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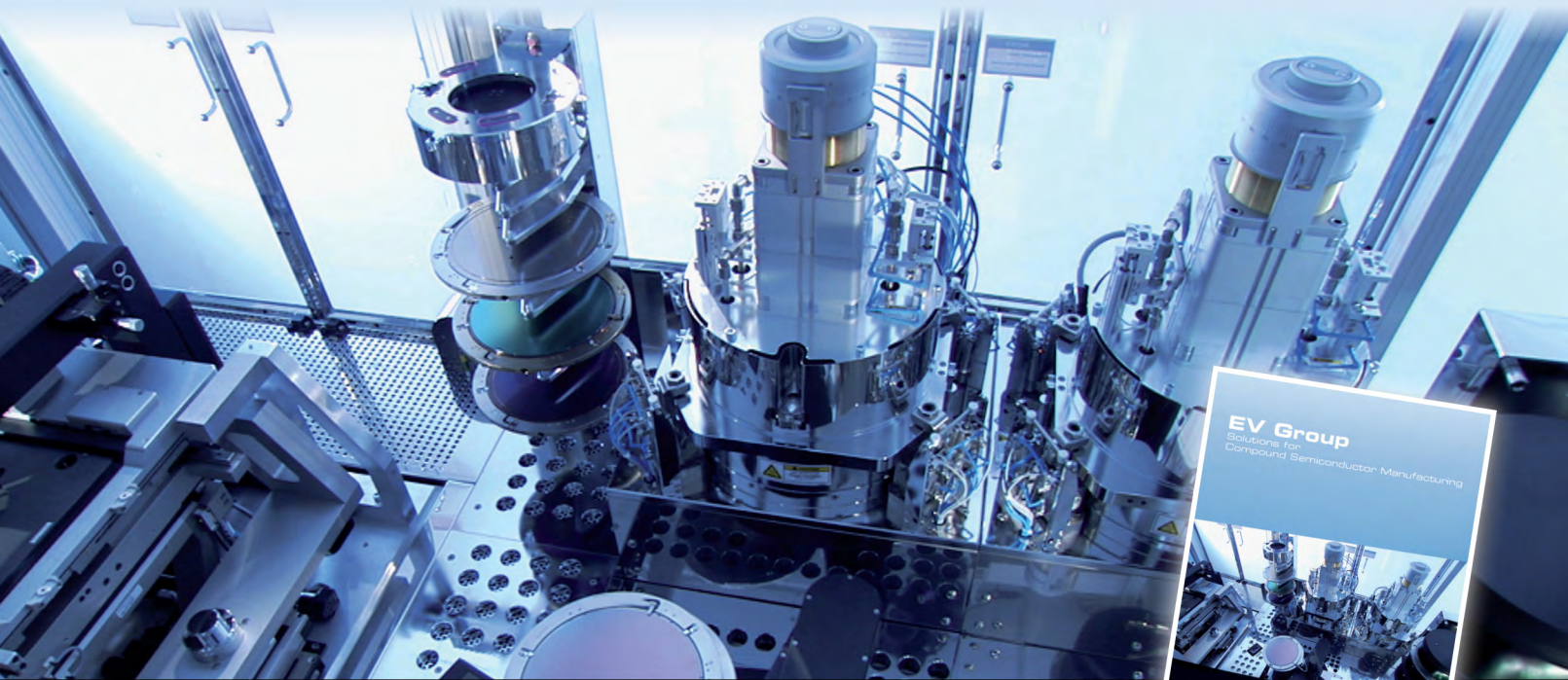

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semiconductorTODAY

COMPOUNDS & ADVANCED SILICON

Vol. 9 • Issue 5 • June/July 2014

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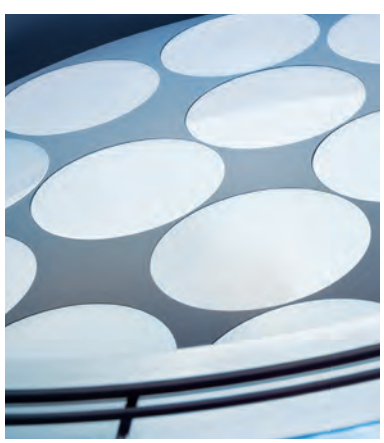
III-Vs on silicon: report from VLSI Symposium

Fraunhofer ISE sets solar module efficiency record of 36.7%

Anadigics cutting 30% of staff • GaN Systems expands
Orbotech to acquire SPTS • Epistar acquiring Formosa Epitaxy

Light Up a Brighter World

MaxBright MHP MOCVD System



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contents

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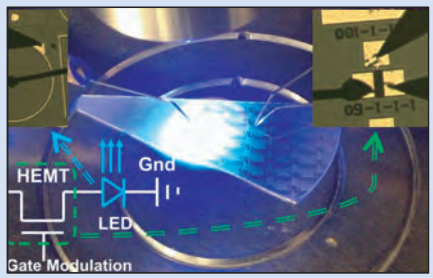
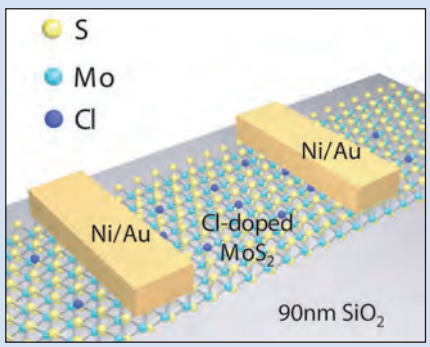
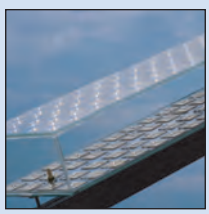
p24 GaN Systems has moved into a new headquarters and R&D facility.



p71 Blue light emission during on-testing of integrated HEMT-LED device fabricated by Hong Kong University of Science and Technology (inset: circuit schematic).



p90 Structure of thin MoS_2, which is promising for future thin, flexible and transparent electronic devices.



Cover: The Fraunhofer Institute for Solar Energy Systems ISE in Freiburg, Germany has achieved record solar module efficiency of 36.7% by adapting the concentrating lens to a new four-junction solar cell structure of CPV solar system maker Soitec. **p60**

editorial

Integration and consolidation

On pages 78–83 of this issue we report on the 2014 Symposium on VLSI Technology and Circuits, focusing on the increasing attention being paid to integrating III-V materials on silicon substrates, specifically III-V MOSFETs for extending the performance of CMOS to future technology generations. In addition, on pages 77, 84–86 and 90 we report further research presented at VLSI, including what is reckoned to be the highest-performing III-V MOSFET (by UCSB).

As well as integration of microelectronic circuits, on pages 70–71 we cover research by Hong Kong University of Science and Technology (HKUST) on the monolithic integration of microelectronics and optoelectronics, specifically nitride-based high-electron-mobility transistors (HEMTs) and light-emitting diodes (on sapphire substrates). Such HEMT–LED integration could "reduce the form factor and manufacturing cost of an LED lighting system and greatly improve the system stability and reliability", it is reckoned.

Integration of a business nature is reported on pages 50–51 concerning the pending acquisition by Epistar Corp (Taiwan's largest manufacturer of LED epiwafers and chips) of fellow Taiwanese LED epiwafer and chip maker Formosa Epitaxy Inc (FOREPI). With a combined capacity of well over 400 metal-organic chemical vapor deposition (MOCVD) reactors, Epistar's share of global GaN LED wafer capacity should be boosted from 11% to 15%, reckons market research firm IHS Technology. Second-placed Sanan Optoelectronics of China (a shareholder in FOREPI) will have less than half the capacity of the combined Epistar–FOREPI.

IHS also reckons that, following the LED industry oversupply of 2011–2013, manufacturing capacity utilizations have been stable and high for some time, and that wafer surplus will fall from 27% in 2013 to 10% in 2014 then below 10% from 2015 to 2018, due to adoption by the lighting market, Just before closing for press (too late to cover fully in this issue), MOCVD system maker Aixtron reported a 5% rebound in revenue from Q1 to Q2/2014 and a fifth consecutive quarter of order growth (up 25% year-on-year); see www.semiconductor-today.com/news_items/2014/JUL/AIXTRON_290714.shtml. Meanwhile, for first-half 2014 rival Veeco has reported MOCVD order growth of almost 80% year-on-year, with further growth expected in second-half 2014.

Also just before closing for press, Analog Devices closed its acquisition of device maker Hittite Microwave. Meanwhile, RF Micro Devices and TriQuint, which have both just scheduled shareholder meetings for 5 September regarding their pending merger, have both reported higher-than-expected sequential revenue growth in Q1/2014 (of 23.6% and 30%, respectively), as has rival Skyworks (22%)— see pages (10–13). In contrast, Anadigics has lowered its Q2 revenue forecast from growth of 8–12% to just level with Q1. while announcing 140 job cuts (30% of staffing). Despite stronger-than-expected infrastructure-related business, falling demand for legacy mobile products has led to reduced in-house GaAs wafer demand (echoing TriQuint's shift in capacity from active GaAs devices to filters, which has lured RFMD).

This trend is highlighted on page 8 by market research firm Strategy Analytics, which notes that bulk GaAs substrate demand will rise at a compound annual average growth rate of under 1% through 2018.

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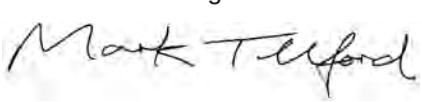

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***Semiconductor Today* covers the R&D and manufacturing of compound semiconductor and advanced silicon materials and devices** (e.g. GaAs, InP and SiGe wafers, chips and modules for microelectronic and optoelectronic devices such as RFICs, lasers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

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- feature articles (technology, markets, regional profiles);
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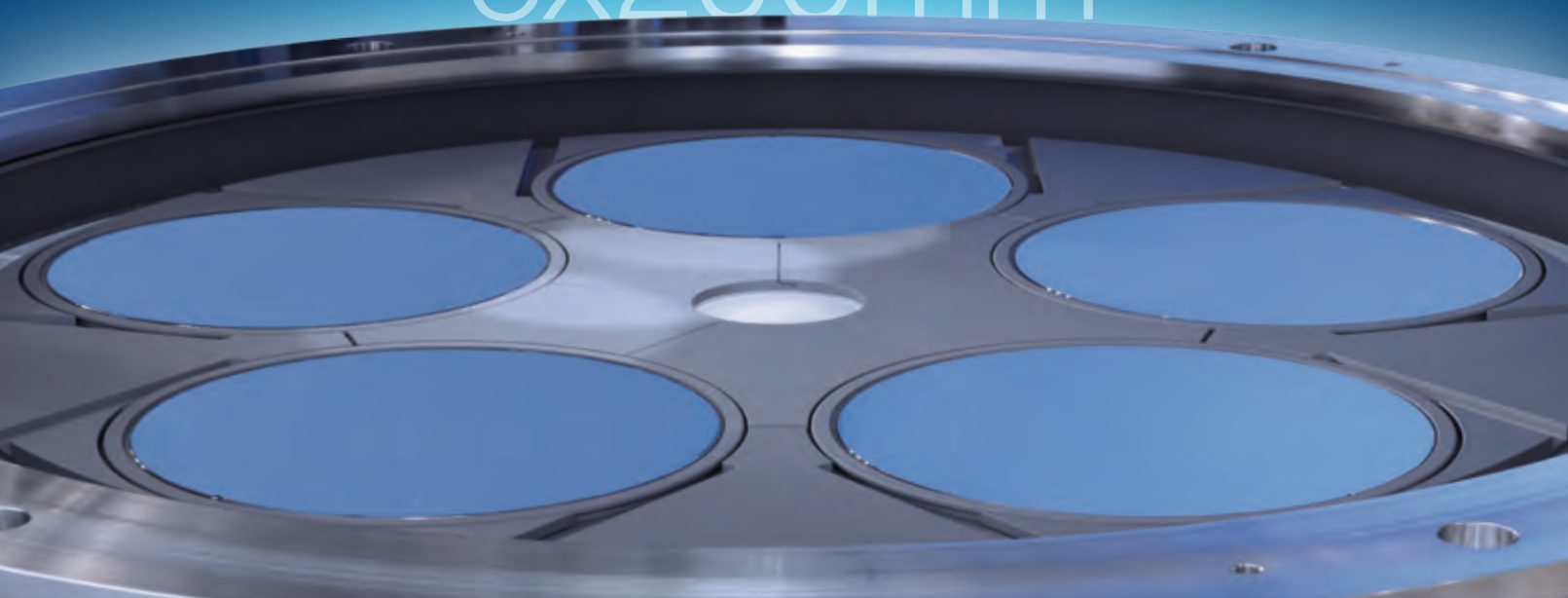

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news

Compound semiconductor market to grow at CAGR of 12.63% to $104.55bn in 2020

Asia-Pacific leading the market

The compound semiconductor market will increase at a compound annual growth rate (CAGR) of 12.63% from 2014 to $104.55bn in 2020, according to the new report 'Compound Semiconductor Market by Type (III-V, II-VI, IV-IV, sapphire), Deposition Technology (CVD, MBE, HVPE, Ammonothermal, MOVPE, LPE, ALD), Product (Power, Opto-electronic), Application, and Geography-2013–2020' from MarketsandMarkets.

In the report, the overall compound semiconductor market is segmented into five major segments: compound semiconductor types, deposition technology, products, application, and geography. Deposition technologies include technologies such as chemical vapor deposition (CVD), molecular beam epitaxy (MBE), hydride vapor phase epitaxy (HVPE), ammonothermal, metal-organic vapor phase epitaxy (MOVPE), liquid phase epitaxy (LPE) and atomic layer deposition (ALD). The device types covered include high-speed and high-power devices, and LEDs, lasers and sensors (IR-visible-UV). Applications sectors discussed in the report include information and communication technology, aerospace and defense, industrial, power, solar and wind, consumer electronics, automotive, and medical. Market growth is being driven by optical devices, photovoltaic cells and modules, and wireless communication products, notes the report.

Of the four major geographic segments (the Americas, Europe, Asia-Pacific, and Rest of the World), APAC is considered to be the market leader in the overall compound semiconductor market.

www.marketsandmarkets.com

LED lighting to comprise nearly 94% of street lighting sales by 2023

but street lighting revenue to fall from $2.5bn in 2014 to $2.3bn in 2023

The market share of LEDs in street lighting worldwide will grow from 53.3% in 2014 to 93.8% in 2023, as falling prices for LED street lights are spurring a global transition from older lamp technologies to newer, more efficient, and more controllable LEDs, according to Navigant Research's report 'Smart Street Lighting: LEDs, Communications Equipment, and Network Management Software for Roadway and Highway Lighting: Global Market Analysis and Forecasts'. The whiter light of LED street lights offers city residents improved night-time visibility, while the greater energy efficiency and longevity offer city managers cost savings from reductions in both energy consumption and maintenance costs.

However, as LED prices continue to erode and the long lifespan of LED lamps results in fewer replacements, overall revenue from street lighting will begin to fall. Navigant forecasts that global street lighting revenue will decline from $2.5bn in 2014 to $2.3bn in 2023.

"The increase in sales of LED street lights has been surprisingly swift, with some companies reporting that more than half their sales are LEDs and others already planning to discontinue their non-LED product lines," says senior research analyst Jesse Foote. "At the same time, a rising number of cities are deploying networked control systems along with their new LED street lights, and the range of features available from those systems is expanding."

Although LED street lights appear to be on track for a nearly complete takeover of the market, the adoption of networked control systems for street lights has followed a somewhat slower path. One critical challenge for the networked control industry is a lack of standardization and the large number of diverse players competing in this space, says the report. Questions remain over the best networking technology for street light control – power line or radio frequency, and mesh or point-to-multipoint.

The report analyzes the global market for roadway and highway lighting. It provides an analysis of the market issues, including drivers and trends, barriers, and ownership models, associated with lamps, luminaires, and lighting controls in these street lighting applications. Global market forecasts for unit sales and revenue, segmented by region, application, and equipment and construction type, extend through 2023. The report also examines the key codes, standards, and technologies related to street lighting, as well as the competitive landscape.

www.navigantresearch.com/research/smart-street-lighting

VCSEL market growing at CAGR of 33.1% from $501m in 2013 to over $2bn in 2018

Optical fiber data transmission to reach $615m and analog broadband signal transmission to reach $293m

The vertical-cavity surface-emitting laser (VCSEL) market is increasing at a compound annual growth rate (CAGR) of 33.1% from $501m in 2013 to nearly $2.1bn in 2018, estimates BCC Research in its report 'Vertical-Cavity Surface-Emitting Lasers (VCSEL): Technologies and Global Markets'.

In the report, the VCSEL market is segmented by material type - gallium nitride (GaN), gallium arsenide (GaAs), indium phosphide (InP) and others (AlGaAs, InGaAsN, etc) – and by color (red, green, blue-violet, infrared and others).

The report also segments the VCSEL market into the following categories by application: optical fiber data transmission; analog broadband signal transmission; absorption spectroscopy (TDLAS), laser printers, computer mice, biological tissue analysis, chip-scale atomic clocks and others.

Optical fiber data transmission is the largest segment, at $158.1m in 2013, and is estimated to be growing at a CAGR of 31.2% to about $615.1m by 2018. The use of VCSELs has increased in the optical communications industry over the past 15 years, notes the report, and they are expected to dominate the optical communications sector in the coming years.

In particular, extensive R&D on VCSELs by companies and defense contractors worldwide has resulted in high power conversion efficiency of 63.4% currently, compared with typical power conversion of 20-25% for other types of commercially available laser, the report notes.

The analog broadband signal transmission segment is reckoned to be growing at a CAGR of 37.3% from $60m in 2013 to about $292.8m in 2018.

Growth in the VCSEL market is further being spurred by demand for consumer electronics products and other high-end applications such as gesture recognition and 3D imaging. Technologies such as industrial sensing will also drive demand for VCSELs in the future, it is expected.

www.bccresearch.com

CPV market growing at a CAGR of 34% to 2018

The global solar concentrated photovoltaic (CPV) market will grow at a compound annual growth rate (CAGR) of 34.1% during 2013–2018, forecasts market research firm TechNavio. A major driver is the reduction in average installation prices of CPV systems, says the report 'Global Solar Concentrated Photovoltaic Market 2014–2018', which segments the market into high-concentrated, medium-concentrated and low-concentrated photovoltaic, depending on the degree of concentration of CPV systems.

A CPV system uses an optical device to concentrate sunlight by a factor of 500-1000 in focusing it onto the solar cells, increasing their solar energy conversion efficiency while also reducing the size of the cells to a small fraction of the CPV module area (aiding the cost-efficient use of multi-junction solar cells). CPV requires a high level of radiation concentration to increase its output, while solar trackers help to follow the sun's rays during the day in order to maximize the capture of sunlight.

The main focus of solar CPV companies worldwide is to increase CPV system efficiency, which will help to reduce the overall system costs, notes Sandle Research. The efficiency of CPV modules is about 30%, which is already higher than solar PV and CSP (concentrating solar power) technologies. However, there is still huge scope for improvement to further reduce the overall cost, the report adds.

With increased efficiency and declining overall costs, CPV technology will soon achieve grid parity in many countries across the world, reckons the report. With CPV manufacturing companies achieving economies of scale and obtaining government support, the average prices of these systems are declining. This has resulted in CPV systems becoming affordable, leading to an increase in the number of installations across the world.

However, the pick-up of CPV technology is still slow compared with its sister PV and thin-film solar segments.

CPV is gaining competitiveness in areas with high direct normal irradiation (DNI). In particular, installations have increased in recent years in Spain, the USA, Australia, China and India, which receive high solar radiation. CPV is a relatively immature technology compared to other PV technologies, and an increase in concentration and efficiency will lead to a reduction in its levelized cost of electricity (LCOE), says the report. CPV is expected to achieve lower LCOE than PV technologies during the forecast period. Moreover, lower land requirements for CPV provide an advantage over PV, the report adds.

www.technavio.com

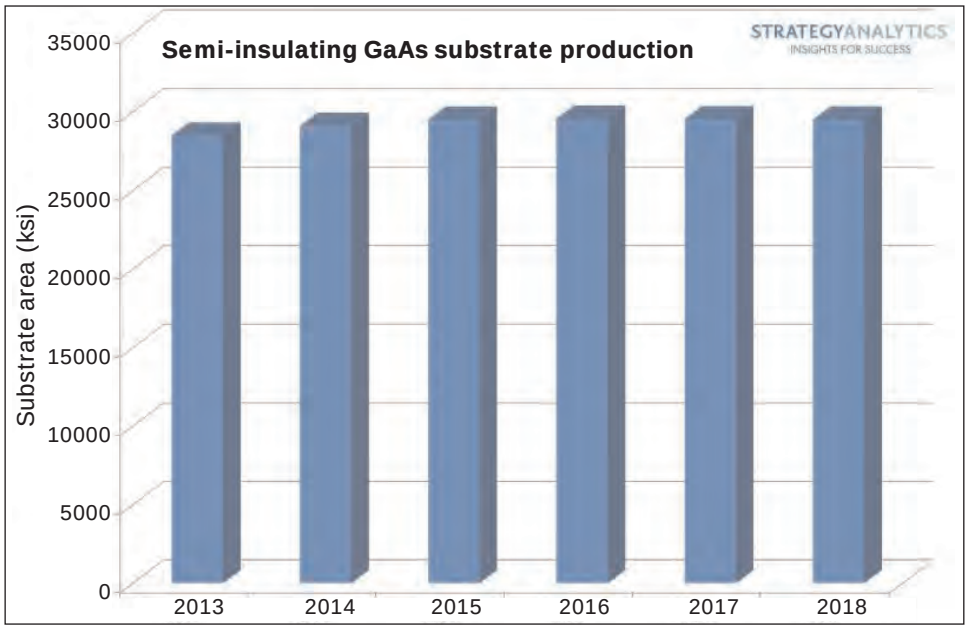
GaAs bulk substrate market revenue shrank 8% in 2013

Return to historic price erosion to drive market down to $160m in 2018

Despite strong growth in the gallium arsenide device market, GaAs bulk substrate manufacturers saw both production and revenues decline for the second consecutive year, according to the Strategy Analytics Advanced Semiconductor Applications (ASA) report 'Semi-Insulating GaAs Bulk Substrate Markets: 2013–2018', which forecasts that new mobile architectures, competing technologies and flattening GaAs device growth rates will result in further declines in the total available market (TAM).

The report concludes that demand for semi-insulating GaAs bulk substrates fell by nearly 2% in 2013. This volume decline plus increasing price erosion caused revenues to decline by 8%.

Bulk substrate demand will hence rise at a compound annual average growth rate (CAAGR) of under 1% through 2018. With price erosion returning to historical levels, the slow growth of substrate production will drop revenue to $160m in 2018.



"There will be challenging times ahead for GaAs substrate manufacturers," notes Eric Higham, service director, Advanced Semiconductor Applications. "The emergence of CMOS PAs and multi-mode, multi-band GaAs PAs will both act to slow growth and reduce revenue," he adds.

"The good news is that prior disruptions in the GaAs bulk substrate supply chain appear to have been addressed, but this means a return to historical price erosion rates that will pull revenues down," forecasts Asif Anwar, director in the Strategic Technologies Practice.

www.strategyanalytics.com

SiC market to grow at 42% to $3182.9m by 2020

The silicon carbide semiconductor market will increase at a compound annual growth rate (CAGR) of 42% from 2014 to $3182.89m in 2020, according to a new report from MarketsandMarkets ('Silicon carbide (SiC) in semiconductor market by technology, product, and application (Automotive, Defense, Computers, Consumer Electronics, ICT, Industrial, Medical, Railways, and Solar), by geography — forecast and analysis to 2013 — 2020').

Semiconductor devices based on SiC such as high-power and high-temperature devices are useful in harsh conditions, notes the report. Silicon-based semiconductor devices are slowly exiting the market and being replaced aggressively with more powerful SiC, it adds.

The growth in SiC-based devices is due mainly to the fact that it has found its application in the high-voltage power electronics market (generally above 1kV). Sectors such as industrial and power hence account for a major share of SiC-based device revenue. The automotive and transportation sectors (including electric vehicle, railways, and airways) are also expected to be huge potential application for silicon carbide.

The overall silicon carbide based semiconductor market is segmented into four major segments — technology, products, applications, and geography. All the segments are separately classified in the report. The silicon carbide based semiconductor market is expected to grow by 2020, at an estimated CAGR of 42.03% from 2014 to 2020.

The market in APAC (China and India etc, excluding Japan) is the largest geographic sector by revenue, followed by North America and Europe, respectively. Japan (considered to be the birthplace of SiC) accounted for 13.83% of the total SiC-based semiconductor market in terms of value in 2013.

Players cited in the report as being involved in the development of the SiC-based semiconductor market include Cree Inc, Fairchild Semiconductor International Inc, Genesic Semiconductor Inc, Microsemi Corp and Norstel AB in the USA, Infineon Technologies AG in Germany, Renesas Electronics Corp, ROHM Co Ltd and Toshiba Corp in Japan, and STMicroelectronics N.V. in Switzerland.

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TriQuint's revenue rebounds from customer inventory adjustment by more-than-expected 30% in Q2/2014

Demand driven by 4G build-out in China

For second-quarter 2014, RF front-end component maker TriQuint Semiconductor Inc of Hillsboro, OR, USA has reported revenue of $230.8m, up 30% on $177.6m last quarter and 21% on $190.1m a year ago, and above the guidance of $215–225m.

End-market revenue split was:

- 63% from Mobile Devices,
- 26% from Network Infrastructure,
- 11% Defense & Aerospace.

Of total revenue, Americas comprised 18%, Europe 4%, and Asia 78% (including China about 50%). Subcontract assembly firm Foxconn Technology Group accounted for 25% of total revenue and Huawei Technologies 11% (due partly to optical product revenue rising by 50%).

Sequential growth was strong for each of TriQuint's markets, with Defense & Aerospace up 15.9% to $26.4m, Network Infrastructure up 16.2% to $60m, and Mobile Devices up 40% to $144.4m. The latter was driven by a return to normal demand from the firm's major customer (following a Q1 inventory adjustment) plus strong demand for bulk acoustic wave (BAW) filters to support LTE smartphones (primarily in China). In particular, in the base-station market, revenue was up 77% from Q2/2013 to Q2/2014 (to $25.2m) and up 55% on a year-to-date basis.

"We continue to experience strong demand supporting the worldwide 4G LTE buildup, increased on last year primarily from China," says president & CEO Ralph Quinsey. "Growth in LTE is favorably impacting both our Mobile and Network Infrastructure markets, with strong pull in China to support ramping smartphones demand and to build out base-stations in optical communications networks," he adds.

On a non-GAAP basis, gross margin has risen further, from 31.3% a year ago and 35.3% last quarter to 41.7% (well above the guidance of 37–38%), aided by efficient factory execution, cost reductions and better product portfolio management (migrating away from commodity products and non-strategic foundry towards higher-value products). "Active management of our portfolio, highlighted by strong growth in our premium filter business and reductions in lower-margin discrete amplifiers, contributed to the 1000 basis point improvement in gross margin over Q2/2013," notes chief financial officer Steve Buhaly. Utilization rates in total are still in the mid-60s range (higher for filter factories than for the firm's GaAs fabs).

Operating expenses were $72m, up slightly on last quarter (and above the expected $68–70m). Engineering materials expense was relatively high, as TriQuint finished development of key products.

Net income was $23.6m ($0.13 per diluted share, well above the forecast $0.06–0.08), compared with net losses of $9.4m ($0.06 per share) last quarter and $10.9m ($0.07 per share) a year ago.

Capital expenditures of $21.3m (mainly for premium filter capacity) were slightly below depreciation. During the quarter, cash and investments rose by $60m to $223.5m, driven by operating results and cash proceeds from employee stock option exercises.

During the quarter, TriQuint sold premium filters to over 50 unique customers. Discrete filter revenue is on track to more than double in 2014. Also, the firm's new 5GHz WLAN front-end modules won a chip-set reference design. TriQuint also completed gallium nitride (GaN) performance, cost and capacity goals as part of the US Defense Production Act Title III program.

During Q2, for infrastructure and defense products (IDP) TriQuint launched 51 new products (exceeding the firm's quarterly record of 41 products), including 33 for defense applications, nearly all based on GaN. In May, TriQuint was recognized by the US Department of Defense for achieving significant milestones for GaN manufacturing readiness and maturity. "New product launches are the lifeblood of future revenue growth and profitability in these markets," says Quinsey. "For the full year we remain on track for another record year of new product introductions," he adds.

"Demand from phone manufacturers in China was up sharply in Q2, and I anticipate the strength will continue into the second half of the year," says Quinsey. "The LTE opportunity in China is just beginning, and it represents one of our larger growth opportunities for the next several years."

For second-half 2014, TriQuint expects revenue of $550–600m, up 11% year-on-year. However, the discontinued low-margin mobile amplifier products and non-strategic foundry business account for 7–8% of lost year-on-year revenue growth, which would otherwise be 18% in second-half 2014. Full-year revenue is expected to fall by about $100m from 2013 to 2014 (relinquishing about 10% of annual revenue growth to exit the low-margin active device category).

While the split of revenue between third- and fourth-quarter 2014 depends on major program timing, for Q3 the firm expects revenue of $255–265m (up 4% year-on-year). Gross margin should be 43–45%, driven by strong execution, higher factory utilization and product mix. Operating expenses are expected to be relatively steady, at about $70m. Net income per diluted share should be $0.23–0.25.

"We continue to see robust demand in our infrastructure and mobile markets as worldwide demand for 4G LTE services ramp up with very strong demand for LTE base-station products and premium filters for

smartphones," says Quinsey. "We expect to exceed our goal of 500 basis points of gross margin improvement year over year and are now targeting 2014 full-year non-GAAP gross margins to be more than 40%. Additionally, we expect full-year non-GAAP EPS to be up more than 6 times our 2013 results."

"Capital expenditures are expected to increase to at least $50m as we respond to an exciting set of market opportunities and begin executing a doubling of our premium filter BAW and TC-SAW capacity," says Buhaly. "Strength in premium filters continues to be a tailwind for TriQuint, with increasing demands for differentiated products," adds Quinsey. "In response to growing market demand, we plan to further expand our capacity with both BAW and TC-SAW [with a doubling of BAW capacity comprising about two thirds of the CapEx]. This new capacity is expected to come online beginning late this year and throughout 2015, effectively doubling our capability."

TriQuint's expected merger with RFMD is on track for second-half 2014. It is planning for shareholder votes this summer, and China anti-trust approval in second-half 2014.

www.triquint.com

RFMD grows 23% quarter-to-quarter to record $316.3m

3G/4G rises from 85% to 90% of CPG revenue as 2G falls below 10%

For its fiscal first-quarter 2015 (to 28 June 2014), RF Micro Devices Inc of Greensboro, NC, USA has reported record revenue of $316.3m, up 23.6% on $256m last quarter and up 8% on $293m a year ago (and well above the $305m forecast at the end of April).

"Revenue strength was broad-based and well diversified," comments chief financial officer Dean Priddy. RFMD had two greater-than-10% customers.

Revenue for RFMD's Multi-Market Products Group (MPG) was $55m (17.5% of total revenue), up 5% sequentially across multiple markets, supported primarily by 4G wireless infrastructure and high-performance Wi-Fi in smartphones and enterprise applications.

Revenue for the Cellular Products Group (CPG) was $261m (82.5% of total revenue). During the quarter, CPG secured new customer engagements for RF Fusion (a complete RF front end solution for 4G world phones and tablets, for production later this year). CPG also supported the ramp of multiple 3G/4G smartphones, driving 3G/4G to more than 90% of CPG revenue (up from 85% last quarter and 80% the prior quarter) and 2G to below 10% (falling from 15% last quarter and 20% the prior quarter). In addition, CPG enabled the proliferation of envelope tracking (ET) power amplifiers across multiple smartphone platforms, leading to ET power management integrated circuit (PMIC) revenue being anticipated across multiple basebands later this year.

"RFMD is benefiting from multiple long-term secular trends that are in the early stages of adoption," comments president & CEO Bob Bruggeworth. "They are supporting a wave of connectivity and interconnectivity that is playing out globally across a broad range of wireless air standards," he adds.

On a non-GAAP basis, gross margin has soared further, from 35.1% a year ago and 42% last quarter to a record 47.1%. Operating expenses have fallen from $74m last quarter to $70m (22% of revenue), due to R&D expenses cut from $47.6m to $42.6m while general & administrative (G&A) expenses were $11m and sales & marketing was $16.5m.

Net income has risen from $25.6m ($0.09 per diluted share) a year ago and $33.4m ($0.12 per share) last quarter to $71.3m (a record $0.24 per share, doubling sequentially, and well above the $0.17 forecast at the end of April).

Operating cash flow was $36.3m (up from $31.7m last quarter). Capital expenditure was $9.8m (up from $7.3m). Hence, free cash flow was $26.5m (up from $24.4m). However, cash, cash equivalents and short-term investments fell from $244m to $197m, since RFMD repaid $87.5m of convertible debt during the quarter and is now debt-free.

"RFMD is enjoying positive market dynamics creating sustainable, long-term opportunities for growth and diversification, and we are positioned better than ever to translate our diversified revenue growth into superior financial performance," reckons Bob Bruggeworth.

"In the September quarter, RFMD anticipates broad-based revenue growth supported by new smartphone ramps, content increases in LTE, deepening penetration of 802.11 ac, and continued broad market strength," says Bruggeworth. Considering the demand environment in its end-markets, for its fiscal second-quarter 2015 (to end-September 2014) RFMD expects revenue to grow 9% on last quarter to $345m. "We expect our diversified revenue growth to outpace the growth rate of our underlying markets and drive continued robust growth in RFMD's gross profit, operating profit, and earnings per share," adds Bruggeworth. Gross margin should be roughly flat to up 25 basis points sequentially. Operating expenses are expected to be relatively unchanged. Diluted earnings per share should be about $0.27.

"We are committed to delivering gross margin that is consistently industry-leading with operating expenses at 20% of revenue," says Priddy. "We continue to unlock new opportunities to expand margin, and we anticipate continued robust improvements in operating income, earnings per share, and free cash flow."

www.rfmd.com

Anadigics lowers revenue guidance and cuts costs, including 30% of staff

Resources realigned to infrastructure market while reducing in-house costs from legacy mobile

Broadband wireless and wireline communications component maker Anadigics Inc of Warren, NJ, USA says that it is restructuring its business model to lower its operating costs and better align resources to address growth opportunities in rapidly expanding infrastructure markets.

"With a strong infrastructure design-win trajectory, I'm pleased we're able to accelerate our strategy to expand in infrastructure markets, and with that, lower our fixed manufacturing and operating costs," says chairman & CEO Ron Michels. "These steps, coupled with our previously announced $10m cost-savings initiatives, should enable the company to deliver significant EBITDA improvements and profitability leverage from a lower breakeven revenue level," he believes.

Strategic restructuring

Since the Q1/2014 earnings call (in early May), Anadigics has made stronger-than-expected progress in infrastructure-targeted activities and experienced a decline in demand for some of its legacy mobile products. In response, it is restructuring to expand its presence in the infrastructure space and reduce fixed costs associated with the legacy mobile business.

Anadigics' infrastructure-targeted products have higher revenue- and profit-per-wafer than mobile-targeted products. The firm believes that, with an increasing percentage of future revenue coming from infrastructure products, its manufacturing capability and staff can be resized to better match the new wafer quantity required.

The reduced in-house wafer demand is expected to enable more efficient manufacturing operations and allow the firm to monetize certain excess wafer processing equipment. Proceeds from the sales are expected to help offset a significant portion of the cash costs of the restructuring.

Infrastructure

Anadigics designs and manufactures radio-frequency and optical products for infrastructure applications including cable television, cellular wireless small-cell, WiFi and machine-to-machine (M2M) markets, which are currently expanding to support growing global demand for high-data-rate connectivity to the Internet. Anadigics believes that these infrastructure build-outs demand high-performance products, creating a high-value and target-rich environment for its core technologies and competencies.

Mobile

Anadigics also designs and manufactures RF power amplifier and front-end products for mobile applications including handsets, tablets and data cards in the cellular 3G/4G and WiFi markets. The firm says that the latest products in its mobile-targeted portfolio are gaining design-win traction. Anadigics will continue to focus on and support strategic mobile markets, and may expand its existing partnerships with external wafer foundries to benefit from the lower fixed-cost business model that those relationships can deliver.

Anadigics has made stronger-than-expected progress in infrastructure-targeted activities and experienced a decline in demand for some of its legacy mobile products

Anadigics notes that, going forward, it is committed to maintaining its level of technical and commercial support to mobile-product customers for all existing and new opportunities.

Cost improvements

Anadigics says that — in addition to its previously announced program targeting $10m in annual savings — its latest restructuring initiative enables it to implement cost efficiency improvements that should lower cash costs by over $15m annually ($5m in manufacturing and $10m in operating costs).

About 140 posts (30% of staffing) will be cut. The firm expects a cash workforce restructuring charge of $2.3m and a non-cash charge of $5m for fixed asset and inventory write-downs. Proceeds from equipment sales should largely offset the cash costs of the restructuring.

"We are aligning the company's R&D investment focus and in-house manufacturing capacity toward a higher mix of infrastructure products," says chief financial officer Terry Gallagher. "The efficiencies gained through this action are expected to strengthen our presence in key infrastructure markets, reduce fixed costs and enable an expected EBITDA (earnings before interest, taxes, depreciation, and amortization) breakeven revenue level of approximately $26–27m."

Q2 guidance update

For second-quarter 2014, Anadigics expects revenue of about $23m, roughly level with Q1/2014's $23.3m (rather than the guidance given in early May of growth of 8–12%). However, infrastructure will contribute a larger percentage of revenue than in Q1. Anadigics hence expects a sequential improvement in non-GAAP gross margin (from 10.9%). Also, due to the previously announced expense reduction program, operating costs should be lower than Q1's $12.1m. Anadigics therefore expects to report a non-GAAP loss per share of about $0.10 (cut slightly from Q1's $0.11).

www.anadigics.com

Skyworks exceeds raised quarterly earnings and revenue guidance, up 35% year-on-year to $587m

Wireless proliferation & Internet of Things connectivity driving growth

For fiscal third-quarter 2014 (ended 27 June), Skyworks Solutions Inc of Woburn, MA, USA (which makes analog & mixed-signal semiconductors) has reported revenue of $587m, up 22% on $481m last quarter and 34.6% on $436.1m a year ago, and better than the guidance, which was raised on 3 June from $535m (up 11% sequentially and 23% year-on-year) to $570m (up 19% sequentially and 31% year-on-year).

Of total revenue, power amplifiers represented 41%, integrated mobile systems 33%, and broad markets 26% — roughly in line with fiscal first-half 2014.

On a non-GAAP basis, gross margin rose further, from 44% a year ago and 44.7% last quarter to 45.4%, driven by the better-than-expected revenue plus strength in the integrated systems solutions portfolio.

Operating expenses have risen further, from $84.8m last quarter to $87.5m, due mainly to selling, general & administrative (SG&A) expenses rising from $31.7m to $33.7, with R&D expenses rising slightly from $53.1m to $53.8m.

Operating income has risen further, from $111.9m a year ago and $130.4m last quarter to $179.1m, as Skyworks leveraged operating expenses, reaped the benefits of recent capital investments, and continued to expand margin-enhancing custom integrated solutions and precision analog products. Operating margin has continued to rise, from 25.7% a year ago and 27.1% last quarter to 30.5%.

Net income has leapt from $103.8m ($0.54 per diluted share) a year ago and $118.6m ($0.62 per diluted share) last quarter to $160.8m ($0.83 per diluted share), up on guidance of $0.80 (which had been raised from $0.73 on 3 June) and the fifth consecutive quarter of above-20% year-on-year earnings growth.

Cash flow from operations was $199m. Capital expenditure has risen again, from $41.8m last quarter to $68m, in support of upcoming demand forecast (deployed mostly to expand assembly & test capabilities). Depreciation was $24m. During the quarter, cash and cash equivalents rose from $798m to $893.3m. Skyworks repurchased 1 million shares of common stock (representing a $41m investment). The board of directors also declared a cash dividend of $0.11 per share, payable on 21 August to stockholders of record at the close of business on 7 August.

"Skyworks is entering a new and exciting growth phase driven by global wireless proliferation and the Internet of Things," says chairman & CEO David J. Aldrich. "We are capitalizing on the macro trend to connect virtually everyone and everything, all the time," he adds. "Our high-performance analog solutions and system-level integration capabilities — coupled with our operational agility and scalability — are enabling us to connect the previously unconnected. Accordingly, Skyworks is setting the pace for analog semiconductor industry growth in terms of both revenue and value creation."

"Skyworks is executing to our strategy to grow substantially faster than the broader analog semiconductor industry while delivering best-in-class financial returns," says executive VP & chief financial officer Donald W. Palette. "Given our broad customer demand and expanding product pipeline, we are forecasting sustainable, above-market growth for the foreseeable future."

We are forecasting sustainable, above-market growth for the foreseeable future

For fiscal fourth-quarter 2014 (to end September), Skyworks expects revenue to grow 16% quarter-on-quarter and 43% year-on-year to $680m, reflecting broad-based strength driven by new product ramps, content gains, growth across emerging markets, ongoing 802.11ac deployments, and the expanding set of opportunities within the Internet of Things. Gross margin should grow to 45.5–46%, despite operating expenses rising to about $92m. Diluted earnings per share should is expected to leap to $1.00, up 56% year-on-year. The sixth consecutive quarter of above-20% year-on-year earnings growth reflects "sustained strength and demand for our products, our differentiation in the marketplace, and the consistency of our execution," comments Palette.

Skyworks remains on track to close its joint venture with Japan's Panasonic Corp (announced in late April) by the end of fiscal 2014. Post-close, Skyworks will own a controlling interest in what is reckoned to be the performance leader in temperature-compensated surface acoustic wave (TC SAW) filters, with cumulative shipments approaching 0.25 billion units. "We expect the venture to broaden our technology portfolio, further enrich our systems capabilities, and enhance our financial returns," says Palette. "We anticipate the transaction will provide at least 100 basis points of gross margin accretion in fiscal 2015," he adds.

"We expect the combination of above-market top line growth, gross margin expansion and earnings leverage to fuel continued outperformance in our financials, putting us on a path of $5 in annualized EPS over the next couple of years [requiring annual growth of about 20–25%]," concludes Palette.

www.skyworksinc.com

RFaxis partners with GreenPeak

RFaxis Inc of Irvine, CA, USA, which designs RF semiconductors and embedded antenna solutions for wireless connectivity and cellular mobility, has partnered with 'smart home' low-power radio communication semiconductor firm GreenPeak Technologies of Utrecht, The Netherlands on a chip-set reference design to address the needs of the emerging 'Internet of Things' market opportunities for home automation and smart home/smart living initiatives. GreenPeak has selected the RFaxis RFX2411 CMOS ZigBee/ISM RF front-end IC (RFeIC) to pair with its GP711 ZigBee PRO/RF4CE SoC (system-on-chip).

The combination is said to provide simplified RF design with robust RF link quality that developers require for efficient and effective Internet of Things (IoT) performance in a variety of home automation/smart home applications.

"Their fully integrated and cost-effective RF front-ends are ideal for our GP711 ZigBee PRO chips, which will help us to accelerate our plans within our strategic market targets," says Vincent Vermeer, GreenPeak's director of marketing and business development.

The RFX2411 is a fully integrated, single-chip, single-die RFeIC that incorporates all the RF functionality needed for IEEE 802.15.4/ZigBee, wireless sensor network, and any other wireless systems in the 2.4GHz ISM band. Its integrates the PA, LNA, transmit & receive switching circuitry with antenna diversity support, the associated matching network, and the harmonic filter, all in a CMOS single-chip device. Suitable for high-power applications like home automation, smart house/smart living and smart power environments, the RFX2411 combines superior performance, high sensitivity and efficiency, low noise, small form factor, and low cost, claims RFaxis.

The GP711 SoC is an IEEE 802.15.4 communication controller for integration into a ZigBee RF4CE, ZigBee PRO, and/or ZigBee IP controller or node. With its multi-stack operation, it supports simultaneous operation of multiple ZigBee profiles inRF4CE and ZigBee PRO/IP running in the host processor. It is fully compliant with the IEEE 802.15.4 standard, providing robust spread spectrum data communication and optimized for low cost while providing superior performance in smart-home applications, it is claimed. GreenPeak's solutions target smart home/smart living, IoT and M2M communications market segments, covering a wide range of products such as home automation gateways, home security, home healthcare, set-top boxes, lighting control, and smart energy.

www.greenpeak.com

RFaxis & CSR to launch reference platforms for wireless connectivity in automotive, consumer and Internet of Things segments

RFaxis Inc is partnering with UK chipmaker CSR plc for reference designs aimed at multiple wireless connectivity markets.

CSR provides connectivity chipsets for Wi-Fi/Bluetooth, including wireless audio and whole-home coverage. The reference designs feature RFaxis single-chip, single-die CMOS RF front-end integrated circuit (RFeIC) technology and will be paired with CSR's UniFi CSR6030 2.4GHz 802.11n Wi-Fi solution and CSR8811 and CSR8311 Bluetooth low-energy radio chipsets.

These reference platforms are targeted at automotive infotainment, consumer electronics, IoT (Internet of Things), and M2M (machine-to-machine) communications market segments, covering a wide range of products such as in-car entertainment (ICE) systems, car kits, wireless speakers, health and fitness computer wearables, personal navigation devices (PNDs), cameras, scanners, and printers.

"Our innovative CMOS RF front-end technology helps simplify CSR's design process and accelerates time to market while delivering high performance at a competitive cost," claims Raymond Biagan, VP of worldwide sales at RFaxis.

"The company's fully integrated low-cost RF front-ends will enable us to further accelerate our attach rates within our strategic focus areas," comments Thomas Carmody, CSR's head of Connectivity Marketing.

"Apart from reducing the time to design and market, RFaxis RFeIC's level of integration offers device manufacturers a very simple solution that can be implemented as a plug and play," comments Frost & Sullivan industry analyst Swapnadeep Nayak. "The RFaxis technology helps OEMs reduce their product development cycles to as low as a few weeks, while competing solutions take months," he adds. "It satisfies every performance criterion set forth by component manufacturers and original equipment manufacturers (OEMs)."

The reference platforms feature the CSR UniFi CSR6030 2.4GHz WLAN 802.11n system-on-chip (SoC) paired with RFaxis' RFX8422S 2.4GHz 11n CMOS RFeIC with integrated high-efficiency linear power amplifier (PA), receive low-noise amplifier (LNA) with bypass, antenna switch, directional-coupler-based power detector, harmonic filters, and associated RF matching and decoupling in a single-chip, single-die package in bulk CMOS. Also featured is the CSR BlueCore CSR8811 (QFN) or CSR8311 (WLCSP) Bluetooth v4.0 SoC paired with RFaxis' RFX2401C 2.4GHz Bluetooth/ISM/ZigBee RFeIC for Class 1 operation with extended range.

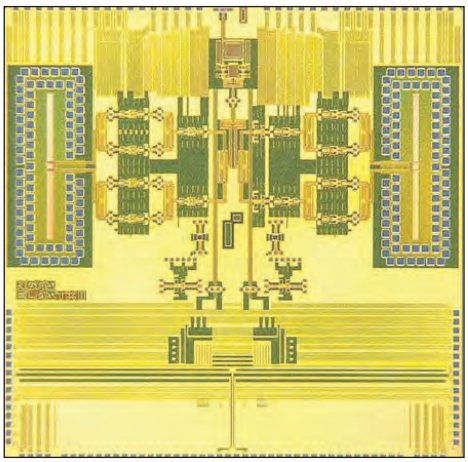
www.csr.com
www.rfaxis.com

DARPA's ELASTx program demonstrates 94GHz fully integrated all-silicon system-on-a-chip transmitter

Prototype targeted at smaller, lighter, less costly and more capable military RF communications systems

Researchers with the program 'Efficient Linearized All-Silicon Transmitter ICs' (ELASTx) of the US Defense Advanced Research Projects Agency (DARPA) have demonstrated an all-silicon system-on-a-chip (SoC) transmitter that operates at 94GHz. This marks the first time that a silicon-only SoC has achieved such a high frequency, which falls in the millimeter-wave range used for many military applications such as radar, guidance systems and communications. The DARPA performer for the all-silicon SoC is Northrop Grumman Aerospace Systems.

Many existing compact, high-data-rate millimeter-wave wireless communications systems use integrated circuits made with gallium arsenide (GaAs) or gallium nitride (GaN) that provide high power and efficiency in small packages but are costly to produce and difficult to integrate with the silicon electronics that provide most other radio functions. Silicon ICs are less expensive to manufacture in volume than those with gallium compounds but until now have not demonstrated sufficient power output and efficiency at millimeter-wave frequencies used for communications and other military applications such as radar and guidance systems.



