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The most promising wide bandgap semiconductor to date?

III-V MOSFETs
Laying the foundations for joining the silicon roadmap

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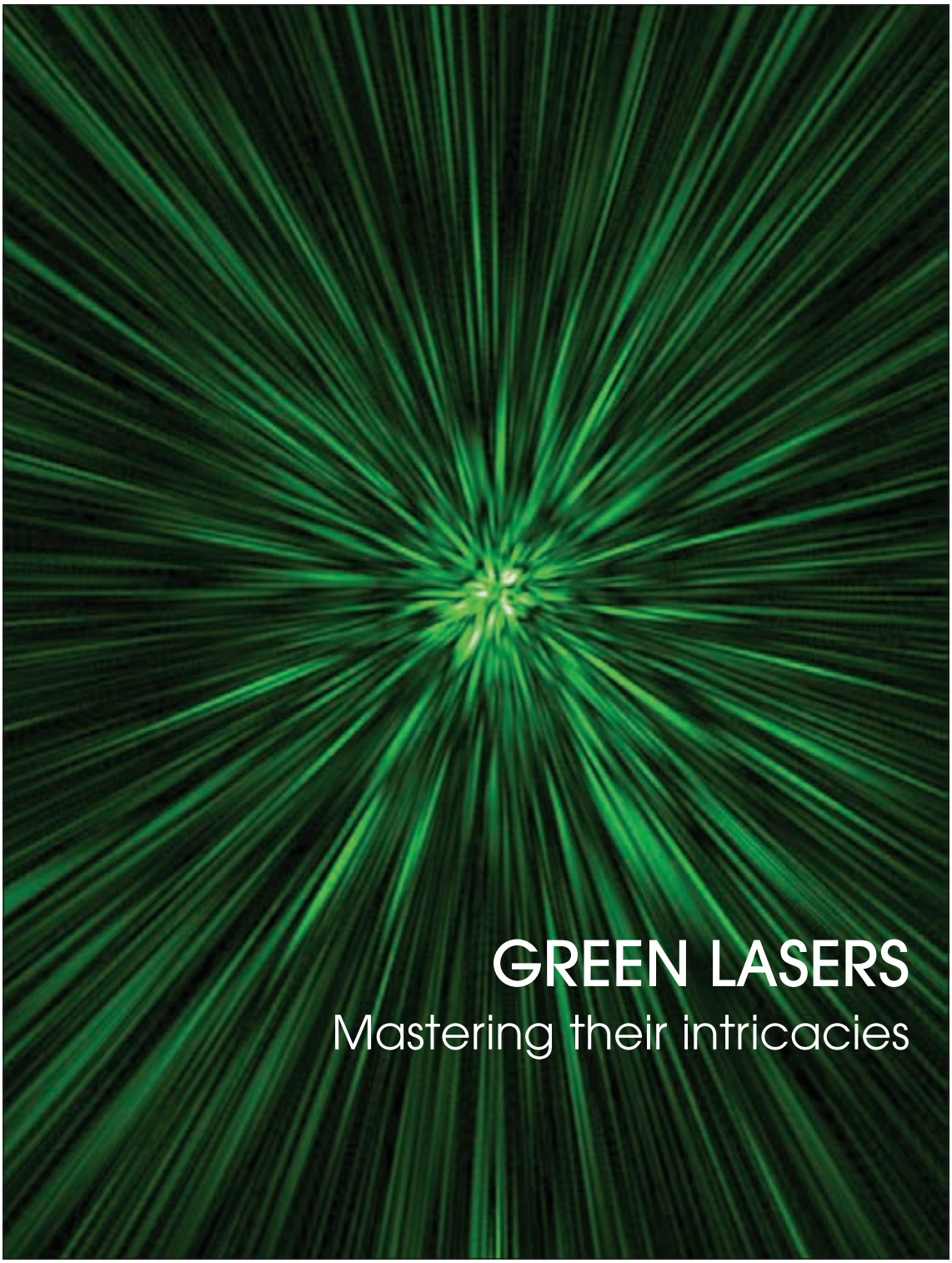
A horrendous year for CS stocks

Lasers
Ultra-low power VCSELs for optical interconnects

LED droop
New theory explains LED behaviour at various temperatures

Defect reduction
Serpentine masks and BN layers improve GaN



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June 2012 Volume 18 Number 4

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The perfect wide bandgap material

When it comes to power devices, what is going to replace silicon as the dominant material?

That's a tough question, and if you ask around you'll get various answers. If you court the opinion of SiC diode and transistor manufacturers, you'll be told that the future belongs to them. But that's certainly not a view shared by the developers of GaN devices.

A more balanced view comes from the analysts. They expect both classes of device to have some success, with SiC being favoured at higher voltages, such as 600 V or more.

But there is another wide bandgap material that hardly anyone is talking about that has the potential to upset the applecart: Gallium oxide. This compound (Ga_2O_3) has some great attributes, including an incredibly wide bandgap of almost 5 eV that should unleash ultra-high efficiency devices with tremendous breakdown voltages.

One of the weaknesses afflicting the more established wide bandgap devices is the lack of an affordable, native substrate. To be cost-competitive, GaN devices must be grown on silicon. However, this requires the development of complex deposition processes to control stresses and strains associated with hetero-epitaxy. Such issues don't plague SiC substrates, but prices are very high and unlikely to fall fast.

In stark contrast, if Ga_2O_3 substrates were made in volume, their price would be very attractive. That's because they can be made with the approach used for the manufacture of bulk sapphire.

Development of Ga_2O_3 devices is in its infancy, with researchers from the National Institute of Communications Technology in Japan leading the way (they tell their story in the feature "Gallium oxide trumps traditional wide bandgap semiconductors", which starts on page 21 of this issue).

As you'd expect for any nascent technology, device performance is inferior to that associated with state-of-the-art SiC and GaN devices. But compared to their ancestors, Ga_2O_3 devices hold their own in some areas, while excelling in others.

If Ga_2O_3 power electronics is to take off, researchers in this field will have to address several issues. For example, there are currently no reports of hole conduction in *p*-type layers, and devices processing technologies must be developed alongside the production of substrates at least 4 inches in diameter. And once that's done, products will have to be brought to market that can compete with the performance of next-generation GaN and SiC devices.

So success will be hard won, and could take many years to achieve. And in my view, while it's certainly possible that Ga_2O_3 will make a commercial impact, it will not happen until at least 2020.

Richard Stevenson
Editor

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Volume 18 Number 4

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news

Transphorm delivers 600 V GaN-on-silicon products

CALIFORNIAN start-up Transphorm has revealed its latest breakthrough in which reduce the large and growing problem of electrical energy waste in power conversion. The company says it is the first company to provide a qualified 600V GaN solution to inefficient power conversion. In 2011, the company announced its first GaN-on-silicon products: power transistors, diodes and modules, based on its patented, high-performance EZ GaN technology.

"The opportunity for widespread energy efficiency gains is staggering and our GaN solutions offer unprecedented energy gains," says Umesh Mishra, CEO of Transphorm. "In the motor segment alone, Transphorm's innovations create the potential to save 2.5 percent of U.S. electricity generation through enhanced electro-mechanical efficiency of the full drive and motor system—equivalent to the energy saving potential of replacing incandescent lighting with white LEDs." Transphorm's efficient, compact, and easy-to-embed solutions cut energy waste by 50 percent today and simplify the design and manufacturing of a wide variety of electrical systems and devices, including motor drives, power supplies and inverters for solar panels and electric vehicles. To demonstrate the performance advantage of its patented GaN based technology, Transphorm will showcase at the PCIM exhibition its EZ GaN based, DC-to-DC Boost Converter running at more than 99 percent efficiency and our Tru-Sine motor drive delivering 2-8 percent higher efficiency at 100 KHz vs. state of the art IGBT based motor drives at 15KHz.

"Our team continues to expand its lead in high voltage GaN, with a broad portfolio of transistors, diodes and modules- now possible on low cost silicon substrate platform," says Primit Parikh, President of Transphorm. "For customers looking for a low-risk roadmap to the next generation of power conversion technology, Transphorm's EZ-GaN Application Boards provide for a simpler design-in and faster time to market."

Electric power waste that occurs during power conversion is equivalent to the daily output of 318 coal plants, and it costs the U.S. economy $40 billion per year. Transphorm's GaN products come in industry-standard packages and are designed for optimum high-frequency switching. The company's proprietary EZ GaN platform can reduce power system size, increase energy density and deliver high efficiencies across the grid, from HVACs to hybrids, and from servers to solar panels.

Emcore to provide III-V solar panels to NASA

EMCORE has won a solar panel manufacturing contract by NASA's Jet Propulsion Laboratory (JPL) for its Soil Moisture Active Passive (SMAP) mission targeted for launch in late 2014.

Solar panels populated with Emcore's most advanced ZTJ triple-junction solar cells will power the SMAP spacecraft and instrument suite in near-polar, sun-synchronous orbit for the duration of mission.

Emcore's 3rd generation triple-junction (ZTJ) solar cells with n-on-p polarity are built on a 140-μm uniform thickness germanium substrate. They have a low solar cell mass of 84 mg/cm^2 and a minimum average efficiency of 29.5%. The SMAP mission will provide global measurements of soil moisture and its freeze/thaw state. These measurements will be used to enhance understanding of processes that link the planet's water, energy and carbon cycles, and to extend the capabilities of weather and climate prediction models. SMAP data will also be used to quantify net carbon flux in boreal landscapes and to develop improved flood prediction and drought monitoring capabilities.

"We are honoured to continue supporting these critical missions for NASA," says Christopher Larocca, Chief Operating Officer for Emcore. "Emcore successfully delivered solar panels to JPL last year for the Mars Science Laboratory (MSL) mission and have delivered, or are in the process of delivering, solar panels for several other NASA missions including the Lunar Atmosphere and Dust Environment Explorer (LADEE), Lunar Reconnaissance Orbiter (LRO), and the Magnetospheric Multi-Scale (MMS) missions. We look forward to working with NASA and JPL once again on this program."

TriQuint to speed up GaN power switching

THE DEFENCE ADVANCED RESEARCH PROJECTS AGENCY (DARPA) has entrusted TriQuint with leading a $12.3 million development program focused on ultra-fast GaN switch technology for the Microscale Power Conversion (MPC) program.

TriQuint says its new GaN modulator has the potential to enable highly-efficient RF transmitters substantially smaller than current solutions.

DARPA chose TriQuint as the prime contractor for MPC Technical Area I, which seeks to develop a high-speed, DC-to-DC switch (modulator) and related process technology based on the company's innovative enhancement-mode GaN transistors.

TriQuint's technology aims to improve the integration of power switches with advanced RF amplifiers to facilitate ultra-high efficiency, reduced-size amplifiers for radar and communications applications.

As a pioneer in GaN development and research since 1999, TriQuint currently leads multiple GaN process and manufacturing technology initiatives for DARPA including the Nitride Electronic NeXt-Generation Technology (NEXT) program as well as endeavours for the US Air Force, Army and Naval laboratories. TriQuint is already exploring and bringing derivative devices to market made possible by milestones achieved in its many GaN programs. "The break-through performance demonstrated in 'NEXT' has helped us develop new devices, like our GaN power switches, that will open up additional radar and communications applications. We can substantially improve performance in these types of systems," says TriQuint Vice President and General Manager for Defence Products and Foundry Services, James L. Klein.

The enhancement mode power switching device for the MPC program will be designed to have a blocking voltage of 200 V, ultra-low dynamic on resistance of 1 Ω-mm and a slew rate of 500 V per nanosecond. These capabilities will provide state-of-the-art solid-state technology. RF amplifiers employing these switches will target 75% system efficiency at X-band (8-12 GHz).

TriQuint teamed with Rockwell Collins, the University of Colorado at Boulder and Northrop Grumman, Technical Area II contractors, to create a new generation of RF power amplifiers that use contour modulation for very high efficiency performance that exceeds the capabilities of devices now available.

Dow Corning extends SiC capacity with Aixtron

DOW CORNING has ordered an additional two Aixtron AIX 2800G4 WW planetary reactors for growth on 10 x 100 mm and 6 x 150 mm SiC wafers. The reactors are scheduled to be commissioned in the second quarter of 2012. "Extending our SiC epitaxy capabilities illustrates our commitment to helping our customers grow and succeed and our leadership's commitment to the business," says Tom Zoes, Industry Director, Power Electronics business, Dow Corning Corporation.

"Dow Corning's epitaxy technology on the Aixtron G4 deposition platform provides our customers with materials capability that enables the creation of high performance, next generation power electronics devices addressing the world's growing demand for energy efficient solutions."

Frank Wischmeyer, Vice President and Managing Director of Aixtron AB, Sweden, adds, "We are pleased with the performance of the AIX 2800G4 WW system at Dow Corning. Repeat orders like this are indicators about the quality of our systems and their ability to provide a solid return on investment for our customers."

Toshiba invests in Bridgelux to make the best 8" GaN-on-Silicon LEDs

JUST MONTHS after they started collaborating, Bridgelux, and Toshiba say they have together achieved the industry's top class 8" GaN-on-silicon LED square 1.1mm chip emitting 614mW at less than 3.1V at 350mA.

Toshiba has also made an equity investment in Bridgelux with the intent to jointly pursue an innovative technology in the Solid State Lighting (SSL) space.

This investment will further advance both companies' efforts in the SSL industry, with the view to boost Bridgelux's GaN-on-Silicon LED chip technology development efforts based on Toshiba's advanced silicon process and manufacturing technology development efforts.

"Toshiba and Bridgelux have already been engaged in the development of the technology, and the equity investment brings both companies one step closer to a more strategic relationship and achieving our shared goal of driving down the cost of Solid State solutions for the general lighting market," says Bill Watkins, Bridgelux Chief Executive Officer.

"We are pleased to achieve the best-reported 8" GaN-on-Silicon LED performance through our joint development activities with Bridgelux. We will continue to pursue more advanced development targeting commercialisation of the technology "concludes Makoto Hideshima, Executive Vice President of Semiconductor and Storage Products Company, Corporate Vice President of Toshiba.

SETi & Cascade to develop UV LEDs for water purification

Sensor Electronic Technology, Inc. (SETi) and Cascade Designs, Inc. of Seattle, have signed a Joint Development Agreement to develop the next generation of portable water purification systems for commercial, military and disaster relief/humanitarian applications. The water purification systems will use SETi's germicidal UV LEDs to provide potable water to small groups from any source of fresh water anywhere. Germicidal UV LEDs are a new technology that offer an alternative to mercury lamps or chemical treatment and enables a compact, lightweight and mechanically robust disinfection solution that can stand up to the rigors of military and humanitarian use and, when powered with an alternative energy source, can offer a sustainable source of drinking water for many months.

Through a development program funded by the National Science Foundation (NSF), SETi has already successfully demonstrated the use of its germicidal UV LEDs in a bench top disinfection chamber.

The collaborative effort with Cascade Designs will further this work and lead to the development of the first multi-stage UV LED-based water purification system.

Cascade Designs has forty years of experience developing and manufacturing innovative products for the outdoor and military markets. Under the MSR (Mountain Safety Research) and Platypus brand names, the company has a significant share of the portable, point-of-use water treatment market. Cascade Designs is the standard-issue supplier of sleep pads, snowshoes, camp stoves, and on-the-move water treatment systems for the U.S. Army and Marine Corps.

The companies believe that UV LEDs, combined with proprietary filtration and absorption technologies, will have breakthrough potential for the military and humanitarian relief efforts.

"We see great potential in partnering with SETi," says Joe McSwiney, president of Cascade Designs, Inc. "With SETi's UV LED technology and our experience in designing and manufacturing a broad range of water treatment products, we believe we can develop revolutionary new water treatment systems that will advance the work we're already doing to supply the U.S. military and bring sustainable relief to people around the world who lack potable water."

Remis Gaska, president and CEO of SETi agrees. "With a strong track record of taking new technologies to market, Cascade Designs is the obvious choice for SETi to partner with."

SemiSouth brings on 650V 55 mΩ SiC JFETs

SEMISOUTH says it is delivering the industry's first 650 V SiC JFET power transistors.The fast switching speeds, large current handling capability combined with the superior thermal properties of SiC are ideal for power electronic applications. These devices employ vertical trench JFET structures.

Jeffrey B. Casady, President/CTO of SemiSouth says, "Customers in markets such as EV drive train, UPS, welding, solar, induction heating have long been asking for SiC switches which are very reliable, cost-effective, & capable of high-efficiency at high power densities. We are proud to be the first company to be able to offer such a product our customers will be able to realise enormous benefits by designing in these class-leading 650 V JFETs."

Dieter Liesabeths, Senior VP Sales & Marketing adds, "This product is significant. Markets where we are already in volume production using our 1200 V switch such as solar and UPS, also require lower-voltage switching at 650 V for efficiency & higher power density solutions where grid voltage or bus voltages are lower. The automotive industry is split on the EV drive train with some customers requiring 1200 V and higher, and others requiring only 650 V. We can now serve these markets even better with power transistor solutions from 650 V through 1700 V."

The 650V / 55mΩ SJDA065R055 SiC JFETs feature a temperature coefficient for ease of paralleling and fast switching with no "tail" current at 1500C. RDSONtypical for these new voltage-controlled devices is 0.044Ω, which exhibit a low gate charge and low intrinsic capacitance.

First Solar to promote CdTe in India

FIRST SOLAR has appointed Sujoy Ghosh in a new role as Country Head to lead business development in India and manage the company's new entity based in New Delhi. He reports to Jim Brown, First Solar Executive Vice President for Global Business Development.

With more than 20 years of Industry experience, Ghosh joins First Solar from GE Energy, where he was the regional general manager for the Power Generation business. He has worked in a diverse range of businesses from transmission and distribution to thermal power generation to renewable energy. Prior to joining GE, Ghosh worked at Tata Honeywell in sales and market development for 13 years.

"India is a land of immense opportunity for solar energy and First Solar, and we will continue to invest here as part of our strategy to develop sustainable, utility-scale solar markets where energy demand is strong and growing," comments Brown. "Sujoy's extensive experience in the energy industry and strong understanding of the Indian market will be invaluable to First Solar as we work to help India meet its energy needs with clean solar power."

"India is taking a progressive approach by incorporating clean, renewable sources of power in its plans to address its growing energy needs," says Ghosh. "I am pleased to join First Solar, which has proven solutions to support India's energy and economic growth."

India is expected to become one of the world's major solar markets due to its strong growth, significant energy demand and abundant solar resource. First Solar entered the Indian PV market in 2011 and is a local market leader for large-scale PV power plants. India accounted for around 8% of the company's net sales in 2011.

Infineon's cool 1200V SiC JFET family moves power into the next dimension

INFINEON TECHNOLOGIES has unveiled the new CoolSiC 1200V SiC JFET family.

Infineon says its revolutionary new product line takes advantage of more than a decade of its experience in SiC technology development as well as high quality, high volume production.

"Infineon has a strong track record in launching break-through technologies aimed at markets requiring highly efficient power management. CoolSiC is again a revolutionary, highly innovative technology specifically designed for reaching new levels of performance in solar inverters," comments Jan-Willem Reynaerts, Product

Infineon's TO-247 CoolSiC 1200V device

Segment Head of High Voltage Power Conversion at Infineon. "With Infineon's new SiC JFET technology we enable our customers to further shape the future of climate saving solutions."

The new CoolSiC 1200V SiC JFETs have dramatically lower switching losses compared to IGBTs, which allow higher switching frequencies to be used without sacrificing overall system efficiency. This enables the use of much smaller passive components, which result in smaller overall solution size, lower weight and reduced system cost.

Alternatively, a higher output power solution can be realised within the same inverter housing.

In order to ensure that the normally-on JFET technology is safe and easy to use, Infineon has developed a concept called Direct Drive Technology.

In this, the JFET is combined with an external Low Voltage MOSFET and a dedicated Driver IC which ensures safe system start-up conditions as well as fast and controlled switching.

The CoolSiC JFET features a monolithically integrated body diode that has a switching performance comparable to an external SiC Schottky barrier diode. This combination is claimed to offer the utmost in efficiency, reliability, safety and ease of use.

API secures $1.5 million funding for F-35 aircraft quality control

Advanced Photonix, Inc (API) has been awarded a follow on 21 month contract from the Air Force for $1.5 million to provide terahertz process control instrumentation.

The contract will support production of the F-35 Joint Strike Fighter (JSF).

The contract is a commercialisation pilot program (CPP) award to optimise the quality of specialty stealth coatings applied by Northrop Grumman to a sub-system on the F-35. The purpose of the CPP is to accelerate the transition of Small Business Innovation Research funded technologies to Phase III production and deployment purchases by the DoD.

Previous Phase I and II contracts demonstrated feasibility in the lab and in Northrop Grumman's facility. This contract funds further application and system development culminating in delivering two production units for deployment on the manufacturing floor by the end of 2013.

Once completed, the system will consist of the T-Ray 4000 control unit which is connected to a miniature terahertz transceiver via a flexible umbilical up to 100 metres in length mounted onto an existing robot arm within a paint booth. The fibre-optic coupled terahertz (THz) technology employed is well suited to the application, as the sensors are small, light weight and freely positionable.

A hand-held version that would allow measurement on cured coatings without the robot is also planned.

The proposed system and software will not only be able to function as a real-time sensor for applying the sprayed-on stealth coating on the F-35 for the Air Force, but also other coatings of interest to the Army and Navy.

The sensors could also be applicable for monitoring and inspecting coatings and paints applied in industrial settings, such as automobile manufacturing.

"Demonstrating the capability of our equipment in a paint booth shows just how robust our terahertz system has become," states Richard (Rick) Kurtz, Chairman and CEO of API. "The success of this contract will allow us to penetrate many applications in both military and industrial markets providing significant long term growth for our T-Ray product line."

F-35 Joint Strike Fighter

Soraa unveils first full spectrum LED MR16 lamp

SORAA, a developer of GaN-on-GaN (gallium nitride-on-gallium nitride) solid-state lighting technology, has launched the VIVID LED MR16 lamp.

The new product is touted to be the first full spectrum LED MR16 lamp with colour quality and rendering superior to both traditional halogen and competitor LED lamps. With a CRI of 95 and R9 over 90, the VIVID LED MR16 is one of the highest output LED MR16 lamps with the best colour performance available on the market today.

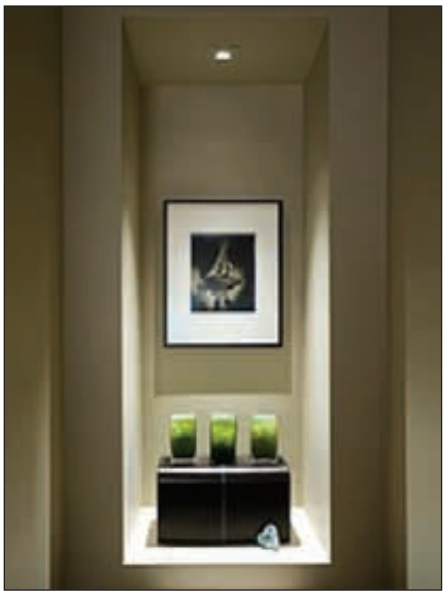
With rich saturated colour rendering and very good colour stability, the VIVID LED MR16 lamp is suited to demanding display applications. Soraa says its VIVID LED MR16 lamp is 75% more energy efficient than comparable halogen lamps.

The lamp is designed to replace standard 40 to 50W MR16 halogen lamps and is available in 2700K and 3000K correlated colour temperatures.

Soraa's proprietary GaN-on-GaN technology allows for LED products that match the black body curve as is produced by halogen and incandescent lamps, widely considered the optimal light colour spectrum. Unlike other LED lamps, Soraa claims its VIVID LED MR16 offers full coverage over the entire spectral range and has no pronounced blue peak or violet and cyan dips common in all other LED lamps. The VIVID LED lamp overcomes the blue overshoot commonly associated with poor colour quality.

"With the launch of the VIVID MR16, we demonstrate a very clear link between performance and our breakthrough GaN-on-GaN technology," comments Soraa CEO Eric Kim. "We believe that with GaN-on-GaN there is no longer any reason to compromise light quality or colour performance in the name of energy efficiency."

"For years, lighting designers have been holding back on embracing LED MR16 lighting mostly due to both inadequate light output and only mediocre colour quality," adds Jim Benya, one of the world's most prominent lighting designers.



"Now, here is the first example of LED MR16 technology providing both high output and excellent colour, allowing large-scale, mainstream adoption of LEDs in the critically important MR16 marketplace."

Nanosolar completes installation of 1 MW CIGS project at Camp Roberts

NTHIN-FILM pioneer Nanosolar has completed a 1 MW ground-mounted solar installation at Camp Roberts, the largest of California's National Guard training facilities, located in San Miguel.

The installation is part of the U.S. Department of Defence's (DoD) Energy Security Technology Certification Program (ESTCP). This relates to testing various green technologies to identify viable solutions to address rising energy costs and minimise the reliance on fossil fuels.

The DoD spends over $4 billion annually on electricity use, accounting for more than 90 percent of the federal government's energy use.

Nanosolar is contributing to the ESTCP program with its solar demonstration project at Camp Roberts, designed to show the effectiveness of using its low-cost, thin-film CIGS utility panels. The installation, which is comprised of 4,992 of

Nanosolar's thin-film panels, will be used to test the capabilities of the product for producing energy in areas where solar irradiance is above average.

At Camp Roberts, strong annual isolation of 1892 kWh/m2 is typical. The project was installed in an area of flat, unused land. "Our project at Camp Roberts shows how our technology can be used for both military and non-military applications, on a path to greater energy independence," says Eugenia Corrales, CEO of Nanosolar.

"Nanosolar is on track to deliver the most cost-efficient solar electricity, with the expectation that we can achieve grid parity with non-renewable energy resources by 2015."

"We are pleased to see Nanosolar fulfil its goal to provide cost-effective renewable energy solutions that address Department of Defence energy security requirements. The U.S. Army alone has identified renewable energy projects that represent $7 billion over the next ten years. We look forward to continuing our work with Nanosolar, as the company expands its deployments across U.S. Defence installations," adds David Odom, Arsenal Venture Partners, the manager of OnPoint Technologies, the U.S. Army's Venture Capital Fund. Founded in 2002, Nanosolar uses a unique high-throughput, roll-to-roll printing process to coat aluminium foil with proprietary CIGS inks. Camp Roberts hosted a ribbon cutting ceremony to mark the completion and energising of this project on May 11, 2012.

SPTS wins China over with its PVD technology

SPTS TECHNOLOGIES has announced that its Sigma fxP PVD system had been selected by a Chinese foundry dedicated to producing RF devices on GaAs substrates. The system will be used to deposit front and backside metal layers including integrated passives for producing monolithic microwave integrated circuits.

China is one of the world's fastest growing markets for mobile phones, and increasing counts of GaAs-based switches and power amplifiers appear in every handset.

SPTS says its production platform, the Sigma fxP system, provides many capabilities for GaAs based RFIC fabrication. "SPTS is proud to be part of China's developing compound semiconductor device manufacturing industry," says Kevin T. Crofton, executive vice president and chief operating officer at SPTS. "We look forward to contributing to our customer's success in their production ramp."

This is SPTS' second new Chinese customer announcement in recent weeks, following a previous announcement from the Shanghai Institute of Microsystem and Information Technology selection of a SPTS' Primaxx Monarch 3 dry release system for MEMS. Chinese domestic production of such components will grow to serve the China market, the world's largest consumer of handsets. The Sigma fxP is a single-wafer cluster tool designed for high-volume PVD processing. The flexible system supports various process chamber configurations and combinations to address a large variety of specific applications.

Deposition process modules are based on a standard design that enables simple technology upgrades. Key applications for the Sigma fxP include thick aluminium alloys for power device and next generation CMOS bondpad and metal seeds for advanced packaging applications.

RFMD's new rGaN-HV process for power devices

RF Micro Devices has extended its GaN process portfolio to include a new technology optimised for high voltage power devices in power conversion applications. RFMD's newest GaN process technology, known as "rGaN-HV", is claimed to enable substantial system cost and energy savings in power conversion applications ranging from 1 to 50 KW. The rGaN-HV delivers device breakdown voltages up to 900 V, high peak current capability, and ultra-fast switching times for GaN power switches and diodes.

The new technology complements RFMD's GaN 1 process, which is optimised for high power RF applications and delivers high breakdown voltage over 400 volts, and RFMD's GaN 2 process, which is optimised for high linearity applications and delivers high breakdown voltage over 300 volts. RFMD will manufacture discrete power device components for customers in its Greensboro, NC, wafer fab facility and provide access to rGaN-HV to foundry customers for their customised power device solutions.

Bob Bruggeworth, President and Chief Executive Officer of RFMD, comments, "The global demand for energy savings through improved power conversion efficiency is creating a tremendous opportunity for high-performance power devices based on RFMD's GaN power process technologies. We expect our newest GaN power process will expand our opportunities in the high-voltage power semiconductor market, and we are pleased to provide access to rGaN-HV to our external foundry customers to support their success in the high-performance power device market."

The challenges for going green

Green GaN lasers are very different from their red and infrared III-V cousins: They are strained, plagued by strong internal electric fields and have massive band offsets. But if you can understand these traits and use some of them to your advantage, it is possible to design devices for plugging the green gap, say Dmitry Sizov, Rajaram Bhat and Chung-En Zah from Corning.

Fans of high definition movies and Sony Playstations are grateful to the inventors and producers of the GaN laser. However, what they are probably unaware of is that these scientists and engineers that refined and developed this violet-emitting laser, which can read the ones and zeros off of optical discs, had to deal with a multitude of tough challenges that do not exist in the traditional III-Vs: Limited availability of native substrates; higher growth temperatures and low chemical reactivity at room temperature; polarization effects resulting from a wurtzite crystal structure; heavy effective mass; high acceptor ionization energy; and limited availability of strain-free heterostructures.

More recently, these issues have hampered efforts within the nitride community to extend laser emission to longer wavelengths, a spectral region known as the green gap. Green lasers are wanted for colour projection systems that combine the output of red, green and blue sources. In addition, these single-chip lasers could win sales in a variety of defence, biomedical, industrial and instrumentation applications.

Chip designers trying to select an architecture for a green laser come up against three major impediments: Strain, because it is not possible to make the device with a set of lattice-matched materials; the need to operate at the high current densities to reach optical amplification, a pre-requisite for lasing; and injecting enough carriers uniformly into an active region plagued with an awkward band structure. The remainder of this article will detail each of these three challenges, before offering some insights into ways to overcome them.

Coping with strain

Lattice matching with nitride materials is very tricky. Differences in crystal structure prevent pairing III-Ns with III-Vs – the wurtzite structure of the former is significantly different from the zinc blende structure of the latter (see

Figure 1). Substituting another group V element for nitrogen is not easy, either, so there are only three ternary alloys available. Two are AlGaN and InGaN, which cannot be lattice matched, and the third is AlInN, which is rarely used due to the challenges associated with the growth of uniform material.

There is also a family of quaternary alloys that allow some degree of bandgap tuning for a given lattice constant: AlInGaN. But this class of material is rarely used, due to strong fluctuations in composition and a tendency for morphology roughening resulting from a large difference in the preferred growth temperatures of AlGaN and InGaN.

Consequently, designers of deep blue and green nitride lasers tend to select AlGaN for the cladding layers and InGaN for the waveguides. To prevent excessive strain, concentrations of aluminium and indium in AlGaN and InGaN are kept within a few percent of each other. However, this leads to a relatively low refractive index contrast between the waveguide core and claddings. Making matters worse, at longer wavelengths, the differences in refractive index between given alloy compositions diminish.

One choice facing every nitride laser designer is that of substrate orientation. Traditionally, nitride lasers have been formed on the *c*-plane, an orientation that allows for significant strain without defect formation, thanks to a relatively large force needed for glide along available glide planes.

Relaxation in nitrides due to dislocation glide occurs at far lower levels of strain when lasers are formed on semi-polar planes – planes in a wurtzite crystal tilted by an angle ß ($0<ß<90$ and $90<ß<180$) with respect to the *c*-plane. There are many semi-polar planes to work with, and it is possible to find orientations that allow sufficient indium incorporation to realise green emission. More importantly, semi-polar planes enable the formation of epitaxial structures with higher optical gain. This is a key advantage for making green lasers, where optical gain is limited (this is discussed in detail later on).

When nitride layers are deposited on semi-polar substrates, strain leads to misfit dislocation arrays at AlGaN/InGaN interfaces between layers over 100 nm-thick that have aluminium and indium contents of just a few percent. If the impact of these misfit dislocations is similar to that in other III-V devices, they will jeopardize reliability.

Our team of researchers at Corning has found that misfit dislocations also act as strong non-radiative recombination channels, and in addition they degrade surface morphology, just like they do in other III-V structures. Fortunately, there are special tricks for sidestepping these relaxation effects and ultimately achieving sufficient optical confinement in semi-polar green lasers with good quantum efficiency. Thanks to these tricks, it is possible to realise high optical gain in green lasers.

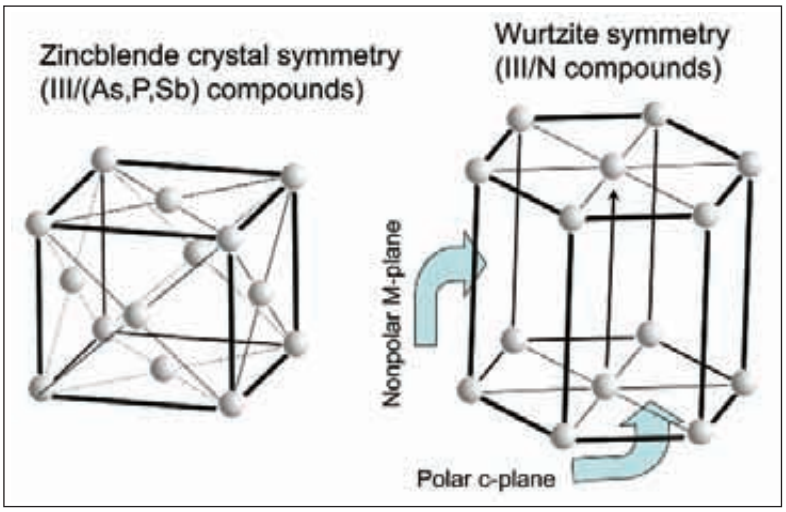


Figure 1. Differences in crystal structure makes the alloying of wurtzite III/N with traditional III/V compounds challenging

Keeping misfit dislocations away from the active region is one way to manage strain. Do this, and strain relaxation is actually beneficial. The key is to grow an InGaN waveguide core over the cladding in a way that leads to dislocations forming at this interface. This increases the lattice constant of the InGaN layer, and it enables the subsequent growth of a green InGaN quantum well with much lower stress, thereby preventing relaxation of this layer.

This must be followed up with the growth of a second InGaN waveguiding layer on top of the well that has the same lattice constant as the bottom waveguide. Doing this enables the coherent growth of a multi-quantum well region sandwiched between InGaN waveguiding layers.

