Schottky Diode Derating for Survivability in a Heavy Ion Environment

Megan C. Casey¹, Jean-Marie Lauenstein¹, Raymond L. Ladbury¹, Edward P. Wilcox², Alyson D. Topper², and Kenneth A. LaBel¹

¹NASA Goddard Space Flight Center
²ASRC Federal Space and Defense, Inc. (AS&D, Inc.)

To be presented by Megan Casey at the Joint Electron Device Engineering Council (JEDEC), Jacksonville, FL, January 13, 2016.
List of Acronyms and Symbols

- **DUT** – Device Under Test
- **I_R** – Reverse Current
- **I_F** – Forward Current
- **LBNL** – Lawrence Berkeley National Laboratory
- **LET** – Linear Energy Transfer
- **MOSFET** – Metal Oxide Semiconductor Field Effect Transistor
- **NEPP** – NASA Electronic Parts and Packaging Program
- **SEE** – Single Event Effects
- **V_R** – Reverse Voltage
- **V_F** – Forward Voltage
- **\( \phi_B \)** – Schottky Barrier Height
Introduction

• In 2011/2012, GSFC observed failures in the output Schottky diodes of DC/DC converters
  ▪ Independent testing of the diodes was undertaken to determine their vulnerability to heavy ions

• Until this point, diodes generally were not considered to be susceptible to SEEs
  ▪ These diode failures could be catastrophic to scientific instruments, or even entire spacecraft

• Power MOSFETs are derated when operating in radiation environments
  ▪ Would a similar approach work for Schottky diodes?
Test Facilities and Technique

- All parts were tested at LBNL’s 88” cyclotron with 1233 MeV Xe (LET = 58.8 MeV-cm²/mg)
- All diodes were reverse biased while irradiated
- After each beam run, $V_F$, $V_R$, $I_F$ and $I_R$ were measured
Parts Tested

• 49 Schottky diodes from 11 manufacturers

• Reverse voltages range from 40 V to 600 V

• Forward currents (per diode) from 5 A to 30 A

• Within the manufacturers, high temperature, high forward voltage lines are compared to low temperature, low forward voltage and low barrier height lines
Observed Radiation Responses

- **Charge Collection**
- **Degradation**
- **Degradation**
- **Catastrophic Failure**
Results

To be presented by Megan Casey at the Joint Electron Device Engineering Council (JEDEC), Jacksonville, FL, January 13, 2016.
Results

By derating to 50% of the reverse voltage, all failures are eliminated for the parts tested.
Failures as a Function of Barrier Height

No failures observed in parts with $\phi_B$ less than 0.72 eV
Failures as a Function of Reverse Current

100% of Reverse Voltage

Strong correlation in susceptibility and low $I_R$ rating
Failures as a Function of Reverse Current

75% of Reverse Voltage

Strong correlation in susceptibility and low $I_R$ rating
Failures as a Function of Forward Voltage

100% of Reverse Voltage

75% of Reverse Voltage

Weaker correlation in susceptibility and high $V_F$ rating

However, product lines billed as low $V_F$ or low $\phi_B$ show very little susceptibility
Conclusions

• Schottky diodes are susceptible to destructive SEEs
  • Failures only occur when diodes are reverse biased

• Failures are much more widespread than originally suspected
  • Failures observed across manufacturers, reverse voltages, and forward current ratings tested

• No failures observed at 50% (or below) of rated reverse voltage

• There appears to be a strong correlation between failures and barrier height, as well as reverse current rating
  • SEE testing should be considered when selecting parts with $\phi_B > 0.72$ eV or with $I_R \leq 200 \mu A$
  • Correlation also exists between failures and forward voltage
Acknowledgments

• This work was sponsored by the NASA Electronic Parts and Packaging Program and the Defense Threat Reduction Agency.

• The authors gratefully acknowledge members of the Radiation Effects and Analysis Group who contributed to the test results presented here.

• The authors would also like to acknowledge the staff at the LBNL cyclotron for their support during these tests.