Photograph of 94GHz all-silicon system-on-a-chip transmitter demonstrated by ELASTx program.

"What normally would require multiple circuit boards, separate metal shielded assemblies and numerous I/O cables we can now miniaturize onto one silicon chip," says DARPA program manager Dev Palmer. "This accomplishment opens the door for co-designing digital CMOS [complementary metal oxide semiconductors] and millimeter-wave capabilities as an integrated system on an all-silicon chip, which should also make possible new design architectures for future military RF systems," he adds.

The all-silicon SoC transmitter uses a digitally assisted power amplifier that dynamically adapts amplifier performance characteristics to changing signal requirements. This capability allows for simultaneous optimization of efficiency and linearity — a key goal of all transmitters and power amplifiers designed to quickly deliver large amounts of data on the emerging, net-dependent battlefield.

"This SoC can support a range of modulation formats, so it's possible to communicate to multiple systems using different waveforms from a single silicon chip," Palmer says. "Its efficient silicon construction will significantly reduce SWAP [size, weight, and power] requirements for millimeter-wave applications, including compact satellite communications ground terminals for frontline troops," he believes. "These new capabilities will provide connectivity to more service members faster and at lower cost," Palmer adds.

www.darpa.mil/Our_Work/MTO/Programs/Efficient_Linearized_All-Silicon_Transmitter_ICs_(ELASTx).aspx

Peregrine and RFMD settle litigation over RF SOI

Peregrine Semiconductor Corp of San Diego, CA, USA — a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-sapphire (SOS) and silicon-on-insulator (SOI) — and RF Micro Devices Inc of Greensboro, NC, USA have settled all outstanding claims between each other. The two parties have entered into patent cross licenses and have agreed to dismiss all related litigation "under terms that recognize Peregrine's unique role in the invention and commercialization of RF SOI technology," says Peregrine's CEO Jim Cable. "This agreement provides validation for the many ways in which Peregrine continues to expand the industry's technological frontiers through both our inventions and commercial products.," he adds.

"We are very pleased to reach an agreement with Peregrine that recognizes the value of their patents and their contribution to the development of RF SOI," states RFMD's president & CEO Bob Bruggeworth. "The signing of this patent cross-license agreement allows RFMD to focus 100% on building the industry's leading portfolio of RF solutions, making this agreement very positive for both our company and our customers."

www.rfmd.com
www.psemi.com

FinScale launches 3D MOSFET architecture and process for licensing and technology transfer

FinScale Inc of Livermore, CA, USA, which develops and licenses device and process innovations for the semiconductor industry, has announced availability of its qFinFET technology, a next-generation 3D MOSFET architecture and manufacturable process transferable to foundries and integrated device manufacturers (IDMs).

FinScale claims that, crafted from a combination of many unique device and process innovations, qFinFET technology offers improvements in performance, power efficiency and circuit density, along with substantially lower leakage, parametric variability and manufacturing costs than available advanced-node FinFET and planar technology alternatives. From a device design optimized for quantum effects, ballistic transport and the nano-material properties of silicon, the quantum FinFET device architecture is intended to scale to the end of the silicon MOSFET era.

"The technology shift from planar to 3D device architectures has opened new degrees of freedom and exciting opportunities for new innovations," says George Cheroff, an IBM Research manager and semiconductor pioneer who envisioned and developed the first n-channel planar MOSFET process used for memory and logic circuits in computers. "The qFinFET technology elegantly combines the advantages of current FinFET and planar FD-SOI technologies, and mitigates their inherent weaknesses to provide a unifying platform that will put the semiconductor industry back on track with Moore's Law," he reckons.

"qFinFET offers manufacturers a high-yield 3D process for building scalable aspect-ratio fins that can be formed without double patterning down to the 14/16nm node, and provide increased performance and transistor width (W) per unit area," says president & CEO Jeffrey Wolf. "Resulting fin transistor topologies deliver additional area reductions, and offer designers further area-saving and performance-boosting opportunities to differentiate at the cell library and circuit level when integrated with leading middle-of-line (MOL) technologies," he adds.

"We conceived the Quantum FinFET by pushing silicon to its quantum scaling limits, while seeking to maximize carrier mobility, electrostatic gate control, yield and reliability," says chief technology officer Dr Victor Koldyaev. "Using this approach we designed the qFinFET front-end-of-line (FEOL) device and process solution for the 7 and 10nm generations, and were pleased that the same device concept would significantly boost parametric performance and economic returns for manufacturers back to the 28/32nm node. We then laid out standard cells, SRAMs, eDRAMs and 2-bit/cell non-volatile memories using industry standard design rules and realized that we could readily exceed the best published results at those nodes and give manufacturers and designers opportunities for further improvement."

FinScale reckons that qFinFET technology offers unique benefits for foundries and IDMs. The included high-density and high-performance logic and memory configurations, along with inherent low-noise analog/RF device characteristics, make qFinFET a robust SoC platform, either on bulk or silicon-on-insulator (SOI) substrates. Standalone DRAM, flash and SRAM memory designers and manufacturers can configure the included bit cells into dense arrays, and build dense, highly reliable sense amplifiers and low-leakage pass transistors.

FinScale presented its qFinFET technology on 8 July at the Silicon Innovation Forum of the SEMICON West 2014 event in San Francisco.

www.finscale.com

BeRex adds family of MESFET chips

BeRex Inc of San Jose, CA, USA (which designs and manufactures RF and microwave GaAs devices) has launched a new family of low-phase-noise, high-linearity MESFET chips to complement its line of pHEMT transistors.

The new BCF-series addresses the need for low phase noise with high gain and power in both broad-band and narrow-band applications (such as single- and multi-stage amplifiers, oscillators, synthesizers, etc) ranging in frequency from DC to 26.5GHz. Typical applications require a high level of OIP3 (output third-order intercept point) linearity and a low phase noise that cannot be easily achieved with other technologies, it is claimed.

The BCF-series family consists of seven devices, each fabricated using a 0.25µm gate length and with a gate width of 200µm, 300µm, 400µm, 600µm, 800µm, 1200µm or 2400µm, depending on the client's gain and power requirements (up to 1 Watt for the largest 2400µm device).

The BCF-series of MESFET chips is produced in the USA using what's claimed to be state-of-the-art metallization, plus Si3N4 passivation to optimize reliability.

"These parts, along with our existing pHEMT family of packaged and bare-die FET products, go a long ways towards fulfilling the commitment to our clients of becoming their one-stop source for their RF and microwave FET needs," says VP of research & development Dr Alex Yoo.

www.berex.com

Soitec seeing widespread adoption of eSI substrates by RF semiconductor firms

Soitec of Bernin, France, which makes engineered substrates including silicon-on-insulator (SOI) wafers and III-V epiwafers, has reached an early milestone in the adoption of its proprietary Enhanced Signal Integrity (eSI) substrates, which are used for manufacturing radio-frequency devices providing a power boost for 4G/LTE applications. Since beginning eSI production, Soitec estimates that it has shipped enough of these substrates to fabricate more than 1.4 billion RF front-end devices.

Soitec says that, as eSI offers what is claimed to be the best cost-performance trade-off, it is seeing strong and growing demand from most of the leading RF foundries, which are already shipping wireless communication ICs built on eSI substrates. As a result, Soitec is now shipping more eSI products than high-resistivity HR-SOI wafers, which are also used in fabricating RF devices.

Soitec is now shipping more eSI products than high-resistivity HR-SOI wafers, which are also used in fabricating RF devices... We are already working on next-generation products to address future LTE Advanced challenges

"In parallel, we are already working on next-generation products to address future LTE Advanced challenges," says Bernard Aspar, senior VP & general manager of Soitec's Communication & Power business unit.

Based on Smart Cut technology, eSI products are the first 'trap-rich' type of material in full production, says Soitec. These substrates have a significant impact on the final devices' performance, the firm adds. The eSI substrates are designed by introducing a trap-rich layer between the high-resistivity handle wafer and the buried oxide. This limits the parasitic surface conduction present in standard HR-SOI substrates, boosting the performance of RF devices. Because this layer is built into the substrate, it reduces the number of process steps and relaxes design rules, leading to a highly competitive performance and die cost, including a smaller area per function, claims Soitec. RF designers can therefore integrate diverse functions such as switches, power amplifiers and antenna tuners with what is reckoned to be excellent RF isolation, good insertion loss, better thermal conductivity and better signal integrity than other technologies.

www.soitec.com

GE to lead $500m five-year State-funded New York Power Electronics Manufacturing Consortium

Partners to have access to 6" SiC tools and baseline process flow from GE at CNSE Nano Tech fab

At the GE Global Research Center in Niskayuna, Schenectady County, NY, Governor Andrew M. Cuomo has announced that New York State will partner with over 100 private companies, led by General Electric (GE) and including GlobalFoundries, Lockheed Martin and IBM, to launch the New York Power Electronics Manufacturing Consortium (NY-PEMC). The public-private partnership will invest more than $500m over five years, focused on the development of next-generation wide-bandgap semiconductor materials and processes at the State-owned R&D facility in Albany, NY.

"This partnership will create thousands of new jobs in Upstate New York [including at least 500 in the Capital region], tapping into our highly trained workforce and existing centers of high-tech research and development," says Cuomo.

Managed through the newly merged State University of New York (SUNY) College of Nanoscale Science and Engineering (CNSE)/SUNY Institute of Technology (SUNYIT), wide-bandgap semiconductors enable power devices to get smaller, faster and more efficient as silicon reaches its limits. "Power electronics is one of the fastest-growing global markets," comments SUNY CNSE/SUNYIT's CEO & officer in charge Dr Alain Kaloyeros

The Albany site will act as a global 'open-innovation' user-shared facility, enabling the expansion and growth of corporate partners as well as small- and medium-sized enterprises (SMEs).

NY-PEMC places New York at the forefront of the next revolution in power, believes GE's chairman & CEO Jeff Immelt. "By partnering, we are bringing breakthrough reliable technology to market faster and at lower cost so our customers and global industries see major productivity gains and operate at peak efficiency."

GE will be a lead partner in the fab, housed at the CNSE Nano Tech complex, which aims to develop and produce low-cost 6" silicon carbide (SiC) wafers. The advantages of SiC-based power electronic devices over silicon include the capacity to handle much higher frequencies and temperatures, reducing the size and cost for companion filtering and cooling systems. Also, the devices can be half the size of similar silicon devices, providing increased power density and reliability. Currently, SiC technology can be cost prohibitive to smaller- to medium-size companies. All NY-PEMC partner companies will have access to 6" SiC tools and a baseline process flow, contributed by GE, where they can make their own enhancements in preparation for high-volume, cost-effective manufacturing.

The partnership is enabled by the START-UP NY tax-free initiative, in addition to $135m in New York State funds provided to CNSE for the establishment of the NY-PEMC facilities, which will attract $365m in private funds and know-how (including more than $100m from GE) to support personnel, equipment and process flow, tool installation, facilities and materials, making a total 5-year investment of $500m. Collaboration with CNSE should enable the expansion and growth of both major corporate partners and small- and medium-sized enterprises within a power electronics device and systems integration eco-system.

www.sunycnse.com
www.sunyit.edu
www.geglobalresearch.com
www1.eere.energy.gov/manufacturing/innovation/facilities/wbg.html

TriQuint showcases high-performance GaN solutions

TriQuint Semiconductor Inc of Hillsboro, OR, USA showcased its new technologies at June's IEEE MTT-S International Microwave Symposium (IMS 2014) in Tampa.

"TriQuint is on track to deliver more than 75 new products to the infrastructure and defense markets in the first half of 2014, adding to our record of 130 products released in 2013," notes VP & general manager James Klein, Infrastructure and Defense Products.

Also at IMS, TriQuint technologists gave the following presentations:

- 'New GaN and GaAs Solutions Overview' by Grant Wilcox;
'Broadband High-Efficiency GaN Power Amplifiers' by Bumjin Kim, Mark Greene and Matt Osmsus;
- 'Advances in Low Noise Technology' by Jingshi Yao, Xiaopeng Sun and Bary Lin;
- 'GaN-Based Power Supplies and Power Supply Modulators for Efficient Powering of RF PAs' by David Fanning, Vipan Kumar, Charles Campbell and JL Jimenez;
- 'Compact Ku-Band Transmit–Receive MMIC for Airborne Phased Array Applications' by Donald Allen and Rajkumar Santhakumar;
- 'Slant Field Plate Model for Field Effect Transistors' by Robert Coffie;
- 'Efficiency and Linearity Enhancement of Microwave GaN PAs using Harmonic Injection' by Dr Michael Dean Roberg.

www.triquint.com

CNSE/SUNYIT plans for III-V and beyond-III-V materials

At SEMICON West in San Francisco (8–10 July), researchers from the newly merged State University of New York (SUNY) College of Nanoscale Science and Engineering (CNSE)/ SUNY Institute of Technology (SUNYIT) in Albany, NY, USA, in addition to scientists from corporate partners including Applied Materials, ASML, GLOBALFOUNDRIES, IBM, Intel, KLA-Tencor, Nikon Precision, Samsung, SEMATECH, Tokyo Electron and TSMC, took part in presentations and informational sessions on the advancement of semiconductor-based R&D — including innovations paving the way for the transition to the new 450mm wafer standard.

Also, presenters detailed the four new technology development centers based at Albany Nanotech Complex, which will be jointly managed by CNSE/SUNYIT and SEMATECH. The centers will focus on chemical mechanical polishing/planarization (CMP), 3D (computer chip packaging), resist, and III-V compounds, enabling firms to assess materials, test new tooling, and validate designs via access to CNSE/SUNYIT's fabrication facilities and engineering know-how, as well as SEMATECH's network of consortium members.

Presentations by CNSE/SUNYIT researchers and corporate partners provided industry updates, specifically detailing progress made by the G450C (Global 450mm Consortium). Presentation topics include '450mm Lithography', '450mm Notchless Wafer Update', 'G450C Technology Development Program Status', '450mm Transition Status and Briefing', 'Readiness of Advanced Lithography Technologies for High-Volume Manufacturing', 'Chemical Mechanical Polishing Market Trends and Technology Advances', 'Sustainable Manufacturing Forum: Next Generation Eco Fab', and 'Driving Transistor Technology Sub-10nm: Process and Equipment Directions'.

Specifically, in 'Driving Transistor Technology Sub-10nm: Process and Equipment Directions', CNSE presented its development focus on materials beyond silicon. III-V layers are being evaluated as channel materials for next-generation devices. CNSE has established an ecosystem for collaborative III-V work with industrial and research partner institutions, and is developing modules for III-V gate stack, contact and source-drain engineering that are compliant with environmental guidelines while driving to device performance targets.

Beyond III-V, CNSE is working with partners from academia, industry and federal research programs on the growth, device design and integrated module development for 2D materials layers, targeting their introduction into mainstream processing. Initial successes have been made in graphene growth and transfer onto 300mm substrates for clean, repeatable processing through the CNSE development facility.

www.sunycnse.com

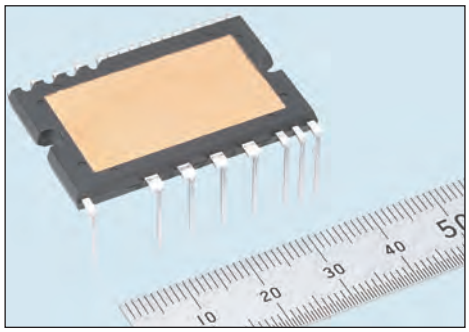
Mitsubishi launches super-mini full-SiC DIPPFC module

Tokyo-based Mitsubishi Electric Corp has launched a transfer-molded super-mini dual in-line package power factor correction (DIPPFC) module incorporating silicon carbide (SiC) transistors and diodes that is expected to help reduce the power consumption and size of home appliances. The new 20A_{rms}/600V PSF20L91A6-A module were exhibited at MOTORTECH JAPAN during the TECHNO-FRONTIER 2014 event in Tokyo (23–25 July).

Built-in chips include a PFC circuit comprising two SiC metal-oxide semiconductor field-effect transistors (MOSFETs), two SiC Schottky-barrier diodes (SBDs) and one LVIC chip. Other functions include short-circuit protection (using external shunt resistor) and a control power supply under-voltage (UV) protection (Fo output on N-side protection).

Mitsubishi Electric notes that SiC contributes to both lower power consumption and compact size:

- Power loss is reduced by about 45% compared to silicon products, contributing to improved energy conversion.
- The SiC Schottky-barrier diode (SBD) reduces recovery current power consumption and electromagnetic interference (EMI) noise.
- The SiC metal-oxide semiconductor field-effect transistor (MOSFET) achieves maximum 40kHz high-frequency switching and contributes to the downsizing of peripheral components, such as reactors and heat-sinks.
- Power factor correction (PFC) and a driving IC contribute to downsizing by reducing the mounting surface area and simplifying wiring.



The new PSF20L91A6-A module.

Mitsubishi Electric also notes a simplified design for inverter systems:

- Adoption of the same 24.0mm x 38.0mm x 3.5mm package as the dual in-line package intelligent power module (DIPIPM) simplifies the installation of heat-sinks.
- The interleave method for PFC decreases the ripple current and simplifies the noise filter circuit.

Mitsubishi Electric commercialized its first DIPIPM transfer-molded intelligent power module in 1997 and over the years has contributed to miniaturization and energy-savings in inverter systems. The technology has gained increased importance because annual power consumption has become an important index of energy savings in consumer appliances, such as air conditioners, says the firm.

Development of the DIPPFC module was supported by Japan's New Energy and Industrial Technology Development Organization (NEDO).

www.MitsubishiElectric.com

Raytheon demonstrates prototyping of AESA/GaN technologies into Patriot radar

Raytheon Company of Waltham, MA, USA has demonstrated prototyping of active electronically scanned array (AESA) and gallium nitride (GaN) technologies into the US Patriot Air and Missile Defense System radar. As well as enabling future 360 sensor coverage, the technologies will significantly increase the defended area and decrease the time to detect, discriminate and engage threats, says the firm. The introduction of GaN-based AESA technologies should also further improve reliability and lower the life-cycle costs for the Patriot radar, beyond what has already been achieved with other recent Patriot radar improvements.

"GaN-based AESA technologies represent the future of ground-based sensors and will have future application to Raytheon's entire sensor portfolio," says Ralph Acaba, VP of Integrated Air and Missile Defense at Raytheon's Integrated Defense Systems business in Tewksbury, MA. "Along with the Patriot radar, the entire Patriot system has kept pace with the latest technological advances to ensure over match against current and evolving threats," he adds. "The Patriot that's currently in production and fielded is the most advanced air and missile defense system available today."

Further expanded demonstrations are planned in the months ahead.

Raytheon has been developing GaN over the last 15 years and has invested more than $150m on the technology. It has demonstrated the maturity of the technology in a number of ways, including exceeding the reliability requirement for insertion into the production of military systems. This maturation of GaN resulted in a Manufacturing Readiness Level (MRL) production capability of '8', the highest level obtained by any organization in the defense industry for this technology.

The Patriot air and missile defense system provides protection against threats including aircraft, tactical ballistic missiles, cruise missiles and unmanned aerial vehicles (UAVs). Continually upgraded and enhanced to reflect the latest technology, Patriot is used by 12 nations worldwide. Raytheon is the prime contractor for both domestic and international Patriot Air and Missile Defense Systems and the system integrator for Patriot Advanced Capability-3 missiles.

www.raytheon.com

Germany's NeuLand project cuts energy losses by 35% in power electronics

SiC and GaN-on-Si key to cutting loss in power supplies and inverters

Directed by Infineon Technologies AG together with partners Aixtron, SiCrystal AG and SMA Solar Technology AG, the three-year German project NeuLand (begun in late 2010) has developed highly integrated components and electronic circuits that, in tests during ongoing research, have enabled energy losses to be reduced by 35%.

Key to halving energy losses is the use of silicon carbide (SiC) and gallium nitride on silicon (GaN-on-Si) whose electronic properties enable compact and efficient power electronics circuits. NeuLand is an abbreviation of the German for 'Innovative power devices with high energy efficiency and cost effectiveness based on wide-bandgap compound semiconductors'.

Infineon already uses SiC in its field-effect transistor (JFET) and diodes for the 600–1700V class. These power semiconductors are primarily used in switched-mode power supplies for PCs or TVs and in motor drives. In the future they may also become significant for solar inverters.

SiC has traditionally been a very expensive wafer material. However, there are now more SiC vendors and the number of possible applications has grown. NeuLand project partners have been able to demonstrate that the efficiency of power electronics can be increased by more than a third using SiC- and GaN-based components. For example, solar inverters can benefit from considerable material savings with no change in effectiveness, making them more cost-efficient. But results also show that the cost of SiC components must drop even further for wide-scale application to solar inverters and that, for GaN-based components, further intensive research is required on reliability, service lifetime and costs.

Aixtron was represented in the project as an equipment provider for semiconductor production, while wafer manufacturer SiCrystal was on board for the SiC substrates. Semiconductor manufacturer Infineon researched the power semiconductor devices and the production steps for SiC- and GaN-based components, while system technology expertise in the solar sector was provided by SMA Solar Technology. The project partners say that, with NeuLand, they were able to further expand their respective proficiencies in future-oriented SiC and GaN technologies along a very wide-ranging segment of the value-creation chain.

The NeuLand project was funded by the German Federal Ministry of Education and Research (BMBF) to a total of about €4.7m as a part of the call for proposals on 'Power Electronics for Energy Efficiency Enhancement' (LES) in the German Federal Government's program 'IKT 2020 – Research for Innovation'. The objective of IKT 2020 is to strengthen Germany's position in electronic technologies.

www.infineon.com
www.aixtron.com
www.sicrystal.de
www.sma.de

MACOM adds 90W 2-stage, fully matched surface-mount power module for pulsed avionic applications

M/A-COM Technology Solutions Inc of Lowell, MA, USA has announced the newest entry in its portfolio of GaN in Plastic power module products. Optimized for pulsed avionics applications in the 960–1215MHz band, the MAMG-001214-090PSM 2-stage, fully matched gallium nitride surface-mount power module scales to peak pulse power levels of 100W in a 14mm x 24mm package size.

MACOM says its new high-gain GaN in Plastic power modules support surface-mount technology (SMT) assembly, providing cost and process advantages compared with ceramic-packaged flange-mount components. Delivering benefits in size, weight and power (SWaP) while enabling high-volume manufacturing efficiency, the new GaN power modules feature a land grid array (LGA) pattern for enhanced thermal flow and 'True SMT' assembly, and do not require copper coining or complicated thermal management techniques on the system PC board.

Under pulsed conditions, the modules deliver output power greater than 90W, with 30dB of typical associated power gain and 60% typical power-added efficiency (PAE). Supporting 50V operation and up to 3ms pulse width/duration for improved signal flexibility, MACOM's GaN in Plastic power modules reduce overall power consumption and cooling requirements compared with existing options, the firm claims.

"The ease of application, system benefits and surface-mount automated assembly are of great benefit to the customer, and critically also improve the time to market for rapidly evolving requirements in aviation and radar applications," says product manager Paul Beasly.

www.macom.com/gan

EDA-led project MANGA helps to establish independent European supply chain for GaN technologies

Follow-on project to target qualification of European industrial HEMT epiwafer supplier

Under the leadership of the European Defence Agency (EDA), the multi-national R&D project MANGA (Manufacturable GaN-SiC-substrates and GaN epitaxial wafers supply chain) says that it has succeeded in implementing a supply chain for the realization of power electronics components based on gallium nitride within Europe.

With the aim of optimizing development and manufacturing techniques for power electronics based on gallium nitride (GaN), research institutions, universities and defence-focused industry partners in five European countries (Germany, France, Italy, Sweden and the UK) have worked together over the past four years to produce high-quality GaN-based electronic devices in Europe, without relying on international suppliers. Due to the high efficiency and robustness of the semiconductor, GaN-based power electronic components have already replaced established technologies, mainly in the fields of radar and broadband amplifiers.

With respect to the increasing application of the efficient components in electronic defense and combat systems, the European defence industry is facing increasing demand for the reliable supply of power electronic components. The technology is critical and will provide key enabling capabilities to a broad spectrum of defense applications, reaching from advanced radar and communication antennas to electronic warfare.

Independent supply chain in Europe

To facilitate independent production of GaN-based electronic devices for military applications, it is necessary to implement the entire supply chain within Europe, say the project partners — reaching from the availability of silicon carbide (SiC) substrates for the epitaxial growth of GaN, to the industrial manufacturing of high-electron-mobility transistors (HEMTs). In the scope of the project, GaN-based transistor layers were grown epitaxially on newly developed high-quality SiC-substrates. Applying established foundry processing, these transistor layers were used to produce fully European HEMTs. Both the quality of the SiC-substrates and the performance of the HEMT are comparable to equivalent benchmark-setting components produced in the USA, it is said.

With the aim of optimizing development and manufacturing techniques for power electronics based on GaN, research institutions, universities and defence-focused industry partners in five European countries have worked together over the past four years to produce high-quality GaN-based electronic devices in Europe

Systems with increased reliability

In future projects, it will remain the goal of the EDA to further reduce the European defense industry's dependence on international trade regulations. After having realized independent development and production of state-of-the-art transistors suitable for military applications, the project partners want to focus on improving the reliability and material quality of the transistors. Results from universities participating in the MANGA project, where scientists studied the impact of variations in layer structures on the devices' performance, will help to further optimize the HEMT technology.

In a follow-on project, the project partners want to achieve qualification of an industrial European epiwafer supplier for HEMT structures.

www.eda.europa.eu

Google and IEEE launch $1m Little Box Challenge to create smaller power inverter

Open competition targets 10x shrinkage, focusing on GaN and SiC

Google and the Institute of Electrical and Electronic Engineers' Power Electronics Society (IEEE PELS) have launched the Little Box Challenge, an open competition with a $1m prize to create a much smaller but higher-power-density inverter.

Inverters take direct current from devices such as solar panels and batteries and convert it into alternating current for use in homes, businesses and cars. The problem is that household inverters are too big. Making them smaller would enable more solar-powered homes, more efficient distributed electrical grids, and could help bring electricity to the most remote parts of the planet.

The challenge is to figure out how to shrink an inverter to something smaller than a small laptop (a reduction of >10x in volume). The winning inverter will be the one that achieves the highest power density and meets a list of other specifications, as determined by a panel of judges, while undergoing testing for 100 hours.

The other specifications are:

- must be able to handle up to 2kVA loads;
- must achieve a power density equal to or greater than 50W/in^3;
- must be able to handle loads with power factors from 0.7–1, leading and lagging in an islanded mode;
- must be in a rectangular metal enclosure of no more than 40in^3;
- will be taking in 450V DC power in series with a 10Ω resistor;
- must output 240V, 60Hz AC single-phase power;
- must have a total harmonic distortion + noise on both voltage and current of <5%;
- must have an input ripple current of <20%;
- must have an input ripple voltage of <3%;
- must have a DC–AC efficiency of greater than 95%;
- must maintain a temperature of no more than 60°C during operation everywhere on the outside of the device that can be touched;
- must conform to Electromagnetic Compliance standards as set out in FCC Part 15 B;
- cannot use any external source of cooling (e.g. water) other than air;
- does not require galvanic isolation.

"By participating in this challenge, members of industry and academia can play a pivotal role in a technological innovation that could have a major impact on the world," comments IEEE PELS president Don Tan.

Google and IEEE comment that a promising set of technologies that may allow the achievement of higher power densities are wide-bandgap (WBG) semiconductors such as gallium nitride (GaN) and silicon carbide (SiC). WBG device manufacturers including Cree, EPC, GaN Systems, Monolith Semiconductor Inc, NXP, Rohm Semiconductor, Transphorm, and United Silicon Carbide Inc (USCi) have created web pages describing their technology, how it might enable contestants to win the competition, and opportunities for obtaining some of their devices.

The application deadline is 30 September. Eligible academics may also register and apply for grants to assist in the development of their devices. Registered teams must then submit a technical approach and testing application by 22 July 2015. Up to 18 finalists will be notified of their selection for final testing. They are required to bring their inverters in person to a testing facility in the USA by 21 October 2015. The grand prize winner will be announced in January 2016.

www.littleboxchallenge.com

IN BRIEF

EPC supporting Little Box Challenge

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA, which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) for power management applications, has announced its support for contestants in the Little Box Challenge.

EPC highlights that reducing the cost of solar inverters can have a significant impact on the overall system cost of solar power.

The firm says that eGaN FET power transistors are suitable for this type of application due to their high power-handling capability, ultra-fast switching speeds, and small size:

- High efficiency/low losses – The switching performance of eGaN FETs enables higher switching frequency compared to MOSFET solutions. Higher frequency reduces the size of energy storage elements that dominate inverter size.
- Ultra-fast switching speed – The small size and lateral structure of eGaN FETs give extremely low capacitance and zero QRR. Also, the land grid array (LGA) package gives low inductance. These attributes enable unprecedented switching performance (2–3 times that of a MOSFET). Switching speed is key to raising switching frequency efficiently.
- Small size – GaN is a wide-bandgap device with superior conductivity compared to traditional MOSFET technology, resulting in smaller devices and lower capacitance for the same on resistance ($R_{DS(on)}$).

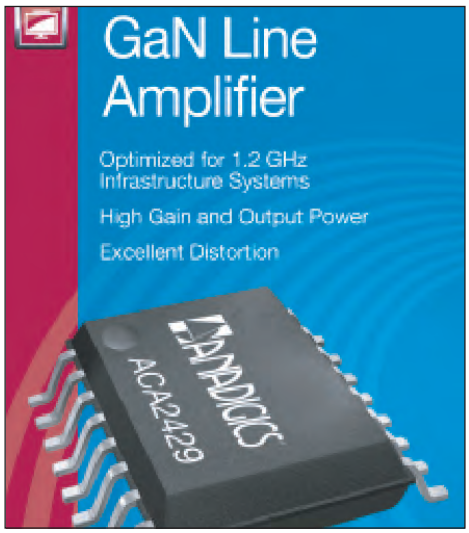
To explore the possibility of using EPC's eGaN FETs in a high-power-density inverter for the Little Box Challenge, go to the web address below.

http://epc-co.com/epc/LittleBoxChallenge.aspx

Anadigics' GaN power doubler chosen by European manufacturer for DOCSIS 3.1 CATV equipment

Anadigics Inc of Warren, NJ, USA is shipping production volumes of its ACA2429 gallium nitride (GaN) power doubler surface-mount IC (launched in July 2013) in support of new DOCSIS 3.1 CATV infrastructure equipment. Using the DOCSIS 3.1 standard, MSOs (multi-system operators) can increase network capacity and offer faster speeds with higher quality of service, says Anadigics.

"CATV service providers worldwide are sharply focused on expanding their customer base in the face of alternative broadband technologies," says Tim Laverick, vice president of Infrastructure Products. "To help them succeed, network equipment manufacturers are leveraging our world-class DOCSIS 3.1 infrastructure solutions," he adds. "The ACA2429 power doubler, now shipping in production volume to a leading European manufacturer, provides reliable, linear power amplification over an expanded frequency range to help CATV service providers offer higher data rates and take full advantage of all that DOCSIS 3.1 has to offer."



Anadigics' ACA2429 power doubler.

The ACA2429 line amplifier leverages the firm's MESFET technology and a GaN output stage, which increases power efficiency and minimizes the operating (bias) current. The power doubler provides 25dB gain with +60dBmV output power and 1.2GHz bandwidth, with only 10W of power consumption. Operating from a voltage of 24V, current consumption is 420mA. The ACA2429 offers what is claimed to be exceptional 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. With a combination of high gain, output power and linearity coupled with low current consumption and BER (bit error rate), the ACA2429 enables higher data speeds as well as distortion-free video and audio.

Offered in a 16-lead SOIC surface-mount package, the ACA2429 line amplifier acts an alternative to hybrid line amplifier module designs.

www.anadigics.com

GaN Systems expands into new HQ and R&D facility

Tenfold increase in lab space to accelerate long-term reliability testing

GaN Systems Inc of Ottawa, Ontario, Canada, a fabless developer of gallium nitride (GaN)-based power switching semiconductors for power conversion and control applications, has moved into its new headquarters and R&D facility at 1145 Innovation Drive, in the heart of Kanata's high-tech community.

The firm says the move was necessitated by its expansion over the past 12 months, and it plans for continued rapid growth as GaN devices replace legacy silicon-based semiconductors in power conversion and control applications worldwide.

"These new facilities will provide the resources and capabilities we need as we move rapidly from R&D to commercialization this year," says CEO Jim Witham. The new HQ and R&D facility is three times larger than the previous premises, with a tenfold increase in laboratory space. The labs have dedicated power and cooling. "When you produce devices that can switch 200A or more, it calls for some highly specialized facilities to fully test them," explains co-founder & president Girvan Patterson. "The power available in this location and our custom-designed labs will enable us to fully explore higher-power applications and substantially accelerate the long-term reliability testing of our devices."

GaN Systems' headquarters in Ottawa.

Staffing has already increased significantly over the past six months, and GaN Systems has expanded its global team as its power conversion devices (based on its proprietary Island Technology) are commercialized.

www.gansystems.com

TriQuint hits targets as part of Title III GaN-on SiC Electronic Warfare MMIC Production Capacity program

RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has reached a defense production milestone, completing the Defense Production Act Title III Gallium Nitride on Silicon Carbide (GaN on SiC) Advanced EW (Electronic Warfare) MMIC Production Capacity program.

"The mission of the DPA Title III program is to create assured, affordable and commercially viable production capabilities and capacities for items essential for national defense, [which] strengthen the economic and technological competitiveness of the US defense industrial base," says Dr Gene Himes, US Air Force Research Laboratory (AFRL) program manager. "This critical mission strengthens the economic and technological competitiveness of the US industrial base, and TriQuint's GaN technology has achieved that goal," he adds.

TriQuint was recognized for its "outstanding contributions to national defense achieved under the Title III Gallium Nitride on Silicon Carbide Radar/Electronic Warfare Monolithic Microwave Integrated Circuit Production Capacity Project," at the final program management review in Washington DC on 8 May. The citation was signed by the Honorable Frank Kendall, Undersecretary of Defense for Acquisition, Technology and Logistics.

"TriQuint has proved its manufacturing readiness and GaN maturity, with yields rivaling established GaAs production, not only for defense production programs but also for our commercial customers," says James Klein, TriQuint's VP & general manager Infrastructure and Defense Products.

TriQuint has shipped more than 119,000 0.25µm GaN power amplifier devices in support of ongoing radar production programs. During phased-array field testing, about 15,000 devices have accumulated over 3.67 million device hours, with no reported device failures. With what is claimed to be industry-leading reliability based on three-temperature accelerated life testing, TriQuint has seen mean time to failure (MTTF) of much greater than 10^7 hours and a superior T1 (the time at which 1% of failures occur) of more than 10^6 hours at 200°C, without pre-conditioning.

As part of the Title III contract, awarded in 2010, TriQuint progressed through three program phases to prove manufacturing readiness at its facility in Richardson, TX. The first phase assessed TriQuint's initial manufacturing readiness. In the second phase, TriQuint worked to refine and improve the production processes, with the aim of reaching the manufacturing readiness needed for low-rate initial production (LRIP) of GaN monolithic microwave integrated circuits (MMICs). In the final phase, TriQuint applied the lessons learned throughout the program, showing that its manufacturing processes are ready to meet full performance, cost and capacity goals, with the capability in place to support full-rate production. TriQuint's Texas facility is an accredited Department of Defense (DoD) Trusted Source for foundry, post-process, assembly & packaging, and RF test services.

Under the guidance of the AFRL's Materials and Manufacturing Directorate, rigorous manufacturing readiness assessment criteria were used to benchmark TriQuint's high-frequency, high-power GaN production capability. The firm says that its ongoing development of GaN-based devices is leading to smaller, more efficient power amplifiers, typically used for DoD radar and electronic warfare programs as well as commercial wireless communications and infrastructure.

www.triquint.com/defense

Advantech's GaN HPAs power HDTV for World Cup

Advantech Wireless of Montreal, Canada, which makes satellite, RF equipment and microwave systems, says that its SapphireBlu Series of UltraLinear GaN-based high-power amplifiers (HPAs) powered the ultra-high-definition television (UHDTV) transmission of the 2014 FIFA World Cup in Brazil.

Due to Advantech's Ku-band UltraLinear GaN-based HPAs combined with its 13m A-Line Antenna in a major DTH Uplink system in LATAM, millions of viewers in Latin America and Brazil were able to follow the transmissions of the World Cup.

"This powerful technology offers unprecedented ground power, linearity and cost savings," says CEO David Gelerman. "For the first time we are able to experience worldwide tournaments and fast-moving sporting events produced in 4K Ultra HD."

Awarded Teleport Technology of the Year 2014 by the World Teleport Association (WTA) as well as 'Vision Award' as Most Innovative Product of the Year 2013, the SapphireBlu Series of UltraLinear GaN-based HPA systems are designed to offer high linear power. The technology is so powerful that it is possible to saturate all transponders of the modern satellite with a single 13m antenna and a single amplifier per polarization, says Advantech. The new systems are redundant ready with no external controller required, suiting single-carrier, multi-carrier and multi-transponder uplinking, the firm adds.

www.advantechwireless.com

GaN FET maker EPC launches wireless power transfer demonstration boards operating at 6.78MHz

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA, which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) for power management applications, has introduced demonstration boards for wireless power transfer in what is claimed to be an innovative high-performance topology; zero voltage switching (ZVS) Class-D. The EPC9506 and EPC9507 amplifier (source) boards utilize the high-frequency switching capability of EPC gallium nitride transistors to facilitate wireless power systems with greater than 75% efficiency.

Wireless power transfer

The popularity of highly resonant wireless power transfer has increased over the last few years, particularly for applications targeting portable device charging, says EPC. The end applications are varied and evolving quickly from mobile device charging to life-extending medical implementations and safety-critical hazardous environments.

The requirements of wireless energy transfer systems include high efficiency, low profile, robustness to changing operating conditions and, in some cases, light weight. These requirements translate into designs that need to be efficient and able to operate at high switching speeds without a bulky heat-sink. Furthermore, the design must be able to operate over a wide range of coupling and load variations. The fast switching capability of eGaN FETs is ideal for highly resonant power transfer applications, claims EPC.

Amplifier demonstration boards

The EPC9506 and EPC9507 are high-efficiency A4WP-compliant zero voltage switching (ZVS), voltage mode Class-D wireless power transfer amplifier (source) boards capable of delivering up to 35W into a DC load while operating at up to 6.78MHz. The boards feature the 40V EPC2014 (EPC9506) and the 100V EPC2007 (EPC9507) eGaN FETs. Both boards are configured to operate in either a half-bridge topology (for single-ended configuration) or full-bridge topology (for differential configuration) and include the gate driver(s) and oscillator that ensure operation of the boards at a fixed frequency.

The fast switching capability of eGaN FETs is ideal for highly resonant power transfer applications

The EPC9506 and EPC9507 demonstration boards are priced at $418.95 each and are available for immediate delivery from Digi-Key.

System demonstration kits

In addition to the stand-alone amplifier (source) boards available now, EPC is introducing a family of full system demonstration kits. The full kits include the amplifier (source) board, a Class 3 A4WP-compliant source coil (transmit coil), and a Category 3 A4WP-compliant device coil with rectifier and DC smoothing capacitor.

http://epc-co.com/epc/Applications/WirelessPower.aspx

EPC introduces plug & play half-bridge converter evaluation board

EPC has introduced DrGaNPLUS evaluation boards, providing an easy-to-use way for power systems designers to evaluate the performance of GaN transistors. The boards are proof-of-concept designs that integrate all necessary components of a half-bridge circuit into a single, extremely small PCB-based module that can be readily mounted to demonstrate the performance of a GaN transistor power conversion solution.

The first DrGaNPLUS board — the EPC9202 100V, 10 A half-bridge power converter — is a plug & play evaluation board that designers can use to quickly and easily evaluate the high performance gained with GaN power transistors. As an example, the board reaches 97% peak efficiency with V_{in} = 48V and V_{out} = 12V, a common power conversion for telecom applications.

The EPC9202 can be driven by a single PWM input and features two EPC2001 eGaN FETs, the Texas Instruments' LM5113 driver, and high-frequency input capacitors. This DrGaNPLUS board is small (just over 9mm on a side) and can mount directly onto a printed circuit board. It has been designed with an optimal layout to minimize the debilitating effects of common source and high-frequency power commutation loop inductances.

"In addition to improved performance, lower cost and reliability, ease-of-use is a critical factor in the adoption of a new technology," says CEO & co-founder Alex Lidow. "With the introduction of DrGaNPLUS evaluation boards, power conversion systems design engineers now have a quick and easy way of assessing the exceptional benefits of incorporating gallium nitride transistors into their power systems circuits," he adds.

EPC9202 demo boards are priced at $45 each and are available for immediate delivery from Digi-Key. A Quick Start Guide (containing set up procedures, circuit diagram, performance curves, and a bill of material) is included with the EPC9202 demo board for reference and ease of use.

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

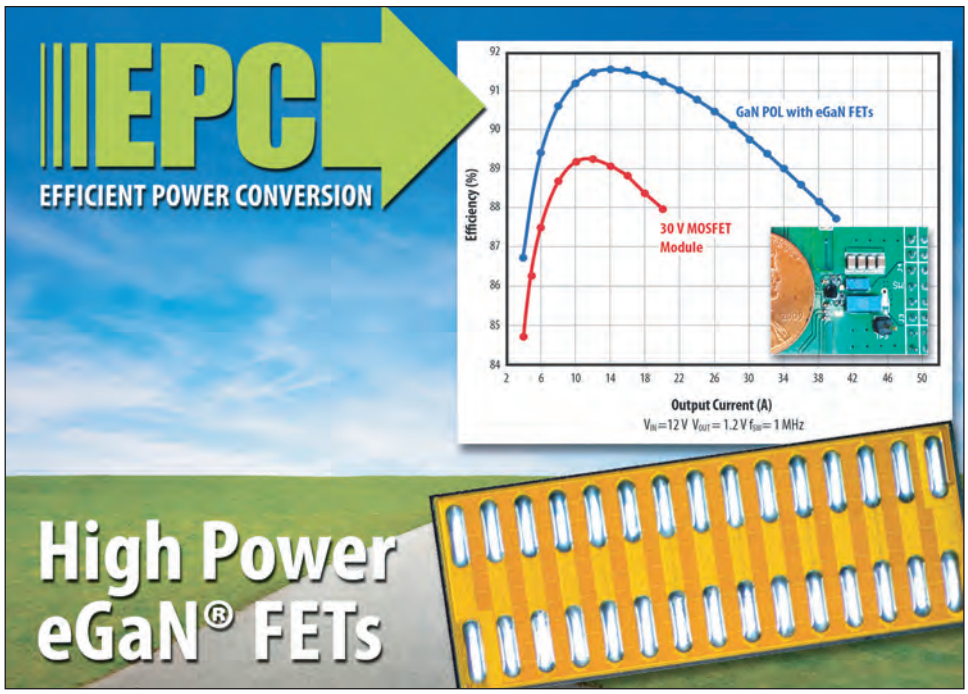
http://epc-co.com/epc/documents/guides/EPC9202_qsg.pdf

EPC launches 'off-the-shelf' high-performance GaN power transistors

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA, which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) for power management applications, has introduced six new-generation power transistor products and corresponding development boards. Ranging from 30V to 200V, the new devices provide a significant reduction in RDS(on), greatly increasing their output current capability in applications such as high-power-density DC–DC converters, point-of-load (POL) converters, synchronous rectification in DC/DC and AC/DC converters, motor drives, LED lighting and industrial automation.

The features of the new devices are as follows:

- *Lower on-resistance ($R_{DS(on)}$)* — The new family of eGaN FETs cuts on-resistance ($R_{DS(on)}$) in half, enabling high-current, high-power-density applications.
- *Improved figure of merit (FOM)* — The latest generation of eGaN FETs cuts the hard-switching FOM in half compared with the previous generation for improved switching performance in high-frequency power conversion applications.
- *Extended voltage range* — Extending the performance benefits of GaN to 30V enables higher-power DC–DC converters, point-of-load (POL) converters, synchronous rectifiers for isolated power supplies, PCs, and servers.
- *Better thermal performance* — Increased temperature capabilities and improved die layout improve the thermal and electrical performance of the Gen 4 family of devices, allowing for higher-power operation under all conditions.
- *Demonstrated power conversion efficiency improvements* — To demonstrate the improved performance of these new eGaN FETs, two buck converters were built. The EPC9018 combines the 30V EPC2023 FET as the synchronous rectifier with the 40V EPC2015 as the control switch of a 12–1.2V DC–DC point of load (POL) converter.



The EPC9019-24 converter.

The 12V–1.2V, 40A POL converter operating at switching frequency of 1MHz achieved efficiencies above 91.5% and demonstrated the superior in-circuit performance of the latest generation of eGaN power devices compared with the state-of-the-art silicon MOSFET modules, claims EPC.

The EPC9019, a 48–12V converter, uses the 80V EPC2021 as the synchronous rectifier switch with the 100V EPC2001 as the control switch. The results of this 48–12V, 30A non-isolated DC–DC intermediate bus converter operating at a switching frequency of 300kHz achieved efficiencies above 98%, again significantly outperforming a comparable converter using state-of-the-art silicon power MOSFETs, EPC claims.

Detailed results of the in-circuit demonstrations of eGaN FETs can be seen at http://bit.ly/EPCAN017.

To simplify the evaluation process of the latest high-performance eGaN FETs, development boards are available to support easy 'in circuit' performance evaluation of each new product being introduced. These boards include all the critical components on a single board that can be easily connected into any existing converter.

The EPC9014 and EPC9031 through EPC9034 development boards are half-bridge configurations with onboard gate drives, featuring various eGaN power transistors. All boards are 2" x 1.5" and contain two eGaN FETs using the Texas Instruments LM5113 gate driver, supply and bypass capacitors. Each board contains all critical components and layout for optimal switching performance.

The EPC9018 and EPC9019 development boards are also available for easy 'in circuit' performance evaluation.

Pricing for the EPC2019–24 power transistors starts at $3.14 each, in 1000-unit quantities. Pricing for corresponding development boards start at $104.40 each. Both are available for immediate delivery from Digi-Key.

http://epc-co.com/epc/Products.aspx

Agilent announces modeling software for three-dimensional FinFETs and gallium nitride HEMTs

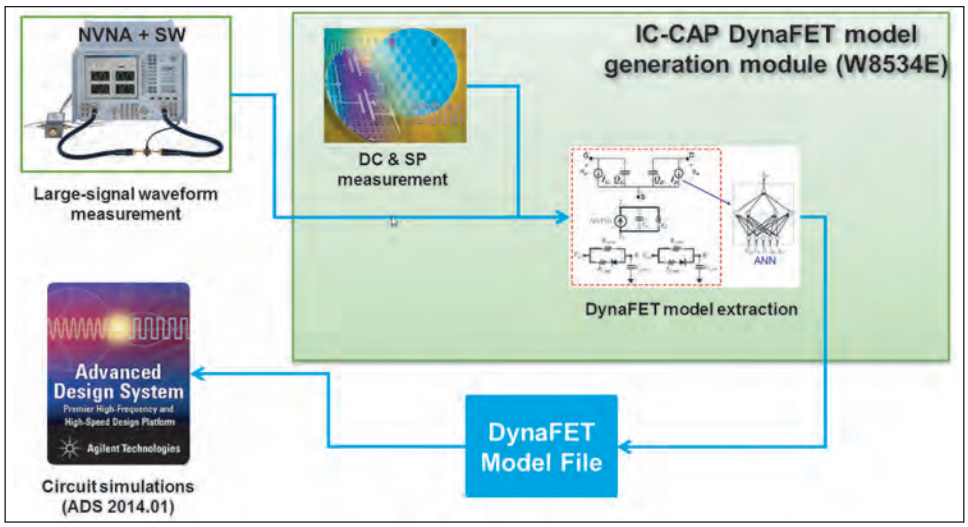
Agilent Technologies Inc of Santa Clara, CA, USA has announced several innovations for the 2014 release of its suite of device modeling and characterization software tools. The suite comprises the Integrated Circuits Characterization and Analysis Program (IC-CAP), Model Builder Program (MBP), and Model Quality Assurance (MQA) software of Agilent EEsof EDA (which supplies electronic design automation software).

IC-CAP software is a device-modeling program that delivers characterization and analysis capabilities for the latest semiconductor modeling processes. Providing efficient and accurate extraction of active device and circuit model parameters, IC-CAP performs modeling tasks including instrument control, data acquisition, graphical analysis, simulation and optimization. It is used by foundries and design houses to characterize foundry processes.

