National Aeronautics
and Space Administration

Destructive Single-Event Failures in Schottky Diodes

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List of Acronyms

- DUT – Device Under Test
- EEE Parts – Electrical, electronic, and electromechanical parts
- EEE-INST-002 – Instructions for EEE Parts Selection, Screening, Qualification, and Derating
- GSFC – Goddard Space Flight Center
- IEEE – Institute of Electrical and Electronics Engineers
- I_R – Reverse Current
- IR – International Rectifier
- LBNL – Lawrence Berkeley National Laboratory Facility's 88-Inch Cyclotron
- LET – Linear Energy Transfer
- MOSFET – Metal-oxide-semiconductor field-effect transistor
- NEPP – NASA Electronic Parts and Packaging program
- NSREC – Nuclear and Space Radiation Effects Conference
- REDW – IEEE Radiation Effects Data Workshop
- SEE – Single-Event Effect
- STMicro – STMicroelectronics
- TAMU – Texas A&M University's Radiation Effects Facility
- V_R – Reverse Voltage
- V_F – Forward Voltage

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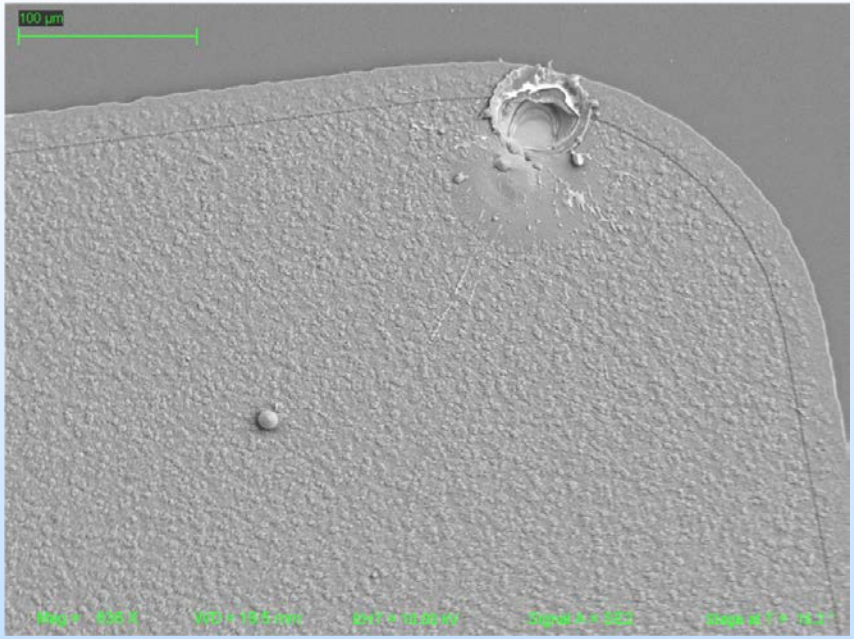
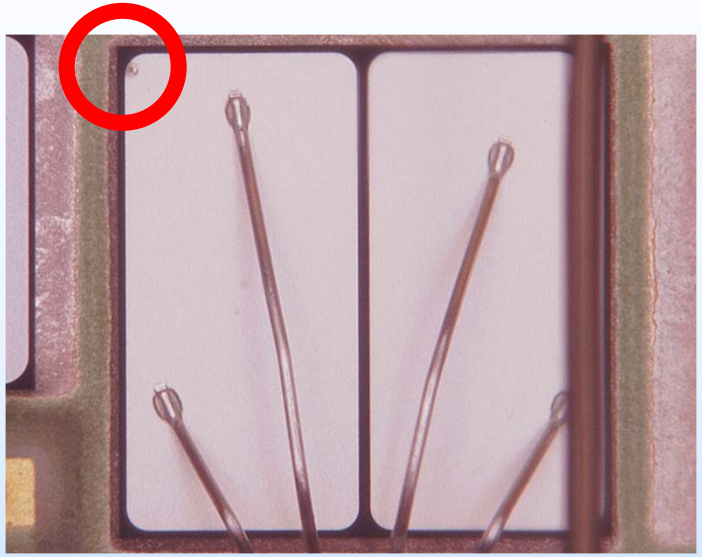


M. V. O'Bryan, *et al.*, *IEEE REDW*, 2012.

Introduction: Destructive Failures in DC-DC Converters

- **Destructive SEEs observed in DC-DC converters by two different manufacturers, IR and Crane Aerospace**
  - **Attributed to the shorting of the anode and the cathode of the output diodes**
- **Diodes generally are not considered to be susceptible to SEEs**
  - **Implication of these diode failures could be catastrophic to scientific instruments, or even entire spacecraft**
- **Under NEPP, the diodes are independently irradiated to identify and understand the failure mechanism, and the severity of the potential impact to NASA missions**



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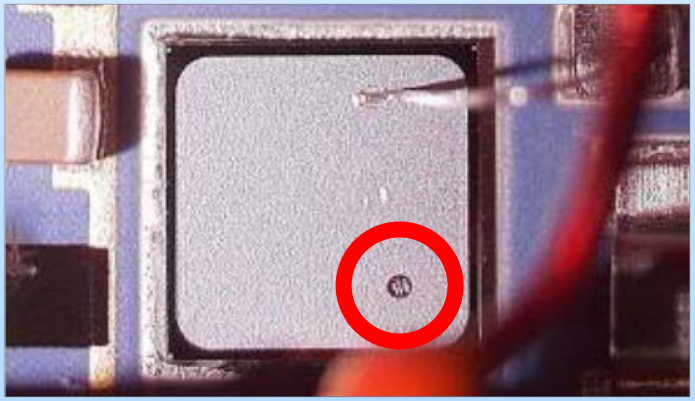