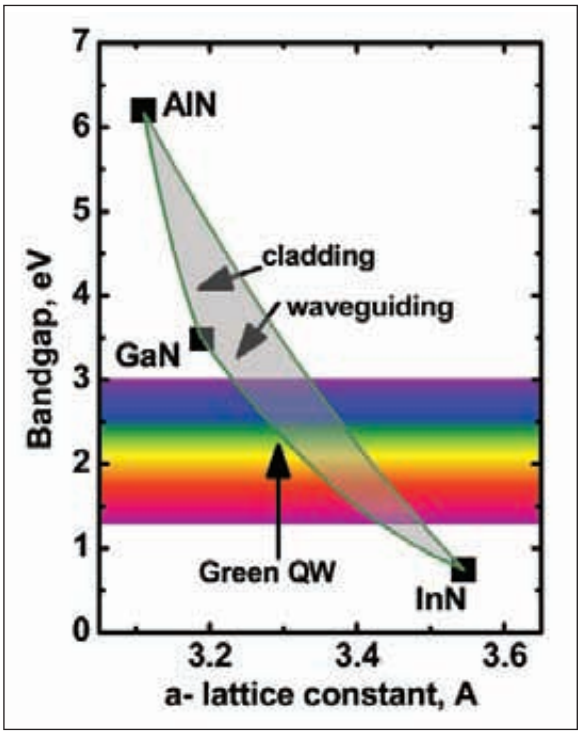
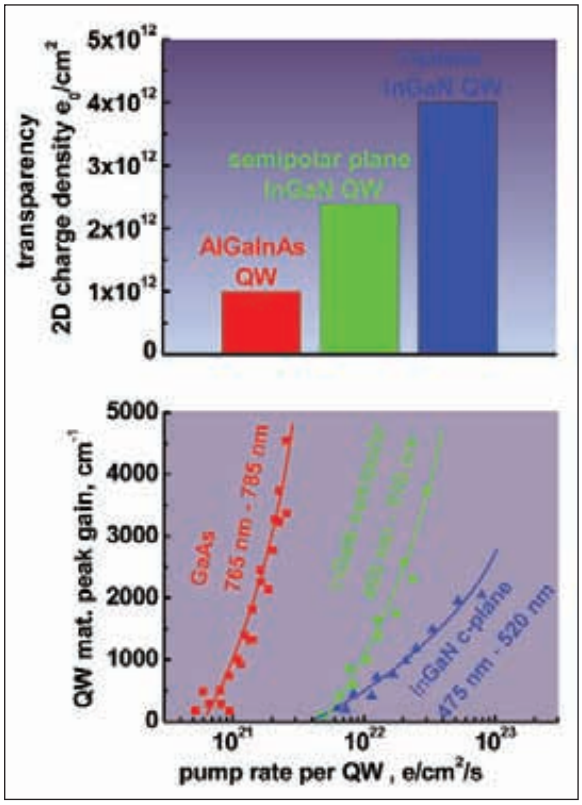


Figure 2. Green laser diodes are composed of lattice-mismatched heterostructures because most of the conventional III/N alloys are lattice mismatched with GaN substrates

Once this is done, engineers must then deposit a lattice-mismatched, relaxed top cladding layer, which will lead to the formation of another array of misfit dislocations, this time on the lower interface of the upper cladding. With this approach, dislocations are only located in the interfaces between waveguiding and cladding layers, where they are too far away from the active region to contribute to non-radiative recombination losses. It is worth noting that the possibility of instantly forming a misfit dislocation array at the interface and growing a relaxed and low-defect-density layer right over it is quite unique for semipolar III-N heterostructures.

There have also been reports of strain relaxation management in III-V zinc-blende structures, such as near-infrared lasers with In(Ga)As quantum wells, quantum dots grown on GaAs substrates, and multi-junction solar cells. However, in order to avoid defects in active regions, those realizations require the growing of bulk transition layers or superlattices, instead of using single interface, like in semipolar III-Ns.

Alternatively, misfit dislocations can be completely avoided with strain-compensating layers. The trick is to balance compressive strain in the wells and the InGaN waveguiding layers with tensile strain in Al(In)GaN barriers. Apparently, when the indium concentration in InGaN layers of the waveguide core is sufficiently high, strain compensation is possible without degrading optical confinement.



This is thanks to one beneficial characteristic of InGaN: Its refractive index increases superlinearly with indium concentration. In other words, the refractive index increases much faster when the separation between the lasing photon energy and the InGaN material bandgap is smaller. Intuitively, simple insertion of the Al(In)GaN layers inside the InGaN waveguide core would reduce its average refractive index. However, due to strain compensation it in fact enables the use more indium in the waveguide, which overcompensates the refractive index reduction, so it is still higher than for the design without strain compensation.

Cranking up the current

The second major challenge facing the developers of green lasers is to design and build a device capable of operating at the very high current densities required for light amplification. In InGaN quantum wells, carrier density is relatively high, due to the high effective mass of both types of carrier – masses of holes and electrons in InGaN are more than 1.4m_e and 0.2m_e, respectively, compared to values of just 0.51m_e and 0.063m_e for electrons and holes in GaAs (m_e is the mass of a free electron). The higher electron and hole effective masses lead to a higher density of electron and hole states. In turn, the higher density of electron and hole states in the InGaN quantum well leads to a higher transparency carrier density, a pre-requisite for lasing, that is more than twice that required for laser diodes based on InGaAs quantum wells.

This hike in transparency carrier density has unwanted ramifications. Recombination current is a super-linear function of carrier concentration – especially at high current densities where non-radiative Auger recombination dominates – so the current density needed to reach transparency in an InGaN quantum well is several times higher than it is in one made from InGaAs (see Figure 3).

Making matters worse, the increases in indium content that push the emission of InGaN quantum wells towards the green also leads to rapid reductions in differential gain. This is not just the result of a hike in non-radiative recombination – there is also significant inhomogeneous line broadening resulting from InGaN alloy fluctuations when the molar concentration of indium in the ternary is around 30 percent, the fraction required for green emission.

Figure 3. (a) The charge carrier density needed to reach transparency is much higher for InGaN QWs – especially c-plane ones – than III/As QWs. (b) As a result, InGaN QWs need much higher pumping for light amplification. Despite this, the differential gain is much lower in green InGaN QWs. (This figure drew on data from P. Blood et al. J. Appl. Phys. ***70*** *1144 (1991))*

Part of the reason behind the high current densities required for lasing in long-wavelength nitride lasers is that the wurtzite III-N crystal has a polar nature. The polarization fields that result from this particular structure reduce electron-hole overlap in the well, a phenomena known as the quantum confined Stark effect (QCSE). To overcome optical losses, current densities in blue and green laser diodes need to hit 2 kA cm^{-2} and over 4 kA cm^{-2}, respectively. These values are an order of magnitude higher than those for lasers based on InGaAs quantum wells.

The low optical gain found in green lasers can be partially addressed with semi-polar substrates: Differential optical gain doubles when a green InGaN quantum well is grown on a semi-polar orientation, rather than the conventional polar one. This benefit of semi-polar orientation is due to a reduction in the QCSE and anisotropic optical gain by the breaking of the 90-degree rotational symmetry of the wurtzite crystal semi-polar plane – a property not associated with conventional III-V compounds, which have a cubic symmetry.

Working with semi-polar lasers is relatively new, and this type of epitaxial structure is still immature. Limits of this approach are still being explored, including the strain management techniques already outlined above. One downside of working with semi-polar lasers is that optical gain is, in most cases, only high in one direction – and this direction is not always favourable for cleaved facet formation. This state of affairs also has its origins in the breaking of plane rotational symmetry.

Low gain is only partly to blame for high-threshold currents, which also result from high optical loss. In the red and infrared spectral ranges served by III-V lasers, intersubband absorption and free carrier absorption are the primary causes of optical loss, and they can be trimmed to less than 1 cm^{-1} for 980 nm lasing. With III-N lasers operating in blue-green, however, losses are ten times higher, due to acceptor-bound absorption.

One undesirable trait associated with III-Ns is the high activation energy of acceptors. Very high acceptor concentrations are needed to realise a desired hole conductivity. With GaN and its related alloys, the only practical acceptor is magnesium, which has an activation energy in excess of 160 meV – at least four times that associated with a range of elements for doping more traditional III-Vs. This means that when using magnesium, if the acceptor concentration is about $1x10^{19}$ cm^{-3}, less than 2 percent of holes contribute to conductivity. So very high levels of magnesium are needed to form layers that have reasonable *p*-conductivity, a necessity for making devices with a low operating voltage. However, a penalty must be paid – high optical absorption.

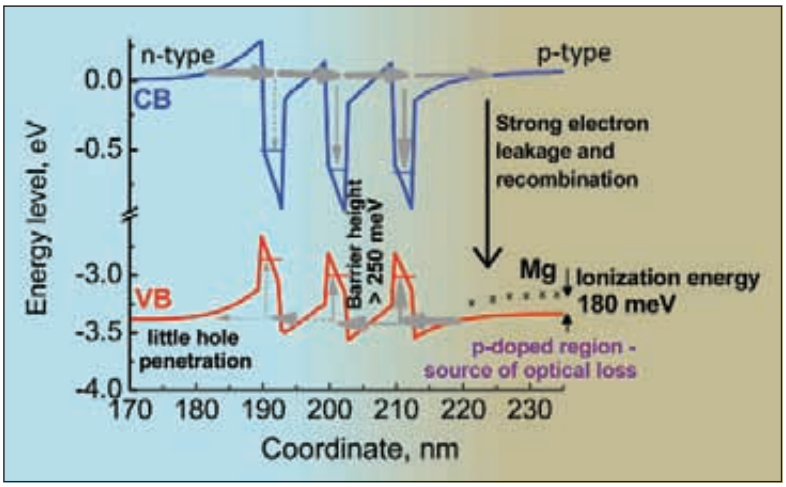


Figure 4. Deep charge carrier confinement inside the QW leaves limited opportunity for carrier distribution among several QWs and is the root cause of injection asymmetry. Heavy magnesium doping is needed to obtain p-conductivity. Asymmetry of carrier injection in the active region causes electron leakage to a heavily p-doped region where carriers can recombine non-radiatively if this process is not blocked

Lasers designers can use several tricks to trim the total optical loss of their devices. They can select a relatively high reflectivity for the front mirror, which also leads to a reduced slope efficiency of output light. In addition, they can keep the *p*-doped region away from the optical mode, while still ensuring that there is sufficient hole injection into the quantum well and the operating voltage of the laser is reasonable. One neat way to do this is to use an asymmetrical waveguide refractive index profile, which shifts the optical mode towards the *n*-side. Although this slightly reduces optical overlap with the active region, it substantially cuts overlap with the *p*-layers.

Injecting electrons and holes

The third major challenge facing developers of green III-N lasers is the injection of carriers into quantum wells that are deep and have a band structure that is severely distorted by the QCSE.

With infrared laser diodes, good carrier transport results from the use of a graded-index, separate-confinement heterostructure. In this class of device, the bandgap increases gradually in both directions away from the quantum well region, and carriers can move in and out of each quantum well, leading to similar populations in every well. However, electrons and holes are still confined within the multi-quantum well region, because this is surrounded by a bandgap gradient that creates electric fields preventing carrier out-diffusion. What's more, this approach also leads to optical confinement, because the material furthest from the wells has the widest bandgap and the lowest refractive index.

Unfortunately, up until now it has proved impossible to transfer this elegant design to green nitride lasers. In our view, this is because of peculiarities associated with the bandstructures of GaN and InGaN used in the barriers and wells. These materials have bandgaps of 3.49 eV and 2.34 eV, so the total band offset exceeds 1 eV. It is hard to determine the precise bandstructure, due to significant variations in the values for the offset ratio of the conduction band to the valence band. However, these differences are not important, because there is no question that the barrier height (given in energy) for each charge carrier exceeds the value of k_BT by a factor of at least ten.

To replicate the graded-index structures found in conventional III-V lasers, engineers must fabricate InGaN barriers with a significantly narrower bandgap than GaN. But this would increase the total amount of indium in the active region, adding compressive strain to wells that are already suffering from this. So the barriers must contain very little or no indium. This means that the rate for carrier thermal escape from a quantum well ground state, which rapidly diminishes with increases in barrier height, is far slower than carrier recombination. Consequently, carriers are trapped in one well until they recombine, and they only travel across the wells by ballistic fly-over.

The upshot of all of this is poor carrier distributions, particularly in *c*-plane lasers. Here, the piezoelectric effects create potential spikes in the barriers, which lead to a drag on ballistic carrier motion. Holes fare worse than electrons, due to a higher average effective mass and lower mobility, and this results in the accumulation of carriers in the quantum wells near the *p*-side.

In *c*-plane green laser diodes and LEDs the well closest to the *p*-side tends to be the one most populated with carrier. This is part of the reason why the *p-n* junction is effectively shifted toward the *p*-side, promoting electron leakage to the *p*-doped region. Any electrons that get this far undergo parasitic nonradiative recombination. To prevent this from degrading device behaviour, an electron-blocking layer is inserted between the wells and the *p*-type region. This thin layer stems the flow of electrons to the *p*-side, but partially blocks hole injection into the quantum wells and fails to address the problem of non-uniform carrier distribution within the active region. When we tried to build *c*-plane green lasers with several quantum wells, only the one or two closest to the p-side provided optical gain, with the rest absorbing light, because they are under-pumped, unless extremely high current is applied.

Semi-polar lasers don't suffer the same fate. Hole injection into several quantum wells is much easier, due to a reduction in the strength of the built-in polarization fields. These weaker fields lower barrier spikes, making carrier fly-over more uniform and ultimately leading to a more even distribution of electrons and holes within the wells.

We have found that this superior band structure in semi-polar lasers also allows designers to dispense with the electron-blocking layer, which is not used in III-V infrared lasers. Thanks to a deeper penetration of holes in the multiple quantum well region, fewer electrons are attracted to the *p*-layers, and there is much less shifting of the position of the *p-n* junction.

There is a silver lining associated with deep carrier confinement in the quantum wells: Reduced sensitivity to changes in temperature. The measure of this sensitivity in laser diodes is the threshold current characteristic temperature T_0. In arsenide- or phosphide-based lasers, carrier confinement is typically 0.2 eV or less, and a significant proportion of carriers leak away from the active region at normal operating temperatures. With green nitride lasers, the far stronger carrier confinement prevents any electron escape from quantum wells with temperatures below 400K.

Switching from non-polar to semi-polar green lasers leads to an even higher value of T_0. We believe that this stems from a combination of the deep carrier confinement found in all forms of nitride laser, plus a particularly large separation of quantum well quantization states. This leads to a lower thermal population of the higher energy bands.

It is clear that III-N materials hold great promise for covering a wide spectral range. When it comes to green III-N lasers, the challenges are quite different to those facing the designers of III-V red and infrared lasers, so a different approach is needed. With III-N green lasers, strain comes into play, there is low optical gain and high optical loss to deal with, and deep carrier confinement combats uniform carrier distributions in the multiple quantum well – but it has a good side too, in the form of diminished device temperature sensitivity. Understanding all of this, and how to navigate a path through these obstacles, holds the key to improving the performance of green lasers.

Gallium oxide trumps traditional wide bandgap semiconductors

Transistors built from Ga_2O_3 have tremendous potential. They have a far higher electric field strength than those made from GaN and SiC, and they can be formed from native substrates produced with simple, low-cost methods, says **Masataka Higashiwaki from the National Institute of Information and Communications Technology (NICT), Japan.**

Two separate developments are needed to secure stable energy supplies in the near future: Widespread adoption of revolutionary technologies that can replace burning of fossil fuels; and the introduction of a multitude of products that consume less energy, a step that will also trim greenhouse gas emissions.

One way to fulfil this latter goal is to turn to more efficient power electronics. This is possible by replacing silicon devices with those made from wide bandgap semiconductors, which have superior material properties, such as higher breakdown voltages and lower switching losses.

The two most promising, highly developed wide bandgap materials for power electronics are GaN and SiC. However, both of them have massive weaknesses when it comes to mass production. In an ideal world, compound semiconductor devices are built on an affordable native substrate, but it is impossible to make GaN and SiC crystals with simple, low-cost methods. Current methods to make GaN lead to sale prices that are prohibitively high for power electronics, and while SiC substrates don't suffer from the same fate, they are still costly and their material quality is far from perfect.

	Si	GaAs	4H-SiC	GaN	β-Ga_2O_3
Bandgap (eV)	1.1	1.4	3.3	3.4	4.8-4.9
Electron mobility (cm^2/Vs)	1,400	8,000	1,000	1,200	300
Breakdown field (MV/cm)	0.3	0.4	2.5	3.3	8
Relative dielectric constant	11.8	12.9	9.7	9.0	10
Baliga's FOM (to Si)	1	15	340	870	3,444

Table 1. In terms of break down field and Baliga's figure of merit, Ga_2O_3 is superior to all the popular compound semiconductor materials

A promising wide bandgap alternative that has been overlooked up until now is Ga_2O_3. Thanks to a bandgap that is significantly larger than that of SiC and GaN, this oxide promises to enable the production of devices with higher breakdown voltages and higher efficiencies than those stemming from its wide bandgap rivals. What's more, Ga_2O_3 power devices could be manufactured at low cost in high volume, because it is possible to produce single-crystal native substrates from a melt using the same method employed for manufacturing sapphire substrates. This platform for making GaN LEDs is now being manufactured in a low-cost commercial process in numbers rivaling those for silicon substrates; there is no major obstacle to prevent Ga_2O_3 substrates from treading the same path.

To try and convert the promise of Ga_2O_3 power devices into a reality, since 2010 I have been working in collaboration with Kyoto University, the Tokyo Institute of Technology, and Tamura and Koha Corporations. Our team has already developed several elemental technologies and hit several key milestones, including the world's first demonstration of Ga_2O_3 transistors.

The character of gallium oxide

Ga_2O_3 has many forms, and to date there have been confirmed reports of five different polytypes, which are denoted α, β, γ, δ and ε. The β-polytype is the most stable, and the four other polytypes are classed as quasi-stable. Since efforts on Ga_2O_3 are in their infancy, there have only been a handful of reports on crystal growth and material properties of this oxide, and they have focused on the β-phase. This polytype has several attractive attributes, including an incredibly wide

bandgap of 4.8-4.9 eV and an n-type conductivity that can be controlled from 10^{16}-10^{19} cm^{-3} through doping with tin or silicon. However, so far there are no reports of clear hole conduction in p-type Ga_2O_3 layers.

Thanks to its wider bandgap than SiC and GaN, the β-polytype of Ga_2O_3 promises to enable fabrication of devices with excellent characteristics, including high breakdown voltages, high power capacity and high efficiency. (See Table 1 for a comparison of the important material properties for power device applications for various popular semiconductors, plus β-Ga_2O_3).

The great material properties of β-Ga_2O_3 indicate that this wide bandgap semiconductor should have a breakdown electric field of 8 MV/cm, three times those of either SiC or GaN. This very high value for the electric field strength is a trump card for Ga_2O_3 because Baliga's figure of merit – the basic parameter to show how suitable a material is for power devices – is far more dependent on breakdown field than mobility. Values for this figure of merit are proportional to the cube of the breakdown field, but only linearly proportional to mobility.

It is possible to use values for the material properties of semiconductors to calculate theoretical limits of on-resistance at a range of breakdown voltages (see Figure 1). Such efforts indicate that the on-resistance of Ga_2O_3 devices can be an order of magnitude lower than those for SiC and GaN devices at the same breakdown voltage.

Preparing a platform

To fabricate Ga_2O_3 devices that can fulfill their potential, one must begin with a native substrate. The good news is that large, single-crystal Ga_2O_3 substrates can be fabricated from the melt at low cost using very little energy. This is in stark contrast to the expensive, energy-consuming methods employed for creating GaN and SiC bulk crystals and substrates: Sublimation, vapor phase epitaxy, and high-pressure synthesis.

Two of the members of our team, the Tamura and Koha companies, have already succeeded in developing 2-inch-diameter single-crystal β-Ga_2O_3 wafers via a melt growth technology known as edge-defined film-fed growth (EFG). This growth technology has a good track record for producing large sapphire substrates, and the same system configuration can be used for making Ga_2O_3 substrates.

This is not the only reason why melt growth is attractive: In principle, melt growth of Ga_2O_3 should never generate micropipe defects, which have historically plagued SiC substrates produced by the most popular method, sublimation. In addition, melt growth does not need a high-pressure environment, which is required for the production of SiC substrates. And on top of these benefits, the size of substrates produced by the EFG method is just determined by the dimensions of the equipment – scaling substrate size is simply a matter of increasing the size of the growth tool.

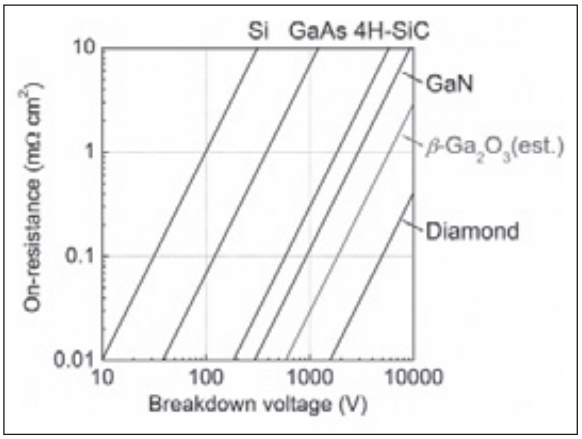


Figure 1. The β-poltype of Ga_2O_3 promises to excel in breakdown voltage and on-resistance

It should be possible to make Ga_2O_3 substrates very cheaply. We estimate that a mass-production system could churn out high-quality, 6-inch-diameter Ga_2O_3 substrates at a unit cost of $120. Thanks to a relatively efficient process, we estimate that the power dissipated per-unit-area of substrate at the time of production is just one-third of that associated with SiC sublimation, due to a lower growth temperature and a higher growth rate.

Building devices

We recently succeeded in fabricating the first field-effect transistors based on a single-crystal Ga_2O_3 channel grown on a β-Ga_2O_3 (010) substrate. These devices were metal-semiconductor field-effect transistors (MESFETs), simple structures that are suitable for demonstrating transistor action. Our devices are certainly not the first oxide transistors ever produced. For several years, oxide semiconductors such as $InGaZnO_4$ (IGZO) and ZnO have been attracting attention

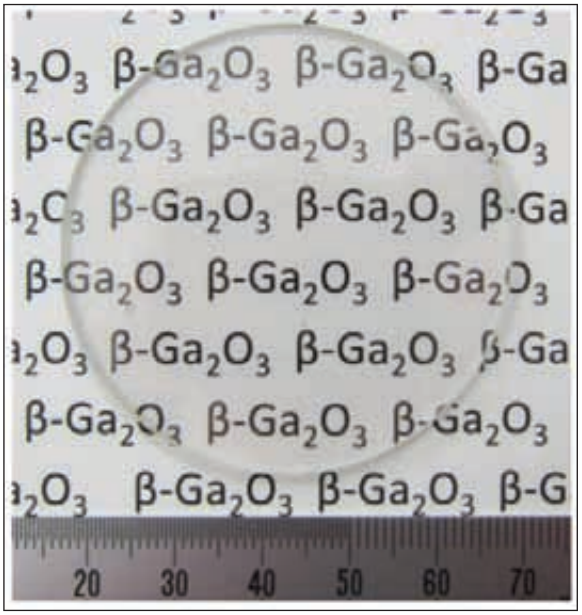


Figure 2. A melt-based process, which is similar to that employed for sapphire production, can yield 2-inch Ga_2O_3 substrates

as new transparent transistor materials for display applications. However, unlike Ga_2O_3, these crystal structures are amorphous and/or polycrystalline, and are consequently unsuitable for the fabrication of high-power devices. To produce our Ga_2O_3 transistor, we deposited a tin-doped n-Ga_2O_3 channel layer on a native substrate by MBE. Conventional Knudsen cells provided the gallium and tin sources, and the oxygen source comprised 5 percent ozone and 95 percent oxygen.

Device isolation techniques have not been developed, so we employed a circular FET pattern (see Figure 3). To form ohmic contacts, we used a mixture of BCl_3 and argon to perform reactive-ion etching, followed by evaporation of Ti/Au. We have found that this etching process substantially reduces contact resistance. After this, we fabricated Schottky gates by Pt/Ti/Au deposition and lift off. MESFETs that did not feature surface dielectric passivation were created that had a 4 μm gate length and a source-drain spacing of 20 μm. The diameter of the inner circular electrodes for the drain was 200 μm.

DC output characteristics for one of our circular Ga_2O_3 MESFETs include a maximum drain current density of 25 mA/mm and perfect pinch-off (see Figure 4). A destructive measurement of the three-terminal breakdown voltage in the off-state, which resulted in burned gate electrodes, produced a value of more than 250 V. Transconductance peaked at 2.3 mS/mm for a 40 V drain bias.

Other promising characteristics of our MESFET include an off-state drain leakage current of just 5 μA/mm and an on/off drain current ratio that could hit 10,000. A high proportion of this leakage current will be associated with the large gate pad (see Figure 3(b)), and the leakage from the gate finger will be at least one order of magnitude below this value. The off-state drain current is comparable to the gate leakage current, indicating that there is a negligibly small leakage through the semi-insulating Ga_2O_3 substrate. It is possible to drive down the off-state current even further by simply adjusting the device configuration.

A benchmark to judge these devices by is that of the performance of the GaN MESFETs of the early 1990s: Our oxide transistors deliver comparable or better performance. It is no surprise that our devices are inferior to the far more mature, state-of-the-art SiC and GaN devices of today, but their combination of high breakdown voltage and low leakage current shows that they have great potential as power devices.

To improve the performance of our fledgling devices, we must address a slew of technological challenges. These include the production of substrates with diameters of more than 4-inches, device processing, and epitaxial growth that includes doping.

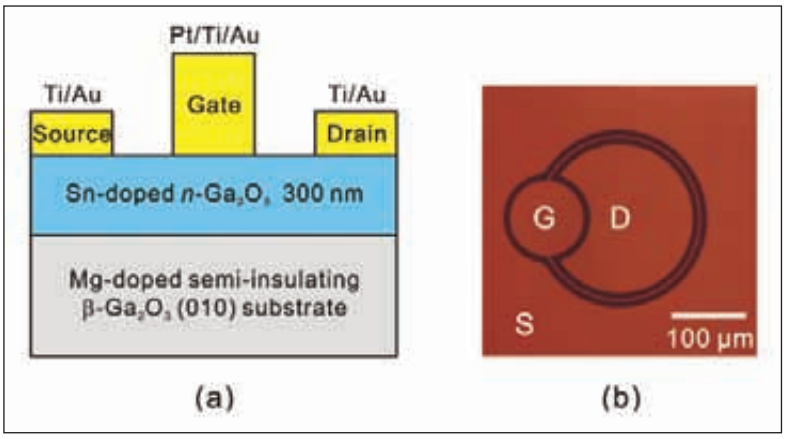


Figure 3. A cross-sectional schematic illustration of the n-Ga_2O_3 MESFET structure (a) and an optical micrograph of the fabricated device (b)

So that our devices can find practical application fast, we want to develop normally off transistors that can serve in switching equipment. The best structures for this purpose are MOSFETs, which are likely to use either Al_2O_3 or SiO_2 for the gate dielectric film. There is good reason to believe that it will be possible to produce such structures with a high-quality, low-defect-density interface, because both materials are oxides. We believe that our recent development of Ga_2O_3 transistors could herald a new era for high-performance power electronics. Such devices will not only help to reduce global energy use; they will also trim energy consumption in the semiconductor industry.

This work is partially supported by the New Energy and Industrial Technology Development Organization (NEDO) and the Japan Science and Technology Agency (JST), Japan.

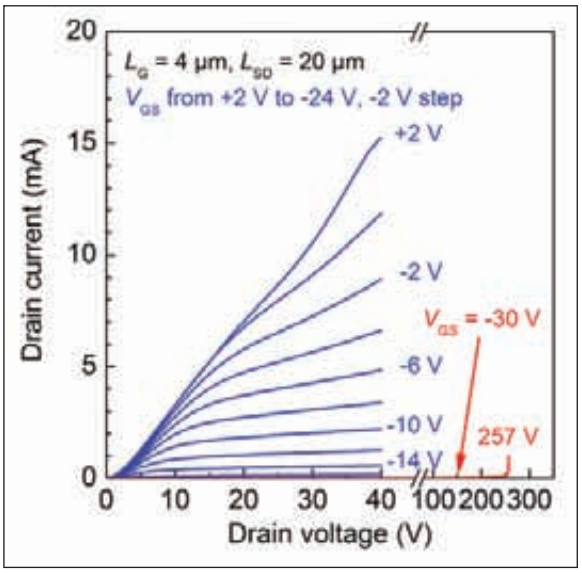


Figure 4. DC characteristics of the n-Ga_2O_3 MESFET

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Daniel Cline, Lux Research
Senior Analyst
WBG devices' electricity grid opportunity

Dr Philippe ROUSSEL, Yole Developpement
Senior Project Manager
GaN and SiC power device manufacturing

Dr Simon Fafard, Cyrium Technologies
CTO
Novel Solar Cell Technology

Bryan Bothwell, TriQuint Semiconductor,
Strategy and Business Development Manager
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TBC, Epistar
High-voltage LED chips

Asif Anwar, Strategy Analytics
Director
The future of GaAs microelectronic manufacturing

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Dr. Rainer KRAUSE, Soitec
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III-Vs and the silicon roadmap

Silicon foundries could switch production from silicon MOSFETs to those based on III-Vs and germanium by the end of this decade. Making this transition is far from trivial, but progress is being made in gate dielectrics, contact resistance, peak current flow and material quality. **Richard Stevenson reports.**

Time and time again, critics have claimed that there will soon come an end to the shrinking of silicon transistors to smaller dimensions. Some have argued that photo-lithography cannot extend beyond optical wavelengths – but tools have been built that can do just that; others have warned that electrons cannot zip about fast enough when transistors reach the nanoscale – but adding a little strain into the material has put that issue to bed; while others have pointed out that high leakage currents will put an end to device scaling – but this issue has not been a show-stopper, thanks to a switch from silicon dioxide to high-*k* dielectrics, such as hafnium dioxide.

Today, claims that the days of the silicon transistor are numbered are still being made – and there's a good chance that this time the critics could well be right. That's because this belief is not just held by those outside the silicon industry, but also some within it:

Year	2011	2015	2018	2019	2020	2024
Gate Pitch (nm)	75	42	30	27	24	15
Physical gate length (nm)	24	17	13	12	11	7

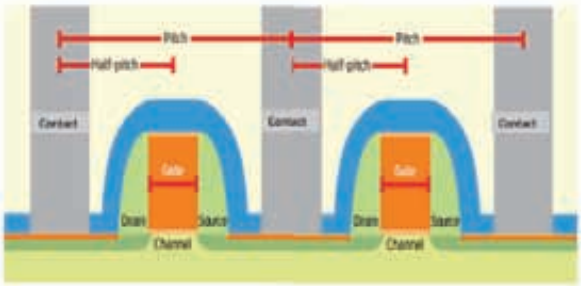


Figure 1. According to the ITRS roadmap, between 2011 and 2024 reductions in gate pitch will be more rapid than those in gate length

Alternatives to silicon are now on the International Technology Roadmap for Semiconductors (ITRS), with III-Vs and germanium predicted to make an impact at the 11 nm node that could be rolled out in 2015.

Iain Thayne from the University of Glasgow, UK, explained the reason for the potential invasion of these new materials into silicon lines at the recent CS Europe conference in Frankfurt, Germany. Thayne, whose efforts at developing III-V transistors initially focused on RF and millimetre-wave front-end applications, argued that compound semiconductors must be introduced to maintain performance as dimensions are reduced.

"Increasing the density of transistors in silicon leads to heating, which will soon approach an air-conditioning limit," said Thayne. He explained that preventing over-heating in the circuits that will be built with tomorrow's transistors requires a reduction in the voltage of the power supply, but no compromise in performance. The only way to satisfy these conditions is to replace silicon transistors with those based on III-Vs and germanium.

He also pointed out that scaling efforts are focused on increasing the density of transistors. Although every new node has a shorter gate length, it also has a reduction in gate pitch, which is scaled even more aggressively (see Figure 1).

Sceptics within the silicon industry have argued that III-Vs will never be suitable for logic circuits, because the drive currents produced by this class of transistor are not high enough, due to the low densities of states associated with compound semiconductors. But Thayne's colleague Asen Asenov has spotted fundamental flaws in this argument: Although the low density of states in III-Vs leads to a lower effective capacitance, these materials combine a high mobility with a low mass, resulting in the injection of carriers with high velocities and increased 'ballisticity'. What's more, the lower density of states means that

carriers are injected with a higher velocity, thanks to their higher energy; and due to superior mobility, these materials can trim access resistance and thereby boost the efficiency of gate modulation.

Material attributes

To optimise III-V MOSFETs, developers must select a material that combines a high carrier velocity with the potential to yield a device with a low operating voltage. According to Thayne, as gate pitch decreases from 75 nm to 15 nm (the value expected in 2024), channel concentration may decrease from 8.5 x 10^{12} cm^{-2} to 5.1 x 10^{12} cm^{-2} while the carrier velocity will increase from 1.3 x 10^{5} ms^{-1} to 3.5 x 10^{5} ms^{-1}. The most promising materials for meeting those requirements are alloys of InGaAs, and work from MIT suggests that $In_{0.7}Ga_{0.3}As$ channels can produce injection velocities above 3 x 10^{5} ms^{-1} at gate lengths below 20 nm.

Thayne discussed additional requirements for the introduction of III-V MOSFETs for logic applications. He said that transistors will need to have a sub-threshold swing of 75 mV/decade so that they could be turned-off easily, and they will probably need to be built with a non-planar architecture, such as the 'Ivy Gate' tri-gate structure employed by Intel for the manufacture of transistors at the 22 nm node. In addition, due to scaling, source and drain dimensions will have to be just a few nanometres, which could lead to an unwanted hike in contact resistance.

The Glasgow team, which has been involved in both the European Dual Logic programme and efforts led by the Semiconductor Research Corporation Non-Classical CMOS Research Center, has focused its efforts in three directions: Gate stack improvements, resolving issues related to the scaling of source and drain contacts, and the development of silicon compatible process flows for III-V MOSFETs.

Efforts have centred on a flatband architecture MOSFET (see Figure 2). This is similar to a HEMT, according to Thayne, because there is delta-doping in a high bandgap material, leading to the transfer of electrons to a low bandgap channel where they create a high-mobility, two-dimensional electron gas. If a high work-function gate metal is formed on top of the dielectric, depletion occurs, driving the device into an off-state at zero bias. Forward biasing of the gate repopulates the channel with carriers.

This MOSFET architecture is claimed to have two key strengths: Immunity to short-channel effects, due to a high bandgap lower barrier; and high mobility, thanks to a combination of no doping in the channel, low interface roughness scattering and a low resistance of the source and drain extension access regions.

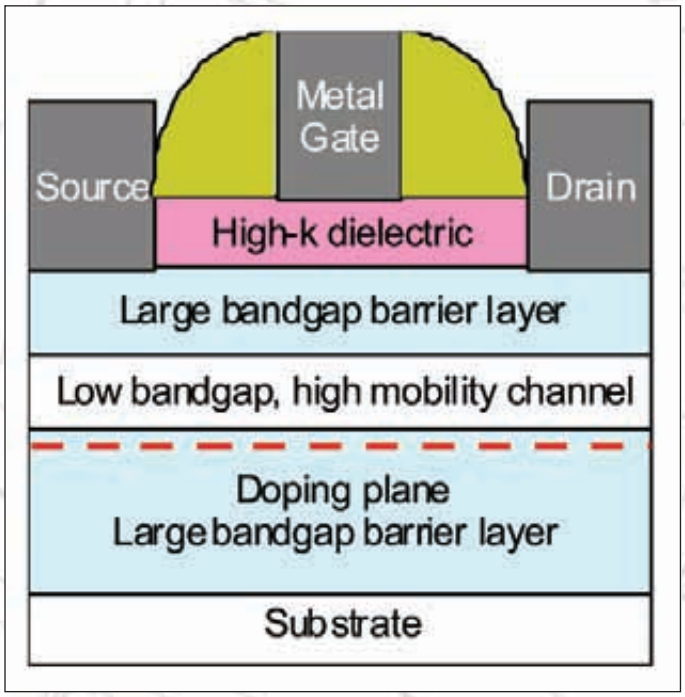
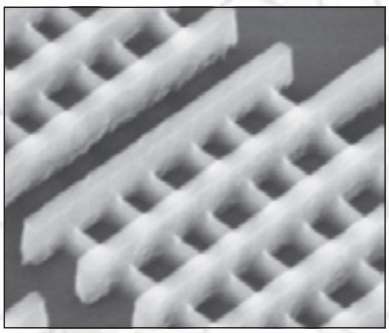


Figure 2. Ian Thayne's group at the University of Glasgow, UK, has developed III-V MOSFETs with a flatband architecture

When the team started developing III-V MOSFETs at the beginning of the previous decade, efforts were partly devoted to establishing a good gate stack. Initially they employed a Veeco Gen III dual chamber MBE system to grow III-V layers by MBE on a semi-insulating GaAs substrate, before transferring the sample under vacuum to a second chamber, where they added a Ga_20 template and a GdGaO layer. The flatband III-V MOSFETs fabricated from these wafers produced mobilities in excess of 5000 cm^2 $V^{-1}s^{-1}$ at sheet carrier densities above 2 x 10^{12} cm^{-2}, and transistors with a 1 μm gate length had a transconductance of 357 μS/μm and a sub-threshold swing of 68 mV/decade.



To increase injection velocity, the researchers switched to $In_{0.53}Ga_{0.47}As$ channels and Al_2O_3 dielectrics, which were deposited by a 60-cycle atomic layer deposition process. The benefits of this new structure included gains in mobility – at an electron density of 2 x 10^{12} cm^{-2} mobility topped 6000 cm^2 $V^{-1}s^{-1}$.

For surface-channel transistors with a 1 μm gate and a 2.5 nm-thick Al_2O_3 dielectric, transconductance hit 432 μS/μm, but the sub-threshold swing reached 150 mV/decade.

