Best PCIM Ever

PCIM 2011 from May 17 - 19 attracted more than 730 conference delegates (2010: 619), 6600 exhibition visitors and 298 exhibitors with additionally 67 represented companies. With these figures PCIM is growing from year to year (20% in exhibitors,) and among the largest power electronic events worldwide. PCIM Europe 2012 will take place from May 8 - 10 again in Nuremberg.

"With these figures this is the best PCIM in history", Mesago's president Udo Weller pointed out. "In particular the increase of conference delegates backs us as the leading power electronics conference in Europe". The economical environment for this year's event couldn't have been better. In 2010 all of the PCIM exhibitors experienced extraordinary growth (+40% and more) after the downturn in 2009 (-24% down to $10 billion for discrete power semiconductors and modules).

And the demand for power electronics is set to increase with the increased usage of electricity. The International Energy Agency (IEA) anticipates that global energy consumption will increase by over 35% in the next 20 years. About one third of the energy used worldwide is consumed in the form of electricity. This electric power is transmitted over long distances and often a great deal of energy is lost in the process. The intelligent deployment of power semiconductors counteracts this energy loss by enabling energy to be generated, distributed and converted with minimum loss. Using these energy-saving chips can also significantly increase the energy efficiency of electronic devices and machinery to secure maximum energy savings. The importance of thrifty energy use is gaining momentum as the world population continues to grow: it represents one of the largest energy resources available.

Awards for outstanding papers

Three Young Engineer Awards (€1000,00 each) have been handed over at the opening ceremony sponsored by ECPE, Infineon Technologies and Mitsubishi Electric.

Anna Mayer, University of Federal Armed Forces, Munich/Germany was awarded for her paper "**Control Concept of the Modular High Frequency Converter for Vehicle Applications**". For future electric vehicles, new power electronic systems are required. Beside low weight and a small volume, low losses and an excellent dynamic behavior are demanded. These requirements cannot be met with conventional converters like 2-level IGBT converters or NPCs. The new Modular High Frequency-Converter (MHF) enables essential improvements of these problems. Main points are very high efficiency, ultra light weight and "fault ride through" capability. It is especially suited for future cars with multi-motor drives and integrated power electronics. For the MHF converter a new control concept, based on the modular concept of the hardware, was developed. The paper showed the results of this concept, including the main points dynamic torque control, disturbance on battery voltage, and continued (redundant) operation after defects.

Hitoshi Uemura, Mitsubishi Electric Japan, received the YEA for the paper "**Optimized design against cosmic ray failure for HVIGBT Modules**". The newly developed HVIGBT has been improved the robustness against cosmic ray induced failure in comparison with conventional IGBT. The key factors are the distribution of electric field strength by LPT structure with optimized carrier lifetime control and minimized crystal defect in silicon by the strengthened gettering during wafer processing. Consequently the SEB failure spot moved from the collector side to emitter side proved by the analysis of the neutron irradiation experiment and investigation of failed HVIGBT chips.

Finally Johannes Kolb, Karlsruhe Institute for Technology, received the YEA with "**A novel control scheme for low frequency operation of the Modular Multilevel Converter**". The paper presented a coherent control strategy for the Modular Multilevel Converter (MMC) which is able to generate output voltages at low frequency. Here the challenge of balancing the capacitor voltages in this operation mode has to be met. The solution consists by the derivation of the decoupled current control on the one hand and the balance of active power on the other hand. The combination of these fundamentals leads to a feedforward control which includes a modulation scheme for balancing the energies in the cells. This approach has been tested in a simulation. The results demonstrate the basic functions and the high quality of the input and output waveforms. A symmetrical energy distribution in the arms is achieved and simultaneously no AC currents occur in the DC source. This technique is qualified to control a

¶PCIM's Young Engineer (€1000.00) and BEST Paper (€1000.00 + PCIM China trip) Awards were handed over at the opening ceremony by Achim Scharf (PEE, left), Uwe Scheuermann (SEMIKRON), Thomas Harder (ECPE), Sebastian Liebig (BPA), Gourab Majumdar (Mitsubishi), Anna Mayer (YEA), Hitoshi Uemura (YEA), Johannes Kolb (YEA), and Leo Lorenz (Infineon, right)

MMC at low output frequency for feeding a three-phase motor in the start-up period.

