4th ECPE SiC & GaN User Forum
Potential of Wide Bandgap Semiconductors in Power Electronic Applications
— Report of Conclusions —

European Center for Power Electronics e. V. (ECPE)
www.ECPE.org

Birmingham (UK), 01.-02. September 2011

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General

After the Silicon Carbide (SiC) User Forums organised by ECPE in 2006, 2007 and 2009, technology has advanced significantly and time had come to continue the exchange between experts involved in converter and device development: The fourth User Forum focused on recent developments, in particular of SiC transistors and of first Gallium Nitride (GaN) power devices. Typical power electronic systems the use of wide bandgap devices is highly promising for have been presented in conjunction with SiC and GaN devices themselves which are the base for future system development. Renowned experts from all over the world have been invited to give an overview in a keynote, to foster physical understanding, to in depth explain their research and development work in technical presentations and to share their knowledge in discussion forums as an indispensable part of the event. The User Forum this way established a platform to share experience and ideas, to discuss and find out which power electronic systems are predestinated for usage of SiC or GaN and how to appropriately design-in those novel, almost ideal but also challenging components. It aimed at finding and pointing out approaches to exploit the high potential of those devices and to support their beneficial introduction in power electronic systems. User Forum 2011 took place right after EPE-ECCE Europe conference in Birmingham. Prof. Andreas Lindemann (Otto-von-Guericke-Universität Magdeburg, Germany) took the chair together with Prof. Phil Mawby (University of Warwick, UK) and Mr. Thomas Harder (ECPE). The major findings of the event are summarised in the following:

State of the Art and Trends

Starting in the beginning of the supply chain, SiC material situation has relaxed with respect to defect density and also some cost reduction, which is a remarkable, but nevertheless comparable

development as Silicon (Si) has undergone earlier. Consequently GaN on Si for power devices is still in an earlier stage, promising an attractive cost structure but still requiring considerable research and development effort for further commercialisation.

On the device side, SiC Schottky diodes up to 1700V blocking voltage and some tens of Amps nominal current are a well-introduced commercial product for use in switched mode power supplies, power factor correction stages etc. Based on this and as already demonstrated in laboratory, the diode current and voltage ratings might be further increased in future for industrial applications to exploit their advantageous switching behaviour in high power electronics, where they can complement Si IGBTs as free wheeling diodes, leading to significantly lower switching losses compared to Si diodes.

The development of SiC transistors was in the focus of this year's ECPE User Forum: Compared to Si, a surprising variety of SiC transistor types has established which constitutes an attractive playground for circuit designers: There are SiC MOSFETs, bipolar transistors and junction FETs (JFETs). The SiC MOSFETs behave in a similar way as Si MOSFETs although still concerned by some stability and mobility issues; the former fact is attractive because control circuitry known from Si MOSFETs can basically be re-used for these normally-off devices. In contrast, normally-off JFETs should be turned on with a gate voltage that leads to some current flow. The performance of normally-on JFETs can be exploited optimally with a modified cascode circuit, where the low voltage, normally-off Si MOSFET is only used as a backup to block, when no driver supply is available, while otherwise the JFET is controlled itself. A major step to commercialise this will be modules ioncorporating the cascodes and in particular driver ICs for these modules, this way providing a fast switch with the same logic interface as used for conventional solutions. Care needs to be taken in package and circuit design especially regarding parasitics which should be reduced because of the steep switching slopes; some new approaches have been elaborated to achieve this. SiC bipolar transistors finally are driven with a base current; their switching times are comparable to unipolar MOSFETs' or JFETs'. Transistor devices have recently been released as commercial products with ratings comparable to aforementioned SiC diodes'. Photovoltaic inverters can be expected to be a key application for commercial introduction of SiC transistors: Here the prerequisite can be expected to be met reasonably quickly that reduced system cost will compensate higher device cost. Reliability of course is a further key issue for industrial application: There is plenty of experience with SiC Schottky diodes; SiC transistors have been qualified and released, field experience will now need to prove that the tests have been appropriately chosen. GaN high electron mobility transistors (HEMTs) in this respect have been presented to fill a particular niche — their exceptional irradiation hardness is a prerequisite for use in collider physics detectors. In addition, the potential of circuit integration can be expected to also make them attractive for variuos volume applications.

Outlook and Conclusion

Device and system related research and development has led to remarkable results: Power electronics with wide bandgap SiC and GaN semiconductors is established on an industrial level. Nevertheless, this process will go on with future R&D covering the areas from material level via device structures, technology and packaging, circuit and control issues up to system design as outlined above. This way, wide bandgap power electronics can contribute to solve actual challenges, aiming e. g. at energy efficiency, increasing usage of electric energy from renewable sources or electromobility. The European Center for Power Electronics ECPE fosters this; an update about further progress can be obtained on the occasion of the next ECPE SiC & GaN User Forum.