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Radiation Hardness of SiC TrenchMOSFET Devices

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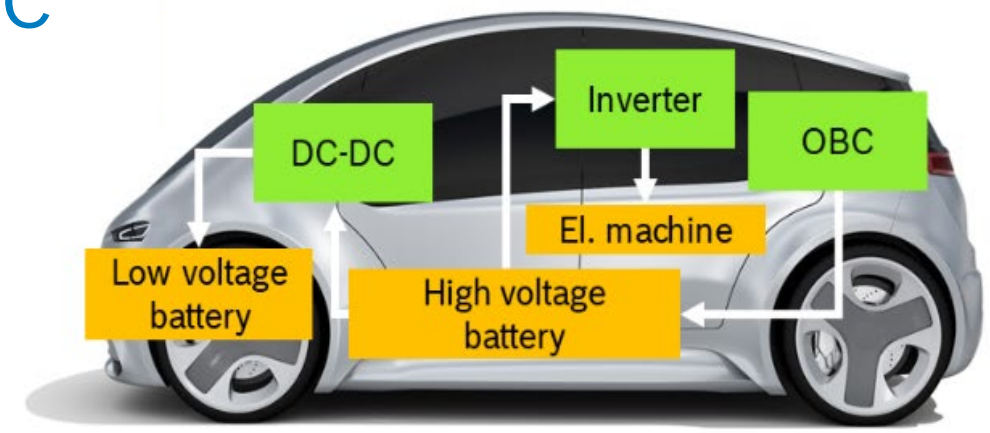
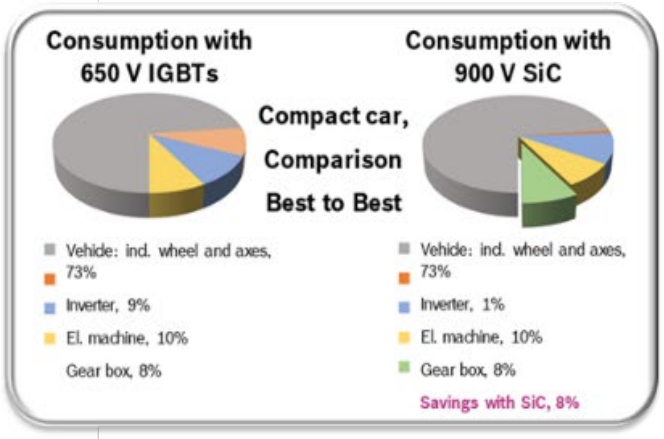
Advantage of SiC





- SiC advantageous on automotive electronics for 750 V and 1200 V application
- Possible Applications
  - Inverter
  - High-Voltage – Low Voltage (DCDC) Converter
  - On-Board Charger (OBC)

Cost savings on system level using SiC

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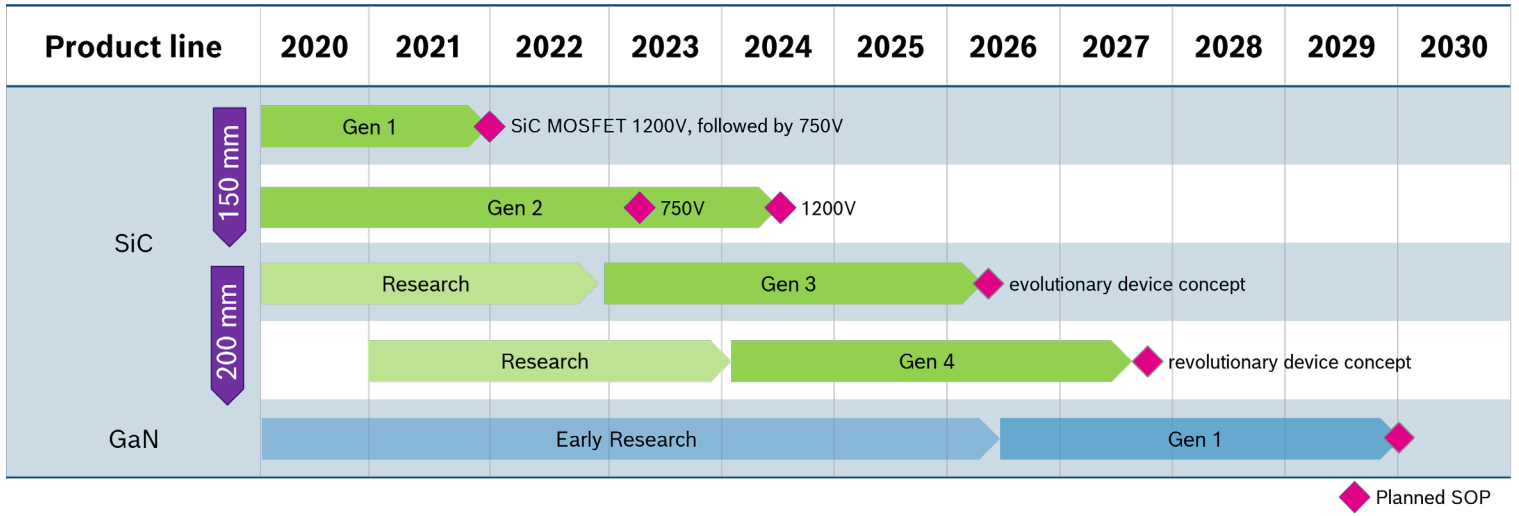
Generations of Bosch T-MOS



