Schottky Diode Derating for Survivability in a Heavy Ion Environment

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List of Acronyms and Symbols

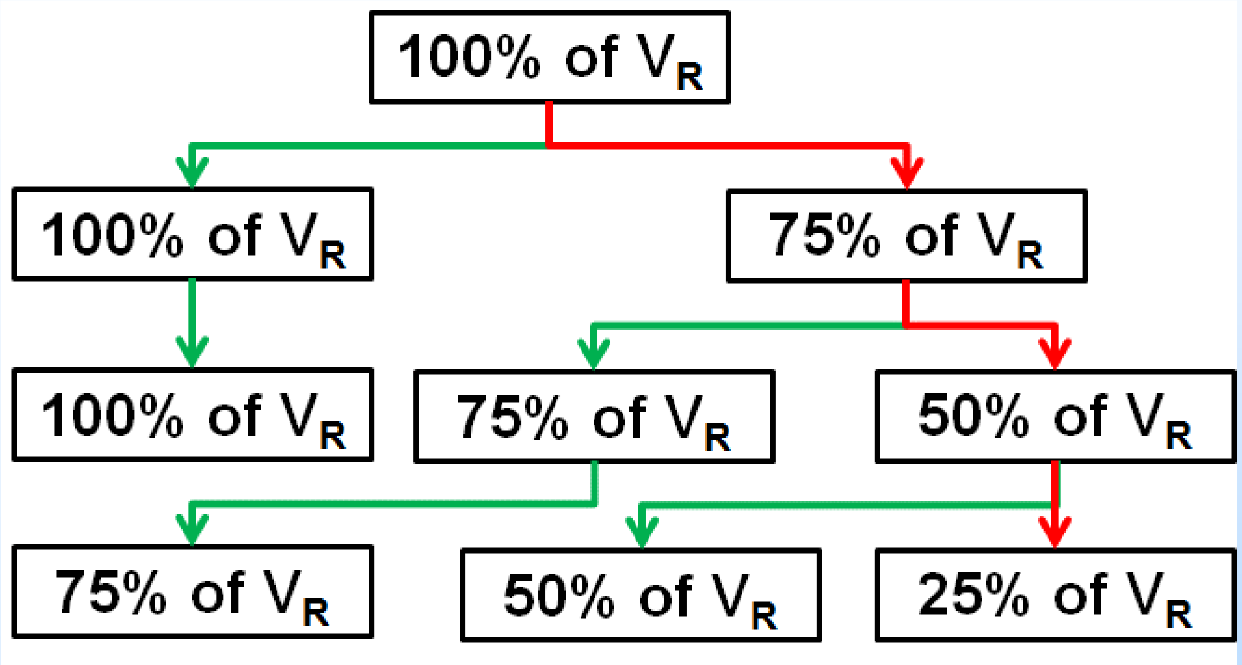
- DUT – Device Under Test
- I_R – Reverse Current
- I_F – Forward Current
- LBNL – Lawrence Berkeley National Laboratory
- LET – Linear Energy Transfer
- MOSFET – Metal Oxide Semiconductor Field Effect Transistor
- NEPP – NASA Electronic Parts and Packaging Program
- SEE – Single Event Effects
- V_R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

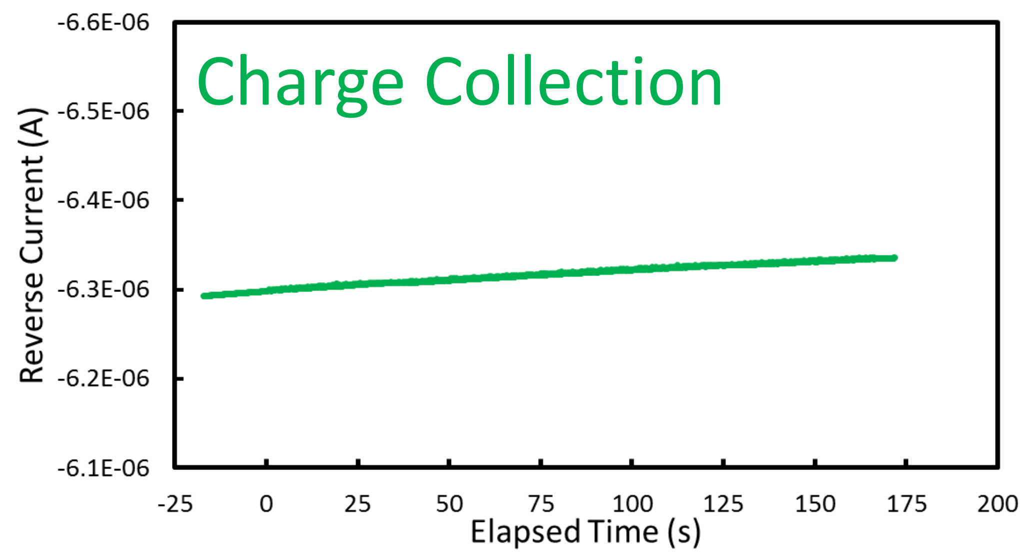
- All parts were tested at LBNL's 88" cyclotron with 1233 MeV Xe (LET = 58.8 MeV-cm^2/mg)
- All diodes were reverse biased while irradiated
- After each beam run, V_F, V_R, I_F and I_R were measured