The Best Paper Award (BPA) has been given to Sebastian Liebig from Liebherr Electronic (Germany) for his work "**Concept and prototyping of an active mains filter for aerospace application**". This award sponsored by Power Electronics Europe and SEMIKRON includes a €1000,00 price and invitation to PCIM China 2012.

One major topic in aerospace applications is the substitution of hydraulic or pneumatic systems with electrical systems such as electrical environmental condition system (E-ECS). Conventionally, the DC-link voltage is generated using state-of-the-art topologies, most commonly active power factor correction (APFC) or autotransformer rectifier unit (ATRU). The active parallel power filter (APF) represents an interesting alternative to these topologies, since it has to be designed only for the sum of 5th and 7th harmonic power. This promises less weight and volume, which is a crucial topic for all aerospace systems. Due to high supply frequencies, which can vary between 360 and 800Hz, the use of active filters in airplanes is more complex. The current control algorithm has to be robust and accurate during steady state conditions. During frequency steps or ramps, the active filter must remain stable and follow with reasonable compensation performance but without faults or control loss. To ensure that both requirements are met, the control algorithm is split into two main parts - robust reference current generation based on instantaneous power theory and accurate harmonics regulation, which ensures the power quality. For the EMC design, the entire power electronic device is divided into several impedance matrices. The switching of active filter and motor inverter is translated into a voltage spectrum, which results together with impedance matrices in distortion currents. The influence of input and output filters can be calculated by simply adding another two matrices.

The full power prototype is being set up with customized SP3-modules from Microsemi using 1700V SiC MOSFET and SiC diode chips (both from Cree). The loss comparison with a 1200V NPT-IGBT in an SP3-module reveals that SiC technology leads to 64% reduced losses at 60 kHz. Even at 100kHz the MOSFET offers a 50% benefit compared to the IGBT at 60kHz.

Responding to the question why the press is sponsoring the BPA, PEE editor-in-chief Achim Scharf pointed out: "As with PCIM also PEE is a marketplace for information exchange about new technologies and applications and with that we are looking always for developments in power electronics or power systems and support that as best as we can".

GaN and SiC gain great interest

Also in future electric vehicles device technologies which can withstand high temperatures such as GaN and SiC are of great interest. "In the year 2020 around 10% of automobile production or seven million will be electric vehicles. GaN and SiC can be used for the power train, because cost decrease for the power system including cooling efforts justifies the application of these power semiconductors. Additionally, to get rid of rare earth materials for electric motors reluctance motors will be used", said Renault's Director of Advanced Technologies Patrick Bastard in his keynote. Through Renault's partner Nissan SiC power modules made by Rohm are already applied in vehicles.

Thus technical progress will go on in order to improve more and more performances and economics efficiency of electrical vehicles. Furthermore, in addition to technical progress concerning the car itself, it is important to keep in mind that electrical vehicles have really to be considered in the global context of electricity production and distribution. Communication between car and infrastructure as well as control of EV charge through optimized strategies are also key issues in order to take advantage as much as possible of a large EV fleet, from a technical point of view but also from an environmental one. This is also a big challenge, especially in the context of emerging smart grids.

With the acquisition of TranSiC, a Swedish Silicon Carbide (SiC) power transistor company based in Kista, Fairchild Semiconductor (**www.fairchildsemi.com**) widened at PCIM its power semiconductor offering. TranSiC's high gain SiC bipolar devices are suited for high-power conversion applications in down-hole drilling, solar inverters, wind-powered inverters, electric and hybrid electric vehicles, industrial drives, UPS and light rail traction applications. These markets are projected by Yole Development to approach $1 billion by 2020. Fairchild is sampling initial 1200V products up to 50A ratings in targeted applications. Future offerings are in development to expand the voltage and current range, and to continue to drive improved energy saving.