MBP is a one-stop solution that provides both automation and flexibility for high-volume, high-throughput device modeling. It includes built-in characterization and modeling capabilities as well as an open interface for modeling strategy customization. It is widely used both by foundries and design houses to extract and customize SPICE model libraries.

MQA provides a complete solution and framework to fabless design companies, IDMs and foundries for SPICE model library validation, comparison, and documentation. It performs model QA, comparison, and documentation automatically to ensure design success using advanced process technologies, says Agilent.

"Over the past few years, we've steadily expanded our device modeling platform through internal development and acquisition of key technologies," says Brian Chen, Agilent's device modeling planning manager. "This marks the first release of our entire portfolio and represents a significant advancement toward our vision of being a partner that uniquely delivers a complete end-to-end, measurement-to-modeling solution."



The DynaFET model extraction package is an integral part of Agilent's GaN HEMT characterization, modeling and simulation solution.

Advanced modeling capabilities

The new software release features three advanced device modeling packages for Agilent's DynaFET, BSIM6, and BSIM-CMG models.

BSIM6 is the industry-standard model for bulk MOSFETs, offering key improvements for analog/RF applications over its predecessor BSIM4. BSIM-CMG is the industry-standard model for sub-20nm 3D FinFET technologies. Modeling solutions for both BSIM6 and BSIM-CMG in the 2014 release are designed to help the semiconductor industry understand and use these new technologies.

The DynaFET modeling package is based on internally developed technology and is an integral part of Agilent's gallium nitride high-electron-mobility transistor (GaN HEMT) characterization, modeling and simulation solution. The GaN HEMT modeling package provides a GUI-based turnkey solution for DynaFET model generation.

Using artificial neural networks for charge and current formulations, and incorporating trapping/de-trapping and self-heating effects, the time-domain DynaFET model is capable of fitting accurately to DC, linear and large-signal measurement data — all simultaneously. This allows a single model file to be used for the design of different applications under various bias conditions, all with accurate simulation results, says Agilent.

Additional enhancements

The 2014 device modeling and characterization software release also provides new and enhanced features designed to improve productivity across the end-to-end work flow of device characterization, model generation and model validation. These enhancements include:

- a programming editor;
- faster simulation speed with major simulators;
- expanded mismatch and variation modeling solutions; and
- a streamlined and flexible user interface to create, manage, monitor and debug measurement test plans.

Agilent's 2014 device modeling and characterization software release will be available in July.

www.agilent.com/find/eesof-iccap
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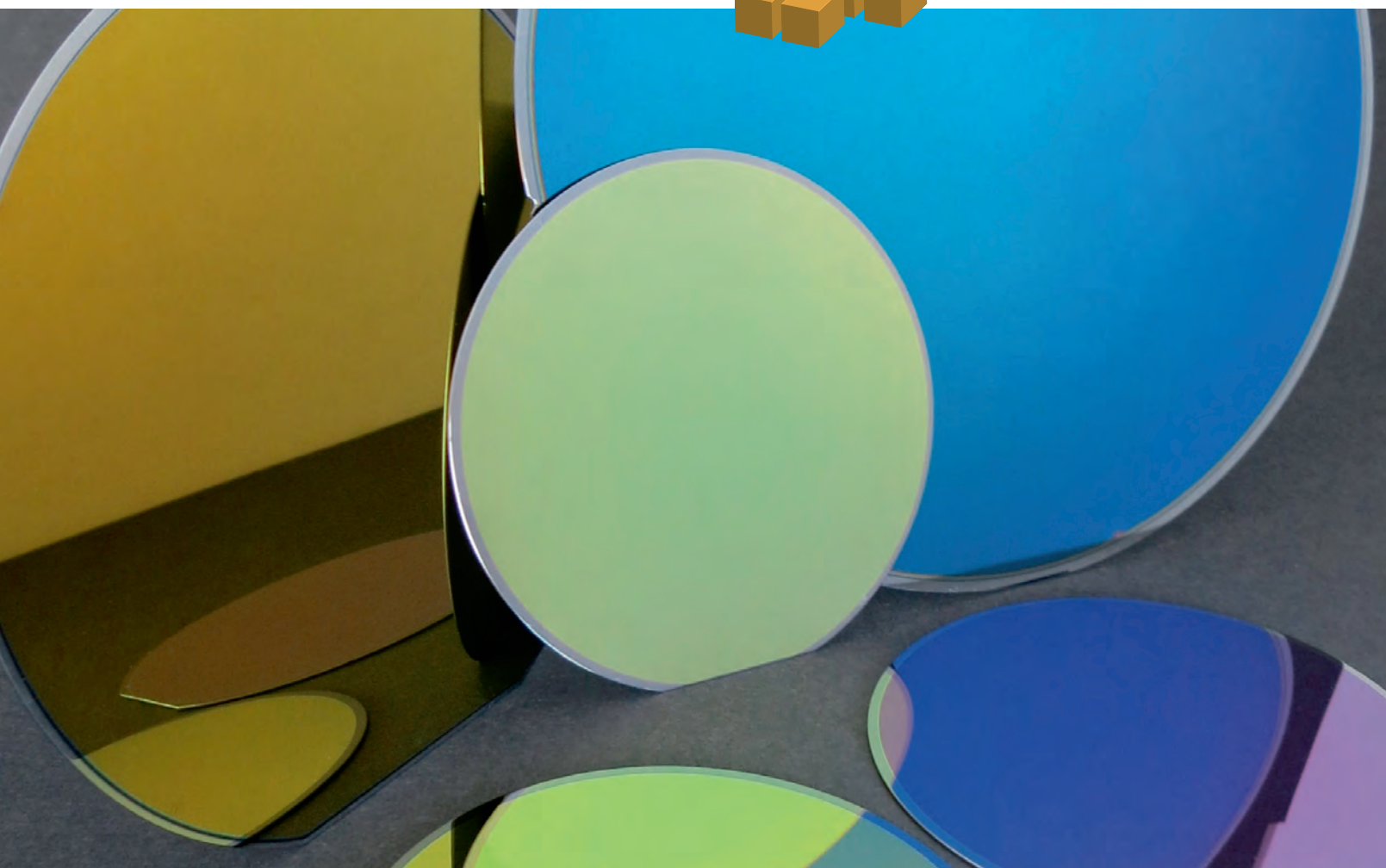

III-N MOCVD HEMT
Rare Earth Oxide (REO)
Silicon

GaN-on-Si Epiwafers

Translucent's revolutionary GaN-on-Si technology employs a patented Rare Earth Oxide (REO) layer that electrically isolates the device layers from the substrate and also provides a physical barrier to stop silicon diffusion.

- Insulating REO buffer isolates GaN from silicon
- REO enables superior high voltage device performance at a competitive price

Germanium
Silicon

Ge-on-Si Epiwafers

Translucent's germanium-on-silicon technology forms the foundation for our photonics materials and multi-junction solar cells for Concentrated Photovoltaic (CPV) applications.

- Germanium directly on silicon
- Tailored bandgap via Group IV alloys

Silex a subsidiary of Silex Systems Limited (ASX: SLX)

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IQE's first-half revenue down 17% year-on-year to £52m, but profits rise after recovery from wireless destocking

As indicated at the end of 2013, a trading statement from epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK for first-half 2014 shows revenue impacted by destocking at some major customers (due to softness in the handset market at the end of 2013 and into the start of 2014) coupled with the strength of sterling (which also had an adverse translational effect). IQE hence expects first-half revenue of about £52m, down 17% on first-half 2013's £63m. In constant currency, sales were down about 10%.

Although revenue was down, a combination of efficiency gains, economies of scale, and sales mix has improved profitability. IQE expects EBITDA (earnings before interest, taxes, depreciation and amortization) of about £11m, up 5% on first-half 2013's £10.5m. Net debt is expected to be less than £36m (cut from first-half 2013's £37.5m) despite one-off reorganization and restructuring cash costs of £3m during first-half 2014. IQE also invested in a strategic inventory build of about £2m during first-half 2014 as part of its synergy program.

"Improvement in profitability reflects the work we have done to improve efficiencies and deliver economies of scale," says CEO Dr Drew Nelson. "We remain on track to deliver further synergies during the second half," he adds. During Q2/2014, wireless demand began to recover from the customer destocking that took place earlier in the year. Customers order levels have improved, and IQE is seeing positive customer forecasts for the rest of the year. This outlook mainly reflects accelerating TD-LTE smartphone adoption in China, new handset launches, and increasing adoption of new dual-band WiFi (802.11ac). "Destocking was concluded during Q2 and customers are forecasting an upbeat second half," says Nelson.

In the photonics business, IQE expects 20% revenue growth in constant currency against first-half 2013, reflecting the transition from R&D to high-volume production, and following a number of contract wins in the past year. "Our investment in photonics technology is delivering tangible benefits, and has resulted in multiple contract wins," says Nelson. This business is primed for continuing strong performance, the firm reckons.

IQE's concentrated photovoltaic (CPV) solar business is in the final stages of qualification and remains on track to move from customer qualification to production in second-half 2014. With continued progress in the end market and a new strategic investor involved with CPV cell manufacturing partner Solar Junction Corp of San Jose, CA, USA, IQE reckons that the outlook for its engagement in this rapidly growing market looks highly attractive.

The development of advanced products including GaN materials and compound semiconductor on silicon technologies is progressing well, says the firm, with some major technical and commercial milestones being delivered in first-half 2014. These point to a transition to volume production over the next 2–3 years, reckons IQE, as these technologies replace silicon and other materials in rapidly growing markets for energy-efficient devices such as LEDs and power semiconductors.

www.iqep.com

IQE wins new volume supply deal for photonics epi

New contract guarantees IQE minimum 80% of customer's business

IQE has entered into a new multi-year volume manufacturing agreement worth over £1m a year to supply epitaxial wafers for optical communications applications.

The supply deal is with an existing key strategic customer that already has a significant presence in the Asia-Pacific including the rapidly growing market for photonics in China. The contract increases IQE's share with a guaranteed minimum of 80% of the customer's business, which is expected to be worth over £1m in additional annual revenues to IQE's photonics business unit.

IQE says customers are increasingly seeking to ensure security of supply through entering into long-term agreements to support products and devices for LTE backbone communications for base-stations, Gigabit passive optical networks (GPON) and fiber-to-the-home (FTTH) at 2.5G and 10G, migrating to 100G over the coming years.

The deal also includes scope for adding new products currently undergoing qualification, such as avalanche photo-diodes (APDs) for high-speed, long-reach detectors.

The contract takes the form of a vendor-managed inventory (VMI) agreement, enabling IQE to optimize production efficiency and manage short-term fluctuations in demand.

"IQE provides the key enabling technology that is helping to meet the ever increasing demands on optical communications driven by trends such as 'big data' and 'The Internet of Things'," says CEO Dr Drew Nelson. "As the importance of photonic applications continues to grow, customers increasingly need to ensure security of supply to meet the needs of their technology roadmaps and are seeking to enter into volume manufacturing agreements," he adds. "IQE is the global leader in wafer outsourcing and is seen by its customers as their key strategic partner to support this rapidly growing industry sector."

Riber's first-half revenue down 39% year-on-year to €4.8m

Upturn in orders at end of Q2, but firm still rolling out savings plan

For first-half 2014, Riber has reported a drop in revenue of 39% from €7.8m a year ago to €4.8m (71% from Europe, 17% from North America, and 12% from Asia). This includes €3m for Q2/2014, up 67% on €1.8m last quarter but down 41% on €5.1m a year ago.

For first-half 2014, MBE Systems revenue was €2.1m (two research systems), less than half the €4.8m a year ago. However, all of this fell in Q2/2014 (with none in Q1), in view of the difficult economic environment and a delivery plan focused on second-half 2014. In first-half 2014 Riber received orders for three systems worth a total of €3.2m which, for contractual reasons, will be delivered and billed during second-half 2014.

First-half 2014 revenue from Services & Accessories was €2.3m (down 10% on €2.5m a year ago). This comprised €0.8m in Q2 and €1.5m in Q1/2014.

First-half 2014 revenue from Cells & Sources fell slightly from €0.5m a year ago to €0.4m (€0.1m in Q2 and €0.3m in Q1).

The 13% year-on-year drop in revenue for Services & Accessories and Cells & Sources combined is attributed to the weak level of demand from industrial customers. However, this contraction has been limited by the development of sales to research centers and laboratories, driving strong year-on-year growth in the order book.

At the end of June, total order backlog was €8m (including eight systems), down 31% on €11.7m a year ago but up 21% on €6.6m at the end of March. During Q2/2014, Riber received orders for four MBE research systems(from China, Turkey and South Africa). Although the Systems order book was still down 46% on €10.2m a year ago, it rose 22% from €4.5m at the end of Q1 to €5.5m at the end of Q2. Also, an additional order for a research system (to be delivered in 2014) was recorded in July, after the end of Q2. In addition, the Services & Accessories order book rose slightly from €2m at the end of Q1 to €2.1m at the end of Q2, up 68% on €1.3m a year ago.

Our company is rolling out a savings plan in line with the situation, is reducing both manufacturing lead-times and working capital requirements with the introduction of lean manufacturing, and is further strengthening a determined commercial approach across all its product lines, including organic LEDs

The Cells & Sources order book doubled from €0.2m at the end of Q1 to €0.4m at the end of Q2 (also doubling from €0.2m a year ago).

"The first half of the year was marked by the adoption of the new Compact 21 DZ, as well as an upturn in orders at the end of the second quarter, confirming Riber's leading position for research markets," says Frederick Goutard, chairman of the executive board. "However, as these commercial achievements are not expected to offset the sharp contraction affecting industrial markets, our company is rolling out a savings plan in line with the situation, is reducing both manufacturing lead-times and working capital requirements with the introduction of lean manufacturing, and is further strengthening a determined commercial approach across all its product lines, including organic LEDs (OLED)," he adds. "Faced with a significant market downturn, Riber's management team is highly focused on facing the operational and business challenges."

Riber is also moving forward with the implementation of its diversification strategy, signing distribution agreements for thin-film deposition products with complementary technologies to MBE.

First-half earnings and the outlook for the full year will be issued on 26 September.

Riber sells third Compact 21 DZ research MBE system

Riber S.A. of Bezons, France, which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells, says it has received a purchase order for a third Compact 21 DZ research MBE system.

Previously, two systems were sold during first-half 2014, following the commercial launch of the Compact 21 DZ on the market at the end of 2013.

The system will enable a "leading European laboratory" to increase its development capabilities for designing III-V semiconductor devices.

The Compact 21 DZ system is designed specifically for fundamental research on new compound semiconductors, particularly structures based on III-V, II-VI, gallium nitride (GaN) materials, graphene, oxides, etc. Riber says that it is suited to the development of emerging technologies, such as UV LEDs or high-performance solar cells. Compact and flexible, the system is designed to meet the needs of users aiming to minimize their fixed costs.

www.riber.com

Riber distribution deal with CVD & ALD firm AnnealSys

Riber S.A. of Bezons, France, which makes molecular beam epitaxy (MBE) systems and evaporation sources and effusion cells, has signed a distribution agreement with AnnealSys SAS of Montpellier, France, which specializes in vapour-phase chemical deposition processes.

AnnealSys designs and produces rapid thermal annealing (RTA) furnaces and chemical vapour deposition (CVD) and atomic layer deposition (ALD) systems, which make it possible to deposit complex materials for a wide range of applications, from semiconductors to solar cells, LEDs and microsystems.

AnnealSys' equipment is aimed primarily at research laboratories and universities, while also meeting the needs of industrial operators for producing small batches. Founded in 2004, the firm has built up unique CVD and ALD expertise, particularly for the integration of direct liquid injection vaporizers, making it possible to implement a wide variety of chemical precursors and to develop processes for growing new materials.

Initially, the partnership between Riber and AnnealSys will focus on CVD and ALD products and the American and Asian regions.

With this commercial agreement, AnnealSys is aiming to accelerate its sales growth internationally by capitalizing on Riber's sales capabilities and reputation in the research community.

Riber says the agreement represents an opportunity for it to continue moving forward with its technical diversification into other thin-film deposition techniques. The firm says that the commercial partnership will strengthen the range of equipment and services that it offers. The development is also in line with the diversification strategy presented to shareholders at the latest general meeting.

www.annealsys.com

Riber announces changes to boards

In June, Riber acknowledged the resignation, for personal reasons, of Noel Goutard as a supervisory board member.

The supervisory board also decided to not renew the terms of office of Pierre Bouchaïb and Michel Picault as management board members. Bouchaïb was invited to sit on the management board as a guest until he retires at the end of 2014.

Although the number of members serving in the executive bodies is still higher than legally required, the supervisory board is looking into several options for replacements.

www.riber.com

Veeco expands R&D portfolio by partnering with Agnitron

Refurbished systems & upgraded software control for materials research

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has formed a strategic partnership with Agnitron Technology Inc of Eden Prairie, MN, a focused compound semiconductor R&D company specializing in the refurbishment and upgrade of Veeco legacy metal-organic chemical vapor deposition (MOCVD) equipment.

The partnership will allow universities and institutions to obtain low-cost, reliable MOCVD systems for materials R&D applications. Also, Veeco R&D MOCVD system users will be able to upgrade to Agnitron's IMPERIUM software platform and have access to the firm's technical support team.

"Veeco's technology has served the compound semiconductor R&D and mass-production markets for decades," says William J. Miller, Ph.D., executive VP of Veeco Process Equipment. "We are taking the next step to expand our R&D reach with Agnitron's combined MOCVD refurbishment capabilities and differentiated software solutions," he adds. "Together, we are launching compelling product offerings to a customer base that we know extremely well – leading research universities and labs around the world."

IMPERIUM control software is available as an upgrade on Veeco's legacy Discovery and Explorer Series MOCVD systems, providing increased functionality, productivity and support from the legacy EpiView software. As a Veeco Certified Partner, Agnitron will leverage Veeco's worldwide sales and service to expand its reach beyond the North American market.

"Partnering with a compound semiconductor equipment leader like Veeco allows us to meet the increasing worldwide demand for highly capable, low-cost MOCVD solutions in the R&D space," says Agnitron's president & CEO Dr Andrei Osinsky. "Veeco's customer connectivity will open doors to new markets in need of complete turnkey MOCVD solutions that are available with matched system components based on specific system and process needs."

Veeco and Agnitron exhibited at the 17th International Conference on Metal Organic Vapor Phase Epitaxy (ICMOVPE) in Lausanne, Switzerland (13–18 July).

www.agnitron.com

Agnitron shipping 1500°C reactor upgrade for Veeco D180 system

Agnitron is shipping its latest 1500°C+ reactor upgrade for the Veeco MOCVD D-series Legacy System platform. The single 2"- or 3"-wafer, vertical quartz tube reactor upgrade will be fitted to a D180 system at the Korean Photonics Technology Institute (Kopti) in Gwangju, Seoul, South Korea. The upgrade shipped in July after completion of final preshipment verification testing. Installation and configuration of Agnitron's proprietary Imperium-MOCVD control software is included as a standard feature with the high temperature reactor upgrade.

Agnitron says that the high-temperature radio-frequency (HT-RF) reactor upgrade provides an economical high-temperature growth capability to researchers aiming for the highest-quality aluminium nitride (AlN) epitaxial films, which are grown at process temperatures above 1400°C. In addition, the HT-RF reactor can grow all nitride-based materials and is also suitable for silicon carbide (SiC).

"Ultra-low gas flows of the HT-RF reactor translate to hydride gas consumption 15% that of a D180 reactor, making this a very capable yet economical choice for researchers," reckons Ross Miller, director of Agnitron's technology development, who also mentions that atomic layer deposition (ALD)-style switching manifolds are available as an option for supporting migration-enhanced epitaxy growth techniques.

Currently, the HT-RF reactor is offered as a standalone upgrade for the Veeco Legacy D125 and D180 nitride MOCVD platforms as well as in the form of an Agnitron original design complete MOCVD system known as Agilis. The Agilis provides all the process capabilities of the HT-RF reactor but in a cabinet with all-new electronics and digital hardware communication protocols. The system also provides a much more compact footprint than the D-series Veeco platforms.

An identical HT-RF reactor upgrade is currently in operation at Agnitron's facility for the growth of AlN as part of the power electronics research program 'Investigation of Donor and Acceptor Ion Implantation in AlN' funded in May by the US Department of Energy (DoE) under its Small Business Innovation Research (SBIR) program.

Agnitron partners with 3L

The HT-RF D180 Reactor Upgrade is being supplied to Kopti with the support of 3L Corp in Korea. Agnitron says that 3L is the only company based in Korea offering the combination of MOCVD hardware, process and gallium nitride growth support. 3L's experience with MOCVD includes more than 100 MOCVD system installations as well as many system relocations, with a proven record of providing services for stable MOCVD system operation since 2010. 3L is the exclusive supplier in Korea for Agnitron's HT-RF reactor upgrade and Agilis systems.

www.3Lcorp.co.kr
www.agnitron.com
www.veeco.com

Veeco partners with software provider Rudolph

Technology-specific software to aid user productivity & equipment CoO

Veeco Instruments Inc of Plainview, NY, USA has formed a strategic partnership with Rudolph Technologies Inc of Flanders, NJ, USA, which provides defect inspection, process control metrology, and data analysis systems and software. The collaboration allows users of Veeco's etch and deposition equipment access to Rudolph's fault detection and predictive maintenance software to increase system productivity and improve manufacturing efficiency.

As part of the partnership, Rudolph and Veeco will also develop technology-specific software solutions that work in unison with Veeco's existing software to enhance tool performance for its new etch and deposition equipment, as well as upgrades for Veeco's large global installed base. Rudolph's software framework applies to many tool types and processes. When combined with Veeco's tools and system knowledge, the software optimizes real-time and historical data, freeing system users from manual monitoring of equipment and processes, Veeco says.

"Aggregating data is essential to improving yields, maintaining system up-time and lowering production costs," says Guy Shechter, vice president, Veeco Certified Equipment and Services Marketing. "Rudolph's software platform supports Veeco's goal of delivering innovative high-performing etch and deposition systems," he adds. "We expect to optimize equipment production, prevent process failures and anticipate maintenance work more efficiently."

The scalable software system architecture is flexible enough to use in a variety of high-tech manufacturing environments, allowing OEMs to optimize equipment productivity for their target markets and applications. Rudolph currently has thousands of software monitoring tools in hundreds of different process areas worldwide, enabling users to run more efficiently and achieve higher yields, the firm says.

"Partnering with a capital equipment leader like Veeco demonstrates the importance of yield analysis and data-mining in maximizing production results, not just for fabs but also for top OEMs," says Michael Plisinski, VP & general manager of Rudolph's Data Analysis and Review business unit. "By combining Veeco's process know-how and equipment knowledge with our tailored software solutions, the partnership will help Veeco improve their customer's bottom-line results through more efficient manufacturing."

www.rudolphtech.com
www.veeco.com

Veeco brokerage site for pre-owned MOCVD, PVD & IBE equipment

Veeco has introduced the Veeco MarketPlace website, an original equipment manufacturer (OEM) brokerage website that helps both buyers and sellers determine fair prices for pre-owned Veeco metal-organic chemical vapor deposition (MOCVD), physical vapor deposition (PVD) and ion beam etch (IBE) equipment. The site will also feature assets from Veeco Certified Partners, such as secondary equipment supplier SurplusGLOBAL Inc, to further expand the inventory levels of ready-to-purchase used equipment.

The Veeco Marketplace site brings together buyers and sellers to view, sell and buy pre-owned Veeco equipment on a protected website. All equipment posted on the website is eligible for Veeco service, including pre-purchase assessments and logistical services, which are available exclusively through Veeco.

"The Veeco MarketPlace provides an easy-to-use platform that is specifically designed to produce transparent and fair transactions," says Veeco executive vice president William J. Miller Ph.D. "As the OEM and market leader in MOCVD and other etch and deposition technologies, Veeco is uniquely qualified to add value to pre-owned systems by providing thorough assessments, rigorous equipment testing and quick installations," he adds.

The Veeco MarketPlace allows potential buyers to gain visibility to available pre-owned equipment in the market and decide whether to purchase it as-is or with Veeco value-added services. The services include equipment audits, refurbish-and-repair programs, upgrades and relocation services. Sellers post their assets on the site and have access to Veeco's worldwide dedicated sales team who market and promote the full value of the asset to a specific target market.

"With this new site, sellers gain access to their targeted customers through and with OEM support, and buyers can make quick, informed decisions on prices and purchases," notes Guy Shechter, VP, Veeco Certified Equipment and Services Marketing. "Once the buyer and seller agree on the fair market value for the asset, Veeco can provide valuable services and upgrades to extend the life and improve the productivity of the system."

The Veeco MarketPlace website features user-friendly navigation, including easy product search pull-down menus and keyword search fields. Product details include descriptions, photographs, country of origin and condition of the equipment.

www.veecomarketplace.com
www.surplusglobal.com

Enkris uses Aixtron MOCVD system to demonstrate high-voltage GaN HEMT structures on 200mm silicon

Enkris Semiconductor Inc of Suzhou, Jiangsu, China has demonstrated the manufacture of high-voltage gallium nitride high-electron-mobility transistor (HEMT) structures on 200mm silicon (GaN-on-Si) using a metal-organic chemical vapor deposition (MOCVD) system from Aixtron SE of Aachen, Germany. Enkris' main products are GaN epiwafers for electronics applications including both wireless communications and high-voltage power switching devices.

GaN-on-Si power devices have attracted much attention from both academics and industry because of their potential applications in power electronics, says Aixtron. Due to the defective nature of hetero-epitaxial GaN layers grown on silicon, GaN-on-Si power devices have suffered from high buffer leakage. Most recently, Enkris has produced high-voltage GaN HEMT materials on 200mm silicon with what is said to be excellent uniformity and low buffer leakage combined with thickness uniformity of <0.5% without edge exclusion. Under special conditions, the uniformity value can be improved even further, it is reckoned.

"It has been well accepted that GaN on large-size silicon substrates is the most cost-effective way to achieve high-volume production of GaN power devices. However, a large wafer bow combined with a high buffer leakage has hindered the further development of the GaN-on-Si technology so far," says Enkris' co-founder Dr Cheng Kai. "Our process on 200mm silicon substrates shows that high break-down voltage (less than 1600V) GaN power devices with low leakage currently can be achieved with relatively thin buffer layers of 4µm. They simplify the growth process, minimize the wafer bow and reduce the epi-cost significantly," he adds. "Based on our processes, which were applied on an Aixtron system, GaN-on-Si power devices may reach even higher voltages in the near future," Kai reckons.

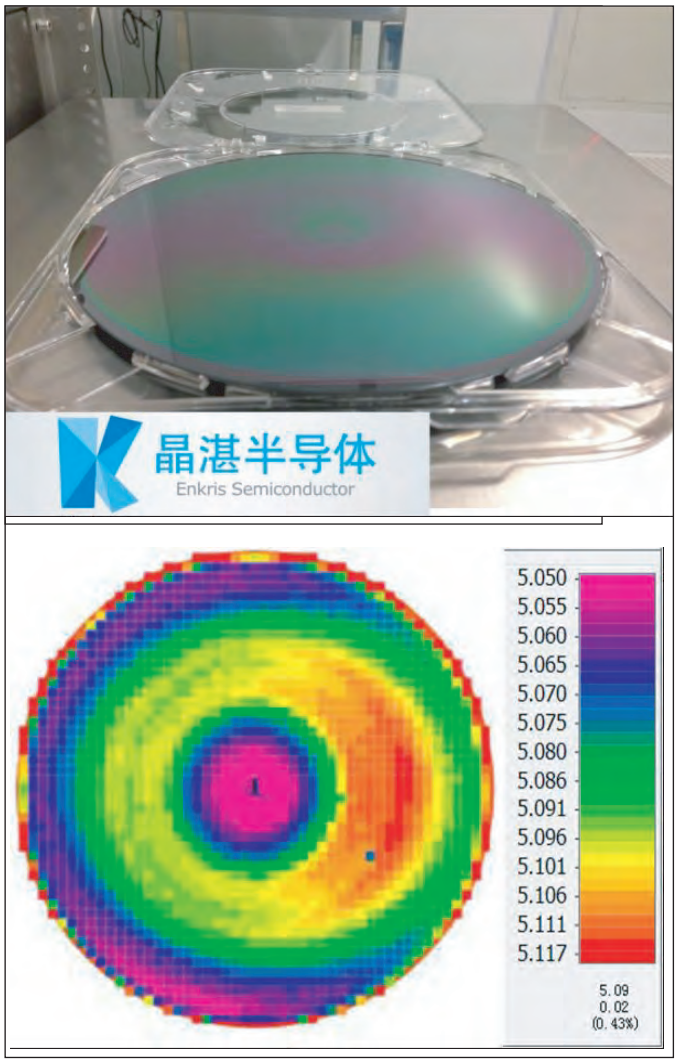


Figure 1: Thickness mapping of 200mm GaN-on-silicon wafers.

"Enkris' remarkable success in achieving excellent layer quality and material properties show the capability of our technology for high-voltage GaN HEMT applications," says Dr Frank Wischmeyer, vice president of Power Electronics at Aixtron. "Our MOCVD technology is enabling the integration of wide-bandgap semi-conductors on large-diameter silicon substrates," he adds. "Aixtron is committed to support the power electronics industry advancing toward high-volume 200mm GaN-on-Si device manufacturing."

www.enkris.com
www.aixtron.com

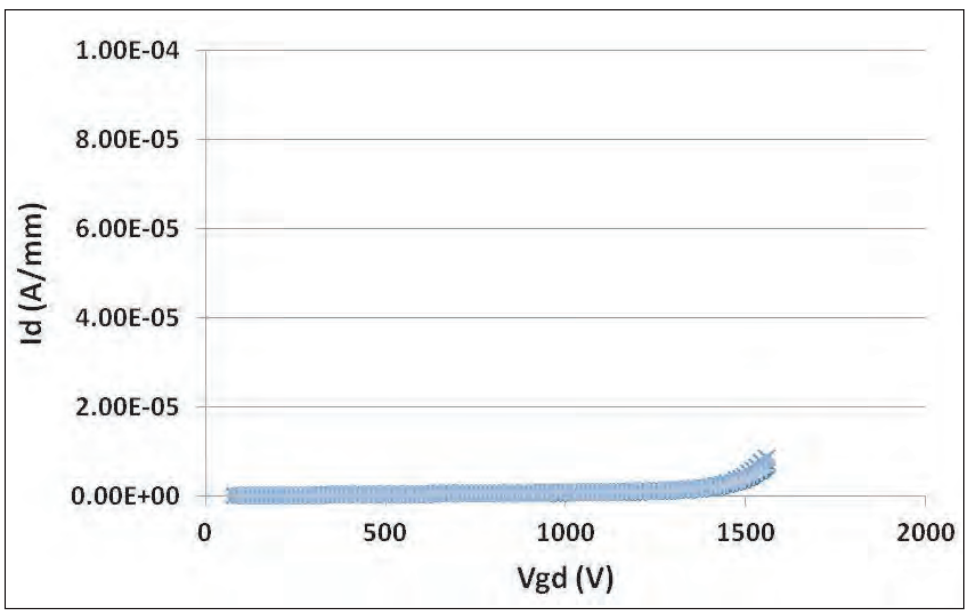


Figure 2: Current leakage of devices fabricated on 200mm GaN-on-Si.

Finisar buys Aixtron system for capacity expansion and development of new InP-based products

Deposition equipment maker Aixtron SE of Aachen, Germany says that optical communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA has ordered an AIX 2800G4-TM metal-organic chemical vapor deposition (MOCVD) system for the design and manufacture of tunable lasers, high-speed modulators and photonic integrated circuits (PICs) at its facility in Järfälla, near Stockholm, Sweden (which focuses on active optical components such as tunable lasers).

"We need an MOCVD system to support our plans for capacity expansion," says Patrik Evaldsson, VP & general manager, Finisar Sweden. "In our selection, it was important that the system should also support our focus on developing new, more highly integrated indium phosphide products," he adds.

The system should also support our focus on developing new, more highly integrated indium phosphide products

"Finisar Corporation is already very familiar with Aixtron's Planetary Reactor technology, as several tools are currently in production for lasers and photodetectors," comments Dr Frank Schulte, vice president Aixtron Europe. The order from Finisar for another G4 means the continuation of the firms' long-standing cooperation, he adds.

www.finisar.com
www.aixtron.com

IN BRIEF

LayTec signs Jsun International as sales and service partner for PV metrology in China

In-situ metrology system maker LayTec AG of Berlin, Germany has signed an agreement with Jsun International Ltd of Suzhou, China regarding sales and service cooperation in the China photovoltaics (PV) market.

Jsun is a well established distributor of advanced production equipment for solar cells and modules.

LayTec says that, through cooperation with JSun International, it will be able to provide its Chinese PV customers with superior metrology tools and services.

www.laytec.de

Oxford Instruments' Nanotechnology Seminar at China's Institute of Semiconductors to start with 2D materials

UK etch and deposition equipment maker Oxford Instruments' seminar at the Institute of Semiconductors, Chinese Academy of Sciences (IOS-CAS) in Beijing (24–25 September) will discuss nanotechnology solutions for multiple applications, starting with half-day plenary sessions on 2D materials with guest plenary speaker Dr Aravind Vijayaraghavan from the National Graphene Institute in Manchester, UK, and on Quantum Information Processing with guest plenary speaker professor David Cory from the Institute for Quantum Computing, University of Waterloo, Canada.

Two parallel sessions will focus on thin-film processing and materials characterization, surface science and cryogenic environments, and a wide range of topics will be covered within each technical area. These sessions will include guest international and Chinese speakers from research institutions, speakers from the host institute, and technical experts from Oxford Instruments.

Confirmed speakers include the following (with more to be announced soon):

- Dr Aravind Vijayaraghavan, National Graphene Institute, Manchester, UK;
- professor David Cory, Institute for Quantum Computing, University of Waterloo, Canada;
- professor Guoxing Miao, Institute for Quantum Computing, University of Waterloo, Canada;
- professor He Ke, Tsinghua University, Institute of Physics, CAS, China;
- Dr Wang Xiaodong, Institute of Semiconductors, CAS, China;
- professor Erwin Kessels, Technische Universiteit Eindhoven (TU/e), The Netherlands;
- professor Zeng Yi, Institute of Semiconductors, CAS, China;
- professor Robert Klie, University of Illinois Chicago, USA;
- professor Xinran Wang, Nanjing University, China; and
- professor Zhihai Cheng, National Centre for Nanoscience and Technology, China.

The thin-film processing sessions will review the latest technical advances in etch and deposition, including: atomic layer deposition (ALD), magnetron sputtering, inductively coupled plasma (ICP) plasma-enhanced chemical vapor deposition (PECVD), nanoscale etch, micro-electro-mechanical system (MEMS), and molecular beam epitaxy (MBE).

Materials Characterization, Surface Science and Cryogenic Environment sessions will cover multiple topics and technologies including: ultra-high-vacuum scanning probe microscopy (SPM), cryo-free low-temperature solutions, x-ray photoelectron spectroscopy (XPS)/electron spectroscopy for chemical analysis (ESCA), an introduction to atomic force microscopy (AFM) and applications such as nanomechanics, in-situ heating and tensile characterization using electron backscatter diffraction (EBSD), measuring layer thicknesses and compositions using energy-dispersive spectroscopy (EDS), nanomanipulation and fabrication within the scanning electron microscope (SEM)/focused ion beam (FIB) system.

"This seminar has been extremely well organised with competent speakers covering a variety of processes and tools for nanofabrication," comments the host of last year's Nanotechnology Tools seminar in India, professor Rudra Pratap (chairperson at the Centre for Nano Science and Engineering, Indian Institute of Science, IISC Bangalore). "It is great to have practitioners of the art give talks and provide tips and solutions based on their experience, something that cannot be found in text books," he adds.

"This workshop is a great opportunity for a wide range of scientists in research and manufacturing to discover practical aspects of many new and established processes, technologies and applications, directly from renowned scientists and a leading manufacturer with over 50 years in the industry," comments Mark Sefton, sector head of Oxford Instruments NanoSolutions. "Delegates appreciate the informal workshop atmosphere of these events, encouraging delegates to participate through open discussion and sharing their questions and experiences."

www.oxford-instruments.cn/

Grünwald buys controlling stake in SEMSYSCO

Grünwald Equity Group of Grünwald, Germany (a group of long-term equity investors with experience in actively developing medium sized companies) has acquired a controlling interest in wet processing equipment maker SEMSYSCO Semiconductor Systems Corporation GmbH of Salzburg, Austria from The Thompson Group Inc of Kalispell, MT, USA.

"The investment by Grünwald Equity secures the company's access to capital for supporting the growth of the existing portfolio as well as the planned expansion of products in the fields of advanced packaging and automotive power semiconductor applications," says Herbert Ötzlinger, CEO and shareholder of SEMSYSCO.

"In the recent months we have been impressed both by the highly customer-oriented approach of SEMSYSCO and the responsive time-to-market for the company's products," comments Grünwald Equity's managing partner Max Graf von Moy.

www.semsysco.com

Morgan Advanced Materials announces improved CVD SiC and pBN ceramic materials

Morgan Advanced Materials has announced advances in its Technical Ceramics business' range of materials grown using chemical vapor deposition (CVD) processes. Its CVD silicon carbide (SiC) and pyrolytic boron nitride (pBN) materials suit applications including rapid thermal processing (RTP) and plasma etch process chamber components, plus metal-organic CVD (MOCVD) tools for high-brightness white LED manufacturing using indium gallium nitride (InGaN).

Morgan says that its improved CVD SiC growth capability enables the manufacture at production volumes of components with diameters of 300mm+ and thicknesses of more than 10mm for recently developed plasma etch applications. Through access to ultrasonic machining capability, Morgan offers high-tolerance CNC machining and precision hard grinding, as well as the patented Rmax process for producing focus CVD SiC ring shapes.

Morgan says that its high-purity (99.999%+) SiC material has high thermal conductivity, is resistant to chemical erosion, and features minimal particulate generation, making it suitable for use in chlorine and fluorine plasma etch processes. The material is suited for use in producing GDMs (gas distribution plates) where the material's erosion resistance can lead to long life and extended tool PM (preventative maintenance) schedules. Ultrasonic drilling can provide holes with diameters as small as 0.5mm, for custom etch applications.

CVD SiC and pBN materials suit applications including RTP and plasma etch process chamber components, plus MOCVD tools

High-purity (99.99%+) PBN materials have a working temperature in excess of 1500°C, and feature high electrical resistivity and high dielectric strength. Since they have extremely low out-gassing and are non-wetting and non-toxic, the PBN materials are inert to most acids, alkalis and organic solvents and have high thermal conductivity in the 'a' direction. The materials are suitable for manufacturing PBN-coated graphite heaters and PBN effusion cell components,

www.mtccvdmaterials.com/cvd

ClassOne opens wet-process applications lab

Customers to be able to develop wet-chemistry applications on 100–200mm substrates

At the Semicon West show in San Francisco, wet-chemical equipment maker ClassOne Technology of Kalispell, MT, USA announced the opening of a major new cleanroom and applications lab in Atlanta, Georgia. The Class 100 facility will focus specifically on wet chemical processing such as electroplating, metal lift-off, resist strip, polymer removal, front-end-of-line (FEOL) and back-end-of-line (BEOL) cleaning, dielectric and metal etching etc. The new lab will complement ClassOne's existing metrology cleanroom lab in Atlanta, considerably expanding the total size and capabilities of the facility.

"In addition to a broad array of wet-processing tools, the lab also provides a full complement of metrology equipment and instrumentation, which allows users to measure and analyze defects, film thickness, film stress and virtually all the other features and qualities of dielectric and metal films," says Kevin Witt, ClassOne's VP of Technology. Also, if additional analysis is needed, ClassOne has access to the lab at the Institute for Electronics and Nanotechnology at nearby Georgia Institute of Technology (Georgia Tech).

ClassOne says that its new facility will enable customers to explore and develop wet-chemistry applications on all types of substrates in all sizes from 100 to 200mm. The lab will also serve as a working showcase of ClassOne Technology's own wet-processing tools, including electroplating, SAT (spray acid tool), SST (spray solvent tool) and SRD (spin rinse dryer) systems. Customers will be able to evaluate equipment first hand and 'try before they buy'. In addition, the new facility will provide ClassOne with a laboratory for developing, testing and enhancing its new equipment.

ClassOne launches electroplating tool for smaller-substrate users

Wet-chemical equipment maker ClassOne Technology of Kalispell, MT, USA has launched its Solstice line of electroplating tools, designed specifically for the smaller-substrate users in emerging technologies such as MEMS, LEDs, power devices, RF communications, interposers, photonics and microfluidics. The price of Solstice is less than half of equivalent 300mm tools from the large manufacturers, the firm claims.

"The bigger equipment companies have focused on building ever-smaller devices on ever-larger substrates," says ClassOne's VP of technology Kevin Witt. "They've been serving the market segment that buys expensive high-end tools — but they've left the cost-conscious 100-200mm people behind. Up till now, the smaller-substrate users either had to buy used equipment or pay top dollar to get the big manufacturers to build them a 200mm-or-smaller plating tool," he adds.

"This is literally the first automated plating tool that can deliver advanced performance on smaller substrates at affordable prices," claims ClassOne's president Byron Exarcos.

ClassOne's new Solstice LT system.

The Solstice comes in two models. The fully automated cassette-to-cassette Solstice S8 provides up to eight process chambers for throughputs up to 75wph (wafers per hour), with system prices starting at $1m. The semi-automated Solstice LT features one or two chambers for development and pilot lines, with systems starting at $350,000. So, emerging technology users now have an affordable, scalable path from wet bench to volume production and higher return on investment (ROI), says the firm.

The plating equipment enables multiple types of metal deposition with chemical pre-wet, etch, rinse and drying processes, all on a single-wafer automated system — and all driven by the long-proven Solaris controller on a Windows 7 platform. The result is plating performance in a flexible, modern tool that's designed — and priced — for smaller users and emerging technologies, says the firm.

Formed in early 2013 as a sister company to refurbished process tool supplier ClassOne Equipment (which has over 2500 systems installed), ClassOne Technology's charter is to provide innovative systems to smaller-substrate users.

www.ClassOne.com

Avantor highlights new cleaning chemistries

At the SEMICON West 2014 trade show in San Francisco (8–10 July), Avantor Performance Materials of Center Valley, PA, USA highlighted advancements in electronics process chemistries, including two new products for photoresist and post-etch residue removal.

Avantor's electronic chemicals and materials are sold under the company's J.T.Baker brand and are used in front end of line (FEOL), back end of line (BEOL) and far BEOL surface treatment, including selective etch, post-etch residue removal, photoresist stripping and other manufacturing processes.

The new products extend Avantor's J.T.Baker CLκ and ALEG product lines to further serve the emerging needs of semiconductor, LED and MEMS manufacturing:

- J.T.Baker ALEG-368 NMP-free organic film stripper and residue remover for lines, via and bond pad cleaning is developed for technologies containing aluminium interconnects. The ALEG-368 formulation removes ash residue, sidewall polymers, and bulk photoresist, and is NMP-free in response to environmental and regulatory concerns. The material is proven for LED applications, supports the integration of environmental, health & safety (EH&S) roadmaps, and allows for process optimization and cost reduction programs.
- J.T.Baker CLκ-228 photoresist stripper and post-etch residue remover for advanced copper technologies. Proven for 1x nm technology nodes, CLκ-228 enables advanced material integration in BEOL through its ability to remove fluorocarbon-based etch residues. A second product feature is efficient photoresist removal, providing fast throughput for any photoresist rework needs in multiple patterning processes. CLκ-228 is compatible with porous low-κ dielectrics, including etch-damaged low-κ, enabling CD retention. Processed and filtered to 12nm, it yields very low liquid particle counts (LPC). CLκ-228 is compatible with copper, tungsten, and titanium nitride.

"The additions to our CLκ and ALEG product families are a direct result of productive collaborations with our customers," says Gary Dailey, VP of global marketing for Avantor's Electronic Materials business. "Customers choose to collaborate with us because of our expertise in advanced cleaning chemistries, our world-class applications centers, and the J.T.Baker brand's history of performance and reliability."

Also at SEMICON West, Avantor showcased its technical capabilities and resources to help semiconductor tool builders and fab operators meet their process improvement goals more quickly and speed up ramp time to the next node.

www.avantormaterials.com/Electronic-Materials

CyberOptics extends airborne particle sensor line to 150mm

At SEMICON West in San Francisco (8–10 July), CyberOptics Corp of Minneapolis, MN, USA (which provides inspection and sensing systems for electronics assembly and semiconductor process equipment) showcased its most efficient and effective wireless measurement devices for chamber gapping, leveling, wafer handoff teaching, vibration and airborne particle measurement.

CyberOptics demonstrated the new ReticleSense airborne particle sensor (APSR), which is an extension of the wafer-shaped WaferSense airborne particle sensor (APS) line adopted by major fabs and OEM equipment makers worldwide.

To address the market demand for airborne particle measurement in 150mm silicon and GaAs fabs as well as LED fabs in China, Europe, Japan, the USA and Taiwan, CyberOptics also announced an extension of its APS line to include a 150mm wafer form factor.

With APS technology, equipment engineers can quickly and wirelessly monitor, identify and troubleshoot airborne particles in real-time within semiconductor process tools and automated material handling systems. WaferSense and ReticleSense airborne particle sensors enable engineers to shorten equipment qualification, release to production and maintenance cycles, all while reducing costs, claims CyberOptics. By using the WaferSense APS, customers have experienced up to 88% time savings, up to 95% reduction in costs, and up to 20x the throughput with half the manpower resource requirements relative to legacy surface scan wafer methods, the firm reckons.

"Minimizing airborne particles in the semiconductor industry and other markets operating under stringent manufacturing quality and productivity standards is critical," says president & CEO Subodh Kulkarni. "CyberOptics is delivering on our customers' needs for airborne particle measurement in various form factors that help improve fab productivity while continuing to reduce costs," he adds.

The accuracy, precision and versatility of the specialized WaferSense and ReticleSense measurement portfolio can enable improvements in fab yields and equipment uptime for semiconductor fabs and OEMs, says CyberOptics.

WaferSense measurement tools including the Auto Leveling System (ALS), the Auto Gapping System (AGS), the Auto Vibration System (AVS), the Auto Teaching System (ATS) and Airborne Particle Sensor (APS) are available in 150, 200, 300 and 450mm wafer sizes. The ReticleSense Airborne Particle Sensor (APRS) and Auto Leveling System (ALSR) products are available in a reticle-shaped form factor.

www.cyberoptics.com

Orbotech acquiring SPTS for $370m

Orbotech Ltd of Yavne, Israel (which makes production equipment for manufacturers of printed circuit boards, flat-panel displays and other electronic components) has signed a definitive share purchase agreement to acquire plasma etch, deposition and thermal wafer processing equipment maker SPTS Technologies Group Ltd of Newport, Wales, UK from European private equity firm Bridgepoint and others for about $370m in cash (including repayment or assumption of debt).

SPTS offers plasma etch, physical vapor deposition (PVD), chemical vapor deposition (CVD) and thermal wafer processing solutions for the advanced packaging, micro-electro-mechanical systems (MEMS), LED, high-speed RF on GaAs, and power management device markets. The firm has manufacturing facilities in Allentown, PA and San Jose, CA, USA, as well as in Newport. Through the acquisition, Orbotech expects to accelerate the execution of its growth and diversification strategy, and is moving up the electronics value chain. The firm expects that, by building on SPTS' technological and commercial position, it will be able to offer solutions for a broad range of demanding micro manufacturing applications. Also, the combination should expand Orbotech's presence in Europe and North America and provide SPTS with greater reach in the Pacific region, particularly China.

"Orbotech identified advanced packaging as a strategic and natural extension of its business into an adjacent high-growth market," says Orbotech's CEO Asher Levy. "SPTS benefits from established, long-standing partnerships with major industry players. It is a well-known and highly respected brand with deep domain expertise in those segments in which it operates. Acquiring SPTS allows us to accelerate the expansion into advanced packaging, with multiple manufacturing solutions ideally suited for this growing segment," he adds. "By combining the extensive know-how and core assets of both companies we will continue to enhance Orbotech's portfolio and industry leadership while focusing our efforts on driving profitable growth," Levy concludes.

"Together, we will be a powerhouse of expertise in micro manufacturing, providing a broad solution set of mission-critical capabilities to serve designers and manufacturers across the dynamic electronics industry landscape," reckons SPTS' president & chief operating officer Kevin Crofton. "We are excited about the opportunity to leverage Orbotech's strong presence in the Pacific as well as its products and technologies," he adds.