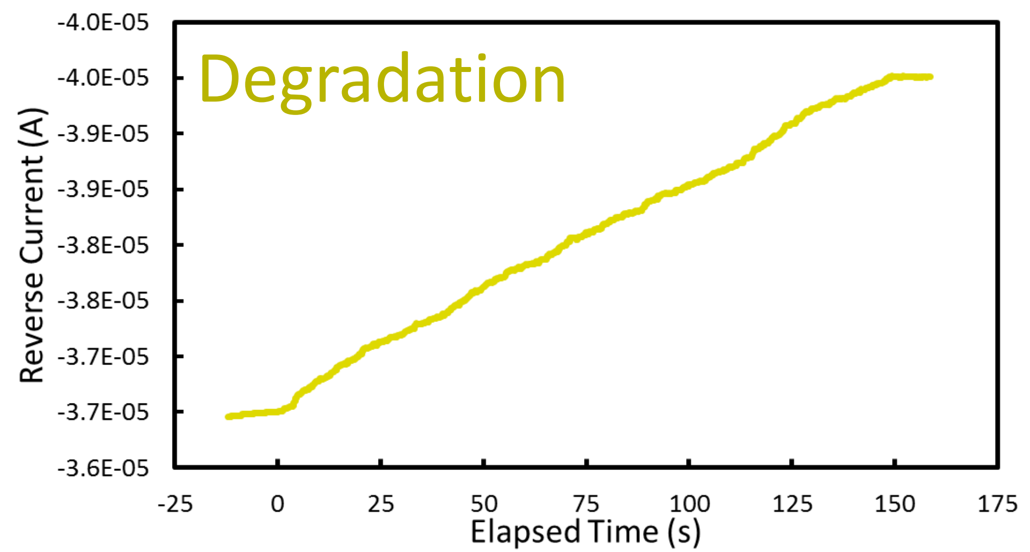


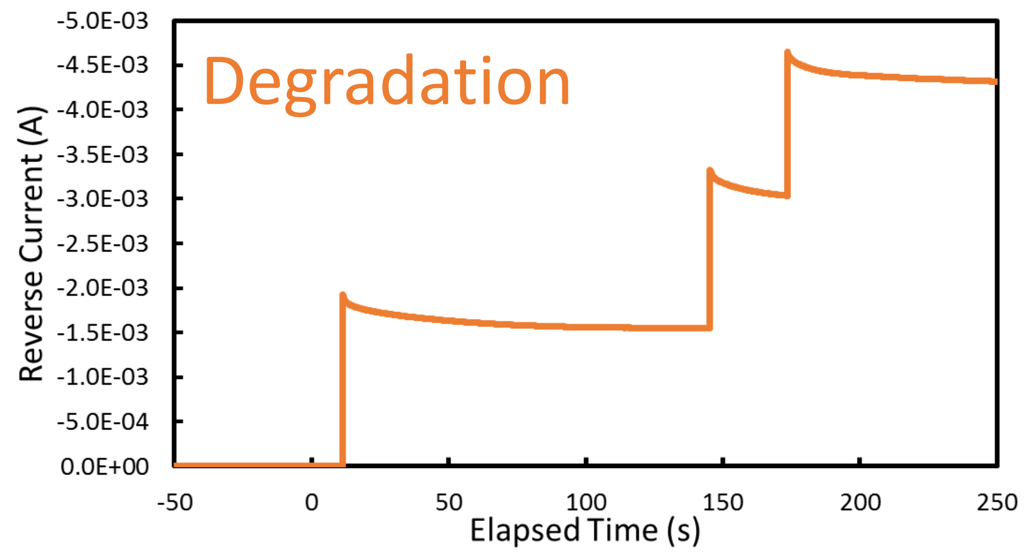
Parts Tested

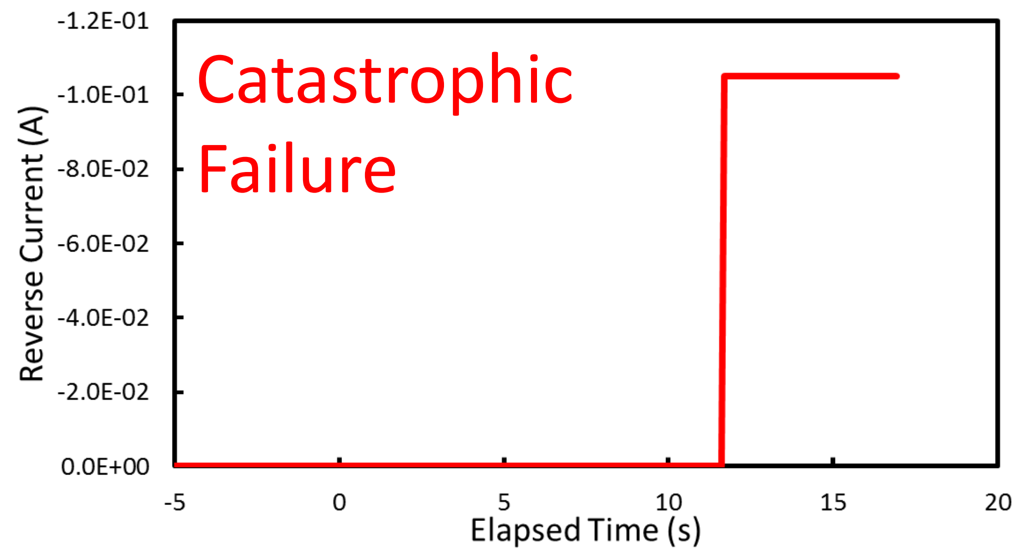
- 49 Schottky diodes from 11 manufacturers
- Reverse voltages range from 40 V to 600 V
- Forward currents (per diode) from 5 A to 30 A
- Within the manufacturers, high temperature, high forward voltage lines are compared to low temperature, low forward voltage and low barrier height lines