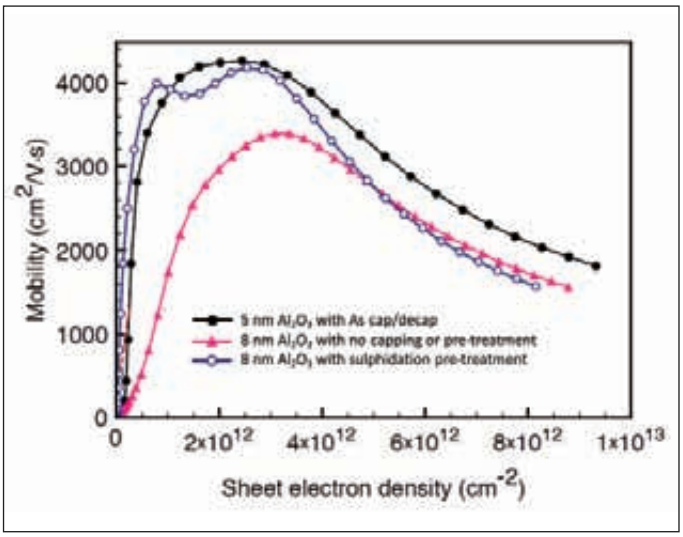


Figure 3. A sulphidation process developed by researchers at the Tyndall Institute can offset most of the degradation in mobility resulting from the removal of an arsenic cap. This is a promising result for non-planar transistors, which will not have pristine interfaces

Intel's move from planar transistors to three-dimensional varaints points the way to production of non-planar devices, which will not have pristine interfaces. To consider the implications of this trend, Thayne, in partnership with Paul McIntyre at Stanford and Paul Hurley at the Tyndall Institute, has looked at the impact of various treatments of transistor performance.

The team compared three wafers. Two of them were removed from the MBE chamber after the growth of III-V materials: A gate dielectric was added to one wafer without any intermediate surface treatment, so air-exposed oxides were likely to be present in the dielectric-semiconductor interface; and a optimised sulphidation treatment was applied to the other prior to deposition of the high-*k* dielectric. The third wafer had as arsenic cap deposited in the MBE chamber to prevent oxidation in air. This cap was removed in the atomic layer deposition tool at Stanford, enabling the gate deposition on a pristine surface. Measurements of the mobility of MOSFETs made from these wafers reveals that it is possible to produce interfaces as good as those on pristine surfaces if a sulphidation process is performed (see Figure 3).

The second issue that Thayne and his co-workers have investigated is the fabrication of low resistance source and drain contacts with dimensions of just a few nanometres. The ITRS roadmap dictates that as gate pitch is reduced from 75 nm in 2011 to just 15 nm in 2024, source and drain contacts must be trimmed from 21 nm to 2 nm, while source and drain resistances are cut from 160 Ωμm to 110 Ωμm.

'Traditional' approaches will not succeed – experiments and simulations reveal that contact resistance rises rapidly when the contact size enters the nanoscale. Several groups have recently developed different approaches for overcoming this problem, including that from Glasgow, which has turned to NiInAs to fabricate an ultra-low resistance, shallow, metallic source-drain. According to Thayne, this is the first source-drain technology that can meet the most aggressive ITRS specification for the 12 nm technology node, which corresponds to a gate pitch of 27 nm.

The third strand of research at the Nanoelectronics Research Centre is the development of approaches for forming fully self-aligned III-V MOSFETs with silicon compatible process flows. The team has pioneered two different designs: 'Gate first' and 'replacement gate' architectures. The former has been used to form $In_{0.3}Ga_{0.7}As$ flatband MOSFETs with a GaO/GaGdO dielectric stack and a 100 nm gate length. These transistors exhibit a peak drain current of 250 μA/μm, transconductance of 150 μS/μm and a sub-threshold swing of 150 mV/decade. Sub-threshold swing falls to 130 mV/decade with the replacement gate architecture, which has a modest on-state performance due to a very high access resistance of 18 kΩμm. This issue can be addressed by improving the source drain anneal, which is needed to supress material diffusion in very small devices.

Into the third dimension

One team that is following Intel's lead and taking III-V MOSFETs into the third-dimension is Peide Ye's group from Purdue University. Ye detailed an evolution path for FETs, which begins with a bulk III-V planar architecture and ends with a III-V gate-all-around HFET (see Figure 4). His team have recently fabricated the latter structure, which is built on InP substrates and features a *p*-doped InGaAs channel, or multiple channels, wrapped in a 10 nm-thick layer of Al_2O_3 and a thicker layer of WN (see Figure 5 for details). Devices with 4 parallel channels, a 50 nm gate length and a 30 nm fin width produce a very low gate leakage, a peak

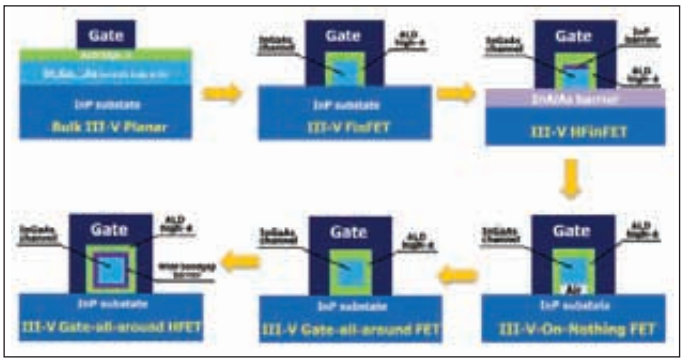


Figure 4. According to Peide Ye from Purdue University, III-V MOSFETs have evolved from planar structures to those that wrap a dielectric right around the channel

The second issue that Thayne and his co-workers have investigated is the fabrication of low resistance source and drain contacts with dimensions of just a few nanometres. The ITRS roadmap dictates that as gate pitch is reduced from 75 nm in 2011 to just 15 nm in 2024

current of 1170 μA/μm and a sub-threshold swing of 150 mV/decade.

These devices have several promising attributes for making an impact on the ITRS roadmap. Reductions in gate length result in an increase in current and transconductance, and the transistors appear to be immune from short channel effects. What's more, reductions in the dimensions of the nanowire channels lead to a hike in current flow, thanks to quantum confinement.

Recently, Ye has had a paper accepted for publication in *Electronics Letters* that details these findings. He and his team found that the current increased by 40 percent when nanowire widths were reduced from 50 nm to 30 nm, while mobility and transconductance increased by 34 percent and just over 20 percent, respectively.

To understand why thinning of the nanowires has lead to an increase in current – this is the opposite of what one would expect – the team simulated device behaviour using Sentaurus Device, a tool made by Synopsys. Simulations revealed that nanowires operate in the volume inversion regime, which means that the electron density reduces at the edges of the nanowire and increases in its inner region. Electrons can then, on average, travel faster through the channel because it is increasingly likely that these chage carriers are away from the interface, where scattering impedes progress. Simulations suggest that the proportion of electrons in the middle of the wire increases as its dimensions are reduced, with a very promising electron density profile reached for a width of 10 nm.

Building on silicon

If compound semiconductor MOSFETs are to move into production, they must be made on large diameter silicon substrates. Forming high quality germanium and III-V transistors on silicon is tricky, due to differences in lattice constants and crystal structures, but progress in this direction is being made by Matty Caymax's group at imec, Belgium. At CS Europe Caymax detailed efforts to form high-quality germanium and III-V devices on silicon, the latter achieved using trenches with a cup-shaped bottom (more details can be found at *imec prepares the ground for III-V transistors on silicon*, Compound Semiconductor March 2011 p.12). This approach (see Figure 6) eliminates anti-phase domains that lead to device shorting. "The best result that we have right now is a defect density of 2 x 10^8 cm^{-2}," said Caymax. "This is not sufficient – we have to work to get a lower dislocation density."

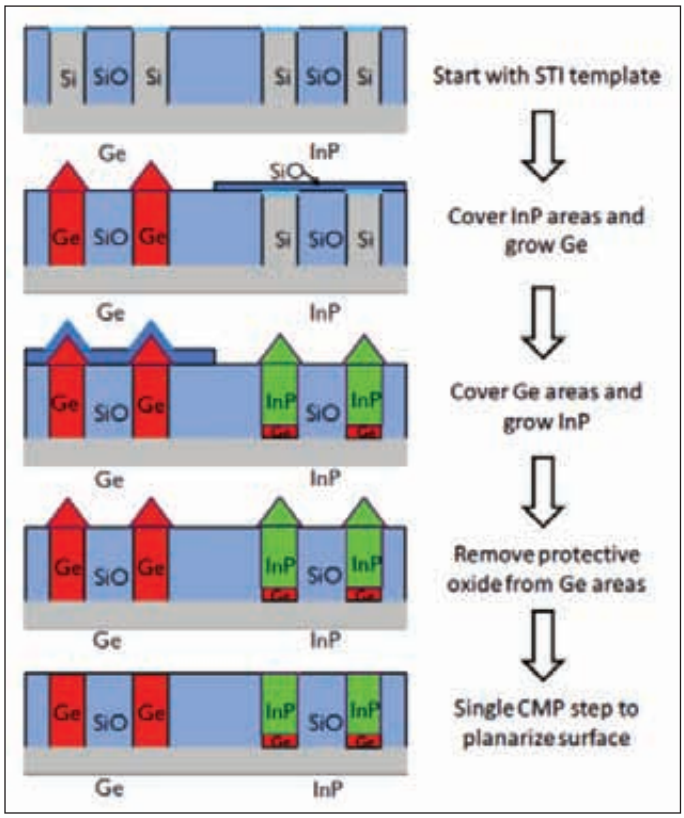


Figure 6. Researchers at imec are developing processes to unite germanium and III-V transistors on a silicon substrate

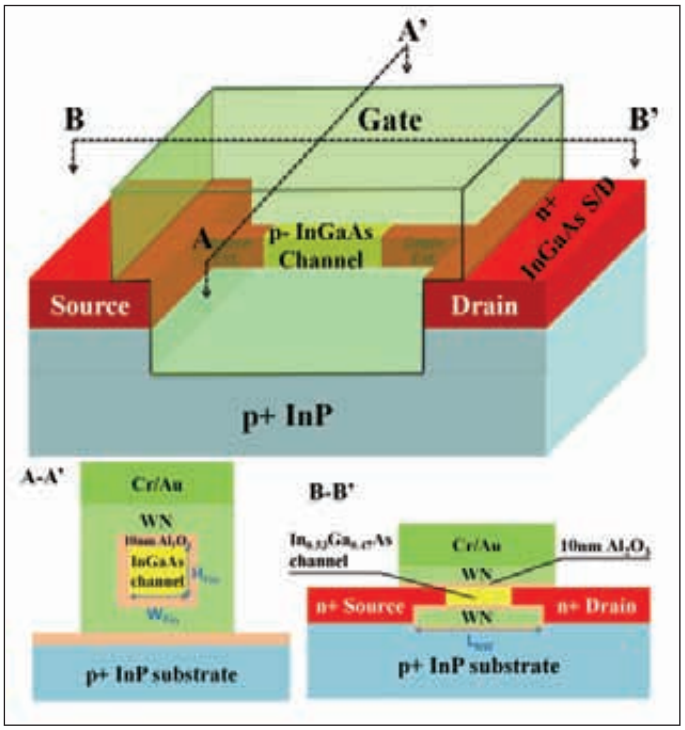


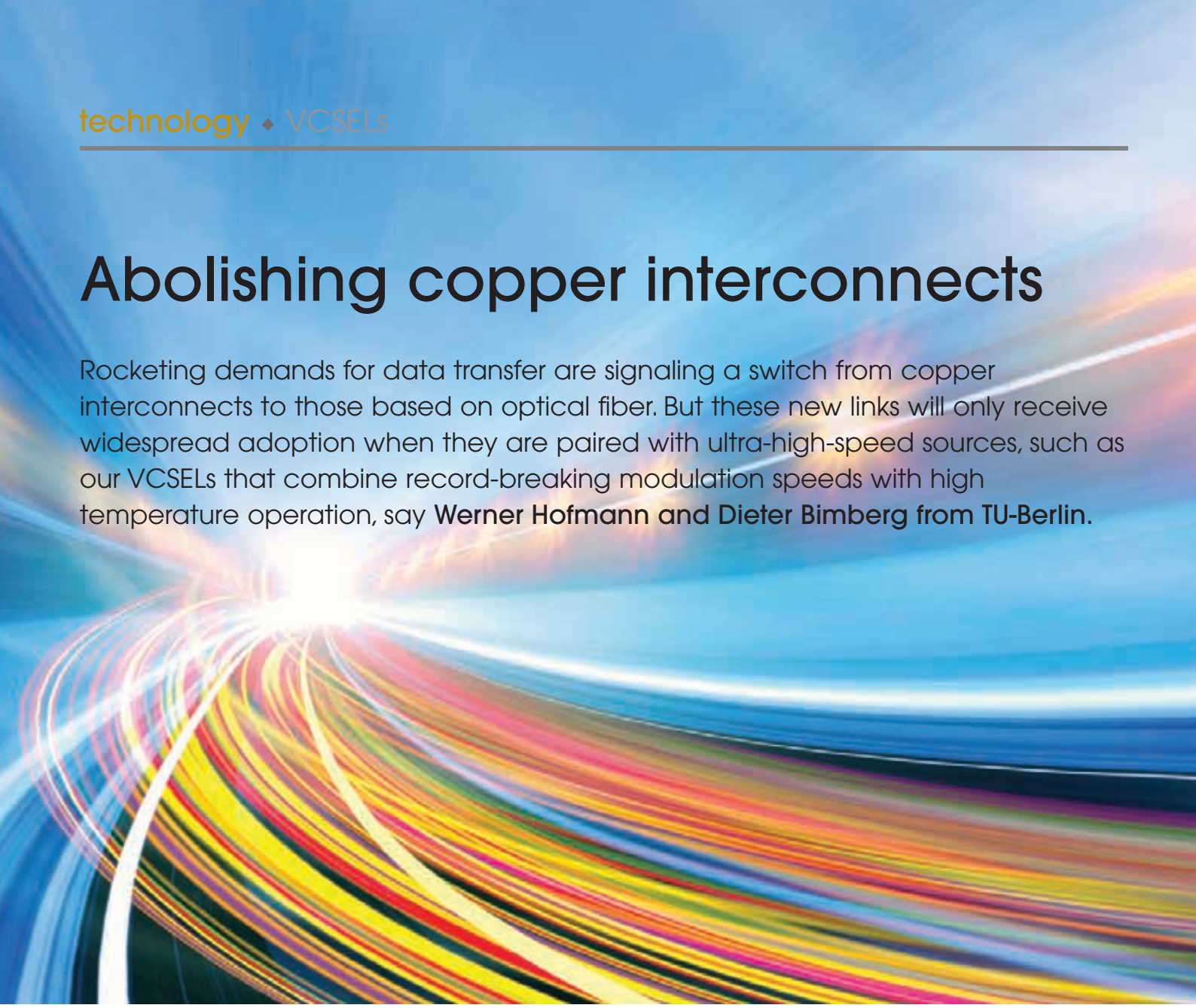
Figure 5. Peide Ye's group at Purdue University have pioneered the III-V gate-all-around FET. Transistors that they have built so far feature a gate length of 50-120 nm, a fin width of either 30 nm or 50 nm, and 1, 4, 9 or 19 parallel wires with a length of 150-200 nm and an Al_2O_3 dielectric with a thickness of 10 nm

Transistors made recently suffer from a high junction leakage. To investigate the origin of this leakage, the team have carried out atom probe tomography, a technique that has revealed that some atoms are located in places where they should not be: Some germanium is found in InP, and some indium and phosphorous atoms are located in germanium and the underlying silicon substrate.

Caymax's team, like those headed by Ye and Thayne, still has work to do to help III-Vs to make an impact in future logic applications. But the results to date are promising, showing ways to overcome many tough hurdles, and it seems that when silicon CMOS finally runs out of steam in a few years' time, compound semiconductors will be there to pick up the pieces.

Abolishing copper interconnects

Rocketing demands for data transfer are signaling a switch from copper interconnects to those based on optical fiber. But these new links will only receive widespread adoption when they are paired with ultra-high-speed sources, such as our VCSELs that combine record-breaking modulation speeds with high temperature operation, say **Werner Hofmann and Dieter Bimberg from TU-Berlin.**



Today's interconnects, like those of yesteryear, are predominantly made from copper. This material is readily available and easy to process, but it is far from ideal for making data transmission links. Speeds are limited due to high levels of damping that suppress signal-to-noise ratios, and crosstalk plagues interconnects at higher frequencies.

One can get around these weaknesses by moving to higher signal levels and multiple parallel links. This has happened with CPUs, which incorporate more and more pins and use bigger and bigger heat-sinks for cooling. But this approach has its limits, and the days of copper-based technology are vanishing fast for the supercomputer.

In this arena, every new generation of machine must deliver a tremendous hike in computational speed, while costing little more than its predecessor and consuming hardly any more energy. To meet these requirements, the PetaFlop Supercomputer that IBM unveiled in 2008 incorporated 48,000 optical links. And according to this industry's roadmap, the ExaFlop mainframes of the next decade will feature a staggering 320 million optical interconnects, each performing at far greater levels than those in the 2008 machine: Data transmission through each link will have to be five times higher, energy consumption 50 times less, and the price lower by a factor of 400. Improvements in energy consumption must be this great, because the vast majority of energy consumed by these computers takes place in interconnects.

The delay in the uptake optical interconnects is partly due to strong competition from copper links, which are cheap to produce. Cash has been tight in the optical interconnect industry, hampering investment in new technologies, and big players in the optics industry have focused on markets offering a better short-term return on investment. But that tide is now turning. There is growing realization that optical interconnect technologies are needed, and companies are injecting large sums of cash into their R&D departments to make this happen.

Although funding is flowing, success is never instantaneous. This explains the dilemma that is

resulting from the postponed transition from copper to optics. Concerns are so severe that they have led to the publication of articles with headlines such as The End of Supercomputing. Such tories have appeared because it is possible to show that all of the world's electrical energy generation could go into just bits and bytes, by extrapolating current growth in bandwidth demand, using today´s values for energy consumption per transmitted bit for supercomputers and data-centers.

The ill informed may try to brush aside this looming catastrophe, arguing that humanity doesn't need supercomputers. What they don't know is that the Internet is run by large data-centers – when you press a single button for an Internet search, 300 computers scurry away to deliver rapid suggestions. How can these computers communicate, before transmitting the information to the end user? That's right! By interconnects. Thousands of them.

All theses computers are built around microelectronics, which yield circuits that are far more compact than those built with integrated optics, due to the far shorter wavelength of electrons than photons. Billions and billions of dollars have been poured into the development of silicon microelectronics, but all that funding cannot overcome a fundamental limitation: Optics is much more energy-efficient for interconnects once the bandwidth-length product exceeds a certain value, which is now considered to be relatively low. This limitation of microelectronics is propelling the world towards optical interconnects while one key issue is still to be resolved: How to realize the electrical to optical transition? The existing technologies employed in long-haul links are too expensive and energy hungry to be suitable for use in short and ultra-short optical links.

Turning to VCSELs

The most suitable, simplest high-speed optical source is the directly modulated laser. If this is to combine excellent beam quality with low cost and frugal use of energy, the VCSEL has to be the technology of choice. Used in short optical interconnects, VCSELs must excel on three fronts: They must deliver high serial bandwidths, allow dense packaging, and operate without cooling.

System design rules, such as Amdahl's law, can reveal the required serial bandwidth. Applying this law shows that it is possible to avoid bottlenecks in a supercomputer by matching computational power to interconnect bandwidth and memory capacity. However, simply adding more links to increase bandwidth can lead to penalties, in terms of complexity and cost. What's more, with one particular technology, there is a limit to the number of links that can be connected. In 2011, these considerations led system designers from Google to state that 40 Gbit/s will be the desired bandwidth for their next-generation data-centers.

To enable system scalability, the optical chips employed in these links must be housed in very dense packaging. One of the strengths of the VCSEL is its small footprint – it is an order of magnitude smaller than it edge-emitting cousins. It is also compatible with a compact hybrid package design, such as that adopted in the IBM TERABUS project. Here, a tiny package resulted from

Keys to successful VCSEL research include a high yield full-wafer fabrication process, systematic design variation and automated evaluation

placing bottom-emitting devices with electrical fanout on one side, and using the other side for optics. Such a design requires a transparent substrate, thereby preventing the use of 850 nm VCSELs, the standard source for multi-mode fiber links providing data transmission over hundreds of meters.

980 nm VCSELs are suitable, due to transparency of the GaAs substrate at this wavelength, and they have one big benefit over their shorter wavelength siblings: They enable the construction of distributed Bragg mirrors with binary layers, rather than more complex ternary variants that degrade the thermal conductivity of the chip. Thanks to this advantage, devices built with binary mirrors can operate at much higher ambient temperatures, such as those found when lasers are placed in uncooled dense arrays or integrated on top of a high-performance silicon CPU or memory.

Record-performing VCSEL devices

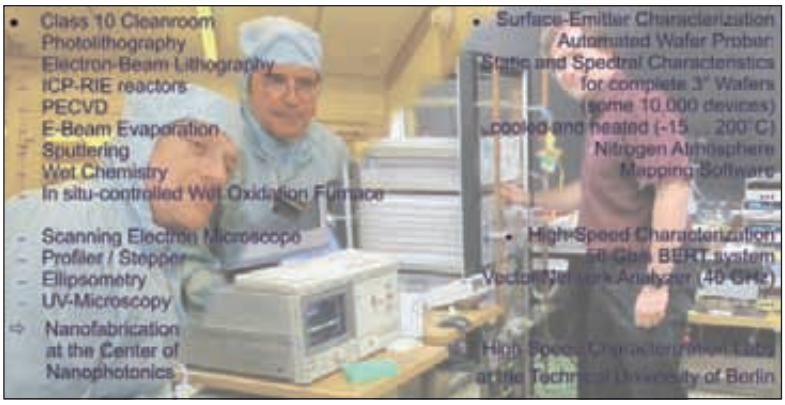
Taking these considerations into account, out team of researchers at the Center of Nanophotonics at the Technical University of Berlin has focused on 980-nm VCSEL devices of ultimate bandwidth under direct modulation. The VCSEL is a well-established device manufactured in very high-volumes, so if our efforts are to be beneficial outside the lab, they must employ processes used in industry. To that end, we fabricate full three-inch VCSEL wafers with a very high production yield. Our lines of enquiry for improving VCSEL performance are transferred into the mask layout, which features systematically varying device design parameters. After processing in our own class-10 cleanroom dedicated to the development of III-Vs, a robot automatically measures the performance characteristics of thousands of devices.

We use home-built software to handle the vast amount of data generated by these measurements. This enables us to unveil the best chip design from statistical evaluation of measured data. The winning formula is verified with data-transmission and system experiments.

A great strength of this approach is that it enables rapid progress, by exploiting advantages of techniques used in industry and academia. We are able to carry out every step in-house, from simulation to design, epitaxial growth, device processing and a wide range of characterization techniques, including high-speed data-transmission experiments. This is an enviable suite of facilities that many groups do not have.

Efforts in our lab have recently led to tremendous improvements in the performance of 980 nm VCSELs over a wide temperature range. Devices fabricated from a single VCSEL wafer have broken the record for the highest speed, enabled 40 Gbit/s operation at temperatures up to 40 °C, and set a new benchmark for energy efficiency at bit rates beyond 30 Gbit/s (see Figures 1 and 2).

Steps that we took to hit these record-breaking speeds



with our 980 nm VCSELs included a reduction in the cavity length to half the wavelength of light, and a decrease in the reflectivity of the out-coupling mirror to cut photon lifetime and realize higher modulation speeds. We used oxide aperture layers made from 20 nm-thick layers of $Al_{0.98}Ga_{0.02}As$ that were positioned very close to the active region to reduce parasitic capacitance. These apertures were positioned very close to the active region to avoid damping of the resonance frequency by carrier transport.

Fig.2. A successful VCSEL research effort must combine expertise in material growth and device fabrication expertise with dedicated characterizati on capabilities, such as measurement robots that can candle thousands of devices

We produced a range of 980 nm VCSELs with oxide-aperture diameters from 1 μm to 10 μm. Designs had six different active media, between three and seven quantum wells with widths of 4 nm to 6 nm, and barriers with and without phosphorous. Unlike our previous generation of VCSELs, these lasers had an abrupt interface, rather than a graded one, around the active region. This change improved carrier confinement at high temperatures.

Testing this portfolio of devices revealed that VCSELs with aperture diameters between 5 μm and 7 μm could combine high output powers with high modulation bandwidths. Typical characteristics for a 6 μm diameter oxide aperture VCSEL were a threshold current of 0.9 mA at 20 °C, a peak power of 8 mW at a rollover current of 22 mA, and continuous wave operation up to 200 °C.

VCSELs with a 5 μm aperture delivered the most impressive performance at low temperatures. Butt-coupled to a 3 m multi-mode fiber, these devices

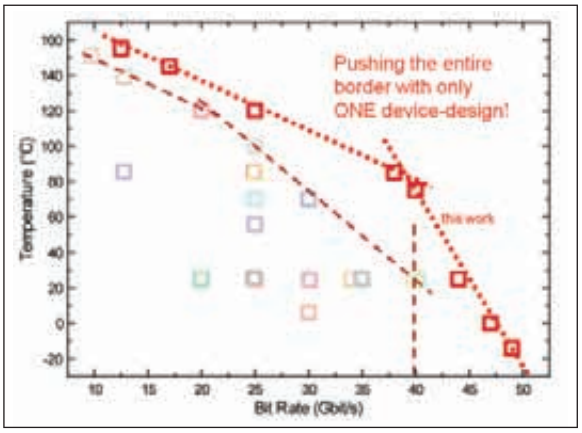


Fig 3. Figure 1. Summary of the results achieved on high-speed temperature-stable VCSELs at TU Berlin in 2011 compared to previously published results from various groups

enabled data transmission rates of 49 Gbit/s at -14 °C and 47 Gbit/s at 0 °C. Larger apertures were needed at higher temperatures to deliver more power to the detector. Transmission at rates of 12.5 Gbit/s, 17 Gbit/s and 25 Gbit/s were possible at 155 °C, 145 °C and 120 °C, respectively. These results illustrate that a laser – especially a VCSEL – is a highly nonlinear, coupled system. Gains in operating temperature come at the expense of transmission speeds, and VCSEL performance can be improved substantially with chip cooling.

Efforts are already underway at bringing these advanced VCSEL devices to market. TU-Berlin´s spin-off company, VI-Systems GmbH is working on providing detectors and devices for the commercial 850-nm waveband, and we are working with them to develop a VCSEL operating in this spectral range. We have found that the devices, which are closer to those serving the existing multi-mode VCSEL market than our 980 nm designs, require just one-tenth of the energy of a regular VCSEL to send a bit (see Table 1 for details).

The energy consumption by these VCSELs is so frugal that they can meet the projections of the International Technology Roadmap for Semiconductors for energy efficient interconnects of 2015. Hitting this benchmark today proves that VCSELs are a technology that can already deliver the low-cost, energy-efficient, high-speed interconnects needed to overcome the bottleneck brought about by copper.

Future requirements on VCSELs

Even if these novel devices can accommodate the demand for the next few years, it would be naive to believe that no further progress is needed. Fortunately, there is the potential for far higher speeds from monolithic electro-optical modulated VCSELs – according to our studies, they could hit serial bandwidths of around 100 Gbit/s. And advanced coding schemes should lead to further gains in serial bandwidths and link robustness.

Another trend that we can expect to see is the development of high-contrast meta-structures, which should open up degrees of freedom in device design, such as multiple wavelengths on a single VCSEL array. Meanwhile, if there are moves to longer wavelengths, like 1.3-1.6 μm, this will enable compatibility with silicon waveguides that form part of optical silicon-based chips.

The spectral range is accessible with different classes of laser: InP-based VCSELs, which are well understood and commercially available from the likes of Vertilas and Beam Express and quantum-dot devices, grown on cheaper GaAs substrates.

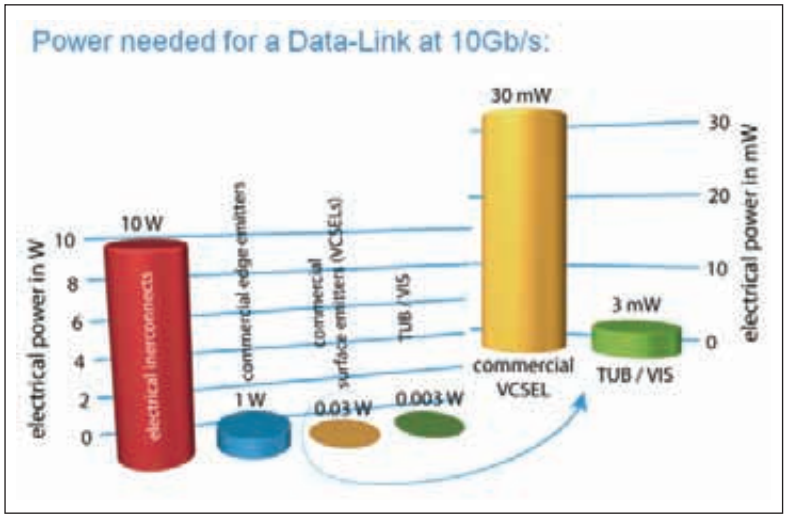


Fig 2.. The gain in energy-efficiency resulting from the transition from copper to optical interconnects are substantial. However, a VCSEL is another two orders of magnitudes more energy efficient that optical interconnects derived from long-haul data-com modules. The VCSELs demonstrated recently in Berlin gain yet another order of magnitude

Looking further into the future, when data traffic hits levels that are unthinkable today, even the footprint of a VCSEL might be too big. To address this, we are working in partnership with researchers at the University of Illinois at Urbana Champaign to develop nano-cavity lasers with metal cladding. This will shrink the output of optical sources for interconnects by a further two orders of magnitude, taking us into a realm where interconnects based on copper are never, ever considered.

Affiliation	TUB/VIS	TUB	NCU/NTU	Furukawa
Bit rate (Gb/s)	17/25	35	12.5	10
EDR (fJ/bit)	83/117	287	227	180
HBR (mW/Tbps)	69/99	233	109	140
Wavelength (nm)	850	980	850	1060
Year of publication	2011	2011	2011	2010

Table 1. A comparison of the best results in energy-efficient data transmission, including values for the energy-to-data-ratio (EDR) and the heat-to-bit rate-ratio (HBR). The recently achieved results in Berlin won the Green Photonics Award 2012 at Photonics West in San Francisco

Further reading

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III-V shares head south

During the last 12 months the share prices of all the leading III-V chipmakers have fallen. But why has the value of some companies dropped by just a few percent, while others have plummeted by more than two-thirds? **Richard Stevenson investigates.**

It's been a tough 12 months for everyone owning a portfolio of III-V shares. The share price of all the leading, publicly traded players in the compound semiconductor market has fallen in the year leading up to April 30, 2012, and in a few instances, share prices have lost more than half their value.

In some cases, it is easy to understand the lacklustre performance. The LED industry is suffering from overcapacity, which drives down chip prices and squeezes margins. And unfortunately, until solid-state lighting really takes off, this sector is going to resemble a bloodbath. What's more, the pain felt here also has knock-on effects, such as declining MOCVD tool purchases, which hits the likes of Aixtron and Veeco.

However, in other sectors of the III-V industry, it is not as obvious why share prices have fallen across the board. For example, total revenue in the GaAs microelectronic market is expected to rise by about 6 percent per annum for the next few years, according to market analyst Strategy Analytics. However, this rise in growth is far less than the 35 percent hike in 2010, and it is probably this deceleration that is behind the drop in share prices.

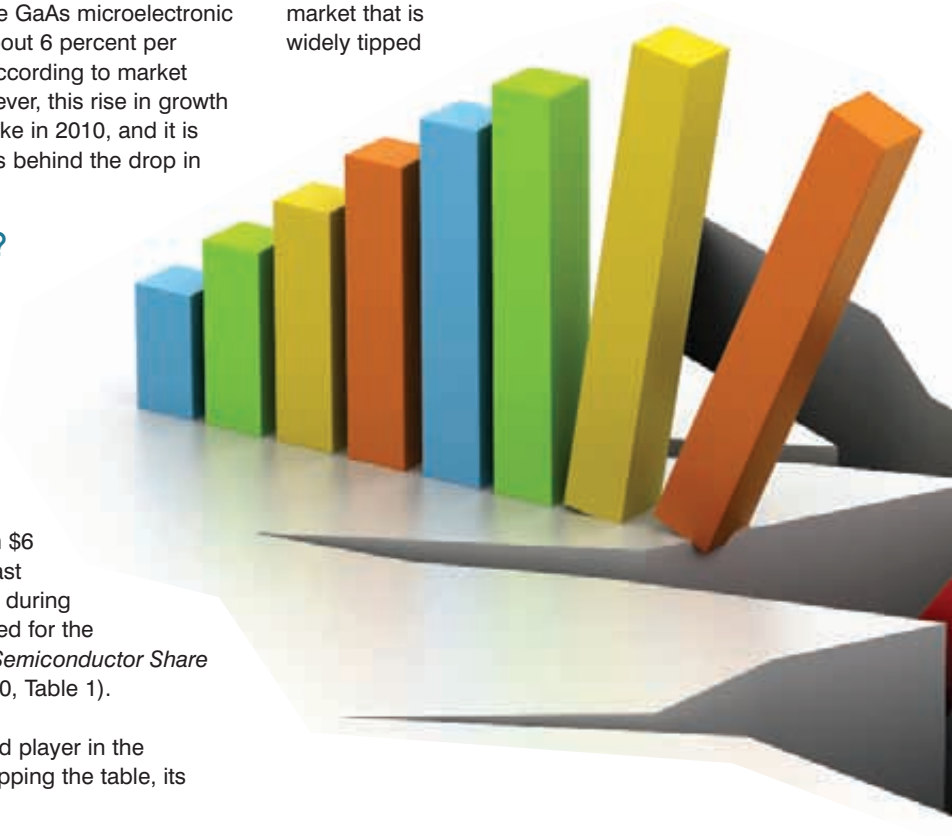
The return of telecos?

The company that performed best over the last 12 months is Infinera, a manufacturer of large-scale InP photonic chips, which it uses to build its own systems, primarily for long-haul optical networks. The share price of this firm, which is based in Sunnyvale, California, has hovered between $6 and just over $8.50 during the last year, and fell by just 2.4 percent during the period of evaluation employed for the construction of the *Compound Semiconductor Share Price Leader Board* (see page 40, Table 1).

Although this vertically integrated player in the telecommunications sector is topping the table, its financial results are far from impressive. For example, in its 2011 fiscal year that ended on 31 December 2011, company sales were $404.9 million, down from $454.4 million for the previous year, while losses increased from $27.9 million to $81.7 million and gross margins fell from 45 percent to 41 percent.

This trend is maintained in the most recent quarterly results, with sales of $104.7 million, losses of $11.2 million and a gross margin of 40 percent for the first quarter of 2012. Operating in this manner is eroding the company's reserves: At the end of quarter one, 2012, the value of cash, cash-equivalents-restricted-cash and investments fell by $13 million to $240 million.

However, Infinera's management team has good reason to be very optimistic about the company's long-term future. It's operating in a market that is widely tipped



to undergo tremendous growth, and it has recently launched unrivalled products that are attracting attention.

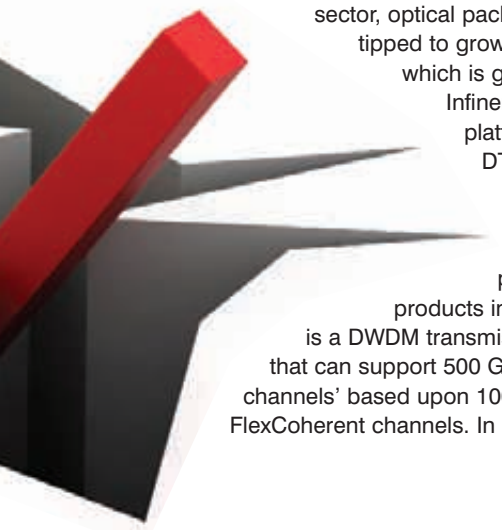
The later point was discussed in more detail in a conference call following the company's first quarter 2012 results. In that call, Infinera's CEO and President Thomas Fallon cited three reasons for traffic growth in optical networks: The cloud, mobile and video.

