



Single-Event Threats for Diodes – It's Not Just Schottky Diodes

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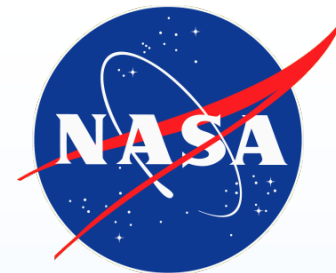
Acronyms

- DUT – Device Under Test
- GSFC – Goddard Space Flight Center
- I_F – Forward Current
- I_R – Reverse Current
- RF – Radio Frequency
- SBD – Super Barrier Diode
- SEE – Single-Event Effects
- V_R – Reverse Voltage
- V_F – Forward Voltage



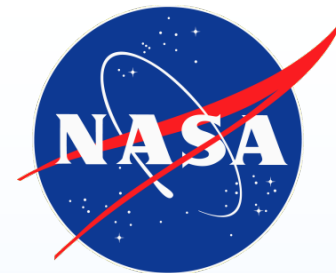
Introduction

- Since 2011, GSFC has been investigating destructive SEEs in Schottky diodes
 - We have recommended a 50% V_R derating for operation in heavy-ion environments
- During this investigation, several super barrier diodes were also irradiated and experienced failures identical to the Schottky diodes that were tested
 - In retrospect, this is not totally unexpected as SBDs also have a Schottky junction, but also employs an insulating layer between the metal and semiconductor material
 - However, this led us to question whether the failure mechanism is limited to diodes with Schottky junctions or if it exists in other diode types as well



Test Facilities and Technique

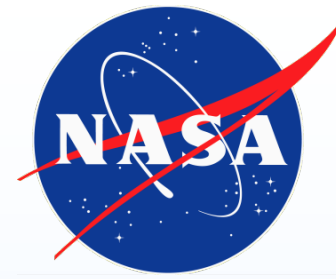
- All parts were tested at LBNL's 88-inch cyclotron with 1233 MeV Xe (LET = 58.8 MeV-cm²/mg)
- All diodes were irradiated under reverse bias and at room temperature
- After each beam run, V_F , V_R , I_F and I_R were measured
- Because a 50% derating has been found to be sufficient for Schottky diodes, that was the initial test voltage
- A minimum of 3 DUTs per part type were tested



Parts Tested

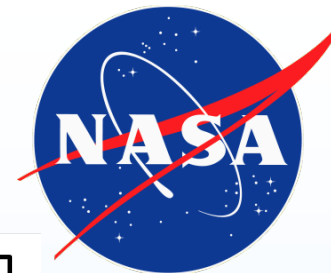
- 30 diodes from 10 manufacturers
- 5 diode types: avalanche, RF PiN, super barrier, switching, and Zener
- Reverse voltages range from 35 V to 200 V
- Forward currents (per diode) from 2 mA to 10 A
- Within the manufacturers, high temperature, high forward voltage lines are compared to low temperature, low forward voltage and low barrier height lines