Observed Radiation Responses

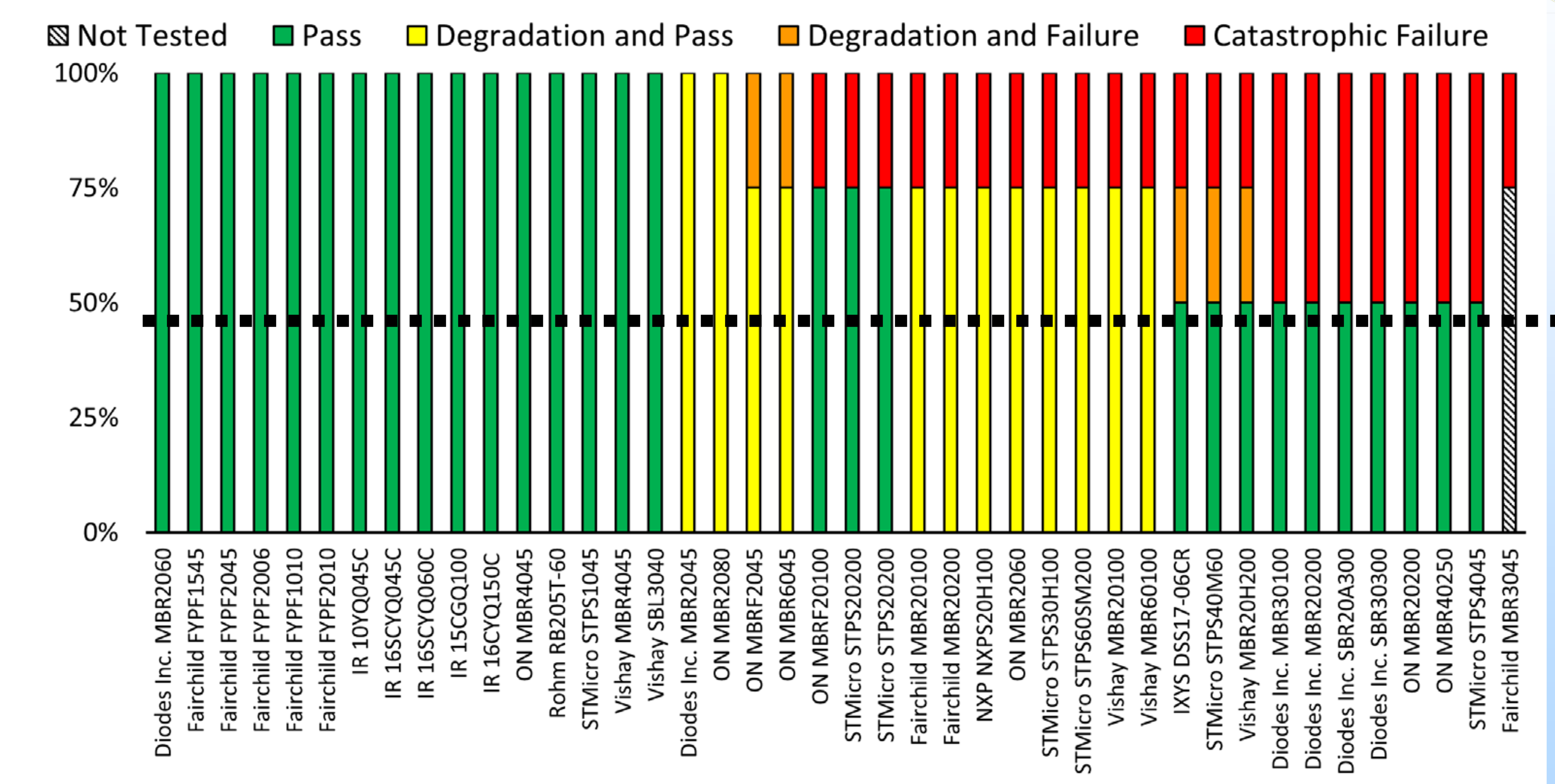








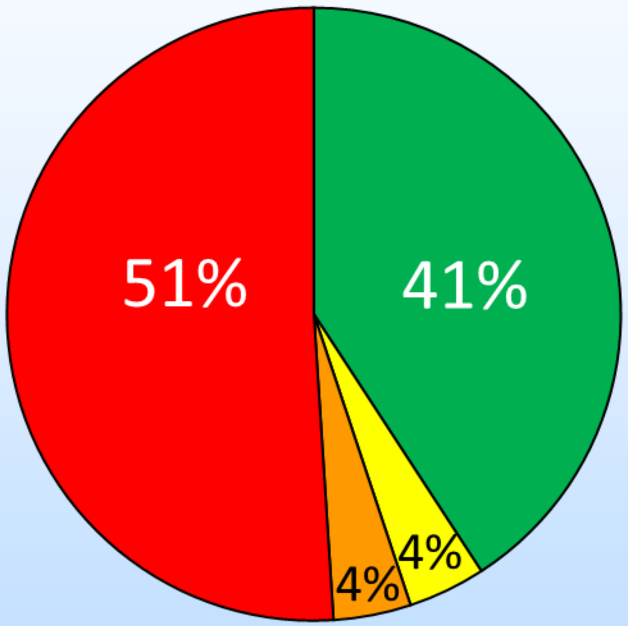
Results



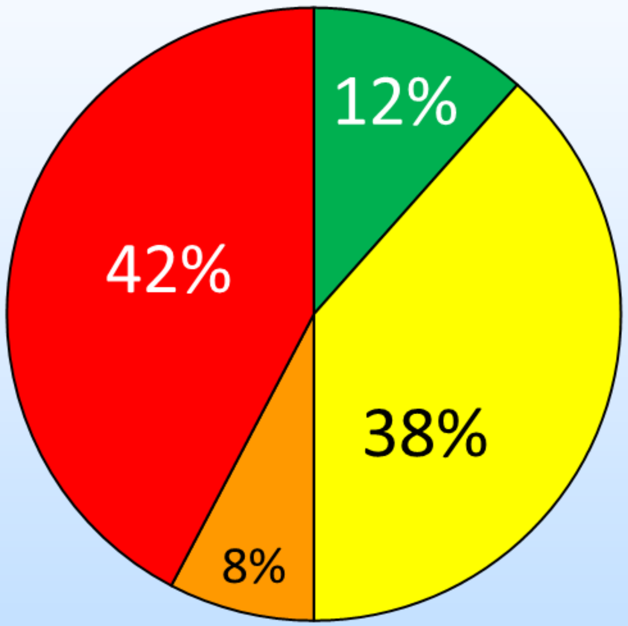
Not Tested
Pass
Degradation and Pass
Degradation and Failure
Catastrophic Failure
100%
75%
50%
25%
0%
Diodes Inc. MBR2060
Fairchild FYPF1545
Fairchild FYPF2045
Fairchild FYPF2006
Fairchild FYPF1010
Fairchild FYPF2010
IR 10YQ045C
IR 16SCYQ045C
IR 16SCYQ060C
IR 15CGQ100
IR 16CYQ150C
ON MBR4045
Rohm RB205T-60
STMicro STPS1045
Vishay MBR4045
Vishay SBL3040
Diodes Inc. MBR2045
ON MBR2080
ON MBRF2045
ON MBR6045
ON MBRF20100
STMicro STPS20200
STMicro STPS20200
Fairchild MBR20100
Fairchild MBR20200
NXP NXPS20H100
ON MBR2060
STMicro STPS30H100
STMicro STPS60SM200
Vishay MBR20100
Vishay MBR60100
IXYS DSS17-06CR
STMicro STPS40M60
Vishay MBR20H200
Diodes Inc. MBR30100
Diodes Inc. MBR20200
Diodes Inc. SBR20A300
Diodes Inc. SBR30300
ON MBR20200
ON MBR40250
STMicro STPS4045
Fairchild MBR3045

