



Radiation and SiC Power Devices

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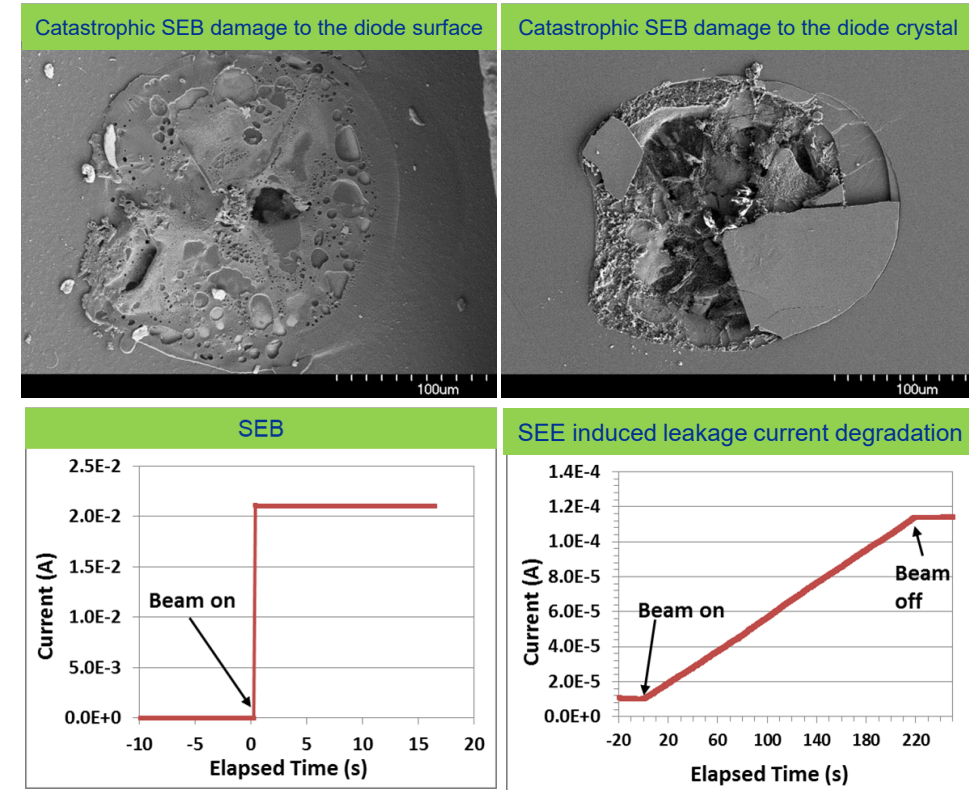
NASA Glenn Research Center,
Cleveland OH

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Types of Radiation

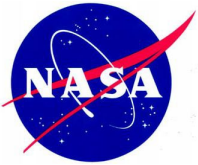
- Galactic Cosmic Ray & Terrestrial Cosmic Ray
 - Galactic cosmic rays (GCR)
 - Heavy ions
 - Issue in space
 - Terrestrial cosmic rays (TCR)
 - Fast neutrons created by GCR interacting with the atmosphere
 - Issue in Earth's atmosphere
 - Flux is a function of altitude, but present down to sea level
 - Both GCR and TCR have caused
 - Single event burnout (SEB) in SiC parts (catastrophic)
 - Single event gate rupture
 - Damage only occurs if the diode or FET is biased in blocking mode
 - Only GCR have been shown to create leakage damage (non reversible)
 - Leakage current damage occurs at a lower blocking voltage than the threshold for SEB





Types of Radiation (continued)

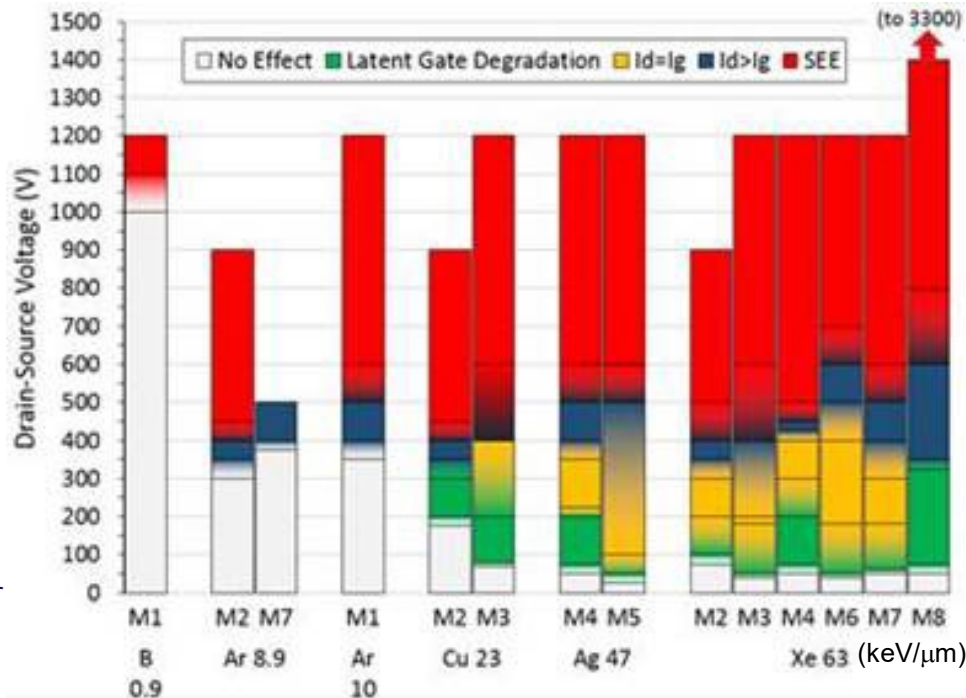
- Total Ionizing Dose (TID)
 - The measure of the total energy absorbed by matter caused by ionizing particles (ex/ protons, electrons, gamma rays, X-rays)
 - No significant damage to SiC devices below 400 krad(Si)
 - A. Akturk, *et al.*, “Space and Terrestrial Radiation Response of Silicon Carbide Power MOSFETs” presented at the 2017 IEEE Radiation Effects Data Workshop (REDW), 2017.
- Displacement Damage Dose (DDD)
 - Structural damage imparted on the crystal lattice of the device by energetic particles (non-ionizing energy loss)
 - Most radiation hardness issues for SC based devices have not been attributed to DDD