According to Forrester Research, a market analyst firmbased in Cambridge, MA, the cloud service market could be worth almost $240 billion by 2020. And with most applications in future expected to be based in the cloud, bandwidth in networks will have to grow to be large enough to accommodate massive, short-lived hikes in data transfer to deal with any disasters.

The second driver cited by Fallon for the growth of optical networks, mobile traffic, is growing rapidly thanks to tremendous growth in the sale of smartphones, tablets and laptops with a wireless connection. Data usage is tipped to increase 18-fold by 2016, and to support this, their has been a massive rollout in 3G, 4G and Wi-Fi networks. Mobile communication is not exclusively wireless, however, as data is also routed through an optical backbone.

Thirdly, Fallon argues that optical capacity must increase to cater for the growth of streaming video from multiple sources: User-generated content, such as that found on YouTube; aggregators, including Netflix and Amazon; and content creators, such as NBO. Video quality is increasing from standard definition to high-definition, with 3D just around the corner, and it is inevitable that this trend will contribute to the rise in data transmitted through optical networks.

To cater for this, investment in optical transport is on the up. For example, 19 million miles of optical fibre was deployed in the US in 2011, the most since 2000, according to the London based analyst CRU Group. This fibre will need to be 'lit', and Dell'Oro Group of Redwood City, CA, predicts that this should drive a 10 percent per year growth in the DWDM (dense wavelength division multiplexing) market through to 2016. Within this sector, optical packet transport is tipped to grow at 22 percent, which is great news for Infinera's latest platform, the DTN-X.



Fallon argues that this platform is three products in one. Firstly, it is a DWDM transmission system that can support 500 Gbit/s 'super-channels' based upon 100 Gbit/s FlexCoherent channels. In addition, it is an integrated OTN (optical transport network) switching system, which will initially have a capacity of 5 terabits, but eventually have an upper limit of 100 terabits. "This will enable operators to tame these large pipes, through the grooming of traffic down to 1 Gigabit granularity," explained Fallon. Lastly, the system is designed allows upgrading to MPLS (multi-protocol label switching), a step that can improve network efficiency.

Right: Infinera's recently launched DTN X combines: A DWDM transmission system that can support 500 Gbit/s 'super-channels'; an optical transport network switching system; and an opportunity to upgrade to multi-protocol label switching, a step that can improve network efficiency

By late April, Infinera had four purchase orders for DTN-X systems – three with existing customers, and another with a new customer, Cable&Wireless. In addition, several other potential purchasers were in active contract negotiations with the company.

Infinera expects shipments of the DTN-X to take off, with sales appearing on quarterly balance sheets in the second half of this year. Interest in this platform has already led to a cut in orders for the forerunner, the DTN, and Infinera is ramping production of components for the new system. This state of affairs is expected to lead to a small fall in revenue to $92 million to $100 million for the second quarter 2012, and a loss of $16 million to $21 million for this period. But the longer-term prospects are more positive, with revenues for the second half of this year expected to be in the range $230 million to $250 million.

If this trend can continue, with Infinera's shipments of the DTN-X increasing rapidly while gross margins fall through greater economies of scale, the company's share price seems destined to head north. This will be welcomed by long-term investors, who have maintained faith in Infinera's disruptive technology and are looking for a good return on shares that they bought back in summer 2007 for $13 when the company had its initial public offering.

Reaching skywards

Skyworks, in second place with a fall in share price of 12 percent, has seen the value of its stock plummet from April 2011 until the end of that year, and climb

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steadily ever since (see Figure 2). Two strong quarters have helped that recovery. For the first fiscal quarter 2012, which finished on December 30, 2011, the company reported sales of $393.7 million, up 17 percent year-over-year, plus a profit of $96.2 million. Results for the following quarter, which is traditionally weaker, were equally impressive: Sales of $364.7 million, up 12 percent year-over-year, and a profit of $79.8 million. In addition, during those three months the company has paid off the lasts of its debts.

One of the big, recent changes at Skyworks that has helped the company to grow its revenue is diversification, both in terms of products and addressable markets.

Part of this move has involved the $200 million cash acquisition of Advanced Analogic Technologies, which will allow Skyworks to compete in the $2 billion market for power managements ICs used in displays.

"We are clearly not just a PA company [anymore], but rather a full-service RF and analogue specialist focused on mobile Internet and adjacent high-growth market opportunities," explained David Aldrich, Skyworks' president and CEO in a conference call discussing second quarter 2012 results.

Aldrich went on to give an example of the expanded deployment of Skyworks components in handsets. According to a teardown published by Chipworks, the Galaxy Note from Samsung contains an RF engine produced by Skyworks, plus the company's antenna switch module, band switches, GPS low noise amplifier and a wireless networking front-end module.

In cases like this, where Skyworks provides a rafter of products into a single design, its total sales per handset can be $10 or more. And this trend of increasing the dollar-content-per-phone looks set to continue, due to a rise in the number of frequency bands built into smartphones – one design that Skyworks has seen sports a staggering 23 bands.

Sales of smartphones continue to rise, and shipments could hit 4 billion units between 2011 and 2015. This will help to swell Skyworks' revenue, which should also grow as the firm ships more and more wireless radios into an incredibly wide variety of non-mobile segments that extend beyond just gaming, PCs, TVs and set-top boxes. Earlier this year, the company announced design wins in the entire line-up of General Electric smart appliances, including washers, dryers, refrigerators, dishwashers and ovens. In addition, products from Skyworks are featuring in a remote heart monitoring device from Medtronic, radio applications for emergency responders and Ericsson basestations.

All this activity will help to increase Skyworks' sales, which are expected to hit $383 million in the third quarter 2012. Alongside this revenue growth, the company expects improvements in gross margins that should spur the next quarter's profit to about $84 million.

Diversified tools sales

Third on the leader board is French manufacturer of deposition equipment, Riber, which has seen the value of its shares drop by 18.5 percent in the 12 months leading up to 30 April 2012. Over this period there have been no wild swings in share price that has been a little higher in 2012 than it was in the latter half of 2011.

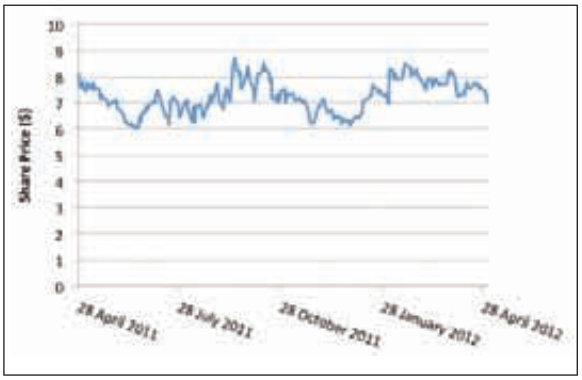

Figure 1. Infinera's share price has been steady over the last 12 months

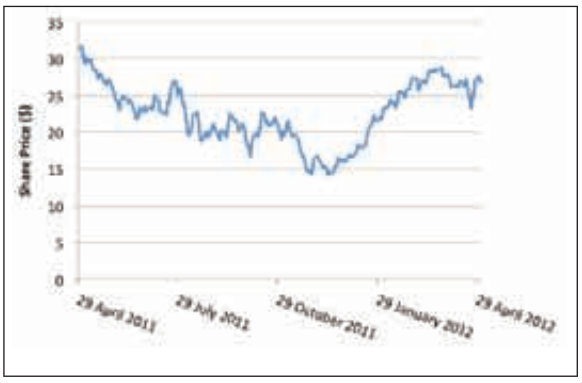

Figure 2. Skyworks share price has been a tale of two halves: heading south in the latter part of 2011, but climbing back up during the start of this year

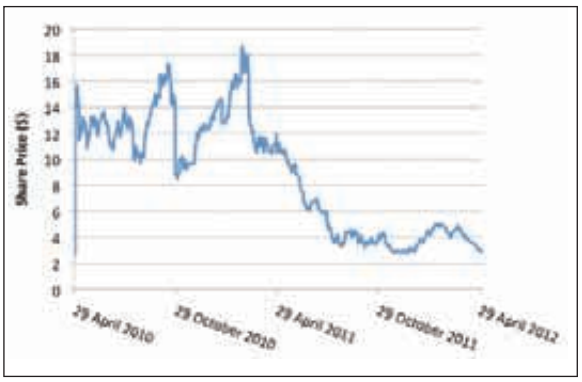

Figure 3. Oclaro has had a bad 12 months on the stock market. Will the merger with Opnext turn the situation around?

Compound Semiconductor share price leaderboard

Rank	Company	Ticker	Share value, April 29, 2011 ($)	Share value, April 30, 2012 ($)	% appreciation	Change in Rank
1	NASDAQ composite	IXIC	2869.74	3060.06	6.6	+11
2	Infineon	INFN	7.60	7.42	-2.4	+15
3	Skyworks	SKWS	31.39	27.59	-12.1	+3
4	Riber (Paris)	RIB	4.66*	3.83*	-18.3	+1
5	Hittite	HITT	65.06	52.88	-18.7	+5
6	Cree	CREE	40.55	30.81	-24.0	+15
7	AXT	AXTI	6.77	5.11	-24.5	+11
8	Kopin	KOPN	4.88	3.64	-25.4	+8
9	IPG Photonics	IPGP	59.66	49.00	-29.7	-8
10	RFMD	RFMD	6.54	4.35	-33.5	+3
11	Finisar	FNSR	26.45	16.53	-37.5	-5
12	JDSU	JDSU	20.08	12.45	-38.0	-4
13	Veeco	VECO	50.60	30.23	-40.3	+2
14	IQE (london)	IQE	0.7361*	0.4230*	-42.5	-12
15	Analogics	ANAD	3.93	2.25	-42.7	+4
16	Aixtron (Frankfurt)	AIX	36.66*	18.41*	-49.8	-5
17	Emcore	EMKR	10.33	4.58	-55.6	-
18	TriQuint	TQNT	13.34	4.76	-64.3	-13
19	Rubicon	RBCN	28.20	9.66	-65.7	-3
20	Oclaro	OCLR	10.48	2.93	-72.0	•

* Converted to dollars using the exchange rates on 30 April of 1 EURO = 1.326 USD and 1 GBP = 1.6268 USD

Table 1. In the last 12 months none of the compound semiconductor chipmakers has performed better than the NASDAQ

Riber reported strong results for the last fiscal year, which finished on 31 December 2011. Sales of MBE systems rose by a modest 4 percent, but revenue for cells and sources leapt nearly four-fold. Investment in capital equipment for new production lines for making organic LED screens in Asia accounted for this hike, and helped to drive up Riber's year-over-year revenue by 40 percent to €29.0 million. Profit also jumped, rising from €1.8 million in 2010 to €4.3 million in 2011.

At the end of March, the company recorded quarterly revenue of €6.2 million, up 8 percent compared to the same quarter of 2011. During those 12 months the order book fell by €1.8 million to €19.5 million, which included requests for shipments of 13 research systems and one production machine by the end of next year.

The weakening order book results from a contraction in orders of cells and sources for OLED production. However, Riber is now preparing a new generation of cells to catch the next wave of investment in this industry.

Teleco woes

Propping up this year's table is US-headquartered Oclaro, which was formed in 2009 through the merger of telecom component makers Bookham and Avanex. Back in March 2011 Oclaro's shares hit $18, the high-point since the merger, but they plummeted throughout that summer, and are now worth less than $3.

Oclaro posted weak quarterly figures during that period of falling share value. Revenue for the fourth fiscal quarter 2011 that finished on 28 July 2011 was $109.2 million, down $6.5 million quarter-over-quarter, and more worrying, operating loss rocketed from $6.6 million to $33.6 million (however, the latter did include $20 million of impairment charges). The company blamed an extended slowdown in the telecom sector for the poor figures. Three months on, revenue had fallen to $105.8 million, in line with previous guidance, losses were reduced to $9.6 million, but production in Thailand had been halted due to flooding.

This flooding impacted second quarter 2012 revenue, which fell to $86.5 million, and contributed to high operating losses – $33.6 million, which includes $9.1 million of flood-related write-offs.

The impact of the floods also made an impact on the most recent quarterly earnings, which were announced on April 26. Sales had risen slightly quarter-over-quarter to $88.7 million, and could have been about $4 million higher still, if it had not been for a 10 day stoppage at the Shenzhen factory, which has subsequently been resolved. Oclaro is trying to sell this factory, and is planning to move production from this site to Malaysia, where it believes there is a much more stable manufacturing environment.

Another, bigger change for Oclaro will be its merger with Opnext. Oclaro's chairman and CEO Alain Couder believes that this move will be welcomed by customers, who want to work with fewer, more strategic suppliers who can deliver the breadth of technologies they need.

"Through this merger, [Oclaro's and Opnext's] complementary and vertically-integrated product portfolios, scale, and heritage of technology innovation will put the merged company in that valued strategic partner and leadership role."

The merger should position the new company as the second biggest player in the optical components and modules market, behind Finisar. But can this marriage can halt the declining share prices of both companies, and create a profitable enterprise? Time will tell, and the result should be evident on next year's leader board, which will hopefully show that III-V shares have lost that sinking feeling.

- Disclaimer. Richard Stevenson holds a small number of shares in IQE

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Saturation of radiative recombination gets the blame for LED droop

As LEDs plunge to cryogenic temperatures, droop kicks in at lower drive currents due to diminished utilization of the active region.

A TEAM of Korean researchers is proposing an alternative explanation for variations in LED droop with temperature. The researchers account for droop, the decline in device efficiency as the current is cranked up, with a theory involving carrier overflow, reduced effective active volume and saturation of the radiative recombination rate.

The researchers from Hanyang University, Korea, started by measuring the internal quantum efficiency (IQE) of blue and green InGaN LEDs at drive currents ranging from less than 1 μA to just below 10 mA at temperatures from 50K to 300K.

At cryogenic temperatures LEDs suffered from severe droop, attributed to carrier overflow. It is claimed that the degree of overflow is governed by the extent of the reduction in effective active volume and the subsequent saturation of the radiative recombination rate.

Measurements were made on blue and green LEDs with indium compositions of 20 percent and 35 percent and chip sizes of 350 μm by 430 μm and 400 μm by 400 μm, respectively. These devices were placed in a closed-cycle cryostat and temperatures measured at an aluminium plate that mounts to the TO package of the LED.

"The thermal resistance from the aluminium plate to the LED chip is not considered high, and even if there is a temperature gradient from the aluminium plate to the active layer of the LED, it shouldn't be high for the given current level that the efficiency droop starts to occur," says corresponding author Jong-In Shim from Hanynag University.

Shim points out that for temperatures below 100 K, droop kicks in below 0.1 mA, so power dissipating at the chip will be very small. He believes, therefore, that any differences between the actual and recorded temperatures for the LED will not be big enough to have impact on the conclusions that have been drawn from these measurements.

One of the findings of these measurements was that when the reduction in the temperature of blue and green LEDs was small, IQE increased and there was no significant change in the onset of droop. Shim and his co-workers believe that this occurs because decreases in temperature lead to a monotonic reduction in the number of defects in the quantum well that undergo non-radiative recombination.

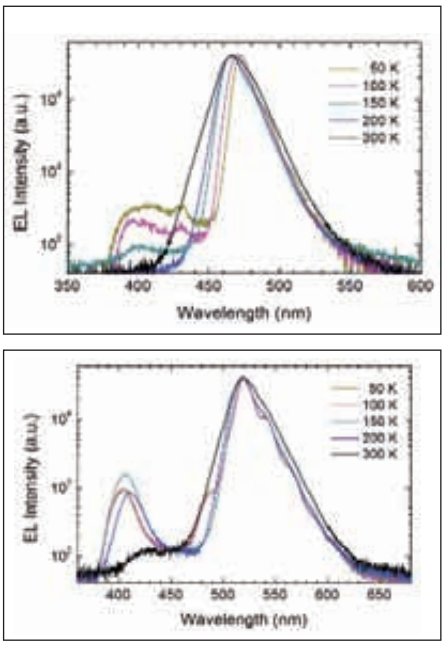
When temperature falls further – below 200 K for blue LEDs and less than 250 K for their green siblings – device behaviour changes dramatically, with droop kicking in at a far lower drive current.

This led the team to draw two conclusions: The dominant droop mechanism undergoes a qualitative change at low temperatures; and Auger recombination is not a major cause of droop, because it cannot account for severe droop at low temperatures.

To shed more light on the cause of droop, the team measured electroluminescence spectra at various temperatures. In both LEDs, reductions in temperature led to the emergence of an emission peak around 400 nm (see Figure). This peak is claimed to originate from the overflow of electrons to the p-GaN cladding layer, where they undergo a recombination process involving a magnesium acceptor level.

Shim and his colleagues believe that electron overflow is the dominant cause of droop at low temperatures. And they argue that the degree of this overflow gets more severe as the temperature plummets because the radiative recombination rate saturates at lower currents, and the non-radiative recombination rate reduces.

Saturation of the radiative recombination rate is thought to occur at lower currents, due to a reduction in the effective active volume. This volume diminishes as temperature falls, due to a reduction in the utilization of the active region, which is associated with degradation in carrier transport. Specifically, the combination of inferior hole transport at lower temperatures and the activation of



Cooling unveils electron overflow

fewer holes leads to a reduction in utilization of the wells, trimming the effective active volume. The upshot is an earlier saturation of the radiative recombination rate, and a greater overflow of electrons into p-GaN.

Measurements by the researchers also suggest that electron overflow is more severe in green LEDs than blue ones. One reason for this is that the green variants have greater indium, leading to wells with greater inhomogeneity and more indium clustering.

Competing theories

Shim and his co-workers are not alone in studying the influence of temperature on LED efficiency and using these measurements to draw conclusions on the origins of droop. For example, Fred Schubert's group – which has measured the efficiency of blue LEDs at various currents and temperatures – claims that droop is caused by transport issues that stem from asymmetry in electron and hole concentrations, plus differences in carrier injection (see *Appl. Phys. Lett.* **99** 25115 (2011)).

"It is true that transport is one of the factors that affects efficiency droop, but we

think that there is another factor, which is more important, [saturation of the re-combination rate," says Shim.

According to him, the model proposed by Schubert's group is predominantly based on a *p-n* homojunction, and fails to consider the active region where recombination occurs. In particular, it fails to explain the following three experimental observations: Photoluminescence induces efficiency droop, LEDs of different colours are subjected to different levels of droop, and variations in device architecture impact LED behaviour.

Regarding his first point, Shim cites independent work by Osram and Philips Lumileds showing that resonant photoluminescence (PL) induces an efficiency droop similar to electroluminescence (EL). "This indicates that there is another factor in the efficiency droop, which is inherent in quantum wells," says Shim.

Expanding on his second point, Shim adds that the ultraviolet LEDs incorporating *p*-type AlGaN are expected to show more carrier asymmetry than the *p*-GaN used in blue and green LEDs. "However, UV LEDs show less efficiency droop than blue green LEDs."

Schubert can counter many of the issues raised by Shim. He argues that measurements performed by his team show that resonant-PL droop occurs at much higher excitation densities than EL droop. "Therefore, the resonant-PL droop does not need to have the same physical origin as the EL droop. I would not rule out carrier leakage as an explanation for the PL droop."

According to Schubert, two factors can explain why green LEDs are more prone to droop than their blue cousins: Stronger polarization fields that supress carrier capture; and inferior *p*-type material quality, including lower *p*-type concentration and mobility that ultimately stems from the need for lower growth temperatures.

Schubert's team have just published a paper with an analytical model for LED droop (see Appl. Phys. Lett. **100** 161106 (2012)). With this model, a widening of the active region reduces droop – in other words, differences in the design of the active region do impact device behaviour. Claims based indium clustering that appear in the Korean conjecture are also controversial – Colin Humphreys' group at Cambridge University, which has investigated GaN-based structures using scanning electron microscopes and atom probe tomography, claims that there is no indium clustering in quantum wells.

Shim's response to this body of work is that indium can be locally segregated around point or line defects. He cites reports by others of clustering from atom probe tomography and near-field scanning optical microscopy measurements (see *Stat. Sol. RRL* **3** 100 (2009) and *Appl. Phys Lett.* **87** 161104 (2005), respectively).

He and his co-workers will continue to study LED droop. In particular, they plan to carry out measurements of radiative and non-radiative recombination lifetimes, study the correlation between the degree of saturation in radiative recombination rate and efficiency droop, and investigate structures that suppress efficiency droop.

D.-S. Shin et al. Appl. Phys. Lett. **100** 153506 (2012)

Mechanical transfer with boron nitride

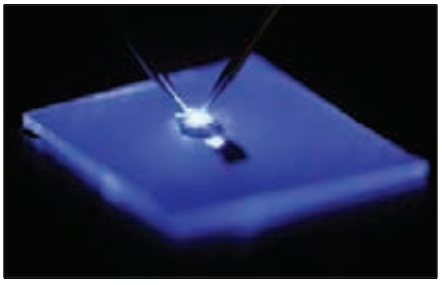
Unlike etching or laser-lift off, mechanical approaches for separating GaN epitaxial structures from their substrates can be quick, simple and scalable to large areas.

A mechanical approach for separating GaN devices from their sapphire substrates promises to replace the sacrificial etching and laser lift-off techniques used in today's fabs, thanks to the recent development of BN films by engineers at NTT Basic Research Laboratories, Taiwan.

This team has demonstrated the strength of its approach by first depositing hexagonal BN films on sapphire substrates, and then growing various structures onto these templates , including: AlGaN/GaN structures with high electron mobility, and epitaxial layers for making multiple-quantum well LEDs. High-quality chips from 5 mm square to 2 cm square have been extracted from these wafers by mechanical lift-off and transferred to other substrates.

Corresponding author Yasuyuki Kobayashi believes that the BN-based mechanical transfer process could be popular with both LED and HEMT manufacturers: "We have already demonstrated that a very thin flexible GaN-based LED can be fabricated in a pair of laminate films, which may be of interest to LED manufacturers. Our technology also makes it feasible to transfer AlGaN/GaN HEMTs onto any materials having high thermal conductivity, which may be attractive for transistor manufacturers who have been suffering from heating problems."

NTT has already filed several patent applications for its process, and it plans to license the technology to other chipmakers.



The Japanese lab started working on BN, a wide bandgap material that could be used for making devices operating in the deep ultraviolet spectral range, in 2005. Growth of single phase, hexagonal BN by MOCVD followed in 2007, and in 2008 this growth technology yielded epitaxial films of this wide bandgap semiconductor on sapphire.

"This success opened an avenue of one-step, damage-free release and transfer of a wide range of GaN-based devices," claims Kobayashi. Epitaxial growth of BN by MOCVD is very challenging. "No lattice-matched substrate is available for BN, at least in affordable form," says Kobayashi. He explained that specially designed substrate heating equipment is needed to achieve substrate temperatures of 1300 °C to 1500 °C, which are reported to be optimal for the growth of BN films.

To demonstrate the promise of their technology, the team deposited a BN layer on sapphire, before adding different

structures. They found that inserting an AlN layer between the buffer and LED improved surface morphology – when GaN is grown directly onto hexagonal BN, it forms a rough, irregular island-shaped surface morphology, and is polycrystalline. Thanks to the addition of AlN, it is possible to form GaN films with a step-like flat surface and a root-mean-square roughness over a 5 μm by 5 μm area of just 0.69 nm, according to atomic force microscopy measurements. Dark-field transmission electron microscopy reveals another benefit of the AlN layer: It acts as a dislocation filter, decreasing the density of threading dislocations in GaN. In this layer, the predominant type of defect is a mixed dislocation, which has a density of 8.6×10^9 cm^{-2}.

Deposition of a 25 nm-thick $Al_{0.28}Ga_{0.72}N$ layer demonstrated the device quality of GaN. When removed from the substrate, characterization of the 2 cm square sample revealed a two-dimensional electron gas mobility of 1,100 cm^2 V^{-1} s^{-1} and a sheet carrier density of 1×10^{13} cm^{-2} at room temperature.

The engineers from NTT have also fabricated an LED with a ten period multiple-quantum well and compared its performance to a conventional device, grown on a typical low-temperature AlN buffer layer. They found that electroluminescence intensities of the transferred LED at currents ranging from 10 mA to 50 mA were comparable to, or higher than, those produced by the control. The reason: Reflection from the backside contact indium.

Spectral width of the electroluminescence produced by both types of LEDs is similar, indicating that the active region maintains its quality during the transfer process.

A battery-powered LED prototype has also been fabricated by the team. A 2 mm square-release LED that is 3.4 μm-thick has been sandwiched between two commercially available laminate films featuring T-shaped Pd/Au electrodes. Application of indium tin oxide contact layers and a thermally activated sealing process creates a violet-blue emitting, flexible source.

Today's targets for the team include an increase in the area of detachable devices, followed by improvements in the performance of conventional devices, such as LEDs and transistors, that can be transferred onto other materials.

Y. Kobayashi et al. Nature **484** 223 (2012)

Slashing defects in GaN-on-sapphire films

Serpentine mask paves the way to ultra-high-quality GaN epilayers

AN INTERNATIONAL collaboration has produced incredibly high-quality GaN on sapphire with a fabrication process involving a single epitaxial growth step.

" We expect that the devices benefiting the most from this technology are the ones requiring very high performance," says Tahong Xie from the University of California Los Angeles. "These devices include lasers, power transistors pushing the limit for power handling, photodetectors requiring extremely low dark current, and LEDs for solid-state lighting,"

Xie's group, working with researchers at Peking University, has produced GaN films with a dislocation density of just 7×10^5 cm^{-2} by using a serpentine mask to block threading dislocations.

His initial idea for using this form of mask structure dates back to 2001 and draws on popular epitaxial lateral overgrowth approaches and dislocation necking. owever, it overcomes the deficiencies associated with these technologies.

If device manufacturers were to employ this serpentine mask technology, they could trim production costs, thanks to a simplified epitaxial process. What's more, chipmakers would benefit from a four-fold reduction in the size of highly defective regions, such as coalescence fronts, compared to GaN

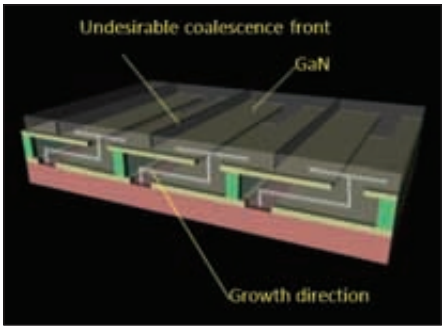


Figure 1: The serpentine mask is formed by a combination of SiN_x and SiO_2 film growth, photolithography and etching.

material formed by conventional epitaxial layer overgrowth techniques.

Fabrication of GaN films by the process pioneered by Xie and his co-workers begins with CVD deposition of a 100 nm-thick layer of SiN_x on (0001) sapphire. A set of [11$\bar{2}$0]-orientated stripes are then formed with standard photolithographic processes, before 200 nm-thick films of SiO_2 and SiN_x are deposited onto this mask.

Another set of stripes in SiN_x is then formed, separated by window areas and offset from the lower openings (see Figure 1). Finally, etching with hydrofluoric acid exposes the sapphire in the lower window. To form high-quality nitride layers, engineers deposit a 25 nm-thick GaN nucleation layer on this serpentine mask at 530 °C, followed by epitaxial growth at 1040 °C (see Figure 2).

GaN islands formed at the edge of this mask that are probably riddled with gallium vacancies. In the centre of the mask material quality is far higher, thanks to complete coalescence of GaN to create a film with a mirror-like surface.

Here the width of X-ray diffraction peaks is narrower than it is for GaN grown on sapphire, defect densities are lower by several orders of magnitude and photoluminescence intensity is 16 times higher. The US-China collaboration is now partnering with engineers at National Cheng Kung University, Taiwan, to grow lasers and LEDs on these low-defect-density substrates.

L. Li et al. Appl. Phys. Express **5** 051001 (2012)

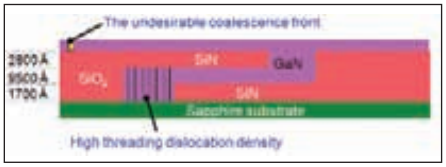


Figure 2: As more GaN is deposited, material quality improves, because this structure can block threading dislocations

Breaking conventional concepts in SiGe thermoelectric materials

Using a modulation-doping strategy in 3D bulk silicon germanium thermoelectric materials enhances their carrier mobility and hence electrical conductivity by over 50 percent

In the last couple of decades thermoelectrics have been drawing more and more research interest due to the limited availability and the negative environmental impact of conventional energy strategies.

In the past, as a measuring stick of the conversion efficiency, the term 'dimensionless figure-of-merit,' also referred to as ZT, has been widely used. A high ZT value usually promises high thermoelectric performance. Typically, good thermoelectric materials should combine low thermal conductivity and good electrical conductivity.

Striving to enhance the performance of thermoelectric materials, researchers from Boston College and MIT have recently reported a novel materials design to achieve a 30 to 40 percent enhancement in the peak ZT value for *n*-type SiGe semiconducting alloys.

Bo Yu from Boston college,who is lead author of a paper describing the recent work, says that SiGe has been almost the exclusive choice for high temperature thermoelectric applications. This material has been used in the radioisotope thermoelectric generators employed by US NASA ever since 1976. However, the broader application of SiGe has been limited by the fact that germanium, which is used to reduce the thermal conductivity in such alloys, is extremely expensive and the cost has to justify the performance.

The scientists reported that the modulation-doping strategy, conventionally used in the thin-film semiconductor industry, could also be utilised in the 3D bulk thermoelectric materials to enhance their carrier mobility and therefore the electrical conductivity, by over 50 percent in this case.

By improvising materials design, the team also achieved a simultaneous reduction in the thermal conductivity, which combines to provide a high ZT value of about 1.3 at 900 °C.

"To improve materials ZT is extremely challenging because all the internal parameters are closely related to each other. Once you change one of them, the others may most likely change accordingly to the other extreme, leading to no net improvement. As a result, a more popular trend in this field of study is to look into new opportunities, or say a new material system. However, our study proved that opportunities are still there for the existing materials, if one could work smartly enough to find some alternative material designs," explains Bo Yu.

Zhifeng Ren also points out that this reported ZT peak value competes well with the state-of-art *n*-type SiGe alloy materials while the new material design requires over 30 percent less of germanium.

"That is a significant advantage to cut down the fabrication cost. We want all the materials we studied in the group to be really used by peopl ," adds Ren.

Bo Yu *et al.* Nano Letters **12** 2077 (2012)

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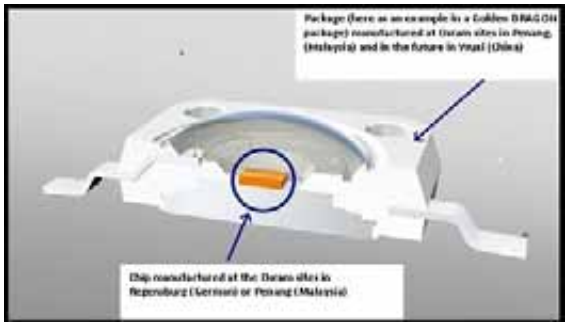
News Digest Contents

LEDs

Osram extends its LED capacity in China

The new plant, which will assemble III-V nitride based LED chips into lighting components strengthens the company's position in the lighting industry's largest market Osram has signed a contract with the Wuxi New District Administrative Committee to build a new assembly plant in the Chinese province of Jiangsu. LED chips will be packaged in housings at the new backend facility starting in late 2013; with the Regensburg and Penang (frontend) plants exclusively continuing to make the actual LED chips.



"The new assembly plant will improve our access to the world's largest single market in the lighting industry," says Aldo Kamper, CEO of the Osram Opto Semiconductors business unit. "As one of the world's most renowned LED lighting corporations, Osram's new plant in Wuxi will definitely enhance the development of the LED industry in both Wuxi Municipality and Jiangsu Province," adds Lixin Huang, Member of the Standing Committee of Jiangsu Provincial CPC Committee and Secretary of Wuxi Municipal CPC Committee in China. In the face of sharply rising demand for LED-based products, Osram has opted to set up a further plant in Wuxi, China, to augment the capacity of its chip plants in Regensburg, Germany and Penang, Malaysia. With this move, the company is strengthening its access to the lighting industry's largest single market worldwide.

The new plant is scheduled to be up and running by the end of 2013 and may need up to 1,600 employees when fully operational. The new backend facility at Wuxi near Shanghai will install LED chips manufactured in the frontend plants at Regensburg and Penang in their housings. The new assembly plant in Wuxi will also enhance the Penang plant by manufacturing general, automotive and industrial lighting products for key segments of the Chinese market. The plant's added back-end LED capacity, will enable the company to capitalise on China's fast-growing market and support the two plants in Germany and Malaysia. "We have attained a leading position in the semiconductor sector over the course of about 40 years. The facility in China marks another step forward in extending this lead," points out Aldo Kamper.

Osram Golden DRAGON Plus LED

Market researchers at IMS Research have predicted strong growth for opto semiconductors such as LED components and laser diodes with average growth rates of around five percent worldwide in the coming years. The fastest growth is expected to come in China at the same time, with an average growth rate of ten percent. This growth potential extends beyond components. According to a market survey conducted by McKinsey, the rapidly growing Asian region today already accounts for around 35 percent of today's global general lighting market. This share is expected to increase to 45 percent by 2020. The Chinese market alone, worth over €8 billion today, is expected to more than double by 2020. In fiscal 2011, Osram generated about one fifth of the Group's revenue in the Asia-Pacific region, where it employs over 16,000 people.

Osram says this workforce is larger than that of any other region worldwide, and roughly half of it is employed in China.

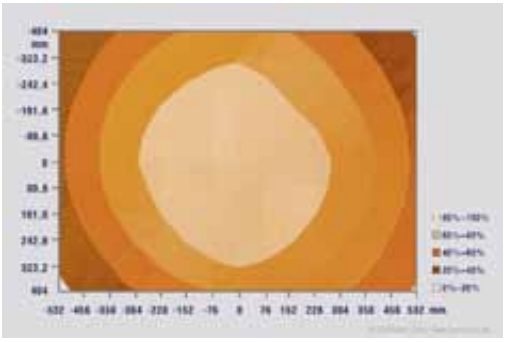
Oslux LED offers new design options for smartphones

Osram Opto's new flash LED harmonises form and function Osram Opto has added a new type of LED to its Oslux family. With no need for flash applications to be compromised, Osram says its specially shaped lens makes its Oslux LED suitable for discreet fitting into a device. Thanks to its high output power, the new LED is also capable of capturing excellent illuminated shots using cellphones.

No conflict between functionality and design with the new Oslux LED

Much of the time, manufacturers of high-end smartphones have to choose between design and functionality. A major challenge in this case is combining the actual camera with the lighting needed. Technical components can look bulky with some cellphones. What's more, the recesses in the enclosure also make the device less robust. According to Matthias Winter, responsible for marketing LED consumer applications at Osram Opto Semiconductors, "These days a smartphone is more than ever a design object. With the Oslux LED we bring form and function together." With the new Oslux LED for flash applications Osram Optosays it is supporting smartphone manufacturers in their attempt to combine shape and function.

The Oslux LED has two chips with a square millimetre of light surface each. The light-emitting surface of the rectangular LED is optimised for the optics of the cellphone – the surface is flat and finishes properly with the cover.



The Oslux LED temperature profile

This means the Oslux LED can be installed inconspicuously in the phone. No additional covers or lenses are necessary. With its symmetrical emission, the LED can be installed vertically or horizontally. When switched off, the LED is barely noticeable, but when in use, high quality white light illuminates the target area. Osram says its UX:3 chip technology in the Oslux LED provides very consistent illumination for photos. Even at a distance of 1m a brightness level of 150 lux is achieved. When flashing, the light is evenly distributed and shines into the corners of the rectangular illuminated image. This means no round spot is generated in the centre like what sometimes happens in conventional flashing. The elements of the flash are integrated into a single component, making the Oslux LED compact. Osram says it is also durable and resistant to shocks and vibrations and the high power means it can cope with multiple repeated flashes. With a luminous efficacy of 150 lux at 320 mA the module comes in a 9 x 6 x 2.9 mm package. It has a 1,062 x 808 mm illumination target window and the colour temperature is 4,500K.

LED lighting company Cree Announces CFO Transition

Cree, Inc. announced that John Kurtzweil has resigned as executive vice president-finance and chief financial officer, to pursue other opportunities, and that Michael McDevitt has been appointed CFO on an interim basis.

Cree has commissioned a search for a replacement through Russell Reynolds Associates, executive search consultants.

Mr. Kurtzweil plans to continue as a Cree employee

until June 15, 2012, to assist with the transition of his responsibilities. “The decision to leave Cree was a very difficult one for me as the past six years have been personally rewarding,” said Mr. Kurtzweil. “At this point in my career, however, I decided to move to Extreme Networks, a smaller firm where I can have a more hands-on role in growing the business.”

