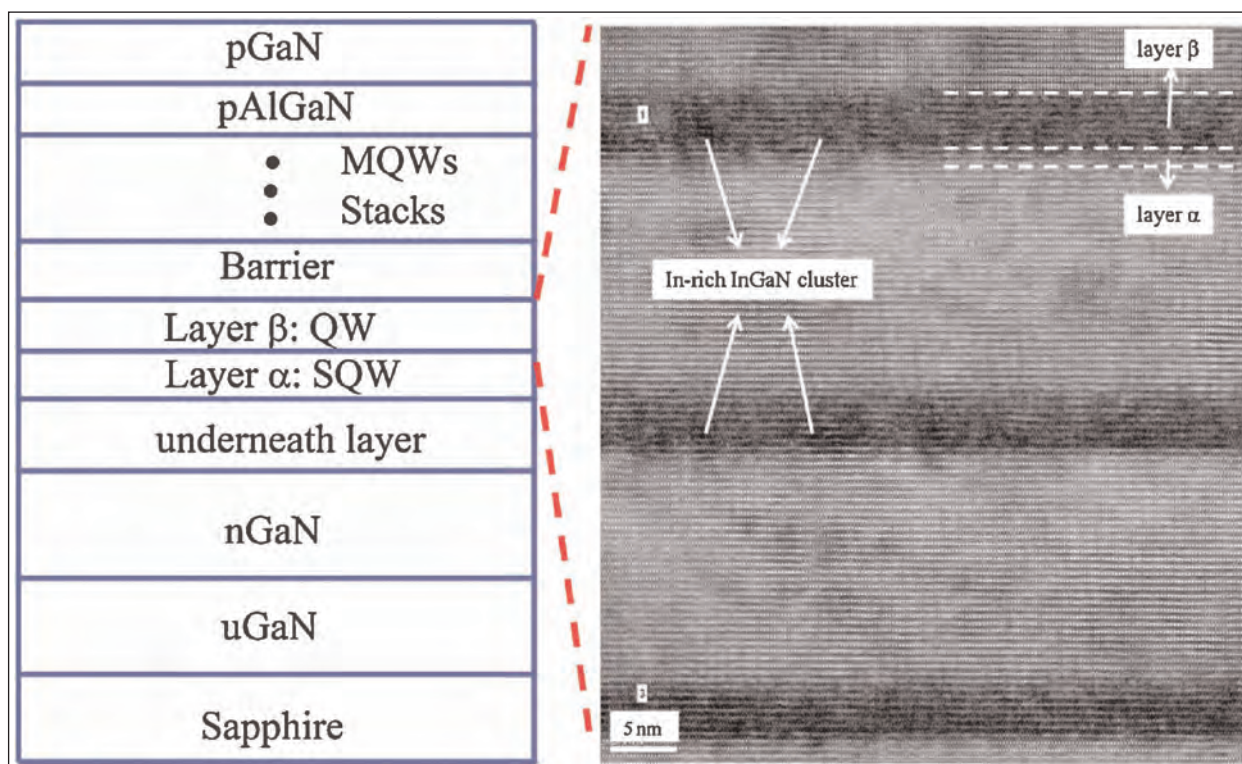


Figure 1. Epitaxial structure, left, and HRTEM image of active region, right.

adding phosphor layers. The researchers see their development as providing “a simple method for the fabrication of phosphor-free color-tunable monolithic LEDs and also an alternative for high-color-quality general lighting”.

The nitride semiconductor layers (Figure 1) were grown on c-plane sapphire using metal-organic chemical vapor deposition (MOCVD). The quantum wells consisted of a combination of low-indium-content (13%, layer α) InGaN 1nm shallow wells (SQW) and deeper high-indium-content (46%, layer β) InGaN 3nm wells. Barriers between the wells were 17nm pure GaN. Growth of the α layer before the main β well improved crystal quality, served as a carrier reservoir, and enabled shorter-wavelength emissions.

High-resolution transmission electron micrographic (HRTEM) study showed indium-rich InGaN clusters of 2–4nm diameter embedded in the deep quantum well regions. The researchers attribute the clusters to strong indium phase separation and composition fluctuations due to the large biaxial strain from the large lattice mismatch between InN and GaN (11%). The indium-rich clusters in high-indium-content InGaN result in deep localization centers for carrier recombination. Clusters are a common feature of high-indium-content (more than 20% In) InGaN.

Photoluminescence showed peaks at 2.12eV (P1) and 2.91eV (P2). The P1 peak is attributed to the shallow well, while P2 correlates with the deep well with localized centers. Temperature-dependent measurements suggested internal quantum efficiencies of 10.4% and 14.1% for P1 and P2, respectively.

Standard mesa-type LEDs of 500 μ m x 1000 μ m size were produced with indium tin oxide (ITO) transparent conductor current spreader on the p-contact layer. The contact electrodes were chromium/platinum/gold.

The spectral content of electroluminescence (EL) emission shifted significantly with increasing current from red (5mA) through yellow (10–20mA) to ‘white’ (100mA). The turn-on voltage of the device was 2V and the forward voltage at 100mA was 3.06V.

The spectra of the emissions showed a dominant red (631nm) peak at 5mA. This peak blue-shifted to 615nm and 608nm at 10mA and 20mA, respectively. The width of the peak broadens from a full-width at half-maximum (FWHM) of 185meV at 5mA to 274meV at 60mA. The broadening is attributed to filling of the deeper localization states as the current increases that allows shallower localization states to become active. Above 60mA, a second peak appears at 473nm, attributed to the shallow well.

The researchers plotted Commission International de l'Éclairage (CIE) chromaticity coordinates and determined the color temperature at the various currents (Figure 2). The color rendering index (CRI) at 250mA was 85.6. ▶

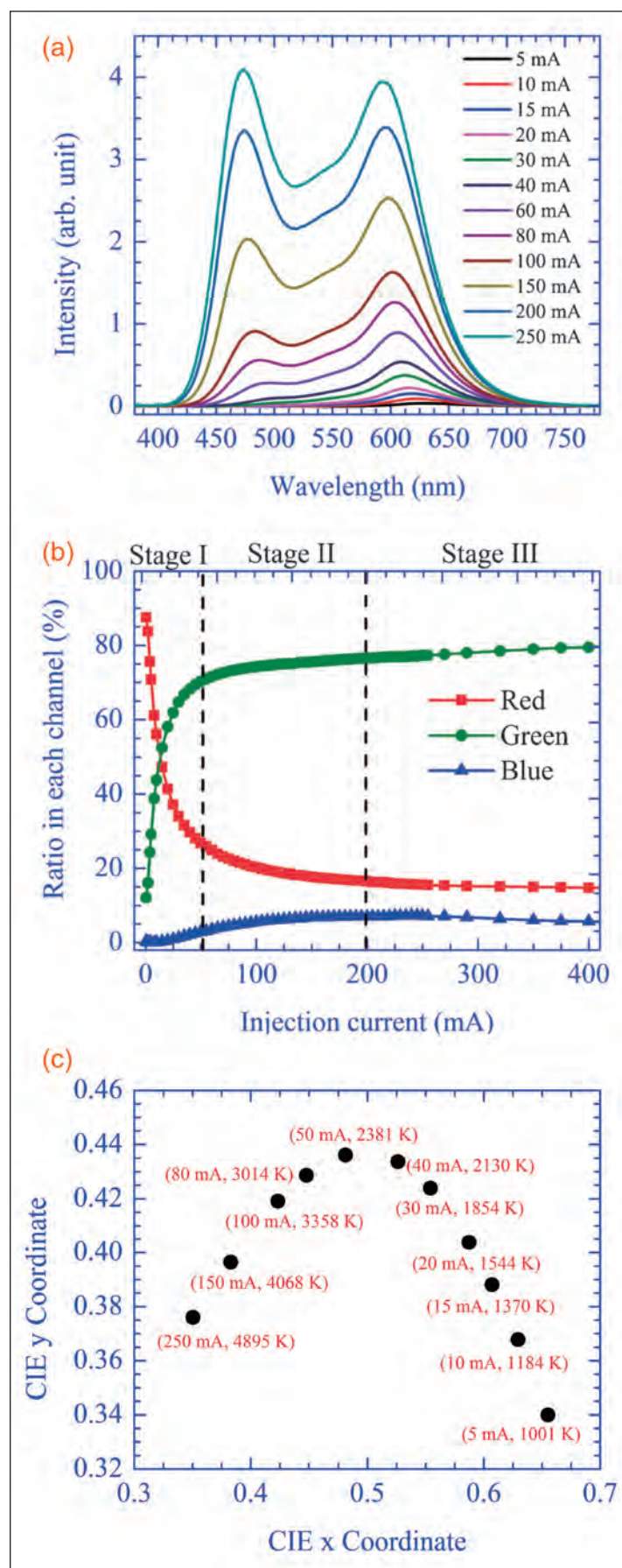


Figure 2. (a) EL spectra at various injection currents. (b) Intensity ratio in red/green/blue channels versus injection current. (c) CIE chromaticity coordinates at various injection currents.

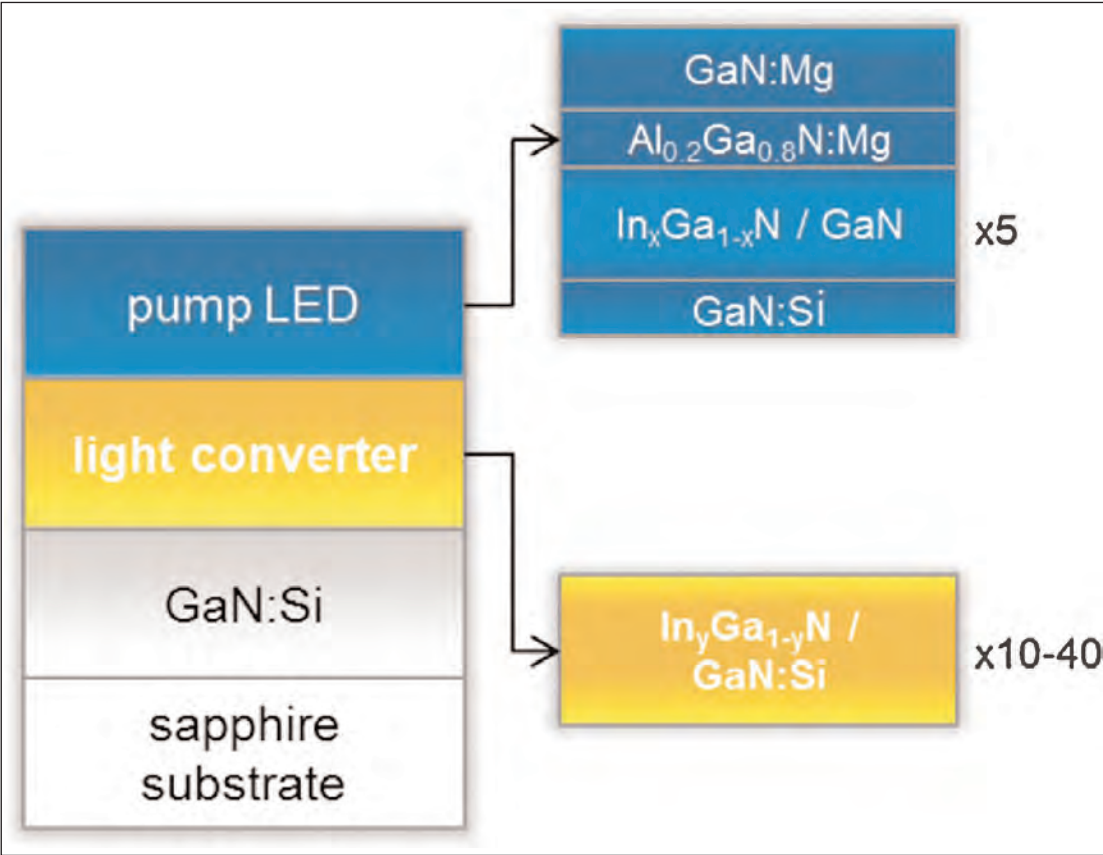


Figure 3. Structure of monolithic LED with light converter.