- Bosch SiC Trench-MOSFET 2nd generation in production
- 3rd Generation Bosch SiC Trench-MOSFET in development

Development of SiC technologies for 1200 V and 750 V

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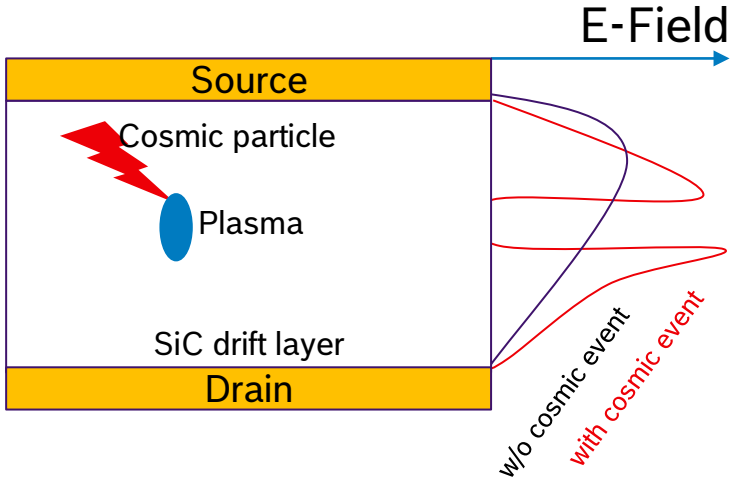
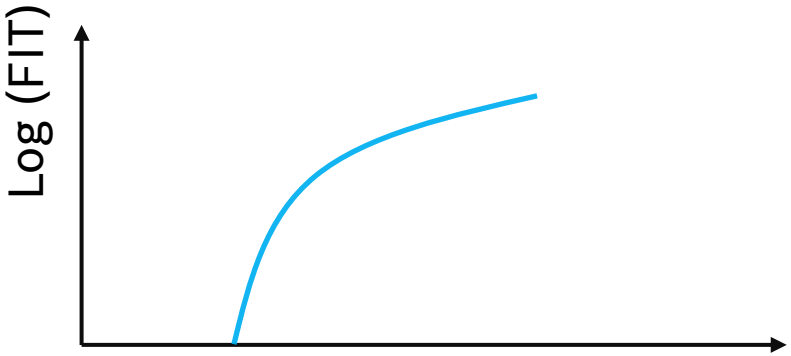
Radiation Hardness

- Cosmic particles with high energies can interact with a SiC atom in the epi of a high voltage power devices
- Cosmic radiation can also destroy high voltage power devices at sea level
- An electron-hole plasma is created distorting the electric field
- The nearer the devices is operated at its avalanche voltage the higher the probability for a lethal failure



Sketch of the electrical field in a SiC MOSFET with and without interaction with a cosmic particle



Failure probability plotted against the operation voltage / avalanche voltage ratio

