PhD Public Defence

Title: Characterisation and Analysis of high Voltage Silicon Carbide Mosfet

Location: Pontoppidanstræde 111, auditorium

Time: Friday 15 September 2017 at 13.00

PhD defendant: Emanuel Petre Eni

Supervisor: Professor Remus Teodorescu

Moderator: Associate Professor Dezso Sera

Opponents: Professor Francesco Iannuzzo, Dept. of Energy Technology, Aalborg University (Chairman)
Professor Johann Walter Kolar, ETH Zurich, Switzerland
Arnost Kopta, ABB Zurich, Switzerland

All are welcome. The defence will be in English.

After the defence there will be an informal reception in Pontoppidanstræde 111 (coffee room).
Abstract:

Silicon-Carbide materials, due to their physical properties, promise to provide improved performances in semiconductor switching devices in terms of breakdown voltages, switching frequency and operating temperatures. Continuous research in this field has already brought to the market SiC devices with voltages up to 3.3 kV which demonstrated superior performances compared to their Si counterparts in terms of efficiency and operating junction temperature. This also translated to a certain extent in improved reliability when considering the lower operating temperature of the Si devices for a similarly size heatsink.

Due to material properties and continuous research, 10 kV 4H-SiC devices are currently under development as engineering samples. These promise to be a good candidate for replacing Si based IBGTs in the high power high voltage applications where an improved efficiency and higher switching frequency could decrease the converter costs and size while offsetting the semiconductor higher price.

A very important requirement for power electronics devices employed in power converters is their reliability and behavior during transients such as short-circuits. This is highly relevant as the device needs to be able to sustain and safely turn-off such a transient in order for it to be consider as a suitable candidate for high voltage high power converters, where reliability is a key requirement.

Therefore the investigation of the behavior of the 10 kV 4H-SiC device during short-circuit and its degradation mechanism is of high interest. This summarizes both degradation during single event long short-circuit pulses but also during short and repetitive short-circuit events, which initially would not appear as a stress.

The work focused on studying the 10 kV first generation 4H-SiC DMOSFETs from Wolfspeed both in terms of device static and dynamic characteristics and short-circuit capability. As SiC still has to reach the technology maturity of Si, a theoretical comparison between SiC and Si highlights the better material properties of 4H-SiC in unipolar power devices. This was also emphasized by comparing the two semiconductor material figures of merit.

The dynamic behavior of the 10 KV SiC is studied to investigate the device behavior during operation at different voltages which the devices is expected to encounter during normal operation. The analysis provided a large 3D matrix of switching losses versus currents drain voltage and gate voltages for a large range of temperatures.

As the device showed promising results during switching, the short-circuit withstand capability, a relevant parameter for grid connected applications, has been investigated. This in term showed the device degrading at long pulses, with the degradation accumulating as the pulse lengths increased. Thermal simulations showed temperatures inside the package reaching surface metalization melting point. This triggered further investigations into the degradation mechanism in an attempt to isolate the possible root causes of the degradation. While the investigation could not find the exact culprit, as the device physical characteristics have not been shared by the manufacturer, it managed to narrow down the list of possible causes and identify the electrical parameters that degraded the most. Based on this, different hypothesis have been proposed in order to explain the observed degradation, some which have coincided with other findings published in literature.

In the end, it was clear that the high temperature reached in the device during long short-circuit transient was the main cause of the degradation. This high temperature in the device estimated based on the thermal simulation was confirmed and by a Scanning Electron Microscope investigation. Degradation of the SiC crystal structure, charges implanted in the oxide during the short-circuit, interface state charges
or other similar material defects associated with the high temperature stressing and high electric field experienced during short-circuit are the most plausible explanation for the degradation in device mobility.