► Monolithic pump/light conversion

Researchers in France have developed a monolithic metal-organic chemical vapor phase epitaxy (MOVPE) process for growing indium gallium nitride (InGaN) LEDs with a multiple quantum well (MQW) light converter as an alternative to phosphors [Benjamin Damilano et al, Appl. Phys. Express, vol6, p092105, 2013]. The research involved Centre de Recherche sur l’Hétéro-Epitaxie et ses Applications–Centre National de la Recherche Scientifique (CRHEA-CNRS) and University of Nice Sophia-Antipolis.

The short-wavelength LED region was used as a pump for photoluminescence from an InGaN MQW structure that emits longer wavelengths. The researchers have previously developed such structures with a production process using molecular beam epitaxy (MBE), sometimes in combination with MOVPE. Commercial production of InGaN LEDs is usually based on MOVPE.

A problem with MOVPE is that it uses higher growth temperatures than MBE that can degrade high-indium-content InGaN needed for longer wavelengths.

Table 1. Structures of various light converter sections.

Sample	A	B	C	D
Number of QWs	20	10	40	40
In _y Ga _{1-y} N thickness (nm)	1.6	3.4	3.1	3.1
In composition (y)	0.26	0.18	0.22	0.28
GaN:Si barrier thickness (nm)	21	18	18	18

The researchers developed an MOVPE process that uses a lower temperature, but does not degrade the pump LED performance.

The nitride semiconductor layers (Figure 3) were grown on commercial n-type silicon-doped GaN on sapphire using MOVPE. First, a 0.5µm layer of GaN:Si was grown at 1080°C. The temperature was reduced to 715–780°C for the In_yGa_{1-y}N layers in the light conversion MQW.

The researchers found that they were able to produce light conversion from violet into blue to red (490–605nm). Although spectral purity is often desired in colored LEDs, for white light

sources with good CRIs, the researchers wanted broad photoluminescence peaks. Such broadening can occur due to fluctuations in the InGaN alloy composition or from QW interface roughness.

Four pump/converter structures were produced with varying light converter regions (Table 1). The InGaN of the pump MQW was grown at 800°C.

The standard growth temperature for GaN and AlGaIn of ~1080°C was found to result in poor performance. In particular, the light converter regions showed signs of indium metal clustering. Thus, a lower temperature of 970°C was adopted while, at the same time, the p-doping effect of magnesium (Mg) had to be re-optimized for the lower growth temperature.

The samples were used to produce on-wafer LEDs by scratching the top surface with a diamond tip, exposing the GaN:Si layer of the pump LED. The electrical contacts with the GaN:Si and GaN:Mg layers were made with indium metal.

Despite the non-standard growth, the researchers were able to produce violet LEDs with ~2mW output power at 20mA, similar to values obtained for devices grown at higher temperatures. The peak of the pump’s emission spectrum was around 400nm.

The effect of the light converters (Figure 4) was to add peaks at 490nm (sample A), 526nm (B), 551nm (C), and 605nm (D). The researchers describe these devices as emitting blue, green, yellow-green, and white-orange light, respectively.

The fractions of the long-wavelength peak relative to the total electroluminescence intensity were, in order, 60%, 55%, 70% and 43%. Despite the expected degradation in performance from increased indium content, sample C shows an increased fraction of the longer-wavelength peak. The researchers ascribe this to greater absorption from the use of 40 quantum wells rather than the 10 of sample B.

The 50mA luminous powers for samples A–D were 86lm, 264lm, 67lm, and 5lm, respectively. Since lumens corrects for the eye's sensitivity to light of different wavelengths with a maximum in the green part of the spectrum (683lm/W at 555nm), the optimum luminous power is for sample B. Previous attempts to use a pump/light converter structure have produced 200lm for material grown using a mix of MOVPE (converter) and MBE (pump). Sample B beats this previous achievement by 32%.

In terms of chromatic coordinates, sample D is near that of a blackbody of temperature 2100K. This tint is between warm white and candlelight.

The researchers believe the work could be extended to include a range of emissions from the converter section. This could be used to improve

the CRI to bring it more in line with a white light source at various color temperatures. ►

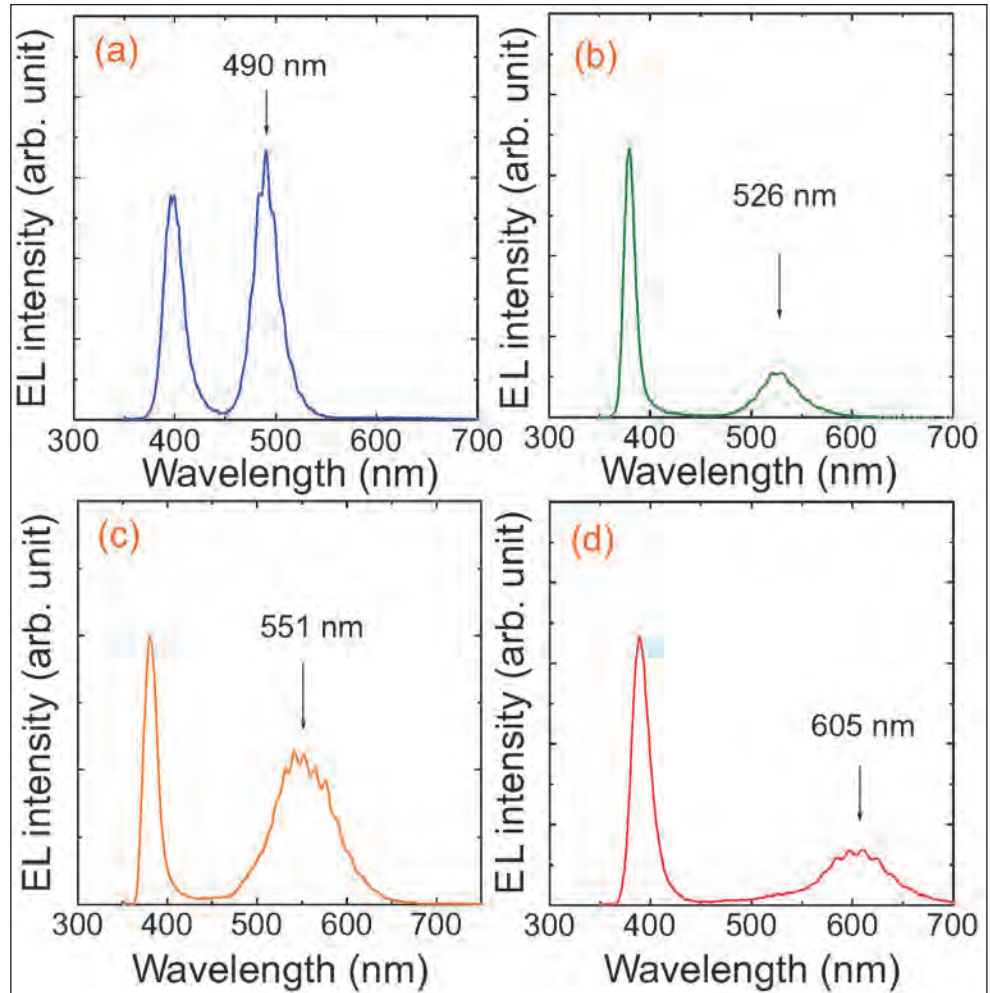


Figure 4. (a)–(d) RT EL spectra under continuous wave conditions at a current of 20mA corresponding to samples A–D.

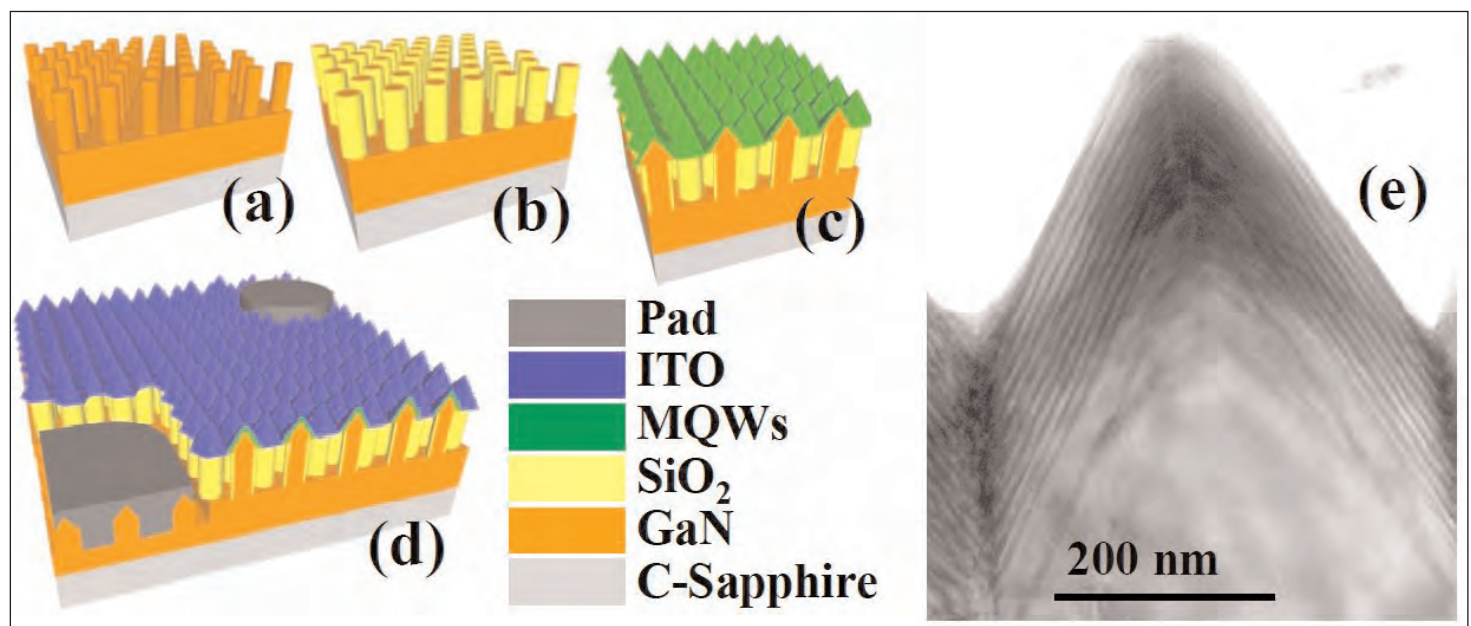


Figure 5. Nanopyramid LED fabrication: (a) Patterned top-down etch of nanopillars. (b) Sidewall coated with oxide. (c) Nanopyramid followed by MQW growth. (d) Top surface ITO deposition and metal pad fabrication. (e) HRTEM cross-section from sample after MQW growth.

