7th ECPE SiC & GaN User Forum
Potential of Wide Bandgap Semiconductors in Power Electronic Applications
— Report of Conclusions —

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Andreas Lindemann
Otto-von-Guericke-Universität Magdeburg
Chair for Power Electronics
www.uni-magdeburg.de/llge

Overview

ECPE wide bandgap user forum recently celebrated a decadal anniversary: As premier event of this kind it has accompanied the development of Silicon Carbide (SiC), Gallium Nitride (GaN) and other wide bandgap power semiconductor devices and their design-in into circuits and systems for more than ten years. Following several other European venues the seventh event took place in March at Nürnberg. The highest number of registrations ever showed the great interest of power electronics community in this actual subject. Main technical focus has been on new developments with SiC and GaN transistors including system and circuit design, related aspects like packaging and parasitics, and an outlook on future prospects. Renowned experts from industry and research institutes all over the world have been invited to explain state of the art and trends, to foster physical understanding, to in depth explain their research and development work in technical presentations and to share their knowledge in discussions. The wide bandgap user forum this way has established a valuable platform to exchange experience and ideas, to show best practise of power electronic systems with SiC or GaN, to discuss and find out how to appropriately design-in those almost ideal but also challenging components, and which open issues need to be addressed. It aimed at pointing out approaches to fully exploit the high potential of wide bandgap devices for the benefit of modern electric and electronic systems in a variety of applications. Presentations of results of relevant European research projects impressively complemented this aspect. Some main topics of this year's ECPE wide bandgap user forum are summarised in the following:

State of the Art and Trends

SiC power electronics is well established in the voltage range 600V, 1200V and 1700V. Circuits make use of diodes and increasingly transistors where the diversity of types observed in recent years today converges to MOSFETs. Devices and their base material have reached a considerable level of maturity, also permitting to understand and implement useful device properties like avalanche ruggedness. Packaging still is a issue with some novel approaches, usually without wire bonds, demonstrated by research institutes and industry. Package related parasitics will influence electromagnetic compatibility (EMC) as they tend to foster current or voltage oscillations respectively in conjunction with switching actions. Besides optimised packages dedicated gate drivers promise to counteract this undesirable effect. As appropriate for a user forum, related practical aspects of lab work like suitable current sensing have also been addressed. Research and development with regard to SiC devices aim at exploiting higher power ranges using devices with higher voltage or current ratings, the latter also being achievable through parallel connection. Obviously devices used in durable goods such as photovoltaic inverters in the Megawatt range, wind converters or traction converters of railway rolling stock, serving as application examples, will need to prove an appropriately high level of reliability. The experience already gained thus significantly fosters the pursued evolution towards higher power levels of compact and highly efficient SiC converters.

GaN devices — mostly transistors with blocking voltages up to 600V — and circuits employing them have been realised and concurrently are subject to considerable research and development: On device level, main interest is dedicated to parameter stability, reliability and ruggedness. Intermediate results have shown actual achievements in particular of optimised stability, and unveiled approaches for a deeper understanding of underlying mechanisms. GaN devices are mainly used in switched mode power supplies with moderate nominal power. As such, automotive on board chargers in electric or hybrid vehicles might become a lead application. Accepting the challenge of holistic system design permits to create innovative solutions, together optimising semiconductor devices, passives — i. e., capacitors and inductors or transformers — and assembly, for example permitting to integrate the transformer into the printed circuit board. While miniaturisation may be limited by the application — e. g. single phase inverters requiring a certain capacity to compensate the ripple of instantaneous power — experience has been gained that resonant switching is advantageous when employing frequencies above 100...150kHz. Below, hard switching with fast GaN devices would still be efficient. The aforementioned considerations related to packaging, drivers and EMC of course apply for GaN devices and circuits as well.

The user forum's review intendedly hasn't been restricted to SiC and GaN: In their particular field of application both kinds of devices compete with Silicon (Si) power semiconductors. While the latters still are produced in the highest volume, the formers increasingly replace and complement them in circuits and applications their particular properties — in many cases especially switching speed — are advantageous for. Two alternatives have been presented as well, promising extraordinary characteristics at moderate cost: 3C SiC exhibits a different structure of the atomic lattice, enabling the use of different production technology being currently under development, especially with the aim to avoid wafer bow and stress. Tentatively Schottky diodes, MOSFETs and IGBTs up to 1200V seem feasible. It is further suggested to assemble such MOSFETs in a lead frame based surface mount package, thus constituting a compact phaseleg circuit. As a different approach, vertical Gallium Oxide (Ga_2O_3) Schottky diodes are proposed as a potential cost efficient solution for the voltage range between 600V and 1200V, competing with SiC and GaN.

Conclusion and Outlook

Power electronics is an enabling technology for a multitude of rapidly growing applications: It permits to increase energy efficiency, to feed electrical energy from renewable sources into the grid, to control drives and power supplies in electric vehicles or also to control machinery and robots in any modern production environment. Wide bandgap devices and the related circuits and systems are a fascinating and rapidly evolving part of power electronics as the aforementioned up-to-date contributions to ECPE wide bandgap user forum have impressively underlined. This important subject is continuously followed up by the ECPE wide bandgap working group; an update about further progress in this area will be available on the occasion of the next ECPE SiC & GaN User Forum.