Diodes Tested

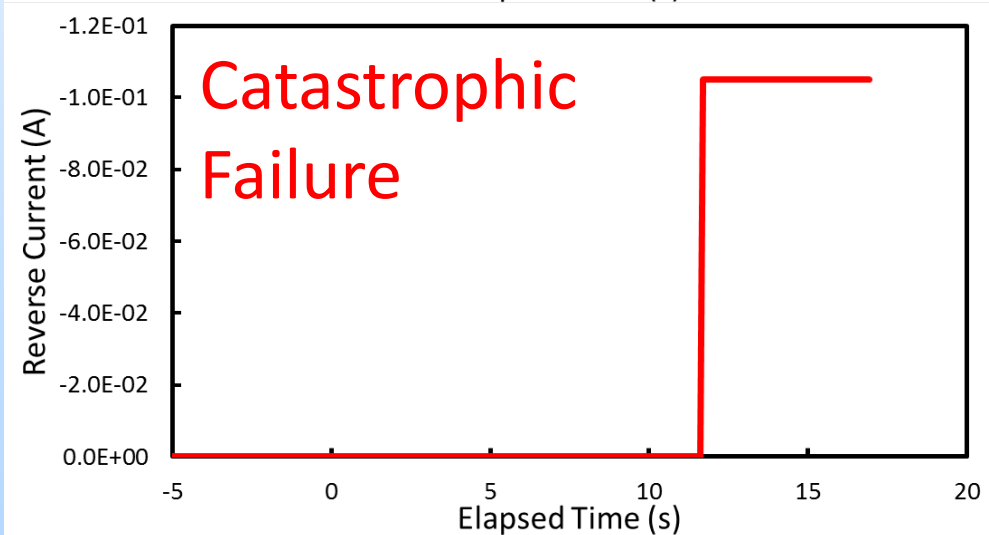
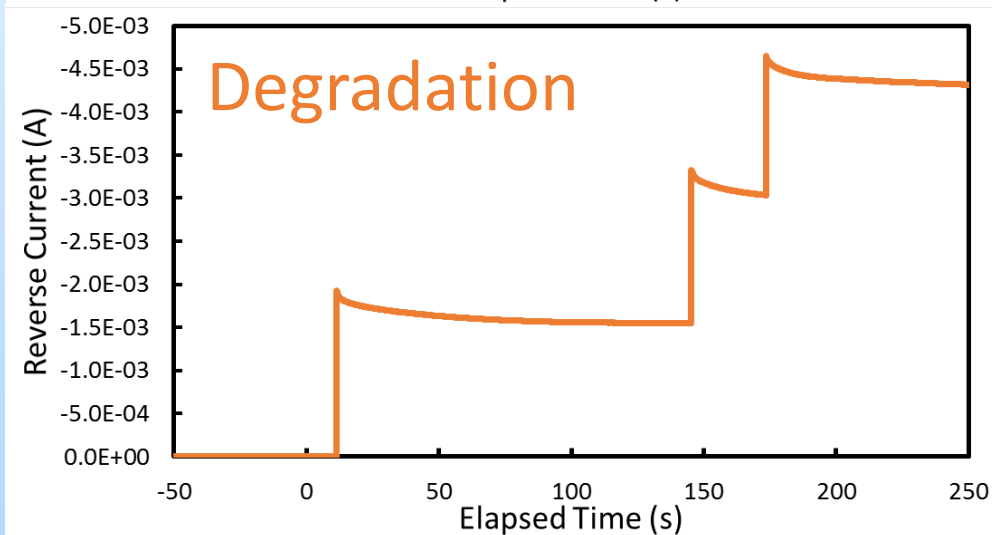
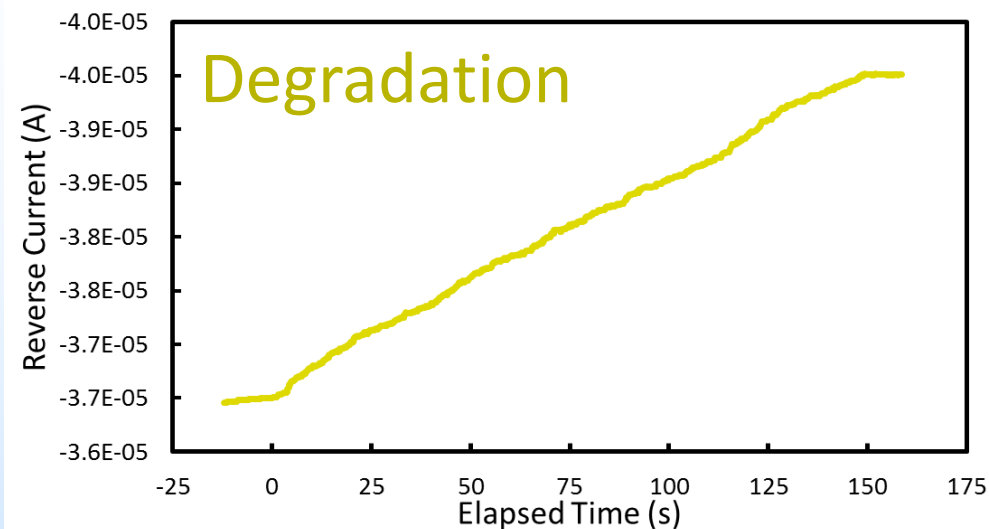
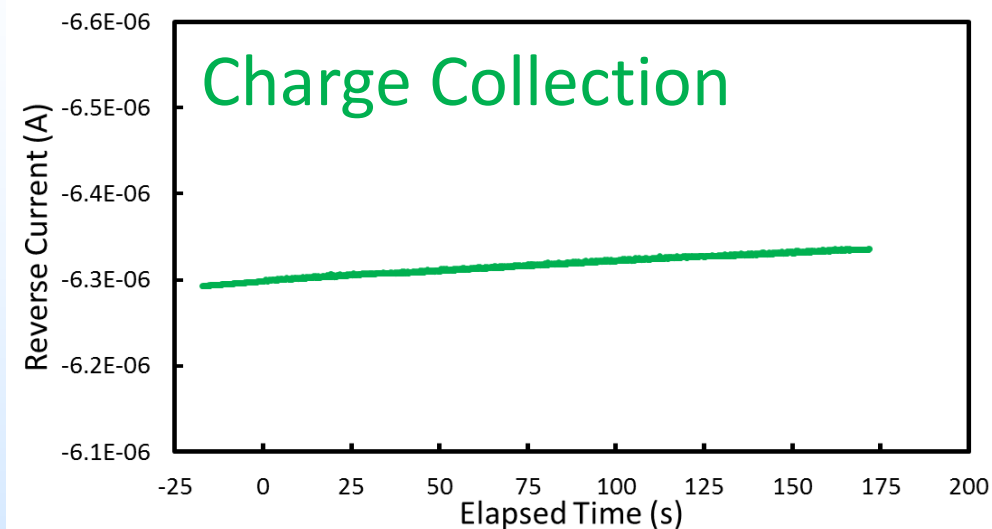