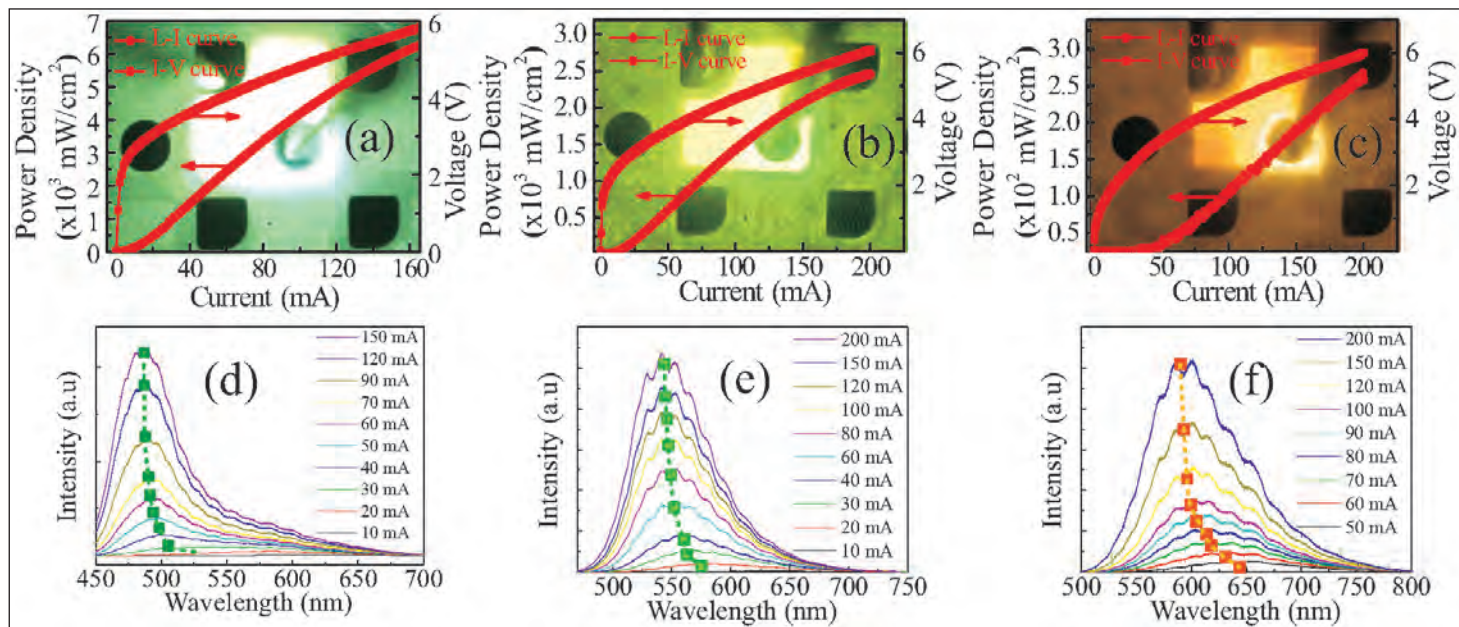


Figure 6. (a)–(c) Optical microscope images of G-, O-, and A-LED under electrical injection. (d)–(f) Electroluminescence spectra versus injection current.

► Nanopyramids

Researchers in Taiwan have used nanopyramid nitride semiconductor structures to create long-wavelength green, olivine and amber LED structures [Shih-Pang Chang, *Optics Express*, Vol. 21, p23030, 2013].

The team was variously based at National Chiao Tung University and Academia Sinica's Research Center for Applied Sciences. The researchers also used technical expertise from Epistar Corp, LuxtalTek Corp and Industrial Technology Research Institute (ITRI), all similarly based in Taiwan.

The device performances compared favorably with LEDs produced on c-plane sapphire. It is thought that producing the light-emitting structures on the semi-polar facets of hexagonal GaN nano-pyramids reduces the spontaneous and strain-dependent (piezo-) electric fields that arise in indium gallium nitride (InGaN) quantum wells. These fields in polar c-plane devices keep the electrons and holes from recombining into photons, reducing efficiency.

Although semi-polar and even non-polar substrates can be produced, they are not readily available.

The fabrication process (Figure 5) began with an n-GaN template on sapphire. First, nanocolumns were formed in a patterned etch. The column sidewalls were coated with spin-on glass (SiO₂). The GaN semiconductor nanopyramids, with additional InGaN/GaN nitride (2nm/8nm) MQWs and p-GaN top contact, were grown by MOCVD on the tops of the nanocolumns. The spin-on-glass coating was aimed at blocking regrowth of nitride semiconductor on the sidewalls of the columns.

Further processing included applying an ITO transparent top contact and mesa etching to reach the n-GaN contact layer to create 300µm x 300µm LEDs. Three

different emission types were produced by varying the indium content of the InGaN wells. The peak wavelengths at 100mA were 500nm (green/G), 550nm (olivine/O), and 600nm (amber/A).

Temperature-dependent photoluminescence measurements between 20K and 300K were used to give internal quantum efficiency assessments: 30%, 25%, and 21%, for the G-, O-, and A-LEDs, respectively. The values are high compared with a typical value of 12% for c-plane MQWs emitting at 570nm. The decline in IQE for higher-indium-content quantum wells is attributed to a "larger internal polarization field which results in larger electron-hole wave function separation".

The behavior of the photoluminescence lifetime temperature dependence is also different from traditional c-plane MQWs. In particular, there is no red-blue-red shift ('S-curve') behavior. The researchers comment: "The absence of S-curve implies a significant reduction of localized potentials for MQWs grown on the nanopyramid facets."

Under electrical injection (Figure 6), the turn-on voltage of the LEDs was around 3V. At higher currents the voltage increases significantly to 6V at 200mA, higher than usual for c-plane LEDs. The researchers

The device performances compared favorably with LEDs produced on c-plane sapphire. It is thought that the light-emitting structures on the semi-polar facets of hexagonal GaN nanopyramids reduces the spontaneous and strain-dependent (piezo-) electric fields that arise in InGaN quantum wells

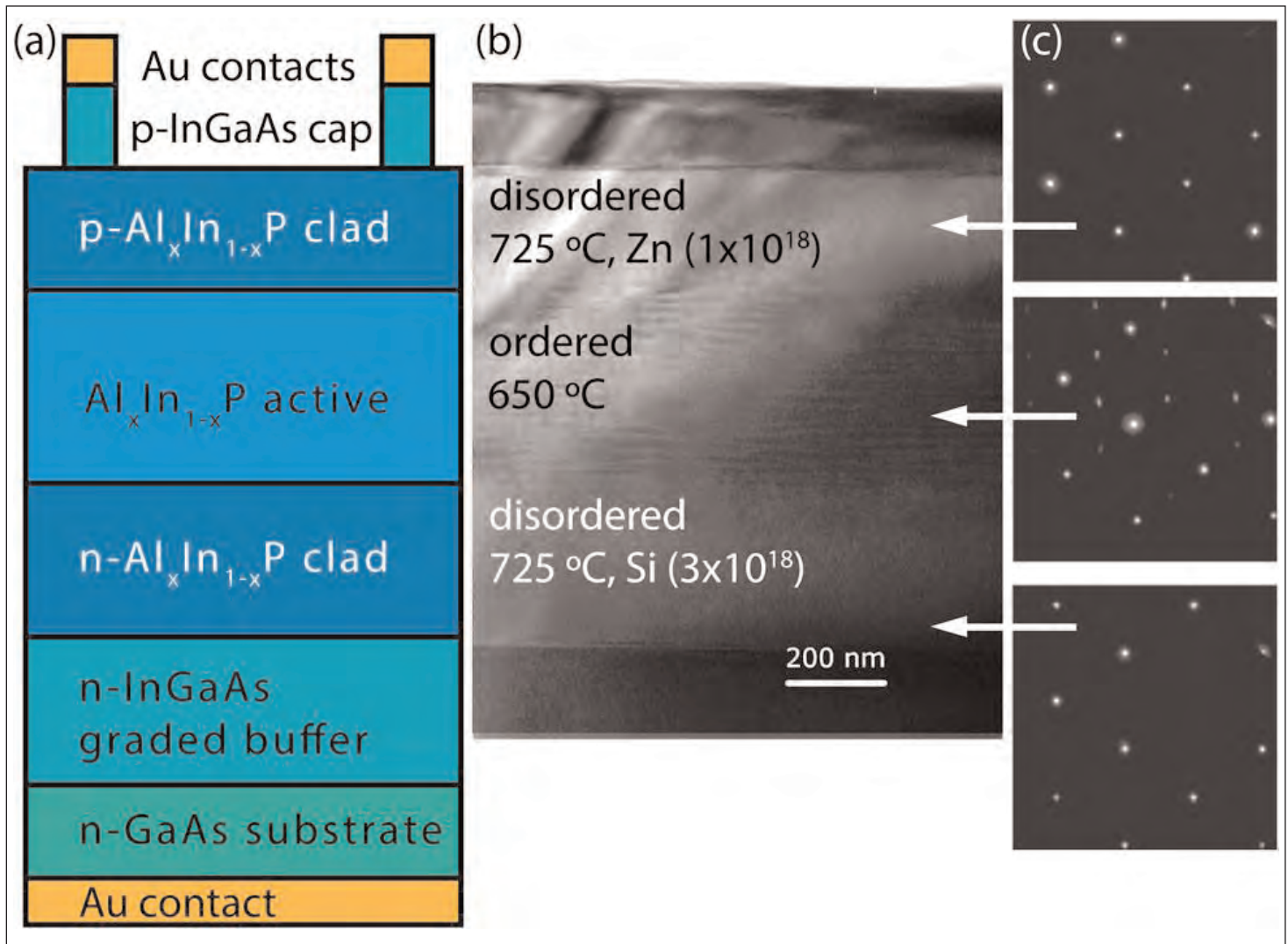


Figure 7. (a) Schematic of AlInP double-heterostructure LED device on graded InGaAs virtual substrate. (b) Transmission electron micrograph (TEM) of typical order-disorder heterostructure LED (device 1) with Al_{0.39}In_{0.41}P. (c) Transmission electron diffraction show both variants of CuPt-B type ordering occur in active layer, but ordering is suppressed in cladding.

believe that the diodes had high series resistance due to an imperfect contact between the ITO layer and the corrugated surface of the nanopyramid array.

Light output from the devices is slow to turn on, particularly in the longer wavelength A-LED, which does not operate before 40mA. This problem is attributed to current leakage effects. A high amount of defects in the base and apex regions is blamed.

With increased current the spectrum peak of light output undergoes a blueshift of 13nm, 25nm, and 50nm, for the G-, O-, and A-LEDs, respectively. "These blue-shift values are, nevertheless, still relatively small compared with that in a c-plane MQW," the researchers point out.

The indium composition gradient leads to rather broad emission spectra with full-width at half-maximum values, respectively, for the G-, O-, and A-LEDs of 60nm, 80nm, and 110nm. The researchers see possible applications for LEDs with even broader spectra as phosphor-free white-light LEDs.

Order–disorder route to amber–green

Researchers based in the USA have used a double-heterostructuring based on order–disorder properties of aluminium indium phosphide (AlInP) to produce 'amber–green' LEDs [Theresa M. Christian et al, J. Appl. Phys., vol114, p074505, 2013]. The research involved collaboration of National Renewable Energy Laboratory (NREL), University of Colorado Boulder, and Massachusetts Institute of Technology.