Results

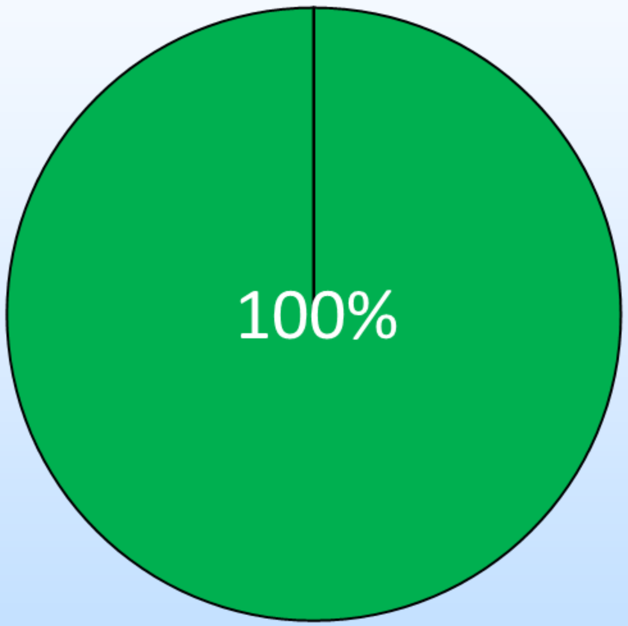
100% of Reverse Voltage



75% of Reverse Voltage

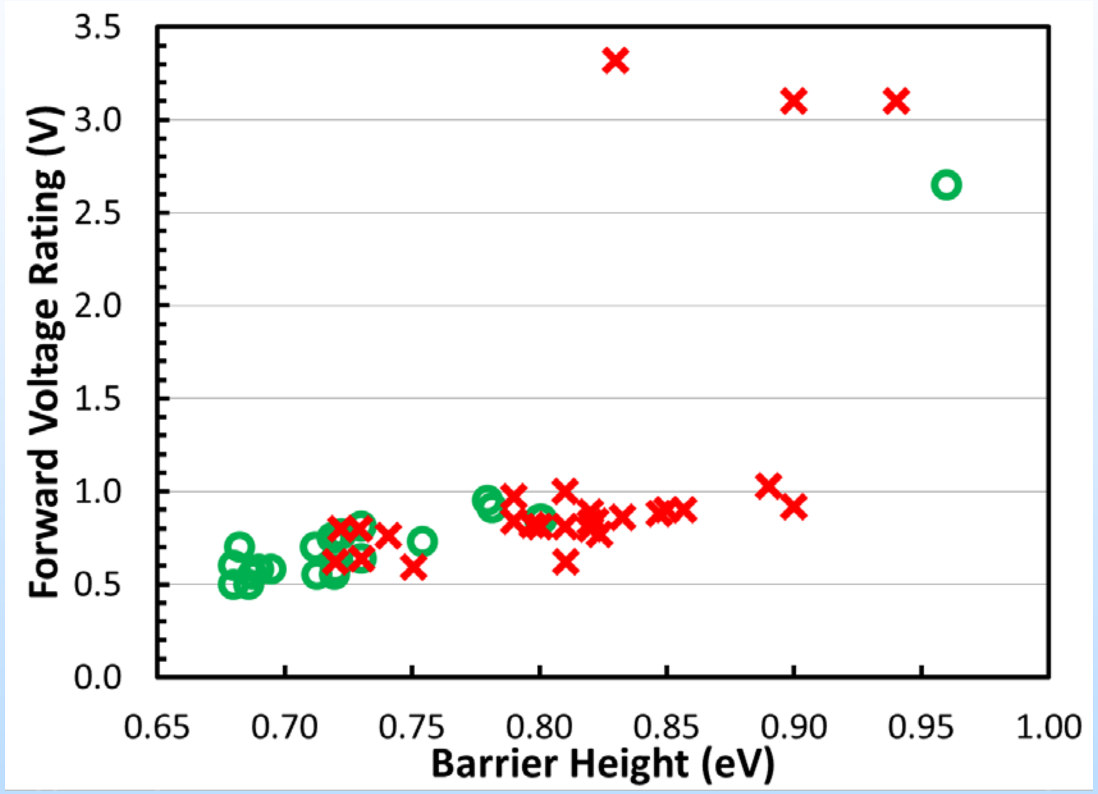


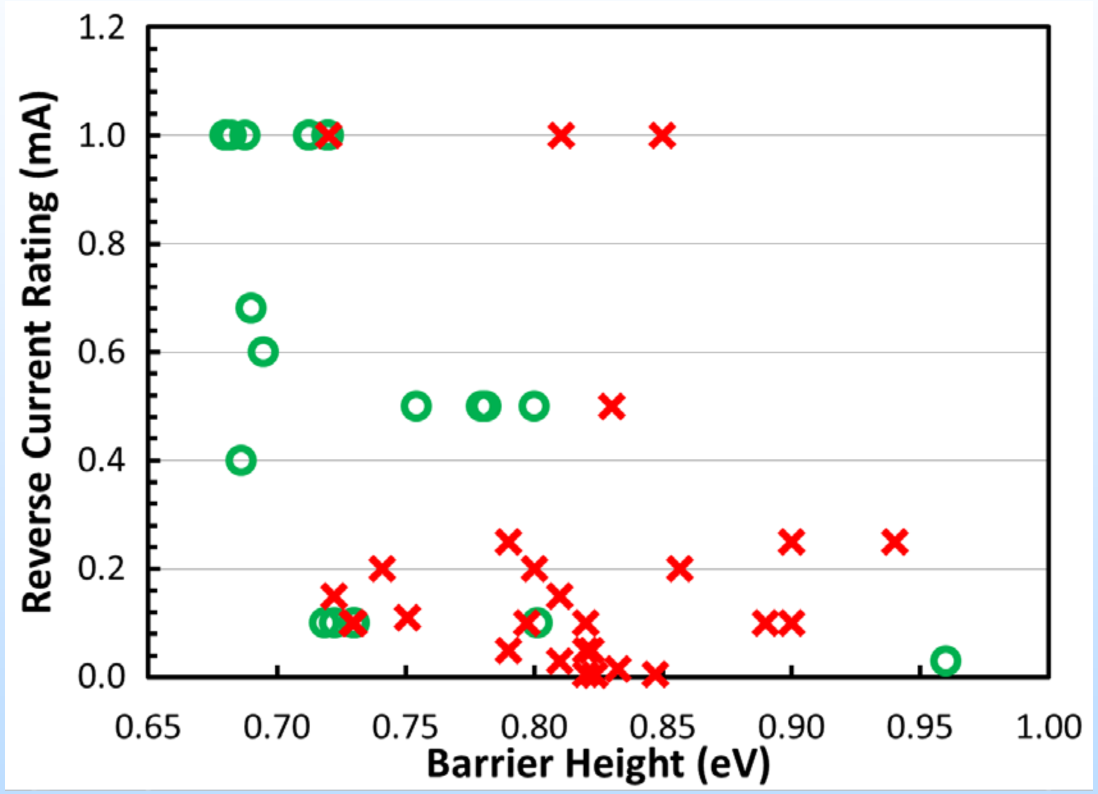
50% of Reverse Voltage



By derating to 50% of the reverse voltage, all failures are eliminated for the parts tested