| Diode Type | Manufacturer | Part Number | Reverse Voltage | Forward Current |
|---------------|--------------|----------------|-----------------|-----------------|
| Avalanche | NXP Semi | BAS29,215 | 90 V | 200 mA |
| Super Barrier | Diodes Inc | SBR1U200P1-7 | 200 V | 1 A |
| Super Barrier | Diodes Inc | SBR1045D1-13 | 45 V | 10 A |
| Super Barrier | Diodes Inc | SBR160S23-7 | 60 V | 900 mA |
| Super Barrier | Diodes Inc | SBRT10U60D1-13 | 60 V | 10 A |
| Zener | Diodes Inc | BZX84C47-7-F | 47 V | 10 mA |
| Zener | NXP Semi | BZX84-B47,215 | 47 V | 10 mA |
| Zener | NXP Semi | BZX84-C56,215 | 56 V | 10 mA |
| Zener | NXP Semi | BZX84-C68,215 | 68 V | 10 mA |
| Zener | NXP Semi | BZX84-A75,215 | 75 V | 10 mA |
| Zener | On Semi | BZX84C56LT1G | 56 V | 10 mA |
| Zener | On Semi | BZX84C68LT1G | 68 V | 10 mA |
| Zener | On Semi | BZX84C75LT1G | 75 V | 10 mA |
| Zener | Vishay | BZX84C56-E3-08 | 56 V | 2 mA |