Copper-platinum B-type ordering in AlInP consists of spontaneous segregation into alternating aluminium- and indium-rich (111) planes. One effect of the ordering is expected to be a reduced bandgap. A similar order–disorder structure is used in high-brightness aluminium gallium indium phosphide (AlGa)InP LEDs.

The epitaxial structures were produced on gallium arsenide (GaAs) in a Thomas Swan/Aixtron low-pressure MOCVD system with a close-coupled showerhead. Growth began with a 250nm homoepitaxial layer of GaAs before applying compressively graded InGaAs

Table 2. Selected properties of the AlInP devices.

	Substrate	Al fraction	Active region	EL peak (300K)
Device 1	Miscut 6A	0.39	400nm	566 nm
Device 2	Miscut 6A	0.36	300nm	600 nm
Device 2B	(111)B	0.36	300nm	586 nm

buffer with lattice mismatch rate of 0.5%/μm. The ‘virtual substrate’ structure was capped with a constant composition 0.7μm InGaAs buffer layer.

The LED layers consisted of a double heterostructure of AlInP n- and p-type cladding around an undoped active region (Figure 7). The cladding layers were grown at 725°C and the active region at 650°C. The lower temperature growth of the active region was designed to promote ordering.

An InGaAs cap on the p-cladding was used for ohmic contact with gold electrodes. The epitaxial structure was annealed at 425°C for a minute after growth. The gold on the p-side was in a grid form that was used as a mask for etch removal of the underlying InGaAs cap.

Three sample types were produced (Table 2) with different AlInP compositions. Also in one case a (111)B substrate was used to suppress atomic ordering of the AlInP alloy. The other devices were grown on (100) substrates miscut 6° in the (111) direction (‘Miscut 6A’). Material grown on such miscut substrates tends to demonstrate improved material qualities such as better compositional homogeneity and surface smoothness.

material ordering.” However, the devices actually produced were estimated to have bandgap shifts of only 20–60meV, indicating room for improvement.

A reference device with GaInP active region and AlGaInP cladding was also produced on Miscut 6A substrates. The device used as reference was the brightest among several produced using conditions similar to those for the AlInP devices. Commercial Ga_{0.51}In_{0.49}P LEDs can achieve external quantum efficiencies of more than 55%.

Pulsed current measurements were used to avoid self-heating affecting light output measurements. The light outputs of the 566nm (amber–green) and 600nm (orange ~ 590–635nm) emitting devices at 1A/cm² injection current density were, respectively, 23% and 39% that of the ~650nm (red ~ 700–635nm) standard GaInP reference device (Figure 8).

The researchers comment: “The performance of the Al_xIn_{1-x}P devices relative to a similar-quality, unoptimized Ga_{0.51}In_{0.49}P device strongly indicate that an Al_xIn_{1-x}P material system holds promise for effective light emission in the amber–green wavelength range.”

The disordered device 2B was compared with the ordered active region device 2. The researchers recognized the likely poorer quality of device 2B since it was grown using a process optimized for device 2. The light outputs were therefore normalized separately at 1A/cm² to remove the material quality effect. Beyond 1A/cm², the light output from device 2 was relatively greater than for device 2B. At 40A/cm², the boost from using an order–disorder heterostructure was a factor of three improvement in light output of device 2 over device 2B. ■

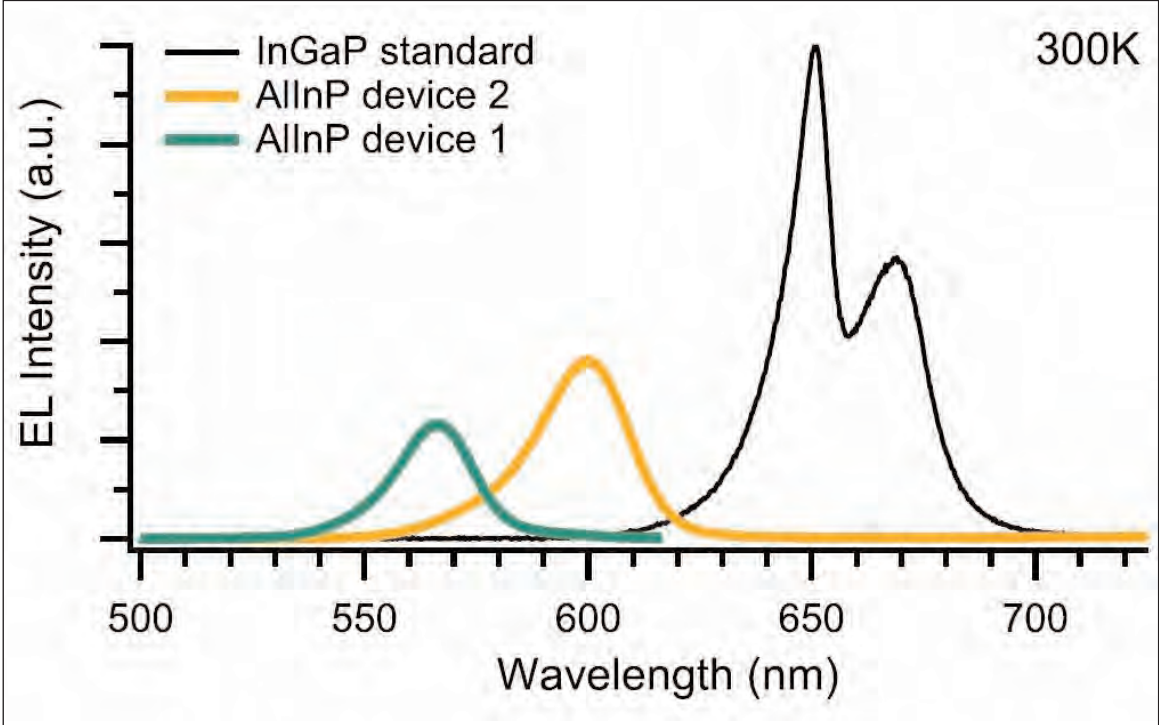


Figure 8. Comparison of room-temperature electroluminescence spectra for devices with mesa area 0.1cm² at 100mA drive current (density 1A/cm²) for both Al_xIn_{1-x}P LEDs compared with reference Ga_{0.51}In_{0.49}P LED.

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Growth switching for higher-efficiency near-green indium gallium nitride LEDs

Devices produced with peak external quantum efficiency of 48.6% at ~520nm wavelength.

Taiwan's National Cheng Kung University has developed near-green light-emitting diodes (LEDs) using a new indium gallium nitride (InGaN) growth process that gives devices with a higher peak external quantum efficiency of 48.6% [Wei-Chih Lai et al, Appl. Phys. Express, vol6, p102101, 2013]. The process involves switching the growth between indium nitride and gallium nitride in 2-second bursts.

Many researchers are seeking to improve the efficiency of green LEDs. At present there are no ideal materials for producing efficient LEDs for the yellow-green gap in the visible spectrum between the red-orange of arsenide- and phosphide-based devices and the blue of indium gallium nitride.

The LED material (Figure 2) was grown on patterned sapphire in a Thomas Swan 19x2-inch close coupled showerhead (CCS) metal-organic chemical vapor deposition (MOCVD) system. The CCS technology is now owned by Aixtron. The sapphire patterning consisted of an array of 3.5µm-diameter cones with 2µm spacing. The height of the cones was 1.3µm.

The nitride semiconductor metal-organic epitaxy sources were trimethyl-gallium, indium and aluminium (TMG, TMI, TMA), along with ammonia (NH₃) for the nitrogen. The InN/GaN switching (Figure 1) was performed in the active light-emitting region multiple quantum well (MQW). The switching loop consisted of 40 cycles of 2 second bursts of TMG and TMI. The ammonia flow was held constant. The researchers also produced a standard MQW (LED I) with constant flow of TMG and TMI during the well growth.

LEDs with a photoluminescence (PL) emission wavelength of 516nm were created. The chip area was 580µm x 1160µm. The LEDs included an indium tin oxide (ITO) transparent conducting electrode.

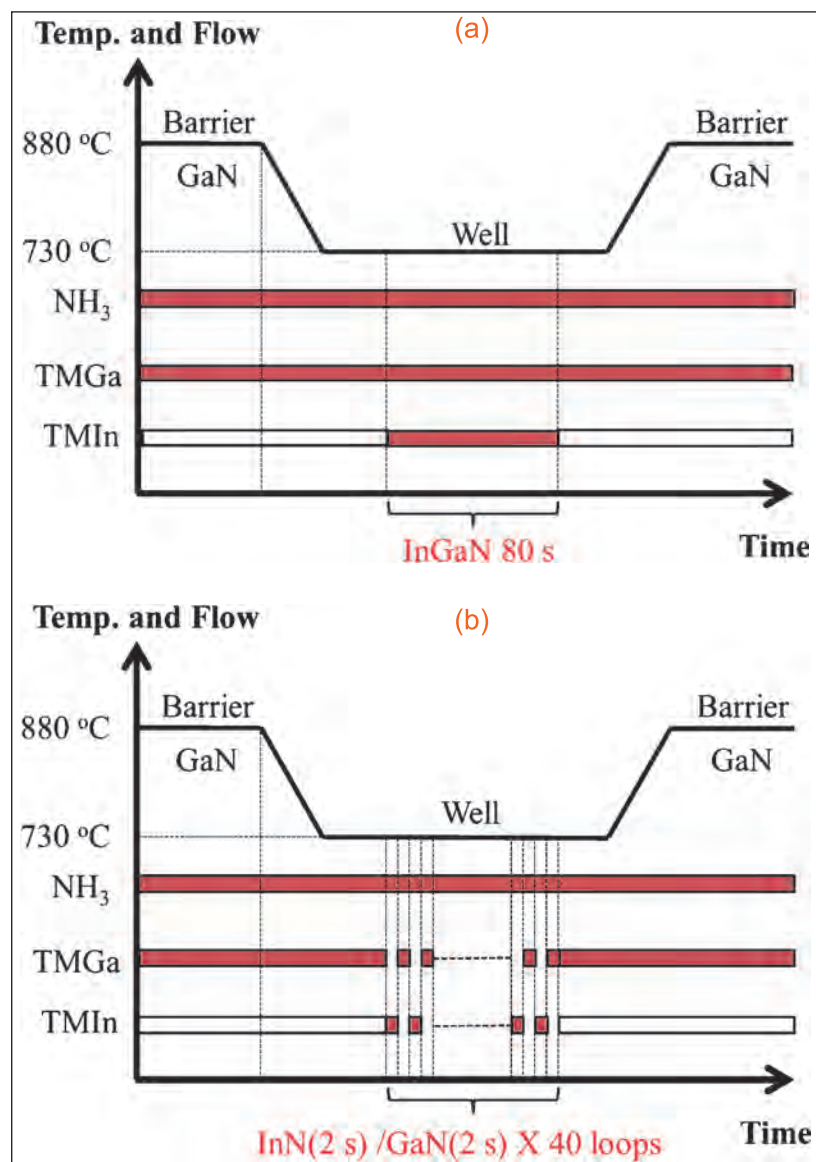


Figure 1. Schematic of source switching sequences of MQW growth of LEDs: (a) I and (b) II.