“We appreciate John’s contributions in helping grow Cree from $400 million in revenues in fiscal 2007 to over a billion dollars in annualized revenues today,” said Chuck Swoboda, Cree chairman and chief executive officer. “He has built a strong finance team and a foundation for future growth. We wish him continued success.”

Mr. Swoboda also commented on Cree’s previously announced business outlook for the fiscal quarter ending in June: “We are encouraged with our progress in growing the business through the first half of the quarter. At this point, we remain on track with our targets.”

Cree’s interim CFO, Mike McDevitt, joined Cree in 2002 as corporate controller and previously served as interim CFO in 2006 during an earlier transition. He has also served as Cree’s director of financial planning and as director of sales operations.

Supply and demand for LEDs to stabilise in 2012

Demand from LCD backlights will continue to dominate LED demand until 2013, when it will reach its peak

The year 2011 was a challenging one for LED makers. After taking off in 2010, the growth in demand from LCD TV backlights dwindled. This was, due to a combination of slower growth in LED backlit LCD TV sales and slower growth in chips used per backlight, due to efficiency increases.

According to the “NPD DisplaySearch Quarterly LED Supply/Demand Market Forecast Report”, the demand for LEDs in LCD backlights did grow slightly, as use in tablet PCs and strong penetration growth in LCD monitors made up for the drop in demand from TV. Growth was also modest in lighting, as the market penetration of LEDs only grew from 1.4% in 2010 to 1.9% in 2011.

At the same time, many new LED suppliers had entered the industry, and were rapidly ramping up production. Measured in standard units of 500 × 500 µm chip size, supply grew by 41% in 2011, compared to only 10% growth in demand. This resulted in a significant over-supply throughout 2011.

“LEDs have been in surplus since the end of 2010, setting the stage for a decrease in LED prices and margins,” says Steven Sher, Analyst, NPD DisplaySearch. “As a result of this surplus situation, there has been almost no investment in LED applications, nor any significant capacity increases in 2012. This is resulting in a halving of the supply/demand glut from 2011 to 2012.”

Figure 1: LED Supply/Demand for Backlight and Lighting Applications (Source: NPD DisplaySearch Quarterly LED Supply/Demand Market Forecast Report)

Due to the growing popularity of new, low-cost direct LED backlight designs for LCD TVs, the demand for LEDs in backlights will continue to increase through 2013. While the number of LED packages per LCD backlight unit will peak in 2012, continued growth in penetration of LED backlights will lead to slight increase in LED demand in 2013.

By 2014, lighting will become the dominant source of demand for LEDs as price reductions and efficacy improvements drive increased adoption.

The penetration of LEDs in lighting is expected to reach 16.8% in 2015. NPD believes spotlights and LED street lights will gain higher penetration in lighting due to government incentive programs, such as the 12th Five-Year Plan in China and the

LED subsidy policy in Taiwan, as well as continued growth in commercial applications. LED bulbs and fluorescent tubes are growing in Japan due to government incentive programs and energy-saving consciousness, especially since the March 2011 earthquake.

Cadmium free green quantum dots for LEDs big in Japan

A Japanese firm is planning on developing a range of LED applications that incorporate Nanoco's red and green quantum dots including the backlighting of LCD displays and LED-based general lighting

Nanoco Group has successfully produced a 1kg batch of green cadmium-free quantum dots for a major Japanese corporation, triggering a US $2 million payment to Nanoco.

Nanoco supplied a 1kg batch of red quantum dots to the same Japanese corporation last year, also attracting a US$2 million payment. The production of the green dots marks another major technical achievement by Nanoco because green dots are significantly more challenging than red ones due to their smaller size.

The firm says it is the only supplier of heavy metal-free quantum dots which show bright emission and can be tuned from ultra-violet, through the visible spectrum, into the near infra-red. The non-toxic CFQD (cadmium-free quantum dots) range is entirely RoHS 2002/95/EC compliant.

The firm is currently supplying CFQD samples to its development partners around the world, where emissions range from 400nm to 650nm.

The green quantum dots were produced at Nanoco's production facility in Runcorn, Cheshire.

The Japanese corporation is planning on developing a range of LED applications that incorporate Nanoco's red and green quantum dots including the backlighting of LCD displays and LED-based general lighting.

The value of using quantum dot LEDs in LCD TV backlighting is much improved colour performance. For general lighting applications Nanoco's quantum dots allow lighting manufacturers to tune the shade of white light produced giving next generation white LED lights the warm feeling of traditional incandescent lights.

Michael Edelman, Nanoco's Chief Executive Officer, comments, "We are delighted to have produced a 1kg batch of green quantum dots to the specification of this major Japanese customer. It is the first time that we have produced green quantum dots on this scale, marking a particular technical achievement as green dots are just a few nanometres in diameter - about half the size of red ones. We now look to forward to the customer progressing to the launch of quantum dot LEDs, and to our on-going supply of quantum dots."

Global QD market to shoot up to $7480.25 million by 2022

Apart from in healthcare, where Quantum Dots hold a large market share, the technology is expected to play a major part in LED lighting and solar cells in the future

A new report, "Quantum Dots (QD) Market - Global

Forecast & Analysis (2012 - 2022)" published by MarketsandMarkets, says the total market for Quantum dots is expected to reach over $7480 million by 2022, at a CAGR of 55.2% from 2012 to 2022.

Quantum Dots (QD) are one of the most advanced area of "semiconductor nanoparticles", and is currently undergoing massive research.

QDs are semiconductor nanoparticles, and, as the name suggests, have size from 2 nm to 10 nm. Due to their miniature property; they are highly versatile and flexible. The uniqueness of QD material lays in the fact that its power intensity depends on the input source and size of QD.

There are several ways to confine excitons in semiconductors, resulting in different methods to produce quantum dots. In general, quantum wires, wells, and dots are grown by advanced epitaxial techniques in nanocrystals produced by chemical methods or by ion implantation, or in nanodevices made by state-of-the-art lithographic techniques.

In the present scenario of QD technology market, Healthcare is the only industry, which has gained significant market share. Healthcare needs high precision in tissue labelling, cancer therapy, tumour detection, etc. and QD-based devices work for the same.

The lighting industry is huge; and after the introduction of efficient lighting like LED, this industry has taken a huge leap. LED lighting and fixtures market has propelled in the last few years and is expected to expand further.

Now companies are looking for the alternate technology for LED lighting. QD lighting will fulfil the need; it is highly efficient and cost-effective. QD Vision has collaborated with Nexxus Lighting to launch its first QD LED light, and soon it will capture the market. Likewise, the company is also working on QD display.

QD technology will play a crucial role in solar energy-oriented industry as well. Researchers have developed QD-based solar cell, which is 50% as efficient as conventional solar cell. University of Toronto has achieved an efficiency of 4.2% conversion with solar cell based on colloidal QDs (CQD). Researchers are also working on QD-based paint that can be applied to panels or walls to capture solar energy.

The global Quantum Dots Market for technology-products and applications is expected to reach $7480.25 million by 2022, at an estimated CAGR of 55.2% from 2012 to 2022. The Americas are holding a leadership position in QD technology market on the whole; followed by Europe and APAC. In the market of ROW, Middle East and Africa are the largest contributors.

Global semiconductor sales escalate

A new report says silicon manufacturer Broadcom and compound semiconductor supplier TriQuint are good examples that illustrate that the semiconductor industry is bouncing back

The semiconductor stock market has not done too badly this year, thanks to the growing demand for tablets and smartphones.

The mobile market relies on both silicon and compound semiconductor devices although silicon dominates in many of these areas.

According to ParagonReport.com, the Semiconductor Industry Association (SIA) recently reported worldwide semiconductor sales showed growth across all regions.

The organisation reported that for March 2012, worldwide sales of semiconductors totalled $23.3 billion, a 1.5 percent increase over the previous month. Sales in Europe and Japan grew 3.8 percent and 1.2 percent respectively.

"We are encouraged to see that sequential growth resumed across all regions, especially in Europe and Japan, in March," says Brian Toohey, president, Semiconductor Industry Association. "We look for seasonal moderate growth to continue in the second quarter and build momentum as 2012 progresses. However, while forecasts for global economic growth are improving, macroeconomic and geopolitical uncertainties remain."

Seoul Semi expands its mid-power LED family

The addition of the 3020 series will provide a smaller footprint with higher light density

Seoul Semiconductor says its new series of mid-power LEDs feature advanced packaging techniques.

The group of LEDs have a high-lumen output and improved thermal efficiencies and the new 3020 series are claimed to offer a solution for general illumination applications requiring distributed light such as replacement lamps and linear strip lighting.

The 3020 family will be offered in the full range of ANSI white space with standard binning and LM-80 testing. The entire family is general illumination class and comes with Colouring Rendering Index (CRI) versions of 80 or 90 minimum and with efficacies as high as 151 lm/watt (cool white) and 136 lm/watt (warm white).

Following in the footsteps of the highly popular 5630 package, this product is particularly suited for small fixtures and omni-directional bulbs which demand the high efficacies and light densities of a small, mid-power LED solution. This new 3020 series can also be used for fluorescent replaement tubes and linear strip products as well as panel and ceiling tile lighting.

The product will be available for sampling from Seoul's three distributors, Avnet Electronics Marketing, Digi-Key Corporation and Mouser Electronics in Q2 2012 and available for mass production shortly thereafter.

SETi honoured with Tibbetts Award at the White House

The aluminium gallium nitride UV LED innovator has been awarded for its role in research and development for the U.S. government under the SBIR program

Sensor Electronic Technology, Inc. (SETi) has received a Tibbetts Award.

The award was presented by the US Small Business Administrator, Karen Mills, to Remis Gaska and Michael Shur, at a ceremony held at the White House.

Image: (from left to right), Roland Tibbetts, Karen Mills (SMA Administrator), Remis Gaska, Sean Greene (Associate Administrator of Investment and Innovation) and Michael Shur

Gaska and Shur founded SETi in 1999 to develop III-nitride based electronic and optoelectronic devices. Under DARPA and SBIR funded programs SETi developed proprietary technology that led to the development of Ultraviolet (UV) LEDs with peak emission wavelengths ranging from 230nm through 365nm.

SETi has over 100 patents covering materials, devices and applications in UV LED technology, many of which were the result of US government backed development under SBIR funding.

The company continues to further its device technology and develop new applications of UV LEDs through multi-agency programs and recently announced more than 10% efficiency in a 275nm LED thanks to the DARPA/ARL CMUVT program.

The Tibbetts Awards, are named after Roland Tibbetts, who was instrumental in developing the SBIR program. The awards are presented to companies and individuals from all over the United States.

Tibbetts award winners are selected based on the economic impact of their technological innovation, and on whether they have met federal research and development needs, encouraged diverse participation in technological innovation, and increased the commercialisation of federal research.

Tiny Zenigata LEDs radiate up to 1550 lumens

Sharp's new nitride LED modules from the new "Mini Zenigata" series offer an efficiency of up to 99 lm/W, a luminous flux of up to a typical 1550 lm and are available with a CRI value of up to 82

Sharp's new Mini Zenigata arrays of type GW5BxxxK05 provide a luminous flux between 1150 and typical 1550 lm with a light output of up to 99 lm/W in standard operation.

Line-up 15W LED lighting module "Mini Zenigata"

The new generation of the 15 W modules is specified for a forward voltage of 39 V with a constant current of 400 mA.

But you can also operate the 15 W arrays with increased constant current of up to 440 mA to achieve a luminous flux of up to 1,650 lm. The 48 dies of the Mini Zeni of type GW5BxRxxK05 are divided electronically into a matrix of four parallel-switched series of twelve, which ensures fail-proof operation.

Sharp says the round shape of the surface emitting light is also new in the 15 W Mini Zeni arrays. The circular LES has a diameter of 8 mm and is filled up to the edge of 48 LED dies. As a result, the new 15W Mini Zeni modules have properties like a high-performance, point light source, which only require simple optics (lens and reflector) unlike multipoint light sources.

Nothing has changed in the dimensions of the carrier made of aluminium oxide. At a compact 15 mm x 12 mm x 1.6 mm, the new Mini Zeni arrays are completely compatible mechanically with their predecessors.

The colour temperatures of the new white light LED arrays are in the range from 2,700 to 5,000 Kelvin with the shades "Natural White", "Warm White" and "Pure White". They are available in two models with CRI values of more than 80 and more than 90. The new Mini Zeni arrays also have high-quality R9 values, two binnings within MacAdam5 as well as good colour consistency and stability values over time under realistic conditions (hot lumen).

Thanks to the very smooth bottom side of the ceramic carrier and the already existing soldering points, the modules can be attached to an appropriate heat sink without a lot of work, ensuring excellent heat dissipation. The modules have a lifetime of 40,000 hours at an operating temperature of maximum 90° C. The light loss is also considerably less compared to conventional lamps and is only 70% after 40,000 operating hours.

The new 15 W Mini Zenigata LED arrays are suitable for numerous applications; they can be used in spot lighting and in LED retrofit lamps.

Samples are initially available in the colour temperatures of 3000 K and 4000 K.

LEDisOne with Optogan enter Italian lighting

The German-based firm has opened a lamps and luminaires sales office in Varese, Italy, by signing a distribution agreement with the company LEDisOne

At the Grand Opening event in Varese, close to Milan, LEDisOne hosted more than 100 official guests, politicians, architects, representatives of industry and universities.

Newly certified distributor LEDisOne is specialised in LED lighting and shows a broad background in the semiconductor industry.

For Optogan the expansion to Italy has been a key target, since the country is considered as the home market for architectural lighting.

“Italy has always been one of the front runners in Solid State Lighting and is traditionally first in adopting new technologies and trends of the indoor lighting industry,“ says Ove Sörensen, Senior Sales Director & Business Development at Optogan GmbH.

He adds, “The potential for LED based lamps and luminaires in this country is on such a high level that we cannot afford to miss this strategic market.”

Besides the architectural lighting and retrofit business LEDisOne will also focus on sportfield and flood lighting. Regional sports clubs and associations have already expressed their interest.

“So far our customers are mainly designers, architects, industrialists and public authorities, but our long-term goal is to collaborate with the government since there are development projects concerning an energy efficient re-design of cities”, states Gabriele Demaria, Managing Director of LEDisOne.

“Within the next year we plan to set up the company structure in terms of additional locations and manpower. We strongly believe we have found in Optogan the right partner to fulfil our ambitious targets.”

Warsaw to use Aixtron CCS reactor for R&D of GaN

The University of Warsaw will use the reactor to pursue gallium nitride research

Aixtron SE has a new MOCVD system order from the University of Warsaw, Poland.

The contract is for one Close Coupled Showerhead (CCS) reactor in a 3 x 2-inch wafer configuration, to be used for the growth of GaN materials.

The system was ordered in the fourth quarter of 2011 and will be delivered in the second half 2012 as part of a project co-financed by the European Union titled “Physics as the basis for new technologies – development of modern research infrastructure at the Faculty of Physics of the University of Warsaw”.

Aixtron Europe’s service support team will install and commission the system at a dedicated cleanroom facility within the Institute of Experimental Physics of the University of Warsaw’s Faculty of Physics.

“Aixtron is an excellent supplier for R&D GaN MOCVD systems and we believe that the longstanding world-renowned expertise of Aixtron’s technology and service will therefore be a key factor for successful development of nitrides technology at the University of Warsaw”, Roman Stepniewski comments.

“We expect the CCS reactor to be the best solution because there are few systems that possess such a good all-round combination of characteristics. It is a very stable platform, optimised for the growth of nitride thin films for a range of requirements, and comes with excellent reliability, ease of use and reproducibility. While we are starting a new research project, we are looking forward to putting the Aixtron CCS reactor into use.”

Frank Schulte, Vice President Aixtron Europe, adds, “We are very pleased to announce this order from the University of Warsaw. Professor Stepniewski’s team has a worldwide reputation for the quality of their work in advanced semiconductor materials, in particular in growth technology and basic studies of nitrides. There is no doubt that like many other research groups, they will quickly find the CCS to be not only a robust route to uniformity and scalability, but also an ideal and sustainable solution for their needs.”

Directional and decorative COB LEDs revealed by Everlight

The Taiwanese firm's latest nitride based LED series are claimed to offer low thermal resistance and high performance. The C52 Series also can achieve the low cost of industry target of over 400lm/$ for a COB LED light source.

Everlight is marketing its 6.4W and 8W Chip-on-Board (COB) LED series, which it claims is one of the highest CRI and highest efficiency COBs on the market.

The brand new and smaller C52 COB LED series is suited for directional and decorative applications such as MR lamps and P35 bulbs.

Everlight's C52 new Chip-on-Board LED

For these types of applications, an LED light source must exhibit compact size, high efficiency, sufficient lumen output, high CRI, high colour uniformity, and proper light distribution to maintain a comfortable and uniform lighting environment, all at consumer acceptable prices.

Everlight boasts its new C52 COB Series has created another ideal LED to address major challenges posed when designing a retrofit like MR, GU or candelabra type, with minimum efficiency requirements, thermal management in limited space, and complexity of design.

Everlight's COB series is a 3.7W multi chip, ceramic substrate based LED that boasts a low thermal resistance (Rth < 1.8°C/W) and superior efficacy of 100lm/W at 3000K CCT and high CRI (> 80Ra). It will be available not only in ANSI 3000K CCT but in all Energy Star / ANSI colour temperature ranges.

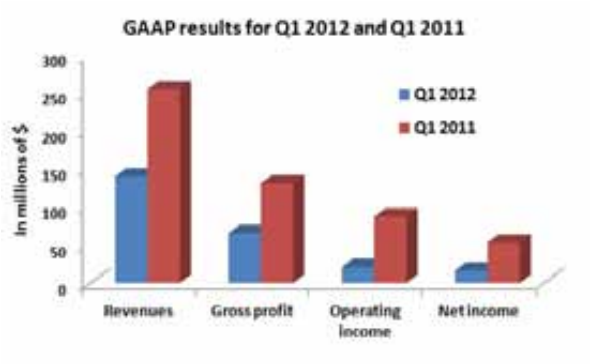
Mechanically, the C52 COB series can be mounted directly on heat sink eliminating the SMT process. This provides more direct thermal dissipation, ease of assembly, and lowering of the system cost in lighting applications.

Everlight's C52 Series is using the standard DC chips configured in series and parallel to provide the most convenient driving conditions for existing driver designs. Also, with a ceramic substrate, users can have higher reliability and better thermal dissipation.

Veeco revenues slump 40.1% but firm is still making a profit

The III-V compound semiconductor, nitride LED and solar equipment manufacturer says it is experiencing growth in its Data Storage and MBE businesses, and services across all its technologies

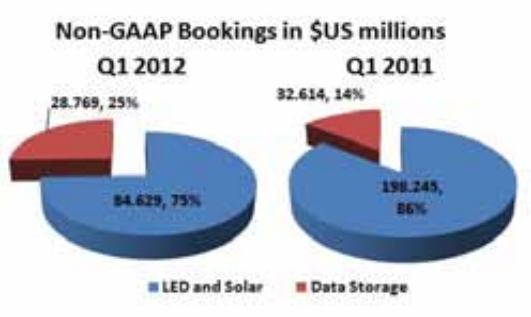
Veeco Instruments has announced its financial results for its "continuing operations" in the first quarter ended March 31, 2012.



John R. Peeler, Veeco's Chief Executive Officer, comments, "We are executing well during the downturn in MOCVD demand. Veeco's first quarter revenue reached the top of our guidance at $140 million. Adjusted EBITA and non-GAAP earnings per share were $25 million and $0.49, respectively, on strong performance on the gross margin line and good expense management."

Veeco generated about $42 million in cash flow from operations, ending the quarter with $524 million in cash and short term investments. First

quarter LED & Solar revenues were $96 million, including $82 million in MOCVD and $14 million in MBE. Data Storage revenues were $44 million.



"As anticipated, we experienced a weak bookings environment in Q1, with total orders of approximately $113 million," continues Peeler. "LED & Solar orders totalled $85 million, with $70 million in MOCVD and $15 million in MBE. MOCVD orders increased 19% sequentially, with system orders from customers in Korea, China, Taiwan, Japan and North America."

MBE orders increased 71% sequentially on production orders from wireless customers but data storage bookings declined 62% sequentially to $29 million as customer consolidation activity temporarily stalled capacity investments. Veeco's book-to-bill ratio was 0.81 to 1 and quarter-end backlog was $305 million.

Second Quarter 2012 Guidance & Outlook

Veeco's second quarter 2012 revenue is currently forecasted to be between $120 million and $145 million. Earnings per share are currently forecasted to be between $0.20 to $0.40 on a GAAP basis.

Peeler comments, "I am proud of our team's ability to execute, stay nimble and deliver solid profitability in a tough year. We are experiencing growth in our Data Storage and MBE businesses, as well as in Services across all of our technologies. Veeco is focused on keeping our infrastructure lean and discretionary costs low, while at the same time developing next-generation technology solutions to drive future growth. We are on track to deliver 2012 revenue of $500-600 million."

He continues, "While MOCVD bookings grew modestly in the first quarter, we have not yet seen a clear inflection in customer buying patterns. LED customers remain cautious about capacity investment plans and it is still unclear when the MOCVD market will recover. Some positive signs are emerging, including increasing tool utilization rates in Korea, Taiwan and China, and a pick-up in customer quoting activity."

"Overall, we are seeing positive trends in LED lighting – lower prices, more LED lamp products, and heightened consumer awareness. LED manufacturers are focused on how to position their businesses for growth as LEDs become the dominant lighting technology. Despite the business decline in 2012, we firmly believe that the future MOCVD market opportunity will be larger than what we have experienced so far. With leading market share, strong LED customer relationships, technology leadership, and lowest cost of ownership production systems, Veeco is poised for substantive long term growth in LED lighting," concludes Peeler.

LED chip companies impressed with Trinity sapphire

The flexible c-axis CHES furnaces allow Trinity Material to serve the rapidly expanding demand for large diameter sapphire substrates, ranging from four inches to eight inches
Trinity Material and ARC Energy have announced that sapphire grown using ARC Energy's Controlled Heat Extraction System (CHES) furnaces has been certified for high quality LED chip production at two leading LED chip companies. Trinity Material in China and ARC Energy have united to use ARC Energy's CHES furnaces for sapphire production.

Sapphire boules are grown on *c*-axis by ARC Energy's CHES method compared to conventional processes where *a*-axis boules are grown and *c*-axis wafers are extracted. "LED chip qualification results prove that CHES wafers perform as well as, or better than sapphire grown by the *a*-axis growth process, without any colour problems at the boule or wafer levels. LED chips manufactured on CHES wafers show a significant increase in light output when compared to devices grown using wafers from conventional*a*-axis-grown boules," says Champion Yi, chief operating officer for Trinity Material.

Trinity Material and ARC Energy are paving the way for new industry expectations and opportunities based on *c*-axis growth orientation for LED manufacturing.

Trinity Material is successfully ramping up to produce very high volumes of sapphire crystals to meet the growing demand for large diameter sapphire wafers in the LED market. "Trinity Material is excited to be a pioneer in China for mass production of CHES sapphire for the LED market," says Jamin Sheng, chief executive officer for Trinity Material. "We look forward to continuing our strong relationship with ARC Energy, and to utilising ARC Energy's leading edge CHES furnaces and our strong production capabilities to ramp up production to high volumes so that we can become a worldwide leader in large diameter sapphire."

ARC Energy's proprietary and fully automated CHES technology produces *c*-axis boules that are the optimum orientation for LED applications and, the firm says when compared with conventional *a*-axis technologies, lead to higher material utilisation and lower overall costs for large diameter sapphire production. "Our unique and flexible *c*-axis CHES furnaces allow Trinity Material to serve the rapidly expanding demand for large diameter sapphire substrates, ranging from four inches to eight inches. We are pleased to partner with Trinity Material to help them expand their business in the LED marketplace," adds Rick Schwerdtfeger, co-founder and chief technology officer for ARC Energy.

Forepi orders six more Aixtron reactors for LED production

Four CRIUS II-XL systems in a 19 x 4-inch wafer configuration and two G5 HT reactors in a 14 x 4-inch wafer configuration, will be used for the manufacturing of UHB gallium nitride based blue and white LEDs

Aixtron SE has announced that long-time customer Formosa Epitaxy Inc. (Forepi) has placed a new order for several MOCVD systems.

The order is for four CRIUS II-XL systems in a 19 x 4-inch wafer configuration and two G5 HT reactors in a 14 x 4-inch wafer configuration.

The tools will be used for the manufacturing of ultra-high brightness (UHB) GaN-based blue and white LEDs.

Forepi placed the order in the second quarter of 2012 and following their delivery between the third and fourth quarter of 2012, the systems will be installed and commissioned at the company's new facility in the Pin-Jen industrial zone, Taiwan.

"Forepi began using the CRIUS II-XL system a few months ago and as we must now make provisions for the capacity increase at our new factory in the Pin-Jen industrial zone, we once again turned to Aixtron to provide the epitaxy systems.With short time-to- production and highest performance, throughput and yield, these systems are best suited to our needs," a spokesperson from Forepi comments. "As we focus on 4-inch substrates, we have great confidence in Aixtron's cutting edge epitaxy technology."

Aixtron's Chief Operating Officer Bernd Schulte, adds, "We are very pleased to once again be able to support one of our longest-standing customers in Taiwan as they continue to expand. An order such as this from Forepi provides further proof of the value of the key features of our equipment, such as seamless process scale-up, excellent uniformity and highest throughput per footprint. All of these factors come together with the most impressive capacity available in today's equipment market."

Cree LED module to replace ceramic metal halide lighting

The firm's new LMH2 device is claimed to deliver unparalleled efficacy and design flexibility and enable up to a five percent increase in system efficacy

Cree is expanding its series of 2000 and 3000 lumen LMH2 module families which deliver lighting manufacturers a new dome lens and universal driver with dimming options.

The new lens enables up to a five percent increase in system efficacy compared to the standard lens

with a hemispherical light pattern.

Cree LMH2 modules enable true 50 W and 70 W ceramic metal halide LED replacements and support an expansive range of lighting applications, including downlights, wall sconces, pendants, flush-mounted, spot, track and ceiling fan lights.

The new LMH2 module is also now available with a 120-277V universal driver with 0/1-10 V dimming capability. The versatile and modular LMH2 LED offers a range of lumen, colour temperatures, driver and beam shape options in one common form factor.

“The new LMH2 delivers the perfect combination of high efficacy, colour quality and controls,” comments Anthony Toniolo, president, DDP & Emerge Lighting. “The Cree LED module provides Data

Featuring Cree TrueWhite Technology, the new LMH2 module is available in 2000 and 3000 lumens and delivers more than 95 lumens per watt at the light source.

The module is available in colour temperatures of 2700 K, 3000 K, 3500 K and 4000 K. Designed for 50,000 hours of operation and dimmable to five percent, the LMH2 comes with Cree’s warranty. The LMH2 light source is also UL-recognised and complies with multiple international regulatory and safety standards. Luminaire makers seeking ENERGY STAR qualification will have access to specification and performance data, including LM-80 reports, which can speed regulatory approvals.

“Lighting manufacturers no longer need to settle for inferior quality and performance offered with ceramic metal halide lighting,” concludes Mike Watson, Cree senior director marketing, LED components.

“Cree’s LMH2 family lets designers quickly and easily convert their traditional lighting portfolio to LEDs and simultaneously deliver their end-users improved color quality, efficacy and performance.”

Soraa to soar with new industry leaders

The gallium nitride-on-gallium nitride LED innovator has taken on Tom Caulfield as COO and Ray Letasi as the VP of Global Sales

Soraa, a developer of GaN-on-GaN solid-state lighting technology, has recruited two experienced executives to its leadership team.

Tom Caulfield has assumed the position of Chief Operating Officer and Ray Letasi joins Soraa as Vice President of Global Sales.

Caulfield has held a number of executive positions in publicly traded and private companies including serving as COO of Ausra, Inc. where he led the repositioning of the company that ultimately led to a strategic partner acquisition. Prior to this, Caulfield served as Executive Vice President of Sales, Marketing and Customer Satisfaction at Novellus Systems. There, he oversaw the world-wide field operations for over 1200 individuals. Caulfield also brings extensive semiconductor industry experience to Soraa having served, over his 17 year tenure, as Vice President of Semiconductor Operations at International Business Machines Corporation.

“Tom will play an integral role in expanding Soraa’s ability to meet the growing market demand for high-performance LED lighting,” says CEO Eric Kim. “With his distinguished track record of senior executive leadership and his unique experience with semiconductor technology and manufacturing - spanning production, manufacturing, equipment engineering and technology and product development - Tom will be key to Soraa’s execution plans in this sector.”

Soraa has also taken on lighting industry veteran Ray Letasi as Vice President of Global Sales. Letasi is the former president and COO of EcoSense Lighting, a global solid-state lighting solutions company. He was formerly Vice President of International Sales for u Kinetics (Now Philips Solid-State Lighting Solutions), and held several Sales Management and Business Development positions during ten years with Color Kinetics, spearheading the company’s Japanese joint venture partnership as well as launching sales, marketing and distribution programs throughout

Europe, Asia Pacific, Japan, and the Middle East. Letasi brings to Soraa nearly 15 years of global business experience in the semiconductor, LED and lighting industries.

“Ray’s extensive experience in the lighting industry gives Soraa a major advantage in navigating a rapidly changing industry landscape,” comments Soraa CEO Kim. “His veteran perspective on the global industry will help build Soraa’s reach internationally.”

Soraa made its public debut in February 2012 when the company launched its flagship family of GaN-on-GaN based LED MR16 lamps. Soraa’s proprietary GaN-on-GaN technology foundation enables the company to produce LEDs that produce much brighter light sources than conventional LEDs and allow the company to develop lighting products with superior performance and sim

Telecoms

A new transceiver for 10GBASE-SR XENPAK applications

The transmitter section incorporates a 1550nm FP laser diode and the receiver section uses an integrated indium gallium arsenide detector preamplifier

GAO Comm has released a 10GBASE-SR XENPAK transceiver which can be used in switches and modules that support XENPAK transceivers.

10GBASE-SR XENPAK fibre optic transceiver

This company says its high performance 10GBASE-SR XENPAK transceiver, model C018XX01, is a fully integrated 10.3Gbit/s optical transceiver module that consists of an 850 nm wavelength optical transmitter and receiver, XAUI interface, Mux and Demux with clock and data recovery (CDR).

It is hot Z-pluggable and features up to 10.3 GBd bi-directional data links and RoHS compliance.

This transceiver uses an 850 nm VCSEL laser diode to achieve a transmission distance of up to 300 m over 50/125 multi-mode fibre. It also allows for MDIO and DOM and has SC connectors.

This 10GBASE-SR XENPAK transceiver belongs to GAO’s family of Extreme compatible transceivers. This line includes a wide variety of Extreme compatible transceivers such as Extreme Compatible 10GBASE-ER XENPAK Transceivers.

The latest addition to the family uses a cooled 1550 nm EML laser diode to achieve a transmission distance of up to 40 km over standard single mode fibre, and an Extreme Compatible 1000Base-LX GBIC Transceiver. This consists of a transmitter section incorporating an advanced FP laser diode and a receiver section which has an integrated InGaAs detector preamplifier (IDP) mounted in an optical header and a limiting post-amplifier IC.

Anadigics ‘ PAs power new ZTE Android smartphones

The devices are manufactured using the firm’s unique indium gallium phosphide HBT technology

Anadigics is shipping production volumes of its AWT6621, AWT6624, AWT6625A, and AWT6628A fourth generation High-Efficiency-at-Low-Power (HELP4) power amplifiers (PAs) to ZTE.

The devices will be used in ZTE’s V889D, V788D, N788, N910, and PF200 smartphones.

The V788D, N788, N910, and PF200 feature a 3.5-inch screen, 5 megapixel camera, and Android 2.3 Gingerbread operating system. The V889D has a 4-inch screen and Android 4.0 Ice Cream Sandwich operating system.

The ZTE V889D is powered by the AWT6621 and AWT6628A power amplifiers and the V788 is enabled by the AWT6621 power amplifier (PA).

ZTE's N788 features Anadigics' AWT6625A power amplifier. The N910 is powered by the AWT6624. and the PF200 is powered by the AWT6624.

"We look forward to working with ZTE as it continues to develop innovative smartphones for the global wireless market," says Michael Canonico, senior vice president of worldwide sales at Anadigics.

"The strength of our product portfolio coupled with our Asia-centric strategy demonstrates Anadigics' commitment to both product and service excellence. Our world-class applications centres in China further support Anadigics' growth initiative."

Anadigics' HELP4 4G PAs use the Company's proprietary InGaP-Plus technology to achieve optimal efficiency across low-range and mid-range output power levels and provide the lowest quiescent currents in the industry.

The AWT6621, AWT6624, AWT6625A, and AWT6628A power amplifiers are suited to WCMDA, HSPA and HSPA+ systems. They are designed to extend battery life in handsets, smart phones, tablets, netbooks, and notebooks.

Anadigics says its HELP4 PAs reduce average current consumption by 30%, compared with previous generation PAs. They also have three mode states to achieve excellent power-added efficiencies at low-range and mid-range output power levels and have a quiescent current of less than 4 mA.

In a 3 mm by 3 mm footprint, the devices display very good linearity at maximum output power and feature internal voltage regulation. They also have an integrated "daisy chainable" directional RF coupler with 20dB directivity.

Transmission in Asia speeds up with Infinera 500 Gb/s InP PICs

A trial showcasing long haul, high-bandwidth optical network transmission across 4,500 km of Pacnet's C2C subsea network employs Infinera's indium phosphide based PIC and FlexCoherent super-channels

Pacnet and Infinera have completed a joint effort demonstrating the successful transmission of more than 3 Tb/s of capacity over 4,500 km of Pacnet's C2C network.

The testing was conducted with Infinera's DTN-X platform, which has begun shipping this quarter and also demonstrated the ability to use FlexCoherent technology to software select the modulation format in order to optimise fibre capacity and reach.

Pacnet owns and operates the pan-Asian submarine cable network touching 21 cable landing stations and extends from India to the U.S. At the heart of this network is EAC-C2C, one of Asia's largest fibre optic submarine cable networks, which spans 36,800 km and serves customers worldwide.

"We are impressed with Infinera's DTN-X platform delivering 500 Gb/s FlexCoherent super-channels and integrated OTN switching without compromise," says Bill Barney, Pacnet CEO.

"Pacnet is dedicated to offering our customers leading-edge communications services across the Pacific Rim. We accomplish this by collaborating

with one of the industry's most innovative suppliers enabling us to build technologically advanced networks globally. This successful test with Infinera demonstrates that Pacnet's network can scale up with the industry's latest high speed optical technologies to deliver faster services to our customers," he adds.

"Long-haul capable 500Gb/s super-channels are critical for carrier networks, especially in submarine applications such as Pacnet," adds Tom Fallon, Infinera CEO. "In fact, the real value of Infinera's DTN-X goes well beyond its sheer size and bandwidth efficiency. The true value is its ability to future proof our customer's most valuable asset, their fibre infrastructure, so they can continue to flexibly grow their network to accommodate wherever their customer demand takes them."

Firecomms takes on fibre communication veteran as CEO

The producer of devices such as 650nm III-V based VCSELs is taking on Hsin Chia to drive strategic expansion of the firm

Firecomms, a developer of fibre optic components, has appointed Hsin Chia, an influential member of the fibre communications industry as CEO.

Hsin Chia, Firecomms CEO

Chia brings a wealth of knowledge and experience to Firecomms that will enable him to drive the company's strategic expansion in its focus markets.

Prior to joining Firecomms, Chia led the cross-functional team at GLOBALFOUNDRIES that developed the company's strategic direction and operational initiatives. He also developed the Industrial Fibre Product division at Avago and drove the product development and manufacturing of cutting edge photonic products in the Optical Networking division of Agilent.

"Since its foundation, Firecomms has opened new markets and developed highly innovative new products for Plastic Optical Fibre," says Chia. "As the company's successful development of the home networking market has been very impressive, I am immensely excited to lead this talented team as we continue to expand and build on this momentum."