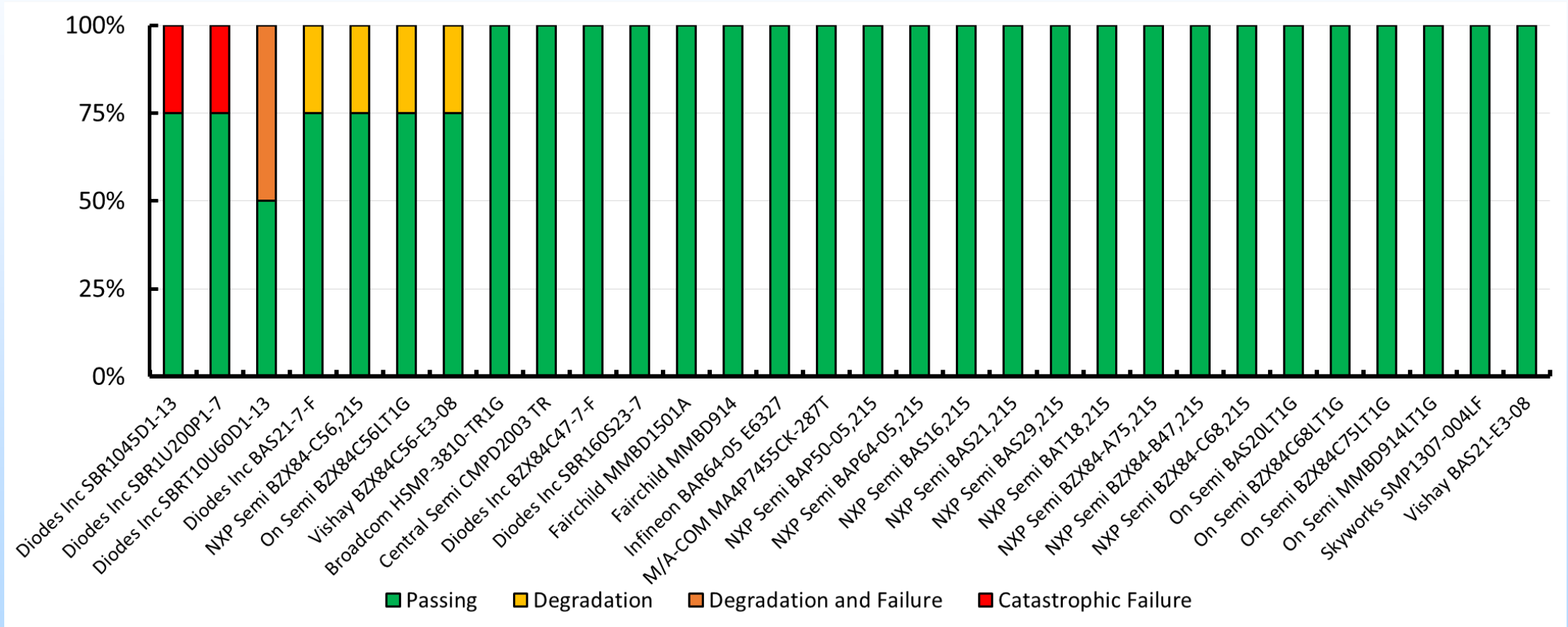
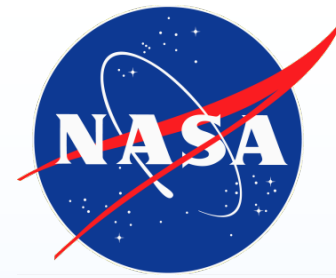
| Diode Type | Manufacturer | Part Number | Reverse Voltage | Forward Current |
|------------|--------------|-----------------|-----------------|-----------------|
| PiN | Broadcom | HSMP-3810-TR1G | 100 V | 1 A |
| PiN | Infineon | BAR64-05 E6327 | 150 V | 100 mA |
| PiN | M/A-COM | MA4P7455CK-287T | 100 V | 150 mA |
| PiN | NXP Semi | BAP64-05,215 | 175 V | 100 mA |
| PiN | NXP Semi | BAT18,215 | 35 V | 100 mA |
| PiN | NXP Semi | BAP50-05,215 | 50 V | 50 mA |
| PiN | Skyworks | SMP1307-004LF | 200 V | 100 mA |
| Switching | Central Semi | CMPD2003 TR | 200 V | 200 mA |
| Switching | Diodes Inc | BAS21-7-F | 200 V | 200 mA |
| Switching | Fairchild | MMBD914 | 100 V | 200 mA |
| Switching | Fairchild | MMBD1501A | 200 V | 200 mA |
| Switching | NXP Semi | BAS16,215 | 100 V | 215 mA |
| Switching | NXP Semi | BAS21,215 | 200 V | 200 mA |
| Switching | On Semi | MMBD914LT1G | 100 V | 200 mA |
| Switching | On Semi | BAS20LT1G | 200 V | 200 mA |
| Switching | Vishay | BAS21-E3-08 | 200 V | 200 mA |