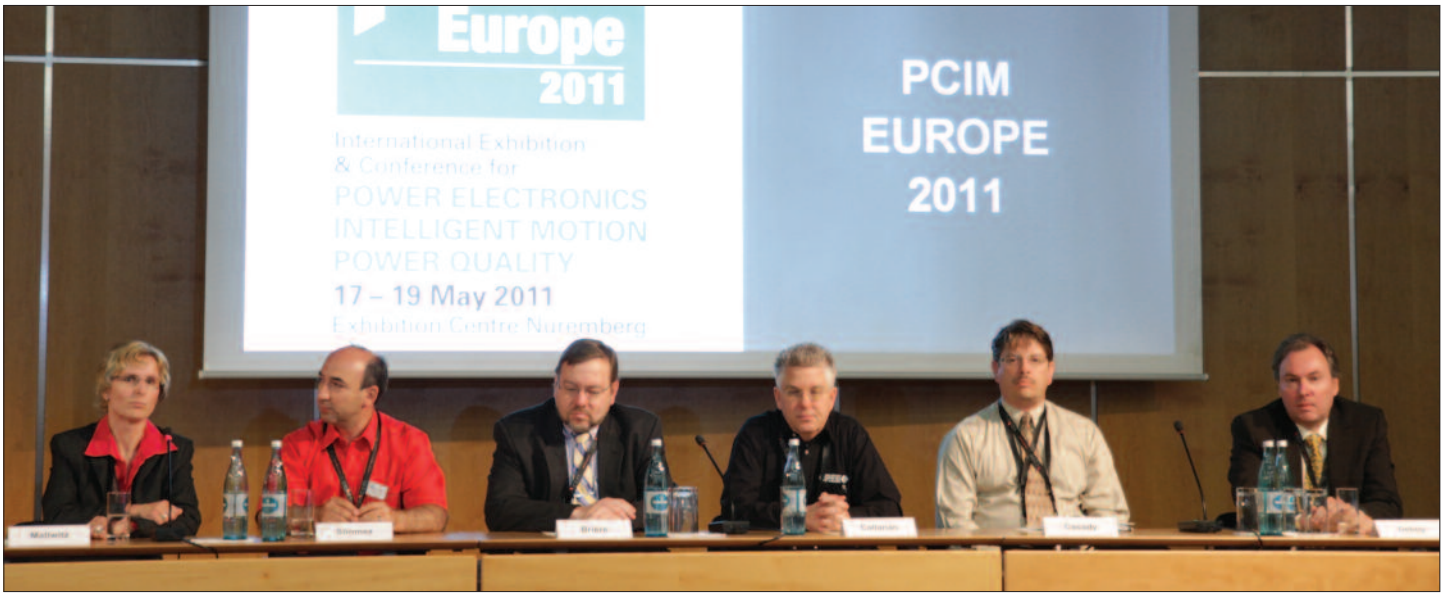
Thus IMS Research forecasts that all the new activity will push the global market for Silicon Carbide power devices to $100 million in 2011.

PEE's Special Session '**High Frequency Switching Devices and Applications**' was another event for supporting new technologies/ applications attracting more than 120 conference delegates. Thus it was the major session on GaN/SiC technologies and devices. Five papers were presented by MicroGaN/Germany, ACOO-IR/USA, Cree/USA, SemiSouth/USA and Infineon-SMA/Austria-Germany.

The first two papers covered GaN power technology. Especially for mains voltage applications, new efficient 600V class devices are required. These devices are within the main product focus of MicroGaN (**www.microgan.de**). "Two basic elements are developed which will enable the layout of all required power circuits - the power diode and the power switch. Additionally, a unique fabrication technology has been developed to reduce chip area, chip price and device parasitics as well as providing compatibility to standard PCB to be competitive on the market", MicroGaN's Ertugrul Sönmez stated.