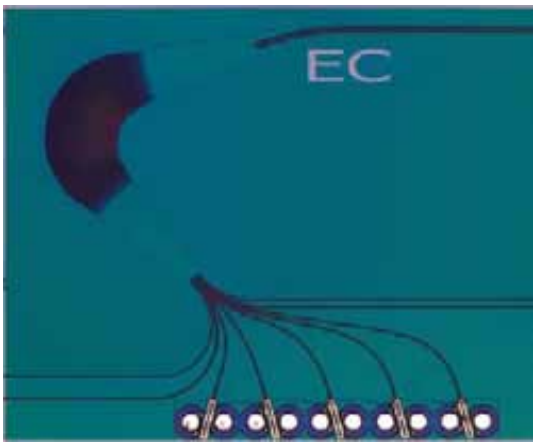
Chia's immediate focus will be on China, where Firecomms has recently expanded its business, and in accelerating the release of innovative new products currently in the pipeline. These will include products like the company's recently announced new Gigabit transceiver, for coupling into POF and large core silica fibres.

Firecomms, a supplier of high-speed optical components optimised for Plastic Optical Fibre , designs and manufactures fibre optic transceivers that drive home, industrial and automotive communication networks.

OneChip shows off its new 40 and 100GBASE InP PIC receiver chips

These indium phosphide chips should enable transceiver manufacturers to address short and intermediate reach, long-wavelength data communications applications more cost-effectively and efficiently than ever before

In the second half of this year, OneChip Photonics will make available engineering samples of its Photonic Integrated Circuit (PIC)-based 40GBASE-LR4 and 100GBASE-LR4 receiver chips for partner testing.



OneChip's 100GBASE-LR4 integrated receiver, which includes a spot-size converted input optical port, an AWG (Arrayed Waveguide Grating) wavelength division multiplexer and 4x25Gbps WPDs (Waveguide PhotoDetectors) at its four output electrical ports

These PIC-based receiver chips, monolithically integrated onto a single InP-based chip, all have the active and passive optical components required to receive 40GBASE-LR4 or 100GBASE-LR4 signals .

They are suited to transceiver manufacturers to address a wide reach range (up to 10km), long-wavelength (around 1300 nm) and data communications applications, including high-density interfaces for next-generation data centre interconnects (NG DCI). OneChip says these chips are far more cost-effective and efficient than other competing devices.

"OneChip's breakthrough PIC technology has proven to be a valuable solution for the very cost-sensitive, high-volume Fibre-to-the-Home market, and we now are extending that technology to the data communications market," says Valery Tolstikhin, Founder and CTO of OneChip Photonics.

"By offering fully integrated receiver and transmitter PICs, we are demonstrating that InP-based wavelength division multiplexing (WDM) components can meet very aggressive cost and footprint points in the data communications market, overall, and in NG DCI applications, in particular."

Karen Liu, Principal Analyst for Components at market research firm Ovum, adds, "The industry is in the midst of switching gears from raw device speed to photonic integration, as optical interconnect speeds reach 40Gbps, 100Gbps and beyond. PIC chips like OneChip's offering will be critical to enable the required cost and density for transceiver and system solutions addressing exploding communications needs in a wide variety of applications."

OneChip also expects to make engineering samples of its 40GBASE-LR4 transmitter optical components and 100GBASE-LR4 single-chip transmitter PICs available around the end of the year, after the release of its PIC-based receiver chips.

The 40GBASE-LR4 transmitter components will include spot-size converted DFB directly modulated lasers at 1271, 1291, 1311, and 1331 nm wavelengths, with integrated monitor photodiodes. The 100GBASE-LR4 transmitter PICs will integrate 4 DFB-EAM externally modulated lasers operating in the 1300 nm window on 800GHz spacing at 25Gbps each, monitor diodes, a WDM combiner, and spot size converter on a single chip.

OneChip says its PIC-based 40GBASE-LR4 and 100GBASE-LR4 integrated receiver chips will cost significantly less to package and manufacture than competing hybrid integration and silicon photonics products, and the chips will have the smallest footprint on the market. OneChip anticipates these PICs will enable LR4 transceivers cost effective enough to be used at short and intermediate range applications in the data centre.

GaAs pHEMT SP3T switch for communication systems

A new high performance gallium arsenide device has been revealed by RFMD

RFMD's new RFSW6131 is a GaAs *p*HEMT Single-Pole Three-Throw (SP3T) switch designed for use in Cellular, 3G, LTE, and other high performance communications systems.

RFSW6131

The device has a symmetric topology and RFMD boasts that it offers excellent linearity and power handling capability. The module is 3V and 5V positive logic compatible and features LF to 6000MHz operation. At 2GHz , it has a low loss of 0.5dB at and an isolation of 27dB .

The RFSW6131 has a high IP3 of 56dBm P0.1dB: 31dBm (at 5V, and 2.2GHz). and comes in a 1.5mm x 1.5mm package.

The device is suited to cellular, 3G, LTE infrastructure applications and WiBro, WiMAX, LTE. It can also be used in wireless backhaul and in GMSK, QPSK, DQPSK and QAM modulation.

The RFSW6131 is currently available in production quantities. Pricing begins at $0.60 each for 1000 pieces.

Renesas markets hardy optocoupler

The device features an aluminium gallium arsenide LED and is suited to harsh application environments like motor control, measuring instruments as well as factory automation

Renesas has revealed a new device which can be used a number of applications. The PS9905 can employed as an IGBT, power MOSFET gate driver and also as a Industrial and solar inverter.

Equipped with a MOSFET-MOSFET output, the PS9905 allows efficient and safe IGBT control. A galvanic isolated AlGaAs LED at input and a photo diode with signal processing circuitry and power amplifier at the output not only allow high switching speeds but also up to 2.5 A output current.

The maximum propagation delay time (tPLH or tPHL) of 0.15µs is guaranteed over the complete operating temperature range from -40 °C to +110 °C.

PS9905

The new IC-output optocoupler has an extra-long creepage distance of 14.5 mm and can be used in applications such as industrial equipment employing the maximum commercial power supply voltage of 690 V or solar power generation systems employing high voltages of up to 1,000 V.

The PS99XX Series devices are housed in a novel 8-pin Long-SDIP (LSDIP) package, which combines the small pin pitch (1.27 mm) with increased distance between the input and the output. Thus despite small space requirement, very good isolation properties are achieved. The device is specified for an isolation voltage of 7500 Vrms.

The module complies with the international safety standards such as UL, CSA, and VDE (optional) making it ideally suited for deployment in harsh application environments like motor control, measuring instruments as well as factory automation.

The PS9905 optocoupler has a high common-mode transient rejection of 25 kV/µs (MIN.) allowing an error free transmission of the control signals

through the isolation layer.

CyOptics selects Verian to enhance SAP functionality

The indium phosphide chip manufacturer has will employ the Verian system as a requisitioning and approval workflow tool that integrates directly into SAP

Verian is providing requisition and workflow automation solutions to CyOptics, an innovator of InP optical chips and components.

“Our employees needed a faster and easier way to make requisitions and route them for approval,” says Kim Leader, Procurement Director for CyOptics. “The Verian system will serve as a requisitioning and approval workflow tool that integrates directly into SAP.”

CyOptics designs, develops and markets a full line of InP optical chips and components for integration into access, metro and long-haul communications. The company’s products are enabled by an automated “nano-tech”-capable manufacturing process that delivers excellent performance, uniformity and cost.

“We’re seeing a growing demand in the marketplace for a requisitioning and approval workflow tool that integrates easily with SAP, Oracle or other ERP systems,” notes Ganesh Sundaresan, Senior Product Manager for Verian.

“In fact, CyOptics will be the third customer this year to integrate Verian’s requisitioning and approval workflow solutions into SAP. Organisations are finding Verian’s solutions are much easier to learn and adopt than tools within the major ERP systems.”

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RFMD reveals InGaP/ GaAs 2.5GHz to 2.7GHz FEM

The FEM uses the firm’s indium gallium phosphide and gallium arsenide technologies

RFMD has introduced the new RFFM7600 FEM for 2.5GHz to 2.7GHz LTE/WiMAX.

The Front End Module (FEM) employs the firm’s proprietary InGaP HBT and GaAs *p*HEMT technologies.

RFFM7600

It contains an integrated 3-Stage Power Amplifier with Tx harmonic filtering and Tx/Rx switching. and operates at a single supply voltage of 5.0V and a typical gain across frequency band of 35dB. The device comes in a 6mm x 6mm laminate package, incorporating surface mounted devices for filtering and matching.

It is suited to applications such as customer premises equipment, data cards and terminals as well as spread-spectrum and MMDS systems.

This product is now available in production quantities. Pricing begins at $4.96 each for 100 pieces.

Avago and TriQuint bury the hatchet on BAW filters

The designer and developer of analogue III-V semiconductor devices and the gallium arsenide and gallium nitride innovator have come to an agreement to cross licensing patents
Avago Technologies, a supplier of analogue interface components for communications, industrial and consumer applications, and RF solutions supplier TriQuint Semiconductors have agreed to settle all claims between the companies concerning intellectual property for bulk acoustic wave (BAW) filters. The two parties have entered into patent cross licenses and have agreed to dismiss all related litigation. The specific terms of the settlement and the resulting licensing agreement are confidential. "We are pleased to have reached an amicable resolution with TriQuint," says Hock Tan, President and CEO of Avago Technologies Limited. "We are happy to have successfully put this litigation behind us," adds Ralph Quinsey, CEO of TriQuint Semiconductor, Inc.

Global semiconductor sales escalate

A new report says silicon manufacturer Broadcom and compound semiconductor supplier TriQuint are good examples that illustrate that the semiconductor industry is bouncing back

The semiconductor stock market has not done too badly this year, thanks to the growing demand for tablets and smartphones.

The mobile market relies on both silicon and compound semiconductor devices although silicon dominates in many of these areas.

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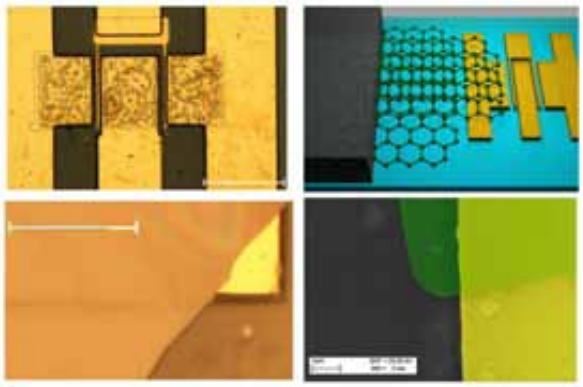
How to cool high-power GaN semiconductor devices

Latest developments in gallium nitride will be used in wireless applications, traffic lights and electric cars

A group of researchers at the University of California, Riverside Bourns College of Engineering have developed a technique to keep cool a semiconductor material used in everything from traffic lights to electric cars. GaN semiconductor materials have been used in bright lights since the 1990s, and are now used in wireless applications due to high efficiency and high voltage operation. However, the applications and market share of GaN electronics is limited because it is difficult to remove heat from them. That could change due to a technique developed by the Nano-Device Laboratory research group led by Alexander Balandin, professor of electrical engineering and founding chair of Materials Science and Engineering program. The research group demonstrated that hot spots in GaN transistors can be lowered by as much 200C through the introduction of alternative heat-escaping channels implemented with graphene multilayers, which are excellent heat conductors. The temperature reduction translates to an increase in the lifetime of the device by a factor of ten. "This represents a transformative change in thermal management," Balandin says. The new approach to thermal management of power electronics with graphene was outlined in a paper "Graphene quilts for thermal management of high-power GaN transistors" that was published on May 8th in Nature Communications.



Clockwise from top left: optical microscopy image of the high-power GaN heterostructure field-effect transistor (HFET); schematic of the graphene-graphite quilt on top of the transistor structure for spreading the heat from the local hot spot near the transistor drain; coloured SEM image of the graphene quilt overlapping transistor; optical microscopy image of the graphene quilt on the device electrode illustrating its flexibility

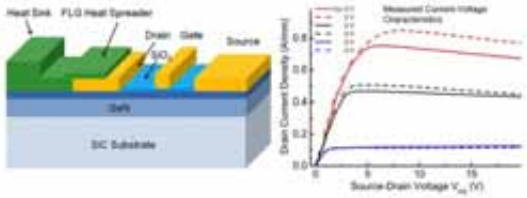
GaN transistors have been commercially available since 2006. The problem with them, like all high power operating devices, is the significant amount of dissipated heat, which has to be fast and efficiently removed. Various thermal management solutions such as flip-chip bonding or composite substrates have been attempted. However, applications have still been limited because of increases in temperature due to dissipated heat. The breakthrough in thermal management of GaN power transistors was achieved by Balandin and three of his electrical engineering graduate students: Guanxiong Liu, Zhong Yan, and Javed Khan, who started working at Intel Corporation this year. Balandin has previously discovered that graphene is an excellent heat conductor.

Few-layer graphene films preserve their excellent thermal properties even when their thickness is only a few nanometres, which is unlike metal or semiconductor films. The latter makes them excellent candidates for applications as the lateral heat spreaders and interconnects. The Balandin group researchers designed and built graphene-graphite “quilts” on top of GaN transistors.

The graphene-graphite quilts’ function was to remove and spread the heat from the hot spots – the opposite of what you expect from the conventional quilts.

From left to right: Guanxiong Liu, Alexander Balandin and Zhong Yan, who worked on the project

Using micro-Raman spectroscopic thermometry the researchers demonstrated that temperature of the hot spots can be lowered by as much 20 degrees Celsius in transistors operating at the large power levels.



From left, cross-sectional schematic of the GaN HFET with graphene quilt for heat spreading; current-voltage characteristics of GaN HFET with and without graphene-based heat spreaders demonstrating improvement in the saturation current due to lower junction temperature in the device with graphene quilt

The computer simulations performed by the group suggested that graphene quilts can perform even better in GaN devices on more thermally resistive substrates. The Balandin group is also known in graphene community for their investigation of low-frequency noise in graphene transistors, development of the first large-area method for quality control of graphene and demonstration of the first selective gas sensor implemented with pristine graphene.

The work on thermal management of GaN transistors with graphene quilts was supported by the Office of Naval Research. Balandin’s research of the thermal properties of graphene was funded by the Semiconductor Research Corporation and the Defence Advanced Research Project Agency.

CyOptics and Verian to enhance SAP InP functionality

Indium phosphide innovator CyOptics will use Verian to requisition and approve a workflow tool that integrates directly into Systems Applications and Products in Data Processing (SAP)

Verian is providing requisition and workflow automation solutions to CyOptics, a pioneer in InP optical chips and components.

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“We are excited to welcome CyOptics to the Verian family of customers,” concludes Tehseen Ali Dahya, President and CEO of Verian. “We look forward to helping CyOptics increase their visibility into SG&A expenditures.”

Say hello to millimetre wave GaN PAs

Millitech’s gallium nitride power amplifiers offer wideband power covering 75 GHz to 102 GHz Millitech is touting its next generation E-Band and W-Band compact and high power solid state power amplifiers.

Millitech GaN Power Amplifier

The GaN based power amplifiers represent a quantum leap in output power at E-Band and W-Band with up to 3 W of output power and up to 20% PAE available in standard models.

The new AMP models offer catered performance over specific allocated bands or wideband power covering 75 GHz to 102 GHz. The E-Band (WR-12) models cover the commercially allocated 71-76GHz and 81-86 GHz bands.

The W-band models cover 75-102 GHz Each amplifier has internal bias circuitry that generates gate control voltages, provides proper voltage sequencing and incorporates reverse voltage protection from a single positive external bias. Single device models are available with nearly 1W of saturated output power.

Standard models also include 2-way and 4-way Solid State Power Amplifiers with up to 3W of saturated output power.

Higher powers and other options are available when combined with diffferent models in the series.

RF Electronics

M/A-COM Technology Announces New 1 Watt Linear RF Driver Amplifier

M/A-COM Technology Solutions, a supplier of high performance analog semiconductor solutions, have introduced a new RF Driver Amplifier for MILCOM and infrastructure applications.

The MAAM-010617 is a 30dBm GaAs MMIC amplifier which exhibits high linearity over a wide input power range. Biased with a single +5V supply, the MAAM-010617 has a quiescent current of 420mA. The amplifier is tunable over the wide frequency range of 30 MHz to 4000 MHz, in order to optimize its performance based on the end application.

Packaged in a lead-free SOT-89 package, the MAAM-010617 is fabricated using an HBT process to realize a constant high linearity over a wide input power and frequency range. The operating bandwidth of this device can be optimized with selective off-chip components.

“The high linearity and frequency range of this part make it an ideal gain block in linear systems,” said Kevin Harrington, Aerospace and Defense Marketing Manager. “The SOT-89 standard package is a good thermally efficient package which is easy to handle during assembly for our customers.”
www.macomtech.com

Anadigics ‘ PAs power new ZTE Android smartphones

The devices are manufactured using the firm’s unique indium gallium phosphide HBT technology

Anadigics is shipping production volumes of its AWT6621, AWT6624, AWT6625A, and AWT6628A fourth generation High-Efficiency-at-Low-Power (HELP4) power amplifiers (PAs) to ZTE.

The devices will be used in ZTE’s V889D, V788D, N788, N910, and PF200 smartphones.

The V788D, N788, N910, and PF200 feature a 3.5-inch screen, 5 megapixel camera, and Android 2.3 Gingerbread operating system. The V889D has a 4-inch screen and Android 4.0 Ice Cream Sandwich operating system.

The ZTE V889D is powered by the AWT6621 and AWT6628A power amplifiers and the V788 is enabled by the AWT6621 power amplifier (PA).

ZTE’s N788 features Anadigics’ AWT6625A power amplifier. The N910 is powered by the AWT6624. and the PF200 is powered by the AWT6624.

“We look forward to working with ZTE as it continues to develop innovative smartphones for the global wireless market,” says Michael Canonico, senior vice president of worldwide sales at Anadigics.

“The strength of our product portfolio coupled with our Asia-centric strategy demonstrates Anadigics’ commitment to both product and service excellence. Our world-class applications centres in China further support Anadigics’ growth initiative.”

Anadigics’ HELP4 4G PAs use the Company’s proprietary InGaP-Plus technology to achieve optimal efficiency across low-range and mid-range output power levels and provide the lowest quiescent currents in the industry.

The AWT6621, AWT6624, AWT6625A, and AWT6628A power amplifiers are suited to WCMDA, HSPA and HSPA+ systems. They are designed to extend battery life in handsets, smart phones, tablets, netbooks, and notebooks.

Anadigics says its HELP4 PAs reduce average current consumption by 30%, compared with previous generation PAs. They also have three

mode states to achieve excellent power-added efficiencies at low-range and mid-range output power levels and have a quiescent current of less than 4 mA.

In a 3 mm by 3 mm footprint, the devices display very good linearity at maximum output power and feature internal voltage regulation. They also have an integrated “daisy chainable” directional RF coupler with 20dB directivity.

GaAs pHEMT SP3T switch for communication systems

A new high performance gallium arsenide device has been revealed by RFMD

RFMD’s new RFSW6131 is a GaAs *p*HEMT Single-Pole Three-Throw (SP3T) switch designed for use in Cellular, 3G, LTE, and other high performance communications systems.

RFSW6131

The device has a symmetric topology and RFMD boasts that it offers excellent linearity and power handling capability. The module is 3V and 5V positive logic compatible and features LF to 6000MHz operation. At 2GHz , it has a low loss of 0.5dB at and an isolation of 27dB .

The RFSW6131 has a high IP3 of 56dBm P0.1dB: 31dBm (at 5V, and 2.2GHz). and comes in a 1.5mm x 1.5mm package.

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TriQuint announces $50 million stock repurchase program

Under this program, stock repurchases may be made from time to time in the open market at prevailing market prices or through privately negotiated transactions at the discretion of Company management

TriQuint Semiconductor is authorising the repurchase of up to $50 million of the Company’s common stock through May 2nd, 2013.

The timing of open market and privately negotiated purchases will be dependent on market conditions and other corporate considerations, including price, corporate and regulatory requirements and alternative investment opportunities.

The program is expected to be funded from existing cash balances and cash generated from operations. The Company is not obligated to repurchase any particular amount of common stock during any period and may choose to suspend or discontinue the repurchase program at any time.

Shares of common stock repurchased by the Company through the repurchase program will become authorised but unissued shares. As of May 3rd, 2012, the Company has approximately 168.2

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Lasers

A new transceiver for 10GBASE-SR XENPAK applications

The transmitter section incorporates a 1550nm FP laser diode and the receiver section uses an integrated indium gallium arsenide detector preamplifier

GAO Comm has released a 10GBASE-SR XENPAK transceiver which can be used in switches and modules that support XENPAK transceivers.

10GBASE-SR XENPAK fibre optic transceiver

This company says its high performance 10GBASE-SR XENPAK transceiver, model C018XX01, is a fully integrated 10.3Gbit/s optical transceiver module that consists of an 850 nm wavelength optical transmitter and receiver, XAUI interface, Mux and Demux with clock and data recovery (CDR).

It is hot Z-pluggable and features up to 10.3 GBd bi-directional data links and RoHS compliance.

This transceiver uses an 850 nm VCSEL laser diode to achieve a transmission distance of up to 300 m over 50/125 multi-mode fibre. It also allows for MDIO and DOM and has SC connectors.

This 10GBASE-SR XENPAK transceiver belongs to GAO's family of Extreme compatible transceivers. This line includes a wide variety of Extreme compatible transceivers such as Extreme Compatible 10GBASE-ER XENPAK Transceivers.

The latest addition to the family uses a cooled 1550 nm EML laser diode to achieve a transmission distance of up to 40 km over standard single mode fibre, and an Extreme Compatible 1000Base-LX GBIC Transceiver. This consists of a transmitter section incorporating an advanced FP laser diode and a receiver section which has an integrated InGaAs detector preamplifier (IDP) mounted in an optical header and a limiting post-amplifier IC.

Using a single nanomaterial to create a multi-colour laser

The lasers are nanometre-sized semiconductor particles called colloidal quantum dots (CQDs) with an inner core of cadmium and selenium alloy and a coating of zinc, cadmium, and sulphur alloy. Adjusting the size of the pyramid-shaped QDs changes the laser light colour

Engineers at Brown University and QD Vision have created nanoscale single crystals that can produce red, green, or blue laser light needed in digital displays.

The size determines colour, but all the pyramid-shaped quantum dots are made the same way of the same elements. In experiments, light

amplification required much less power than previous attempts at the technology. The team's prototypes are claimed to be the first lasers of their kind.

Red, green, and blue lasers have become small and cheap enough to find their way into products ranging from BluRay DVD players to fancy pens. But each colour is made with different semiconductor materials and by elaborate crystal growth processes.

Now a new innovative technology demonstrates all three of those colours coming from one material. That could open the door to making products, such as high-performance digital displays, that employ a variety of laser colours all at once.

VCSEL colloidal quantum dots, also known as nanocrystals, can produce lasers of many colours. Cuong Dang manipulates a green beam that pumps the nanocrystals with energy, in this case producing red laser light. (Credit: Mike Cohea/ Brown University)

"Today in order to create a laser display with arbitrary colours, from white to shades of pink or teal, you'd need these three separate material systems to come together in the form of three distinct lasers that in no way shape or form would have anything in common," notes Arto Nurmikko, professor of engineering at Brown University and senior author of a paper describing the innovation. "Now enter a class of materials called semiconductor quantum dots."

The materials in prototype lasers described in the paper are nanometre-sized semiconductor particles called colloidal quantum dots (CQDs) or nanocrystals with an inner core of cadmium and selenium alloy and a coating of zinc, cadmium, and sulphur alloy and a proprietary organic molecular glue.

Chemists at QD Vision synthesised the nanocrystals using a wet chemistry process that allows them to precisely vary the nanocrystal size by varying the production time. Size is all that needs to change to produce different laser light colours: 4.2 nm cores produce red light, 3.2 nm ones emit green light and 2.5 nm ones shine blue. Different sizes would produce other colours along the spectrum.

The cladding and the nanocrystal structure are critical advances beyond previous attempts to make lasers with colloidal quantum dots, said lead author Cuong Dang, a senior research associate and nanophotonics laboratory manager in Nurmikko's group at Brown. Because of their improved quantum mechanical and electrical performance, he said, the coated pyramids require 10 times less pulsed energy or 1,000 times less power to produce laser light than previous attempts at the technology.

Quantum nail polish

When chemists at QDVision brew a batch of colloidal quantum dots for Brown-designed specifications, Dang and Nurmikko get a vial of a viscous liquid that Nurmikko said somewhat resembles nail polish.

To make a laser, Dang coats a square of glass, or a variety of other shapes, with the liquid. When the liquid evaporates, what's left on the glass are several densely packed solid, highly ordered layers of the nanocrystals. By sandwiching that glass between two specially prepared mirrors, Dang creates one of a VCSEL. The Brown-led team says it was the first to make a working VCSEL with colloidal quantum dots.

The nanocrystals' outer coating alloy of zinc, cadmium, sulphur and that molecular glue is important because it reduces an excited electronic state requirement for lasing and protects the nanocrystals from a kind of crosstalk that makes it hard to produce laser light, Nurmikko says. Every batch of colloidal quantum dots has a few defective ones, but normally just a few are enough to interfere with light amplification.

Faced with a high excited electronic state requirement and destructive crosstalk in a densely packed layer, previous groups have needed to pump their dots with a lot of power to push them past a higher threshold for producing light amplification, a core element of any laser.

Pumping them intensely, however, gives rise to another problem: an excess of excited electronic states called excitons. When there are too many of these excitons among the quantum dots, energy that could be producing light is instead more likely to be lost as heat, mostly through a phenomenon known as the Auger process.

The nanocrystals' structure and outer cladding reduces destructive crosstalk and lowers the energy needed to get the quantum dots to shine. That reduces the energy required to pump the quantum dot laser and significantly reduces the likelihood of exceeding the level of excitons at which the Auger process drains energy away. In addition, a benefit of the new approach's structure is that the dots can act more quickly, releasing light before Auger process can get started, even in the rare cases when it still does start.

"We have managed to show that it's possible to create not only light, but laser light," Nurmikko says. "In principle, we now have some benefits: using the same chemistry for all colours, producing lasers in a very inexpensive way, relatively speaking, and the ability to apply them to all kinds of surfaces regardless of shape. That makes possible all kinds of device configurations for the future."

The US. Department of Energy, the Air Force Office for Scientific Research, and the National Science Foundation supported the research. Dang is a Vietnam Education Foundation (VEF) Scholar.

Further details of this work has been published in the paper,"Red, green and blue lasing enabled by single-exciton gain in colloidal quantum dot films", by Dang *et al*, *Nature Nanotechnology*, 7, 335–339 (2012). DOI:10.1038/nnano.2012.61

VI Systems reveals 40 Gbit/s 850nm VCSEL with HAB pad contacts

The new product line of high speed 850nm gallium arsenide based VCSEL chips are compact and have an ultrahigh modulation rate
VI Systems has launched a new product line for high speed VCSEL chips with a data rate of up to 40 Gbit/s. VIS' new generation of high-speed 850 nm VCSELs and VCSEL arrays (1 x 4 and 1 x 12) feature an ultrahigh -3 dB modulation bandwidth of 20 GHz and a novel HAB contact pad design that overcomes the problems of thick and soft planarisation layers, characteristic to high-speed VCSEL designs, and enables ultra-robust bonding and packaging. VIS says its novel manufacturing approach and array designs are in compliance with the standard 250 µm device-to-device pitch (linear spacing) allowing systems developers to dramatically extend their capabilities in energy efficient data communication. Die-level samples are available now.

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Emcore completes sale of VCSEL product lines to SEDU

The product lines include VCSEL and photodiode components, parallel optical transceiver modules, and active optical cables

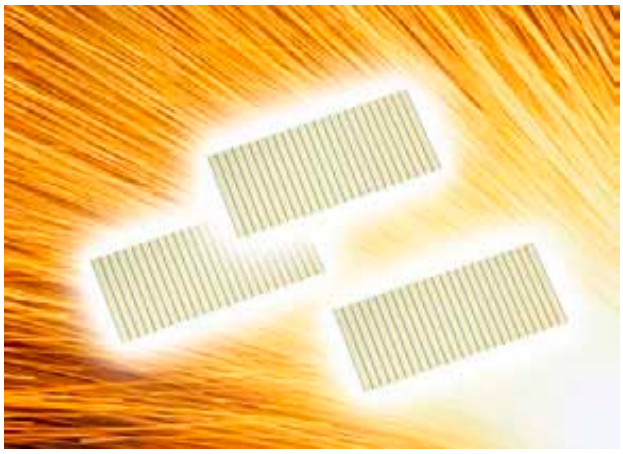
Emcore Corporation has completed the sale of its Vertical Cavity Surface Emitting Lasers (VCSEL)-based product lines to Sumitomo Electric Device Innovations U.S.A., Inc. (SEDU), a subsidiary of Sumitomo Electric Industries, Ltd. (SEI).

As previously disclosed, SEI agreed to pay $17 million in cash for the fixed assets, inventory and intellectual property of the VCSEL-based product lines within Emcore’s fibre optics business unit, subject to closing adjustments.

Osram Opto introduces turbo charged industrial lasers

The company’s new III-V based laser bar family offers 200 W continuous power and an efficiency of up to 65 percent

Osram Opto says its new laser bars can simplify the design of laser systems and reduce their cost. Laserline are now using laser bars from Osram Opto Semiconductors as the core of its latest and most powerful fibre-coupled diode laser series for industrial material processing. The complete system is water-cooled and supplies between 2 and 15 kW power via a fibre with a core diameter of 1 to 2 mm. The overall efficiency reaches maximum levels of more than 40 percent.



Laser bar series SPL BKxx-40WFT

The laser bar series SPL BKxx- 40WFT produces infrared radiation in various wavelengths, ranging from 915 to 1020 nm. As a result of their efficiency values of up to 65 percent, the bars achieve a long operating lifetime of up to 30,000 hours and meet the requirements for industrial laser systems.

The dimension bar width is 10 mm with a cavity length of 4 mm. Besides the optical pumping of fibre lasers, direct material processing, for example welding and cutting of metals in the automotive industry, is one of the main applications of infrared lasers with more than 1 kW power. Direct diode lasers are one of the most efficient laser light sources for such fibre-coupled systems and are a suitable alternative for the previously often used though less efficient carbon dioxide lasers.

Michael Klein, Marketing Manager for laser bars with Osram Opto Semiconductors, emphasises, “Our developments in the field of laser bars push the utilisation of direct diode lasers into ever higher power ranges, thus enabling our customers to open up new markets.

The end-users benefit from the improved technology, e.g. lower investment cost because less laser bars are required to generate the needed power. Furthermore, the cost for electricity and maintenance will also decrease due to high efficiency and long operating lifetime.” This laser has been developed on the basis of results, which Osram Opto Semiconductors discovered in the project HEMILAS, supported by the German Federal Ministry of Education and Research. The main results were the efficiency optimised structure of epitaxy layers and improved mirror technologies with a high damage threshold.

Solar

MiaSolé CIGS large module raises the bar with 15.5% efficiency

The firm says the latest efficiency gains in large area flexible PV modules has set a new industry benchmark

CIGS developer MiaSolé, has announced that the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) has confirmed a 15.5 percent aperture area efficiency on one of its commercial size flexible PV modules.

MiaSolé says this result, for the module measuring 1.68m2, represents over two points of improvement compared to the previous world record for flexible PV of 13.4% set earlier this year.

"Achieving 15.5 percent efficiency is a clear validation of MiaSolé's unique and innovative approach to delivering high efficiency CIGS flexible cell technology," says John Carrington, CEO of MiaSolé.

"MiaSolé's world leading efficiency and low cost flexible PV technology demonstrates the potential of CIGS compared to silicon-based and other thin film technologies."

MiaSolé believes its proprietary cell technology is creating new and compelling opportunities for its customers by bringing high efficiencies to flexible applications. Companies in the building, vehicle and fabric integrated PV markets that were previously unable to realise the potential of solar, can now explore new and innovative applications for high efficiency, flexible solar panels.

"Along with our current capacity to deliver 14.5 percent glass modules, the NREL verification of our flexible modules highlights the progress we are continuously making against our efficiency roadmap and goal of delivering the lowest levelised cost of electricity to our customers," adds Carrington.

The cells for the device were made using MiaSolé's existing production lines in Santa Clara, California. The firm's large area flexible PV module was submitted for evaluation by NREL as part of the company's ongoing process for third party verification.

SoloPower secures another $7.1 million for CIGS development

The CIGS solar panel manufacturer should do well although prices of conventional silicon solar panels are continuing to shrink

CIGS Solar firm SoloPower is building and staffing a $340 million manufacturing facility in North Portland.

The company last year finalised a $197 million loan guarantee.

The firm says the $20 million round of debt and options closed in December by SoloPower CEO Tim Harris was a "critical step" towards completing the Portland facility. This week's financing is a follow-up to the December round.

SoloPower has a number of investors, which include Hudson Clean Energy Partners and Crosslink Capital.

While there have been a number of high-profile loan guarantee-backed flameouts, such as Solyndra, Harris has been adamant that SoloPower is advancing quickly and will be successful.

SoloPower reckons its flexible CIGS solar panels are lighter and easier to install than rack-mounted arrays of silicon-based photovoltaics.

But as Greentech Media's Eric Wesoff points out, the company is wading into a so far unproven market and with the price of conventional silicon solar panels continuing to shrink, its value proposition may be on the decline as well.

EpiGaN starts production of gallium nitride epitaxial material

The new production site of EpiGaN officially opened today in the presence of Flemish Minister Mrs Ingrid Lieten and Limburg Governor Mr Herman Reynders. The company selected the Research Campus Hasselt as the ideal location for the volume production of their gallium nitrid- on-silicon epitaxial material.

EpiGaN is one of the key players in GaN-on-Silicon materials technology. The firm says GaN-on-Silicon will enable a new generation of power electronics, with performance far beyond current silicon technology. This material system will ensure more efficient energy use in power convertors, better power supplies for computers, motor drivers, inverters for solar energy technologies and greener transport with a smaller environmental footprint. EpiGaN is currently offering GaN epitaxial layers deposited either on silicon up to 150 mm or, for specific applications, on SiC. Wafer diameters of 200mm are under development. The availability of large wafers which can be processed in existing silicon CMOS fabs partly explains how GaN-on-silicon technology combines affordability with great performance.

Today EpiGaN is officially opening its production unit at the Research Campus Hasselt (RCH), located within the knowledge triangle Eindhoven-Leuven-Aachen. EpiGaN found there the necessary framework for installing its cleanroom facilities as required for the production of GaN-on-Silicon, while the location in the heart of Europe allows for establishing their business on an international level. Today, EpiGaN employs 6 people and is currently hiring more engineers and sales personnel to support its growing production effort. Last year, EpiGaN sampled its first wafers to Europe, US and Asia.

The company is now takinga new step in ramping up its capacity. “We are very happy that the current installation will allow us to better serve our customers and new-comers in the field of GaN-on-Silicon market for electronics”, says Marianne Germain, CEO EpiGaN. “This is right at the time that device manufacturers are looking for getting access to this new technology, key for their future applications.” Ingrid Lieten, Vice Minister-President of the Flemish Government, adds, “EpiGaN is an outstanding example of what a strategic research institute can and must encompass: Imec has developed an innovative and state-of-the-art technology, the applications of which can lead to the solution of important challenges for society such as the energy issue and mobility. This technology has been transferred to EpiGaN. Moreover, this spin-off has a beneficial effect on employment.” About EpiGaN EpiGaN was incorporated in 2010 by Marianne Germain, CEO, Joff Derluyn, CTO, and Stefan Degroote, COO, as a spin-off from imec. In 2011, the company was joined in its venture by a strong consortium of investors, formed by Robert Bosch Venture Capital, Capricorn CleanTech Fund and LRM, enabling the installation of a new production facility. EpiGaN focuses on providing III-nitride epitaxial material solutions for top performance devices. The firm gives device manufacturers access to technology used in market segments such as power supplies for consumables, hybrid electric vehicles, solar inverters, RF power for base stations and smart grid.

First CdTe solar panel installed on world`s largest solar project

First Solar cadmium telluride modules are being installed at the Topaz solar farm and will create 400 construction jobs during its three-year construction period
Less than two weeks after an official ceremony, MidAmerican Solar and First Solar marked another milestone at Topaz Solar Farms, located in San Luis Obispo County, California. On Wednesday, the first solar panel was installed on what is claimed to be the largest solar project under construction in the world. When complete, the 550-MW AC project will include nearly 9 million CdTe photovoltaic panels. To mark the event, the first solar panel was installed by Greg Abel, chairman, president and CEO of MidAmerican Energy Holdings Company, and Walter Scott, Jr., who serves on the boards of directors for Berkshire Hathaway and MidAmerican.