"Clear market leadership of high-growth niches as well as the application of its technology to emerging niches in the microchip industry have made SPTS strategically attractive," comments Christopher Bell, a partner at Bridgepoint. "With its new shareholder, the business will be well positioned to combine expertise in micro manufacturing to advance further."

The acquisition and related costs are expected to be financed through a combination of cash on hand and about $300m in debt financing under a new term loan facility. The acquisition and financing are expected to close during of third-quarter 2014, each subject to certain closing conditions.

In 2014, under UK GAAP and on a standalone basis for the full year, SPTS is expected to generate revenue of about $180m, gross margin of 48%, and (earnings before interest, taxes, depreciation, and amortization (EBITDA) margin of 25% of its revenue. The acquisition of SPTS is expected to be accretive to Orbotech's non-GAAP earnings immediately after closing and GAAP accretive in 2015. After closing, SPTS' financial statements will be converted to US GAAP to be consistent with Orbotech's financial statements.

Based on Orbotech's and SPTS's financial condition as of end-March, Orbotech estimates that, post closing, it will have about $100m of cash and cash equivalents on an adjusted basis.

www.orbotech.com
www.spts.com

Retiring SPTS CEO to remain non-executive director of BluGlass

BluGlass Ltd of Silverwater, Australia says that its board was notified on 7 May of the sale of plasma etch, deposition and thermal wafer processing equipment maker SPTS Technologies Ltd of Newport, Wales, UK to Orbotech Ltd of Yavne, Israel (which makes production equipment for manufacturers of printed circuit boards, flat-panel displays and other electronic components). SPTS is a substantial shareholder in BluGlass, holding 19.9% of the issued shares.

BluGlass says that Orbotech is at the cutting edge of the electronics industry supply chain, as an innovator of enabling technologies used in the manufacture of consumer and industrial products.

Dr William Johnson has confirmed his commitment to remain as a non-executive director of BluGlass following his retirement as CEO of SPTS.

The board of BluGlass says that it looks forward to developing a constructive relationship with Orbotech over the coming months.

www.bluglass.com.au
www.orbotech.com
www.spts.com

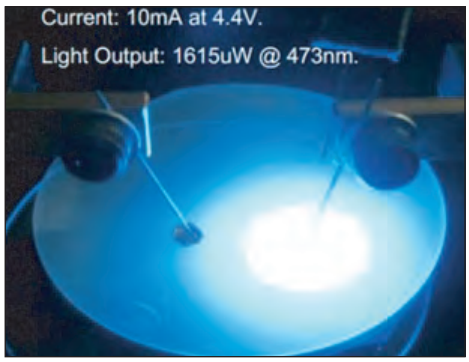
BluGlass demonstrates 10-fold improvement in RPCVD p-GaN light output

Next-generation RPCVD system growing GaN in July

BluGlass Ltd of Silverwater, Australia has demonstrated what it says is the best ever p-GaN light output using its propriety remote-plasma chemical vapor deposition (RPCVD) technology on an metal-organic chemical vapour deposition (MOCVD) partial LED structure. This is a more than 10-fold improvement in LED efficiency over the first p-GaN demonstration data that it reported in December 2012, when the same measuring methodology is applied.

This has been achieved by making improvements in addressing the 'interface challenge', a key technical hurdle that has been limiting the p-GaN performance demonstration in the past.

Spun off from the III-nitride department of Macquarie University of Sydney, Australia in 2005, BluGlass developed a low-temperature process using RPCVD to grow materials including gallium nitride (GaN) and indium gallium nitride (InGaN) on glass substrates, potentially offering cost, throughput and efficiency advantages for the production of LEDs and concentrated solar cells.



Light emission at 473nm (with full width half maximum of 22nm) from RPCVD p-GaN layer grown on MOCVD partial structure.

BluGlass says that the recent breakthroughs are the result of the enhanced plasma system in combination with new process steps that are now yielding continual performance improvements as the firm furthers progress towards its 'Brighter LEDs' milestone.

"The RPCVD p-GaN based LED performance in the last month has undergone a step change improvement," notes chief technology officer Dr Ian Mann. "This has been achieved by focusing on two key aspects — the process steps for initiating the RPCVD p-GaN growth; and in finalizing the last layers grown by MOCVD – in effect, making sure the RPCVD and MOCVD steps are compatible," he adds. "Following these recent developments, we are confident that the team is on the right path to demonstrate that low-temperature RPCVD can enhance the performance of LEDs fabricated solely by MOCVD today." BluGlass aims to demonstrate that an RPCVD top layer (the p-GaN layers) can improve the light output of an LED.

Additionally, the firm's BLG-300 next-generation RPCVD system is nearing completion and was due to be growing GaN later in July. This ex-production-scale system is significantly larger than the current R&D workhorse and will effectively double BluGlass' R&D capacity. The firm says that having multiple RPCVD systems will greatly enhance the team's capability to address the LED milestones, the scaling of the technology towards 8" wafer deposition, and the potential performance advantages of a low-temperature CVD process for GaN-on-silicon.

www.bluglass.com.au

SPTS' president & COO Kevin Crofton elected to SEMI's board

Kevin Crofton, president & chief operating officer of plasma etch, deposition and thermal wafer processing equipment maker SPTS Technologies Ltd of Newport, Wales, UK, has been elected to the board of directors of global industry association SEMI International (which serves the nano- and micro-electronic manufacturing supply chains). His appointment, along with three other newly elected directors, was announced at the annual SEMI membership meeting during the SEMICON West 2014 show in San Francisco (8–10 July).

"Electronics touch so many aspects of our lives each day – from the ways we communicate, the cars we drive, how we monitor our health and keep our families safe," says Crofton. "The companies and people SEMI represents are the innovators, technologist and manufacturers who enable these smarter, faster, more powerful and more affordable electronic products and devices. I am honoured to have the opportunity to serve with my esteemed colleagues to further initiatives that will help support, define and strengthen our industry as we continue to grow and expand into new areas," he adds.

"The SEMI board reflects the regional and market diversity of our worldwide membership," comments SEMI's president & CEO Denny McGuirk.

SEMI's 20 voting directors and 11 emeritus directors represent companies from Europe, China, Japan, Korea, North America, and Taiwan, reflecting the global scope of the association's activities. SEMI directors are elected by the general membership as voting members of the board and can serve a total of five two-year terms.

www.spts.com
www.semi.org

Jordan Valley chosen for in-line GaN-on-Si process control

X-ray metrology and defect detection tool maker Jordan Valley Semiconductors Ltd (JVS) of Migdal Haemek Israel has recently delivered and commissioned its JVX7300L in-line x-ray metrology tool at multiple customers. The systems have been purchased for in-fab process development and automated production monitoring of gallium nitride on silicon (GaN-on-Si) wafers.

"Jordan Valley is well positioned to support this and other emerging applications, with our comprehensive portfolio of x-ray based technologies and tools," believes CEO Isaac Mazor.

"GaN-on-Si technology presents new metrology challenges and requirements that only high-resolution x-ray diffraction (HR-XRD) can adequately address," says Dr Paul Ryan, corporate VP and JV-UK manager. "We have been supporting the manufacturing needs of both the compound and silicon semiconductor industries for many years. Bringing together these technologies, Jordan Valley can provide solutions for the characterization of these advanced material systems, while meeting the customers' stringent process and automation requirements in a short period of development time," he adds. "The JVX7300L provides the highest level of automation, flexibility and robustness for such emerging applications. In choosing the JVX7300L platform, the customers' acknowledged the significant contribution of the product in shortening their process development cycle, together with the ability to use the same tool for production monitoring to help drive yield enhancement."

The JVX7300L is a production-worthy x-ray metrology system for GaN-on-Si and 'More-than-Moore' applications and can be used for both in-fab process development and production monitoring. It supports various x-ray metrology modes, scanning HR-XRD, XRR and (GI)XRD, to provide solutions for a wide range of materials and structures. HR-XRD can measure the composition, thickness strain/relaxation of single and multiple epilayer stacks. Additionally, with XRR and (GI)XRD channels, the tool can provide information on the thickness and density of a wide range of thin films as well as providing unique microstructure information (crystallinity, grain-size and phase) of polycrystalline thin films. Unlike optical or spectroscopic tools, HR-XRD and XRR are first-principles techniques that deliver accurate and precise results without calibration, says the firm.

www.jordanvalley.com

Lake Shore's IMS exhibit features high-frequency probing and characterization technology

Lake Shore Cryotronics Inc of Westerville, near Columbus, OH, USA, which makes scientific sensors, instruments and systems for measurement and control, exhibited at the IEEE MTT International Microwave Symposium (IMS 2014) in Tampa Bay, FL (3–5 June), where it discussed platforms that enable the study of devices and materials using high-frequency measurements.

Platforms include Lake Shore's probe stations for non-destructive probing of materials and test devices, whether for the study of electrical, magneto-transport, DC, RF or microwave properties. Applications include carbon nanotubes (CNT), graphene, MEMS, gallium-nitride (GaN), silicon-germanium (SiGe), superconducting device and organic semiconductor research.

Lake Shore's probe stations are designed for on-wafer probing and measurement of device samples as a function of temperature and field. Interrogating samples at cryogenic temperatures and in high magnetic fields can reveal certain mechanisms of novel materials, particularly in semiconductor and nanoscale device research. Low-temperature operation is becoming increasingly important in the development of new electronic devices, including high-speed SiGe-based transistors.

Lake Shore offers four cryogen-free CCR probe stations and six liquid cryogen models, plus a range of probes, sample holders, and other options to enable users to configure a station for a specific application. These include ground-signal-ground (GSG) style probes, available for 40GHz or 67GHz frequency ranges and designed to ensure optimal microwave measurement performance at cryogenic temperatures.

Lake Shore is also working with several companies and university researchers towards the development of terahertz-frequency, on-wafer contact probing for cryogenic applications. The goal is to enable high-speed device probing and performance measurements at variable temperatures and fields for next-generation electronics R&D.

Lake Shore also discussed its new turnkey Model 8501 THz system for non-contact characterization of materials at variable temperature and in high field. The complete platform features an integrated high-field cryostat and specially designed continuous wave (CW) THz emitter and detector components, supporting the ability to measure at high frequencies (200GHz to 1.5THz). CW THz spectroscopy can reveal properties that other techniques miss because many phenomena have been found to align with these frequencies, and it offers particular potential for characterizing dielectric materials for high-frequency and waveguiding applications.

www.lakeshore.com

KLA-Tencor launches inspection and review portfolio for leading IC technologies

At the SEMICON West 2014 trade show in San Francisco (8–10 July), process control and yield management solutions provider KLA-Tencor Corp of Milpitas, CA, USA launched four new systems — the 2920 Series, Puma 9850, Surfscan SP5 and eDR-7110 — that provide advanced defect inspection and review capability for the development and production of 16nm and below IC devices.

The 2920 Series broadband plasma patterned wafer, Puma 9850 laser scanning patterned wafer, and Surfscan SP5 unpatterned wafer defect inspection systems deliver enhanced sensitivity and significant throughput gains, the firm says. By enabling the discovery and monitoring of yield-critical defects, these inspectors support chipmakers' integration of complex structures, novel materials and new processes at leading-edge design nodes. Each of the inspection systems seamlessly connects with the eDR-7110 electron-beam review system, which utilizes improved automatic defect classification capability to quickly identify detected defects, providing chipmakers with accurate information for determining corrective action.

"As our customers integrate many unique technologies at the 16nm, 14nm and smaller design nodes, they face complex yield and reliability challenges," says Bobby Bell, executive VP of KLA-Tencor's Wafer Inspection Group. "The four systems announced today — flagship products in our inspection and review portfolio — incorporate numerous innovations to help solve defectivity issues across a broad range of applications," he adds. "Our optical inspectors and e-beam review system find and identify critical nanoscale defects, while achieving high productivity for evaluating how these defects vary across a wafer, wafer-to-wafer and lot-to-lot. We believe this portfolio, by producing comprehensive defect information, can help our customers characterize and optimize their advanced processes to accelerate time-to-market."

Utilizing a third-generation broadband plasma illumination source, the 2920 Series patterned wafer defect inspection platform delivers twice the light of its predecessor, enabling the use of a new deep ultraviolet (DUV) wavelength band and what is claimed to be the industry's smallest optical inspection pixel. Along with new advanced algorithms, these optical modes boost sensitivity to subtle protrusions, tiny bridges and other pattern defects on complex IC device architectures, such as FinFETs. In addition, the 2920 Series' novel Accu-ray and Flex Aperture technologies can quickly determine the best optical settings for the capture of critical defect types, significantly reducing the time required to discover and solve process and design issues, the firm says.

With multiple platform enhancements, the Puma 9850 laser scanning patterned wafer defect inspection system provides improved sensitivity across a range of production throughputs to support a diverse array of FinFET and advanced memory inspection applications. Complementing the 2920 Series inspectors, the Puma 9850's higher-sensitivity operating modes facilitate yield-relevant defect capture on after-develop inspection (ADI), photo-cell monitor (PCM), and front-end-of-line (FEOL) line-space etch layers. Higher-speed modes, operating at up to twice the throughput of the Puma 9650, allow for cost-effective excursion monitoring in the film and chemical-mechanical planarization (CMP) process modules.

Multiple 2920 Series, Puma 9850, Surfscan SP5 and eDR-7110 systems have been installed at foundry, logic and memory manufacturers

The Surfscan SP5 unpatterned wafer inspector incorporates enhanced DUV optical technologies that produce sub-20nm defect sensitivity at production throughput, enabling detection of tiny substrate or blanket film defects that can inhibit successful integration of multi-stack IC devices. With throughput up to three times faster than the previous-generation Surfscan SP3, the SP5 maintains high productivity while qualifying and monitoring the increased number of process steps associated with multi-patterning and other leading-edge fabrication techniques.

The eDR-7110 e-beam review system includes a new SEM automatic defect classification (S-ADC) engine that can produce an accurate representation of the defect population during production and can be used during development to dramatically reduce the time required for defect discovery. Moreover, S-ADC results can automatically trigger additional in-line tests, such as compositional analysis or imaging with alternative modes, while the wafer is still on the eDR-7110 — a unique capability that enhances the quality of the defect information provided to engineers for process decisions.

Multiple 2920 Series, Puma 9850, Surfscan SP5 and eDR-7110 systems have been installed at foundry, logic and memory manufacturers worldwide where they are being used for development and production ramp at advanced technology nodes. To maintain the high performance and productivity demanded by IC manufacturing, all four systems are backed by KLA-Tencor's global comprehensive service network.

www.kla-tencor.com/global-services/performance.html

GaN-on-Si LED maker LatticePower raises $80m

Production in China to be expanded, while site sought in USA for R&D and manufacturing

LatticePower Corp of Nanchang, China, which claims to be the first firm to commercialize GaN-on-silicon LED lighting, has announced an $80m initial round of Series D equity financing led by Asia Pacific Resources Development Investment and GSR Ventures and joined by fellow existing investors Mayfield Fund and Crescent HydePark. The firm has also launched an LED mobile flash for smartphones and other handheld devices, joining other lighting products.

At a signing ceremony in Hong Kong, Sonny Wu, co-founder & managing director of GSR and executive chairman of Lattice Power, and LatticePower's CEO Dr Min Wang hosted industry veterans, investment bankers and analysts.

Since 2006, GSR has been the lead investor for LatticePower, spinning the technology out of a local university lab in Jiangxi and building a team of device physics and new-materials PhDs from around the world to overcome the challenges of creating GaN-on-Si LEDs. Developing GaN-on-Si LEDs has been a problem for the industry as a result of the lattice and thermal expansion mismatches between GaN thin film and silicon substrate, says the firm. By developing a series of proprietary technologies to overcome these challenges, LatticePower is able to manufacture reliable and affordable LEDs with over 150lm/W efficacy (competitive with products from other manufacturers), it adds. LatticePower has so far filed over 200 global patents. The firm raised $70m from GSR, Mayfield, AsiaVest Partners of Taiwan, Keytone Ventures of Beijing, and Singapore's Temasek Group in several rounds since 2006. It also raised $55m from the International Finance Corporation in 2010.

The latest round of funding will be used to expand LatticePower's R&D and manufacturing capabilities, finance its sales growth, and to further develop high-performance, affordable GaN-on-Si LED light bulbs and fixtures.

"This new round of funding will allow us build the necessary scale to be competitive in this fast-evolving and growing market and enable the company to meet the growing demand for our industry-leading products from an expanding customer base across the globe," says Wang.

LatticePower will immediately expand production in China and is scouting locations for R&D and manufacturing facilities in the USA. More specific announcements on site selection of these facilities as well as new strategic partnerships will be made in the autumn.

"With dedication and innovation contributed by scientists like Dr Zhao and Dr Sun as well as industry leadership by Dr Min Wang, LatticePower's disruptive silicon-based LED technology has achieved world-class performance — exceeding criteria like ENERGY STAR," notes Wu. "The GaN-on-silicon technology is highly scalable using automated production, making it more affordable than other technologies in the market," he claims. "The company will leverage its proprietary technology to build a global network of R&D teams, starting by integrating a Korean and Taiwanese team in 2014 and expanding to build a US R&D and manufacturing center by 2015."

"This is one of the first technology investments that leverages China-based innovation to solve a difficult industry problem, and it will have a big impact on the global market," comments Francisco Sanchez, former US Under Secretary of Commerce for International Trade. "I am looking forward to the company bringing this R&D and manufacturing to the United States."

This latest round of investment completes a transformation of the firm from a Jiangxi-based R&D startup to a global company with R&D and sales operations in Changzhou, Nanchang, Hong Kong, and Palo Alto, CA, USA.

www.latticepower.com

Plessey expands European distribution with CODICO

UK-based Plessey has entered into a distribution agreement with CODICO GmbH, a demand creation distributor for electronic components, headquartered in Perchtoldsdorf, Austria and with offices across Europe. With CODICO, Plessey is expanding its European network with coverage in Central and East European, Italian and Danish market for its gallium nitride on silicon (GaN-on-Si) LED products.

"The innovative technology of Plessey and CODICO's deep knowledge of the market will enable both companies to turn on a bright light within the solid-state lighting market," says CODICO's president & CEO Sven Krumpel. "GaN-on-Si technology is going to be the next revolution in the lighting field," he believes.

"Plessey is very pleased to work with a distributor that has a wide coverage in the region," comments Plessey's regional sales director David Owen. "CODICO's line-card complements the Plessey LED portfolio in the lighting segment and, together with its focused team that brings considerable knowledge of the lighting industry and customer base, will accelerate the time to market for Plessey GaN-on-Si LEDs in the region," he adds.

www.codico.com

www.plesseysemiconductors.com

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Philips Lighting to spin off Lumileds and Automotive lighting businesses as stand-alone components firm

Freedom to attract investors targets accelerated growth and scale

Royal Philips NV of Amsterdam, The Netherlands (the world's largest lighting producer) has announced that it will start the process of combining its Lumileds (LED components) and Automotive lighting businesses into a stand-alone company within the Philips Group, and will explore strategic options to attract capital from third-party investors for the business. Philips intends to remain a minority shareholder and customer of the new company, and will continue with existing collaboration.

"Philips' strategy in Lighting is to intensify its focus on connected LED lighting systems and services, LED luminaires, and LED lamps for the professional and consumer markets," says Royal Philips' CEO Frans van Houten. "Both our Lumileds and Automotive lighting businesses are strong players in the lighting industry and ready to pursue more growth and scale, independently of Philips Lighting. As a world-leading lighting components business, they will have increased flexibility to attract additional investors to accelerate growth," he adds.

"The combined business will be able to extend its leading portfolio of digital lighting components and achieve robust growth, serving even more customers in the industry, including of course Philips Lighting," says Philips Lighting's CEO Eric Rondolat. "By combining Philips Automotive lighting and Lumileds, the Automotive lighting customers will continue to benefit from a fully integrated end-to-end R&D and supply chain, enabling the adoption of LED technology in automotive applications."

The process to combine Lumileds and Automotive into an integrated business within the Philips Group is expected to be completed in first-half 2015. Associated costs are expected to amount to €30m in second-half 2014. Sales of the combined businesses were about €1.4bn ($1.9bn) in 2013 (compared with about $1.4bn from LED sales for rival Cree Inc of Durham, NC, USA). Lumileds' CEO Pierre-Yves Lesaicherre will be CEO of the new company.

www.philipslumileds.com
www.lighting.philips.com

Lumileds launches CrispWhite Technology for retail settings

Philips Lumileds of San Jose, CA, USA has launched its proprietary CrispWhite Technology, which is claimed to make whites appear vivid and bright while colors appear saturated. LUXEON CoB (chip-on-board) arrays with CrispWhite Technology result in more attractive displays for retail downlights and spotlights, the firm adds.

Proper lighting is central to the perception and evaluation of goods, as it is a critical component of branding, highlighting and presenting merchandise and creating a space where shoppers want to visit, says Lumileds. With CrispWhite Technology, all colors, including white, show the best saturation, the firm claims. Also, unlike CDM (ceramic discharge metal halide) solutions, LUXEON CoB with CrispWhite Technology turns on instantly (an advantage for retail lighting applications).

Lumileds' LUXEON CoB arrays with CrispWhite Technology

"Shop owners have told us that CDM sources do a fine job of rendering warm colors but they would like to save energy and take advantage of the longer lifetime of LEDs," says product line director Eric Senders. Like CDMs, the new CrispWhite LEDs maintain high color rendering index (CRI) and bring out the white color in merchandise by utilizing a second peak in the blue spectrum, creating the optimal illumination for retail displays, it is claimed.

LUXEON CoB with CrispWhite Technology is available in multiple lumen packages, from 800 lumens for MR16 and PAR lamps, all the way up to 7000 lumens to replace 70W and 100W CDM solutions.

www.philipslumileds.com/CrispWhite

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FOREPI merger to boost Epistar from 11% to 15% of global gallium nitride LED epiwafer capacity

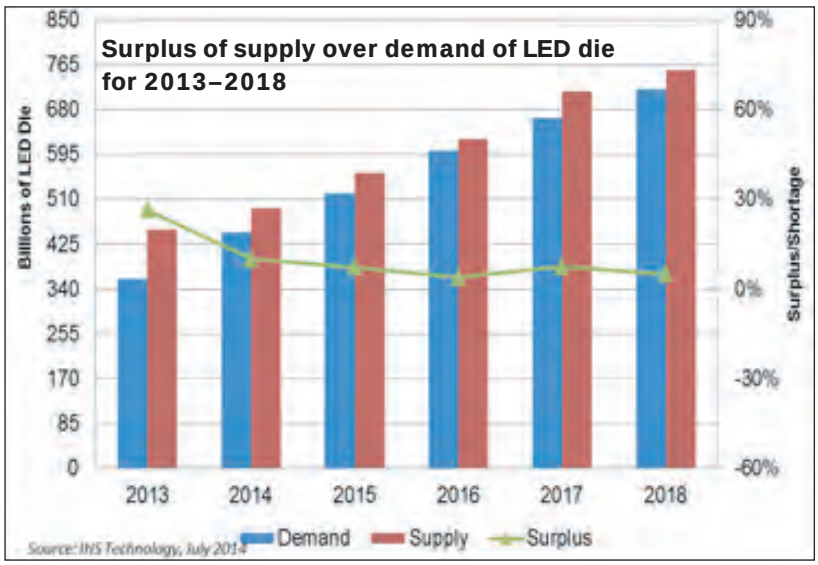
Global wafer surplus to fall from 27% in 2013 to below 10% in 2015–2018

Following the announcement on 30 June that Epistar Corp (Taiwan's largest manufacturer of LED epiwafers and chips) is acquiring fellow Taiwanese LED epiwafer and chip maker Formosa Epitaxy Inc (FOREPI), Epistar will have over 400 metal-organic chemical vapor deposition (MOCVD) reactors including those from FOREPI's China subsidiaries — more than double the gallium nitride (GaN) MOCVD of its nearest competitor, according to a Research Note from IHS Technology.

As a result, Epistar will now take an even clearer lead as the number 1 GaN LED die and epiwafer supplier. Epistar's projected share of 11% of global wafer capacity in fourth-quarter 2014, added to FOREPI's 4%, will mean that the newly united group will account for 15% of total global capacity — an impressive number in such a diverse market with so many players, comments the market research firm. Meanwhile at the packaged LED level, Nichia is the market leader, with 12.5% (as of first-quarter 2014).

Sanan, a shareholder in FOREPI, was previously projected by IHS to challenge Epistar for wafer capacity by the end of 2014. But Sanan will now have under half of Epistar and FOREPI's combined share after the merger. Samsung, ranked third, is another top player for wafer capacity.

The merger may come at a good time for Epistar, which also leads in yielded die and binned die, says IHS. Leading LED firms have long since recovered from 2011–2012 when capacity utilizations were very low, and Epistar and others have had stable, high-capacity utilizations for some time now. At the same time, the oversupply seen from 2011 to 2013 is projected to greatly reduce from 2014 to 2018 because of increased demand in lighting.



According to the latest issue of IHS Technology's 'Quarterly GaN LED Supply and Demand Market Tracker', wafer surplus is projected to fall from 27% in 2013 to 10% in 2014, and will be below 10% from 2015 to 2018, due mostly to the expansion of the lighting market as LED lamps and luminaires gain share at the expense of traditional technologies.

Revenue from GaN packaged LEDs in lighting applications is projected to grow from $5.2bn in 2013 to $6bn in 2014 and then $6.8bn in 2015.

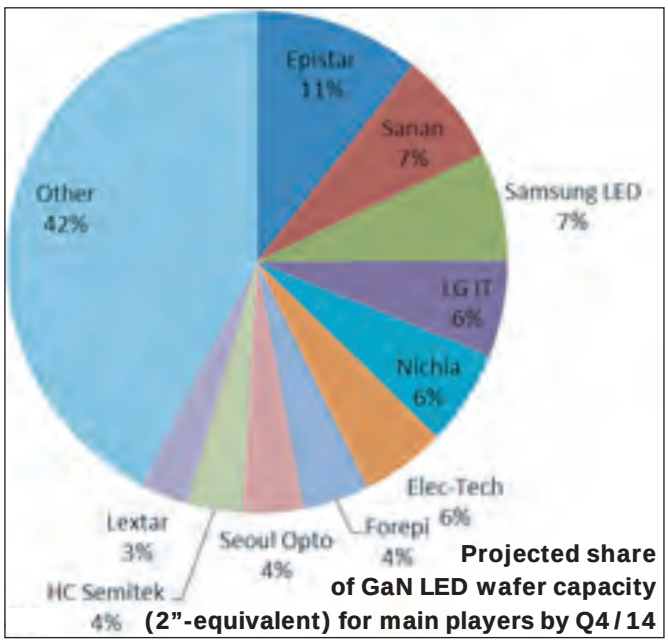
Shipment growth is even stronger, with 2015 shipments forecast to be almost double those of 2013.

Overall, GaN MOCVD system installations are forecast to reach 257 reactors in 2014, with 830 to be needed for the four combined years from 2015 to 2018 inclusive.

The top purchasers of MOCVD systems in 2014 are projected to be leading Chinese companies such as Sanan and HC Semitek. Both recently announced plans for 200 MOCVD reactors. Sanan said it will invest RMB10bn (US$1.6m) to buy 200 for its plant in Xiamen, while HC Semitek expects to reach 200 by 2016. However, it is noted that historically not all LED firms have ordered as many MOCVD reactors as they initially targeted.

The top 10 purchasers of MOCVD systems are expected to have 89% LED market share in 2014 as leading suppliers continue to grow strongly. In comparison, smaller companies and new entrants that joined the market in recent years have often failed to see growth in this competitive market, notes IHS.

www.ihs.com



Projected share of GaN LED wafer capacity (2"-equivalent) for main players by Q4/14

Epistar to acquire FOREPI to expand capacity

Epistar's fully utilized monthly capacity of 950,000 LED epiwafers short of demand by 300,000 epiwafers

Epistar Corp (Taiwan's largest manufacturer of LED epiwafers and chips) is to issue 174.612 million new shares (worth NT$10 each, totalling NT$1746.12m) to acquire fellow Taiwanese LED epiwafer and chip maker Formosa Epitaxy Inc (FOREPI) through a stock swap of 1 Epistar share for 3.448 Formosa Epitaxy shares (to be completed by end-December 2014, pending approval of shareholders of the two firms).

With 385 metal-organic chemical vapour deposition (MOCVD) systems, 1500 R&D engineers and 2600 patents, Epistar is specifically the world's largest manufacturer of aluminium gallium indium phosphide (AlGaInP) epiwafers and chips and second largest of indium gallium nitride (InGaN) epiwafers and chips. It has fully utilized its monthly production capacity of 950,000 LED epiwafers but capacity is still short of demand by more than 300,000 wafers, according to president M.J. Chou. However, expansion entails investment and takes time. Instead, Epistar has sought existing external production capacity to fill the gap, Chou indicated.

With about 400 R&D staff, 400 patents and 103 MOCVD systems giving it a monthly production capacity of more than 200,000 AlGaInP and InGaN LED epiwafers, Formosa Epitaxy was deemed to be the best candidate, following a 6 month search for potential acquisitions (including companies in Taiwan and in China).

The acquisition of Formosa Epitaxy enables the integration of both companies' resources to enlarge operational scale, to lower overall management cost, and to increase overall operational efficiency and international competitiveness, Chou reckons.

While still suffering an operating loss, Formosa Epitaxy hopes that merging with Epistar can reduce production costs and increase average selling price, enabling the operation to enter profitability as soon as third-quarter 2014, comments Formosa Epitaxy's chairman Frank Chien. After the acquisition, Formosa Epitaxy will remain an independent entity.

www.forepi.com.tw
www.epistar.com.tw
www.digitimes.com

VI Systems, UCSB and Technical University of Denmark demonstrate 1060nm VCSEL link at 30Gb

VI Systems GmbH of Berlin, Germany, University of California Santa Barbara (UCSB) and the Technical University of Denmark (DTU) have demonstrated an optical data communication link operating at 30Gbit/s using a 1060nm vertical-cavity surface-emitting laser (VCSEL) transmitter and VI Systems' R40-1300 high-speed receiver module specified for the 900–1350nm wavelength range.

The 1060nm VCSEL light source is a bottom-emitting, highly strained 1060nm quantum well VCSEL developed at professor Larry Coldren's group in UCSB's Department of Electrical and Computer Engineering. The receiver is designed for data rates of up to 40Gbit/s and includes VI Systems' T40-150C080 transimpedance amplifier (TIA) packaged in a fiber-coupled receiver optical subassembly (ROSA).

System analysis and data transmission experiments were performed at professor Tafur Monroy's lab at DTU's Fotonik-Department of Photonics Engineering.

The results of the collaboration between UCSB, DTU and VI Systems will be presented at the European Conference on Optical Communication (ECOC 2014) in Cannes, France (21–25 September).

www.v-i-systems.com

VI Systems awarded US patent for 40G VCSEL technology

VI Systems (a fabless spin-off of the Technical University of Berlin and the A. F. Ioffe Physico-Technical Institute in St Petersburg, Russia) says that the US Patent and Trademark Office (USPTO) has issued a Notice of Allowance for a US patent application.

Patent number US 20130092896 A1 ('Optoelectronic Device with a Wide Bandgap and Method of Making Same') covers the material composition of optoelectronic devices including the firm's ultra-high-speed 40Gbit/s vertical-cavity surface-emitting laser (VCSEL). The firm says that the patent is essential to protect its proprietary concept of ultra-high-speed VCSEL.

The invention pertains to semiconductor light-emitting devices for visible and infrared spectral ranges. It can hence also be applied to LEDs, targeting the bright red, orange, yellow or green spectral ranges.

For optical data communication, VI Systems offers engineering samples of its 40Gbit/s VCSEL at 850nm wavelength as bare die chips (part number V40-850C) or as fiber-coupled test modules. The modules are available in a package with a V-connector but without a VCSEL driver chip (part number V40-850M) or with a built-in 40Gbit/s VCSEL driver and adaptor board for differential signal input through standard RF connectors (part number R40-850).

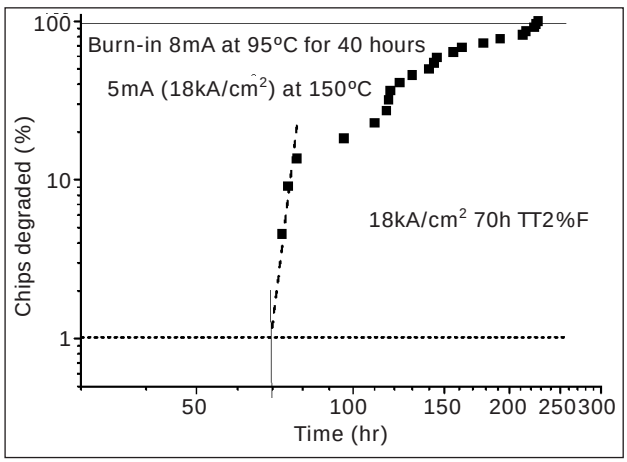
www.v-i-systems.com

VI Systems completes 28G VCSEL reliability study

In May, VI Systems completed a reliability study on the V25-850Cxx VCSEL chip series for data rates up to 28Gbit/s per channel. The study confirmed that the VCSEL chips can be used in constant operation at elevated temperatures with a useful lifetime with a mean time to failure (MTTF) value of more than 35 years.

The chip is available for 100Gbit/s parallel data transmission at 4x25Gb/s (part number V25-850C4) and for the next generation of Infiniband EDR interconnects of up to 300Gbit/s at 12x25.78Gbit/s (part number V25-85012). The firm also offers samples for next-generation 400Gbit/s Ethernet interconnects at 16x25Gbit/s.

The reliability study was performed in the format of a multi-cell accelerated aging test which included 500 individual chips operated at temperature of up to 150°C at three different current density levels.



Aging of chips at 150°C at 18kA/cm².

As a conclusion, it was observed that, for operation at usual operation conditions of 45°C and 18kA/cm², the systematic lifetime is virtually infinite. In case of constant operation at elevated heat sink temperatures (30% humidity, compact environment), a reasonable useful lifetimes with MTTF values of over 35 years for ambient (heatsink) temperatures of up to 90°C can be derived.

EZconn Czech a.s. provided the testbed facility and data acquisition.

www.v-i-systems.com/_data/Reliability_Report_V25-850_VCSEL_short_version.pdf

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Nichia to release blue and green laser diodes for automotive head-up displays

Nichia Corp of Tokushima, Japan says that it aims to commercialize blue and green laser diodes designed specifically for automotive head-up display (HUD) systems.

Though a variety of semiconductor laser diodes have already been commercialized, they will be the first blue and green products for automotive applications, Nichia said. The company plans to start to ship samples in October 2014 and begin volume production in October 2015.

LEDs are currently the most common light sources for automotive HUD systems. Nichia says that, by replacing them with laser diodes, the expected benefits include:

- larger head-up display field of view;
- lower energy consumption;
- higher contrast; and
- an extended range of reproducible colors.

Nichia says that it has achieved improved reliability and quality for the new lasers. A 5.6mm-diameter CAN metal package was chosen for its high-reliability performance for laser diodes. Also, the semiconductor chip has improved luminous efficiency. According to Nikkei Electronics, wall-plug efficiency (WPE) has been improved from 17% to 26% for blue light emission and from 5% to 8% for green light emission.

Nichia aims to start shipping test samples from October, with mass production starting in October 2015.

www.nichia.co.jp/en

Daylight to develop UV laser for aircraft survivability

Daylight Defense LLC has been selected by the US Army to develop next-generation high-power ultraviolet (UV) laser capability.

Daylight Defense is a subsidiary of Daylight Solutions Inc of San Diego, CA, USA, which makes molecular detection and imaging systems based on mid-infrared quantum cascade lasers (QCLs). The subsidiary manufactures QCL-based high-power, multi-color laser systems for defense and homeland security applications, providing mid-wave (MWIR) and long-wave (LWIR) thermal laser beacons and pointers, sensors for stand-off detection of explosives and chemical agents, and high-power illuminators for IR countermeasures. Daylight is partnered with Northrop Grumman Corp for the US Army's Common Infrared Countermeasures (CIRCM) program to develop the next generation of aircraft survivability equipment to defend helicopters against man-portable air-defense systems and other heat-seeking munitions.

The latest US Army award was made under its Small Business Innovation Research (SBIR) program, which provides high-tech US businesses (with fewer than 500 staff) the opportunity to provide innovative R&D solutions in response to critical Army needs.

According to a recent solicitation by the US Army, "the Army is interested in laser sources in the near-UV for applications such as light detection and ranging (LIDAR) and other applications for helicopter survivability".

Additional applications of the technology include battlefield awareness, trace detection using LIDAR backscatter and/or bio-fluorescence, and data storage.

www.daylightsolutions.com/defense-and-security

QD Laser wins Photonics Society's Aron Kressel Award

Kenichi Nishi, Mitsuru Sugawara and Keizo Takemasa of QD Laser Inc of Kanagawa Japan (which was founded in 2006 with funding from Fujitsu Ltd and Mitsui Ventures) have won the IEEE Photonics Society 2014 Aron Kressel Award for "pioneering contributions to the development of temperature-insensitive quantum dot lasers, and their commercialization and mass production for optical communication systems".

The award is given annually to recognize individuals who have made important contributions to optoelectronic device technology having a significant impact on applications in practical systems. The intent is to recognize key contributors to the field in developing critical components that lead to the development of systems enabling new services or capabilities. QD Laser is the second Japanese recipient of the award since 2003.

In 1982 professors Arakawa and Sakaki of the University of Tokyo first proposed using quantum dots in the active layer of the semiconductor laser. The laser has unique features such as low threshold current, low temperature sensitivity, and high-temperature operation.

After over ten years of collaborative R&D between Fujitsu Laboratories Ltd and the University of Tokyo, QD Laser has developed high-density and high-uniformity quantum dot technologies, and commercialized quantum dot lasers as light sources for optical fiber communications.

The awards ceremony will be held on 13 October at the 2014 IEEE Photonics Conference (IPC) in San Diego, CA, USA.

www.qdlaser.com

http://photonicssociety.org/award-info

POET announces technology and regulatory 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 several key updates on its 100nm scaling and prototype initiatives, and the registration of its common shares with the US Securities and Exchange Commission.

100nm scaling and prototype initiatives

The firm's 100nm scaling and prototype initiatives have achieved a culmination point where transition to a third-party foundry is now being negotiated.

The 100nm initiative reduces the feature size of key POET devices down to the 100nm range. In the course of this program, the technical team developed processes critical to the practical application of POET, which will now form the basis of several new patent applications.

The prototype initiative aims to put together several key device building blocks, all with integrated optical and electronic capability, into an integrated circuit or array of ICs. Development of the two initiatives have proceeded in parallel so far, but are technologically linked.

"We are now at a point where the capabilities of a third-party foundry are required for practical demonstration, as well as subsequent third-party validation," notes executive chairman & interim CEO Peter Copetti.

SEC registration statement filed

The firm has registered its common stock on Form 20-F under the Securities Exchange Act of 1934. As a reporting company, POET will file annual and other periodic reports with the SEC (available to the public through the SEC's EDGAR online database). The common stock is already traded in Canada under the symbol 'PTK' on the TSX Venture Exchange.

"Registration with the SEC is in line with the goals of management and the company's board of directors to actively improve corporate governance standards, transparency, and to provide periodic disclosure to the market," says Copetti.

"In the last 12 months, the company's profile and visibility within the semiconductor industry has increased significantly, and the company will need to continue this transparency in its efforts reach out to a global audience of investment and strategic partners," concludes Copetti.

New executive vice chairman to help determine strategic direction

POET Technologies has announced major changes to its board of directors and changes to the slate of board candidates for its annual general meeting (AGM).

Mark Benadiba has retired from the board, vacating the executive vice chairman post.

Along with chairman & interim CEO Peter Copetti and Dr Samuel Peralta, Benadiba was part of a re-invigorated board of directors that in 2012 recognized the inherent value in the semiconductor IP held by the firm; and transformed what is described as a then-faltering photovoltaic firm into what POET is now (aiming to establish a new manufacturing paradigm to further Moore's Law).

Benadiba served as chairman and vice chairman of the firm, setting the groundwork and impetus for its new strategic direction.

Ajit Manocha has now joined the board as executive vice chairman. He will help to determine the strategic direction of the firm, and work with the executive chairman & interim CEO in supporting the strategic direction, specifically: mergers & acquisitions (M&A) and related transitions; joint ventures, collaborations, partnerships and other industry relationships; capital raises; and identification and installation of a permanent CEO.

Manocha was most recently CEO of the world's second-largest semiconductor foundry GlobalFoundries — formerly the manufacturing arm of Advanced Micro Devices (AMD), and expanded via the acquisition of Chartered Semiconductor. Globally, it owns five 200mm fabs and three 300mm fabs. Manocha continues to be an advisor to GlobalFoundries.

Previously, Manocha was advisor to Advanced Technology Investment Company and executive VP of worldwide operations at Spansion, managing global IC manufacturing and supply chain management for its semiconductor division. Earlier he was executive VP & chief manufacturing officer at Philips Semiconductors (now NXP). He has also worked at AT&T Microelectronics and AT&T Bell Laboratories.

Manocha is also on the boards of SVTC Technologies and Signet Solar. He was previously on the boards of International Sematech, Crolles Alliance, and Advanced Semiconductor Manufacturing Corporation (ASMC),and was chairman of Systems-on-Silicon Manufacturing Company (SSMC) in Singapore. Since 2012, he has also served on the US Presidential Committee for Advanced Manufacturing Partnership.

Sheldon Inwentash has been endorsed as a candidate for election to the board at the AGM on 12 August. He is chairman & CEO of Pinetree Capital Ltd, a strategic investment, financial advisory and merchant banking firm, and a major shareholder in POET.

Leon Pierhal has decided not to stand for re-election to the board. He is expected to finish his term of service at the time of the AGM.

www.poet-technologies.com

Imec demos 28Gb/s silicon photonics platform for high-density, low-power WDM optical interconnects

At the Integrated Photonics Research, Silicon and Nanophotonics conference (IPR) in San Diego (13–16 July), nanoelectronics research center Imec of Leuven, Belgium demonstrated improved performance of various key building blocks for high-density low-power wavelength-division multiplexing (WDM) optical interconnects in silicon. Imec says that the achievements represent a key milestone for its fully integrated silicon photonics platform (iSiPP25G) for high-performance optical transceivers, extending the performance towards 28Gb/s and beyond.

Imec has demonstrated, at the wafer-scale, a ring-based WDM filter with an improved thermo-optic tuning efficiency better than 1nm/mW per channel, a thermally tunable 28Gb/s ring modulator with an efficiency of 260pm/mW, and a high-speed germanium photodetector achieving an average responsitivity of 0.85A/W and opto-electrical bandwidth of 50GHz with dark currents at –1.0V below 50nA. The devices are all integrated on Imec's iSiPP25G platform and extend Imec's silicon photonics portfolio, which also includes low-loss (<2.5dB/cm) strip waveguides, highly efficient grating couplers (2.5dB insertion loss), and 25Gb/s Mach-Zehnder modulators.

"Imec's silicon photonics platform provides 28Gb/s performance for integrated photonics circuits for telecom and datacom industries," says Philippe Absil, program director at Imec. "Companies can benefit from our silicon photonics capability through established standard cells, or explore the functionality of their own designs in multi-project wafer (MPW) runs," he adds. "Through our MPW offer, fabless R&D teams can access a cost-efficient silicon photonics solution, with state-of-the-art performance, design flexibility and superior CD and thickness control".

Imec offers the platform for silicon photonics via ePIXfab (supported by Ghent University), Europractice IC service and MOSIS, a provider of low-cost prototyping and small-volume production services for custom ICs. The next passive run is now open for registration (deadline 15 September), with first wafers out in January 2015. Imec's third active ISIPP25G run is now open for registration (deadline 10 November), with first wafers out in June 2015. Support, registration and design kit access will be organized by Imec's services via its Europractice IC service, in collaboration with worldwide MPW partners.

www.imec.be
www.epixfab.eu
http://mosis.com

Advanced Photonix amends lending agreements

Advanced Photonix Inc of Ann Arbor, MI, USA (which designs and makes APD, PIN, and FILTRODE photodetectors, HSOR high-speed optical receivers, and T-Ray terahertz instrumentation) has amended its lending agreements with Silicon Valley Bank (SVB) and Partners for Growth (PFG), given the successful firm underwriting by B. Riley & Co LLC of 6.2 million shares of Class A Common Stock (for net proceeds of about $2.9m). On 30 May, Advanced Photonix had announced the pricing of an underwritten public offering of 5,391,304 shares at $0.53 per share, and granted the underwriter B. Riley a 30-day option to purchase up to an additional 808,696 shares.

Under the terms of the amendment, SVB has agreed to extend the maturity date of the firm's $5m line of credit to 20 June 2016. It has also restored an interest rate matrix based on covenant performance that results in an interest rate on the line of credit ranging from prime rate plus 50 basis points on up to prime rate plus 400 basis points and an interest rate on the term loan ranging from prime plus 75 basis points on up to prime plus 450 basis points.

Also, both SVB and PFG have agreed to convert the three-month trailing adjusted EBITDA (earnings before interest, taxes, depreciation and amortization) covenant into a six-month trailing adjusted EBITDA covenant (measured at each fiscal month end) of negative $850,000 through June 2014, negative $300,000 for July through September 2014, and positive $1 for October through December 2014 and $100,000 each month thereafter, subject to reset upon the submission of the fiscal 2016 budget, but in no case lower than $100,000 on a rolling six-month basis.

SVB and PFG also agreed to reset the existing liquidity ratio covenant to 1.30 to 1.00 through 31 May and 2.0 to 1.0 for all months on or after June 2014, as measured at each month end.

"We are pleased that our lending partners have returned to similar terms that we enjoyed in the past, given the proceeds from our recently completed shelf offering," comments CEO Richard Kurtz. "This $2.9m cash infusion has allowed us to pay down debt and provide the capital we needed to fund our expected growth over the coming years," he adds. "We want to thank our lenders and B. Riley for their assistance and look forward to growing the company in our current fiscal 2015 by more than 20%."

www.advancedphotonix.com

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GigOptix's revenue grows more-than-expected 9% in Q2 to $8m, as datacoms exceeds telecom for first time

Full-year revenue guidance raised from 10% growth to 12%

For second-quarter 2014, 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 $8m, up 9% on $7.4m last quarter (above the guidance of 3-5%) and up 18% on $6.8m a year ago.

In particular, High-Speed Communications revenue grew 23% year-over-year, while datacom-related revenue rose almost 70% and E-band sales tripled from Q2/2013

"For the first time in the company's history our datacom-related revenue was higher than telecom-related revenue, and we believe this trend will continue," says chairman & CEO Dr Avi Katz. "In addition, when you add together the two fastest-growing markets we serve, datacom and the point-to-point wireless backhaul areas, they accounted for 45% of our total revenue in the second quarter, up from 28% in the same quarter last year," he adds.

On a non-GAAP basis, gross margin has fallen from 65% a year ago and 60% last quarter to 59%. However, net income was $0.3m ($0.01 per diluted share), up from $0.1m ($0.00 per share) a year ago and compared with a net loss of $0.7m ($0.02 per share) last quarter. Adjusted EBITDA is up from $0.7m a year ago and just $47,000 last quarter to $1m. During the quarter, cash and cash equivalents fell from $19.9m to $18.5m.

"Our second quarter financial performance, which included strong revenue growth and a return to non-GAAP profitability, further validates our long-term business plan to develop first-mover advantage within the emerging high-speed communications markets," says Katz. "As we move into the second half of fiscal 2014, we will continue to focus primarily on the datacom, wireless point-to-point backhaul radios for the LTE infrastructure small-cells, and high-speed links for the consumer markets that offer the largest TAM [total addressable market] and highest projected growth rates," he adds.

In June, GigOptix announced the acquisition of Tahoe RF Semiconductor Inc, which became effective on the first day of third-quarter 2014. "The purchase adds leading-edge RF/analog RFIC technology to our expanding product portfolio. It is also consistent with our previously stated objective of adding engineering assets to enhance revenue-generating products," says Katz. "This acquisition brought to GigOptix a meaningful CMOS and SiGe RF device IP library for emerging and high-volume applications, such as wide-frequency point-to-point wireless backhaul, including 60GHz V-band to augment our existing 70–90GHz E-band technology. In addition, we gained GPS-GNSS, low-power and low-noise transmitters and amplifiers, and specific consumer electronics and automotive systems. These capabilities have already been incorporated to the company's working plans and business development active engagements," he adds. "We currently believe that these new opportunities should be a catalyst for revenue growth starting in fiscal 2015. When combined with the previously announced inception of the BrPhotonics joint venture, which is meeting our early expectations, along with the growth trends we see in our business, we are confident that by expanding our addressable markets we will continue to improve our higher-margin revenue growth and enhance profitability."