Failures as a Function of Barrier Height

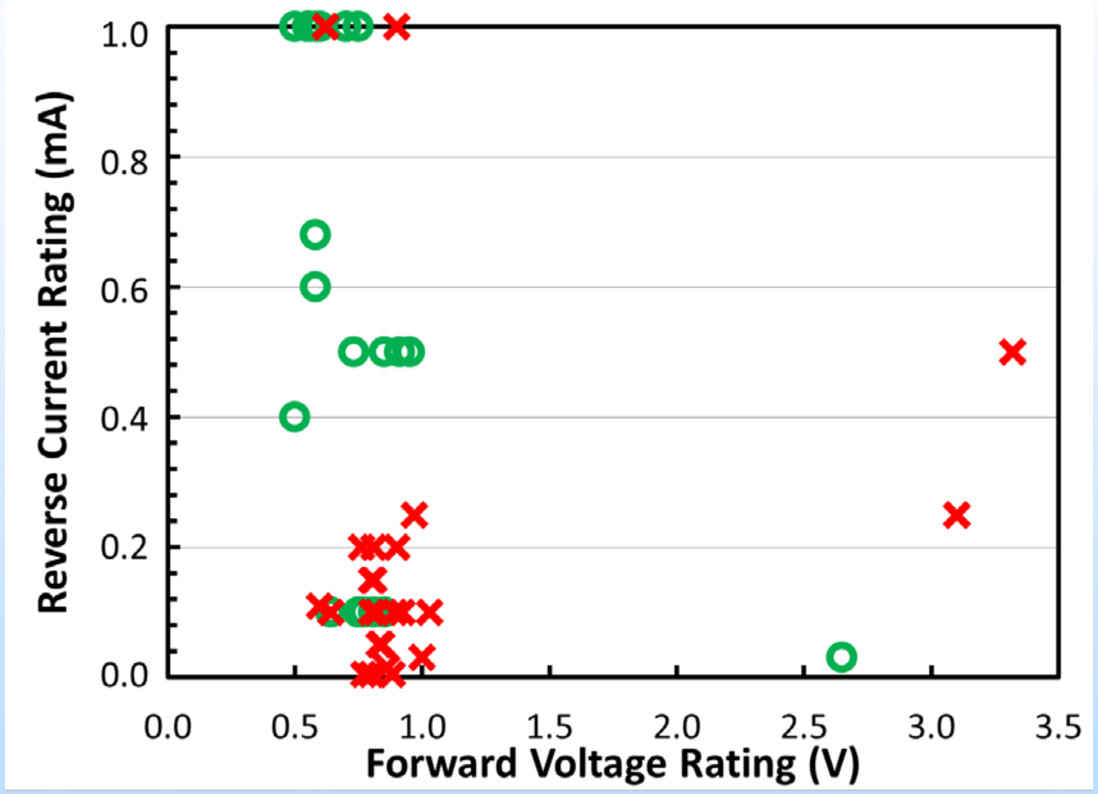


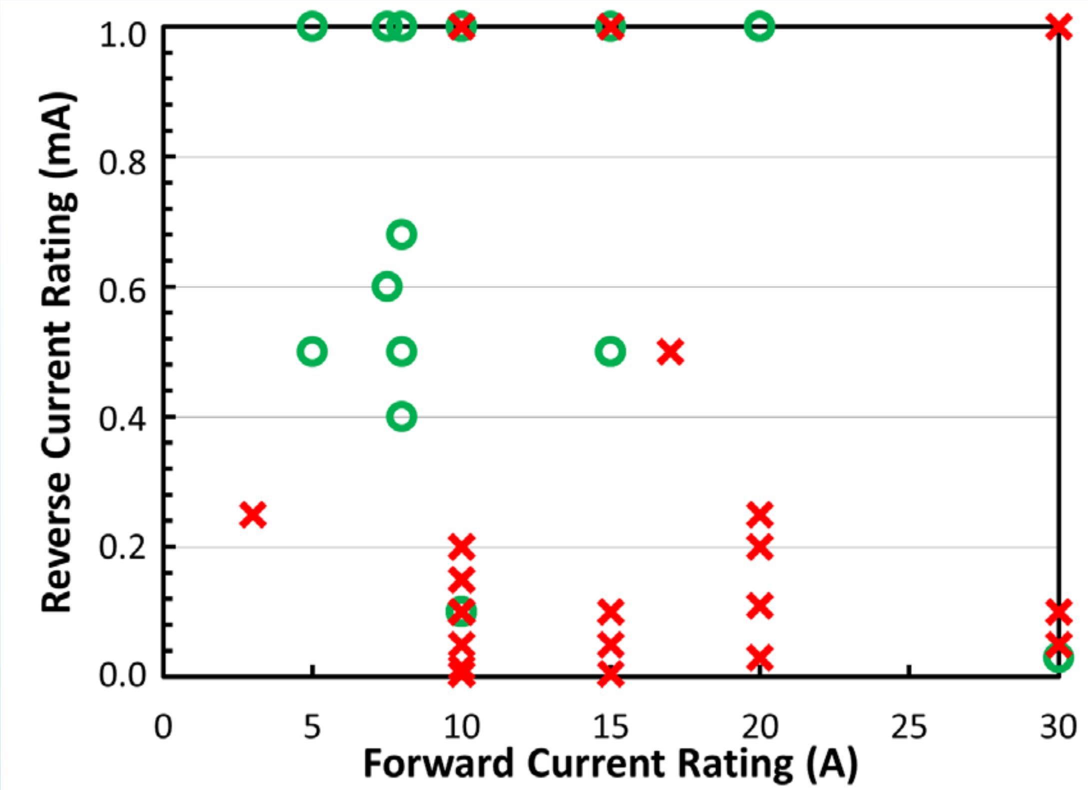


No failures observed in parts with ϕB less than 0.72 eV

Failures as a Function of Reverse Current

100% of Reverse Voltage

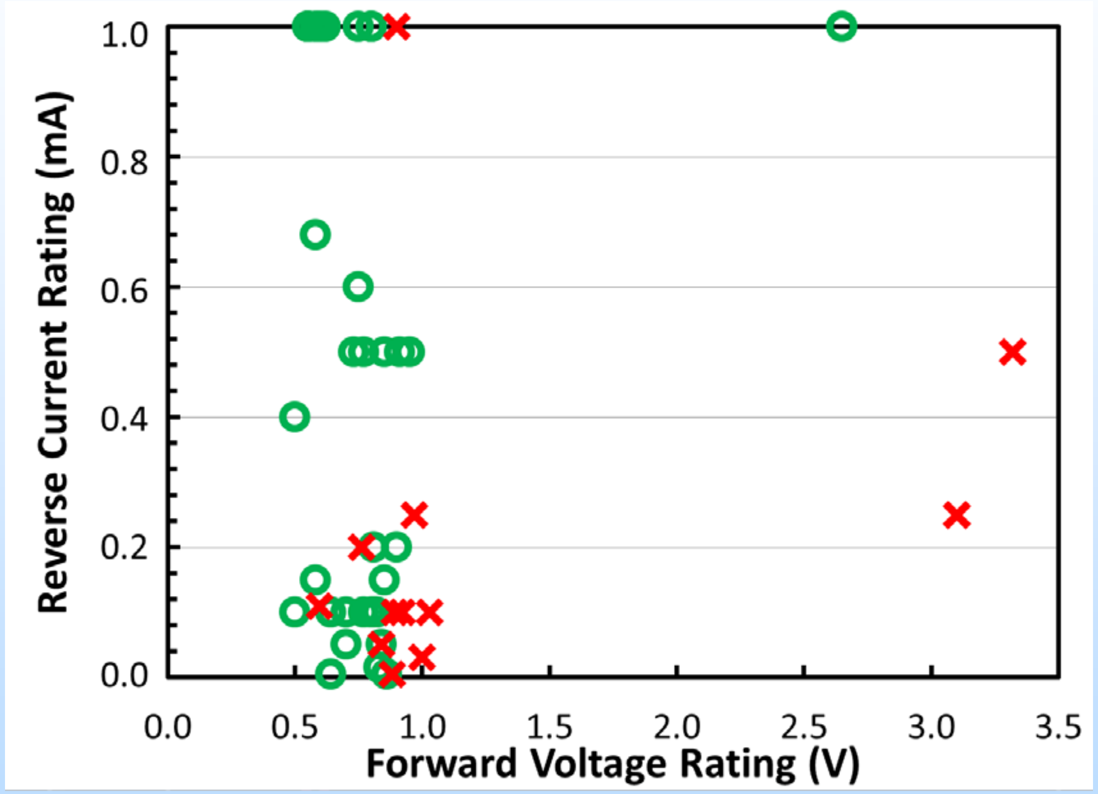