“The installation of this first solar panel is more than symbolic,” says Paul Caudill, president of MidAmerican Solar. “It represents nearly five months of hard construction work put in by a dedicated crew of crafts persons and on-site

supervision, a large majority of whom live in the local area. They are helping us achieve our goal of safely and reliably delivering energy to our customer, Pacific Gas and Electric Company, all while adhering to our core value of respect for the environment."

On May 3rd, MidAmerican Solar and First Solar held a ceremony at the project site to discuss the project's construction schedule, environmental values and community-centred plans for the future with local and state leaders and landowners. The Topaz project will create approximately 400 construction jobs during its three-year construction period.

It will generate nearly $417 million in local economic impact, the majority of which will be generated during construction; and will provide California with renewable electricity. The Topaz project will provide enough energy to power approximately 160,000 average California homes.

"We're very pleased that Topaz has progressed rapidly to the module installation phase," says Jim Lamon, First Solar senior vice president of engineering, procurement and construction, and operations and maintenance.

"We're proud to be working with an energy leader like MidAmerican Solar in bringing utility-scale renewable generation to our country's power grid." The Topaz project is owned by MidAmerican Solar and will be constructed, operated and maintained by First Solar. Construction began in late 2011 and is expected to be complete by early 2015. PG&E will purchase the electricity from the Topaz project under a 25-year power purchase agreement, helping California meet its mandate to generate 33 percent of its power from renewable sources by 2020.

"PG&E is pleased to mark this project milestone with MidAmerican Solar and First Solar," adds John Conway, senior vice president of energy supply for PG&E. "Solar projects such as Topaz will allow us to continue to deliver one of the cleanest energy portfolios in the nation to our customers and help the state meet its green energy goals."

First Solar's CdTe thin-film PV modules generate electricity with no emissions, waste or water use and its systems have the smallest carbon footprint of any PV technology. Each module is approximately 4 feet by 2 feet and weighs 27.5 pounds. Electricity generated by the Topaz project will displace approximately 377,000 metric tons of CO2 per year — the equivalent of taking approximately 73,000 cars off the road.

First Solar's pre-funded collection and recycling program provides a responsible end of life for the PV panels. Over 90 percent of the material is re-used. Less than two weeks after an official ceremony, MidAmerican Solar and First Solar marked another milestone at Topaz Solar Farms, located in San Luis Obispo County, California. On Wednesday, the first solar panel was installed on what is claimed to be the largest solar project under construction in the world. When complete, the 550-MW AC project will include nearly 9 million CdTe photovoltaic panels. To mark the event, the first solar panel was installed by Greg Abel, chairman, president and CEO of MidAmerican Energy Holdings Company, and Walter Scott, Jr., who serves on the boards of directors for Berkshire Hathaway and MidAmerican.

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SolFocus takes on Solar Junction III-V modules for 5 MW order

The firm's compound semiconductor multi-junction solar energy cells will be deployed in California

Solar Junction has signed an agreement with SolFocus for a 5 megawatt (MW) order.

"It is great to see growth in the sales and manufacturing sides at Solar Junction. It's an indication that, 'technical' innovation in solar, will win the day," says Jim Weldon, CEO of Solar Junction. "Our multi-junction solar cell technology provides the pathway to higher efficiency leading to higher performance for CPV system end users."

Solar Junction is continuing to develop high-efficiency solar cells to enhance the competitiveness of concentrated photovoltaics. An optimised cell directly correlates to module performance enhancements and a higher efficiency cell drives LCOE towards grid parity.

"This order evidences SolFocus' confidence in Solar Junction and its cell technology, as the companies work to make CPV cost-competitive and sustainable with quality products," notes Bob Legendre, President and COO of SolFocus.

In March, SolFocus announced a 50 MW project in Baja California, Mexico. The 50 MW project is the first tranche of a planned 450 MW capacity for the facility. Construction is scheduled to begin in late 2012.

Solar Junction's announcement falls on the heels of a SUNPATH award from the U.S. Department of Energy. SUNPATH is part of the DOE's SunShot Program, which aims to increase PV manufacturing in the U.S. through investments in technologies that are sustainable with competitive cost and high performance. The $21.5 million from the SUNPATH award is being used by the firm to achieve 42% median cell efficiency on 150 mm substrates and increase manufacturing capacity

Earlier this year, Solar Junction signed a manufacturing agreement with IQE and continues on a path to ramp up high-volume manufacturing of its multi-junction solar

Ascent Solar CIGS modules to power Chinese railways

The company is working with TSDI and Radiant to deploy its modules in existing and future railway stations

Ascent Solar Technologies has entered into a three way strategic joint development agreement with Shenzhen Radiant Enterprise (Radiant) and Third Railway Survey and Design Institute Group

Corporation (TSDI) of China.
Under the agreement, TSDI will promote the use of leading-edge solar technology in China's rapidly growing public railway infrastructure by installing Ascent Solar CIGS modules on existing and future railway stations in China.

Radiant has been responsible for installing the roofing component on multiple railway station projects throughout China and is well positioned to execute the PV retrofitting of existing railway stations, as well as new installations. The total volume of solar installation on China's public infrastructure is projected to reach 800 MW over the next five years.

TSDI, a subsidiary of the China Railway Group, is a large-scale comprehensive survey and design corporation that has been appointed to build a uniform technical platform for China's national railway system.

TSDI ranks among China's Top 100 firms in terms of overall strength, and holds a Class-A Qualification certificate for Engineering Survey and Design from China's Ministry of Housing and Urban-rural Development. The organisation has designed over 50,000 km of railways in China, including the country's first high-speed railway and first heavy-haul railway. In addition, TSDI designed China's first modern, large-scale multi-modal transport hub, the Beijing South Railway Station.

Shenzhen Radiant Enterprise Co., Ltd., Ascent's strategic partner in East Asia and a pioneer in the metal roofing and façade industry in China, will work closely with Ascent and TSDI to design, engineer and install the solar systems.

"We are honoured to be involved with TSDI through this very important partnership, which will promote Ascent Solar's transformational technology in a high-profile sector of China's public infrastructure. This year, we look forward to working closely with TSDI and Radiant to design and develop systems to be installed beginning in 2013," states Victor Lee, Ascent Solar President and CEO.

Winston Xu, Founder of Shenzhen Radiant Enterprise Co., Ltd. and Ascent Solar Board Member,adds "China's state-of-the-art railway system is one of the largest and fastest growing in the world. Ascent Solar and Radiant Group feel privileged to work with TSDI towards the goal of incorporating green, renewable energy with this important piece of China's infrastructure."

According to the terms of the agreement, the three parties will begin system design and engineering development in the near term, with initial project installations beginning in 2013.

Opel begins trading in the U.S. on OTCQX International

The global supplier of solar related products and III-V compound semiconductor device and process developer, has begun trading in this U.S. stock market

Opel Technologies has begun trading in the United States on the OTCQX International under the symbol "OPELF".

Opel sees a significant benefit to being traded on the OTCQX. The Company believes it will gain greater exposure and liquidity in the United States without the regulatory expense of traditional U.S. listings.

"It has been a near-term strategy of the Company to increase the liquidity of our shares, and we exhibited our commitment to that goal by upgrading to the top tier of the OTC market. Achieving our membership on the OTCQX provides Opel significant accessibility to high liquidity institutional and retail investors in the United States," says Leon M. Pierhal, CEO of Opel Technologies Inc.

Pierhal adds, "The U.S. is the world leader in clean energy and semiconductor investing, and we look forward to sharing Opel's growth story and opportunities with the OTCQX investor base which will benefit all shareholders."

Pierce Atwood, LLP will serve as Opel's Principal American Liaison, responsible for providing guidance on OTCQX requirements and U.S. securities law.

Opel common shares will continue to trade in Canada on the TSX Venture Exchange under the "OPL" symbol.

DuPont PV5400 series reduces cost and increases strength of CIGS modules

The novel formulation boosts efficiency in copper indium gallium (di)selenide solar sells

Axuntek Solar Energy is introducing its new IEC-certified CIGS thin film solar cell modules using DuPont PV5400 series ionomer encapsulant.

These frameless solar modules, which are the first adoption of DuPont PV5400 into CIGS technology, take advantage of the ionomer's excellent clarity and low moisture ingress, which combine to create a highly efficient module with a low cost position due to the elimination of edge seal and frame. The frameless module allows higher density module shipments, reducing shipping costs

Axuntek's new frameless IEC-certified CIGS thin film solar cell modules are enabled by DuPont PV5400 series ionomer encapsulants

"The use of the DuPont PV5400 series ionomer encapsulants in CIGS modules demonstrates multiple benefits of the ionomer encapsulant's inherent qualities," says Penny Perry, global marketing manager, DuPont PV Encapsulants. "It provides strength to enable a frameless design, transparency for more design flexibility and ensures more power output over the life of the module."

"The performance level of the PV5400 encapsulant was a key factor in these frameless solar modules receiving IEC certification," says Ray Lin, sales and marketing manager, Axuntek. "CIGS technology offers the potential to reach higher efficiencies than other thin film technologies, and the choice of encapsulant is important to ensure the highest level of performance and long-term durability. DuPont PV5400 not only increases the modules' durability and production efficiency, but can significantly enhance their long-term power-generating efficiency."

DuPont says its PV5400 Series is an ideal choice for use with CIGS technology. It is claimed to have excellent UV resistance and does not generate free acid under degradation conditions.

As a thermoplastic, it does not require cross-linking and thus has no peroxide or other degradation-inducing additives. The UV stability of ionomers is well demonstrated in its use for more than 15 years as a high-performing interlayer in architectural applications.

As it is up to 100 times stiffer and 5 times stronger than traditional thin film laminating materials, DuPont PV5400 encapsulant also minimies module deflection and increases mechanical strength.

The use of DuPont PV5400 can facilitate the design of modules for high strength applications, as well as meeting building codes for building-integrated window structures. Making use of the good clarity of the ionomer/glass combination, the cell spacing can be adjusted to create "see-through" frameless modules that appeal to the end-user's aesthetic sense.

Global QD market to shoot up to $7480.25 million by 2022

Apart from in healthcare, where Quantum Dots hold a large market share, the technology is expected to play a major part in LED lighting and solar cells in the future

A new report, "Quantum Dots (QD) Market - Global Forecast & Analysis (2012 - 2022)" published by MarketsandMarkets, says the total market for Quantum dots is expected to reach over $7480 million by 2022, at a CAGR of 55.2% from 2012 to 2022.

Quantum Dots (QD) are one of the most advanced area of "semiconductor nanoparticles", and is currently undergoing massive research.

QDs are semiconductor nanoparticles, and, as the name suggests, have size from 2 nm to 10 nm. Due

to their miniature property; they are highly versatile and flexible. The uniqueness of QD material lays in the fact that its power intensity depends on the input source and size of QD.

There are several ways to confine excitons in semiconductors, resulting in different methods to produce quantum dots. In general, quantum wires, wells, and dots are grown by advanced epitaxial techniques in nanocrystals produced by chemical methods or by ion implantation, or in nanodevices made by state-of-the-art lithographic techniques.

In the present scenario of QD technology market, Healthcare is the only industry, which has gained significant market share. Healthcare needs high precision in tissue labelling, cancer therapy, tumour detection, etc. and QD-based devices work for the same.

The lighting industry is huge; and after the introduction of efficient lighting like LED, this industry has taken a huge leap. LED lighting and fixtures market has propelled in the last few years and is expected to expand further.

Now companies are looking for the alternate technology for LED lighting. QD lighting will fulfil the need; it is highly efficient and cost-effective. QD Vision has collaborated with Nexxus Lighting to launch its first QD LED light, and soon it will capture the market. Likewise, the company is also working on QD display.

QD technology will play a crucial role in solar energy-oriented industry as well. Researchers have developed QD-based solar cell, which is 50% as efficient as conventional solar cell. University of Toronto has achieved an efficiency of 4.2% conversion with solar cell based on colloidal QDs (CQD). Researchers are also working on QD-based paint that can be applied to panels or walls to capture solar energy.

The global Quantum Dots Market for technology-products and applications is expected to reach $7480.25 million by 2022, at an estimated CAGR of 55.2% from 2012 to 2022. The Americas are holding a leadership position in QD technology market on the whole; followed by Europe and APAC. In the market of ROW, Middle East and Africa are the largest contributors.

Global semiconductor sales escalate

A new report says silicon manufacturer Broadcom and compound semiconductor supplier TriQuint are good examples that illustrate that the semiconductor industry is bouncing back

The semiconductor stock market has not done too badly this year, thanks to the growing demand for tablets and smartphones.

The mobile market relies on both silicon and compound semiconductor devices although silicon dominates in many of these areas.

According to ParagonReport.com, the Semiconductor Industry Association (SIA) recently reported worldwide semiconductor sales showed growth across all regions.

The organisation reported that for March 2012, worldwide sales of semiconductors totalled $23.3 billion, a 1.5 percent increase over the previous month. Sales in Europe and Japan grew 3.8 percent and 1.2 percent respectively.

“We are encouraged to see that sequential growth resumed across all regions, especially in Europe and Japan, in March,” says Brian Toohey, president, Semiconductor Industry Association. “We look for seasonal moderate growth to continue in the second quarter and build momentum as 2012 progresses. However, while forecasts for global economic growth are improving, macroeconomic and geopolitical uncertainties remain.”

Ascent Solar and Bye Aerospace to develop CIGS technology

One of the concepts currently in development is an unmanned aerial vehicle which stores electric power to enhance its potential for long endurance, quiet operations and low emissions

CIGS developer Ascent Solar Technologies is working with Bye Aerospace to create innovative aircraft programs for the aerospace and defence

markets.

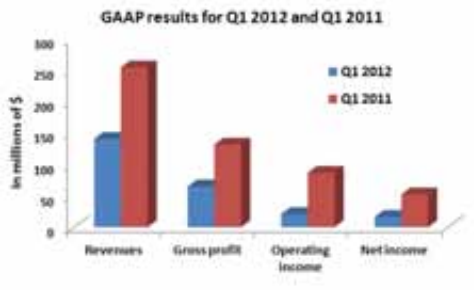
George Bye, Chairman and CEO of Bye Aerospace, says solar energy is a key component to several of Bye Aerospace's programs. "One concept currently in development, the Silent Guardian unmanned aerial vehicle (UAV), relies on thin film solar photovoltaics, stored electric power and other technologies to enhance its potential for long endurance, quiet operations and low emissions," he says. "With Ascent Solar as a development partner, our development time should improve drastically."

Victor Lee, President and CEO of Ascent Solar Technologies, comments, "We are pleased to partner with Bye Aerospace and look forward to furthering their development efforts with our lightweight, durable, flexible thin-film solar modules. Ascent Solar's transformational technology enables renewable power generation in aircraft applications while adding minimal weight to the vehicle. We are excited to apply our technology in collaboration with Bye Aerospace to develop a new generation of UAVs."

Veeco revenues slump 40.1% but firm is still making a profit

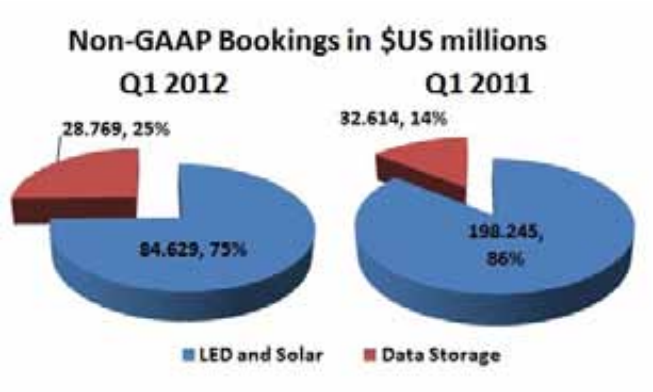
The III-V compound semiconductor, nitride LED and solar equipment manufacturer says it is experiencing growth in its Data Storage and MBE businesses, and services across all its technologies

Veeco Instruments has announced its financial results for its "continuing operations" in the first quarter ended March 31, 2012.



John R. Peeler, Veeco's Chief Executive Officer, comments, "We are executing well during the downturn in MOCVD demand. Veeco's first quarter revenue reached the top of our guidance at $140 million. Adjusted EBITA and non-GAAP earnings per share were $25 million and $0.49, respectively, on strong performance on the gross margin line and good expense management."

Veeco generated about $42 million in cash flow from operations, ending the quarter with $524 million in cash and short term investments. First quarter LED & Solar revenues were $96 million, including $82 million in MOCVD and $14 million in MBE. Data Storage revenues were $44 million.



"As anticipated, we experienced a weak bookings environment in Q1, with total orders of approximately $113 million," continues Peeler. "LED & Solar orders totalled $85 million, with $70 million in MOCVD and $15 million in MBE. MOCVD orders increased 19% sequentially, with system orders from customers in Korea, China, Taiwan, Japan and North America."

MBE orders increased 71% sequentially on production orders from wireless customers but data storage bookings declined 62% sequentially to $29 million as customer consolidation activity temporarily stalled capacity investments. Veeco's book-to-bill ratio was 0.81 to 1 and quarter-end backlog was $305 million.

Second Quarter 2012 Guidance & Outlook

Veeco's second quarter 2012 revenue is currently forecasted to be between $120 million and $145 million. Earnings per share are currently forecasted to be between $0.20 to $0.40 on a GAAP basis.

Peeler comments, "I am proud of our team's ability to execute, stay nimble and deliver solid profitability in a tough year. We are experiencing growth in

our Data Storage and MBE businesses, as well as in Services across all of our technologies. Veeco is focused on keeping our infrastructure lean and discretionary costs low, while at the same time developing next-generation technology solutions to drive future growth. We are on track to deliver 2012 revenue of $500-600 million."

He continues, "While MOCVD bookings grew modestly in the first quarter, we have not yet seen a clear inflection in customer buying patterns. LED customers remain cautious about capacity investment plans and it is still unclear when the MOCVD market will recover. Some positive signs are emerging, including increasing tool utilization rates in Korea, Taiwan and China, and a pick-up in customer quoting activity."

"Overall, we are seeing positive trends in LED lighting – lower prices, more LED lamp products, and heightened consumer awareness. LED manufacturers are focused on how to position their businesses for growth as LEDs become the dominant lighting technology. Despite the business decline in 2012, we firmly believe that the future MOCVD market opportunity will be larger than what we have experienced so far. With leading market share, strong LED customer relationships, technology leadership, and lowest cost of ownership production systems, Veeco is poised for substantive long term growth in LED lighting," concludes Peeler.

Calyxo CdTe cells raise the bar at 16.2% efficiency

The cadmium-telluride cells have been independently tested by manufacturer SGS Germany to officially confirmed the "record" numbers

Calyxo has announced it has beat the last performance barrier of its CdTe photovoltaic devices based made by its proprietary low cost atmospheric deposition technology.

In February this year, the firm announced its modules reached an efficiency of 13.4 percent.

"This result shows the efficiency potential of Calyxo's hot and fast deposition technology. Based on this achievement we are confident to reach 17%-18% cell efficiency and 14-15% top module efficiency later this year", says Michael Bauer, Calyxo's Chief Technology Officer.

Calyxo currently operates a 25 MWp production line with over 150 employees at the manufacturing plant that has been in commercial production since 2009 in Bitterfeld, Wolfen-Thalheim, also known as Solar Valley in Saxony-Anhalt, Germany.

The firm was taken over by Solar Fields, LLC, Toledo, Ohio, U.S.A. after its split from Q-Cells SE which declared insolvency in April 2012.

A new CEO for CdTe innovator First Solar

The cadmium telluride solar manufacturer is restructuring and has made James Hughes the new Chief Executive Office

First Solar has announced that James Hughes has been appointed Chief Executive Officer.

Hughes succeeds Mike Ahearn, First Solar's founder and Chairman, who has been serving as interim CEO since Oct. 2011. Hughes joined First Solar in March as Chief Commercial Officer.

Ahearn will continue in his role as Chairman of the Board.

"Jim has been instrumental in developing the strategic plan that will enable us to compete and win in this new era for the solar industry, and it became clear he is the right person to lead the execution of that plan," says Ahearn.

"Jim brings a wide range of experience that will be invaluable in leading our organization, having owned and operated utilities, built power projects, cultivated partnerships and led profitable growth in a wide array of key markets around the world."

"I am excited for this opportunity to lead First Solar into a new era for the industry," says Hughes. "First Solar is unrivaled in terms of talent and experience and has the premier platform from which to implement solar power at a meaningful scale around the world. The rapid cost reductions

in the industry position solar at the threshold of the mainstream energy markets, and we are well-positioned to capitalize on that opportunity."

Hughes has nearly 20 years of experience in the global energy industry. Before joining First Solar, he served as the CEO of AEI, which owned and operated power distribution, conventional and renewable power generation, natural gas transportation and natural gas distribution businesses in 19 countries. Prior to that, he was President and Chief Operating Officer for Prisma Energy.

Hughes earned a juris doctor from the University of Texas at Austin School of Law, a Certificate of Completion in international business law from Queen Mary's College, University of London, and a bachelor's degree in business administration from Southern Methodist University.

Is the Chinese government monopolising the solar market illegally

Yes, according to U.S. firm Wiley Rein LLP. A new Five-Year Plan for solar is calling for escalation in Chinese government sponsorship of export-intensive, price-subsidised trade central planning Wiley Rein LLP says an array of illegal subsidies have enabled China's state-sponsored solar industry to seize more than half of U.S. and world market share at the expense of U.S. companies and jobs. Now the government of China has issued a new "Five-Year Plan" for the solar industry. It provides for even greater government control and support of the solar industry, according to an analysis commissioned by the Coalition for American Solar Manufacturing (CASM).

The plan to fuel China's export-intensive solar-industry campaign calls for a number of government initiatives, including new policy, financial and price subsidies. These moves are intended to offer more support in industry, financial and tax policy and further aid the development and production of equipment used to produce polysilicon, silicon ingots, wafers, cells and panels within the crystalline-silicon solar industry.

What's more, the portfolio includes plans to support industrialisation of China's as yet undeveloped thin-film industry, specifically harnessing silicon and CIGS solar technologies. The analysis was conducted by Wiley Rein LLP in Washington, D.C.

It focused on China's 12th Five-Year Plan for the Solar Photovoltaic Industry, issued in February 2012 to expand on China's broader 12th Five-Year Plan for National Economic and Social Development. Wiley Rein is representing CASM, a coalition of more than 190 employers representing over 16,000 Americans, in advancing trade cases against the Chinese solar manufacturing industry. In a partial preliminary determination in March, the Department of Commerce announced that at least ten categories of Chinese subsidies for its producers of solar cells and panels were illegal. "These plans significantly increase the government's control over the development of the solar industry, permitting the government to manage virtually every aspect of the industry," the analysis says. "Substantial government assistance is also mandated to carry out the goals identified in these plans." As in previous iterations, the plans designate solar among seven "strategic emerging industries" that warrant massive government support, preferential treatment and tight control, according to the analysis. News reports put total subsidies for all seven industries at $1.5 trillion.

The recently published solar plan, which covers the period up to 2016 reflects the Chinese government's resolve to ensure the industry's continued rapid development by directly managing its planning, policy and growth. In addition, according to the analysis, the solar Five-Year Plan calls for the Chinese industry's continued global expansion and "internationalisation" in keeping with China's "Going Abroad" strategy. China has amassed production capacity that is 32 times greater than domestic demand, resulting in about 95 percent of Chinese solar production being exported overseas.

CASM contends that China's illegal subsidisation of its export drive has enabled its industry to dump product in the U.S. market and unfairly capture market share since 2008. During the same period, the number of China's solar manufacturers listed among the world's ten largest has rocketed from just one to seven in 2011. Meanwhile, at least twelve crystalline silicon U.S. manufacturers have

shuttered plants, declared bankruptcy or staged layoffs. Another of these was CIGS manufacturer, Solyndra who filed for bankruptcy last September.

Significantly, the National Renewable Energy Laboratory has concluded that Chinese producers face a cost disadvantage in producing and delivering solar technology to the U.S. market, compared with domestic producers.

China's new Five-Year Plan provides even greater support for exports than previous government plans that delivered more than half of world industry market share to the Chinese industry, according to the analysis. The 2011-2015 plan calls for the consolidation of "the industry's position in the international market," partly by identifying and promoting "national champions," so that "Chinese PV enterprises' international influence will be greatly enhanced" and be better able "to cope with international competition and market risks." Apart from more than 30 Chinese subsidy programs that CASM has identified as illegal, including the ten that the Department of Commerce has preliminarily sanctioned, the new 12thFive-Year Plan for the Solar Photovoltaic Industry unveils a host of new government initiatives to continue to fuel China's export campaign.

The plan is said to cover virtually every detail of every phase of industrial development, including where new industrial siting should take place. It also specifies the precise levels for environmental performance improvement and the exact standards for cost and power-conversion efficiency improvement. "The Chinese government launched a trade war against the U.S. domestic industry, took over the leadership of the largest American industry trade association and began driving U.S. solar manufacturing pioneers out of business," says Gordon Brinser, president of SolarWorld Industries America Inc., one of the largest U.S. solar manufacturers for more than 35 years. "Our coalition of U.S. producers contested the illegal Chinese governmental interference in the U.S. market and sought enforcement of U.S. and international trade law.

In response, China has rolled out a host of initiatives to further manipulate pricing, snuff out competition and solidify its domination – all on foreign soil. Needless to say, China allows no foreign competition on its own soil." "China is steamrolling American manufacturing and jobs and breaking its trade commitments in plain sight," Brinser adds. "No wonder the American public has grown increasingly anxious about the state of U.S.-China trade. China is scoffing at international trade rules." In the first major ruling in the trade cases, the U.S. International Trade Commission issued a unanimous preliminary ruling on December 2, that Chinese trade practices are harming the U.S. domestic solar industry. On May 17th, the Department of Commerce was expected to announce the extent to which Chinese manufacturers have illegally dumped products in the U.S. market.

Raffi Garabedian takes over as CTO at First Solar

Former Chief Technology Officer Dave Eaglesham is retiring from the cadmium telluride solar innovator

First Solar has announced the retirement of Dave Eaglesham, CTO, and the appointment of Raffi Garabedian as his successor.

Garabedian joined First Solar in 2008 as Director of Disruptive Technologies, and was promoted to Vice President of Advanced Technologies in 2010. He oversaw the Company's advanced research and development (R&D) operations in Santa Clara, California.

Eaglesham joined First Solar in 2006, and during his six years as First Solar's top technologist the Company's R&D group has achieved multiple world records for CdTe cell and module efficiency.

"We thank Dave for his tremendous contribution to our success and his unwavering commitment to our mission, and we wish him the very best," says Mike Ahearn, First Solar's Chairman. "Raffi is an experienced technology leader with a proven track record in our R&D organisation, and we are confident in his ability to execute and extend our technology roadmap going forward."

"I am very proud of what we have achieved, not only in the lab, but on production lines and in solar power plants around the world," adds Eaglesham. "Raffi has been an integral part of our success, and I am very confident in his ability to lead our R&D

program and to carry on our tradition of innovation."

Garabedian earned a BSEE degree from Rensselaer Polytechnic University and an MSEE degree from the University of California at Davis. Prior to joining First Solar, he was founder and CEO of Touchdown Technologies, a semiconductor test equipment company. Prior to that, Garabedian worked in the semiconductor and micro-electromechanical systems (MEMS) industries for over 15 years, developing new products ranging from automotive sensors to telecommunications switching systems, and holds more than 20 issued patents in these fields.

First Solar utilises a continuous manufacturing process which transforms a sheet of glass into a complete solar module in less than 2.5 hours, which contributes to the fast energy payback time and the low carbon footprint of systems of its PV modules.

The firm has also implemented a comprehensive, prefunded solar module collection and recycling program. Anyone wishing to dispose of First Solar modules can request collection at any time, at no additional cost, and First Solar will pick up the modules and recycle up to 90% (by mass) of the material for use in new products.

Power Electronics

EPC GaN technology & TI's driver are a match made in heaven

EPC's new power product shows the performance benefits of its gallium nitride technology when used alongside Texas Instruments' FET driver

Efficient Power Conversion Corporation (EPC) has introduced the EPC9102, a fully functional eighth brick converter.

The board which has a 36 V – 60 V input to 12 V output, is a 375 kHz phase-shifted full bridge (PSFB) eighth brick converter with 17 A maximum output current. The EPC9102 uses the 100 V EPC2001 eGaN FETs in conjunction with the recently introduced LM5113 100V half-bridge gate driver manufactured by Texas Instruments.

LM5113 board

EPC says the LM5113 board is the industry's first driver to optimally drive and fully release the benefits of enhancement mode GaN FETs. The EPC9102 demonstrates the performance capabilities of high switching frequency eGaN FETs when coupled with this eGaN driver.

The converter has a standard eighth brick footprint and height; it measures 2.3" x 0.9" x 0.4". The board has a peak power efficiency of 94.8% while delivering 10 A of current with a 36 V input.

The EPC9102 demonstration circuit was designed to showcase the size and performance that can be achieved at 375 kHz operation using eGaN FETs. EPC did not prioritise maximum output power when designing the device. The company says operating frequency is roughly 50% to 100% higher than similar commercial eighth brick DC-DC power converters.

To assist the power system design engineers, the EPC9102 demonstration board is oversized to allow connections for bench evaluation. There are various probe points aid to simple waveform measurements and efficiency calculation. The board is intended for bench evaluation with low ambient temperature and forced air cooling.

The EPC9102 demo boards are priced at $306.25 each and are available for immediate delivery.

Mitsubishi Electric SiC inverter has the power

The silicon carbide inverter is suited to automotive and industrial applications

Mitsubishi Electric Corporation has developed a prototype forced-air-cooled three-phase 400V output inverter with all SiC power modules. The inverter has a power density of 50kVA per litre.

The inverter is expected to contribute to smaller and lighter power-electronics equipment in automotive and industrial applications, among others.

The module, which is rated at 1,200V/300A, incorporates a SiC MOSFET (metal oxide semiconductor field effect transistor) and SiC SBD (Schottky barrier diode).

To increase power density, electric current density must be increased by lower electric resistance. So Mitsubishi Electric developed low-resistance wiring by using direct lead bonding to connect power semiconductor chips directly to the main terminals, eliminating the use of conventional high-resistance aluminium lead wires.

To achieve high current density, low-loss (low-resistance) power chips also had to be used, but this required the application of high-speed protection circuits to prevent a large destructive current during short circuits.

The company applied a SiC-MOSFET with a built-in current sensor function to its all-SiC power module and used a high-speed short-circuit-protection circuit, making it possible to use a low-resistance SiC-MOSFET even at a high current density.

By doing this, the company successfully achieved a power density of 50kVA per litre by an inverter operation with an output of 156kVA.

While silicon has traditionally been used for power semiconductor devices, in recent years SiC has come to be widely considered as one of the most promising next-generation materials. It has a breakdown electric field that is about 10 times higher than silicon and reduces power loss, meaning there is less CO2 emission.

What's more, the amount of cooling equipment in applications can be reduced, making the overall downsizing and lightening of electronic components for auto

EpiGaN starts production of gallium nitride epitaxial material

The new production site of EpiGaN officially opened today in the presence of Flemish Minister Mrs Ingrid Lieten and Limburg Governor Mr Herman Reynders. The company selected the Research Campus Hasselt as the ideal location for the volume production of their gallium nitrid- on-silicon epitaxial material.

EpiGaN is one of the key players in GaN-on-Silicon materials technology. The firm says GaN-on-Silicon will enable a new generation of power electronics, with performance far beyond current silicon technology. This material system will ensure more efficient energy use in power convertors, better power supplies for computers, motor drivers, inverters for solar energy technologies and greener transport with a smaller environmental footprint. EpiGaN is currently offering GaN epitaxial layers deposited either on silicon up to 150 mm or, for specific applications, on SiC. Wafer diameters of 200mm are under development. The availability of large wafers which can be processed in existing silicon CMOS fabs partly explains how GaN-on-silicon technology combines affordability with great performance.

Today EpiGaN is officially opening its production unit at the Research Campus Hasselt (RCH), located within the knowledge triangle Eindhoven-Leuven-Aachen. EpiGaN found there the necessary framework for installing its cleanroom facilities as required for the production of GaN-on-Silicon, while the location in the heart of Europe allows for establishing their business on an international level. Today, EpiGaN employs 6 people and is currently hiring more engineers and sales personnel to support its growing production effort.

Last year, EpiGaN sampled its first wafers to Europe, US and Asia. The company is now takinga new step in ramping up its capacity. “We are very happy that the current installation will allow us to better serve our customers and new-comers in the field of GaN-on-Silicon market for electronics”, says Marianne Germain, CEO EpiGaN. “This is right at the time that device manufacturers are looking for getting access to this new technology, key for their future applications.” Ingrid Lieten, Vice Minister-President of the Flemish Government, adds, “EpiGaN is an outstanding example of what a strategic research institute can and must encompass: Imec has developed an innovative and state-of-the-art technology, the applications of which can lead to the solution of important challenges for society such as the energy issue and mobility.

This technology has been transferred to EpiGaN. Moreover, this spin-off has a beneficial effect on employment.” About EpiGaN EpiGaN was incorporated in 2010 by Marianne Germain, CEO, Joff Derluyn, CTO, and Stefan Degroote, COO, as a spin-off from imec. In 2011, the company was joined in its venture by a strong consortium of investors, formed by Robert Bosch Venture Capital, Capricorn CleanTech Fund and LRM, enabling the installation of a new production facility. EpiGaN focuses on providing III-nitride epitaxial material solutions for top performance devices. The firm gives device manufacturers access to technology used in market segments such as power supplies for consumables, hybrid electric vehicles, solar inverters, RF power for base stations and smart grid.

EPC enhances its eGaN power with David Reusch

Reusch will be creating benchmark power converter designs and assisting customers in the use of the company’s proprietary gallium nitride FETs for high frequency, high performance power conversion systems

Efficient Power Conversion Corporation (EPC) has recruited David Reusch as its Director of Applications Engineering.

As a member of the EPC applications team, Reusch’s focus will be on designing lower loss and higher power density benchmark circuits that demonstrate the benefits of using transistors.

His initial focus will be on their use in higher voltage DC-DC converters and resonant, soft-switching converters. Reusch’s research and experience in these applications will be shared with customers to accelerate their designs using high performance eGaN FETs. His designs are aimed to demonstrate GaN transistors’ superior performance over MOSFETs.

David Reusch earned a doctorate in electrical engineering from the Virginia Polytechnic Institute and State University (Virginia Tech), where he also earned his bachelor’s and master’s degrees. While working on his Ph.D. he was an NSF Fellow at the Centre for Power Electronics Systems (CPES).

He is active in IEEE organisations and during the last several years has published papers at the Applied Power Electronics Conference (APEC) and the Energy Conversion Congress and Exposition (ECCE

Reusch has also had first-hand experience designing GaN transistors to meet the demands for lower loss and higher power density in power converters.

SemiSouth awarded 30th SiC U.S. patent

The patent allows the silicon carbide innovator to fine tune its vertical channel junction field effect

transistors and diodes to get even closer to the unipolar theoretical limit

SemiSouth Laboratories, a developer of SiC power semiconductor transistors and diodes, has secured its 30th US patent granted by the US Patent and Trademark Office.

SiC devices are rapidly gaining market share in the solar, UPS, traction, wind, automotive, and aerospace industries for their superior performance in high-efficiency, harsh-environment power applications

US Patent 8,169,022 was issued on May 1, 2012, and is entitled "Vertical Junction Field Effect Transistors and Diodes Having Graded Doped Regions and Methods of Making." It was co-invented by Michael Mazzola, a co-founder of SemiSouth in 2000 when the company spun off of Mississippi State University.

"The underlying technology in this patent allows SemiSouth to fine tune their already performance-leading vertical channel junction field effect transistors and diodes to get ever closer to the unipolar theoretical limit. Customers can expect even better value from the products based on this patent," says Mazzola.

"We are excited to receive our 30th US patent," adds Jeffrey B. Casady, SemiSouth President & CTO and company co-founder. "Our technology is state-of-the-art in terms of performance per unit area. SemiSouth products deliver advanced, efficient, cost-effective power solutions that others cannot."

In addition to 30 US patents, SemiSouth possesses 24 patents internationally and has 204 applications pending worldwide.

SemiSouth unveils 1700V / 1400mΩ SiC JFETs

The firm says that by using a depletion mode silicon carbide JFET, designers can achieve a fast start-up using no extra components such as an extra heat sink

SemiSouth Laboratories has unveiled a new 1700V/1400mΩ SiC JFET which it says simplifies start up circuit design in 3-phase auxiliary power supplies.