As part of its ongoing efforts to improve operational efficiencies, GigOptix has implemented an enterprise-wide change in organizational structure. "We will now operate under a functional structure rather than the product line structure we have used for several years," says Katz. "The need for change became more apparent in recent months, more so after the recent acquisition and consolidation of TahoeRF, as we diversified our revenue mix by expanding into parallel markets, such as new RF applications in the wireless and consumer markets," he adds.

To support these efforts, the board has promoted Dr Raluca Dinu to senior VP of global sales & marketing. Dinu has been a key member of the executive team since 2008, most recently as VP & general manager of the High Speed Communications product line. "Her strong technical background in the industries we serve, and long-time relationships with our current and targeted customers, will play a vital role as we expand our revenue channels," says Katz. "We have also assigned Mr Anil Chaudhry to the newly created position of VP of government affairs and strategic accounts," he adds. Chaudhry has been a part of the executive team since 2010, serving as VP & general manager of the Industrial Product Line. "Anil's lengthy service in the semiconductor industry makes him an ideal person to lead this group and grow our businesses and revenues through these crucial venues."

With continued strong demand in its product lines, for Q3/2014 GigOptix expects revenue of $8.2–8.4m, up 3–5% on Q2/2014 and 12–15% year-on-year.

"Based on our third-quarter forecast, and continued confidence in our business over the remainder of the year, particularly in our datacom and wireless lines, we are increasing our revenue outlook in fiscal 2014," notes senior VP & chief financial officer Curt Sacks. The firm now expects full-year revenue to grow 12% on 2013, compared with guidance of 10% provided earlier this year.

www.gigoptix.com

GigOptix adds low-power, small-form-factor surface-mount 4x32Gbps linear quad-channel modulator driver

GigOptix Inc of San Jose, CA, USA (a fabless supplier of analog semiconductor and optical communications components for fiber-optic and wireless networks) has announced sample availability of its newest linear quad-channel Mach-Zehnder Modulator (MZM) driver for low-power 100Gbps DP-QPSK coherent long-haul transmitter applications. Full volume-production shipments are expected to begin in third-quarter 2014.

GigOptix says that the release of the GX62474 low-power consumption linear driver in a small surface-mount technology (SMT) package further strengthens its position in the telecom driver market. The SMT package is optimized for minimum crosstalk and maximum isolation between each of the four channels. The GX62474 is designed to integrate seamlessly into customer modules by providing internal RF input and output DC blocking capacitors. RF supply chokes are provided with the small-form-factor SMT package for best performance and a high level of integration to minimize overall cost. Channel performance optimization has been enabled via independent gain and peak detector controls. Each of the 4x32Gbps broadband amplifiers is capable of driving up to 6Vpp of linear output voltage, suitable for multi-level modulation applications.

The GX62474 has demonstrated power dissipation lower than 2.0W per channel at 5Vpp linear output in a small-form-factor SMT package. The quad 32Gbps linear driver was designed for very low total harmonic distortion, large dynamic range, and very low group delay variation to address linear coherent long-haul telecom systems. It also has a 27GHz typical 3dB bandwidth, very small data skew between channels, and small gain response variation across power supply and temperature. "The GX62474 is an outstanding modulator driver which enables multi-level modulation applications required in today's market and has been sampled already by number of our existing and new telecom key customers," says Marco Cipriani, senior director of engineering.

www.gigoptix.com

MACOM optical components receives Innovation Awards

M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes analog semiconductors, components and subassemblies for analog, RF, microwave and millimeter-wave applications) has been recognized by Lightwave magazine with two Lightwave Innovation Awards. The MAOM-003404 and -003401 modulator driver ICs were each recognized by a panel of expert judges for outstanding technical achievement.

Launched in September 2013, the MAOM-003404 quad-channel modulator driver IC for 100G metro applications is designed to interface with surface-mount Mach–Zehnder modulators requiring differential drive voltages. It enables the lowest-power and smallest-form-factor transmit solution for coherent CFP2 modules, the firm claims. The MAOM-003404 is the only product entered in the Lightwave Innovations Awards program to receive a perfect 5.0 score, cited as a "superb product that sets a new standard for performance and provides groundbreaking and new technical milestones".

Launched this March, the MAOM-003401 quad-channel electro-absorption modulator laser (EML) driver IC provides what is claimed to be the lowest-power EML driver solution for 100G Ethernet applications in an ultra-compact 10mm x 10mm surface-mount package. This single device is all that is required to interface between the clock & data recovery (CDR) IC and the EML, and is a key enabler for CFP2 and CFP4 module solutions for client-side telecom and data-center networks, says the firm. With this driver, the M37049 quad-channel transmit CDR, the M03100/1/2 series of quad-channel transimpedance amplifiers (TIAs), and the M37046 quad-channel receive CDR, MACOM provides a complete transmit and receive lineup with what is claimed to be the lowest power for 100GbE transceivers.

"With the accelerating proliferation of high-performance 100G technology for metro and data-center applications, pluggable modules are transitioning from CFP to CFP2 and CFP4 form factors to enable improved system density," notes MACOM Technology's optoelectronics product line manager Ray Moroney. "We are honored to be recognized by Lightwave with two Lightwave Innovation Awards for the clear performance, size and power benefits that our advanced optical components provide for designers of 100G-enabled network systems," he adds.

"The inaugural Lightwave Innovation Awards program was designed to shine a light on the best of the best products from around the optical communications industry," says Lightwave's group publisher Ernesto Burden. "Based on the assessment of our panel of independent experts, MACOM's innovation in this domain merited two product awards and yielded the only Five Diamond score in the award program."

www.macom.com

Fraunhofer ISE sets PV module efficiency record of 36.7%

Concentrating lens adapted to Soitec's new four-junction solar cell

The Fraunhofer Institute for Solar Energy Systems ISE in Freiburg, Germany has achieved record photovoltaic (PV) solar module efficiency of 36.7%, as measured under Concentrator Standard Testing Conditions (CSTC). This has been done by adapting the concentrating lens to a new solar cell structure.

Fraunhofer ISE has been developing concentrator photovoltaic (CPV) technology for many years, using Fresnel lenses to focus sunlight onto multi-junction solar cells. The institute originated the FLATCON module technology and is continually developing it, leading to the new record.

Fraunhofer ISE's latest, 36.7%-efficient FLATCON CPV module. ©Fraunhofer ISE/Photo: Alexander Wekkeli

Decisive in the latest achievement was the newly developed four-junction solar cell of CPV solar system maker Soitec of Bernin, France, which is based on wafer bonding technology and developed in cooperation with Fraunhofer ISE. This four-junction solar cell was recently implemented into the institute's FLATCON module concept. The module aperture area (the surface area exposed to light) is 832cm^2. Light is concentrated by a factor of 230 suns onto 52 7mm^2 miniature solar cells with the help of 52 16cm^2 Fresnel lenses.

"This success shows that the high efficiencies of Soitec's novel four-junction solar cells can be transferred to the module level," says Dr Andreas Bett, who has led the CPV research at Fraunhofer ISE over many years. For his efforts, Bett has received many awards, including the German Environmental Award 2012 (together with Hansjörg Lerchenmüller of Soitec Solar).

Only several months ago, Fraunhofer ISE — together with Soitec, the French research center CEA-Leti, and the Helmholtz Center in Berlin — announced a new solar cell efficiency record of 44.7% under concentrated light. This cell consisted of four sub-cells consisting of gallium indium phosphide (GaInP), gallium arsenide (GaAs), indium gallium arsenide (GaInAs) and indium phosphide (InP), respectively. Compared with standard silicon solar cells, the manufacture of four-junction solar cells is more expensive, so up to now their terrestrial applications have been exclusively in concentrator systems. Also, CPV systems are installed in sun-rich regions, where such systems can produce solar electricity for less than 8 eurocents per kilowatt-hour.

Key to this technology is the solar cell efficiency and the concentrating optics. In the record module, the new four-junction solar cell was combined with Fresnel lenses manufactured by industry partner ORAFOL Fresnel Optics GmbH of Apolda Germany, based on a new design developed at Fraunhofer ISE. Transfer of this high module efficiency to commercially manufactured modules is expected within 1–2 years.

www.soitec.com
www.ise.fraunhofer.de

First Solar establishes Japan supply agreement with XSOL

First Solar Inc of Tempe, AZ, USA, which makes thin-film photovoltaic modules based on cadmium telluride (CdTe) as well as providing engineering, procurement & construction (EPC) services, and Kyoto-based XSOL Co Ltd, a distributor and integrator of solar systems in Japan, have signed an agreement to supply First Solar's modules in Japan. The agreement targets the installation of 100MWDC per year.

Last November, First Solar announced plans to invest $100m in the development of mega solar power projects in Japan. The agreement with XSOL enables the firm's technology to be supplied to smaller-scale projects as well.

"This agreement with XSOL enables us to deliver safe and clean solar electricity on an even broader basis," says Karl Brutsaert, head of business development for Tokyo-based First Solar Japan. "XSOL is a leader in solar power in Japan," he comments.

"First Solar modules are recognized by third-party scientists as leading in ecological efficiency, and First Solar already has in place a globally proven module recycling program, enabling us to meet our commitments to save the global environment and broaden solar power accessibility," notes XSOL director Akira Waki.

www.xsol.co.jp/en
www.firstsolar.com

First Solar to build largest PV plant in Latin America

First Solar Inc has received board approval from the Overseas Private Investment Corporation (OPIC), the US Government's development finance institution, and IFC, a member of the World Bank Group, for financing to support construction of the 141MWac Luz del Norte solar power plant in Chile's Atacama Desert. The loans, which are expected to close later this summer, clear the way for First Solar to proceed with construction planning at the site, which is near the city of Copiapo.

The OPIC board approved a loan of up to $230m, and the IFC board approved a $60m loan.

The Luz del Norte project is the first of several projects that First Solar has in its regional development pipeline, and will be the firm's initial project to start construction in Chile. The Chilean government's National Energy Strategy includes expansion of the country's renewable energy capacity to 20% of its total generated power by 2025. Energy from Luz del Norte will be supplied into the Chilean Central Interconnected System, contributing significantly towards this goal.

"The Latin American region has a growing need for innovative and efficient energy solutions," comments Tim Rebhorn, senior VP, Americas, for First Solar. "This investment support from OPIC and IFC is instrumental in bringing the project in Chile to life."

Chile's Atacama Desert receives some of the planet's steadiest concentrations of direct sunlight, presenting ideal conditions for solar power generation. Widespread utilization of this resource is relatively new, and Luz del Norte represents an important advance for the development of solar energy in the region, says First Solar.

"The Luz del Norte project is an important step in furthering solar power development in Chile, where the potential for this clean, renewable resource is unrivalled," says OPIC's president & CEO Elizabeth Littlefield.

First Solar has been working closely with the Chilean national government, industry, regional authorities and the local community to design, develop and build the Luz del Norte project, says Rebhorn. Particular effort has been placed on understanding community concerns about environmental impact, national interest in the technology related to connecting the project to the grid, and the broader industry's power requirements, among other important considerations, he notes. "Forming strong, mutually beneficial partnerships with invested constituents is the only way to build a solid foundation for long-term success in this region."

www.firstsolar.com

First Solar & BELECTRIC connect utility-scale plants to UK grid

First Solar and Germany-based BELECTRIC GmbH — the world's largest solar EPC firm — have announced the grid connection of three utility-scale power plants in the UK. Together, the projects will produce about 33.9m kilowatt-hours of electricity per year (sufficient to supply the needs of an estimated 10,200 average homes).

The largest of the three facilities, the 14MW_{AC} Marsh Solar Farm in Wiltshire, is owned by German asset management group KGAL's ESPF 3 renewable energy fund for institutional investors. The 10.5MW_{AC} Weston Longville Solar Farm in Norfolk and the 10MW_{AC} Holton Solar Farm in Suffolk are owned by the BBIP infrastructure fund. Together, the projects will displace about 11,800 tonnes of carbon dioxide per year (equivalent to planting about 3,260,000 trees or removing over 4300 cars from Britain's roads).

The plants have been designed to have a minimal impact on the communities and ecosystems they are located in. For instance, Holton Solar Farm has been constructed on an abandoned World War Two-era airfield, RAF Halesworth, with the full approval of the local community. The site will feature a biodiversity enhancement program to further mitigate its impact on local ecosystems. Similarly, Marsh Solar Farm was also built on a decommissioned airfield. The Weston Longville Solar Farm features a habitat management initiative.

"The United Kingdom is a fast growing photovoltaic market and these plants are an important demonstration of our combined ability to effectively deliver clean, reliable solar energy in the UK," says BELECTRIC's chief business development officer Martin Zembsch. "The plants were completed and grid-connected on schedule and on budget."

BELECTRIC and First Solar share a longstanding partnership that spans over a decade: the two groups entered into a joint venture in 2013 and collaborated on developing the 128MW_{AC} Templin plant in Germany (the largest deployment of First Solar modules in Europe). An estimated 80% of the 1400MW of solar electricity generation capacity installed by BELECTRIC is powered by First Solar modules.

"As the UK embraces the potential of clean and affordable solar electricity, these projects represent a new milestone in the country's development of a sustainable solar energy portfolio," believes Stefan Degener, managing director of First Solar GmbH of Mainz, Germany. "The projects also represent the latest success in First Solar's longstanding partnership with BELECTRIC."

www.belectric.com
www.firstsolar.com

First Solar selected by EDF Renewable Energy to build two PV projects in California totaling 42.76MW

Cadmium telluride (CdTe) thin-film photovoltaic module maker First Solar Inc of Tempe, AZ, USA has been selected as the turnkey engineering, procurement & construction (EPC) contractor for two solar projects under development by EDF Renewable Energy in California.

First Solar and EDF Renewable Energy have signed EPC agreements for the 19.76MWAC CID Solar Project (located in Kings County) and the 23MWAC Cottonwood Solar Project (which consists of two sites: one in Kings County and the other in Kern County). The CID Solar Project has a power purchase agreement (PPA) with Pacific Gas and Electric Company (PG&E). The Cottonwood project has a PPA with Marin Clean Energy.

Both the CID Solar and Cottonwood projects will be built using First Solar's Series 3 Black Plus PV thin-film solar modules, and will provide enhanced grid reliability and stability using the firm's PV plant controls.

It is expected that construction on the projects will begin in second-quarter 2014, with CID Solar completing in October and Cottonwood completing in first-quarter 2015.

First Solar completes sale of 250MW Silver State South project

Cadmium telluride (CdTe) thin-film photovoltaic module maker First Solar Inc of Tempe, AZ, USA has completed its sale of the 250MW$_{AC}$ Silver State South solar project (announced last November) to a subsidiary of NextEra Energy Resources LLC (one of the largest wholesale generators of electric power in the USA, and itself a subsidiary of NextEra Energy Inc of Juno Beach, FL, USA).

Located on about 3000 acres of federally managed land in Clark County, Nevada, Silver State South is adjacent to the 50MW$_{AC}$ Silver State North project, which was developed and built by First Solar and commissioned in 2012.

First Solar developed and designed the Silver State South project, and will provide engineering, procurement and construction (EPC) services to NextEra. Pre-construction activity has begun at the site, and the project is expected to be complete in late 2016. At the peak of construction, the project will create about 500 local full-time jobs. All of the power from Silver State South will be sold to Southern California Edison under a long-term power purchase agreement (PPA).

"Silver State South demonstrates the deep value First Solar provides through our vertically integrated capabilities," says Tim Rebhorn, First Solar's senior VP of business development for the Americas. "We have an unmatched ability to offer industry-leading module technology, best-in-class design, and construction that includes single-axis tracker and proven balance of system components," he adds.

"This is another important milestone as we continue to build our solar business, and we look forward to working with the First Solar team to make this project a reality," comments NextEra Energy Resources' senior VP of development Mike O'Sullivan.

www.NextEraEnergyResources.com
www.firstsolar.com

First Solar sells 50MW Macho Springs Solar Project

First Solar Inc of Tempe, AZ, USA — which makes thin-film photovoltaic modules based on cadmium telluride (CdTe) as well as providing engineering, procurement & construction (EPC) services — has sold the 50MW$_{AC}$ Macho Springs Solar Project to Southern Company subsidiary Southern Power and Turner Renewable Energy. Regional electric utility firm El Paso Electric has a 20-year power purchase agreement (PPA) for all energy generated by the power plant.

Located on about 600 acres of State Trust land near Deming, New Mexico, Macho Springs is the state's largest solar power plant and will generate enough energy to power about 18,000 homes in El Paso Electric's service territory. First Solar developed and constructed the project, working closely with the New Mexico State Land Office and El Paso Electric. The plant will operate on a commercial lease from the State Land Office.

The Macho Springs project will displace more than 40,000 metric tons of CO_2 (equivalent to taking 7500 cars off the road) and will displace more than 340,000 metric tons of water consumption annually in southern New Mexico and west Texas.

Macho Springs is the third project that Southern Power and Turner Renewable Energy have acquired from First Solar. In April 2013, the partnership purchased the 139MW$_{AC}$ Campo Verde Solar Facility in Imperial County, California, and in 2010 the group bought the 30MW$_{AC}$ Cimarron Solar Project adjacent to Ted Turner's Vermejo Park Ranch in northern New Mexico.

www.southerncompany.com
www.firstsolar.com

Singulus receives €15m order from Hanergy for CIGS production system

Singulus Technologies AG of Kahl am Main, Germany, which makes production equipment for the Optical Disc and Solar sectors, has signed an agreement with Apollo Precision (Fujian) Ltd, China, a subsidiary of Hanergy Solar Group (Hanergy) that includes the supply of a TENUIS II production system for buffer layer deposition (a central component for the manufacturing of CIGS thin-film modules).

Buffer layer deposition presents a promising development on the way to the efficient wet-chemical coating of thin-film solar modules made of copper indium gallium diselenide (CIGS) on glass, says Singulus. The second generation of its TENUIS production line is based on a modular cluster, which facilitates a reduction in floor space and the simultaneous one-sided coating of two substrates. Due to new and what are claimed to be unique concepts in terms of dosing and temperature control, Singulus has reduced the process time, boosting production output.

"This contractual agreement with Hanergy, which is the world's No. 1 thin-film solar technology enterprise in terms of scale and technology, will serve as an excellent demonstration for our leading solar segment," reckons CEO Dr Stefan Rinck.

In October 2013, the Hanergy Solar Group achieved PV module energy conversion efficiency of 18.7% using Solibro's CIGS thin-film technology. Subsequently, this May it achieved an efficiency of 21% for a 1.0cm^2 cells, which is one of the highest efficiencies for CIGS thin-film solar cells in the world. These achievements have been confirmed by Germany's Fraunhofer Institute for Solar Energy Systems ISE. Solibro's CIGS process uses the Singulus buffer layer deposition technology. SINGULUS has cooperated with Solibro for a long time on the development of efficient CIGS production equipment.

On 22 January, Hanergy entered into two sales and service contracts for the provision of a total 600MW of CIGS thin-film solar manufacturing turnkey lines to Caofeidian, China. The contract marks an important manufacturing milestone for Hanergy, says Singulus. The TENUIS II production system will be the key component of the Caofeidian project and also represents a key milestone for Singulus in firming up its market position in the CIGS thin-film PV sector, says the firm.

Stion completes 255kW single-axis tracking project

Stion Corp of San Jose, CA, USA, which makes nanostructure-based CIGSS (copper indium gallium sulphur-diselenide) thin-film photovoltaic panels, has completed a 255kW single-axis tracking solar project at the Kern Sanitation Authority (KSA) Waste Water Treatment Plant in Bakersfield, CA.

Stion's project development team was selected by the KSA to provide turn-key development and installation services for the project, which was commissioned during first-quarter 2014. The solar installation will offset a significant portion of the electricity used by KSA to power its water treatment plant, and represents another commitment of the adoption of solar technology by municipal governments, says Stion.

"KSA understood that our continued dependence on traditional energy sources would be costly and insufficient given our anticipated future needs," says KSA's senior engineering manager Ramzi Mansour. "After evaluating the different technology options available to us, we recognized that the Stion solution provided us with the highest Kilowatt hour (kWh) performance and the best overall value."

Stion's 255kW single-axis tracking solar project.

Powered by 1884 thin-film modules, Stion's flat-tracking system expects to generate about 502,000kWh per year for the water treatment plant. "This Stion tracking installation, which is designed to generate 1974kWh/kWp/year, will produce the highest energy yield for a solar system located in this vicinity," comments Stion's senior director of engineering Kevin Mackamul.

"Stion's team was able to analyze KSA's complex needs and develop a competitive and customized turn-key, PPA-financed solution for us," says Mansour. "The solar installation will help to stabilize growing energy costs and the resulting savings benefits are an important component of our continued drive to improve operational efficiencies at the waste water treatment plant."

www.stion.com

Vanguard chooses Ascent's modules for NASA program

Ascent Solar Technologies Inc of Thornton, CO, USA, which makes lightweight, flexible copper indium gallium diselenide (CIGS) thin-film photovoltaic modules that it integrates into its EnerPlex series of consumer products, says that its PV modules have been selected by Vanguard Space Technologies Inc of San Diego, CA for its NASA Small Business Innovative Research (SBIR) program, which aims to develop an economical, lightweight alternative to existing and emerging high-cost solar arrays for high-power space applications.

Founded in 1994, Vanguard specializes in the engineering, tooling, manufacturing, assembly and testing of high-performance, lightweight and precision aerospace structures. Its main product lines include antenna reflectors, spacecraft structures, instrument structures and solar power systems for commercial, defense, military and research satellites. As well as having experience in composite and advanced hybrid technologies for spaceborne applications, Vanguard also has a growing business in space power and optical and thermal products including modular solar panels, flexible solar panels, shielded electromagnetically clean solar panels, solar concentrators, deployable solar arrays and deployable radiator arrays.

Vanguard will utilize proprietary space environment protection technology along with automated manufacturing approaches to create an ultra-thin, high power-to-weight ratio, large space solar array, enabled by Ascent's flexible CIGS technology. Ascent says that it will leverage its experience with space-based solar products to provide space-optimized variants of its production PV.

"Existing and emerging space solar cell technologies, particularly when utilized in very large-scale solar arrays, can present problems to the spacecraft designer, both in terms of cost and availability," says Ascent's chief technology officer Dr Joseph Armstrong. "By starting with our production CIGS monolithically integrated modules, we can provide Vanguard with a module that is tuned for the space environment and, in a similar way to our products enabling novel commercial goods, our space CIGS modules will enable Vanguard to utilize its unique protective coating and design expertise to succeed in their goal of providing NASA an economical pathway for powering these future missions," he adds.

"The advent of our extreme-environment thin-film coatings, automated manufacturing-friendly array design, and Ascent's proven cell technology provides an ideal solution for next-generation durable, affordable, large-area space solar arrays," believes Vanguard's CEO Frank Belknap.

www.vst-inc.com

Ascent Solar announces $32m secured convertible debt agreement

Ascent Solar Technologies Inc of Thornton, CO, USA, which makes lightweight, flexible copper indium gallium diselenide (CIGS) thin-film photovoltaic modules that it integrates into its EnerPlex series of consumer products, has entered into definitive agreements with institutional and certain investors, pursuant to which it will issue $32m principal amount of senior secured convertible notes and warrants to purchase shares of its common stock in a private placement. The transaction was expected to close by 25 July, subject to customary closing conditions. WestPark Capital Inc acted as the sole placement agent.

Ascent Solar will receive $7m in gross proceeds at closing. The remaining gross proceeds of $25m will be placed at closing into control accounts of the company. Those funds will be released for use in installments over the following 18 months.

The notes carry an 8% annual interest rate (subject to certain adjustments) and will mature on the fifth anniversary of closing. They are convertible, in whole or in part (at the holder's option) into shares of Ascent Solar's common stock at a price of $0.5246 per share (subject to certain adjustments).

In connection with the sale of the notes, Ascent Solar will issue to the investors warrants to purchase 26,685,729 shares of its common stock. The warrants are exercisable beginning on the issuance date through the fifth anniversary of closing, at $0.5246 per share (subject to certain adjustments). Any funds received by Ascent Solar from exercise of the warrants would be in addition to the financing proceeds.

"This is the largest financing commitment, by far, that we have received from investors in several years and will provide sufficient capital to finance our expected rapid expansion," says president & CEO Victor Lee.

"The significant size of this funding will dramatically advance Ascent Solar's business plan and execution," says Dr Amit Kumar, chairman of Ascent Solar's board of directors. "The continued growth in our product sales, the expansion of our product portfolio, the expansion of our distribution network, and the initiation of our partnership in China are all attractive aspects of our business going forward."

The complete terms of the financing have been included in a Form 8-K filed by Ascent Solar with the US Securities and Exchange Commission (SEC) on 21 July.

www.AscentSolar.com

Ascent reaches milestone for JV with China's Suqian City

Suqian to credit $77m to Ascent's contribution of proprietary technology

Ascent Solar Technologies Inc of Thornton, CO, USA, which makes lightweight, flexible copper indium gallium diselenide (CIGS) thin-film photovoltaic modules that it integrates into its EnerPlex series of consumer products, has announced the achievement of a milestone related to the Definitive Agreement signed in December 2013 with the Government of the Municipal City of Suqian in Jiangsu Province, China.

As previously announced in July 2013, Suqian will build a facility to manufacture Ascent's proprietary CIGS PV modules on flexible thin films. Ascent and Suqian will also form a joint venture (JV) in which Ascent's share will grow progressively up to 80% based on an ascribed value of its contributions to the JV.

Under the terms of the Definitive Agreement, in phases 1 and 2 of the project, Ascent is required to contribute to the JV manufacturing equipment, intellectual property (IP) assets, proprietary technology and know-how, and cash for its ownership share, and Suqian is required to contribute cash for its ownership share. Phases 1 and 2 require total contributions of RMB800m (about $129m) from Ascent and RMB200m (about $32m) from Suqian.

Ascent and Suqian are also required to ascribe a dollar value to Ascent's non-cash contributions. The major milestone is the agreement by the Suqian government to credit RMB480m (about $77m) to Ascent's contribution of its proprietary technology, which represents 60% towards Ascent's total required contribution of $129m. In order to value Ascent's intellectual property assets, the parties jointly agreed to hire an independent appraisal company in China, which has now completed that review and has submitted the valuation report to each of the JV partners. This report valued Ascent's intellectual property assets at RMB402m (about $65m). The remaining 40% of Ascent's contribution will be in the form of some equipment from its Colorado plant and/or cash. The exact amounts of cash and equipment will be determined at a later date. These amounts will depend on (among other things) an assessment of the contributed equipment by a Chinese appraisal firm mutually selected by Ascent and Suqian.

The actual contributions of cash and other assets into the JV by Ascent and Suqian will happen incrementally over time. In addition, under the Definitive Agreement, Suqian has agreed to provide rent-free use of the 331,000ft^2 manufacturing facility and office space that is currently being built for Ascent in the Suqian Economic and Industrial Development Science Park.

"This agreement underscores the belief by the Suqian government that Ascent's CIGS on flexible thin-film technology has a bright future," states Ascent's president & CEO Victor Lee. "Suqian has chosen Ascent to anchor the Suqian Economic and Industrial Development Science Park," he adds. "We plan to move quickly to next steps in the partnership, with the goal of achieving scaled manufacturing capacity enabling dramatic cost reduction of our CIGS modules."

Ascent Solar's CIGS PV modules take flight on Silent Falcon UAV

Ascent Solar has announced the successful first flights of the production Silent Falcon Unmanned Aircraft Systems (UAS) powered by its lightweight, flexible CIGS thin-film photovoltaic modules.

Jointly developed by SFUAS (which was established in 2010), Ascent Solar and Bye Aerospace Inc of Englewood, near Denver, CO (which was founded in 2007 to apply clean-energy solutions to aircraft designs), the Silent Falcon UAS is a tactical drone that integrates proprietary technology and is designed to be easily deployed. The patent-pending solar/electric powered all-composite and modular small unmanned aircraft system (sUAS) is equipped with an interchangeable wing configuration designed for commercial, public safety and defense applications both domestically and internationally. The combination of efficient aerodynamic design, lightweight composite construction and Ascent's monolithically integrated and lightweight thin film PV modules gives the 25lb Silent Falcon UAS a 6–12 hour flight endurance.

"These first flights represent the culmination of tremendous collaboration between Ascent Solar, Bye Aerospace, and Silent Falcon UAS," says chief technology officer Dr Joseph Armstrong. "Overcoming technological challenges, our teams have demonstrated the ability to integrate our flexible photovoltaics with appropriate power management systems into a feature-rich small unmanned aircraft system enabling extended mission flight time and, as a result, enhanced mission flexibility. More importantly, the photovoltaic modules integrated into the wings represent a lightweight version of our production materials, and as such, are immediately available."

"The Silent Falcon's unprecedented performance and value is ready for the market place as we transitioned from prototype and commenced low rate initial production," says SFUAS's president John Brown. "Our sales teams are targeting domestic, Latin America and the Asia Pacific region."

www.SilentFalconUAS.com
www.ByeAerospace.com
www.AscentSolar.com

Wider-band modulation of blue-green light-emitting diode

Taiwan researchers achieve record optical 3dB modulation bandwidth of 463MHz for an InGaN quantum well device.

Taiwan's National Tsing Hua University has claimed the highest optical 3dB modulation bandwidth of about 463MHz at 50mA for a 500nm-wavelength blue-green indium gallium nitride (InGaN) LED [Chien-Lan Liao et al, IEEE Electron Device Letters, vol35, p563, 2014].

Modulation of such 'green' light is proposed for short-haul data links using low-cost polymethyl methacrylate (PMMA) plastic optical fiber, which has a lower attenuation coefficient and less temperature sensitivity at 500nm wavelengths compared with conventional red sources emitting at 650nm. The researchers also see potential for wireless visible light communication (VLC).

The epitaxial structure for the device (Figure 1) was grown using metal-organic chemical vapor deposition (MOCVD) on c-plane sapphire. The ~90nm active region consisted of five 2.5nm InGaN multiple quantum wells (MQWs) in 14nm GaN barriers. The LED was constructed with a ring-shaped electrode on gallium-doped zinc oxide (GZO) transparent conductor.

The chip size was 380μmx380μm. The fabricated LED substrate was thinned from 425μm to 200μm to improve die singulation and thermal conductivity. The chips were mounted in TO-46 headers without encapsulation.

Modulation of such 'green' light is proposed for short-haul data links using low-cost PMMA plastic optical fiber, which has a lower attenuation coefficient and less temperature sensitivity at 500nm

Different devices with aperture diameters between 75μm and 200μm were produced. The turn-on voltage for all devices was about 2.8V. The peak wavelength was around 500nm, giving a blue-green color. The series resistance of the 75μm device was 14.5Ω and the capacitance under –5V reverse bias

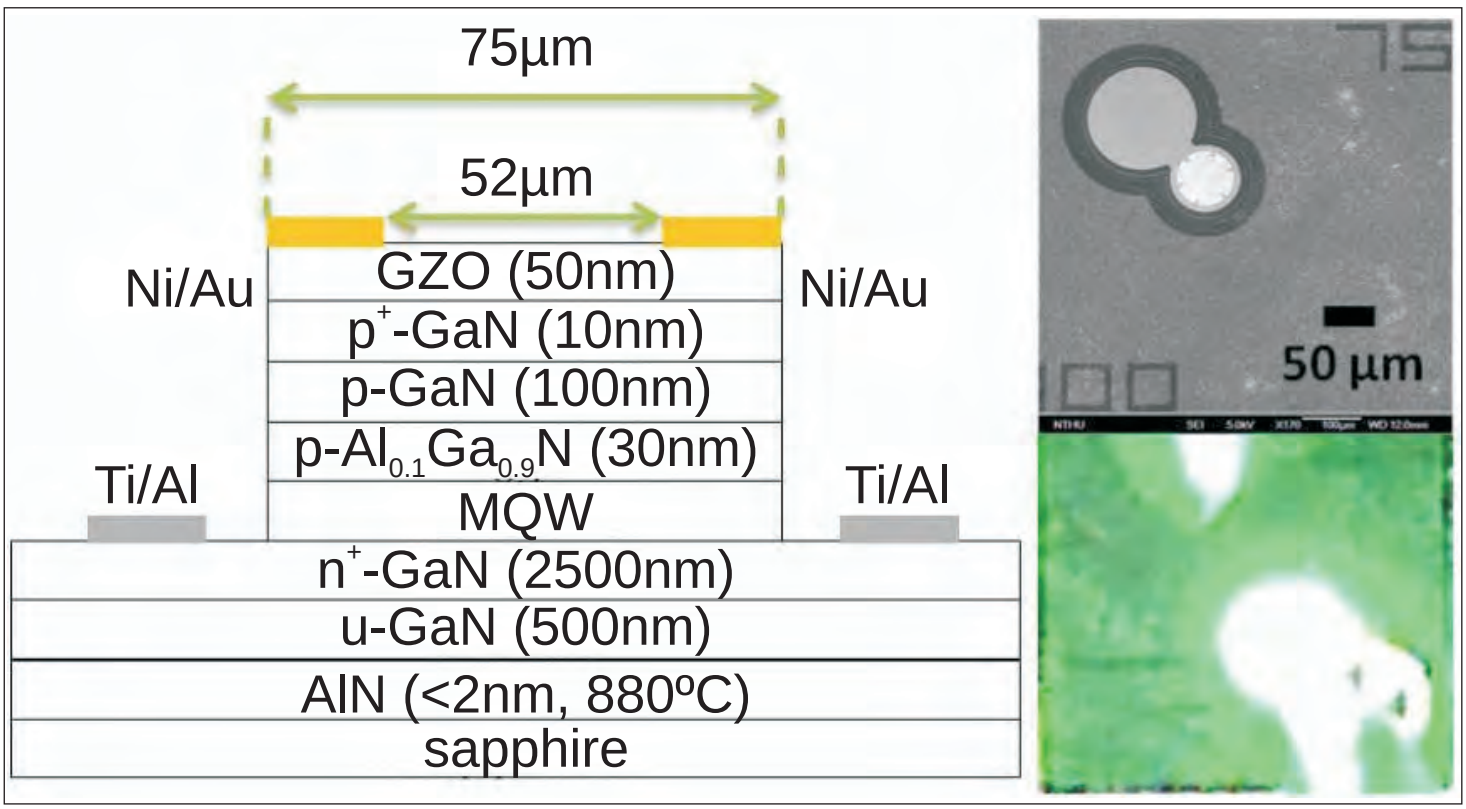

Figure 1. Green LED structure. Insets show top views of LED biased at 1mA injection current observed by field-emission scanning electron microscopy (FE-SEM, JSM-7000F) and optical microscopy.

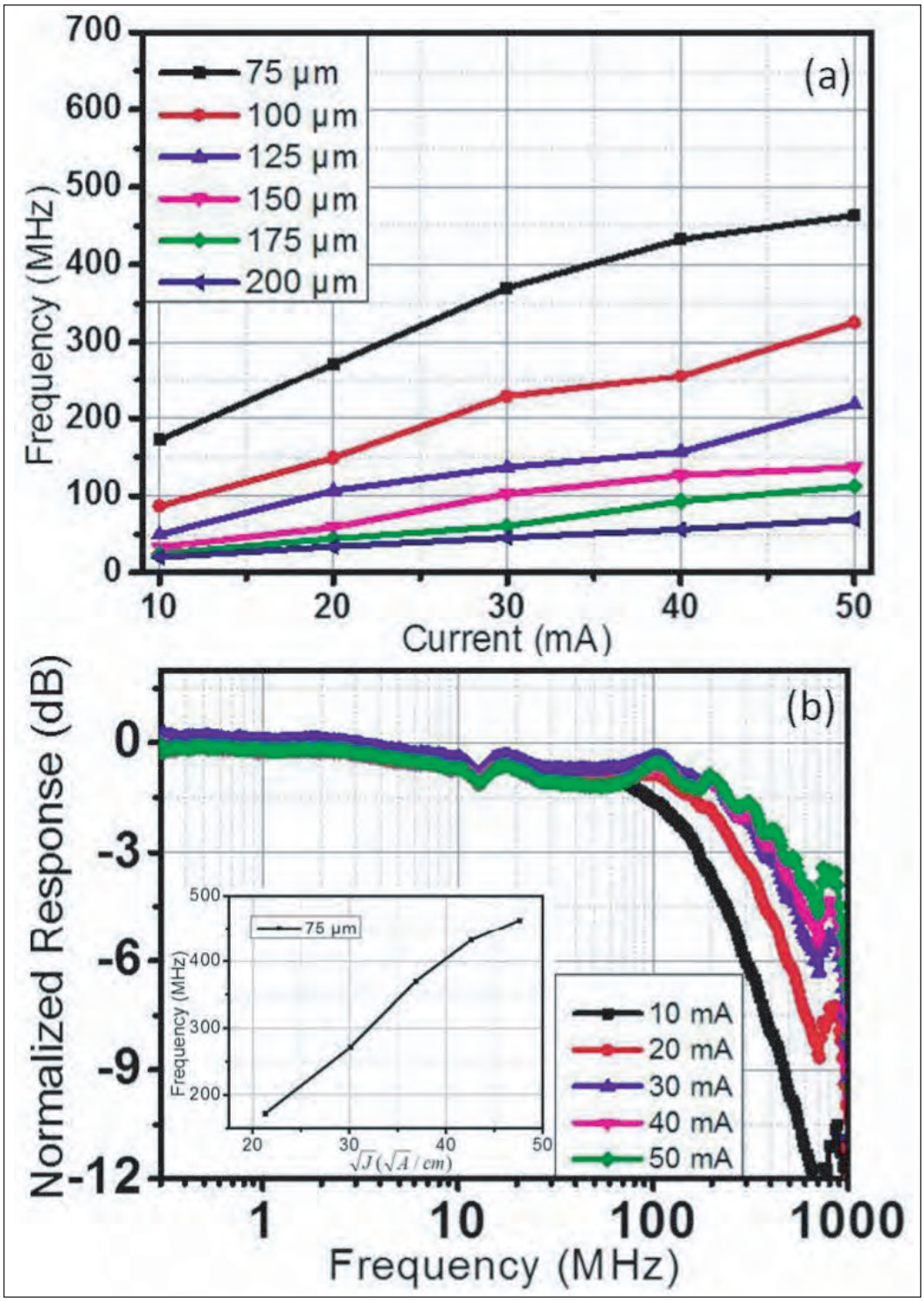

Figure 2. (a) Frequency f_{3dB} response as function of forward current for LEDs with different aperture diameters. (b) Basis for f_{3dB} measurement at different currents for the LED with a mesa diameter of 75µm. Inset shows frequency response as function of square root of current density.

was 4.8pF. The other devices had smaller series resistance but larger capacitances. For high speed, one needs low resistance and capacitance.

The light output powers at 50mA injection current varied from 1.6mW for 75µm aperture to 5.6mW for the 200µm aperture.

The 3dB modulation bandwidth (f_{3dB}, Figure 2a) was 463MHz at 50mA bias for a 75µm aperture. This reduced to 70MHz with 200µm aperture. For current biases between 10mA and 50mA, f_{3dB} was proportional to the square root of the current density for 75µm aperture (Figure 2b). The relation is more complicated with wider apertures.

These results compare with other groups that have achieved 'green' LEDs with bandwidths of 120MHz (50mA current bias, ~500nm wavelength) and 420MHz (520nm true green wavelength). ■

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Author: Mike Cooke

Developing phosphor-free white light from nanopyramid LEDs

Researchers in China have achieved an estimated four-fold improvement in light extraction over planar devices.

Researchers in China have used nitride semiconductor nanopyramid structures to create LEDs with spectra that are similar to those provided by 'white light' LEDs with yellow phosphors [Kui Wu et al, J. Appl. Phys., vol115, p123101, 2014]. The researchers are at the Chinese Academy of Sciences's institutes of Semiconductors and Mechanics, and Tsinghua University. A similar CAS/Tsinghua team previously reported such devices, using a polystyrene nanosphere mask to make holes for selective-area growth of nanopyramids [www.semiconductor-today.com/news_items/2013/DEC/CAS_301213.shtml].

The light-emitting structures are grown on the semipolar facets of the nanopyramid. Growth in semipolar directions of the crystal structure should avoid electric field polarization and strain-dependent effects that make the growth of high-indium-content indium gallium nitride (InGaN) difficult. High-quality high-indium InGaN is needed to achieve longer-wavelength light emission for 'white light'.

The n-GaN template consisted of a 2µm n-type layer on 2µm undoped GaN buffer on sapphire substrate. A mask layer of silicon dioxide was deposited and patterned using

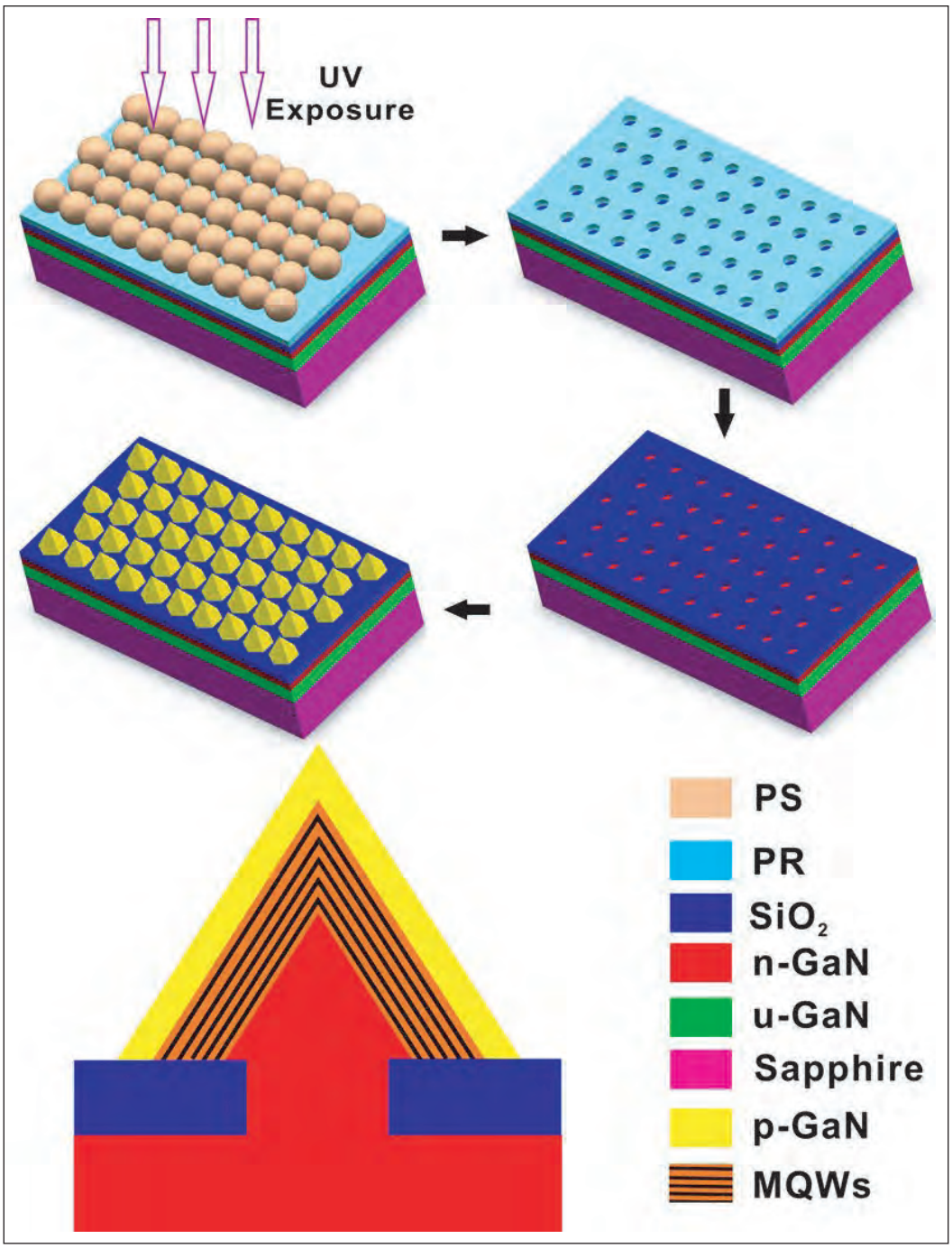

Figure 1. Fabrication schematic for phosphor-free nanopyramid LEDs by nanospherical-lens photolithography.

a hexagonal array of polystyrene nanospheres (Figure 1). The photoresist patterning created 400nm-diameter holes in a 900nm periodic array. The pattern was transferred to the silicon dioxide by inductively coupled plasma (ICP) etch.

Metal-organic chemical vapor deposition (MOCVD) then proceeded to grow the nitride semiconductor material on the exposed n-GaN template. The initial growth was 1050°C n-GaN for 4 minutes to form nanopyramids with {10-11} facets. Next, a five-period InGaN/GaN multiple quantum well (MQW) was grown (720–780°C), followed by a 13 minute 950°C p-GaN layer. The resulting nanopyramids were 600nm high.

The photoluminescence spectra (Figure 2) of the nanopyramids gave two peaks around 445nm (blue) and 550nm (yellow). The balance of the peaks depended on the MQW growth temperature. In particular, the higher-temperature growth increases the blue relative to the yellow peak. The researchers attribute this to the decomposition of the yellow-emitting regions, which have a higher indium content.

The researchers comment: "Interestingly, when grown at 780°C, the nanopyramid LEDs exhibit a spectrum which is similar to white LEDs from blue LEDs combined with yellow phosphors."

Microscopic inspection of electroluminescence showed that the blue radiation comes from the apex of the pyramids, while the yellow radiation comes from the base region. The researchers attribute the yellow emission to the base region having higher indium content and wider, less quantum-confined wells, leading to a smaller energy gap.

The researchers admit that the nanopyramid radiation is still weak: "We believe that the brightness can be improved by optimizing the growth parameters, including the size, aspect ratio, and the structure of MQWs."

Brightness can be improved by optimizing the growth parameters, including the size, aspect ratio, and the structure of MQWs

Also, conventional LED fabrication processes need to be developed to cope with the rough surface of the nanopyramid structures. The researchers are working on device structures and chip processes that will enable detailed electroluminescence characterization of nanopyramid LED structures.

On the basis of finite-difference time domain (FDTD) simulations, the researchers believe that the nanopyramid arrays have a light extraction efficiency about four times higher than for conventional planar MQWs that suffer from a small escape cone at the air-GaN interface due to differences in the index of refraction. The simulations give an escape cone as high as 85°, compared with less than 40° for planar structures. ■

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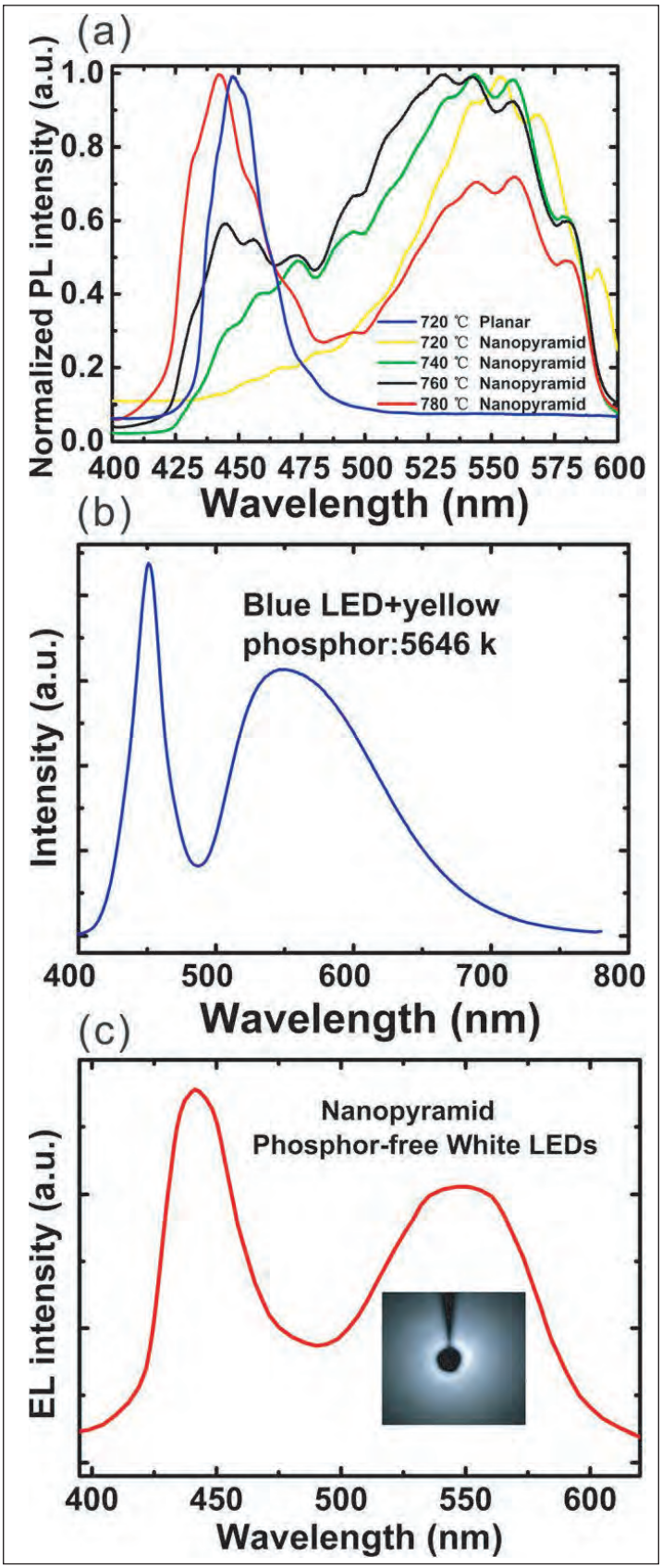

Figure 2. (a) Room-temperature PL spectra of nanopyramid LEDs with MQWs grown at different temperatures, along with reference structure grown on planar template. (b) Spectrum of 'white LED' (blue LED with yellow phosphors). (c) Electroluminescence spectrum of nanopyramid LEDs at 20mA; inset shows corresponding optical microphotograph.