High voltage power devices can be destroyed during operation by cosmic particles

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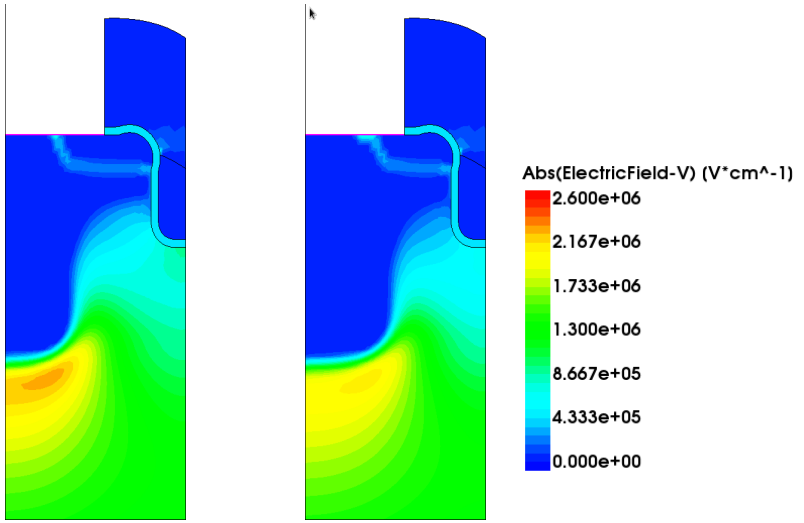
Radiation Hardness - Design

- Final design reduces the electric field in the junction during the blocking state
- Since local failure rate (P_{lf}) depends exponentially on the local field $E(x)$ (Akturk 2019) and is integrated over the entire device volume Ω, to get the total failure probability P_f, the improvement is significant

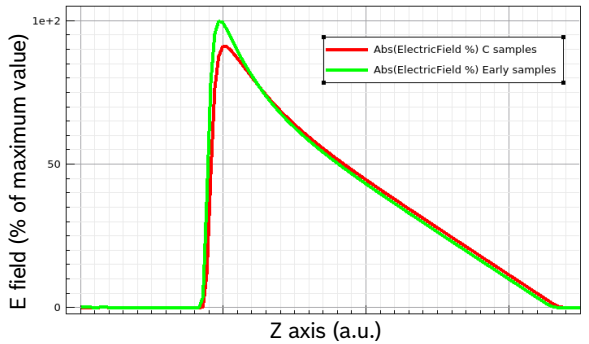
$$P_{lf}(E(x)) = \upsilon_o \exp\left(-\frac{E_b}{E(x)}\right) \qquad P_f = \int_{\Omega} P_{lf}(E)d\Omega.$$

υ_o = 2e11 FIT/cm^3 and E_b = 21 MV/cm are fitting parameters for SiC

A. AKTURK et al, IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 66, NO. 7, JULY 2019



Early samples C Samples



Reduction of the electric fields on the cell by design

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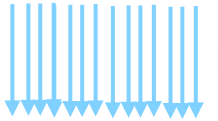
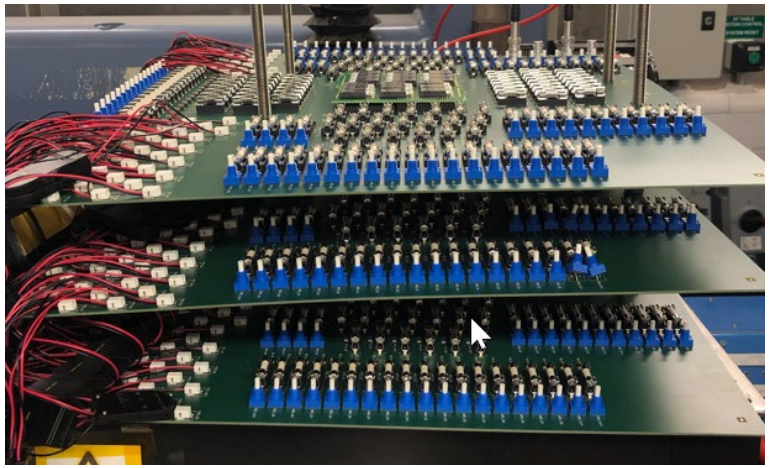
Determination of Radiation Hardness

- The cosmic radiation hardness can be emulated by irradiating the devices with high energy neutrons
- By increase the radiation flux by 6 – 8 orders of magnitude the failure rate can be derived fast
- ~ 250 devices are tested in parallel for each operation voltage in order to achieve the dependency of FIT-rate with respect to the ration of $U_{use}/U_{avalanche}$