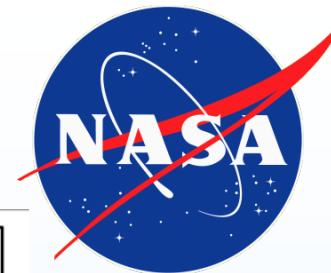


Observed Radiation Responses



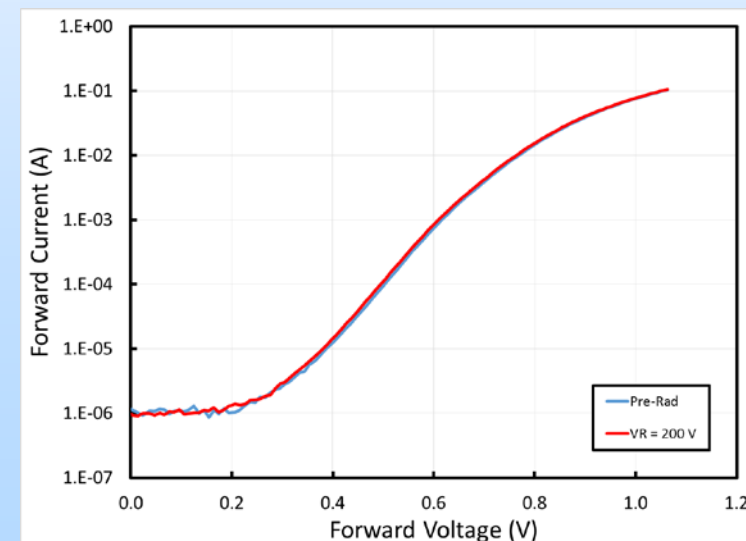
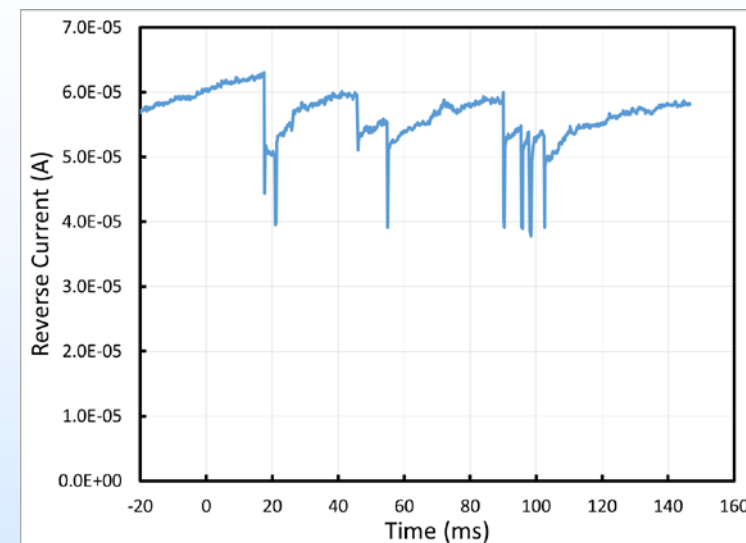
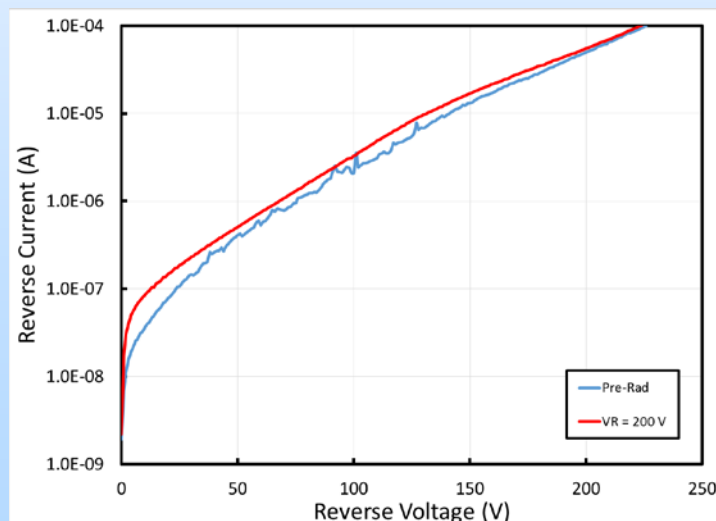
Results





Diodes, Inc. BAS21-7-F Switching Diode

- Small changes in the reverse current were observed during the runs in which these parts were biased at the full-rated 200-V reverse voltage
- Small changes in the I_R - V_R and I_F - V_F plots were observed after the runs
 - How these changes effect the long-term reliability of the parts is unknown





Results

- Previously tested SBDs were high-power ($V_R = 300$ V and $I_R = 10$ and 20 A), but these SBDs were lower power and most still experienced catastrophic failure
 - The exception was an SBD with $V_R = 60$ V and $I_R = 900$ mA
 - The other SBD ratings were: $V_R = 200$ V and $I_R = 1$ A, $V_R = 45$ V and $I_R = 10$ A, and $V_R = 60$ V and $I_R = 10$ A, which are comparable power output to standard Schottky diodes
- All three 56 V Zener diodes experienced degradation (from three different manufacturers), but no other Zeners did



Conclusions

- Only diodes with a Schottky junction appear to experience catastrophic failure under the conditions tested
- Degradation was observed in an RF switching diode and several Zener diodes
 - While all measured electrical parameters remained within specification after degradation was observed, the long-term reliability of these parts is unknown
- Degradation and failure mechanisms are not limited to power devices
- NSREC 2017 poster presentation will show detailed failure analysis, which seems to indicate there are two different failure mechanisms