The second GaN paper by ACOO-IR (**www.irf.com**) described the evolution of this technology up to 600V and possibly beyond. Device ruggedness in application conditions must remain uncompromised with respect to expectations established by the incumbent silicon based technology. "Large forward biased safe operating area is an important indication of such robustness and has been demonstrated on GaN 600V prototype devices to 10A at 600V for 100ns. Device stability under accelerated stress conditions for extended periods of time is

"In the year 2020 around 10% of automobile production or seven million will be electric vehicles. GaN and SiC can be used for the powertrain, because cost decrease for the power system including cooling efforts justifies the application of these power semiconductors", said Renault's Patrick Bastard



PEE's Special Session participants Regine Mallwitz/SMA (left), Ertugrul Sönmez/MicroGaN, Michael Briere/ACOO-IR, Robert Callanan/Cree, Mike Mazzola/SemiSouth, and Gerald Deboy/Infineon Technologies (right)

essential for acceptance in the power electronic community. To date, over 10,000,000 device hours of reliability data has been collected on the low voltage devices released to production by IR in early 2010, with up to 10,000 hours per device. No intrinsic premature device failures have been found to date and parametric stability has been excellent. In addition, initial reliability studies of high voltage GaN based devices have also shown excellent parametric stability to 2000 hours", Michael A. Briere stated.

Cree's (**www.cree.com**) Robert Callanan introduced the new 1.7kV SiC MOSFET which has been used also in the active filter described in PCIM's Best Paper. The demonstrator shows how two of these 1.7kV SiC MOSFETs can easily realize a 10kW, 1kV hard-switched DC/DC converter operating at 32kHz with an efficiency of 97.1% without extensive optimization. Higher efficiency can be achieved through some basic modifications. The modest switching loss of the SiC MOSFET allows higher switching frequencies using hard-switched topologies is definitely possible. This technology enables substantial improvements in size, weight, and efficiency in all aspects of power conversion such as 690V motor drives, auxiliary power converters for traction, solar inverters and wind applications to name a few. This performance utilizing a very simple and robust half-bridge hard-switched topology would be difficult, if not impossible, using Silicon IGBTs.

As SiC devices continue to mature and are integrated in more applications their attractiveness in higher power applications will continue to grow. Thus the need for higher power level, multi-chip power modules must be available packaged in reliable, standard module packages, as shown by Michael Mazzola from SemiSouth (**www.semisouth.com**). However, in order for users to achieve the maximum high speed transients capable with SiC power JFETs at high voltages and currents careful design considerations must be followed for gate drive, wiring, layout, and module parasitic. It is critical to minimize all possible contributors to parasitic inductance within both the power circuit as well as the gate driver that can potentially "ring" with the low device capacitance of the SiC JFET. This concept is not new and is consistent with requirements experienced during the first introduction of the MOSFET. "However, high frequency oscillations experienced during the switching transients of the high-speed normally-off, half-bridge, 1200V, 100A SiC VJFET SP1 module can be significantly reduced and in some cases eliminated with a few strategically placed RC snubbers. This approached allowed for the observation and measurement of record low switching losses of 1.25 mJ at 150°C", Mazzola underlined.

Finally, a joint paper by Infineon and SMA Solar Technology (**www.infineon.com**, **www.sma.de**) presented a new normally-on SiC JFET with monolithically integrated body diode. The device concept achieves ohmic characteristics in forward and reverse direction (when driven in a "synchronous rectification" mode) and extremely low switching losses. It shows a nearly zero reverse recovery performance of its monolithically body diode.