Photograph of the DUTs in DUT carriers that are irradiated with high energy neutrons to derive the failure probability

Cosmic radiation hardness of SiC devices can be derived by neutron irradiation experiments

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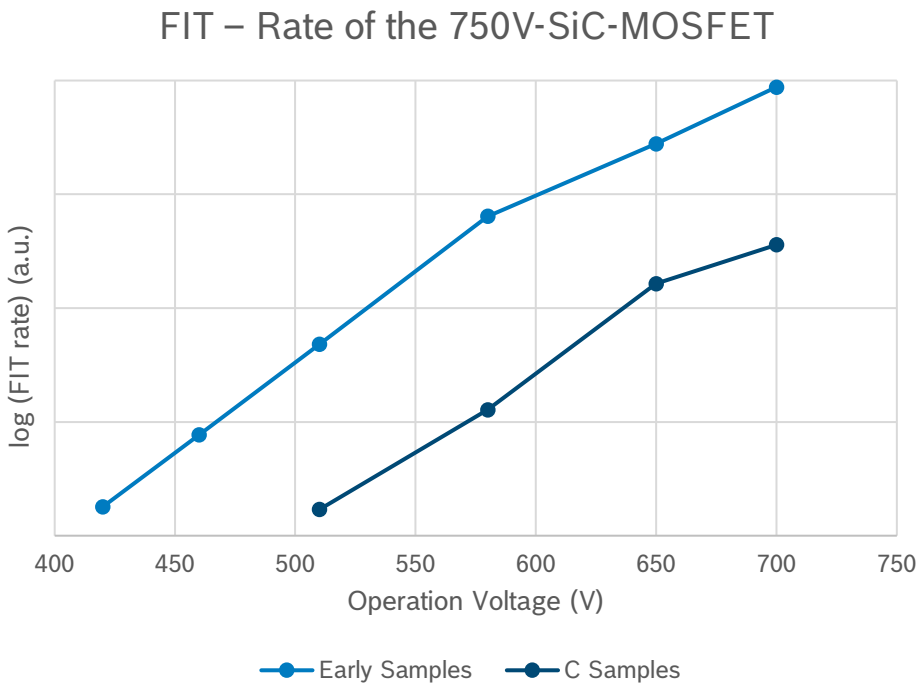
Radiation Hardness - Results

- All Bosch SiC PowerMOSFET technologies are investigated concerning radiation hardness
- For the second-generation radiation hardness was a mayor design target
- Example 750V: Significant reduction of the radiation hardness during samples phases



Failure probability plotted against the operation voltage for the Bosch 750V SiC-MOSFET.