X-ray and PL analysis of the epitaxial material suggested that the switched InN/GaN well growth (LED II) gives better crystal quality. The PL full-width at half-maximum (FWHM) for LED II was 24.6nm, compared with 29.1nm for LED I. The x-ray θ -2 θ diffraction -1-order satellite peak also showed a narrowing for LED II: 89arcsec compared with 93.5arcsec. Broader satellite peaks are associated with increased interface roughness or fluctuations in alloy composition.

Figure 2. General structure of LEDs.

Under current injection of 120mA, the forward voltage of LED I was 3.35V and slightly less at 3.34V for LED II. The reverse leakage current at -15V was 53.7 μ A for LED I and 5.1 μ A for LED II. The shape of the current-voltage curve, as measured by the 'ideality factor', suggested reduced non-radiative recombination for LED II. Non-radiative recombination reduces the efficiency of light emission.

The researchers believe that the better ideality factor and reduced reverse current leakage could be attributed to improved crystal quality for green InGaN/GaN MQWs from LED II's switched InN/GaN growth process.

The electroluminescence (EL) light output power and external quantum efficiency (EQE) data confirm the expectations from the ideality factor and reverse current leakage (Figure 3). At 120mA, the light output powers are 89.5mW and 110.2mW for LEDs I and II, respectively. The respective EQEs are 30.8% and 37.9%. The peak EQE values are 48.6% for LED II and 34.0% for LED I.

One disappointing feature of LED II was a faster efficiency droop at 350mA of 44.6% from the peak value. The corresponding droop for LED I was 30.7%.

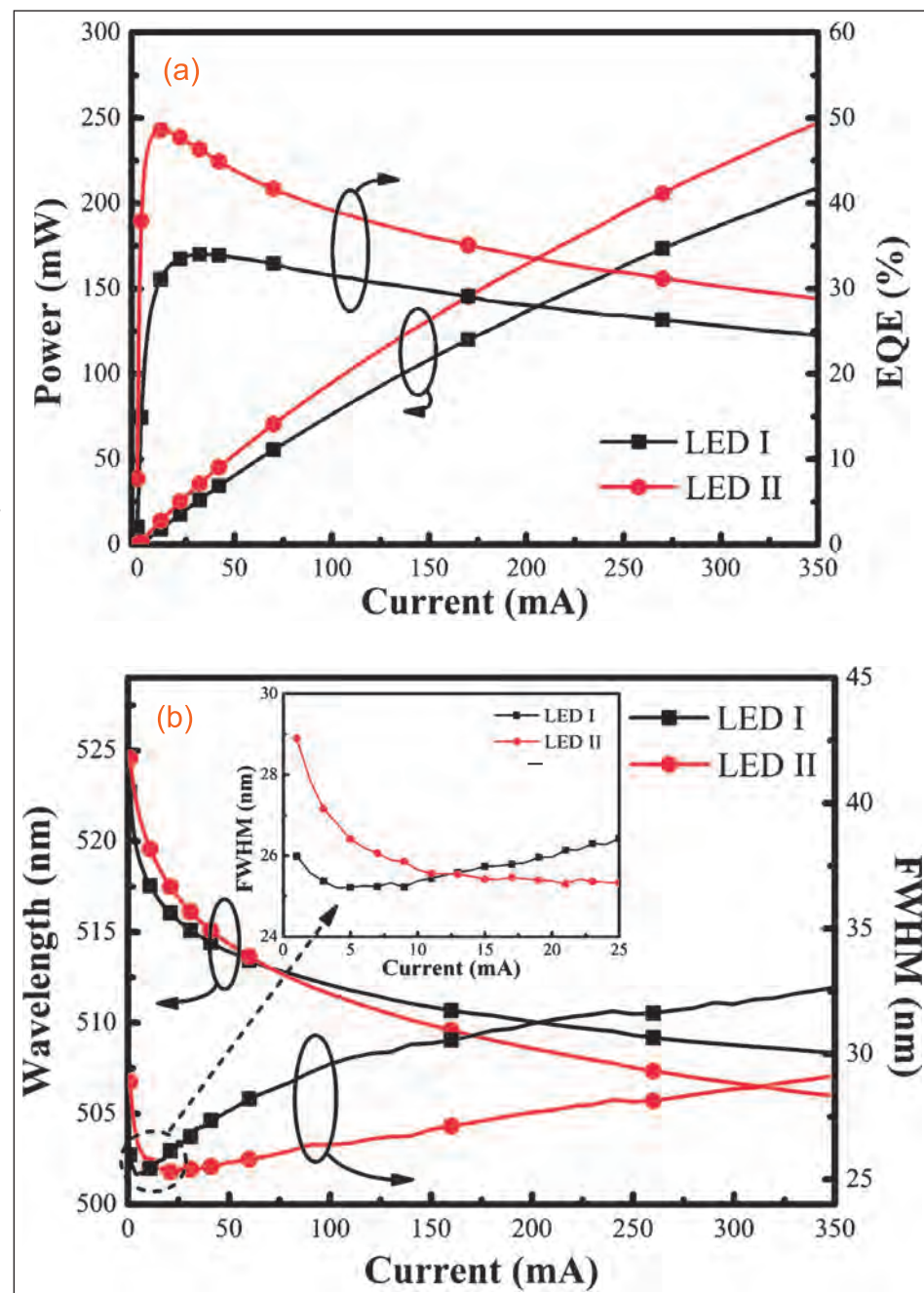
The researchers also studied the blue-shift and FWHM of the EL emission spectrum. This study suggested that the improved crystal quality of LED II may have increased the strain-induced polarization field and thus would lead to a stronger quantum-confined Stark effect (QCSE) where the electrons and holes are pulled apart by large electric fields, reducing light emission. The researchers comment that this would "result in LED II having a larger emission wavelength blue-shift and efficiency drop than LED I". ■

<http://apex.jsap.jp/link?APEX/6/102101>

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Figure 3. (a) Light output power, EQE, and (b) current-dependent emission wavelength and FWHM of LEDs I and II.

Contact	p-GaN	150nm
Electron blocking	p-Al _{0.1} Ga _{0.9} N	20nm
MQW	12x(InGaN/GaN) (730°C/880°C)	3nm/16nm
Strain-release MQW	3x(InGaN/GaN) (800°C)	2nm/14nm
Contact	n-GaN (1050°C)	2 μ m
Buffer	GaN (1050°C)	2 μ m
Nucleation	AlN (900°C)	10nm
Substrate	Patterned sapphire	



Doped barriers reduce polarization and droop effects in blue-green LEDs

Luminous efficiency at 350mA drive current is reduced by just 12.4% rather than the 19.9% of a reference device.

The Chinese Academy of Sciences' Research and Development Center for Semiconductor Lighting has been exploring the effect of p-type doping of the barriers in multiple quantum well blue-green (~500nm) light-emitting diode (LED) structures [Zhang Ning et al, Chin. Phys. Lett., vol30, p087101, 2013].

Producing green light (> 520nm) from indium gallium nitride (InGaN) compound semiconductor material is difficult to achieve efficiently. Filling the green gap between the efficient orange and blue devices of, respectively, phosphide- and nitride-based semiconductors is the goal of much research.

The Chinese research team found that doping the barriers screens the electric field that arises from the polarization fields that occur due to the highly ionic nature of the III-nitride bond. The electric field tends to pull electrons and holes apart, reducing the amount of recombination as photons. As a result of screening these fields, the efficiency droop effect is reduced without impacting the peak performance.

Contact	p-GaN	100nm
Multiple quantum well	5x(InGaN/GaN)	5x(3.5nm/15nm)
Pre-strain	2x(InGaN/GaN)	
Contact	n-GaN (1150°C)	3μm
Buffer	GaN (1150°C)	2μm
Buffer	Low temperature (560°C) GaN	30nm
Substrate	sapphire	

Figure 1. Epitaxial structures of LEDs.

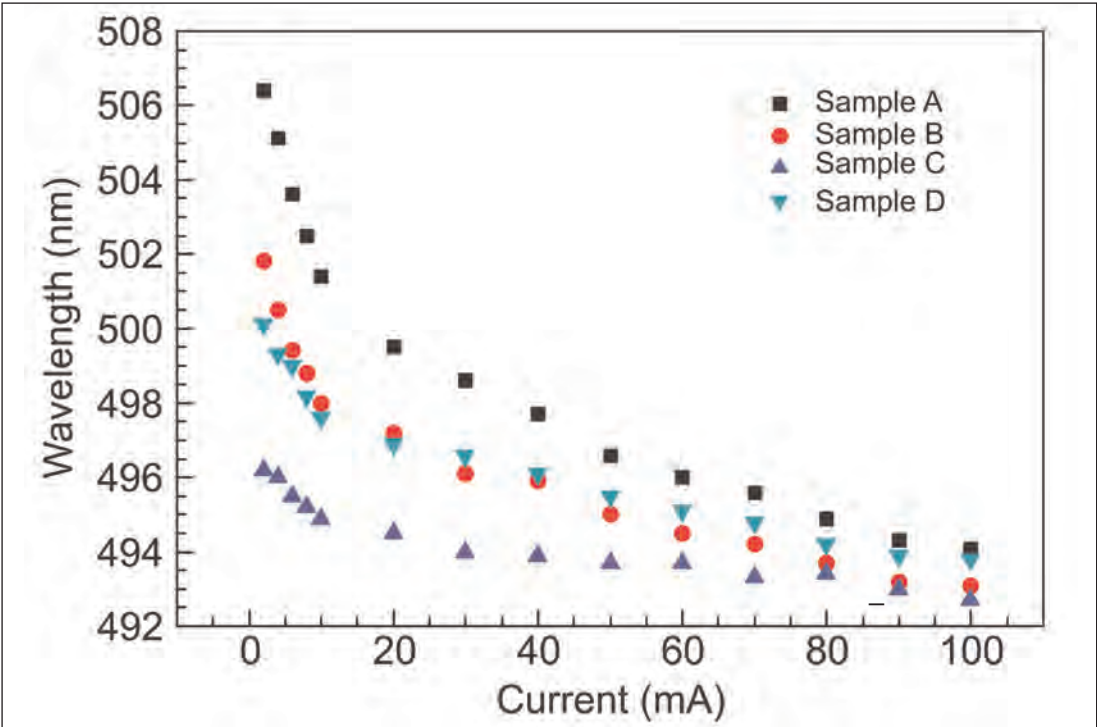


Figure 2. Electroluminescence peak wavelengths with different injection currents for all four samples.

The LED structures (Figure 1) were grown on c-plane sapphire using metal-organic chemical vapor deposition (MOCVD). The silicon n-type and the magnesium (Mg) p-type doping concentrations of the contact layers were both $5 \times 10^{19}/\text{cm}^3$. The Mg-doping concentration of the multiple quantum well (MQW) barriers was varied according to: 0, $2 \times 10^{19}/\text{cm}^3$, $5 \times 10^{19}/\text{cm}^3$, and $8 \times 10^{19}/\text{cm}^3$, labeled respectively as A–D.

The materials were formed into $580\mu\text{m} \times 250\mu\text{m}$ mesa-structure LEDs with indium tin oxide (ITO) transparent conductor on the p-contact, and chromium/gold electrodes on both n- and p-contacts.

Measurements of photocurrent under external reverse bias and illumination by monochromatic light from a $10\text{mW}/\text{cm}^2$ halogen lamp suggested that doping the MQW barriers screened the electric field arising from polarization.