Monolithic integration of nitride HEMTs and LEDs

HKUST develops techniques for applications in smart lighting, LED micro-displays and visible light communication.

Hong Kong University of Science and Technology (HKUST) is developing techniques to monolithically integrate high-electron-mobility transistors (HEMTs) and light-emitting diodes (LEDs) based on aluminium indium gallium nitride (AlInGaN) materials [Zhaojun Liu et al, Appl. Phys. Lett., vol104, p091103, 2014].

The researchers believe that the HEMT-LED integration could find applications in smart lighting, LED micro-displays and visible light communication. Nitride semiconductor HEMTs have the potential to provide superior power management over silicon-based conventional AC–DC conversion through pulse-width modulation or analog current control. Nitride semiconductor transistors enable higher breakdown voltages, higher operating frequencies and wider operating temperatures.

The researchers comment: "Sharing the same GaN-based material platform, monolithic integration of LEDs and HEMTs can potentially reduce the form factor and manufacturing cost of an LED lighting system and greatly improve the system stability and reliability."

However, integration brings challenges in terms of different optimal growth temperatures for AlGaN/GaN HEMTs and InGaN/GaN LEDs. Further problems arise in device fabrication with potential damage from plasma etch processing.

The HKUST HEMT structures were grown on commercial 2-inch LED wafers by metal-organic chemical vapor deposition (MOCVD). The GaN buffer was 170nm, the u-AlGaN back-barrier was 55nm, the u-GaN channel was 200nm, the AlN spacer was 1nm, and the AlGaN top barrier was 20nm. Two methods for integrating HEMTs were compared: growth of the epitaxial layers followed by selective epitaxial removal (SER), leaving HEMT material adjacent to the LED regions; or, deposition and patterning of a silicon dioxide mask, followed by selective epitaxial growth (SEG) of the HEMT layers.

The SER method used inductively coupled plasma to open a window for the LED. For the SEG method, the silicon dioxide mask was removed with a wet buffered oxide etch. Comparison HEMTs were also produced separately on sapphire substrates.

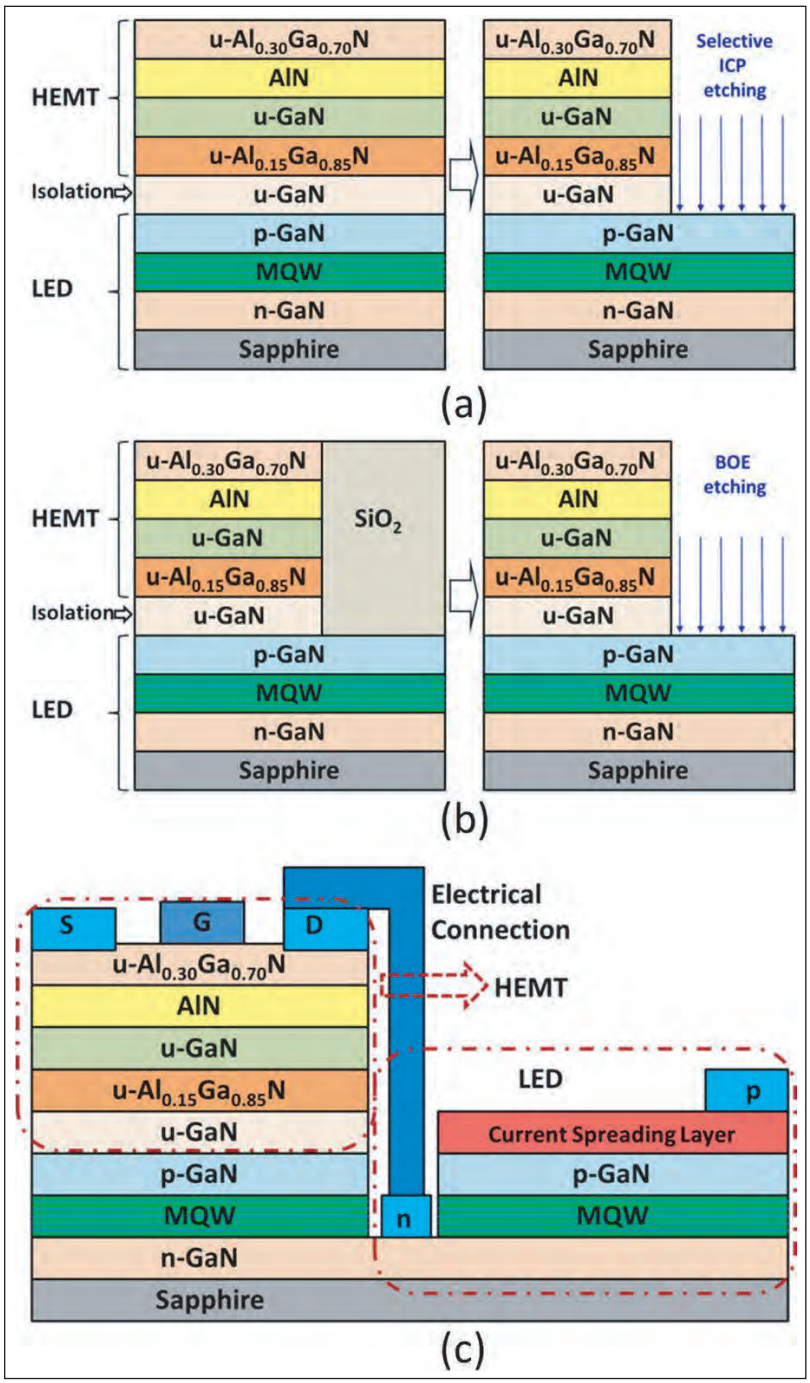

Figure 1. Cross-section of (a) selective epi removal (SER), (b) selective epi growth (SEG), (c) final structure of HEMT-LED.

The MOCVD process was carried out at 1045°C, about 100°C lower than HKUST normally uses for HEMTs. The low growth temperature was the result of optimization aimed at minimizing damage of the LED InGaN quantum wells, which are normally produced at

700–800°C, while maintaining HEMT performance.

Subjecting the LED wafers to a simulated MOCVD process, where temperature was cycled but no source gases were present, resulted in a 5% decrease in the photoluminescence peak intensity of the LED wafer.

At the same time, the HEMT layers from the reduced temperature growth on sapphire created a two-dimensional electron gas (2DEG) with sheet resistance of 330Ω/square, mobility of 1470cm^2/V-s, and carrier concentration of 1.26x10^{13}/cm^2. These 2DEG channel conductivity parameters are described as "good" by the researchers.

The integrated HEMT-LEDs were fabricated with two ICP etch steps to produce the LED and HEMT mesas. Next, the researchers deposited and annealed titanium/aluminium/nickel/gold source–drain electrodes, and then a nickel/gold LED current-spreading layer. The p and n LED electrodes consisted of titanium/aluminium/titanium/gold. The HEMT Schottky gate was nickel/gold. The HEMT was connected to the LED using wirebonding. The researchers describe the wirebonding as a "first generation" step: presumably, in future the connection can be made with a more elegant process.

The HEMT devices demonstrated similar performance for peak on-current (I_{on}) and transconductance (G_m) (Table 1). The researchers say that these results indicate that "acceptable HEMT performance can be achieved with both SER and SEG technologies for monolithic integration". The off-current (I_{off}) of the devices was "slightly larger" than usual for GaN HEMTs as a result of the low growth temperature and parasitic leakage at the re-growth interface.

Professor Kei May Lau comments: "Because of the thin buffer of the HEMT grown on top of the LED, the Ioff and breakdown of the SEG HEMT should be further improved, and that's what we are working on."

The use of the SEG method improved the performance of the LED forward voltage to close to that of the reference: at 20mA injection current, the forward voltage of the SER LED was 17.1V, compared with 3.7V for the SEG LED and 3.1V for the reference. A larger forward voltage indicated power losses due to high parasitic resistance.

The researchers traced the higher parasitic resistance of the SER device mainly to a non-ohmic Schottky contact with the p-type layers of the LED. The researchers attribute the increased injection barrier to the ICP etch process creating a nitrogen deficient p-GaN surface with donor states that reduce the p-type conductivity. The ICP process is difficult to control precisely due to the negligible selectivity between p-doped and undoped GaN.

Although the SEG LED had much improved performance, there was also a slight increase in the band-bending, leading to an increase of 0.2eV over that of the reference device. The researchers comment: "This can be explained by the H_2/NH_3 passivation of the p-type dopant during the HEMT growth. Systematical investigation of the passivation and reactivation issues are underway."

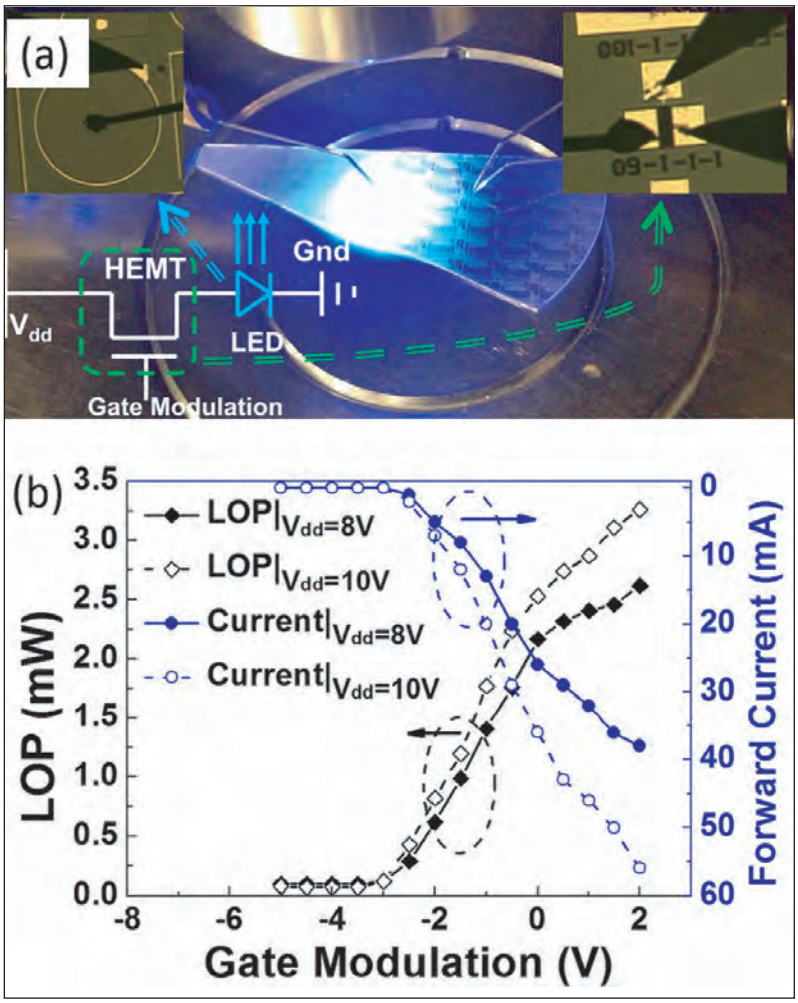

Figure 2. (a) On-testing HEMT-LED emits blue light (inset: circuit schematic). (b) Light output power (LOP) and I–V characteristics of HEMT-LED with modulated gate biases and different V_{dd}.

Table 1. Device results of reference HEMT, sample A (SER), and sample B (SEG).

	Reference	Sample A	Sample B
I_{on} (mA/mm)	1136	1038	940
I_{off} (mA/mm)	0.26	0.34	0.05
G_m (mS/mm)	238	253	245
R_{on} (Ω/mm)	2.84	2.58	3.58
V_{br} (V)	20.0	21.5	33.5

The SEG device demonstrated gate-modulated emission of blue light (Figure 2).

The researchers also see possibilities for an LED growth on HEMT integration architecture. The respective methods have different pros and cons. The team comments: "To further boost the development of the monolithic integration of GaN HEMTs and LEDs, growth and fabrication techniques of both architectures need to be investigated for better device performance." ■

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Author: Mike Cooke

MIT demonstrates first vertical gallium nitride diodes on silicon

A vertical p–n structure achieves soft breakdown of 300V, providing a potential low-cost alternative to GaN-on-sapphire diodes.

Massachusetts Institute of Technology (MIT) has demonstrated gallium nitride (GaN) vertical Schottky and p–n diodes on silicon Si substrates "for the first time" [Yuhao Zhang et al, IEEE Electron Device Letters, published online 10 April 2014].

GaN is being developed for power electronics applications in both vertical and lateral structures. Although the lateral structure has been studied widely, it faces reliability and integration issues. Vertical structures have been realized more recently, but on high-cost small-diameter substrates such as free-standing GaN, silicon carbide (SiC) or sapphire. Potential advantages of vertical electronic structures include smaller chip sizes, better electric field profile with the peak away from the surface, and superior thermal characteristics.

The challenge for growth of GaN structures on silicon is to reduce dislocation densities resulting from the larger lattice mismatch compared with the alternative substrates.

The epitaxial structures for the MIT diodes (Figure 1) were grown on 3-inch (111) silicon substrates by metal-organic chemical vapor deposition (MOCVD).

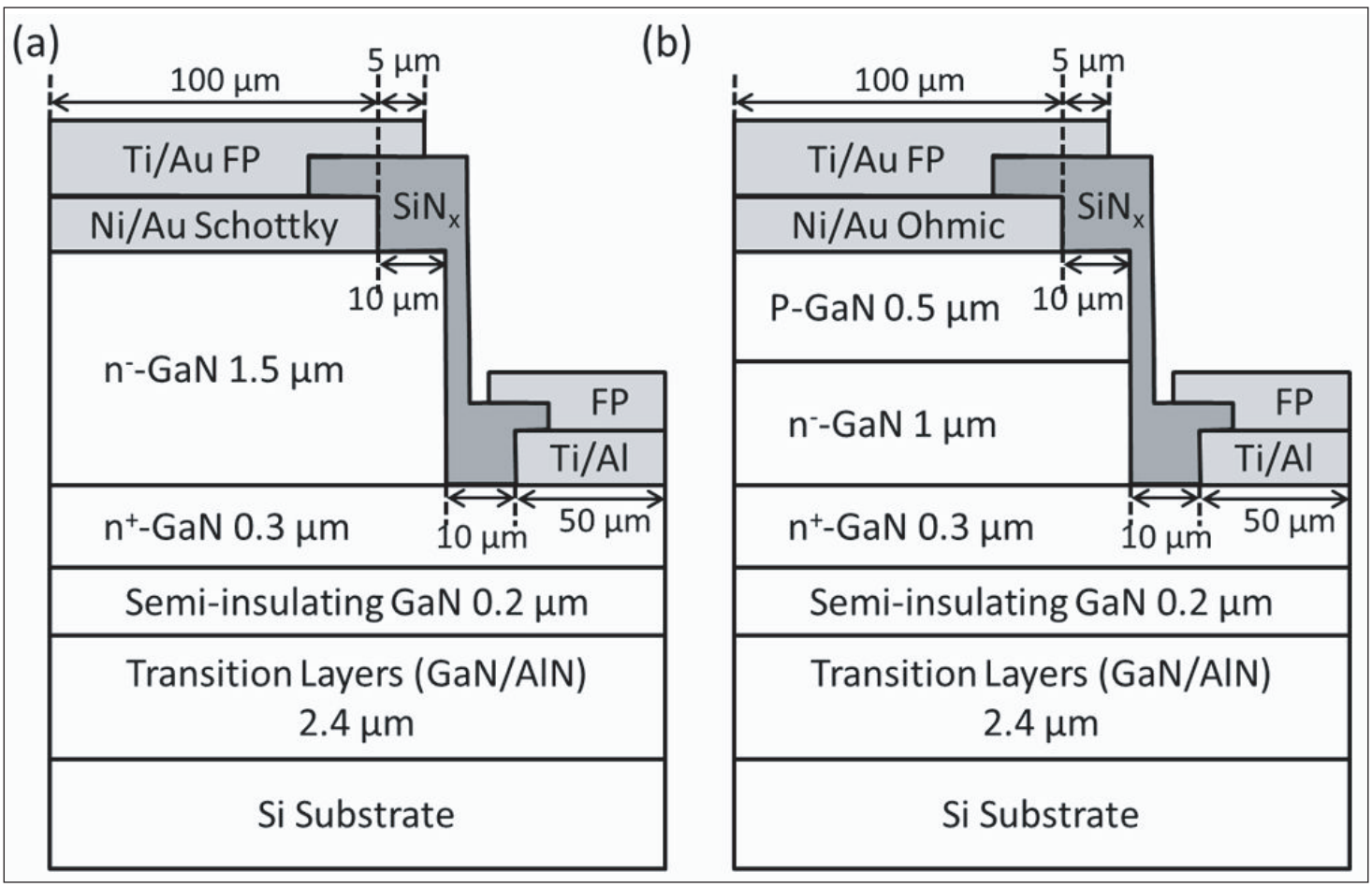

Figure 1. Schematic cross sections of GaN-on-Si vertical (a) Schottky and (b) p–n diodes with passivation and field plate structures.

The estimated dislocation density in the GaN layers was ~10^9/cm^3.

The fabrication consisted of etch for mesa isolation and to access the cathode region (n-contact), deposition of titanium/aluminium in a ring n-contact, and then the deposition of 200µm-diameter nickel/gold circular anode contacts. The p–n diode included a p-GaN layer. For the Schottky barrier diode (SBD), the researchers deposited the anode metals directly on the top lightly doped (n^+) n-GaN layer. The anode metals for the p–n diode were annealed at 550°C for 10 minutes in a nitrogen/oxygen environment to achieve an ohmic contact. The field plates (FP) consisted of silicon nitride passivation and titanium/gold metal bilayer.

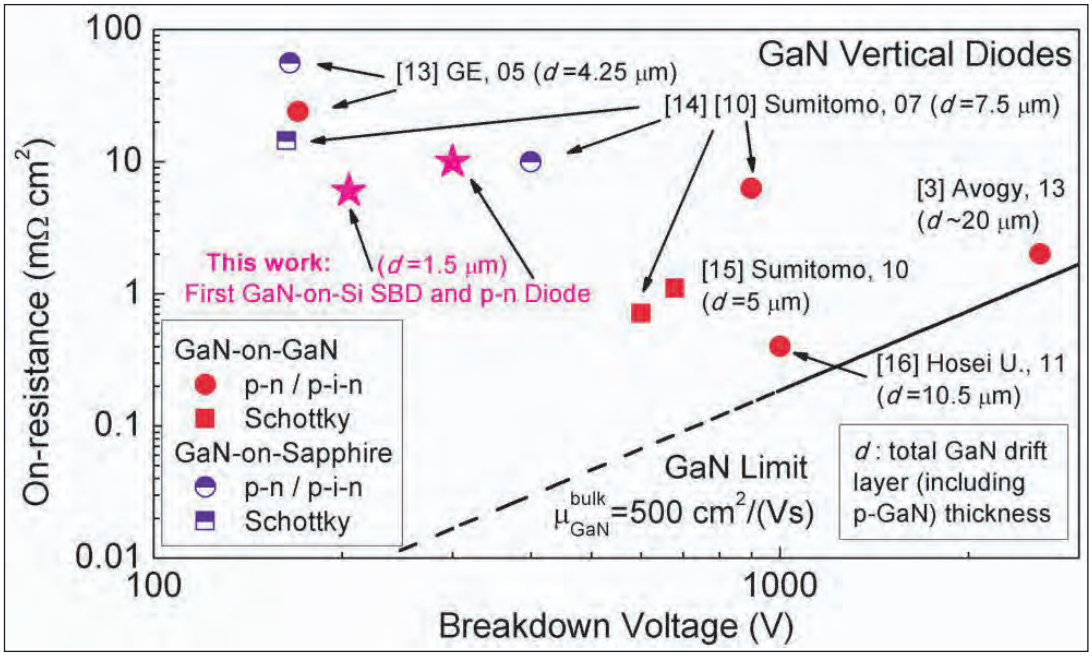

Figure 2. Specific on-resistance versus BV of MIT's GaN-on-Si vertical diodes and GaN-on-sapphire and GaN-on-GaN vertical in previous reports. BV of GaN-on-Si vertical p-n diode is soft.

The researchers developed two technologies to reduce leakage currents. First, a deep inductively coupled plasma reactive-ion etch for GaN, using chlorine/boron trichloride/argon plasma and a metal hard mask. The researchers write: "Under high ion bombardment energies, the use of metal hard mask could eliminate the erosion of mask edge usually observed when using traditional oxide hard mask, and therefore leads to a smoother vertical sidewall and a reduction in sidewall parasitic leakage current."

The second technology was the silicon nitride passivation applied using a sputtering process with an optimized pre-clean. The passivation managed "to effectively reduce the dielectric/GaN interface leakage widely reported for traditional passivation using plasma-enhanced chemical vapor deposition (PECVD) systems."

The p–n diode has higher ideality factor and on-voltage compared with the SBD due to the wide bandgap of GaN and higher resistance of the p-GaN layer, respectively (Table 1).

The Schottky diode suffered destructive breakdown (BV) under reverse bias at 90V without field plate and at 205V with field plate. The researchers comment: "This demonstrates that the FP structure is effective in spreading the electric field at electrode edges, reducing the reverse leakage current and improving the reverse BV."

The p-n diode has a soft breakdown (i.e. reversible) at 300V. At –200V reverse bias the leakage is 10^{-2}A/cm^2, a factor of three orders of magnitude better than that of SBD at the same bias. The p–n diode performance is also comparable to "state-of-the-art leakage reported for lateral AlGaN/GaN diodes on Si and SiC substrates".

The researchers estimate a peak field of ~3MV/cm in the p–n diode under –300V reverse bias, "the highest in all reported GaN-on-Si devices," according to the researchers. However, they point out that this is lower than the 3.4–3.7MV/cm reported for GaN-on-GaN structures, and the theoretically predicted critical field of 3.5–3.8MV/cm for GaN.

The researchers see their devices as providing a potential low-cost alternative to GaN-on-sapphire diodes (Figure 2), commenting that "considering the relatively thin drift layer (1.5µm) in our GaN-on-Si diodes compared to that typical in the GaN-on-sapphire (4–10µm) and GaN-on-GaN (5–20µm) diodes, our 200–300V BV results show great potential for low-cost GaN-on-Si vertical devices to outperform GaN-on-sapphire and GaN-on-GaN vertical devices with further improvement in GaN-on-Si growth technologies that enable a thicker and better-quality GaN drift layer on Si substrates." ■

http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6786327

Author: Mike Cooke

Table 1. Performance at 1A/cm^2 forward current density.

Diode	Ideality (n)	On-resistance (R_{on})	On-voltage (V_{on})
SBD	1.5	6mΩ-cm^2	0.5V
p-n	2.0	10mΩ-cm^2	3.5V

Growing cubic and hexagonal GaN on standard (100) silicon substrates

IBM and Northwestern University develop a growth technique with potential for monolithic integration with CMOS and polarization-free light-emitting devices.

IBM Research's Thomas J. Watson Research Center and Northwestern University have developed a technique to grow hexagonal- and cubic-phase gallium nitride (h-/c-GaN) on standard (100) silicon (Si) [Can Bayram et al, Adv. Funct. Mater., published online 1 April 2014].

Although GaN growth on silicon substrates is being widely developed with a view to reduced production costs for high-power and high-frequency transistors and light-emitting devices, usually the non-standard (111) crystal orientation is chosen to give a better lattice match between Si and GaN.

One disadvantage of using (111) silicon is that it reduces the potential for monolithic integration of high performance silicon CMOS with GaN. CMOS transistors on (111) silicon have inferior characteristics.

The researchers also point to cubic-phase GaN having a polarization-free crystal structure. Spontaneous and strain-dependent polarization fields in heterostructures based on hexagonal-phase GaN lead to internal electric fields that degrade performance, particularly in light-emitting applications.

The IBM/Northwestern technique involves etching grooves in the silicon that expose (111) facets that can seed h-GaN growth. When two GaN growth fronts from opposite facets meet, a c-GaN region develops.

The (100) silicon substrate was prepared with an RCA clean and a silicon dioxide (SiO_2) mask was created using thermal oxide deposition, 193nm photolithography and reactive-ion etch to expose the Si (100) surface (Figures 1a-c). The next step was to etch the silicon in potassium hydroxide (KOH) solution for a minute to selectively give grooves or trenches with (111) facets (Figure 1d).

The growth of GaN on an AlN nucleation layer was performed in a metal-organic chemical vapor deposition (MOCVD) system. The AlN was grown at the low temperature of 700°C and was preceded by ammonia-free heat-up and 'prealuminization' steps to remove native oxide and avoid silicon nitride formation. The AlN layer was at least 60nm thick.

Although GaN growth on silicon substrates is being widely developed with a view to reduced production costs for high-power and high-frequency transistors and light-emitting devices, usually the non-standard (111) crystal orientation is chosen to give a better lattice match between Si and GaN. One disadvantage of using (111) silicon is that it reduces the potential for monolithic integration of high performance silicon CMOS with GaN. CMOS transistors on (111) silicon have inferior characteristics. The researchers also point to cubic-phase GaN having a polarization-free crystal structure. Spontaneous and strain-dependent polarization fields in heterostructures based on hexagonal-phase GaN lead to internal electric fields that degrade performance

The GaN was grown at more than 1150°C, higher than the conventional 1050°C. "Such optimized MOCVD parameters enable a uniform and controlled GaN re-growth over that under conventional condition," according to the researchers.

GaN grown on wide trenches was in the hexagonal wurtzite crystal structure with the Si c-plane growth direction the same as that of the (111) facets of the GaN structure. The researchers found that threading dislocations (TDs) were filtered by m-plane stacking faults so that no TDs were discernable in the topmost GaN, according to cross-sectional transmission electron microscopy (XTEM).

Fast Fourier transform (FFT) electron diffraction analyses also show that the AlN layer is wurtzite on the (111) Si facets but poly-

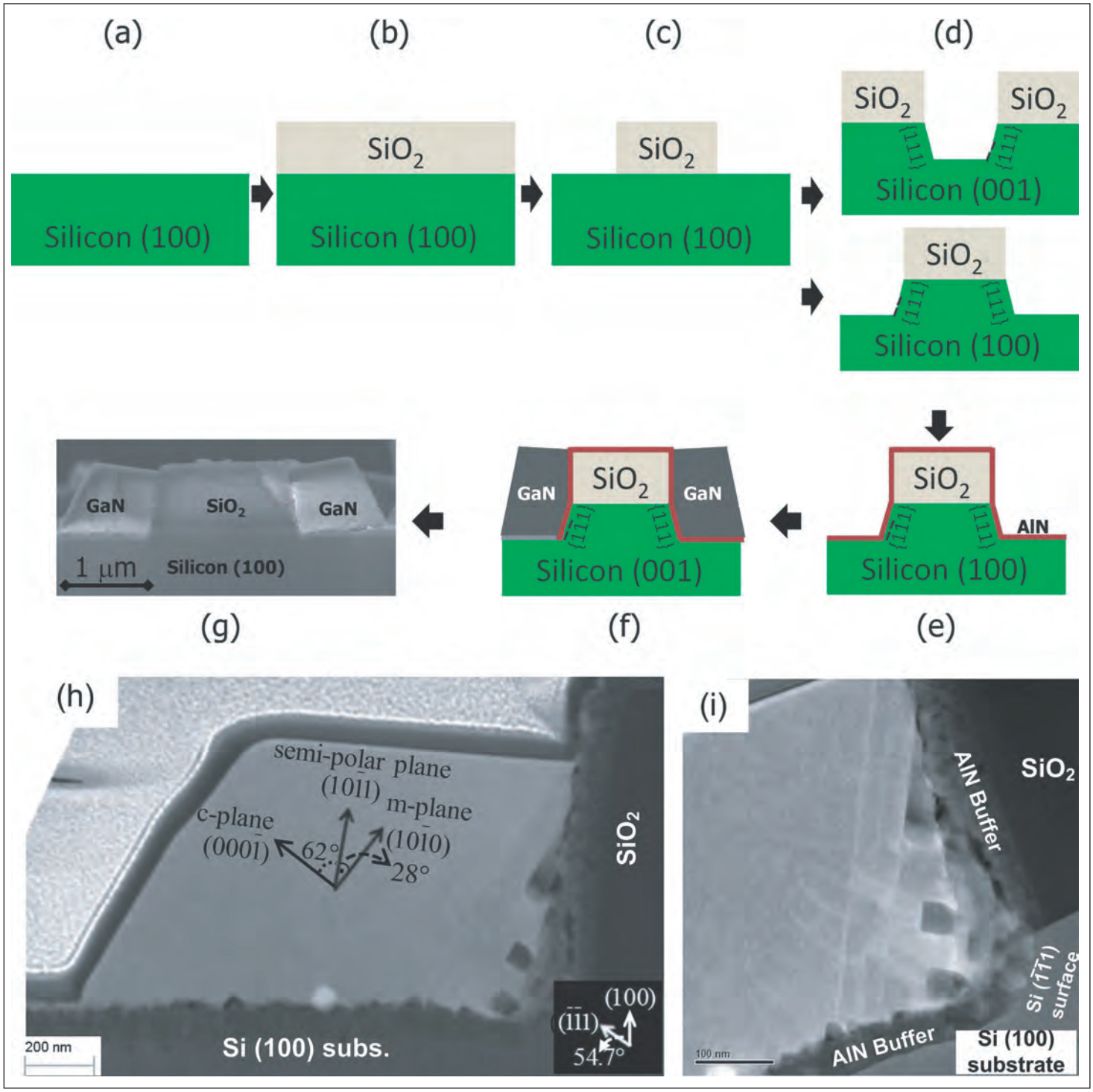

Figure 1. Schematic process flow for silicon (100) substrate preparation and MOCVD growth processes: (a) RCA clean; (b) thermal oxide growth; (c) lithography and reactive ion etch; (d) KOH dip (10%) to give final groove structures: (top) [SiO_2-Si{111}-Si{100}-Si{111}-SiO_2] or (bottom) [SiO_2-Si{111}-Si{100}]; (e) low-temperature AlN buffer deposition, (f) high-temperature GaN layer deposition. (g–i) Cross-sections of wurtzite phase GaN: (g) SEM and (h) HAADF-STEM view with crystallographic directions, and (i) HAADF-STEM view zoomed in GaN{0001}-Si{111} interface.

crystalline on the (100) Si groove bottom.

Moving from wide trenches to narrower grooves, the GaN grown on facing facets meets and forms in the cubic zincblende structure (Figure 2). Different groove openings of 1000nm, 650nm and 250nm were tested. Where the growth fronts meet, a void forms, along with crystallographic faults.

Electron microscopy showed the faults to be phase boundaries. The researchers report: "Bright-field TEM images in Figure 2 reveal no threading dislocations on both c-GaN and h-GaN surfaces." They further believe that the V-shape phase boundaries circumscribing the cubic phase GaN help to suppress TDs propagating, since the cubic phase growth front is aligned with the

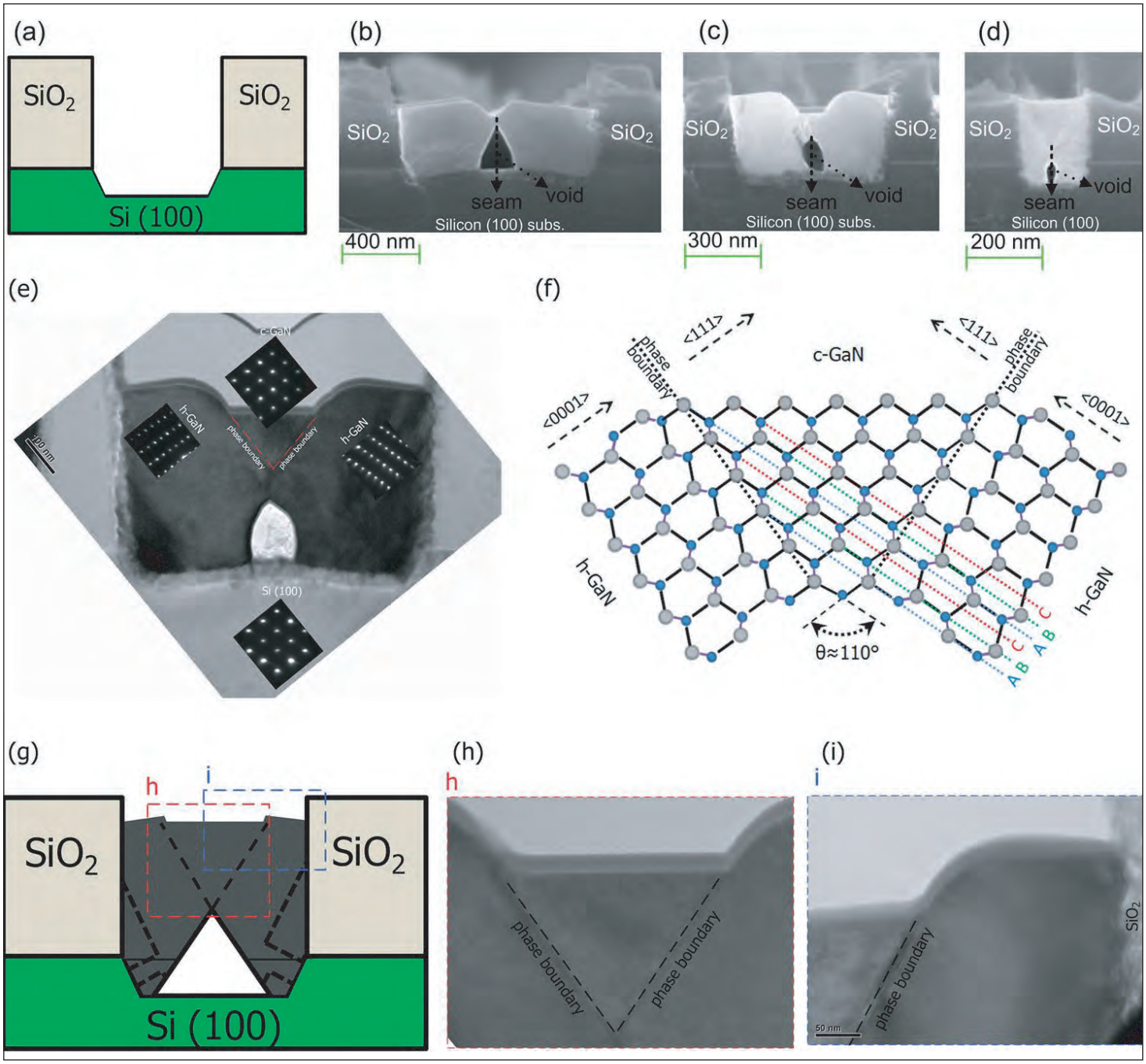

Figure 2. (a) Cross-sectional sketch of [SiO_2-Si{111}-Si{100}-Si{111}-SiO_2] groove structure for GaN re-growth. (b–d) Cross-sectional SEM of GaN grown on grooved Si (100) substrate having openings of (b) 1000 nm, (c) 650nm, and (d) 250nm. (e) Cross-sectional bright-field TEM of partially GaN-filled groove structure. FFT diffraction patterns of boxed regions correspond to c-GaN, h-GaN, and Si (100). (f) Cross-sectional sketch depicting wurtzite to cubic phase transition observed in groove. (g) Cross-sectional sketch of partially GaN-filled groove structure. Bright-field TEM images of (h) c-GaN and (i) h-GaN surfaces reveal no threading dislocations.

Si[100] direction whereas the wurtzite phase growth front is aligned with Si[111].

Micro-Raman spectroscopy, which probes phonon (quantized lattice vibration) characteristics, suggests that the h-GaN and c-GaN regions are stress-free. The researchers believe that the localized epitaxy is the reason for the absence of stress, compared with bulk deposition processes.

Finally, the researchers grew indium gallium nitride multiple quantum wells (InGaN/GaN MQWs) on the c-GaN. 'Intense' photoluminescence peaks were observed from the GaN (~365nm ultraviolet) and InGaN/GaN quantum wells (~420, blue-violet). The GaN peak covered the (~half-maxima) range 360–375nm, and the InGaN/GaN MQW peak was relatively broad (400–450nm). The GaN peak was about 0.8x that of the InGaN/GaN MQW. ■

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Author: Mike Cooke

UCSB reports highest-performing III-V MOSFETs

0.5mA/μm on-current, 100nA/μm off-current and 0.5V operating voltage match or exceed production silicon devices.

At the 2014 Symposium on VLSI Technology, University of California, Santa Barbara (UCSB) reported what are claimed to be the highest-performing III-V MOSFETs.

The research promises to help deliver higher semiconductor performance at lower power consumption levels for next-generation, high-performance servers. The research is supported by Semiconductor Research Corporation (SRC) of Research Triangle Park, NC, USA, the university-research consortium for semiconductors and related technologies.

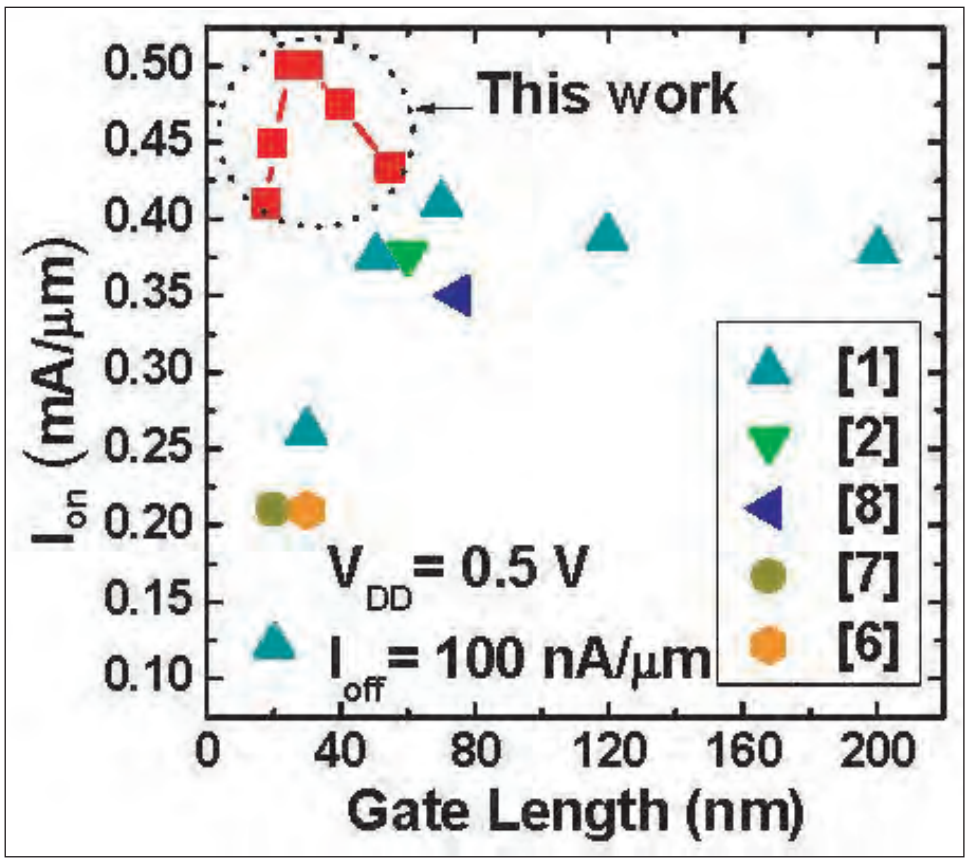
The UCSB team's III-V MOSFETs exhibit for the first time, it is reckoned, on-current, off-current and operating voltage comparable to or exceeding production silicon devices — while being constructed at small dimensions relevant to VLSI (very-large-scale integration) applications.

For the past decade, III-V MOSFETs have been widely studied by a large number of research groups, but none had reported a III-V MOSFET with a performance equal to, let alone surpassing, that of a silicon MOSFET of similar size. In particular, UCSB's transistors have a gate length of 25nm, an on-current of 0.5mA and off-current of 100nA per micron of transistor width, and require only 0.5V to operate.

"The goal in developing new transistors is to reach or beat performance goals while making the transistor smaller — it is no good getting high performance in a big transistor," says Mark Rodwell, professor of Electrical and Computer Engineering at UCSB. "In time, the UCSB III-V MOSFET should perform significantly better than silicon FinFETs of equal size," he adds.

To reach the reported performance, UCSB made three key improvements to the III-V MOSFET structure.

First, the transistors use extremely thin semiconductor channels, some 2.5nm (17 atoms) thick, with the semiconductor being indium arsenide (InAs). Making such thin layers improves the on-current and reduces the off-current. These ultra-thin layers were developed by UCSB Ph.D student Cheng-Ying Huang under the guidance of professor Arthur Gossard.



On-current (I_{on}), at drain–source voltage V_{DS} = 0.5V and off-current I_{off} = 100nA/μm, versus gate length (L_g) compared to the III-V literature.

Next, the transistors use very-high-quality gate insulators as dielectrics between the gate electrode and the semiconductor. These layers consist of a stack of alumina (Al_2O_3, on InAs) and zirconia (ZrO_2), and have a very high capacitance density so that, when the transistor is turned on, a large density of electrons can be induced into the semiconductor channel. Development of these dielectric layers was led by UCSB Ph.D student Varista Chobpattana under the guidance of professor Susanne Stemmer.

Third, the transistors use a vertical spacer layer design, which distributes the field more smoothly within the transistor, avoiding band-to-band tunneling. As with the very thin InAs channel design, the vertical spacer reduces the leakage currents, allowing the transistor's off-current to rival that of silicon MOSFETs. The transistor's overall design, construction and testing was led by Ph.D student Sanghoon Lee under Rodwell's guidance.

"The UCSB team's result goes a long way toward helping the industry address more efficient computing capabilities, with higher performance but lower voltage and energy consumption," comments Kwok Ng, senior director of Device Sciences at SRC. "This research is another critical step in helping ensure the continuation of Moore's Law." ■

www.ece.ucsb.edu/Faculty/rodwell/research_group/highfreq.html

Progress towards combining III-V technology with silicon manufacturing

Mike Cooke reports on contributions to the 'Technology' section of the recent 2014 Symposium on VLSI Technology and Circuits.

Complementary metal-oxide semiconductor (CMOS) transistors based on silicon wafers have been the mainstream of consumer electronics for many decades. As these devices approach atomic limits, new technologies are being sought so that development can continue at the present pace. In the past few years, researchers worldwide have been seeking to combine silicon and III-V electronics — either as a replacement for CMOS or as support for high-frequency functions or optoelectronics.

Silicon provides a low-cost platform for large-scale production, but there are materials with better semiconductor performance. For example, the bulk electron mobility of III-V compound semiconductors such as indium gallium arsenide (InGaAs) can be several times that of silicon (~1400cm^2/V-s). In electronic devices, the effective mobility is usually significantly less than the bulk value.

Combining the two processing traditions will not be easy. Many of the technologies used for III-V device production are not compatible with those used in silicon semiconductor manufacturing.

Here, we look at some contributions towards overcoming the challenges of combining III-V and silicon technology presented at the recent 2014 Symposium on VLSI Technology and Circuits in Hawaii (9–12 June)

First InGaAs FinFETs on 300mm silicon

A team from the IMEC research center in Belgium reported the first InGaAs Fin field-effect transistors (FinFETs) on 300mm Si substrates [Session 4.1]. Such silicon wafers are presently the largest diameter

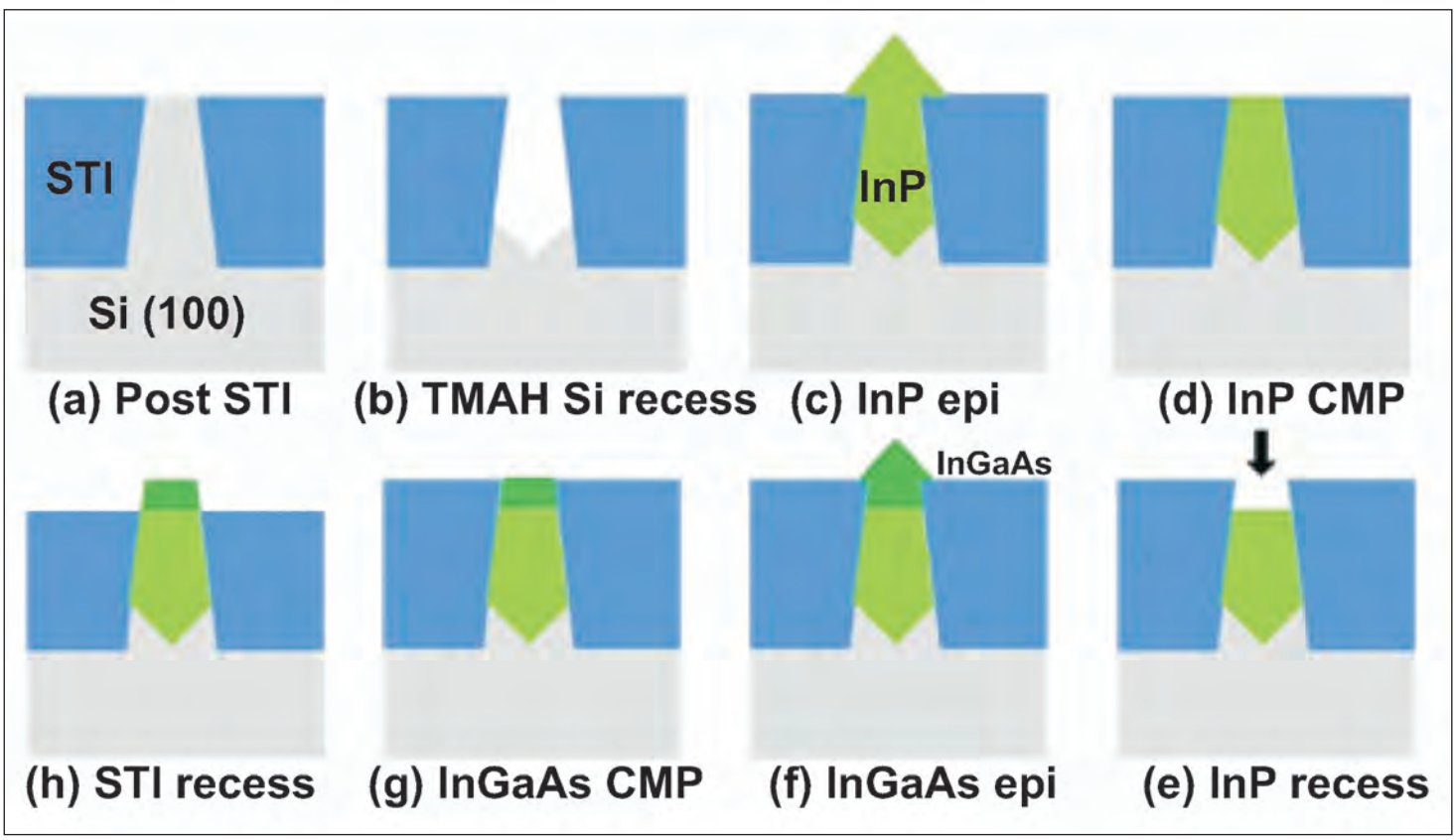


Figure 1. Process flow for IMEC's InGaAs fin formation on 300mm Si (100) substrates.

commercially available and form the basis for mass electronics manufacturing.

