Name of research institute or organization:

ABB Switzerland Ltd, Semiconductors

Title of project:

Cosmic ray induced failures in biased power semiconductor devices

Project leader and team:

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Project description:

For several years it is known that biased high power semiconductor devices like diodes, thyristors or IGBTs might fail suddenly without any previous device wear-out or electrical overload condition. Normally this phenomenon is explained by cosmic rays that trigger inside the biased silicon bulk a localized breakdown event, finally destroying the devices [1-4]. The failure rates increased with the applied bias. Adequate test series for studying device designs are of long duration and expensive. Accelerated tests are feasible at locations with enhanced cosmic ray fluxes (e.g. at Jungfraujoch) or with particle beams. The purpose of the tests at Jungfraujoch is firstly to check the cosmic ray withstand of available devices, secondly to compare these results to corresponding tests at high-flux proton or neutron beams and thirdly to establish suitable design rules for developing future devices.

The test setup was located on a platform (area 0.7 m^2) just below a wooden roof of the Sphinx observatory. The failed devices due to cosmic rays were identified by observing a constant leakage current until the occurance of the failure and by characteristic defects like small spots somewhere on the silicon chip [5,6]. In 2001 about half a dozen different types of power semiconductor devices were tested on this platform.

The typical bias for applications was always around half of the device voltage ratings V_{nom}. Here the requested failure rates due to cosmics should be smaller than one failure every 10^9 $cm^2 \cdot h$ (=device area times test period). Due to the limited number of devices and exposure times the accessible failure rates were limited to biases larger than $(0.7 – 0.8)\cdot V_{nom}$. The bias range was extended to $> 0.5\cdot V_{nom}$ by using neutron or proton beams.

The measured failure rates due to cosmics and particle beams were comparable for biases larger than $0.7\cdot V_{nom}$. Also for the same bias range the predictions for most of the device types were in fair agreement with the test results. As a typical example the failure rates due to cosmics of an IGBT device were compared to the test results at a proton beam and model calculations [4] (Fig. 1).

Up to now the sharp drop of the failure rates below a characteristic bias were only observed with proton and neutron beams. The poor statistics with cosmic tests did not allow to reproduce this drop-off. The model did not predict the sharp drop of the failure rates.

The cosmic rays withstand tests for other device types will also continue in year 2002. In addition a proposal was prepared to clarify the possible drop of the failure rates due to cosmics below a characteristic bias.

Glossary
IGBT: Insulated Gate Bipolar Transistor; voltage controlled power transistor.

References

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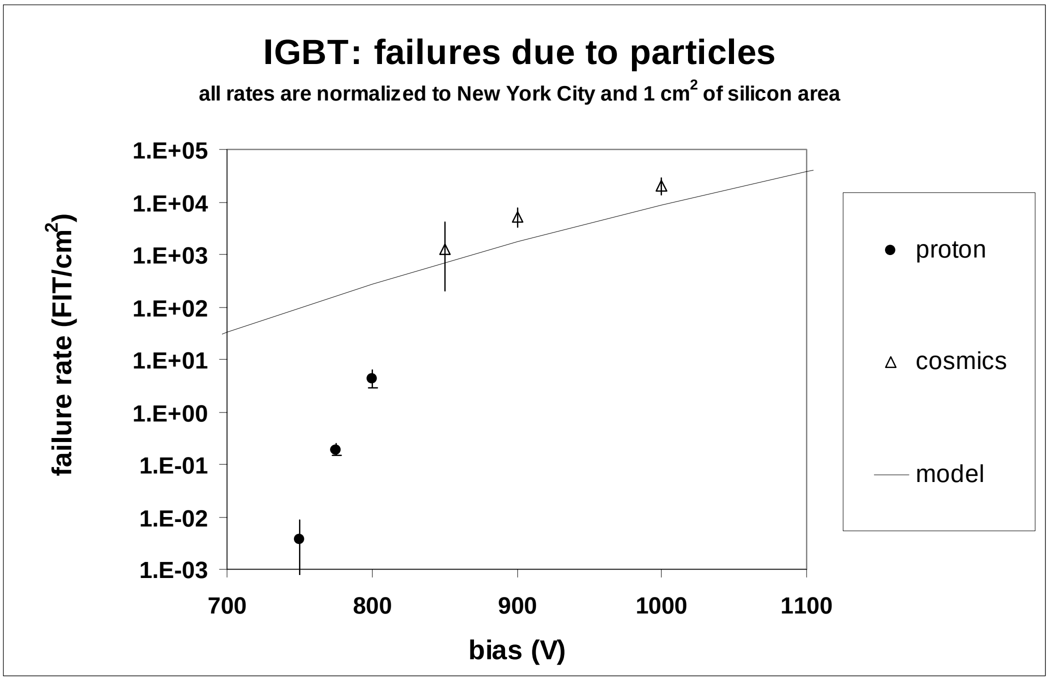

Fig. 1: Failure rates of an IGBT type due to cosmics and protons of 300 MeV kinetic energy. For biases < 850 V the measured failure rates are significantly smaller than the predicted rates. 1 FIT/ cm^2 was one failure every 10^9 device·hour normalized to one cm^2 silicon area.

Key words

Power semiconductor devices, Failures, Cosmics

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