At 20mA, the electroluminescence peak wavelength (Figure 2) got successively shorter ('blue-shift') with increased doping up to sample C (503.2nm for sample A, 494.5nm for sample C). However, the most highly doped sample D had a peak red-shifted by 3.5nm relative to that of sample C. The peaks also blue-shifted with current increasing from 2mA to 100mA: 12.3nm for A, 8.7nm for B, 3.5nm for C, and 6.3nm for D.

The researchers suggest that the screening arises from holes in the barriers migrating to the wells, leaving ionized impurities that partially screen the polarization-dependent electric fields. The blue-shifting effects are explained as being due to the reduced fields leading to an increased effective gap of the wells. The researchers

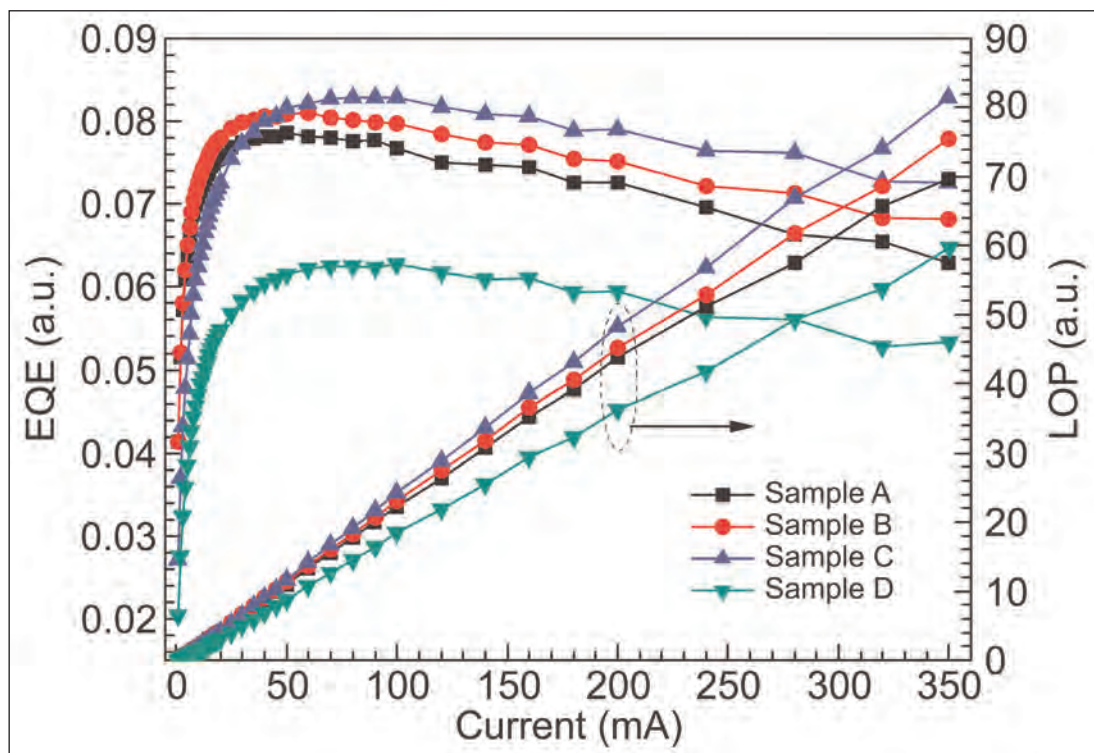


Figure 3. EQE and light output power (LOP) as a function of the current density for all four samples.

believe that the reverse in the blue-shift trend for sample D is due to the formation of Mg-related defects that decrease the ionization ratio.

The reduced polarization of sample C also improves the light output power and external quantum efficiency (EQE) performance up to 350mA over that of the other devices (Figure 3).

Often, reduced efficiency droop is paid for by reduced peak efficiency. However, LEDs of sample C have a peak EQE of 8.3%, while sample A gives 7.85%, B gives 8.05%, and D gives 6.25%.

The droop at 350mA from the peak value was 12.4% for sample C. This compared with 19.9%, 15.7%, and 14.8%, for samples A, B, and D, respectively.

Also, the droop sets in later for sample C, being "insignificant" up to 100mA, compared with sample A where the droop begins at around 50mA. ■

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Indium tin oxide has been used as part of the upper cladding layer to reduce thermal damage in blue/green III-nitride lasers.

Researchers from the universities of California Santa Barbara (UCSB) and of New Mexico (UNM) have demonstrated semi-polar nitride semiconductor blue and green laser diodes (LDs) with part of the upper cladding replaced by indium tin oxide (ITO) [Matthew T. Hardy et al, Appl. Phys. Lett., vol103, p081103, 2013].

Cladding layers use a difference in refractive index to confine light in LD waveguide structures. These layers are also doped to provide injection of electrons and holes into the active light emitting region.

One problem for nitride semiconductor structures aimed at blue and green emission is that the active and waveguide regions contain indium gallium nitride (InGaN) for which the optimum growth temperature is lower than that required for cladding layers of gallium nitride (GaN) or aluminium gallium nitride (AlGaN). The higher temperature needed for the upper cladding layer can damage the underlying InGaN layers.

Replacement of part of the upper cladding with ITO reduces the amount of growth time at elevated temperatures, reducing thermal damage.

The UCSB/UNM team sees its new process as more closely resembling that of light emitting diodes (LEDs) than the usual process for laser diodes that involves AlGaN cladding. One difference is a striking reduction in growth time from ~7 hours for AlGaN-clad

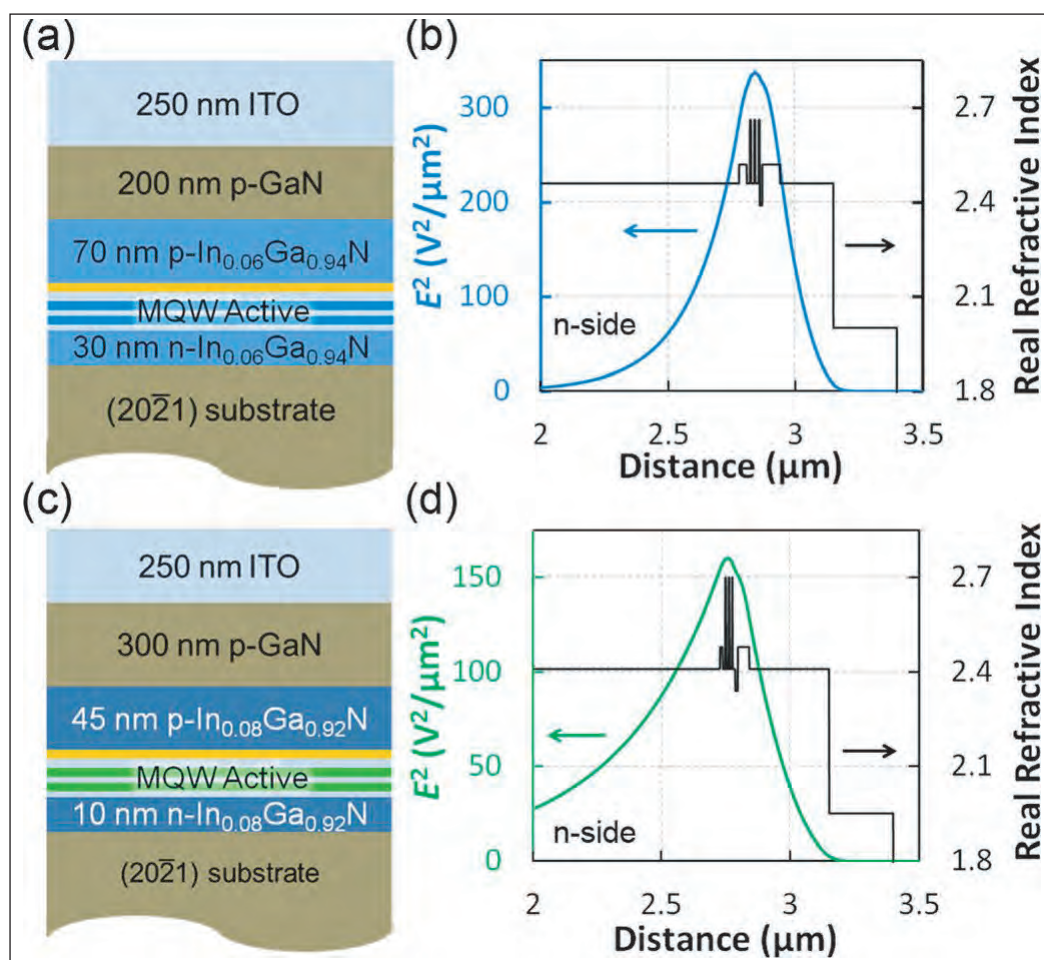


Figure 1. Blue ITO-clad laser diode (a) schematic epitaxial structure and (b) square of the electric field and refractive index as function of distance in the growth direction (transverse mode profile). Green ITO-clad laser diode (c) schematic epitaxial structure and (d) transverse mode profile.

structures to ~3 hours for the nitride epitaxy for the ITO-clad laser diodes.

Mitsubishi provided the freestanding GaN substrates with semipolar crystal orientation (20 $\bar{2}$ 1). Semi-polar light-emitting devices benefit from reduced electric fields that arise from the strongly ionic nature of the chemical bonds in nitride semiconductors. Reduced fields improve the recombination rates of electrons and holes into photons in the active region.

The nitride semiconductor epitaxial structures (Figure 1) were grown using horizontal-flow atmospheric-pressure metal-organic chemical vapor deposition. The thicknesses of the top p-GaN cladding layers were chosen as a compromise between maximizing optical confinement and minimizing the GaN thickness, as determined by simulations.

The growth temperatures of the p-GaN cladding were 950°C for the blue laser and 840°C for the green. The lower temperature for the green laser diode was to avoid thermal damage of the more delicate quantum wells with higher indium content that are used for green emission. Also, triethyl-gallium rather than trimethyl-gallium was used for the green laser diode p-GaN growth to avoid carbon incorporation due to the lower growth temperature. Carbon incorporation can reduce crystal quality and increases resistivity.

The multiple quantum well (MQW) active light-emitting regions were 3-period InGaN/GaN structures. The blue laser diode well/barrier thicknesses were 4.5nm/10nm. The respective thicknesses for the green device were 2.7nm/10nm. Both laser diodes also included an electron blocking layer consisting of 10nm of aluminium gallium nitride ($\text{Al}_{0.2}\text{Ga}_{0.8}\text{N}$) above the MQW. The InGaN waveguide thicknesses were determined from the design/simulation process.

The epitaxial material was formed into ridge waveguide laser diodes with etched facets using a self-aligned via process. The ridges were aligned with the in-plane projection of the c-direction ($[\bar{1}014]$). The reactive ion etch (RIE) was performed using a chlorine-based process that terminated about 100nm above the MQW layer. A 250nm layer of silicon dioxide was deposited and self-aligned vias opened using a lift-off process based on the ridge waveguide photoresist mask.

The 250nm ITO deposition and anneal was performed off-site at MES AFTY Corporation, Tokyo, Japan. MES AFTY used its own electron cyclotron resonance (ECR) plasma deposition system for the ITO growth, along with Chemitronics Co Ltd's Ohmic Alloy system for the anneal.

The off-site ITO process meant that standard lift-off techniques were not possible, so the researchers used a methane/hydrogen/argon RIE process to isolate the devices and to remove ITO from the facets. This etch process was highly selective for ITO with respect to the silicon dioxide and GaN.

The devices were completed with the addition of titanium/gold p-contacts and aluminium/gold n-contacts. No coatings were applied to the facets.

