Investigations on the Failure Mechanism of Power Electronic Devices due to Cosmic Radiation at SNAKE ◇

S. Aschauer [a,b], A. Härtl [a], G. Sölkner [a], F. Hille [a], P. Reichart [c], G. Dollinger [c], and G. Wachutka [b]
[a] Infineon Technologies AG, 85579 Neubiberg
[b] Technische Universität München, Lehrstuhl für Technische Elektrophysik, 80333 München
[c] Universität der Bundeswehr München, Dept. für Luft- und Raumfahrttechnik LRT2, 85577 Neubiberg

INFINEON TECHNOLOGIES AG develops, among other products, semiconductors for high-power electronic applications, like e.g. power inverters for trains (Fig. 1). In this field extremely high requirements on the device reliability are requested for satisfying the customer demands.

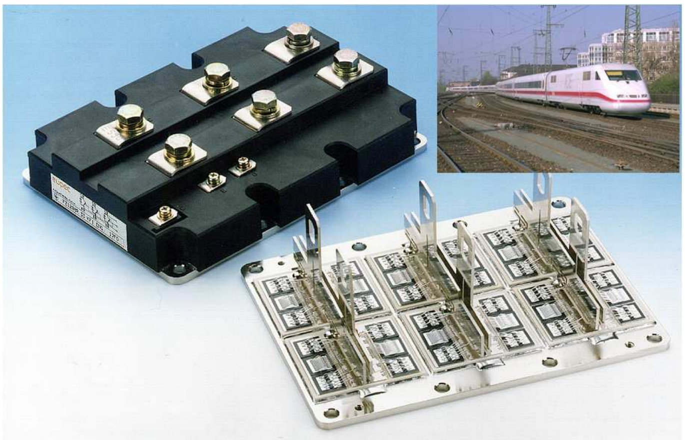

Fig. 1: A power inverter module for transportation applications with 36 power-devices.

But power electronic devices can get destroyed by cosmic rays, a source of defect which can not be suppressed. Therefore, power devices which guarantee robustness against cosmic radiation need to be developed. Hence, an understanding of the failure mechanism is essential. Currently, the failure model is the following: A high energetic particle of the cosmic radiation induces a spallation reaction by hitting a silicon atom within the semiconductor, which results in a recoil ion. This ion deposits its energy in the device and generates a very dense electron-hole plasma along its trajectory. If the device is under reverse bias then this in turn leads to a local breakdown of the electric field. The breakdown causes high peaks of the electric field at the edge of the plasma. But with high internal electric field strength impact ionization can occur in the device, which leads to a so called "streamer". This event ends up in a highly conductive channel across the device, inducing high currents and finally a thermal destruction of the electronic device. Fig. 2 shows a simulated sequence of such a streamer running through a power-diode.

The exact conditions for triggering such a streamer event, i.e. mainly the applied voltage and device design parameters, are still not known very well because they are dependent on many parameters. For further reliability improvements of future devices a better understanding of the failure mechanism is essential. Some of the influencing parameters should be investigated, for example the dependence on the kind of recoil which results from the spallation reaction and dependence on the recoil energy.

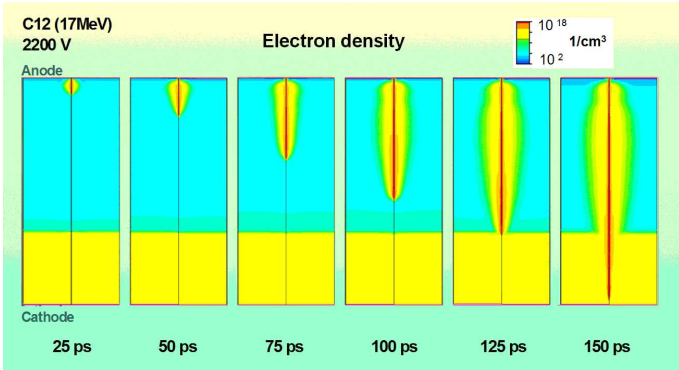

Fig. 2: Simulated electron density in a power-diode during a streamer event [1].

The spallation reaction rate is very low under natural circumstances and failure tests are time-consuming, even at labs high above sea level. A very suitable alternative is to use ion beams from the tandem accelerator, where spallation reactions, or rather the recoil products, can be simulated by ion beams. This gives the unique opportunity to increase the rate of events to a level at which systematic measurements are feasible. With the variety of ions and energies offered by the accelerator, nearly every possible spallation product can be induced.

We use the existing cell irradiation setup at SNAKE [2,3] with an adjustable beam exit to air and single ion counting mechanism. This setup is perfectly suited in order to expose the electronic devices with HV bias electronics and signal readout directly to the beam without large effort. The energy of the ions and an additional air drift length are adjusted for the desired ion range inside the chip. The beam focus of the microprobe is useful to ensure the hit area to be in the center of the device. First irradiations tests with 55 MeV Carbon ions have been successfully performed and show that this setup will be very useful for the investigations of the failure mechanism in following experiments.

References

[1] W. Kaindl *et al.* IEEE ISPSD **16** (2004) 257
[2] G. Dollinger *et al.* Nucl. Instr. and Meth. **B231** (2005) 195
[3] C. Greubel *et al.* Acta Physica Polonica **A109** (2006) 273

◇ corresponding author: Stefan Aschauer, stefan.aschauer@infineon.com