The researchers used a shallow trench isolation template as the basis for creating the InGaAs fins (Figure 1). Such templates consist of shallow trenches filled with dielectric/oxide insulator between silicon fins. The silicon fins were etched out and replaced with indium phosphide (InP) through metal-organic chemical vapor phase epitaxy (MOCVPE). The excess InP was removed with chemical mechanical planarization.

The InP material was further recessed to form the base of the InGaAs fin with target In content of 53% for lattice matching with InP. The InGaAs was doped with magnesium to provide p-type conductivity, overcoming the donor effect of carbon from the metal-organic deposition process. The magnesium doping was needed to avoid buffer leakage, but could not be too high or mobility degradation would result.

After another round of CMP, the fin was revealed with a SiCoNi selective etch of the STI oxide. SiCoNi is an Applied Materials etch process that provides 20:1 selectivity for silicon dioxide (SiO_2) over silicon. SiCoNi is marketed mainly as a 'pre-clean' for cobalt/nickel physical vapor deposition.

Raised source/drain (S/D) regions consisting of silicon-doped n-InAs were grown around dummy gates. A 'high-k last' replacement metal gate (RMG) process was used with a stack consisting of 2nm aluminium oxide (Al_2O_3), 3nm hafnium dioxide (HfO_2), 3nm titanium nitride and tungsten plug contact on titanium liner. The high-k last process avoids thermal degradation during the high-temperature (more than 500ºC) InAs S/D deposition. The equivalent oxide thickness (EOT) of the stack was 1.9nm.

A 50nm-gate-length transistor with optimized buffer/channel doping achieved a subthreshold swing (SS) of 190mV/dec and an extrinsic peak transconductance of 558μS/μm. The researchers comment: "Optimization of the devices for best short-channel and on-state performance will require a more detailed study of the process window for InP and InGaAs Mg doping next to a more aggressive EOT and fin width."

The IMEC team has also been developing InGaAs quantum well (QW) metal-oxide field-effect transistors (MOSFETs) [Session 19.1]. The QWMOSFETs (Figure 2) were grown on indium phosphide substrates. The quantum well structure was grown first up to a 20nm heavily doped n-InGaAs cap layer. The InGaAs cap layer provided protection of the underlying layers during high temperature S/D re-growth.

The device fabrication began with electron-beam lithography in hydrogen silsesquioxane (HSQ) to provide a mask for the S/D metal-organic chemical vapor deposition (MOCVD) re-growth. The S/D regions consisted of $In_{0.53}Ga_{0.47}As$ doped to a concentration of $2x10^{19}/cm^3$.

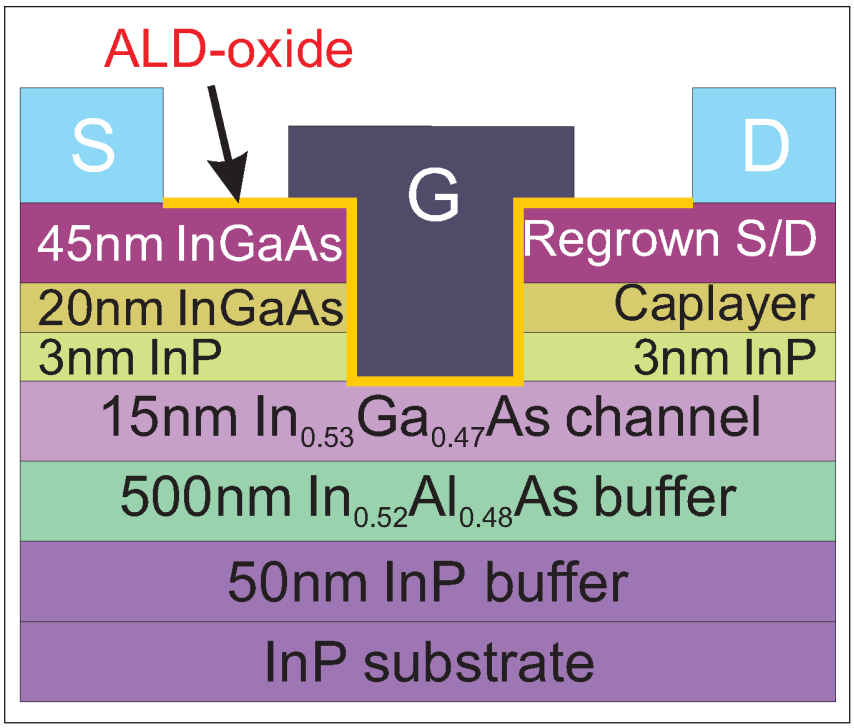


Figure 2. Device with nominal layer thickness.

After forming an isolation mesa, the InGaAs cap and InP layers were removed. A 3-cycle digital etch (atomic layer deposition in reverse) was performed to give a clean InGaAs channel surface on which to deposit the gate dielectric.

Three different gate dielectric recipes were studied: 5nm Al_2O_3, 2nm/3nm Al_2O_3/HfO_2, and 1nm/3nm Al_2O_3/HfO_2. These resulted in equivalent oxide thicknesses (EOTs) of 2.5nm, 1.6nm, 1.1nm, respectively. The gate electrode was aluminium. The completed devices were subjected to annealing in forming gas (H_2/N_2).

Initial tests on the three device types suggested that even the very thin EOT of 1.1nm was sufficient to block gate leakage current and that there was room for further EOT thinning.

A 75nm gate length device with 1.1nm EOT demonstrated an on-current of 470μA/μm at 0.5V drain bias, an off-current of 100nA/μm, and peak extrinsic transconductance of 2.35mS/μm. The SS was 87mV/decade at 0.5V drain and 84mV/decade at 0.05V. The threshold voltage was slightly negative at –0.1V.

The team comments: "Our devices exhibit highest I_{on} and $g_{m,ext}$ among InGaAs-channel MOSFETs at a large L_g range, approaching InAs devices. Meanwhile, SS remains the lowest for planar III-V MOSFETs. These advances emerge from the high-quality dielectric/III-V interface, S/D re-growth, and epitaxy, especially the very low background doping in InAlAs buffer which gives low I_{off} and better electrostatics." ►

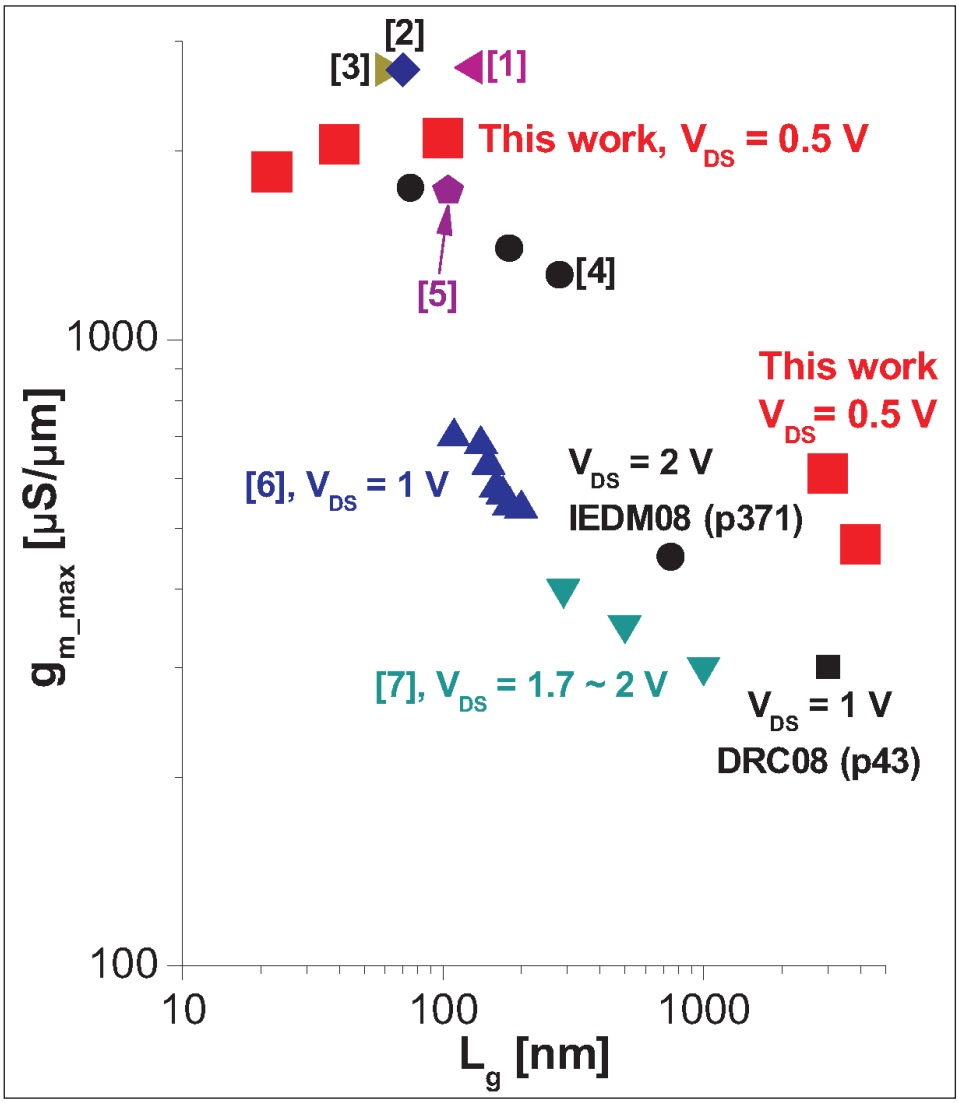


Figure 3. Peak transconductance ($g_{m.max}$) versus gate length for Pennsylvania/Samsung InGaAs QW MOSFETs with re-grown S/D by MOCVD ("this work"), as well as other reports. Long-channel devices exhibit record $g_{m.max}$ behavior.

Pennsylvania State University and Samsung Electronics reported on joint research into the effect of varying the indium content of InGaAs in QW FinFETs (QWFFs) [Session 8.4].

The researchers used heterostructure materials grown using molecular beam epitaxy (MBE). First, a gate recess region was created with a citric acid wet etch selective to indium phosphide. This step cut through the cap layer and produced raised S/D regions. The fins were created with 100nm pitch using electron-beam lithography and chlorine-based plasma etch. The high-k gate dielectric consisted of 1nm/3nm atomic layer deposition (ALD) Al_2O_3/HfO_2. Palladium was used as gate electrode. The S/D ohmic contacts were titanium/gold.

The researchers found that the highest on-current was obtained with $In_{0.7}Ga_{0.3}As$ quantum well fin channels of 38nm width. A 1μm gate-length device had a peak mobility of 3000cm^2/V-s, compared with 1450cm^2/V-s for an $In_{0.53}Ga_{0.47}As$ channel. A non quantum well finFET with $In_{0.53}Ga_{0.47}As$ channel had a mobility of 1000cm^2/V-s.

A short-channel QWFF with gate length 120nm and fin width 55nm achieved a saturation drain current of 1.16mA/μm with the gate at 1V over threshold. The extrinsic peak transconductance was 1.9mS/μm at 0.5V drain bias. The off-current was 30nA/μm. The SS was 236mV/decade.

QW-MOSFET records

Korea Advanced Nano-fab Center (KANC), Yonsei University, SEMATECH and GLOBALFOUNDRIES reported on a gate-last (GL) process for InGaAs QWMOSFETs with record performance [Session 4.3].

The researchers attribute their results to the gate-last process with "selective S/D regrowth by MOCVD to improve scalability and contact resistivity, optimized gate stack process with thin EOT and low [interface trap density] D_{it} to improve SS, and gate-last process to maintain excellent carrier transport of the InGaAs channel."

The device material was grown on InP substrates using MBE. The undoped 10nm $In_{0.7}Ga_{0.3}As$ channel layer was deposited on $In_{0.52}Al_{0.48}As$ back-barrier. The S/D contacts were grown around an HSQ dummy gate.

The transistor fabrication involved mesa isolation, molybdenum S/D contacts, and atomic layer deposition of Al_2O_3/HfO_2 gate dielectric and titanium nitride gate electrode.

Long-gate (5μm) devices with equivalent oxide thickness of 1nm demonstrated SS of 80mV/decade and drain-induced barrier lowering (DIBL) of 22mV/V. The effective mobility was greater than 5500cm^2/V-s.

The researchers comment: "The mobility in this work is one of the highest reported for any surface-channel MOSFET, with EOT close to 1nm. This is a record for a III-V MOSFET, arising from both the optimized GL integration flow and low-D_{it} gate stack process with Al_2O_3/HfO_2 that benefit fully from the high electron mobility associated with the $In_{0.7}Ga_{0.3}As$ channel."

On the basis of the high effective mobility, the device also exhibited record transconductance for longer gate lengths (Figure 3).

A short-gate (40nm) transistor had a somewhat higher SS of 105mV/decade and DIBL of 150mV/V.

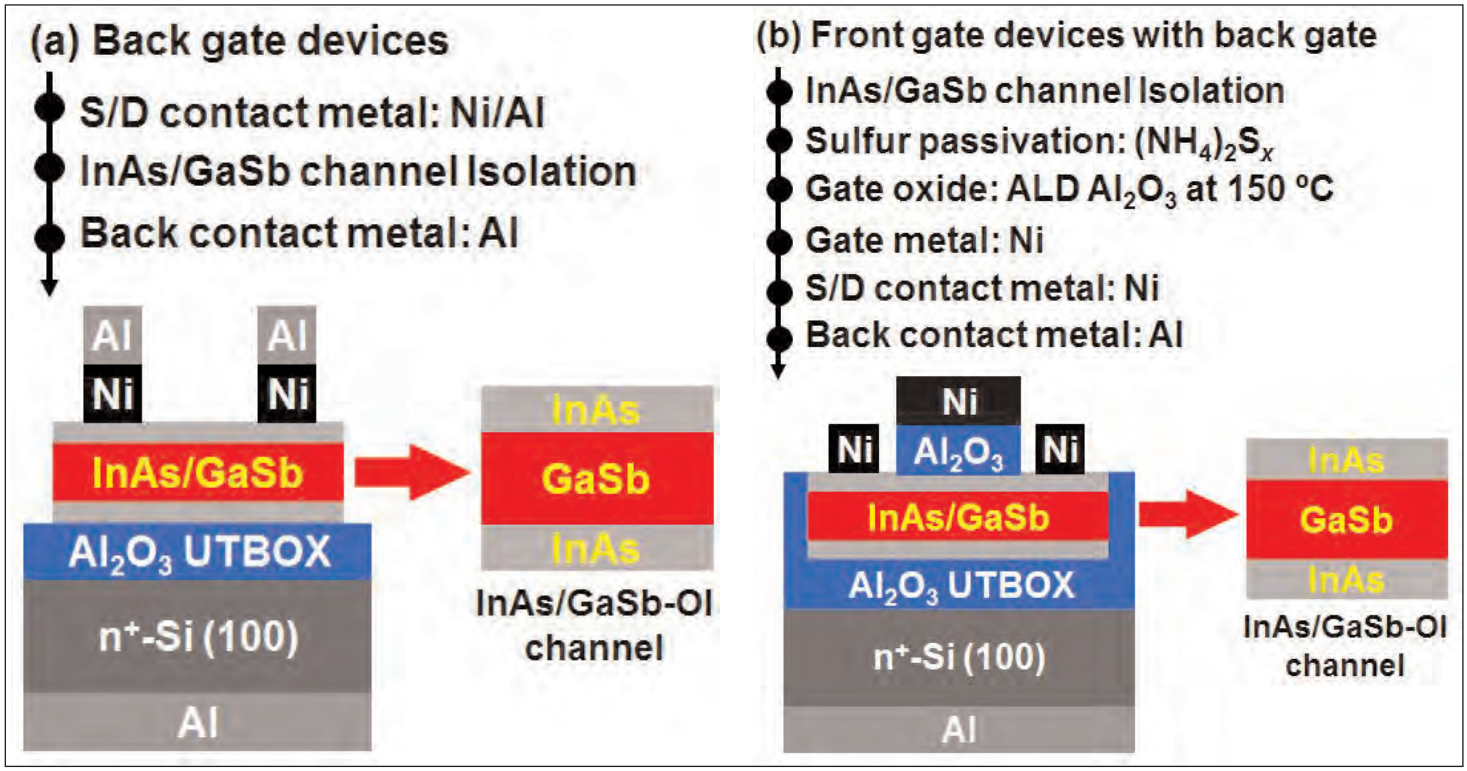


Figure 4. Fabrication process flow of (a) back-gate devices and (b) front-gate devices with back gate.

At 0.5V drain bias, the peak transconductance was "fairly high" at 2mS/μm. Going to even shorter gates of 22nm, the SS more than doubled to 250mV/decade (DIBL 450mV/V). The researchers see this as indicating the need for '3D channel architectures' — in other words, finFETs and the like.

The team believes improved short-channel performance can be achieved through development of a self-aligned process for the S/D contacts.

Single-structure InAs/GaSb CMOS

University of Tokyo, NTT Corporation, and the Japanese JST/CREST funding program have developed a single structure of indium arsenide and gallium antimonide (InAs/GaSb) that can be used to create both n- and p-MOSFETs [Session 4.2]. The aim of the work is to avoid the problems of combining III-V n-type devices with germanium p-type transistors with different structures for complementary metal-oxide semiconductor (CMOS) performance. The researchers believe an all-III-V CMOS solution would be easier to integrate.

The heterostructure consisted of GaSb sandwiched between ultrathin layers of InAs grown on InAs substrate. Simulations suggested that the structure could support both n- and p-type channels where the charge carriers are electrons or holes, respectively. The structure was transferred to silicon through direct wafer bonding. The adhesion was between layers of aluminium oxide on both the III-V heterostructure and the silicon wafer.

Transistors were fabricated in two different configurations (Figure 4). In one type, the electrostatic control was though a simple back gate with an aluminium back contact through the silicon wafer. A more sophisticated transistor consisted of both front- and back-gate contacts.

With just the back gate, the researchers demonstrated both n- and p-MOSFET performance. Hole mobility with an InAs thickness of 2.5nm and GaSb thickness of 20nm was better than silicon-based devices. With 5nm InAs and 20nm GaSb, the electron mobility was 1200cm^2/V-s – again better than bulk silicon. The electron mobility decreased with thinner 2.5nm InAs, but the value was still greater than obtained for ultrathin silicon-on-insulator devices. "These results indicate that III-V channels can maintain an advantage against Si channels even with the ultrathin-body CMOS structures," the researchers say.

The more sophisticated devices allowed the threshold voltage of the front gate to be controlled by the back gate. When the back gate potential was –2V, pMOSFET behavior was observed in devices with 2.5nm InAs and 20nm GaSb. Setting the back gate to –0.5V gave nMOSFET performance in the same devices.

University of Tokyo and JST/CREST have also worked with US company IntelliEPI Inc to develop a direct wafer bonding (DWB) process that could transfer III-V layers to larger-diameter silicon wafers [Session 4.4]. The researchers reported: "We have demonstrated InGaAs-OI MOSFETs on Si by using the InGaAs channels on Si donor wafers, for the first time."

Usually, DWB transfers layers from much smaller wafers of III-V substrates such as InP. These wafers are often limited to diameters of about 2 inches, while

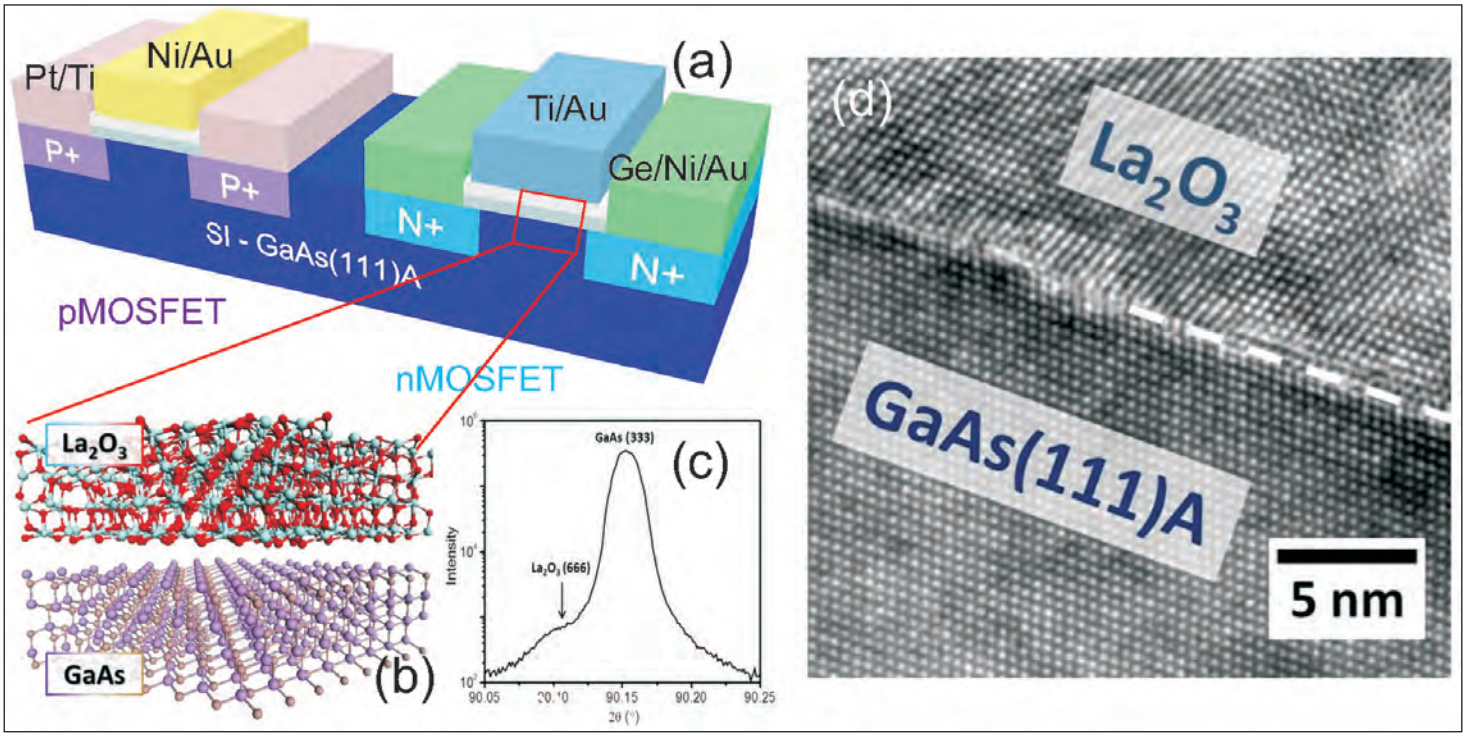


Figure 5. (a) Schematics of GaAs pMOSFET and nMOSFET. (b) Atomic structure view of single-crystalline La_2O_3 layer over GaAs(111)A surface. (c) High-resolution x-ray omega-two theta coupled scan for La_2O_3 on GaAs (111)A. (d) HR-TEM image of a La_2O_3/GaAs(111)A epitaxial interface.

mass-production silicon manufacturing prefers larger 300mm (12-inch) diameter wafers. In the future, large-scale manufacturers plan to implement 450mm diameters.

Instead of using III-V donor wafers to create the heterostructures, a silicon donor wafer was prepared by growing InAlAs/GaAs buffer layers and the InGaAs channel using MBE. The InGaAs channel layer was found to have mobility 6550cm^2/V-s and carrier concentration 1.5x10^{17}/cm^3 at 300K.

The direct wafer bonding was prepared by depositing Al_2O_3 on both the donor and target wafer surfaces, followed by CMP. A further layer of HfO_2 was deposited on the wafers before bonding. The donor wafer silicon handle and buffer layers were removed by etching with tetramethylammonium hydroxide (silicon), citric acid (GaAs), and hydrochloric acid (InAlAs).

The result was "very uniform formation of a high-

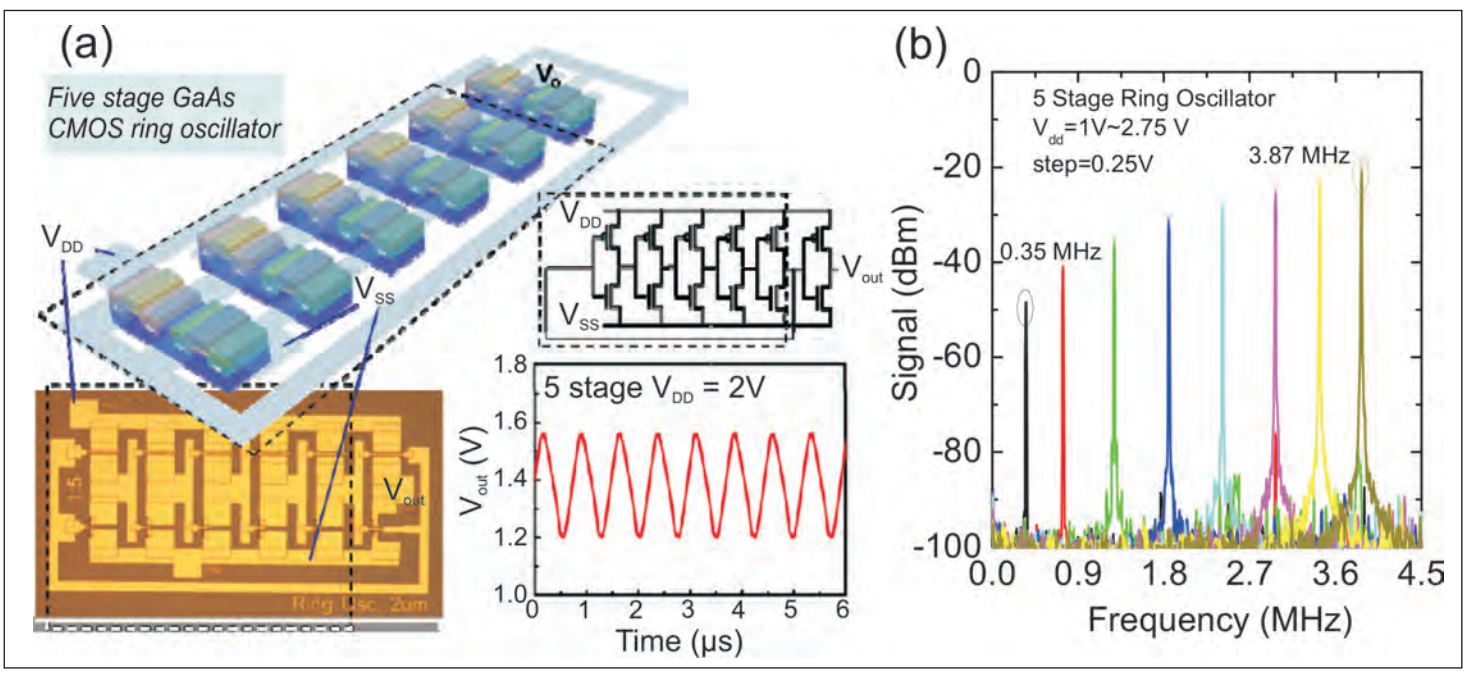


Figure 6. (a) Illustration, circuit schematic, optical micrograph and output characteristics of a GaAs CMOS five-stage ring oscillator. (b) Measured output power spectrum of five-stage GaAs CMOS ring oscillator.

quality 10nm-thick InGaAs-OI wafer on a Si substrate, transferred from a Si donor wafer," according to the researchers. Performance of the InGaAs material was similar to that of InGaAs grown on III-V substrates in terms of photoluminescence and Raman spectroscopy. The root-mean-square surface roughness was 1.4nm, according to atomic force microscopy.

The material was used to create MOSFETs with 10nm Al_2O_3 gate dielectric and tantalum gate metal. The S/D contacts were nickel. With a channel thickness of 9nm and gate length of 1μm, the SS of the MOSFETs was 100mV/decade and the on/off-current ratio was more than 10^6. The effective electron mobility was 1700cm^2/V-s – a three-fold enhancement over silicon-based devices, according to the researchers.

GaAs CMOS

Purdue and Harvard universities jointly claimed the first high-performance GaAs CMOS devices and circuits [Session 6.4]. The researchers used complementary metal-oxide semiconductor (CMOS) field-effect transistors (FETs) created with a lanthanum oxide (La_2O_3) dielectric (Figure 5). The circuits included inverters, NAND and NOR logic gates, and five-stage ring oscillators.

The La_2O_3 dielectric layers of the devices were fabricated with atomic layer epitaxy (ALE). A capping layer of Al_2O_3 was added to protect the La_2O_3 from the air. X-ray analysis suggested that the lattice mismatch between the La_2O_3 and underlying GaAs(111)A material was only 0.04%.

A 1μm-gate-length nMOSFET had a maximum drain current of 376mA/mm at 2V drain bias and 3.5V gate potential. The SS was 74mV/decade. The equivalent oxide thickness was 3nm. The peak effective electron mobility was 1150cm^2/V-s.

Similar pMOSFETs achieved maximum drain currents of 30mA/mm (800ºC) and SS of 270mV/decade (780ºC). Unfortunately, there is a trade-off in annealing temperature between drain current and SS. Higher temperatures lead to higher drain current but also poorer SS and low on/off-current ratio. The peak effective hole mobility for 780ºC annealing was 180cm^2/V-s.

An inverter circuit based on these components achieved a gain of 12 at 3V operating voltage. The NAND/NOR logic gates achieved output voltages of 0V/2.5V with 0V/2.5V inputs. The ring oscillator (Figure 6) frequencies at 1V and 2.75V were 0.35MHz and 3.87MHz, respectively. ■

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Beryllium oxide interlayer reduces interface trapping in InGaAs MOSFETs

A US/Korea team has developed a BeO/HfO_2 bilayer dielectric gate stack for QW MOSFETs for the 7nm technology node and beyond.

Researchers based in USA and South Korea have developed a gate stack for III-V quantum well metal-oxide-semiconductor field-effect transistors (QW MOSFETs) based on a bilayer dielectric of beryllium oxide (BeO) and hafnium dioxide (HfO_2) [D.Koh et al, Appl. Phys. Lett., vol104, p163502, 2014].

BeO has a large energy bandgap of 10.6eV and a larger conduction band offset from indium gallium arsenide (InGaAs) channel material than alternatives such as aluminium oxide (Al_2O_3). Such properties as exhibited by BeO are attractive for avoiding interface traps that adversely affect MOSFET performance. Other attractions of BeO include a 'self-cleaning effect', higher thermal stability, and better performance as an oxygen diffusion barrier.

The US/Korea research involved University of Texas at Austin, USA; SEMATECH Inc, USA; Chungnam National University, South Korea; GLOBALFOUNDRIES, USA; and Texas State University, USA.

The III-V epitaxial structure was grown using molecular beam epitaxy (MBE) on indium phosphide (InP) substrate (Figure 1). The indium aluminium arsenide ($In_{0.52}Al_{0.48}As$) buffer provided a back-barrier for the indium gallium arsenide ($In_{0.7}Ga_{0.3}As$) quantum well. The final layers consisted of 2nm InP and 20nm n^+-$In_{0.53}Ga_{0.47}As$. The n^+-InGaAs reduced the access resistance to the channel and increased channel electron concentration.

Transistor fabrication consisted of electrical isolation with a phosphoric acid wet etch, molybdenum/

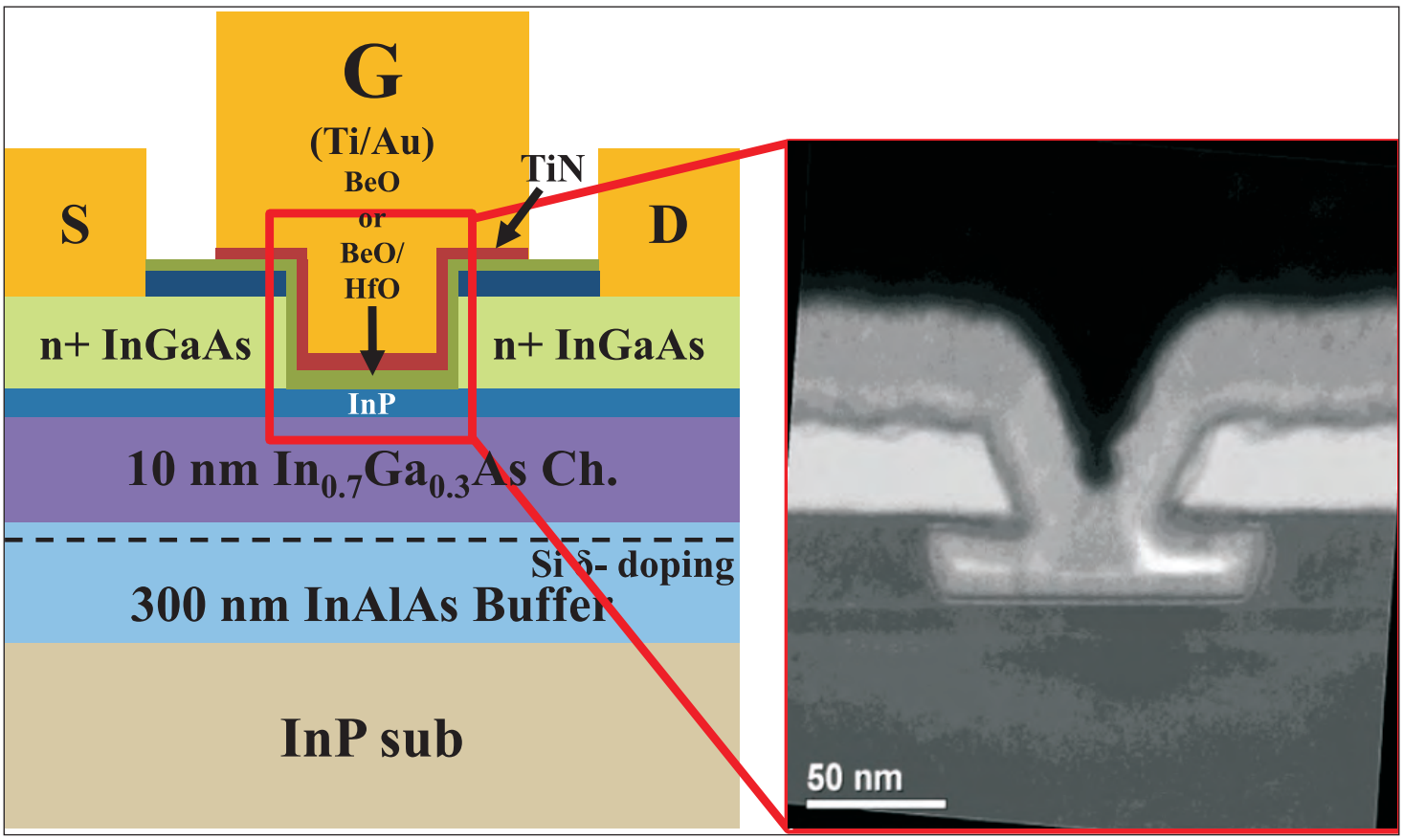

Figure 1. Schematic of QW MOSFETs device structure with BeO or BeO/HfO_2 as gate dielectric.

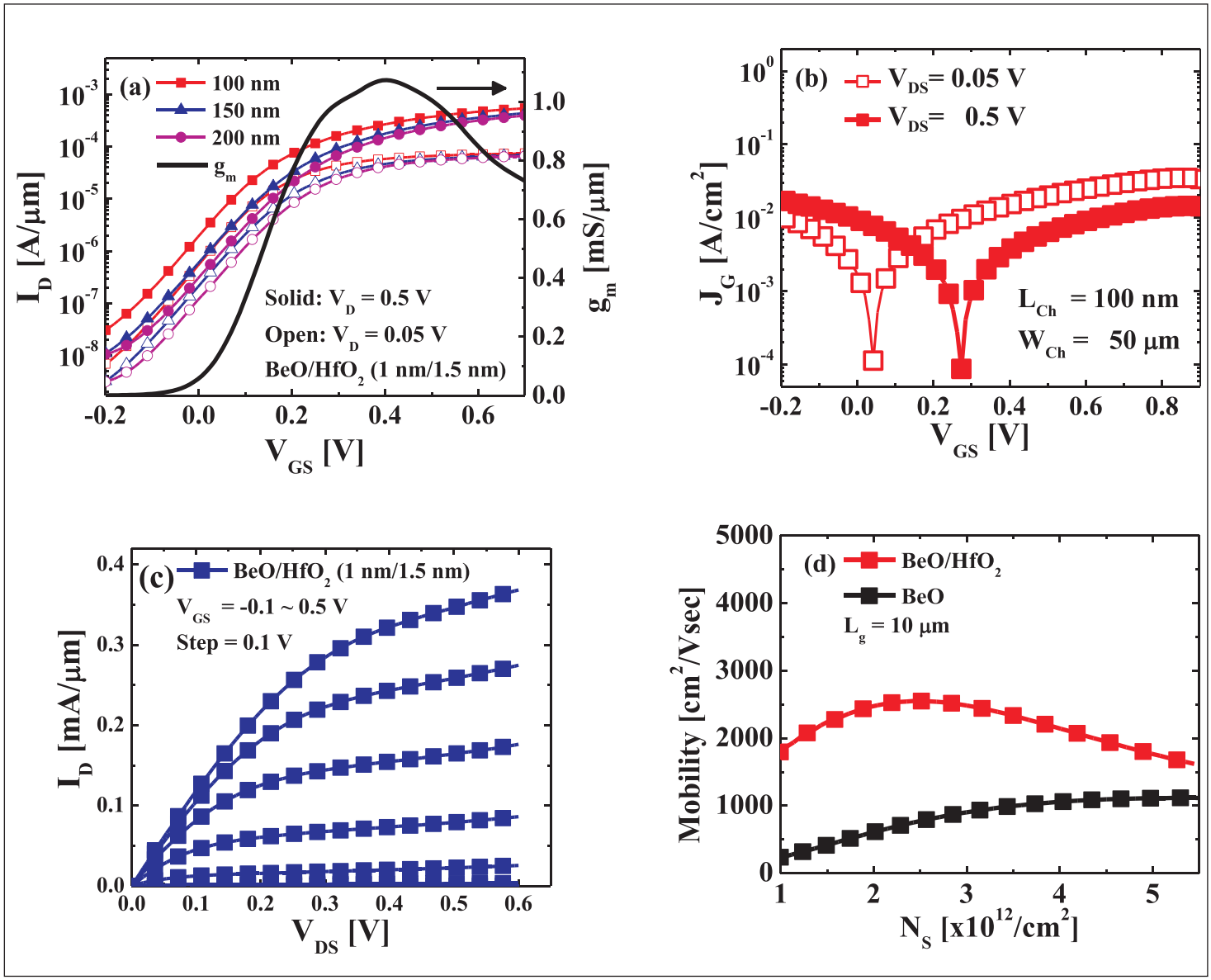

Figure 2. Electrical characteristic of QW MOSFETs with BeO/HfO_2 (1/1.5nm) gate stack. (a) Subthreshold performance with different channel length and transconductance (gm) of 100nm-gate-length device, (b) gate leakage current density of 100nm device, (c) drive current of 100nm QW MOSFET, and (d) mobility enhancement of 10μm-gate 1nm/1.5nm BeO/HfO_2 over 2nm BeO QW MOSFET.

titanium/gold source/drain deposition, and gate stack formation. The patterning for the gate created a hard mask of silicon dioxide. The mask was used as the pattern for an etch down to the InGaAs cap with carbon tetrafluoride plasma, followed by phosphoric acid-based wet etch to the InP layer.

The BeO interface passivation and HfO_2 dielectric (1nm/1.5nm) were applied using 250°C atomic layer deposition (ALD) in a Cambridge Nano system. The gate metal was titanium and the gate contact pad was titanium/gold.

Measurements on MOS capacitors with a BeO/HfO_2 bilayer gave a mid-gap interface trap density of $1x10^{12}$/eV-cm^2. A 2nm BeO dielectric gave a higher density of $2x10^{12}$/eV-cm^2. HfO_2 on its own, or with Al_2O_3 interlayer, tends to produce higher values.

With 100nm gate length, the MOSFET achieved peak transconductance of 1.1mS/μm at 0.5V drain bias (Figure 2). The subthreshold swing was 100mV/decade, which is described as "excellent" by the researchers. The drain-induced barrier lowering was 100mV/V. The gate leakage current density was ~10^{-2}A/cm^2. At 0.6V gate potential, the drive current density was 0.35mA/μm.

The equivalent oxide thickness of the BeO/HfO_2 bilayer stack was 0.93nm. Long-channel effective mobility was 2500cm^2/V-s.

"These results highlight the potential of atomic-layer-deposited BeO for use as a gate dielectric or interface passivation layer for III–V MOSFETs at the 7nm technology node and/or beyond," the researchers comment. ■

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Author: Mike Cooke

Growing InGaAs MOSCAPs directly on (100) silicon substrates

A metamorphic buffer of only 840nm is the thinnest reported to date, according to researchers in Taiwan.

Researchers in Taiwan have produced indium gallium arsenide (InGaAs) metal-oxide-semiconductor capacitors (MOSCAPs) with low interface trap densities directly on silicon [Yueh-Chin Lin etal, Appl. Phys. Express, vol7, p041202, 2014]. InGaAs is a high-mobility semiconductor that should improve transistor characteristics for high-frequency applications.

MOSCAPs with low trap densities are an important step towards producing high-performance MOS field-effect transistors (MOSFETs). In effect, MOSCAPs are MOSFETs without source/drain contacts. Reducing the trap density at the dielectric/semiconductor interface is vital for good electrostatic control by the gate in MOSFETs.

Often, InGaAs heterostructures are grown first on indium phosphide (InP) substrates and then transferred to silicon by wafer bonding techniques. The team from National Chiao-Tung University and Taiwan Semiconductor Manufacturing Company

Table 1. Parameters of InGaAs MOSCAPs with Al_2O_3 annealing at 400°C.

Doping	Interface trap density	Frequency dispersion	Hysteresis
$8.0x10^{16}/cm^3$	$5.80x10^{11}/cm^2$-eV	2.74%/decade	76mV
$1.7x10^{17}/cm^3$	$5.87x10^{11}/cm^2$-eV	2.52%/decade	65mV
$6.2x10^{17}/cm^3$	$5.44x10^{11}/cm^2$-eV	2.37%/decade	84mV

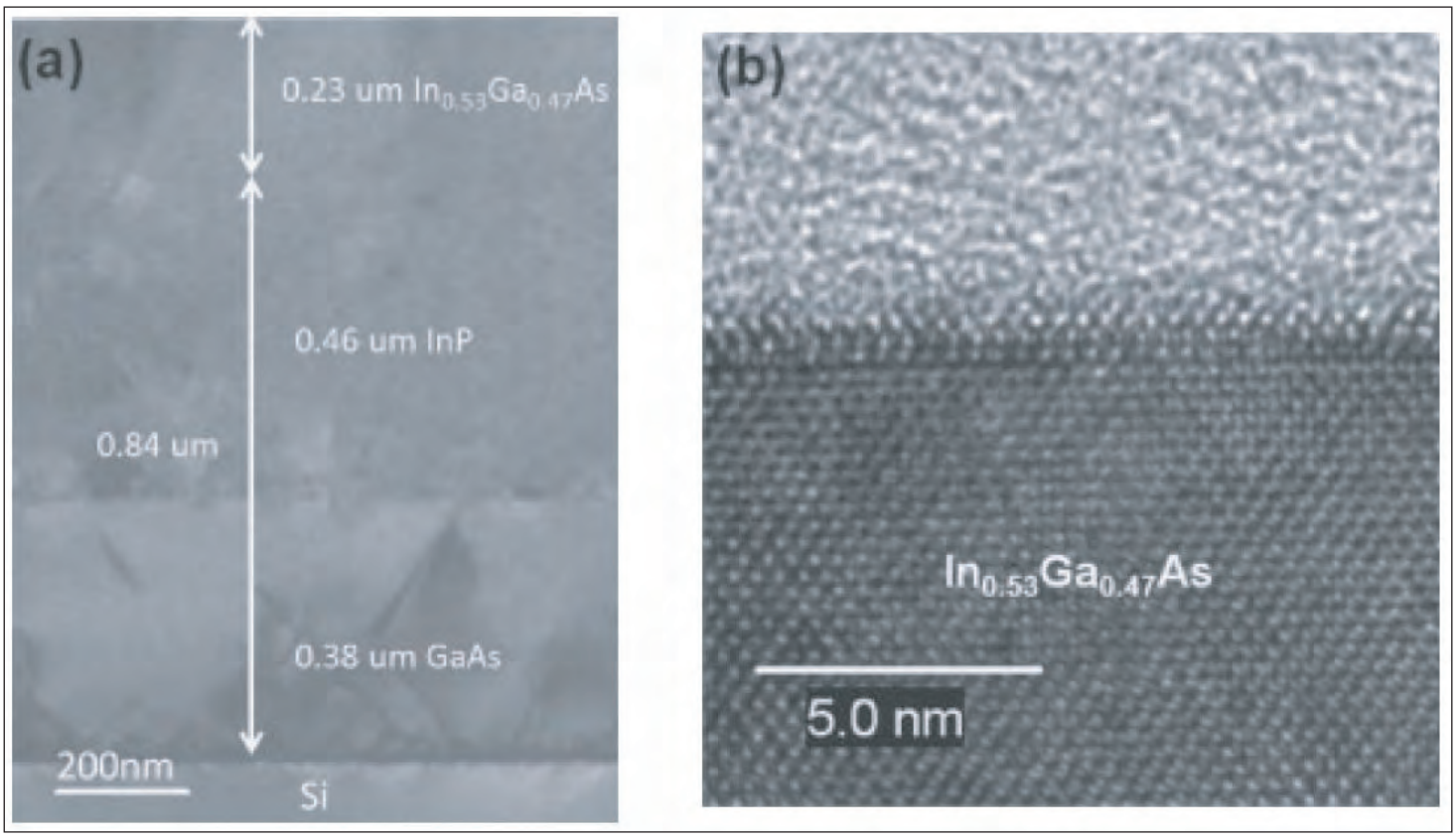

Figure 1. Transmission electron micrographs of InGaAs/Si heterostructure (a) and high-resolution close-up of InGaAs channel region (b).

(TSMC) grew their InGaAs heterostructure (Figure 1) on 300mm (100) silicon (Si) substrates directly by metal-organic chemical vapor deposition (MOCVD).

The first buffer layer of strained GaAs was designed to metamorphically bridge the lattice mismatch between silicon and the InP buffer and lattice-matched $In_{0.53}Ga_{0.47}As$ 'channel'. The GaAs/InP metamorphic combination was 840nm thick: "the thinnest buffer for the growth of $In_{0.53}Ga_{0.47}As$ on a Si substrate reported to date," according to the researchers.

Analysis of the sample suggested that the dislocations were predominantly trapped in the GaAs layer. The dislocations in the $In_{0.53}Ga_{0.47}As$ layer were estimated at 2–3x10^9/cm^2, according to x-ray diffraction (XRD) measurements. Atomic force microscopy (AFM) of the $In_{0.53}Ga_{0.47}As$ surface gave a root-mean square roughness of 1.94nm averaged over a 5µmx5µm field. This in the range given by previous $In_{0.53}Ga_{0.47}As$ growth on Si with thicker GaAs/InP buffers.

Room-temperature Hall mobility measurements gave values in excess of 5000cm^2/V-s, comparable to InGaAs grown on InP substrates.

The metal-oxide-semiconductor capacitors (MOSCAPs) were fabricated by surface treatment, aluminium oxide and gate metal deposition, and Ohmic contact formation. The 8nm-thick oxide was applied using atomic layer deposition (ALD) at 300°C, followed by a 10-minute anneal process in nitrogen gas. The gate metal layers consisted of nickel and gold. The Ohmic contact was constructed by etching the oxide with hydrofluoric acid, revealing the InGaAs surface, and then depositing and annealing gold/germanium/nickel/gold metal contacts.

According to capacitance versus voltage measurements (Figure 2), the aluminium oxide anneal process gave fewer interface traps at 400°C (5.44–5.87x10^{11}/cm^2-eV), compared with a similar sample annealed at 500°C (1.45–1.62x10^{12}/cm^2-eV). With 400°C annealing, the frequency dispersion was small and the hysteresis "excellent" (Table 1).