Pulsed operation of a 7.5x1800µm blue laser diode found a threshold

Researchers would like to add an n-cladding layer with greater refractive index contrast to increase optical confinement factor and enhance device performance

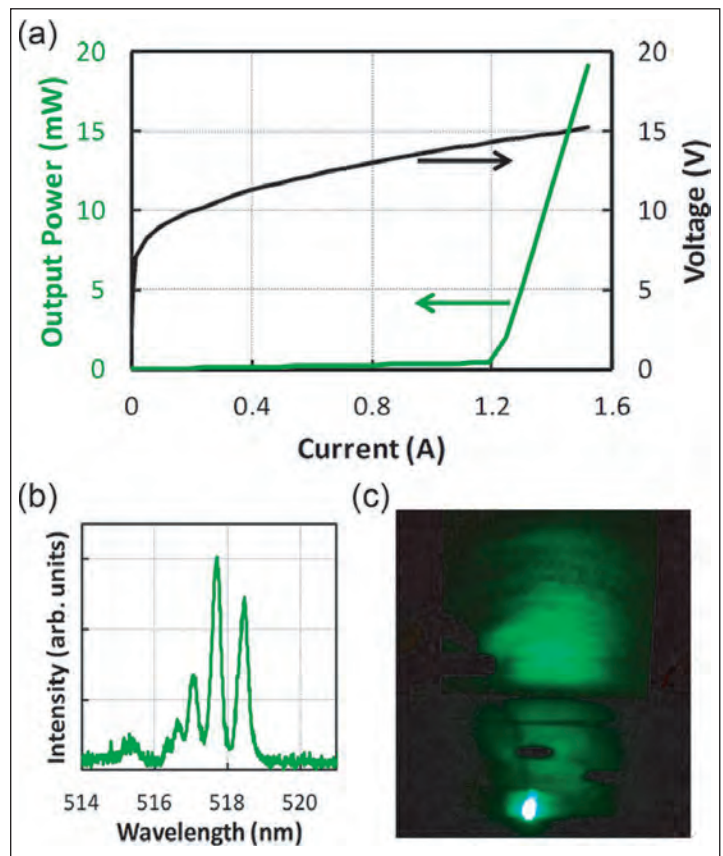


Figure 2. (a) Light–current–voltage characteristics, (b) multi-mode lasing spectra around 518nm, and (c) far-field image for 2x1500µm uncoated ITO-clad green laser diode under pulsed operation.

current of 6.2kA/cm² at 8.9V bias. At 1.2x the threshold current, the spectral peak was centered at 471nm. Similarly, a 2x1500µm green laser diode under pulsed operation had a threshold current of 40kA/cm² at 14V. The emissions were around 518nm at 1.3x threshold (Figure 2). The high operating voltages are blamed tentatively on unoptimized contacts and doping profile.

The researchers comment that the blue laser diode's threshold current is "competitive with other uncoated LDs in this wavelength regime and better than our standard GaN-clad (2021) blue LDs with the same active region and a similar device structure and processing technology."

Another improvement of the ITO-clad LDs is a decrease in differential resistance to 2Ω for the blue device and 3Ω for the green. UCSB's conventional LDs with p-GaN cladding have typical differential resistances in the range 5–8Ω. The researchers attribute the lower differential resistance to reduced p-GaN thickness and the much lower bulk resistivity of ITO.

The researchers would like to add an n-cladding layer with greater refractive index contrast to increase the optical confinement factor and to enhance device performance. ■

<http://link.aip.org/link/doi/10.1063/1.4819171>

Author: Mike Cooke

Copper with titanium nitride offers alternative GaN HEMT gate stack

New structure demonstrates good electrical, thermal and reliability performance against nickel/gold gates.

Taiwan's National Chiao-Tung University has developed a titanium nitride/copper (TiN/Cu) gate structure for aluminium gallium nitride (AlGaIn) high-electron-mobility transistors (HEMTs) that shows improvements over a comparison nickel/gold stack [Yueh-Chin Lin et al, Appl. Phys. Express, vol6, p091003, 2013].

Among the motivations for the switch in gate materials, the researchers cite recent price increases in gold. Attractions for a copper-based gate include good electrical conductivity, high melting point, high thermal stability, good adhesion to dielectrics, and lower cost.

However, copper cannot be simply applied since the metal would diffuse quickly into the AlGaIn barrier, reducing the Schottky barrier and degrading transistor performance. Thus, a thin layer of TiN is needed as a barrier against copper diffusion into the AlGaIn.

The titanium nitride/copper (TiN/Cu) gate electrodes were applied to epitaxial material consisting of GaN buffer and AlGaIn barrier. The HEMT fabrication consisted of mesa isolation, and ohmic contact and gate formation. The ohmic contacts comprised an annealed stack of titanium/aluminium/nickel/gold metals. The annealing was carried out at 800°C for a minute in nitrogen.

The TiN/Cu (50nm/200nm) gate was applied using reactive sputtering. The TiN source was a titanium metal target in nitrogen/argon atmosphere under 200V DC power. The gate length was 2µm. A comparison device with a nickel/gold (50nm/200nm) gate was also produced on the same epitaxial wafer.

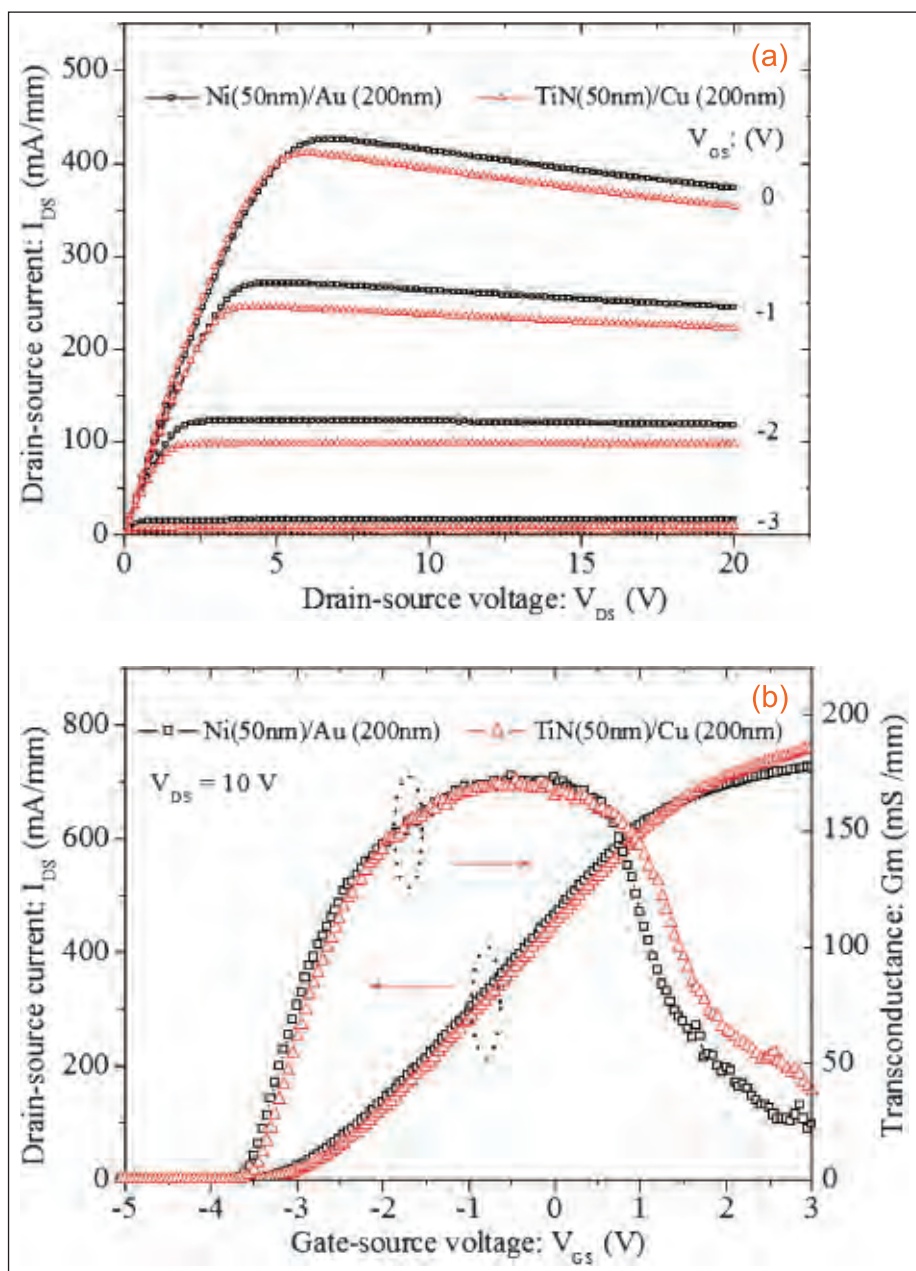


Figure 1. Comparison of DC characteristics for TiN (50nm)/Cu (200nm)- and Ni (50nm)/Au (200nm)-gated AlGaIn/GaN HEMTs: (a) drain current (I_{DS}) versus voltage (V_{DS}) curves, and (b) transconductance (G_m) and drain current (I_{DS}) versus gate potential (V_{GS}) curves.

The DC characteristics of the TiN/Cu gate structure showed higher maximum drain current at 3V gate potential than the Ni/Au electrode (Figure 1). The researchers attribute this to the higher Schottky barrier height of TiN on GaN. Also, the OFF-state breakdown voltage was edged up from 325V for the Ni/Au device to 346V for the TiN/Cu HEMT.

High-voltage stress tests were carried out on both devices for up to 3 hours with 200V drain and -5V gate potentials. The source-drain and gate-drain distances were 20µm and 15µm, respectively. Both device types showed current degradation that could be attributed to electrically induced mechanical stress creating defects in the AlGaIn barrier and/or near the gate edge. Also playing a role is charge injection from the gate electrode.

For 1 hour stress, the drain current was reduced to 70% (down 30%) of the unstressed value in the Ni/Au HEMT, compared with the 93% result for the TiN/Cu gate (down 7%). The researchers comment: "The smaller current degradation for the TiN/Cu-gated HEMT indicates that TiN is more stable than Ni on AlGaIn, and fewer electrical defects were produced for the TiN/Cu-gated HEMTs than for the Ni/Au-gated HEMTs. This may be caused by the fact that it is easier for Ni to react with AlGaIn when the device was under high-voltage stress."

The longer 3 hour stress resulted in degradation of the drain current of 35% and 19% for the Ni/Au and TiN/Cu gates, respectively. Some 10 minutes after the stress, the degradations had recovered, respectively, to 17% and 4%. This indicates that much of the injected charge was released.

