6th ECPE SiC & GaN User Forum
Potential of Wide Bandgap Semiconductors in Power Electronic Applications
— Report of Conclusions —

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Overview

ECPE wide bandgap user forums have established as an international event where users — i. e., engineers developing advanced power electronic converters — and manufacturers of Silicon Carbide (SiC) and Gallium Nitride (GaN) devices meet biannually for a fruitful exchange. It recently was prepared in conjunction with a newly established ECPE SiC & GaN technical committee and hosted by University of Warwick (UK). The highest number of registrations ever showed the great interest of the community in this actual subject. Main technical focus has been on new developments with SiC and GaN transistors including system and circuit design or related aspects like packaging and parasitics. Renowned experts from 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 share experience and ideas, to show best practise of power electronic systems with of 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 exploit the high potential of those devices and to support their beneficial introduction in power electronic systems. Connected meetings of relevant research projects impressively complemented this aspect. The main topics of this year's ECPE wide bandgap user forum are summarised in the following:

State of the Art and Trends

SiC FETs are established as commercial products in the voltage range up to some 1200V. Higher voltage classes have been successfully demonstrated and sampled; breakdown voltages above 10kV might in future advantageously be covered by SiC IGBTs as already demonstrated. GaN transistors are competing SiC especially in the voltage range up to 1200V with principally better characteristics, however typically as normally-on devices still with more constraints regarding reliability and robustness. Examples of cheaper GaN on Silicon (Si) and even better performing GaN on SiC devices and related applications have been shown, underlining the cost benefit for power electronics using a technology which is well established in radio frequency electronics. Packaging with low parasitics and potentially high temperature capability is a known issue with partially contradictory aims, e. g. regarding required creepage distances for high voltage components versus low parasitic inductance: Related issues are already addressed in industry, implementing evolutionary progress as has been shown with several examples of state-of-the-art packages, while research goes further proposing more sophisticated approaches for future generations. Device and packaging technology directly determine robustness and reliability which is an ongoing research topic where important intermediate results have been shown with respect to SiC: There is a strong impact of device design e. g. on surge current or cosmic ray withstand capability, permitting to receive very rugged and reliable devices when properly designed; to prolong lifetime under power cycling conditions the higher thermal conductivity of the material needs to be taken into account, leading to a different temperature distribution and thus potentially even more thermo-mechanical stress. Robustness and reliability are further affected by the drivers which may include features like protection schemes — e. g. fast short-circuit protection — or control to achieve synchronous rectification, reducing SiC transistor's bipolar reverse diode's conduction time to a minimum and this way increasing efficiency. As contributions from industry and researchers impressively outlined, challenges in driver design result from the high voltage change rates achievable with wide bandgap devices, the partially low threshold voltages in particular of normally-off devices and last but not least potential high temperature operation in vicinity to the power semiconductors.

A major part of presentations has been dedicated to systems and circuits: Device cost versus system benefit is a known issue which has been generally addressed in a presentation and a dedicated forum discussion. Further contributions gave details about several applications: For automotive use, promising a high future production volume, an efficient power supply for LED lights with GaN transistors has been investigated, while in the higher power range a SiC traction converter has been demonstrated to achieve higher fuel efficiency and also miniaturise the converter. It has been impressive to see that even utility vehicles like a bus and light rail carriages have been equipped with SiC traction converters. A wide range of nominal power is also covered by the presented power supplies, starting at low power domestic converters and reaching up to the discussed idea to equip converters for high voltage DC transmission in utility scale with SiC devices with high blocking voltages. In the latter case the modular multilevel converter (MMC) is a viable solution also with Si devices, so SiC can be expected to establish when feasible for the required high current ratings and offering the benefit of loss reduction, mainly referring to conduction losses because of the property of MMC to add the relatively low switching frequencies of its submodules to a resulting higher frequency. It was interesting to observe the introduction of SiC devices to industrial niche applications with special requirements, like pulsed power or induction heating applying high frequency resonant switching. In the latter case a cost benefit regarding investment in devices and energy losses during operation could be impressively demonstrated.

Conclusion and Outlook

Power electronics is an enabling technology to increase energy efficiency, to feed electrical energy from renewable sources into the grid, for electromobility or also for control in any modern production environment. Wide bandgap devices and the related circuits and systems are a fascinating and rapidly evolving part of it as the aforementioned up-to-date contributions to ECPE wide bandgap user forum have impressively underlined. The issue is continuously followed up by the respective ECPE technical committee; an update about further progress in this area will further be available on the occasion of the next ECPE SiC & GaN User Forum.