Results demonstrate the potential of integrating an InGaAs-based material on a 12" Si substrate by MOCVD for future high-performance low-power logic device applications and mainstream manufacturing

The researchers conclude the performance of the Al_2O_3/InGaAs/Si MOSCAPs was comparable to Al_2O_3/InGaAs on lattice-matched InP. "The results demonstrate the potential of integrating an InGaAs-based material on a 12-inch silicon substrate by MOCVD for future high-performance low-power logic device applications and mainstream manufacturing." ■

http://iopscience.iop.org/1882-0786/7/4/041202/article

Author: Mike Cooke

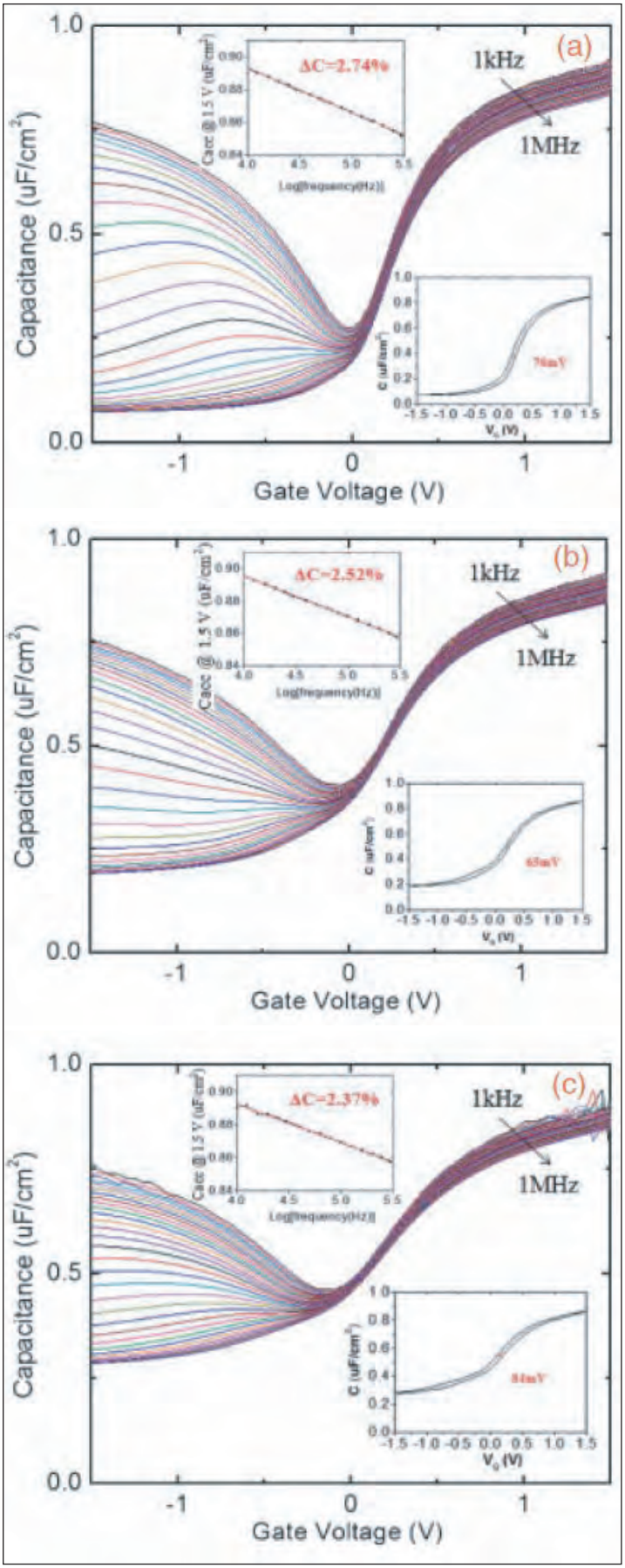

Figure 2. Capacitance-voltage curves for samples with silicon-doped InGaAs layers with oxide annealed at 400°C: (a) 8.0x10^{16}/cm^3, (b) 1.7x10^{17}/cm^3, (c) 6.2x10^{17}/cm^3.

Top-down InGaAs nanowire fabrication enabled by novel etch processing

MIT shows how plasma etch surface damage can be mitigated by using digital etch repair cycles following ICP-RIE etch.

Massachusetts Institute of Technology (MIT) researchers Xin Zhao and Jesús A. del Alamo have developed a 'novel' inductively coupled plasma reactive-ion etch (ICP-RIE) process that can produce sub-20nm vertical indium gallium arsenide (InGaAs) nanowires (NWs) with aspect ratios exceeding 10 [IEEE Electron Device Letters, published online 4 April 2014]. The technique also uses an extra 'digital etch' to mitigate surface damage of the nanowires caused by the aggressive ICP-RIE.

Vertical nanowire transistors could be a means to pack more devices into three-dimensional (3D) integrated circuits. Using a high-mobility semiconductor nanowire such as InGaAs should lead to higher performance. The technique often used by researchers to create such nanowires involves a gold seed placed on the surface of the substrate that subsequently drags out a nanowire in a 'bottom-up' growth process.

However, such bottom-up growth processes are difficult to control in manufacture and some researchers would like to develop a more traditional 'top-down' fabrication. Also, the use of gold would be forbidden in devices that included silicon CMOS components alongside the high-mobility transistors.

The MIT etch process was performed on $In_{0.53}Ga_{0.47}As$ heterostructure material grown on indium phosphide (InP) substrates using metal-organic chemical vapor deposition (MOCVD). The InGaAs heterostructure consisted of an 80nm undoped channel sandwiched between n+ silicon-doped contacts.

The vertical nanowire patterning was defined by electron-beam lithography on hydrogen silsesquioxane (HSQ) resist to give a mask for the RIE. Zhao and del Alamo used a SAMCO RIE-200iP ICP system with a heated chuck and backside helium cooling.

The plasma chemistry consisted of boron trichloride,

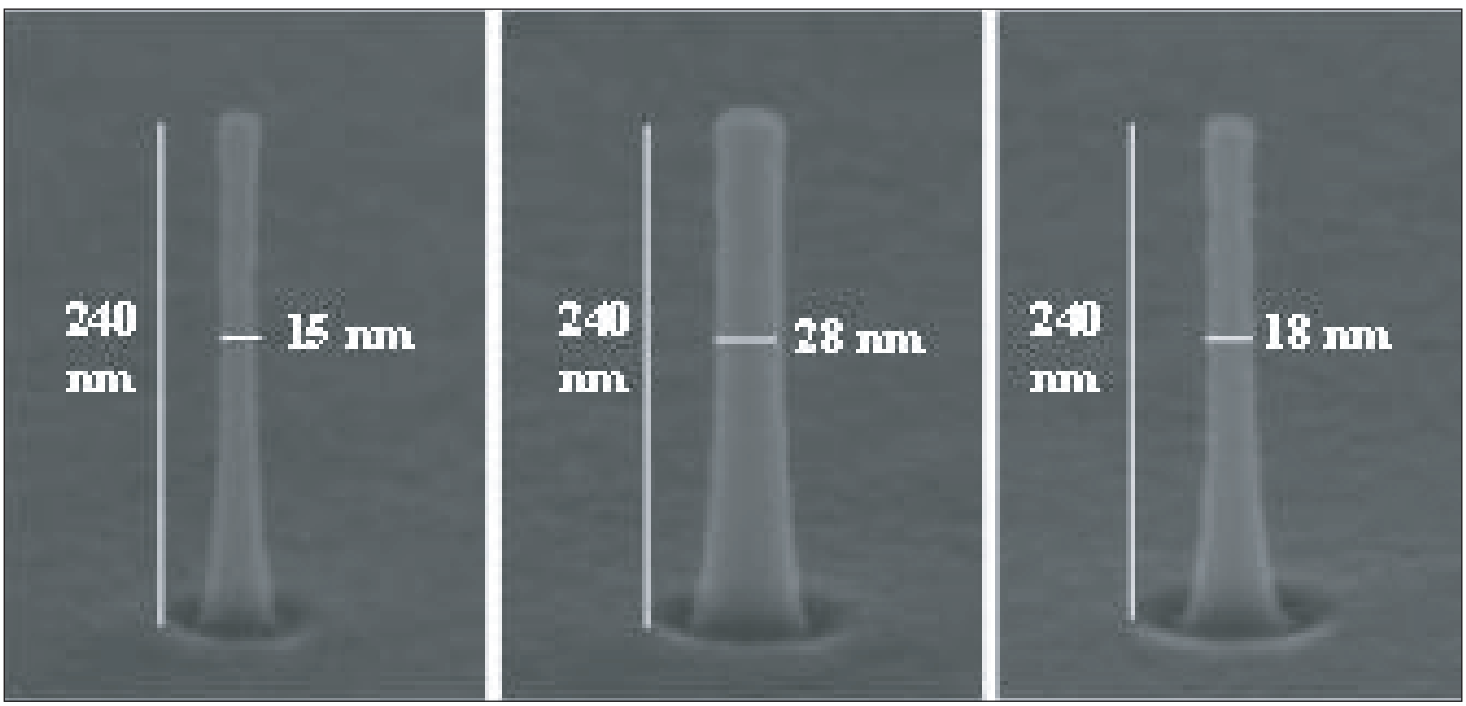

Figure 1. (a) 15nm-diameter InGaAs NW defined by optimized RIE technique with aspect ratio greater than 15. (b) 28nm-diameter InGaAs NW fabricated by RIE. (c) Same NW as in (b) after five subsequent cycles of digital etch.

silicon tetrachloride and argon ($BCl_3/SiCl_4/Ar$). The $SiCl_4$ was found to improve the verticality of the sidewalls. The BCl_3/Ar balance affects surface roughness and selectivity against the HSQ mask.

Zhao and del Alamo sought to optimize substrate temperature (250°C), gas flows (7sccm/0.55sccm/7sccm for BCl_3, $SiCl_4$ and Ar, respectively), chamber pressure (0.2Pa), and ICP and RF platen powers (20W/160W). These conditions etch at a rate of 1.8nm/second with an 8:1 selectivity against the HSQ mask. The substrate bias voltage was 280V.

The optimized process was used to create vertical nanowires of 15nm and 28nm diameters and 240nm heights. Zhao and del Alamo admit that further process development is needed to address "a slight footing behavior towards the bottom of the nanowire and some degree of trenching" (Figure 1).

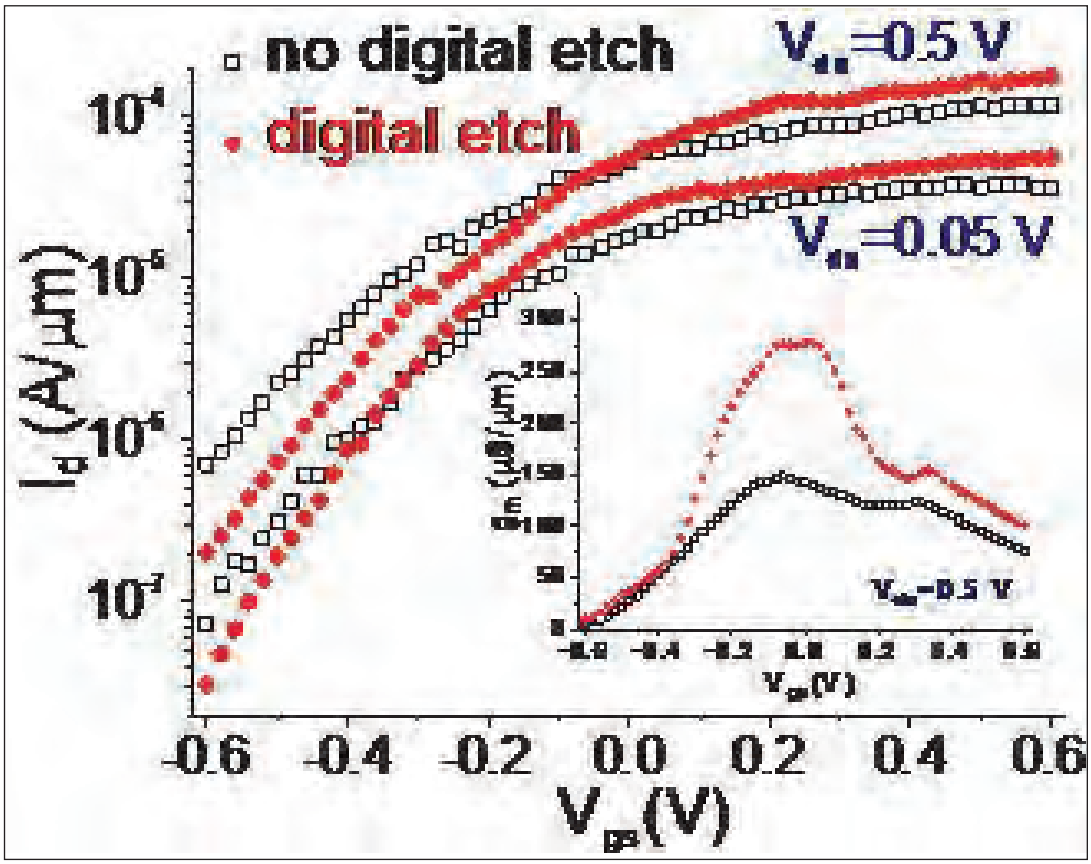

Figure 2. Impact of digital etch on subthreshold and transconductance (inset) characteristics of 30nm-diameter gate-all-around InGaAs NW-MOSFETs.

The digital etch process consisted of a two-step cycle: a self-limiting low-power O_2 plasma oxidation and a diluted sulfuric acid (H_2SO_4) rinse to remove the oxide. Several cycles of the process were carried out to repair RIE damage from the vertical sidewalls of the nanowires. One cycle of the digital etch process resulted in a ~2nm reduction in nanowire diameter.

Zhao and del Alamo fabricated gate-all-around nanowire transistors with 4.5nm atomic layer deposition (ALD) aluminium oxide gate dielectric (with an equivalent oxide thickness of 2.2nm). The channel was nominally 80nm — the thickness of the undoped channel layer in the InGaAs heterostructure.

Top-down devices match the short-channel and transconductance performance of transistors made with bottom-up techniques. However, planar III-V MOSFETs have demonstrated better transconductance. The researchers blame the high equivalent oxide thickness of their dielectric and the high series resistance of the contacts

The researchers compared 30nm-diameter nanowire transistors with and without 10-cycle digital etch (Figure 2). The RIE for the digital etch transistors created 50nm-diameter wires that were reduced to 30nm diameter by the digital etch. Scanning electron microscopy (SEM) was used to confirm that the wires for the two types of device were of identical diameter within experimental uncertainties.

The effect of digital etch was to reduce the subthreshold swing from 190mV/dec to 150mV/dec at 0.05V drain bias. Also, the transconductance with 0.5V drain bias increased from 155μS/μm to 280μS/μm with digital etch. The on-current at 1V gate overdrive and 0.5V drain bias was 205μA/μm with digital etch, but only 130μA/μm without. The on-resistance for both devices was 760Ω-μm.

The improvements are attributed to the reduction in sidewall damage provided by the digital etch.

Zhao and del Alamo comment that their top-down devices match the short-channel and transconductance performance of transistors made with bottom-up techniques. However, planar III-V MOSFETs have demonstrated better transconductance. The researchers blame the high equivalent oxide thickness of their dielectric and the high series resistance of the contacts. ■

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Author: Mike Cooke

Chloride-based chemical doping yields low-contact-resistance molybdenum disulfide field-effect transistors

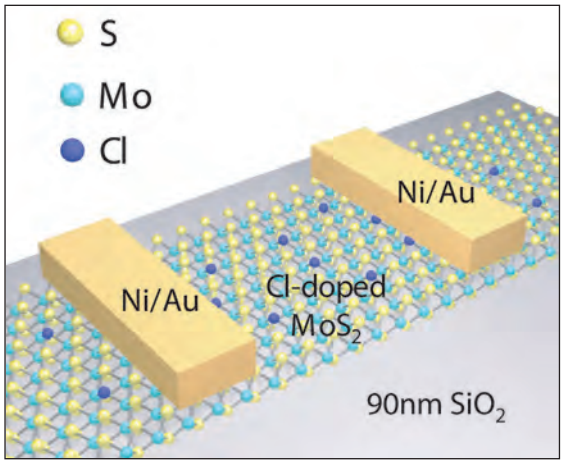
SRC- and SEMATECH-supported Purdue research presented at VLSI

At the 2014 Symposia on VLSI Technology and Circuits in Honolulu, Hawaii (9–13 June), a team at Purdue University, SEMATECH of Albany, NY, USA (the international research consortium of semiconductor device, equipment, and materials manufacturers) and the State University of New York (SUNY) College of Nanoscale Science and Engineering (CNSE, where SEMATECH is based) has presented a chemical doping technique that has reduced contact resistance (R_c) by 10-fold and specific contact resistivity (ρ_c) by 100-fold to enable the demonstration of high-performance molybdenum disulfide (MoS_2) field-effect transistors (FETs).

The paper 'High-Performance MoS_2 Field-Effect Transistors Enabled by Chloride Doping: Record Low Contact Resistance (0.5kΩ·μm) and Record High Drain Current (460μA/μm)' was authored by Purdue doctoral students Lingming Yang, Yuchen Du, Han Liu and Heng Wu; SEMATECH researchers Kausik Majumdar, Py Hung, Robert Tieckelmann and Chris Hobbs; CNSE researcher Michael Hatzistergos; Intel's Wilman Tsai; and Purdue professor of electrical and computer engineering Peide Ye.

The research is said to be an important milestone for the realization of ultra-scaled low-power two-dimensional (2D) MoS_2 FETs and the advancement of photonic and electronic devices based on transition metal dichalcogenide (TMD) materials such as solar cells, photo-transistors and low-power logic FETs. The work is supported by SEMATECH and Semiconductor Research Corporation (SRC) of Research Triangle Park, NC, USA (the university-research consortium for semiconductors and related technologies).

As part of the research, the team leveraged MoS_2, which has been studied closely by the semiconductor industry in recent years due to its potential applications in electrical and optical devices. However, high contact resistance significantly limits the device performance of MoS_2 FETs. One method for resolving this is to dope the MoS_2 film, but doping the atomically thin film is non-trivial and requires a simple and reliable process technique. The technique used by the research team provides an effective and straightforward way for 'molecular layer doping' of the MoS_2 film with the chloride-based chemical doping reagent 1,2 dichloroethane (DCE) to significantly reduce the contact resistance.



The structure of extremely thin MoS_2 (a single-atomic layer of molybdenum sandwiched between single-atomic layers of sulfide and doped with DCE), which is particularly promising for future thin, flexible and transparent electronic devices for displays, touch pads and other applications. (Purdue University photo/Lingming Yang)

"Compared with other chemical doping materials such as PEI (polyethylene imine) and potassium, our doping technology shows superior transistor performance, including higher drive current, higher on/off current ratio and lower contact resistance," says Ye.

To obtain high-performance FETs, three parts of the device need to be carefully engineered: the semiconductor channel (carrier density and its mobility); the semiconductor-oxide interface; and the semiconductor-metal contact. The research is particularly aimed at eliminating the last major roadblock toward demonstration of high-performance MoS_2 FETs, namely high contact resistance.

Fabricated at Purdue, the MoS_2 FETs using the doping technique can now be reproduced in a semiconductor manufacturing environment and show the best electrical performance among all the reported TMD-based FETs, it is claimed. The contact resistance (0.5kΩ·μm) with the doping technique is 10 times lower than the controlled samples. The drive current (460μA/μm) is twice that of the best value in prior literature.

"Due to recent advances such as the research being presented at the VLSI Symposium, 2D materials are gaining a lot of attention in the semiconductor industry," says Satyavolu Papa Rao, SEMATECH's director of Process Technology. "The collaborative effort among world-class researchers and engineers from this team is a prime example of how consortium-university-industry partnerships further enable the development of cutting-edge process techniques," he adds.

"Improved contacts are always desirable for all electronic and optical devices," notes Kwok Ng, senior director of Device Sciences at SRC. "The doping technique presented by this research team provides a valid way to achieve low contact resistance for MoS_2 as well as other TMD materials." ■

www.sematech.org/research/materials
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Silicon photonics market to grow at CAGR of 38% from $25m in 2013 to $700m in

Emerging optical data centers of big Internet firms to trigger growth

Beyond all of the hype and tumult, market drivers and technological developments are converging to ensure a bright future for silicon photonics, according to the 'Silicon Photonics 2014' report from Yole Développement. Indeed, although the silicon photonics market has just kicked off, volume production is already close.

Big data is getting bigger by the second, and transporting it with existing technologies will push the limits of power consumption, density and weight. The report's authors are convinced that photons will replace electrons, and that silicon photonics will be the mid-term platform to assist this transition.

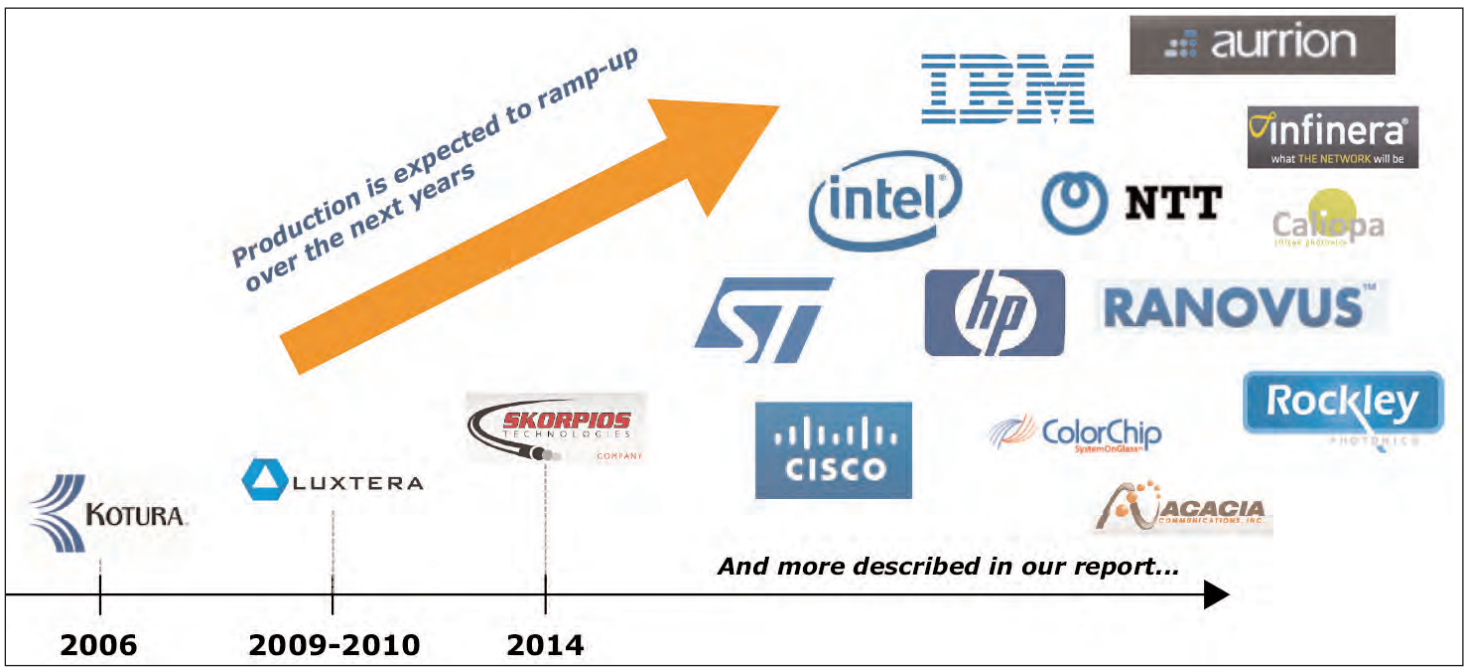
Silicon photonics offers the advantages of silicon technology: low cost, higher integration, more embedded functionalities, and higher interconnect density. It also provides two other key advantages:

- low power consumption (particularly compared with copper-based solutions, which are expensive and require high electrical consumption);
- reliability (especially important for data centers, where a typical rack server's lifespan is two years before replacement).

As silicon photonics evolves and chips become more sophisticated, Yole expects the technology to be used more often in processing tasks such as interconnecting multiple cores within processor chips to boost access to shared cache and buses

Back in 2006, variable optical attenuators (VOAs) were the market's first silicon photonics products. Today, there are still just a few silicon photonics products on the market — i.e. VOAs, active optical cables (AOCs) and transceivers from Luxtera, Kotura/Mellanox and Cisco/Lightwire — but big companies (e.g. Intel, HP and IBM) are close to realizing silicon photonics products. Big OEMs such as Facebook, Google and Amazon are developing their own optical data-center technology in partnership with chip firms (such as Facebook with Intel).

"In the short-term, silicon photonics will be the platform solution for future high-power, high-bandwidth



Silicon photonics roadmap.

Company	Date	Transaction value	Acquirer
COGO Optronics (CAN)	March 2013	TOTAL ~US$1B	**TeraXion** (CAN)
Cyoptics (US)	April 2013		**Avago** (US)
Kotura (US)	May 2013		**Mellanox** (US)
IPTronics (US)	June 2013		**Mellanox** (US)
Caliopa (BE)	September 2013		**Huawei** (CHINA)

Sampling of silicon photonics acquisitions.

data centers," says Dr Eric Mounier, senior technology & market analyst, MEMS Devices & Technologies, at Yole. Silicon photonics chips will be deployed in high-speed signal transmission systems that greatly exceed the capabilities of copper cabling, i.e. for data centers and high-performance computing (HPC). In addition, as silicon photonics evolves and chips become more sophisticated, Yole expects the technology to be used more often in processing tasks such as interconnecting multiple cores within processor chips to boost access to shared cache and buses. Yole also analyzed the prospects of silicon photonics being used for telecom, consumer, medical and biosensors applications, compared with competing technologies.

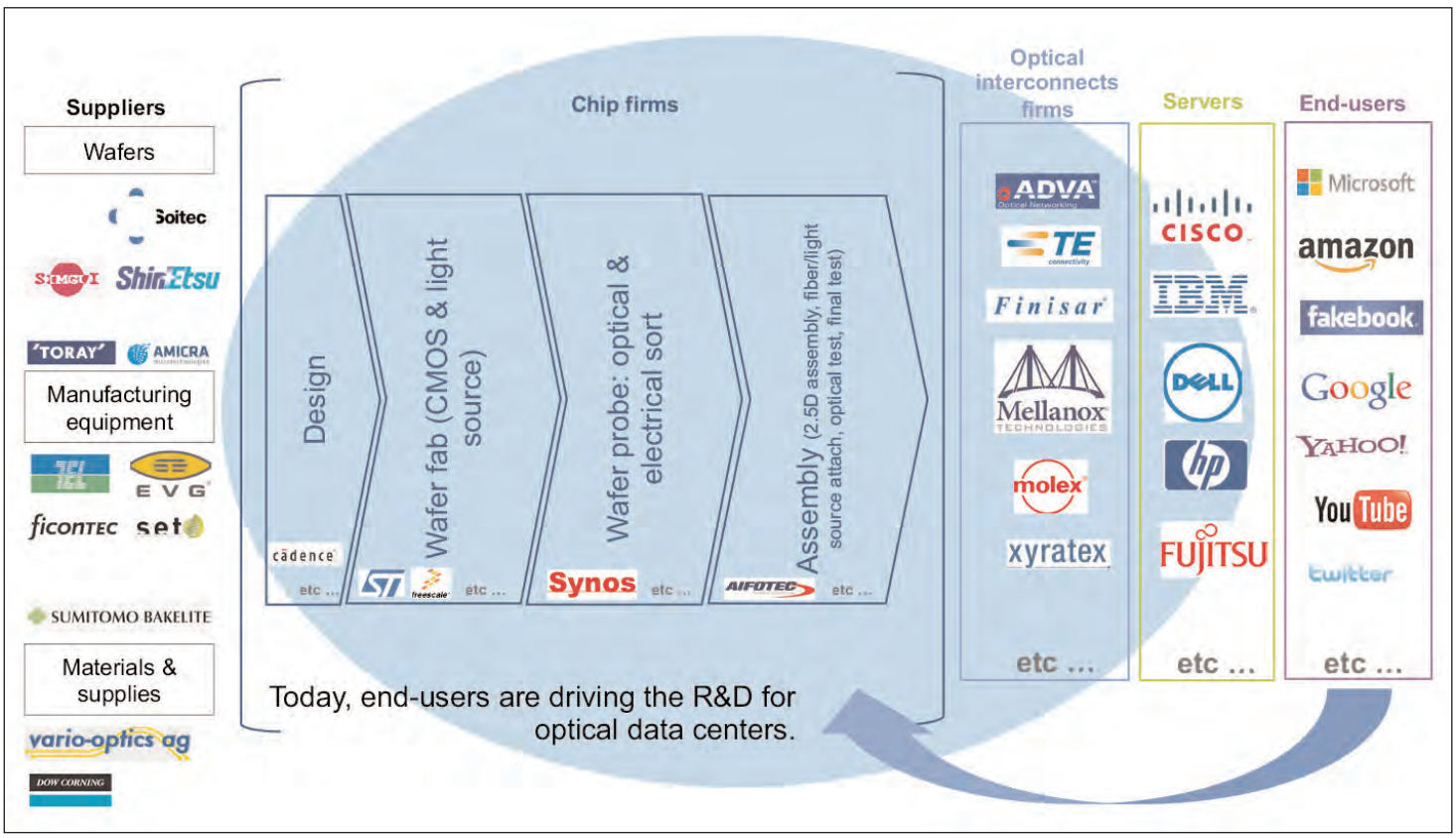
Acquisitions and consolidation ongoing

The report estimates that almost $1bn has been spent in the past three years on acquisitions of silicon photonics companies. This is not surprisingly, says Yole, considering that silicon photonics is seen as the optical technology that will be leveraged for future bottlenecks for interconnects in data centers and HPCs in the short term.

The main motivations for such acquisitions are:

- to handle increasing traffic in data centers; and
- to strengthen a company's portfolio in 40GB and 100GB optical engines.

Acquisitions are generally made by module/system makers as a means of enlarging their technologies portfolio, since this is a faster, cheaper route than R&D



Silicon photonics supply chain.

investment, notes Yole. "We also see big players such as Intel taking both approaches (acquisitions and R&D), while others have decided not to invest in silicon photonics since they think future designs will be accessible via foundry services," says the report. "In fact, many IC foundries have started proposing silicon photonics wafer foundry services, so this could create additional acquisition opportunities in the near future."

Technical choices and new opportunities

Silicon photonics is a field that mixes optics, CMOS, MEMS and 3D stacking technologies. Yole notes that over the past several years it has become clear that some technical choices will be better than others for successful commercial development:

- The light source is a big integration challenge. A silicon laser is probably years away from realization, so the different approaches are likely to be either attached laser (i.e. Luxtera) or indium phosphide (InP) wafer-to-wafer/die-to-wafer bonding, followed by post-processing (i.e. Intel or Leti).
- There has also been a shift from monolithic integration for electronics/photonics to hybrid integration, since critical dimensions are very different. Currently, the favored approach seems to be two-chip hybrid integration (the Cu-pillar from STMicroelectronics, for example), since the critical dimensions of semiconductors and photonics are likely to be at least one order of magnitude different.
- The fiber choice: multi-mode versus single mode is also on the table.

"Silicon photonics is a business opportunity for different player types: OSATS (outsourced assembly & test houses), MEMS firms, semiconductors companies etc, because it involves different challenges for packaging, optical alignment and electronics integration," explains Claire Troadec, Technology & Market Analyst, Semiconductor Manufacturing, at Yole. "The need for very diverse technologies creates a need for different packaging/micro-machining/manufacturing approaches," she adds.

Turning point expected in 2018

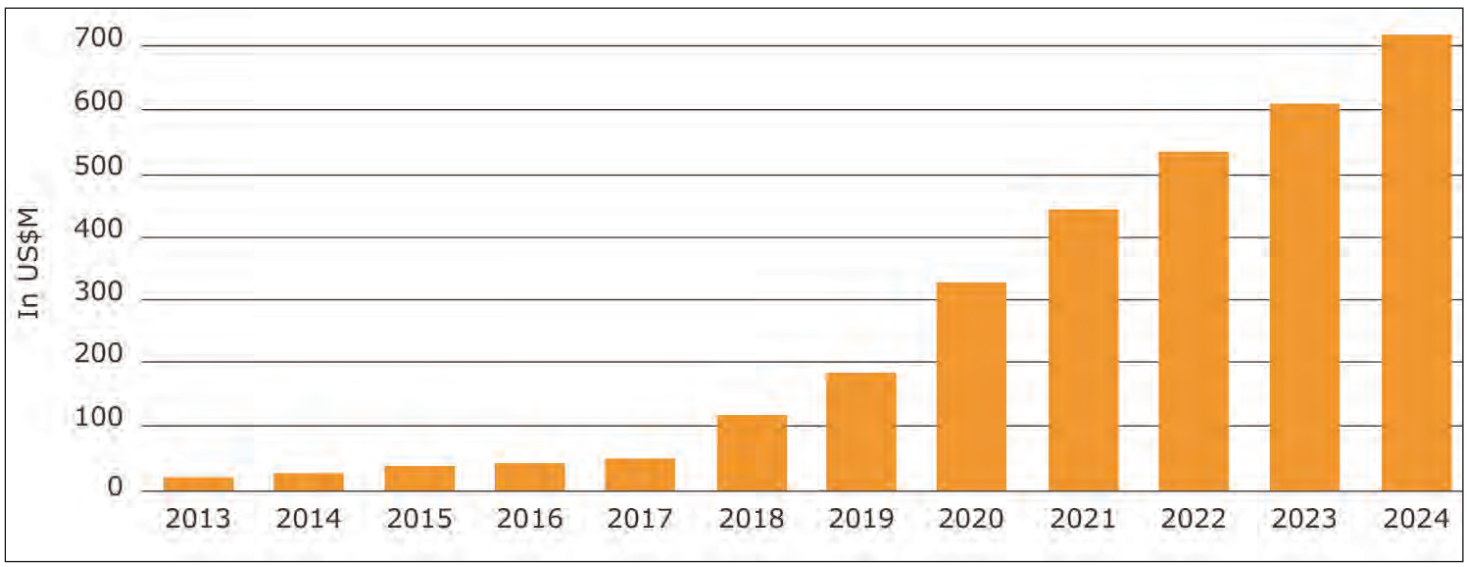
In the report, Yole provides a forecast of the silicon photonics market for four different applications: HPC, future-generation optical data centers, telecoms and others (including sensors, medical and consumer).

The firm looked at the following modules/devices: transceivers (for AOCs) and embedded optics (from mid-board optics to interposers to intra-chip interconnects), and forecasts have been calculated in US$m, millions of units and wafer starts. It is estimated that the silicon photonics device market will increase at a compound annual growth rate (CAGR) of 38% from about $25m in 2013 to more than $700m in 2024, triggered in 2018 by emerging optical data centers from big Internet companies (Google, Facebook, etc).

the silicon photonics device market will increase at a compound annual growth rate (CAGR) of 38% from about $25m in 2013 to more than $700m in 2024, triggered in 2018 by emerging optical data centers from big Internet companies (Google, Facebook, etc)

Non-datacom/telecom sectors will have only a small portion of market value, since these applications are still far from market maturity, notes Yole. "However, we are at a turning point where the market is increasing again, and Intel - which is very active in this field - could contribute to a quick ramp-up of silicon photonics," the market research firm concludes. ■

www.i-micronews.com/reports/Silicon-Photonics-2014-report/8/445



Silicon photonics market forecast.

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metalorganicsAP@akzonobel.com
Americas:
AkzoNobel Functional Chemicals,
Chicago,
USA
Tel. +31 800 828 7929 (US only)
Tel: +1 312 544 7000
Fax: +1 312 544 7188
metalorganicsNA@akzonobel.com
Europe, Middle East and Africa:
AkzoNobel Functional Chemicals,
Amersfoort,
The Netherlands
Tel. +31 33 467 6656
Fax: +31 33 467 6101
metalorganicsEU@akzonobel.com

Cambridge Chemical Company Ltd
Unit 5 Chesterton Mills,
French's Road,
Cambridge CB4 3NP,
UK
Tel: +44 (0)1223 352244
Fax: +44 (0)1223 352444
www.camchem.co.uk

Dow Electronic Materials
60 Willow Street,
North Andover, MA 01845,
USA
Tel: +1 978 557 1700
Fax: +1 978 557 1701
www.metalorganics.com

Matheson Tri-Gas
6775 Central Avenue,
Newark, CA 94560,
USA
Tel: +1 510 793 2559
Fax: +1 510 790 6241
www.mathesontrigas.com

Mining & Chemical Products Ltd
(see section 1 for full contact details)

Praxair Electronics
542 Route 303, Orangeburg,
NY 10962,
USA
Tel: +1 845 398 8242
Fax: +1 845 398 8304
www.praxair.com/electronics

SAFC Hitech
Power Road, Bromborough,
Wirral, Merseyside CH62 3QF,
UK
Tel: +44 151 334 2774
Fax: +44 151 334 6422
www.safchitech.com

Williams Advanced Materials
2978 Main Street,
Buffalo, NY 14214,
USA
Tel: +1 716 837 1000
Fax: +1 716 833 2926
www.williams-adv.com

6 Deposition equipment

AIXTRON SE
Dornkaulstr. 2,
52134 Herzogenrath,
Germany
Tel: +49 2407 9030 0
Fax: +49 2407 9030 40
www.aixtron.com

AIXTRON is a leading provider of deposition equipment to the semiconductor industry. The company's technology solutions are used by a diverse range of customers worldwide to build advanced components for electronic and optoelectronic applications (photonic) based on compound, silicon, or organic semiconductor materials and, more recently, carbon nanotubes (CNT), graphene and other nanomaterials.

Oxford Instruments Plasma Technology
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Bristol, Avon BS49 4AP,
UK
Tel: +44 1934 837 000
Fax: +44 1934 837 001
www.oxford-instruments.co.uk

We provide flexible tools and processes for precise materials deposition, etching and controlled nanostructure growth. Core technologies include plasma and ion-beam deposition and etch and ALD.

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6600 Reutte,
Austria
Tel: +43 5672 600 0
Fax: +43 5672 600 500
E-mail info@plansee.com
www.plansee.com

Plasma-Therm LLC
10050 16th Street North,
St. Petersburg, FL 33716,
USA
Tel: +1 727 577 4999
Fax: +1 727 577 7035
www.plasmatherm.com

Plasma-Therm, LLC is an established leading provider of advanced plasma processing equipment for the semiconductor industry and related specialty markets.

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France
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Fax: +33 (0) 1 39 47 45 62
www.riber.com

SVT Associates Inc
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Eden Prairie, MN 55344,
USA
Tel: +1 952 934 2100
Fax: +1 952 934 2737
www.svta.com

Temescal, a part of Ferrotec
4569-C Las Positas Rd,
Livermore,
CA 94551,
USA
Tel: +1 925 245 5817
Fax: +1 925 449-4096
www.temescal.net

Temescal, the expert in metallization systems for the processing of compound semiconductor-based substrates, provides the finest evaporation systems available. Multi-layer coatings of materials such as Ti, Pt, Au, Pd, Ag, NiCr, Al, Cr, Cu, Mo, Nb, SiO_2, with high uniformity are guaranteed. Today the world's most sophisticated handsets, optical, wireless and telecom systems rely on millions of devices that are made using Temescal deposition systems and components.

Veeco Instruments Inc
100 Sunnyside Blvd.,
Woodbury, NY 11797,
USA
Tel: +1 516 677 0200
Fax: +1 516 714 1231
www.veeco.com

Veeco is a world-leading supplier of compound semiconductor equipment, and the only company offering both MOCVD and MBE solutions. With complementary AFM technology and the industry's most advanced Process Integration Center, Veeco tools help grow and measure nanoscale devices in worldwide LED/wireless, data

storage, semiconductor and scientific research markets—offering important choices, delivering ideal solutions.

7 Wafer processing materials

Air Products and Chemicals Inc
7201 Hamilton Blvd.,
Allentown, PA 18195, USA
Tel: +1 610 481 4911
www.airproducts.com/compound

MicroChem Corp
1254 Chestnut St. Newton,
MA 02464, USA
Tel: +1 617 965 5511
Fax: +1 617 965 5818
www.microchem.com

Praxair Electronics
(see section 5 for full contact details)

8 Wafer processing equipment

EV Group
DI Erich Thallner Strasse 1,
St. Florian/Inn, 4782,
Austria
Tel: +43 7712 5311 0
Fax: +43 7712 5311 4600
www.EVGroup.com
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Fax: +44 (0) 1389 879 042
www.logitech.uk.com
Logitech Ltd is a leading designer and manufacturer of high-precision cutting, lapping, polishing and CMP equipment enabling high-specification surface finishes to be prepared with precise geometric accuracy.

Oxford Instruments Plasma Technology
(see section 6 for full contact details)

Plasma-Therm LLC
(see section 6 for full contact details)

SAMCO International Inc
532 Weddell Drive,
Sunnyvale, CA, USA
Tel: +1 408 734 0459
Fax: +1 408 734 0961
www.samcointl.com

SPTS Technology Ltd
Ringland Way,
Newport NP18 2TA, UK
Tel: +44 (0)1633 414000
Fax: +44 (0)1633 414141
www.spts.com

SUSS MicroTec AG
Schleißheimer Strasse 90,
85748 Garching,
Germany
Tel: +49 89 32007 0
Fax: +49 89 32007 162
www.suss.com

Veeco Instruments Inc
(see section 6 for full contact details)

9 Materials & metals

Goodfellow Cambridge Ltd
Ermine Business Park, Huntingdon,
Cambridgeshire PE29 6WR,
UK
Tel: +44 (0) 1480 424800
Fax: +44 (0) 1480 424900
www.goodfellow.com
Goodfellow supplies small quantities of metals and materials for research, development, prototyping and specialised manufacturing operations.

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

10 Gas and liquid handling equipment

Air Products and Chemicals Inc
(see section 7 for full contact details)

Cambridge Fluid Systems
12 Trafalgar Way, Bar Hill,
Cambridge CB3 8SQ, UK
Tel: +44 (0)1954 786800
Fax: +44 (0)1954 786818
www.cambridge-fluid.com

CS CLEAN SYSTEMS AG
Fraunhoferstrasse 4,
Ismaning, 85737,
Germany
Tel: +49 89 96 24 00 0
Fax: +49 89 96 24 00 122
www.cscleansystems.com

SAES Pure Gas Inc
4175 Santa Fe Road,
San Luis Obispo, CA 93401,
USA
Tel: +1 805 541 9299
Fax: +1 805 541 9399
www.saesgetters.com

11 Process monitoring and control

k-Space Associates Inc
2182 Bishop Circle East, Dexter,
MI 48130, USA
Tel: +1 734 426 7977
Fax: +1 734 426 7955
www.k-space.com
k-Space Associates Inc specializes in in-situ, real-time thin-film process monitoring tools for MBE, MOCVD, PVD, and thermal evaporation. Applications and materials include the research and production line monitoring of compound semiconductor-based electronic, optoelectronic, and photovoltaic devices.

KLA-Tencor
One Technology Dr,
1-2221I, Milpitas,
CA 95035, USA
Tel: +1 408 875 3000
Fax: +1 408 875 4144
www.kla-tencor.com

LayTec AG
Seesener Str. 10–13,
10709 Berlin,
Germany
Tel: +49 30 89 00 55 0
Fax: +49 30 89 00 180
www.laytec.de
LayTec develops and manufactures optical in-situ and in-line metrology systems for thin-film processes with particular focus on compound semiconductor and photovoltaic applications. Its know-how is based on optical techniques: reflectometry, emissivity corrected pyrometry, curvature measurements and reflectance anisotropy spectroscopy.

Optical Reference Systems Ltd
OpTIC Technium,
St Asaph Business Park,
St Asaph, LL17 0JD, UK
Tel: +44 (0)1745 535 188
Fax: +44 (0)1745 535 186
www.ors-ltd.com

WEP (Ingenieurbüro Wolff für Elektronik- und Programmentwicklungen)
Bregstrasse 90, D-78120
Furtwangen im Schwarzwald,
Germany
Tel: +49 7723 9197 0
Fax: +49 7723 9197 22
www.wepcontrol.com

12 Inspection equipment

Bruker 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

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 8586 74 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: +33 169 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

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
Brownlow House, 50–51
High Holborn, London WC1V 6EG,
UK
Tel: +44 (0)20 7405 8411
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

Yole Développement
45 rue Sainte Geneviève,
69006 Lyon,
France
Tel: +33 472 83 01 86
www.yole.fr

event calendar

If you would like your event listed in *Semiconductor Today*'s Event Calendar, then please e-mail all details to the Editor at mark@semiconductor-today.com

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

24–29 August 2014
International Workshop on Nitride Semiconductors (IWN2014)
Wroclaw, Poland.
E-mail: contact@iwn2014.pl
http://iwn2014.pl

27–29 August 2014
IEEE Photonics Society's 11th International Conference on Group IV Photonics (GFP-2014)
Cité Internationale Universitaire de Paris, France
E-mail: m.figueroa@ieee.org
www.gfp-ieee.org

1–4 September 2014
14th International Conference on Numerical Simulation of Optoelectronic Devices (NUSOD)
Caixa Forum, Palma de Mallorca, Spain
E-mail: uibcongres@uib.es
www.nusod.org/2014

3–5 September 2014
SEMICON Taiwan
TWTC Nangang Exhibition Hall, Taipei, Taiwan
E-mail: nsun@semi.org
www.semicontaiwan.org

7–10 September 2014
24th IEEE Semiconductor Laser Conference (ISLC)
Meliá Palas Atenea, Palma de Mallorca, Spain
E-mail: m.figueroa@ieee.org
www.islc-ieee.org

7–11 September 2014
8th International Workshop on Zinc Oxide and Related Materials (IWZnO 2014)
Sheraton on the Falls Hotel, Niagara Falls, Ontario, Canada
E-mail: kriss@mrs.org
www.mrs.org/IWZnO-2014

16–18 September 2014
The LED Show
Los Angeles Convention Center, CA, USA
E-mail: registration@pennwell.com
www.theledshow.com

21–25 September 2014
40th European Conference on Optical Communication (ECOC 2014)
Cannes, France
E-mail: contact@ecoc2014.org
www.ecoc2014.org

22–24 September 2014
LEDs and the SSL Ecosystem 2014: Lighting in the Information Age
Hyatt Cambridge in Cambridge, MA, USA

advertisers' index

E-mail: jcarter@smithers.com
www.ledsconference.com

22–25 September 2014
SPIE Security+Defence 2014
Amsterdam RAI Exhibition and Convention Centre, The Netherlands
E-mail: info@spieeurope.org
http://spie.org/security-defence-europe.xml

5–9 October 2014
Mid-IR Optoelectronics: Materials and Devices (MIOMD-XII)
CORUM convention center, Montpellier, France
E-mail: miomd2014@miomd2014.org
www.miomd2014.org

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
SEMICON Europa
Alpexpo, Grenoble, France
E-mail: eweller@semi.org
www.semiconeuropa.org

7–9 October 2014
Solar Power International (SPI '14)
Las Vegas Convention Center
E-mail: plangdon@solarenergytradeshows.com
www.solarpowerinternational.com

9 October 2014
SEMI International Standards Program: Compound Semiconductor Materials (TC), DGKK Arbeitskreis
TU Bergakademie Freiberg, Germany
E-mail: abusch@semi.org
www.semi.org/eu/node/8826

9–10 October 2014
Invest in Photonics
Bordeaux, France
E-mail: pitch@invest-in-photonics.com
www.invest-in-photonics.com

12–15 October 2014
23rd European Workshop on Heterostructure Technology (HeTech2014)
Justus Liebig University Giessen, Germany
E-mail: info@hetech2014.org
www.hetech2014.org

12–16 October 2014
27th IEEE Photonics Conference (IPC 2014)
Hyatt Regency La Jolla, San Diego, CA, USA
E-mail: i.donnelly@ieee.org
www.ipc-ieee.org

15–17 October 2014
LED Japan/Strategies in Light
Pacifico Yokohama, Japan
E-mail: registration@pennwell.com
www.sil-ledjapan.com

21–23 October 2014
Strategies in Light Europe
M.O.C. Event Centre, Munich, Germany
E-mail: registration@pennwell.com
www.sileurope.com

11–13 November 2014
Avionics Fiber-Optics and Photonics Conference 2014 (AVFOP)
Hyatt Regency Atlanta, Georgia, USA
E-mail: m.figueroa@ieee.org
www.avfop-ieee.org

3–5 December 2014
SEMICON Japan 2014
Tokyo Big Sight, Japan
E-mail: jeventinfo@semi.org
www.semiconjapan.org

15–17 December 2014
IEEE International Electron Devices Meeting (IEDM 2014)
Hilton San Francisco, CA, USA
E-mail: iedm@his.com
www.ieee-iedm.org

4–6 February 2015
SEMICON Korea 2015
COEX, Seoul, Korea
E-mail: semiconkorea@semi.org
www.semiconkorea.org

7–12 February 2015
SPIE Photonics West 2015
Moscone Center San Francisco, CA, USA
E-mail: customerservice@spie.org
http://spie.org/photonics-west.xml

24–26 February 2015
Strategies in Light
Sands Expo & Convention Center, Las Vegas, NV, USA
E-mail: registration@pennwell.com
www.strategiesinlight.com

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