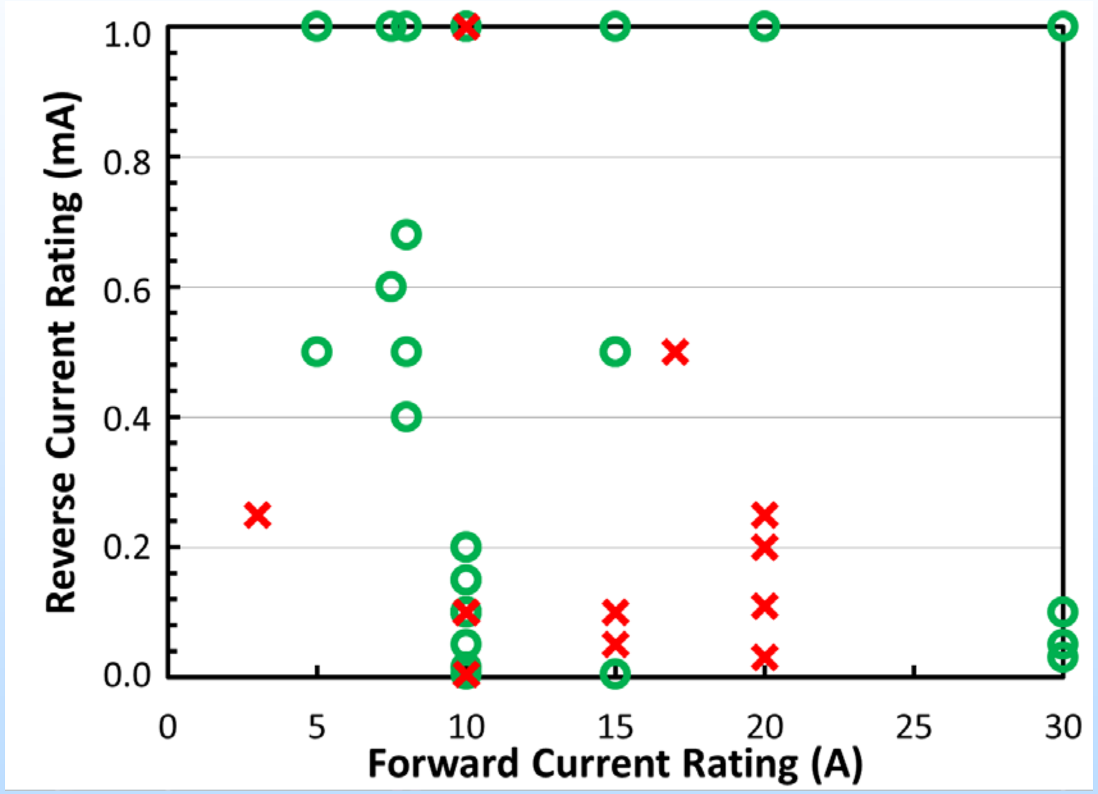


Strong correlation in susceptibility and low I_R rating

Failures as a Function of Reverse Current

75% of Reverse Voltage

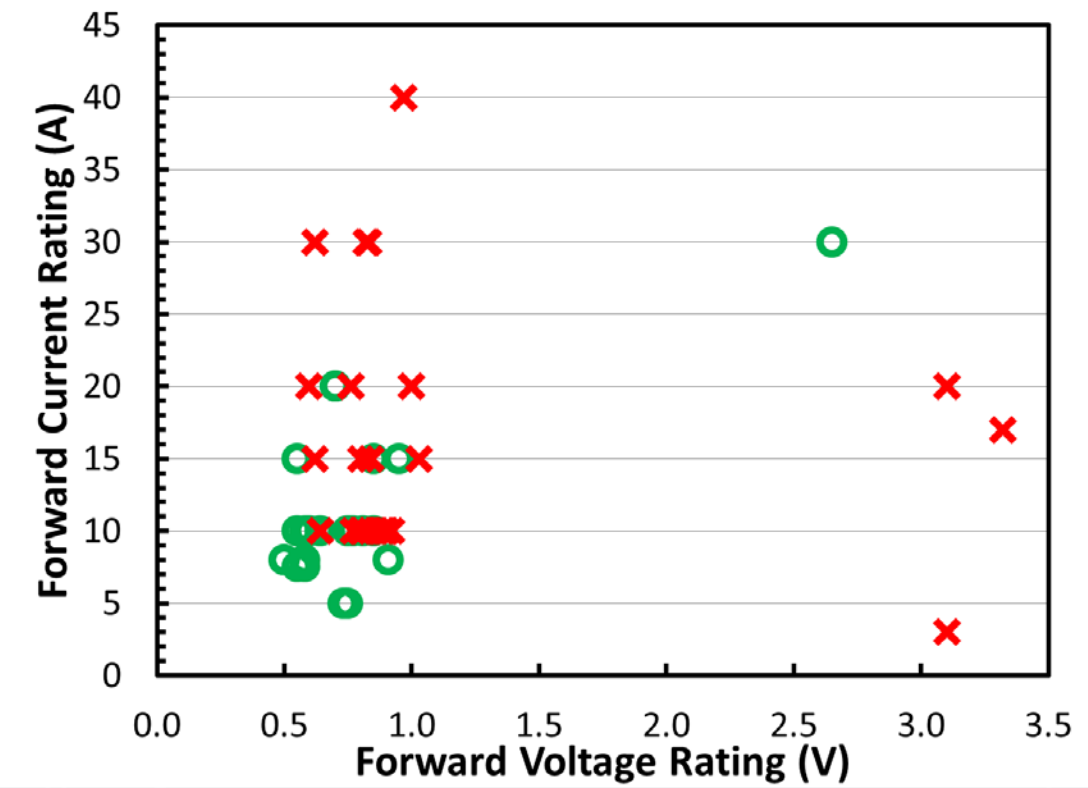




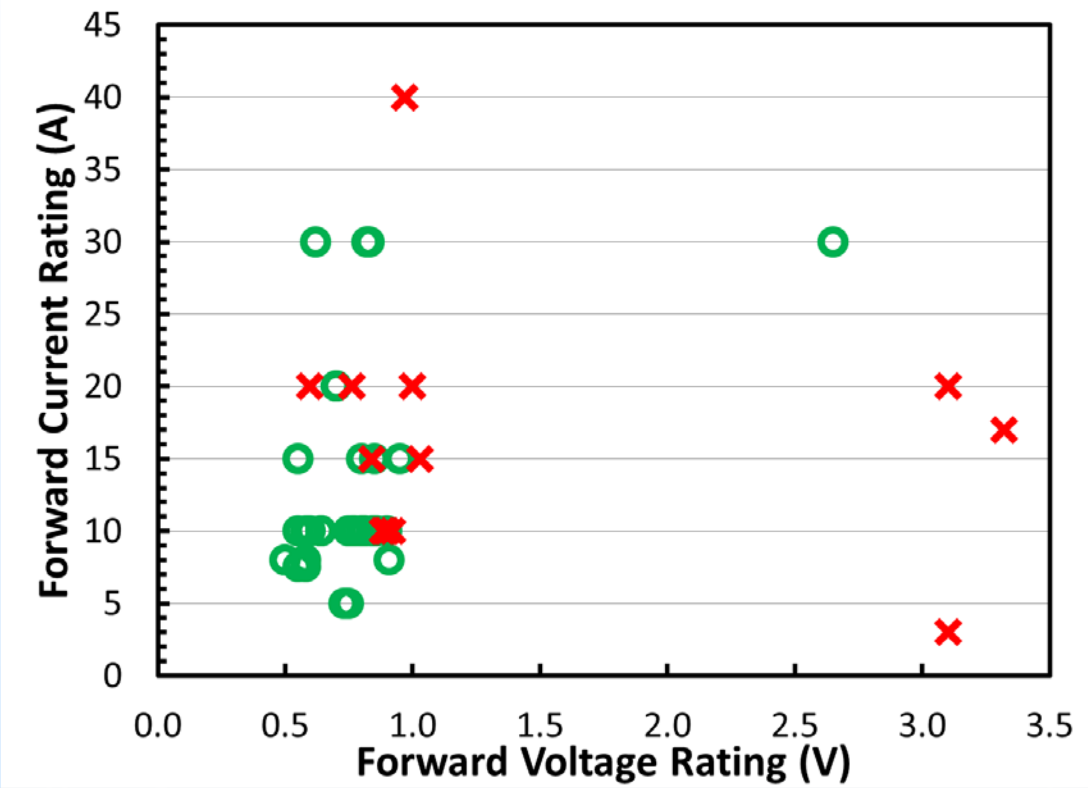
Strong correlation in susceptibility and low I_R rating

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 ϕ_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 $I_R \leq 200$ µA
  - Correlation also exists between failures and forward voltage

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