Safety requirements can be fulfilled by combining the direct driven normally-on SiC JFET with a low-voltage MOSFET in a Cascode arrangement. This pair of switches operates like one normally-off switch in critical situations. "The new SiC JFET allows full usage of the integrated body diode. It saves anti-parallel diodes in the topology, which are otherwise required in the case of reactive power", explained Infineon's presenter Gerald Deboy. "The standard inverter based on Si switches achieves a maximum efficiency of 98.2%. For the inverter equipped with the new SiC JFETs 98.8% system efficiencies can be obtained", SMA's Regine Mallwitz pointed out.

The presented papers will be published in this and the following issue.

News from the exhibition

Speaking about recovering from the crisis in 2009, according to local sources Nuremberg-based SEMIKRON (**www.semikron.com**) faced a loss of 30% down to €325 million in 2009. "But we grew by almost 70% in 2010", Head of Product Management Thomas Grashoff underlined. The privately-held company is one of the major power module suppliers and as such a indicator of how the market develops. Wind and solar power as well as automotive were and are the major growth drivers for SEMIKRON as well for the European power electronics industry in general.

At PCIM Semikron introduced a space-saving packaging technology which removes bond wires, solders and thermal paste. The new SKiN Technology is based on a flexible foil and sintered connections, doubling the current density to 3 A/cm^2 compared with 1.5 A/cm^2 achievable with standard wire bond technology. "The converter volume can therefore be reduced by 35%. This reliable and space-saving technology is the optimum solution for vehicle and wind power applications", Grashoff commented.

Wire bonding has been the main method of connecting the chip upper to a DBC substrate for the past 25 years. Wire bonding is not up to the higher current density that technical advances have brought about, meaning reliability is impaired by bond lifting. With the new so-called SkiN packaging, a sintered foil replaces the wire bonds on the chips, and the underside of the chip is sintered to the DBC. This results in better thermal and electrical chip connection, since sintered layers have a lower thermal resistance than

"Our SkiN technology features sintering instead of soldering and a flexible foil instead of bonding resulting in 30% higher current carrying capability and higher reliability by a factor of 10", stated SEMIKRON's Thomas Grashoff

solder equivalents. The sintered foil connects the chip across its entire surface, whereas bond wires connect the chips at the contact points only.

This results in a higher current carrying capacity and 10 times the load cycle capability - unthinkable with the restrictive wire bonding used in power electronics in the past. "We are approaching with SkiN 2 million load cycles to failure compared to 200,000 in standard technology. Thanks to the high load cycle capability higher operating temperatures are possible. Given the move towards new materials such as SiC and GaN, these elevated temperatures can then be fully exploited as well as higher switching frequencies up to 70kHz", Grashoff pointed out. With SKiN technology it is now possible that a 3MW wind power converter can be fit into a single switch cabinet. Another example is a 90kW converter for hybrid and electric vehicles which can be 35% smaller than the smallest converter on the market today.

Vincotech (**www.vincotech.com**), another Germany-based power module maker recently acquired by Mitsubishi Electric, reported growth of 110% in sales of power modules in 2010 and 74% in the first Quarter of 2011. "Since end of December 2010 we are part of Mitsubishi Electric, but we operate independently and stay with Infineon Technologies as main IGBT supplier, though we now have access to Mitsubishi's chips", CEO Joachim Fietz pointed out.

At PCIM Vincotech has introduced power modules equipped with Normally-Off SiC JFETs from SemiSouth. Engineered for highly efficient solar inverters, these new products feature a 1200V dual booster input stage and a 1200V MNPC (1 module per phase) inverter stage housed in a flow0 package with just 12mm assembly height. The modules support highly efficient, three-phase solar inverters ranging up to 30kW combining multiple 10A diodes and 100mΩ JFETs. The on-board, high-frequency DC link capacitors enhance fast-switching, low-inductive designs and help minimize voltage overshoots. Due to the acquisition by Mitsubishi the company announced that it will add the latest Mitsubishi IGBT technology to its range of MiniSKiiP® PIM modules. The new modules ranging from 15A/1200V to 100A/1200V in three different housings. All modules feature a 3-phase input rectifier, a 3-phase output inverter, a brake chopper, and an added thermistor to measure temperatures (PIM topology). Pins match the previous version's array to enable easy upgrading. The modules will also be offered with pre-applied thermal grease. Samples are in the works for September 2011, with serial production slate for Q1 2012. "Our MiniSKiiP business in total makes 20% of our revenues or 200,000 modules quarterly", VP R&D Peter Sontheimer emphasized.

