9th ECPE SiC & GaN User Forum

"Potential of Wide Bandgap Semiconductors in Power Electronic Applications"
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The biannual ECPE Wide Bandgap User Forum is dedicated to report and discuss state of the art and prospects of SiC and GaN devices in power electronic systems.

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Overview

Major progress has been achieved in the meantime: Today SiC transistors and diodes are available within a wide voltage range and from various manufacturers; they are used in a variety of products. Application-specific aspects gain importance, such as qualification when exposed to demanding mission profiles in electric vehicles. Of course research and development to optimise the devices continuously and extend their operational range continue in parallel. In a similar way GaN power transistors have matured and penetrated various applications while research and development are ongoing as well. In addition, R&D is dedicated to further devices based on other materials.

This year's ECPE wide bandgap user forum was special since it had been postponed due to the pandemic situation, this way permitting it to be carried out as one of the first hybrid events in the area of power electronics this year, with some of the participants taking part on site and others remotely; the exchange which became possible again this way was highly appreciated.

State of the Art and Trends

From application point of view, 650V GaN HEMTs are competing with charge compensated silicon MOSFETs in particular in power supplies; in addition optimised 650V SiC MOSFETs might replace the formers as well. This permits to increase the efficiency or the power density of the respective converters which are usually single phase off-grid versions with power factor correction, or DC-DC converters such as in the on-board grid of electric vehicles. Switching frequency may reach up to considerable 1MHz in this voltage class. Similar aims — optimisation of efficiency or power density — can be realised with SiC MOSFETs for 1200V or higher blocking voltages in converters connected to the three-phase grid, e. g. being part of wind generator systems. In this voltage range solutions with silicon transistors and SiC diodes may in addition still permit an optimisation compared to converters with silicon devices only. The usage of SiC and GaN devices of course requires that they are qualified, reach an appropriate reliability under consideration of the mission profile and also provide enough ruggedness. Major progress in device development, standardisation and qualification has been reported in this respect as well as ongoing work: E. g. bipolar degradation doesn't constitute a problem in today's SiC devices when operated in the range of nominal current, and their power cycling capability has been successfully optimised to reach a comparable level as conventional silicon devices, taking into account the different material properties. This has been reached with newly developed packages which often use sinter connections and partially permit double-sided cooling. Ongoing work e. g. refers to the methods for power cycling tests which need to cope with the known drift effects of SiC MOSFETs' threshold voltage.

Their short circuit capability would be desirable in many applications but increasing it by device design turns out to be costly. As an alternative, the devices may be monitored using e. g. dedicated driver circuits, allowing to turn short circuits off immediately and detect possible damages. While earlier mostly drivers for silicon MOSFETs have been used to control SiC and GaN transistors, the latters' increasing use has permitted the development of dedicated drivers. This is in particular promising for GaN HEMTs with their relatively low allowed gate voltage range; as the devices are lateral anyway, the integration of a driver circuit and also possibly of more circuit elements — like a complete phaseleg — constitutes a promising approach, which amongst others solves many issues related to inductive parasitics in conventional packages and circuit layouts.

This is directly related to the addressed aspect of circuit and system design: Electromagnetic compatibility plays an important role here and will be strongly influenced by oscillations triggered by the switching actions; recent methods to minimise these effects have been explained as well as the impact of voltage change rates on isolation systems. Obviously designers can use a variety of tools to investigate particular aspects, nevertheless their holistic knowledge and experience of how to properly design a circuit with wide bandgap devices is of great importance. As a further outlook, device and circuit optimisation for special requirements — like under high temperature conditions or exposure to cosmic ray — has been addressed. This may require measures concerning the semiconductor devices themselves as well as their packages. Probing even further, devices made of gallium oxide or diamond are under investigation.

Conclusion and Outlook

The findings as briefly summarised above illustrate the fast development of wide bandgap power semiconductors and their successful use in industry. This is beneficial for power electronics as a key technology in various areas, such as energy efficiency, usage of renewable sources for electric energy supply, e-mobility or also automation. Both, SiC and GaN devices are available in continuously increasing production volumes. They are widely applied in commercial products and allow to optimise those with respect to e. g. efficiency or miniaturisation. Nevertheless, research, development and also standardisation are ongoing to further exploit the possibilities of wide bandgap devices in power electronics. The European Center for Power Electronics (ECPE) is a stakeholder in this area, bringing together industrial partners and research institutions. After the broad interest of far more than 200 international participants this year, ECPE will anounce the next SiC & GaN User Forum in 2023. There will be the occasion to report the progress achieved since today — and to celebrate the jubilee of the 10th event within this successful series.

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