GCR induced Single Event Burnout (SEB)

- Have characterized SEB and leakage current in diodes and MOSFETs
 - DR Ball, *et al.*, ITNS 67 (1), 22 (2019).
 - AF Witulski, *et al.*, ITNS 65 (1), 256 (2017).
- Have determined the cause of SEB is second breakdown
 - JA McPherson, *et al.*, ITNS 68 (5), 651 (2021)
 - Still don't know specific origins of leakage current

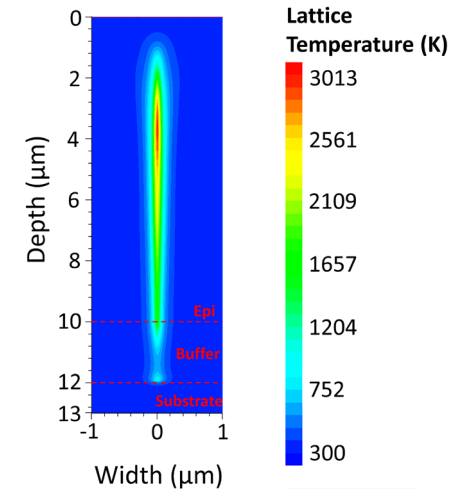
M1 1200 V
M2 900 V
M3 1200 V
M4 1200 V
M5 1200 V
M6 1200 V
M7 1200 V
M8 3300 V



Courtesy of Jean-Marie Lauenstein Ph.D,
NASA Goddard Space Flight Center.

For more information see:

J. -M. Lauenstein *et al.*, "Space Radiation Effects on SiC Power Device Reliability," 2021 IEEE International Reliability Physics Symposium (IRPS), 2021, pp. 1-8,
doi: 10.1109/IRPS46558.2021.9405180



Mesoplasma formed during second breakdown
process

Courtesy of A. Woodworth, PhD
NASA Glenn Research Center, and J. McPherson
PhD Rensselaer Polytechnic Institute

For more information see:

J.A. McPherson, *et al.* "Ion-Induced Mesoplasma Formation and Thermal Destruction in 4H-SiC Power MOSFET Devices," *IEEE Transactions on Nuclear Science*, 2021.
doi:10.1109/TNS.2021.3068196



TCR induced Single Event Burnout

- Neutron flux is a function of altitude (well understood)
- Neutron-material interactions are relatively low compared to those of heavy ions
- Failure rates typically characterized by failures-in-time (FIT) for a given bias
- A. Akturk, *et al.*, "Terrestrial neutron-induced failures in silicon carbide power MOSFETs and diodes," IEEE Transactions on Nuclear Science Vol. 65, No. 6, 2018, pp. 1248-1254.
 - FIT 100 for 1200V MOSFET @ ~1200V
 - FIT 100 for 1200V Schottky diode >1200V
- Neutron induced leakage current has not been observed



A Word About High Electron Mobility Transistors (HEMT)

- 300V space rated GaN/AlGaN HEMTs on the market
- Susceptibility to SEB and single-event dielectric rupture (SEDR) in commercial-grade GaN/AlGaN HEMTs generally worsens with increasing voltage rating
 - J.-M. Lauenstein, "Wide Bandgap Power Device Radiation Reliability," NEPP ETW, 2021
https://nepp.nasa.gov/workshops/etw2021/talks/15-JUN-21_Tues/1230_Lauenstein-WBG-20210017526_v2.pdf
- Some questions about TID-material defect interactions that impact reliability still to be answered
 - D. M. Fleetwood, E. X. Zhang, R. D. Schrimpf and S. T. Pantelides, "Radiation Effects in AlGaN/GaN HEMTs," in IEEE Transactions on Nuclear Science, 2022 doi: 10.1109/TNS.2022.3147143
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Thank you!