High growth is also expected at Geneva-based LEM (**www.lem.com**) , the leading manufacturer (1,300 employees) of current transducers. "Our guidance for fiscal year 2010/11 is around CHF300 million", said CEO Francois Gabella at PCIM. In 2008/9 LEM reported sales of CHF186 million.

At PCIM LEM has introduced the CTSR family of current transducers for use in a range of safety-critical applications including solar installations. Two transducers in the new series measure AC or DC leakage nominal currents, from values as small as 300 and 600mA RMS, with spectral components up to 9.5kHz. The residual or leakage currents that the CTSR family is designed to measure can arise in fault conditions in a number of industrial or power-generation scenarios. Examples include solar panels that are coupled to an earthed grid, or in failure modes such as a short circuits or earth faults. The connection of a solar panel to the grid raises safety concerns; if a fault occurs there is a potentially serious safety issue around any human in contact with the system. Models with higher nominal current range up to 3A RMS to meet the needs of specific customers can be developed on request. As well as ensuring safety in solar inverter installations, LEM's CTSR range is also suited for a range of applications that includes symmetry fault detection in medium power inverters or failure detection in power sources.

Also International Rectifier (**www.irf.com**) reported impressive figures. Revenues for the third quarter fiscal year 2011 was $296.7 million, a 5.3% increase from $281.7 million in the second quarter

"Since end of December 2010 we are part of Mitsubishi Electric, but we operate independently and stay with Infineon Technologies as main IGBT supplier, though we now have access to Mitsubishi's chips", Vincotech's Joachim Fietz pointed out

fiscal year 2011 and a 22.7% increase from $241.9 million in the third quarter fiscal year 2010. "For the June quarter, we expect revenues of $320 million", CEO Oleg Khaykin stated.

At PCIM the company introduced the AUIR3330S Intelligent Power Switch (IPS) with a proprietary active di/dt control feature that reduces conducted EMI and switching losses to simplify design in automotive motor drive applications. The new 40 V high-side device combines bootstrap regulator, charge pump and high-side driver into a single package. The load can be driven up to 40kHz at 100% duty cycle. Additionally, the IPS features programmable over-current and over-temperature protection required by applications operating in harsh automotive environments such as pumps and fans, and current sensing feedback, a diagnostic function, very low current consumption in sleep mode and ESD protection. "Our new active di/dt control drastically reduces conducted EMI on the input supply without increasing switching losses, enabling a reduction in the size of the EMI filter and the heat sink for more efficient compact motor systems", said Marc Legrain, IR's Executive Director Automotive Product Business Unit.

Fuji Electric Co., Ltd. (**www.fujielectric.com**) and Freescale Semiconductor (**www.freescale.com**) entered into an alliance on IGBT technology and products for HEVs and EVs. Working with Fuji Electric, Freescale will add high-power IGBT products to its existing portfolio of solutions for electronic powertrain applications, market those products to its automotive customers and define and produce new products based on customer input. "We are pleased to work with Freescale on IGBT technology and draw on their automotive capability", commented Kuniaki Yanagisawa, General Manager of Fuji Electric's Electronic Devices Business Headquarters.