Traditional solutions either use an HV bleed resistor which results in a slow start-up at low line voltages and a high quiescent power loss, or are MOSFET-based which necessitate overload protection and can suffer from high power losses in the MOSFET under fault condition e.g. short circuit. Applications Engineer, Nigel Springett explains, "By using a depletion mode JFET, designers can achieve a fast start-up using no extra components. Our JFETs need no extra heat sink for this application." The SJDT170R1400 will come in a newly developed SMD D2PAK-7L package in order to simplify PCB layout and optimise switching performance due to lower inductance.

This package will have a high creepage distance of 6.85mm in order to support 1700V applications and is 16 x 10 x 4.4mm. "We are confident that the SJDT170R1400 will become the de-facto standard for all auxiliary 3phase power supplies, as the benefits for the users are superior compared to traditional High Voltage MOSFET solutions and the cost become less for the total solution", says Sr. Vice President Sales & Marketing, Dieter Liesabeths. SemiSouth is initially sampling the normally on 1700V/1400mΩ SJDP170R1400 in TO-247-3L packaging; the SJDT170R1400 in surface mount D2PAK-7L high creepage package will sample in Q3 of 2012.

Avago and TriQuint bury the hatchet on BAW filters

The designer and developer of analogue III-V semiconductor devices and the gallium arsenide and gallium nitride innovator have come to an agreement to cross licensing patents

Avago Technologies, a supplier of analogue interface components for communications, industrial and consumer applications, and RF solutions supplier TriQuint Semiconductors have agreed to settle all claims between the companies concerning intellectual property for bulk acoustic wave (BAW) filters. The two parties have entered into patent cross licenses and have agreed to dismiss all related litigation. The specific terms of the settlement and the resulting licensing agreement are confidential. “We are pleased to have reached an amicable resolution with TriQuint,” says Hock Tan, President and CEO of Avago Technologies Limited. “We are happy to have successfully put this litigation behind us,” adds Ralph Quinsey, CEO of TriQuint Semiconductor, Inc.

SemiSouth brings on 650V 55mΩ SiC JFETs

The fast switching, high current handling and superior thermal properties of silicon carbide devices are ideal for solar inverters, SMPS, PFC circuits, induction heating, UPS and motor drives

SemiSouth says it is delivering the industry’s first 650 V SiC JFET power transistors.

The fast switching speeds, large current handling capability combined with the superior thermal properties of SiC are ideal for power electronic applications. These devices employ vertical trench JFET structures .

Jeffrey B. Casady, President/CTO of SemiSouth says, “Customers in markets such as EV drive train, UPS, welding, solar, induction heating have long been asking for SiC switches which are very reliable, cost-effective, & capable of high-efficiency at high power densities. We are proud to be the first company to be able to offer such a product our customers will be able to realise enormous benefits by designing in these class-leading 650 V JFETs.”

Dieter Liesabeths, Senior VP Sales & Marketing adds, “This product is significant. Markets where we are already in volume production using our 1200 V switch such as solar and UPS, also require lower-voltage switching at 650 V for efficiency & higher power density solutions where grid voltage or bus voltages are lower. The automotive industry is split on the EV drive train with some customers requiring 1200 V and higher, and others requiring only 650 V. We can now serve these markets even better with power transistor solutions from 650 V through 1700 V.”

The 650V / 55mΩ SJDA065R055 SiC JFETs feature a temperature coefficient for ease of paralleling and fast switching with no “tail” current at 1500C. RDSONtypical for these new voltage-controlled devices is 0.044Ω, which exhibit a low gate charge and low intrinsic capacitance.

Global semiconductor sales escalate

A new report says silicon manufacturer Broadcom and compound semiconductor supplier TriQuint are good examples that illustrate that the semiconductor industry is bouncing back

The semiconductor stock market has not done too badly this year, thanks to the growing demand for tablets and smartphones.

The mobile market relies on both silicon and compound semiconductor devices although silicon dominates in many of these areas.

According to ParagonReport.com, the Semiconductor Industry Association (SIA) recently reported worldwide semiconductor sales showed growth across all regions.

The organisation reported that for March 2012, worldwide sales of semiconductors totalled $23.3 billion, a 1.5 percent increase over the previous month. Sales in Europe and Japan grew 3.8 percent

and 1.2 percent respectively.

"We are encouraged to see that sequential growth resumed across all regions, especially in Europe and Japan, in March," says Brian Toohey, president, Semiconductor Industry Association. "We look for seasonal moderate growth to continue in the second quarter and build momentum as 2012 progresses. However, while forecasts for global economic growth are improving, macroeconomic and geopolitical uncertainties remain."

Infineon CEO resigns

Peter Bauer is resigning as CEO of new gallium nitride-on-silicon developer Infineon Technologies AG effective September 30, 2012 due to health reasons

Reinhard Ploss has been appointed new CEO of Infineon Technologies AG. The appointment will become effective on October 1st, 2012.

Sadly, current CEO of Infineon AG, Peter Bauer, will resign his post at the end of the current fiscal year due to health reasons.

Peter Bauer suffers from osteoporosis. During the last several years he already endured numerous fractures of the vertebrae. Recently, his condition significantly worsened and, after due consideration, he informed the Supervisory Board of his decision to leave.

"This is a very difficult decision for me," says Peter Bauer. "After so many eventful years together, Infineon and its employees are very dear to my heart. However, due to the uncertainties posed by my illness I can no longer dedicate the undivided attention required by the office of the CEO to lead Infineon into the future."

He continues, "I feel that I have a duty to my health, my family and the company to step down from my current position. I thank all our employees, business partners, customers, investors, my fellow Board members and the members of the Supervisory Board for their unrelenting confidence and support, especially during difficult times, and hope for understanding regarding my decision."

Wolfgang Mayrhuber, Chairman of Infineon's Supervisory Board comments, "The Supervisory Board deeply regrets that Peter Bauer resigns his post as CEO of Infineon Technologies AG due to health reasons, but has full understanding and great respect for the very personal reasons behind the decision."

"Peter Bauer has a very authentic, employee-oriented management style. He distinguished himself through his intense commitment, depth of knowledge, clear objectives and focus on performance, as well as his perseverance and dedication to teamwork. These characteristics earned him great recognition among our customers, investors and employees."

"The Supervisory Board is grateful for Peter Bauer's outstanding contribution to the company. With the support of his management, he prepared the company for the future. Infineon is stable and profitable today, with attractive products, state of the art manufacturing and competent employees led by an excellent management team."

Reinhard Ploss will be Peter Bauer's successor to the post of CEO and is a member of the Infineon AG Management Board. He is currently responsible for production, development, technology and human resources.

"The selection of my long-time colleague, Dr. Reinhard Ploss, as successor, makes me very happy," states Bauer. "Reinhard Ploss is a highly experienced manager with excellent knowledge of our industry. He enjoys high acceptance within the company and among our international business partners. Infineon is very well positioned for the future. We address the right trends with our focus on Energy Efficiency, Mobility and Security and we have a proven management with a track record of success."

"The Supervisory board is pleased to appoint Dr. Reinhard Ploss as CEO of Infineon Technologies AG," says Mayrhuber. "He brings with him both extensive technical expertise and a broad business background. Dr. Ploss currently serves on the Infineon management board with responsibilities as Chief Technical Officer, Chief Operations Officer and Labour Director. During his term, he successfully improved Infineon's competitiveness in manufacturing and innovation. In our dynamic and

highly competitive business, the balance between change and stability is a critical success factor. Dr. Ploss masters this balance. His appointment preserves continuity. The Supervisory Board firmly believes that he, together with his fellow board members Dominik Asam and Arunjai Mittal, will carry on with Infineon's successful strategy."

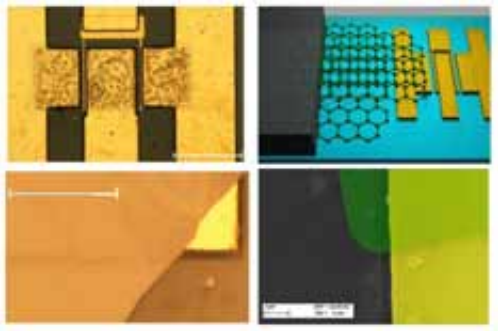
Bauer began his career in 1985 at Siemens Semiconductors, which was eventually carved-out into Infineon Technologies AG. He was already part of the Management Board when Infineon went public in 2000 and, in 2008, became the company's CEO. Under his leadership, Infineon executed an extremely successful restructuring and refinancing program in response to the 2009 financial crisis and decisively focused its strategy on profitable growth in the areas of Energy Efficiency, Mobility and Security.

Reinhard Ploss has been with the company for over 25 years and presides over much knowledge of the complex semiconductor industry. After numerous leadership roles in development and manufacturing, he assumed responsibility for Infineon's Automotive and Industrial units, encompassing products underlying many of Infineon's sales today. Ploss was appointed to the Infineon Management Board in 2007.

How to cool high-power GaN semiconductor devices

Latest developments in gallium nitride will be used in wireless applications, traffic lights and electric cars

A group of researchers at the University of California, Riverside Bourns College of Engineering have developed a technique to keep cool a semiconductor material used in everything from traffic lights to electric cars. GaN semiconductor materials have been used in bright lights since the 1990s, and are now used in wireless applications due to high efficiency and high voltage operation. However, the applications and market share of GaN electronics is limited because it is difficult to remove heat from them. That could change due to a technique developed by the Nano-Device Laboratory research group led by Alexander Balandin, professor of electrical engineering and founding chair of Materials Science and Engineering program. The research group demonstrated that hot spots in GaN transistors can be lowered by as much 200C through the introduction of alternative heat-escaping channels implemented with graphene multilayers, which are excellent heat conductors. The temperature reduction translates to an increase in the lifetime of the device by a factor of ten. "This represents a transformative change in thermal management," Balandin says. The new approach to thermal management of power electronics with graphene was outlined in a paper "Graphene quilts for thermal management of high-power GaN transistors" that was published on May 8thin Nature Communications.



Clockwise from top left: optical microscopy image of the high-power GaN heterostructure field-effect transistor (HFET); schematic of the graphene-graphite quilt on top of the transistor structure for spreading the heat from the local hot spot near the transistor drain; coloured SEM image of the graphene quilt overlapping transistor; optical microscopy image of the graphene quilt on the device electrode illustrating its flexibility

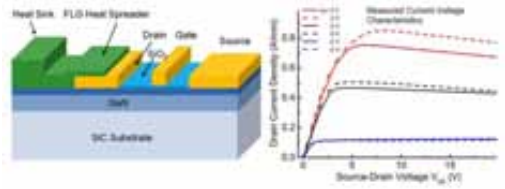
GaN transistors have been commercially available since 2006.

The problem with them, like all high power operating devices, is the significant amount of dissipated heat, which has to be fast and efficiently removed. Various thermal management solutions such as flip-chip bonding or composite substrates have been attempted. However, applications have still been limited because of increases in temperature due to dissipated heat. The breakthrough in thermal management of GaN power transistors was achieved by Balandin and three of his electrical engineering graduate students: Guanxiong Liu, Zhong Yan, and Javed Khan, who started working at Intel Corporation this year. Balandin has previously discovered that graphene is an excellent heat conductor.

Few-layer graphene films preserve their excellent thermal properties even when their thickness is only a few nanometres, which is unlike metal or semiconductor films. The latter makes them excellent candidates for applications as the lateral heat spreaders and interconnects. The Balandin group researchers designed and built graphene-graphite "quilts" on top of GaN transistors. The graphene-graphite quilts' function was to remove and spread the heat from the hot spots – the opposite of what you expect from the conventional quilts.

From left to right: Guanxiong Liu, Alexander Balandin and Zhong Yan, who worked on the project

Using micro-Raman spectroscopic thermometry the researchers demonstrated that temperature of the hot spots can be lowered by as much 20 degrees Celsius in transistors operating at the large power levels.



From left, cross-sectional schematic of the GaN HFET with graphene quilt for heat spreading; current-voltage characteristics of GaN HFET with and without graphene-based heat spreaders demonstrating improvement in the saturation current due to lower junction temperature in the device with graphene quilt

The computer simulations performed by the group suggested that graphene quilts can perform even better in GaN devices on more thermally resistive substrates. The Balandin group is also known in graphene community for their investigation of low-frequency noise in graphene transistors, development of the first large-area method for quality control of graphene and demonstration of the first selective gas sensor implemented with pristine graphene. The work on thermal management of GaN transistors with graphene quilts was supported by the Office of Naval Research. Balandin's research of the thermal properties of graphene was funded by the Semiconductor Research Corporation and the Defence Advanced Research Project Agency.

Say hello to millimetre wave GaN PAs

Millitech's gallium nitride power amplifiers offer wideband power covering 75 GHz to 102 GHz Millitech is touting its next generation E-Band and W-Band compact and high power solid state power amplifiers.

Millitech GaN Power Amplifier

The GaN based power amplifiers represent a quantum leap in output power at E-Band and W-Band with up to 3 W of output power and up to 20% PAE available in standard models.

The new AMP models offer catered performance over specific allocated bands or wideband power covering 75 GHz to 102 GHz. The E-Band (WR-12) models cover the commercially allocated 71-76GHz and 81-86 GHz bands.

The W-band models cover 75-102 GHz Each amplifier has internal bias circuitry that generates gate control voltages, provides proper voltage sequencing and incorporates reverse voltage protection from a single positive external bias. Single device models are available with nearly 1W of saturated output power. Standard models also include 2-way and 4-way Solid State Power Amplifiers with up to 3W of saturated output power.

Higher powers and other options are available when combined with diffferent models in the series.

Warsaw to use Aixtron CCS reactor for R&D of GaN

The University of Warsaw will use the reactor to pursue gallium nitride research

Aixtron SE has a new MOCVD system order from the University of Warsaw, Poland.

The contract is for one Close Coupled Showerhead (CCS) reactor in a 3 x 2-inch wafer configuration, to be used for the growth of GaN materials.

The system was ordered in the fourth quarter of 2011 and will be delivered in the second half 2012 as part of a project co-financed by the European Union titled "Physics as the basis for new technologies – development of modern research infrastructure at the Faculty of Physics of the University of Warsaw".

Aixtron Europe's service support team will install and commission the system at a dedicated cleanroom facility within the Institute of Experimental Physics of the University of Warsaw's Faculty of Physics.

"Aixtron is an excellent supplier for R&D GaN MOCVD systems and we believe that the longstanding world-renowned expertise of Aixtron's technology and service will therefore be a key factor for successful development of nitrides technology at the University of Warsaw", Roman Stepniewski comments.

"We expect the CCS reactor to be the best solution because there are few systems that possess such a good all-round combination of characteristics. It is a very stable platform, optimised for the growth of nitride thin films for a range of requirements, and comes with excellent reliability, ease of use and reproducibility. While we are starting a new research project, we are looking forward to putting the Aixtron CCS reactor into use."

Frank Schulte, Vice President Aixtron Europe, adds, "We are very pleased to announce this order from the University of Warsaw. Professor Stepniewski's team has a worldwide reputation for the quality of their work in advanced semiconductor materials, in particular in growth technology and basic studies of nitrides. There is no doubt that like many other research groups, they will quickly find the CCS to be not only a robust route to uniformity and scalability, but also an ideal and sustainable solution for their needs."

SiC powers GE Aviation to exploit the Florida market

Investment in electrical power technology for commercial and military uses will focus on silicon carbide to create more passenger and storage space at the same time as increasing electrical power

GE Aviation has expanded into a new facility in Pompano Beach, which includes a 30% increase in square footage and an R & D lab capable of advanced development of SiC-based power conversion products for air, land and sea-based platforms.

"This new facility enables us to continue work on GE-developed SiC technology, with the potential of reducing the weight on an aircraft by more than 400 lbs.," says Vic Bonneau, president of Electrical Power for GE Aviation Systems. "GE is committed to Florida and is investing approximately $20 million in program work and R&D related to our Pompano Beach facility over the next five years."

The 30,000 square foot facility is located at 2705 Gateway Drive in Pompano Beach. A new lab in the facility will provide increased capacity for developing, testing and manufacturing advanced electrical power conversion products used on civil and military platforms.

"This is a significant event for GE and for Pompano Beach," continues Bonneau. "Our workers here are helping to bring innovation from the research lab to the manufacturing floor, and that helps keep U.S. manufacturing competitive."

Space and weight are premiums on aircraft. Airlines are constantly trying to balance the need to create more passenger and storage space, while also meeting increased demand for electrical power on

the plane. GE's SiC power devices will address this need on both fronts.

Bonneau adds, "An important part of our strategy is to aggressively invest in the kinds of technologies that will solve large problems for our customers 10 year from now."

GE Aviation in Pompano Beach, Florida was established in 1965 and is a designer and manufacturer of special application electronic power subsystems for military and other "high-end" applications.

GaN Systems & APEI have the power to package GaN transistors

The firms believe advanced packaging is the key to unlocking the vast potential of gallium nitride for high power applications

GaN Systems and Arkansas Power Electronics International Inc. (APEI) are collaborating on the development of a high-temperature, high-performance package optimised for GaN transistors and diodes.

This co-development is funded in part by the Government of Canada through Sustainable Development Technology Canada (SDTC) with the goal of demonstrating the efficiency, performance, and reliability of GaN power devices in a power converter for hybrid and electric vehicles (HEVs and EVs).

"As gallium nitride is just beginning to gain acceptance for the next generation of power semiconductors, prospective users are keen to see the technology validated through real system design implementations," says Girvan Patterson, CEO of GaN Systems.

GaN Transistor

"Advanced packaging is the key that unlocks the vast potential of gallium nitride in high-power applications so we are delighted to be collaborating with a world leader on a package and system design that will maximise the benefits of this exciting technology. This important partnership also marks a powerful endorsement of our patented, island-based topology, validating our unique design approach."

GaN offers dramatic efficiency advantages over conventional silicon devices when used in power conversion systems. "For some time APEI has been looking for an opportunity to get more heavily involved in developing products for newly-emerging gallium nitride device technology," notes Alexander Lostetter, President and CEO of APEI. "Our partnership with a pioneer such as GaN Systems will be very exciting for us, resulting in new power module and converter technologies for an industry that is demanding increased energy efficiency, higher performance and reliability, and smaller size and weight."

"SDTC works to ensure that different partners - from innovators to end-users - are involved in the development and demonstration of new technologies," adds Vicky Sharpe, President and CEO of SDTC. "GaN Systems and APEI are showing the clear benefits of this approach. By working together, they will make sure that users' needs are reflected in the product's development early enough to pave a smooth path to market."

GeneSiC bare dies marketed by Micross

The pioneer in silicon carbide technology is offering its products to industrial, military, aerospace, and energy customers

GeneSiC Semiconductor has signed an agreement establishing Micross as a global supplier of GeneSiC's bare die products.

The driving force behind the agreement is the shared commitment of both companies to increase the availability of SiC bare die to industrial, military, aerospace, and energy (particularly, drilling and exploration) customers.

For years, silicon has been the building block of semiconductor design and fabrication because of its natural abundance, processing ease and relatively useful, although limited, temperature range. SiC, which is a manmade compound, offers enhanced performance, a broader temperature range, greater reliability, and natural radiation resistance.

Until recently, challenges and costs associated with SiC production had limited its use among semiconductor manufacturers, but GeneSiC, with its design and fabrication advances, says it has successfully increased yields. This has resulted in more competitive pricing and offerings, such as GeneSiC's Schottky diodes, which offer significant design and performance advantages.

Extending those advantages to bare die customers will be Micross' role under the new agreement. As the leading independent distributor of die products worldwide, Micross has both the product and assembly expertise required to certify the GeneSiC bare die for high-temp/high-reliability applications, as well as the sales channels needed to reach potential customers around the globe.

What's more, with its technical knowledge and resources, Micross can provide long-term product support to all die customers.

"This agreement is a natural fit," says GeneSiC's Chief Business Development Officer, Michael DiGangi. "With Micross' marketing and product support, we can confidently grow this part of our business, knowing that our die customers will be served in a manner second to none."

Tony Hamby, Micross' General Manager for Die Distribution in the US, shares DiGangi's enthusiasm for the new relationship and explains, "Having GeneSiC as a technology partner will be a great advantage for our customers, who, by virtue of their specialty applications, are always pushing performance limits, just like GeneSiC."

Equipment and Materials

5N Plus to issue $40 million worth of new shares

The agreement made by the provider of group III materials used in the MOCVD industry ,consists of a $20 million public bought□deal offering and a $20 million concurrent private placement

5N Plus has entered into agreements regarding an equity financing of an aggregate of 12,903,613 units at a price of $3.10 per unit, for aggregate gross proceeds of $40 million.

The firm is a producer of purified metals such as gallium, germanium, indium, selenium and tellurium, which are used in the manufacture of compound semiconductor wafers. 5N Plus is also a provider of inorganic chemicals such as CdTe and CdS used in the solar industry.

5N Plus intends to use the net proceeds from the financing to reduce its indebtedness under its revolving credit facility and for general corporate purposes.

Each unit will be comprised of one common share and one□half of a common share purchase warrant. Each full warrant will entitle its holder to acquire one additional common share of 5N Plus at a price of $5.00 for 24 months.

In connection with the financing, 5N Plus entered into an agreement with a syndicate of underwriters led by National Bank Financial Inc. The deal is pursuant to the underwriters purchasing, on a

bought deal basis, 6,452,000 units of 5N Plus at a price of $3.10 per unit, for aggregate gross proceeds to 5N Plus of $20 million.

The units will be offered by way of short form prospectus in each of the provinces of Canada, as well as in the United States under applicable registration statement exemptions.

5N Plus granted an over allotment option to the underwriters of the offering, entitling them to purchase, for a period of 30 days from the closing of the offering, up to 967,800 million additional units at a price of $3.10 per unit, for additional gross proceeds to 5N Plus of $3 million, to cover overallotments and for market stabilization purposes, if any.

5N Plus also entered into an agreement with Investissement Québec pursuant to which Investissement Québec agreed to purchase, by way of concurrent private placement, 6,451,613 units of 5N Plus at a price of $3.10 per unit, for aggregate gross proceeds to 5N Plus of $20 million.

The common shares and warrants issued under the private placement will be subject to a statutory four month hold period.

In connection with the public bought deal offering, 5N Plus will file a preliminary short form prospectus in all provinces of Canada by May 23, 2012. The prospectus offering and concurrent private placement are subject to all standard regulatory approvals, including that of the Toronto Stock Exchange, and are expected to close on or about June 6, 2012.

The public bought deal offering and the concurrent private placement are subject to customary closing conditions.

Hillsboro “Center for Excellence” opened by Edwards

The new facility will focus on customer service & training for the semiconductor manufacturing industry

Edwards, a global manufacturer of vacuum and abatement equipment and services, has opened a new “Center for Excellence” vacuum and abatement support facility in Hillsboro, Oregon, USA.

The 11,000 square foot facility will employ 30 people and will serve the local semiconductor manufacturing industry.

“The new facility further strengthens Edwards’ commitment to supporting our customers,” comments Ron Krisanda, chief operating officer, Edwards. “The Hillsboro facility will house a wide selection of products, including some of the latest models of dry vacuum pumps, which will be dedicated for training. A wide variety of courses will be available for customers as well as Edwards’ own service and support personnel.”

Edwards is a manufacturer of sophisticated vacuum products and abatement systems and a provider of related value-added services for the manufacture of semiconductors, flat panel displays, LEDs and solar cells and a leader in vacuum technology for industrial, pharmaceutical, chemical, scientific, process, glass coating and food packaging industries as well as a wide range of R&D applications.

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John R. Peeler becomes Chairman of Veeco

The restructuring also includes the retirement from the Board of Joel A. Elftmann, after 18 years of service, whose term had expired

Edward H. Braun, formerly Chairman of Veeco Instruments' Board, has transitioned his Chairman role to John R. Peeler, Chief Executive Officer.

Peeler will now hold the title of Chairman and Chief Executive Officer. Braun will remain an active member of Veeco's Board of Directors.

According to Braun, age 72, "Since John became Veeco's CEO nearly five years ago, his leadership and vision have transitioned the Company from an industry player to an industry leader. John and his team have delivered world-class products, gained market leadership in their core technologies, and delivered strong results. I am proud of the entire Veeco team and look forward to continuing to serve on the Board and sharing in the Company's future growth and accomplishments."

Veeco's Board now consists of seven members, including Lead Director Roger D. McDaniel.

Peeler concludes, "I would like to take this opportunity to thank Ed for his stewardship of the Company and for his continued valuable participation on our Board as Chairman of our Strategy Committee. He will continue to be a trusted partner and an important sounding-board for me, the entire Veeco Board, and our leadership team. I would also like to wish Joel all the best and thank him for his many years of dedicated service to the Company."

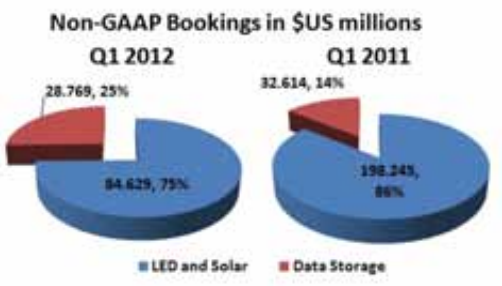
Veeco revenues slump 40.1% but firm is still making a profit

The III-V compound semiconductor, nitride LED and solar equipment manufacturer says it is experiencing growth in its Data Storage and MBE businesses, and services across all its technologies

Veeco Instruments has announced its financial results for its "continuing operations" in the first quarter ended March 31, 2012.

John R. Peeler, Veeco's Chief Executive Officer, comments, "We are executing well during the downturn in MOCVD demand. Veeco's first quarter revenue reached the top of our guidance at $140 million. Adjusted EBITA and non-GAAP earnings per share were $25 million and $0.49, respectively, on strong performance on the gross margin line and good expense management."

Veeco generated about $42 million in cash flow from operations, ending the quarter with $524 million in cash and short term investments. First quarter LED & Solar revenues were $96 million, including $82 million in MOCVD and $14 million in MBE. Data Storage revenues were $44 million.



"As anticipated, we experienced a weak bookings environment in Q1, with total orders of

approximately $113 million," continues Peeler. "LED & Solar orders totalled $85 million, with $70 million in MOCVD and $15 million in MBE. MOCVD orders increased 19% sequentially, with system orders from customers in Korea, China, Taiwan, Japan and North America."

MBE orders increased 71% sequentially on production orders from wireless customers but data storage bookings declined 62% sequentially to $29 million as customer consolidation activity temporarily stalled capacity investments. Veeco's book-to-bill ratio was 0.81 to 1 and quarter-end backlog was $305 million.

Second Quarter 2012 Guidance & Outlook

Veeco's second quarter 2012 revenue is currently forecasted to be between $120 million and $145 million. Earnings per share are currently forecasted to be between $0.20 to $0.40 on a GAAP basis.

Peeler comments, "I am proud of our team's ability to execute, stay nimble and deliver solid profitability in a tough year. We are experiencing growth in our Data Storage and MBE businesses, as well as in Services across all of our technologies. Veeco is focused on keeping our infrastructure lean and discretionary costs low, while at the same time developing next-generation technology solutions to drive future growth. We are on track to deliver 2012 revenue of $500-600 million."

He continues, "While MOCVD bookings grew modestly in the first quarter, we have not yet seen a clear inflection in customer buying patterns. LED customers remain cautious about capacity investment plans and it is still unclear when the MOCVD market will recover. Some positive signs are emerging, including increasing tool utilization rates in Korea, Taiwan and China, and a pick-up in customer quoting activity."

"Overall, we are seeing positive trends in LED lighting – lower prices, more LED lamp products, and heightened consumer awareness. LED manufacturers are focused on how to position their businesses for growth as LEDs become the dominant lighting technology. Despite the business decline in 2012, we firmly believe that the future MOCVD market opportunity will be larger than what we have experienced so far. With leading market share, strong LED customer relationships, technology leadership, and lowest cost of ownership production systems, Veeco is poised for substantive long term growth in LED lighting," concludes Peeler.

Forepi orders six more Aixtron reactors for LED production

Four CRIUS II-XL systems in a 19 x 4-inch wafer configuration and two G5 HT reactors in a 14 x 4-inch wafer configuration, will be used for the manufacturing of UHB gallium nitride based blue and white LEDs

Aixtron SE has announced that long-time customer Formosa Epitaxy Inc. (Forepi) has placed a new order for several MOCVD systems.

The order is for four CRIUS II-XL systems in a 19 x 4-inch wafer configuration and two G5 HT reactors in a 14 x 4-inch wafer configuration.

The tools will be used for the manufacturing of ultra-high brightness (UHB) GaN-based blue and white LEDs.

Forepi placed the order in the second quarter of 2012 and following their delivery between the third and fourth quarter of 2012, the systems will be installed and commissioned at the company's new facility in the Pin-Jen industrial zone, Taiwan.

"Forepi began using the CRIUS II-XL system a few months ago and as we must now make provisions for the capacity increase at our new factory in the Pin-Jen industrial zone, we once again turned to Aixtron to provide the epitaxy systems.With short time-to- production and highest performance, throughput and yield, these systems are best suited to our needs," a spokesperson from Forepi comments. "As we focus on 4-inch substrates, we have great confidence in Aixtron's cutting edge epitaxy technology."

Aixtron's Chief Operating Officer Bernd Schulte, adds, "We are very pleased to once again be able to support one of our longest-standing customers in Taiwan as they continue to expand. An order such as this from Forepi provides further proof of the

value of the key features of our equipment, such as seamless process scale-up, excellent uniformity and highest throughput per footprint. All of these factors come together with the most impressive capacity available in today's equipment market."

Novel Devices

Using a single nanomaterial to create a multi-colour laser

The lasers are nanometre-sized semiconductor particles called colloidal quantum dots (CQDs) with an inner core of cadmium and selenium alloy and a coating of zinc, cadmium, and sulphur alloy. Adjusting the size of the pyramid-shaped QDs changes the laser light colour

Engineers at Brown University and QD Vision have created nanoscale single crystals that can produce red, green, or blue laser light needed in digital displays.

The size determines colour, but all the pyramid-shaped quantum dots are made the same way of the same elements. In experiments, light amplification required much less power than previous attempts at the technology. The team's prototypes are claimed to be the first lasers of their kind.

Red, green, and blue lasers have become small and cheap enough to find their way into products ranging from BluRay DVD players to fancy pens. But each colour is made with different semiconductor materials and by elaborate crystal growth processes.

Now a new innovative technology demonstrates all three of those colours coming from one material. That could open the door to making products, such as high-performance digital displays, that employ a variety of laser colours all at once.

VCSEL colloidal quantum dots, also known as nanocrystals, can produce lasers of many colours. Cuong Dang manipulates a green beam that pumps the nanocrystals with energy, in this case producing red laser light. (Credit: Mike Cohea/ Brown University)

"Today in order to create a laser display with arbitrary colours, from white to shades of pink or teal, you'd need these three separate material systems to come together in the form of three distinct lasers that in no way shape or form would have anything in common," notes Arto Nurmikko, professor of engineering at Brown University and senior author of a paper describing the innovation. "Now enter a class of materials called semiconductor quantum dots."

The materials in prototype lasers described in the paper are nanometre-sized semiconductor particles called colloidal quantum dots (CQDs) or nanocrystals with an inner core of cadmium and selenium alloy and a coating of zinc, cadmium, and sulphur alloy and a proprietary organic molecular glue.

Chemists at QD Vision synthesised the nanocrystals using a wet chemistry process that allows them to precisely vary the nanocrystal size by varying the production time. Size is all that needs to change to produce different laser light colours: 4.2 nm cores produce red light, 3.2 nm ones emit green light and 2.5 nm ones shine blue. Different sizes would produce other colours along the spectrum.

The cladding and the nanocrystal structure are critical advances beyond previous attempts to make lasers with colloidal quantum dots, said lead author Cuong Dang, a senior research associate and nanophotonics laboratory manager in Nurmikko's

group at Brown. Because of their improved quantum mechanical and electrical performance, he said, the coated pyramids require 10 times less pulsed energy or 1,000 times less power to produce laser light than previous attempts at the technology.

Quantum nail polish

When chemists at QDVision brew a batch of colloidal quantum dots for Brown-designed specifications, Dang and Nurmikko get a vial of a viscous liquid that Nurmikko said somewhat resembles nail polish.

To make a laser, Dang coats a square of glass, or a variety of other shapes, with the liquid. When the liquid evaporates, what's left on the glass are several densely packed solid, highly ordered layers of the nanocrystals. By sandwiching that glass between two specially prepared mirrors, Dang creates one of a VCSEL. The Brown-led team says it was the first to make a working VCSEL with colloidal quantum dots.

The nanocrystals' outer coating alloy of zinc, cadmium, sulphur and that molecular glue is important because it reduces an excited electronic state requirement for lasing and protects the nanocrystals from a kind of crosstalk that makes it hard to produce laser light, Nurmikko says. Every batch of colloidal quantum dots has a few defective ones, but normally just a few are enough to interfere with light amplification.

Faced with a high excited electronic state requirement and destructive crosstalk in a densely packed layer, previous groups have needed to pump their dots with a lot of power to push them past a higher threshold for producing light amplification, a core element of any laser.

Pumping them intensely, however, gives rise to another problem: an excess of excited electronic states called excitons. When there are too many of these excitons among the quantum dots, energy that could be producing light is instead more likely to be lost as heat, mostly through a phenomenon known as the Auger process.

The nanocrystals' structure and outer cladding reduces destructive crosstalk and lowers the energy needed to get the quantum dots to shine. That reduces the energy required to pump the quantum dot laser and significantly reduces the likelihood of exceeding the level of excitons at which the Auger process drains energy away. In addition, a benefit of the new approach's structure is that the dots can act more quickly, releasing light before Auger process can get started, even in the rare cases when it still does start.

"We have managed to show that it's possible to create not only light, but laser light," Nurmikko says. "In principle, we now have some benefits: using the same chemistry for all colours, producing lasers in a very inexpensive way, relatively speaking, and the ability to apply them to all kinds of surfaces regardless of shape. That makes possible all kinds of device configurations for the future."

The US. Department of Energy, the Air Force Office for Scientific Research, and the National Science Foundation supported the research. Dang is a Vietnam Education Foundation (VEF) Scholar.

Further details of this work has been published in the paper,"Red, green and blue lasing enabled by single-exciton gain in colloidal quantum dot films", by Dang *et al*, *Nature Nanotechnology*, 7, 335–339 (2012). DOI:10.1038/nnano.2012.61

Global QD market to shoot up to $7480.25 million by 2022

Apart from in healthcare, where Quantum Dots hold a large market share, the technology is expected to play a major part in LED lighting and solar cells in the future

A new report, "Quantum Dots (QD) Market - Global Forecast & Analysis (2012 - 2022)" published by MarketsandMarkets, says the total market for Quantum dots is expected to reach over $7480 million by 2022, at a CAGR of 55.2% from 2012 to 2022.

Quantum Dots (QD) are one of the most advanced area of "semiconductor nanoparticles", and is currently undergoing massive research.

QDs are semiconductor nanoparticles, and, as the name suggests, have size from 2 nm to 10 nm. Due

to their miniature property; they are highly versatile and flexible. The uniqueness of QD material lays in the fact that its power intensity depends on the input source and size of QD.

There are several ways to confine excitons in semiconductors, resulting in different methods to produce quantum dots. In general, quantum wires, wells, and dots are grown by advanced epitaxial techniques in nanocrystals produced by chemical methods or by ion implantation, or in nanodevices made by state-of-the-art lithographic techniques.

In the present scenario of QD technology market, Healthcare is the only industry, which has gained significant market share. Healthcare needs high precision in tissue labelling, cancer therapy, tumour detection, etc. and QD-based devices work for the same.

The lighting industry is huge; and after the introduction of efficient lighting like LED, this industry has taken a huge leap. LED lighting and fixtures market has propelled in the last few years and is expected to expand further.

Now companies are looking for the alternate technology for LED lighting. QD lighting will fulfil the need; it is highly efficient and cost-effective. QD Vision has collaborated with Nexxus Lighting to launch its first QD LED light, and soon it will capture the market. Likewise, the company is also working on QD display.

QD technology will play a crucial role in solar energy-oriented industry as well. Researchers have developed QD-based solar cell, which is 50% as efficient as conventional solar cell. University of Toronto has achieved an efficiency of 4.2% conversion with solar cell based on colloidal QDs (CQD). Researchers are also working on QD-based paint that can be applied to panels or walls to capture solar energy.

The global Quantum Dots Market for technology-products and applications is expected to reach $7480.25 million by 2022, at an estimated CAGR of 55.2% from 2012 to 2022. The Americas are holding a leadership position in QD technology market on the whole; followed by Europe and APAC. In the market of ROW, Middle East and Africa are the largest contributors.