The researchers also performed extended 200V high-voltage stress testing up to 32 hours for OFF-state drain and gate currents, along with ON-state drain cur-

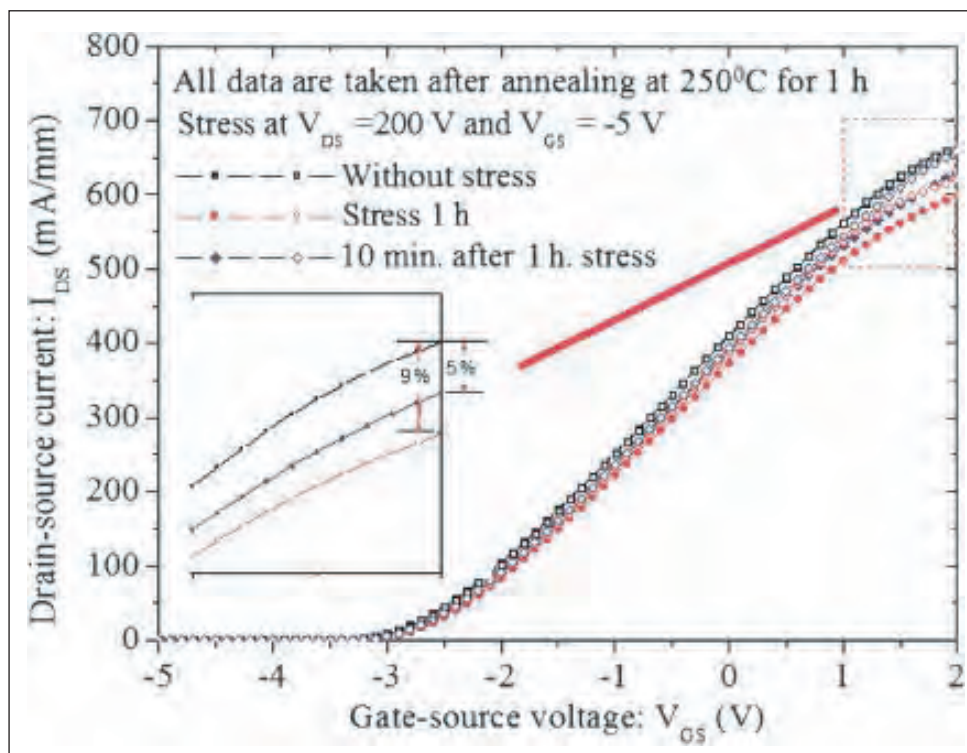


Figure 2. I_{DS} versus V_{GS} curves for TiN (50nm)/Cu (200nm)-gated AlGaIn/GaN HEMTs annealed at 250°C for 1 hour for device without high-voltage stress, with high-voltage stress and 10 min after the high-voltage stress was terminated.

rent. The ON drain current reduced from 400mA/mm to 372mA/mm over the period for the TiN/Cu HEMT. The OFF drain and gate currents remained around 0.4mA/mm and 0.3mA/mm over the period. The Ni/Au HEMT showed rapid degradation in ON drain current, failing after 10 hours.

Thermal stability testing consisted of annealing at 250°C for 1 hour. The TiN/Cu device showed no change in performance. After an hour of high-voltage stress the drain current was down 9% (Figure 2). The performance was restored after 10 minutes, indicating that "the TiN/Cu gate structure has excellent thermal stability". The Ni/Au HEMT subjected to thermal and a few minutes of high-voltage stress failed after a few minutes. ■

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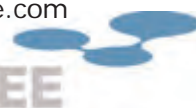
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Bregstrasse 90, D-78120
Furtwangen im Schwarzwald,
Germany
Tel: +49 7723 9197 0
Fax: +49 7723 9197 22
www.wepcontrol.com

12 Inspection equipment

Bruker AXS GmbH

Oestliche Rheinbrueckenstrasse 49,
Karlsruhe, 76187,
Germany
Tel: +49 (0)721 595 2888
Fax: +49 (0)721 595 4587
www.bruker-axs.de

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

Keithley Instruments Inc

28775 Aurora Road,
Cleveland, OH 44139, USA
Tel: +1 440.248.0400
Fax: +1 440.248.6168
www.keithley.com

SUSS MicroTec Test Systems

228 Suss Drive,
Waterbury Center, VT 05677,
USA
Tel: +1 800 685 7877
Fax: +1 802 244 7853
www.suss.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)

Williams Advanced Materials

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

Ismeca Europe Semiconductor SA

Helvetie 283, La Chaux-de-Fonds,
2301, Switzerland
Tel: +41 329257111
Fax: +41 329257115
www.ismeca.com

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

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: +1 858 674 4681
www.quikicpak.com

18 Chip foundry**Compound Semiconductor Technologies Ltd**

Block 7, Kelvin Campus,
West of Scotland, Glasgow,
Scotland G20 0TH,
UK
Tel: +44 141 579 3000
Fax: +44 141 579 3040
www.compoundsemi.co.uk

United Monolithic Semiconductors

Route departementale 128,
BP46, Orsay, 91401,
France
Tel: +33 1 69 33 04 72
Fax: +33 1 69 33 02 92
www.ums-gaas.com

19 Facility equipment**MEI, LLC**

3474 18th Avenue SE,
Albany, OR 97322-7014,
USA
Tel: +1 541 917 3626
Fax: +1 541 917 3623
www.marlerenterprises.net

20 Facility consumables**PLANSEE High Performance Materials**

6600 Reutte, Austria
Tel: +43 5672 600 0
Fax: +43 5672 600 500
E-mail info@plansee.com
www.plansee.com


PLANSEE
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**Ansoft Corp**

4 Station Square, Suite 200,
Pittsburgh, PA 15219, USA
Tel: +1 412 261 3200
Fax: +1 412 471 9427
www.ansoft.com

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**Class One Equipment Inc**

5302 Snapfinger Woods Drive,

Decatur, GA 30035, USA

Tel: +1 770 808 8708

Fax: +1 770 808 8308

www.ClassOneEquipment.com

23 Services**Henry Butcher International**

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High Holborn, London WC1V 6EG,
UK
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Fax: +44 (0)20 7405 9772
www.henrybutcher.com

M+W Zander Holding AG

Lotterbergstrasse 30,
Stuttgart,
Germany
Tel: +49 711 8804 1141
Fax: +49 711 8804 1950
www.mw-zander.com

24 Consulting**Fishbone Consulting SARL**

8 Rue de la Grange aux Moines,
78460 Choisel,
France
Tel: + 33 (0)1 30 47 29 03
E-mail: jean-luc.ledys@neuf.fr

25 Resources**SEMI Global Headquarters**

3081 Zanker Road,
San Jose, CA 95134, USA
Tel: +1 408 943 6900
Fax: +1 408 428 9600
www.semi.org

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45 rue Sainte Geneviève,
69006 Lyon,
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www.yole.fr

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Intersolar India 2013

Bombay Exhibition Centre (BEC), Mumbai, India

E-mail: steffen@intersolar.in

www.intersolar.in

12–14 November 2013

LASER World of Photonics India

Bombay Exhibition Centre (BEC), Mumbai, India

E-mail: bhupinder.singh@mmi-india.in

www.world-of-photonics.net/en/laser-india/start

9–11 December 2013

IEEE International Electron Devices Meeting (IEDM 2013)

Hilton Washington and Towers, Washington DC, USA

E-mail: iedm@his.com

www.ieee.org/conference/iedm

11–12 December 2013

MicroNanoConference '13

De ReeHorst, Ede, The Netherlands

E-mail: info@micronanoconference.org

www.micronanoconference.org

20–22 January 2014

14th Topical Meeting on Silicon Monolithic Integrated Circuits in RF Systems (SiRF 2014)

Newport Beach, CA, USA

www.silicon-rf.org/sirf2014

22–24 January 2014

TMCS IV: Theory Modelling and Computational Methods for Semiconductors

Salford, UK

E-mail: info@tmcsuk.org

www.tmcsuk.org/conferences/TMCSIV

28–30 January 2014

6th International Symposium on Optronics in Defence and Security (OPTRO 2014)

OECD Conference Center, Paris, France

E-mail: optro2014@aaaf.asso.fr

www.optro2014.com

1–6 February 2014

SPIE Photonics West 2014

Moscone Center San Francisco, CA, USA

E-mail: customerservice@spie.org

<http://spie.org/photonics-west.xml>

1–6 February 2014

OPTO 2014 – Optoelectronic Materials, Devices and Applications (part of Photonics West)

Moscone Center, San Francisco, CA, USA

<http://spie.org/opto.xml>

10–11 February 2014

SolarTech Germany 2014

Berlin, Germany

E-mail: pl@greenworldconferences.com

www.greenworldconferences.com

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23-26 February 2014

LED CHINA 2014

China Import and Export Fair Pazhou Complex,
Guangzhou, China

E-mail: led-trust@ubm.com

www.LEDChina-gz.com

23-27 February 2014

SPIE Advanced Lithography 2014

San Jose Convention Center and San Jose Marriott,
CA, USA

E-mail: customerservice@spie.org

http://spie.org/advanced-lithography.xml

25-27 February 2014

15th Strategies in Light Conference

Santa Clara Convention Center, CA, USA

E-mail: registration@pennwell.com

www.strategiesinlight.com

9-13 March 2014

**Optical Fiber Communication Conference
and Exposition/National Fiber Optic
Engineers Conference
(OFC/NFOEC 2014)**

Moscone Convention Center, San Francisco, CA, USA

E-mail: info@ofcconference.org

www.ofcnfoec.org

16-20 March 2014

**29th annual IEEE Applied Power Electronics
Conference and Exposition (APEC 2014)**

Fort Worth Convention Center, TX, USA

E-mail: apec@apec-conf.org

www.apec-conf.org

18-20 March 2014

Laser World of Photonics China

SNIEC – Shanghai New International Expo Centre,
China

E-mail: laser@mmi-shanghai.com

www.photonicschina.net

18-20 March 2014

**Laser Optics – International Trade Fair and
Congress for Optical Technologies and
Microsystems**

Berlin ExpoCenter City, Berlin, Germany

E-mail: kubeerkens@messe-berlin.de

www.laser-optics-Berlin.de

18-20 March 2014

Image Sensors (IS2014)

Park Plaza Victoria, London, UK

E-mail: rstead@smithers.com

http://image-sensors.com

25-27 March 2014

IPC APEX EXPO 2014

Las Vegas, NV, USA

E-mail: registration@ipc.org

www.IPCAPEXEXPO.org

25-27 March 2014

Intersolar China 2013

China National Agricultural Exhibition Center (CNAEC),
Beijing, China

E-mail: pang@intersolarchina.com

www.intersolarchina.com

14-17 April 2014

SPIE Photonics Europe 2014

SQUARE Brussels Meeting Centre, Belgium

E-mail: customerservice@spie.org

http://spie.org/photonics-europe.xml

5-9 May 2014

**SPIE DSS 2014, incorporating:
SPIE Security + Defence 2014
SPIE Sensing Technology + Applications 2014**

Baltimore Convention Center, MD, USA

E-mail: customerservice@spie.org

http://spie.org/defense-security-sensing.xml

11-16 May 2014

225th Electrochemical Society (ECS) Meeting

Orlando, FL, USA

E-mail: meetings@electrochem.org

www.electrochem.org/meetings/biannual/fut_mtgs.htm

17-21 August 2014

SPIE Optics + Photonics 2014

San Diego Convention Center, CA, USA

E-mail: customerservice@spie.org

http://spie.org/optics-photonics.xml

5-10 October 2014

226th Electrochemical Society (ECS) Meeting

Moon Palace Resort, Cancun, Mexico

E-mail: meetings@electrochem.org

www.electrochem.org/meetings/biannual/fut_mtgs.htm

7-9 October 2014

Solar Power International (SPI '14)

Las Vegas Convention Center

E-mail: plangdon@solarenergytradeshows.com

www.solarpowerinternational.com

12-16 October 2014

IEEE Photonics Conference (IPC) 2014

Hyatt Regency La Jolla, San Diego, CA, USA

E-mail: i.donnelly@ieee.org

www.ipc-ieee.org

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