SemiSouth (**www.semisouth.com**) launched the TO-247 SDP60S120D 1200V, 60A SiC power Schottky diode, featuring a positive temperature coefficient for ease of paralleling and temperature-independent switching behavior. "The new Schottky diode also exhibits a zero reverse recovery current and zero forward recovery voltage and can replace three paralleled 20A parts reducing power dissipation by over 12% as well as saving space and cost", commentd Dieter Liesabeths, Director of Sales. The company also launched new 45mΩ, 1200 V, normally-on trench SiC power JFETs. These devices target a range of application spaces, including solar inverters, SMPS, induction heating, UPS, wind applications, and motor drives. Featuring a positive temperature coefficient, the SJDP120R045 JFETs also offer fast switching with no 'tail' current - even up to its high 175°C maximum operating temperature in a TO-247 package. The device is also available in bare die form (SJDC120R045) for module partners.

IR's Marc Legrain showing demo board featuring AUIR3330S Intelligent Power Switch with a proprietary active di/dt control feature that reduces conducted EMI and switching losses to simplify design in automotive motor drive applications

Infineon Technologies (**www.infineon.com**) has purchased real estate and manufacturing facilities from the insolvency Qimonda for a total of €100.6 million. The deal covers cleanroom and manufacturing facilities as well as 300mm manufacturing equipment for potential volume processing of thin 300mm power semiconductor wafers. For this purpose a pilot line is set-up at the company's site in Villach/Austria. Some of the new machinery will be used for completion of the pilot line in Villach. About the start and the location of a 300mm volume production the company will decide during the current fiscal year.

At PCIM the company announced the expansion of its Reverse Conducting (RC) 600V IGBT with two new switching power devices that achieve up to 96% efficiency in target applications. The new devices allow design of energy efficient, electric-motor driven consumer appliances that use smaller components and thus have a lower overall cost compared to alternative systems.

Also the 1200V SiC diode portfolio has been extended with 1200V diodes in the new TO-247HC (High Creepage) package. This new package layout is fully compatible with the industry standard TO-247 and can therefore easily be placed in already existing designs, without extra efforts. The higher creepage distance increases the safety margin against the risk of short circuits, especially arcing, which might be triggered by the presence of dust or dirt inside the system. This reduces the need of additional chemical (silicone gel or cream) or mechanical solutions (sheaths or foils) needed to avoid any pollution between the package leads, with all the benefits of a lean and fast manufacturing process.

In higher power ranges Infineon has launched 4.5kV IHV modules combining TrenchSTOP™ and FieldSTOP™ technology and complement the modules in the 3300V and 6500V ranges. While the FieldSTOP structure ensures a significant reduction in switching losses, the TrenchSTOP cell minimizes on-state power losses because of its low saturation voltage. This results in lower losses and reduced cooling requirements, which ultimately decreases the system costs. The advantages of the TrenchSTOP technology furthermore include good ruggedness and short circuit behavior, increased reliability and low electromagnetic interference (EMI). Infineon will sampling the 4.5kV IHV modules for IGBT3/EC3 initially in the IHM-B housing with a storage temperature down to -55°C and an operating temperature up to 150°C by end 2011, and secondly in the highly insulated 6.5kV housing by mid 2012. ABB (**www.abb.com/semiconductors**) presented a newly developed 3.3kV high-temperature module generation rated at 1500A, which combines the dynamic properties of the previous SPT+ version with the 150°C operation capability. This high-temperature operation was previously not possible due to the high leakage currents generated in the IGBTs and the diodes. In the new version the leakage current for the IGBT by optimizing the buffer and anode design results in an overall reduction by at least 30%, while keeping the bipolar gain and therefore also the important dynamic properties similar. The main improvement step has been taken on the diode-side. "Although the radiation lifetime control has been identified being rather prone to leakage current, we were able to reduce the leakage current by at least a factor of 2 by carefully adjusting the irradiation conditions to the newly developed buffered anode doping profile. This anode-design separates the radiation defects generated by the local lifetime control laterally from the space charge region formed during blocking. The challenge has been to maintain the high safe-operating area of the previous diode generation and combine it with the desired high temperature operation. The diode is able to withstand a very high dI/dt of more then 7kA/µs and the peak power is exceeding 5.6MW", explained ABB's speaker Sven