Significant improvement of radiation hardness of SiC TrenchMOSFETs

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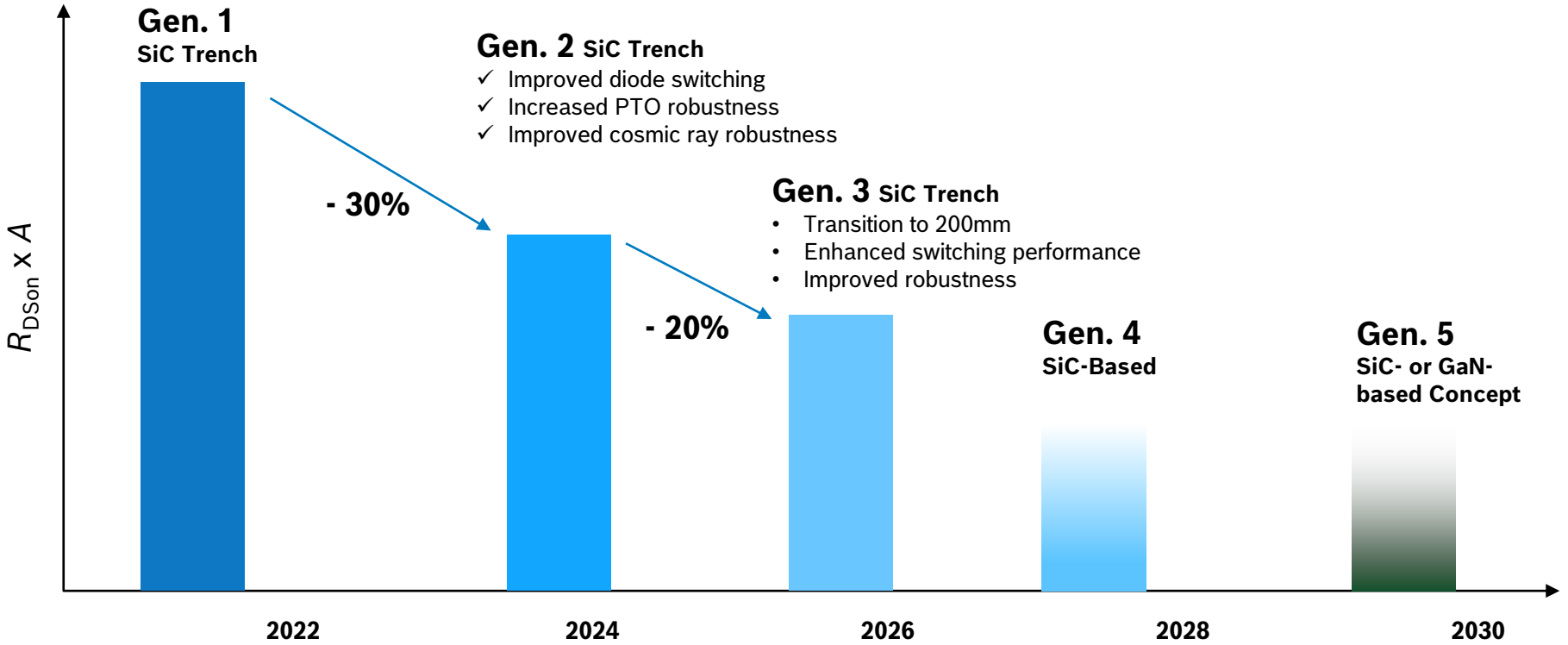
WBG Semiconductor Roadmap



Continuous semiconductor innovations for automotive market

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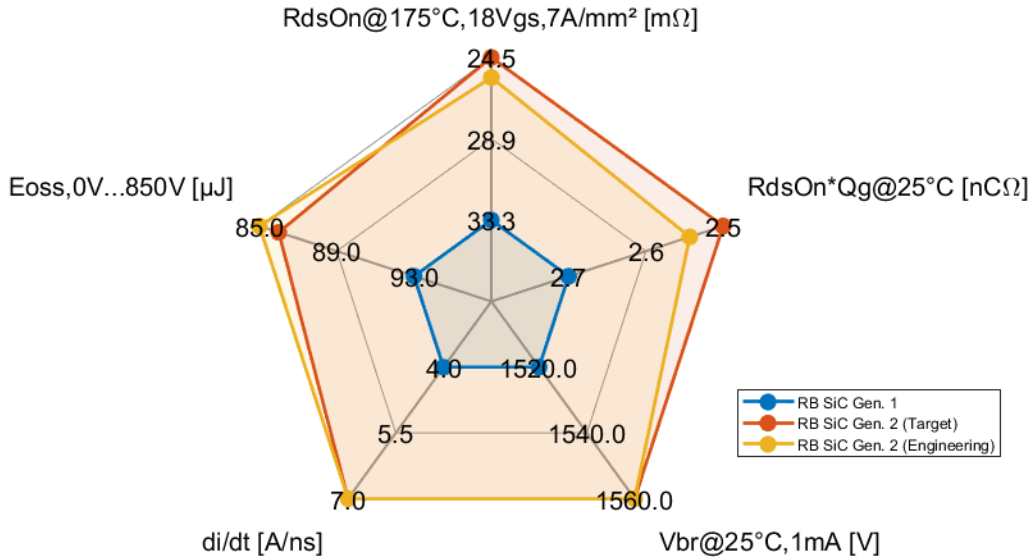
Improvements

Comparison of Gen2 to Gen1 (1200 V)

- ~ 26 % reduction of static losses (R_{DSon*A} @ 175°C)
- Improvement of softness factor during switching by factor of 2
- Reduction of voltage overshoots during switching
- Improvement of radiation hardness by ~ factor of 20



Comparison of the most important SiC-MOSFET parameters between Bosch Gen1 and Gen2.

Bosch SiC Gen2 compared to Gen1

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Thank You

TRANSFORM

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