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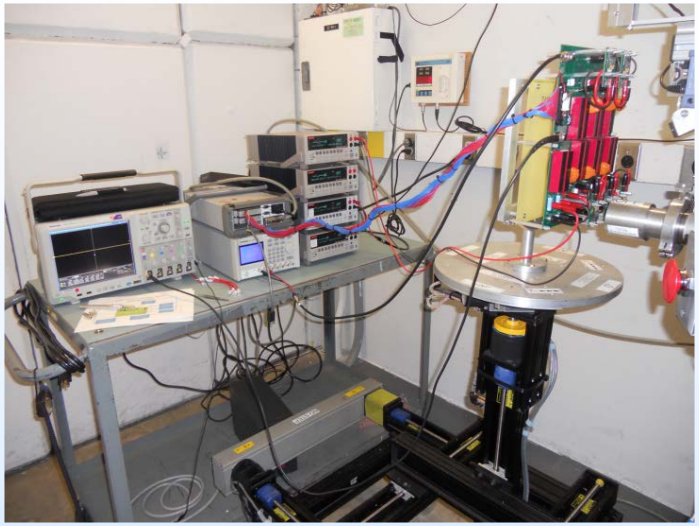
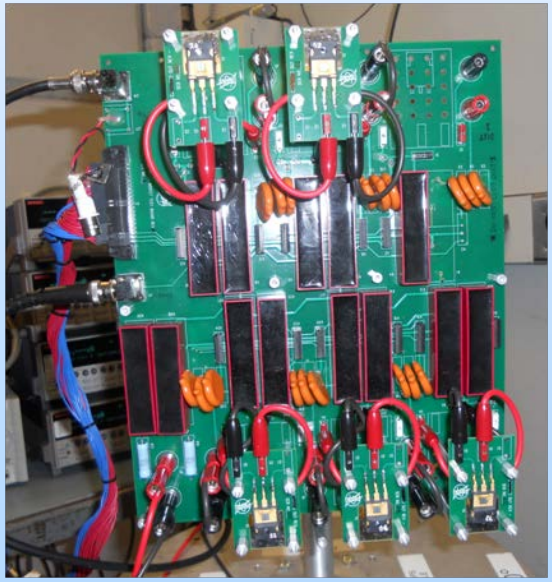
Parts Tested and Test Set-Up

- **Diodes Tested**
  - **ON Semiconductor MBR20200CT**
    - **Dual 200 V, 10 A Schottky diode**
    - **45 diodes were irradiated**
  - **Equivalent to Sensitron SD125SB45A**
    - **45 V, 15 A Schottky diode**
    - **4 diodes were irradiated**
  - **ST Micro STPS20100**
    - **Dual 100 V, 10 A Schottky diode**
    - **3 diodes were irradiated**
- **Test Set-Up**
  - **Experiments were conducted using GSFC High-Voltage Power MOSFET Motherboard**





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Test Facilities and Beam Conditions

Facility	Ion	Energy (MeV)	LET at Normal Incidence (MeV-cm^2/mg)	Range in Si (µm)
TAMU	Ar	944	5.60	193
	Kr	1032	27.80	170
	Xe	1512	51.5	120
	Ta	2076	77.3	119
LBNL	O	183	2.19	226
	Ne	216	3.49	175
	V	508	14.59	113
	Ag	10	48.15	90
	Xe	1232	58.78	90

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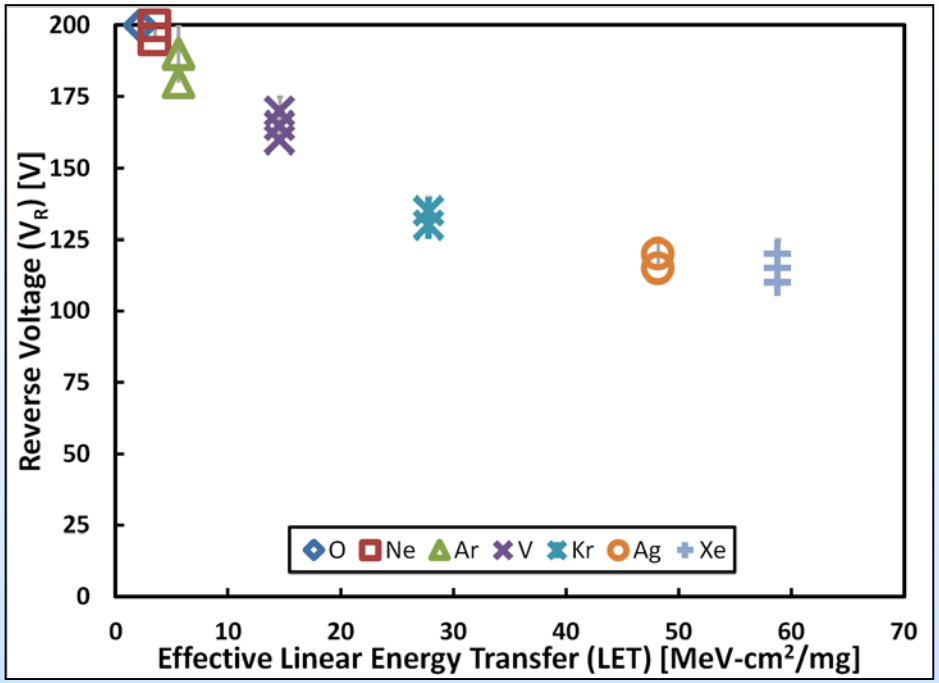
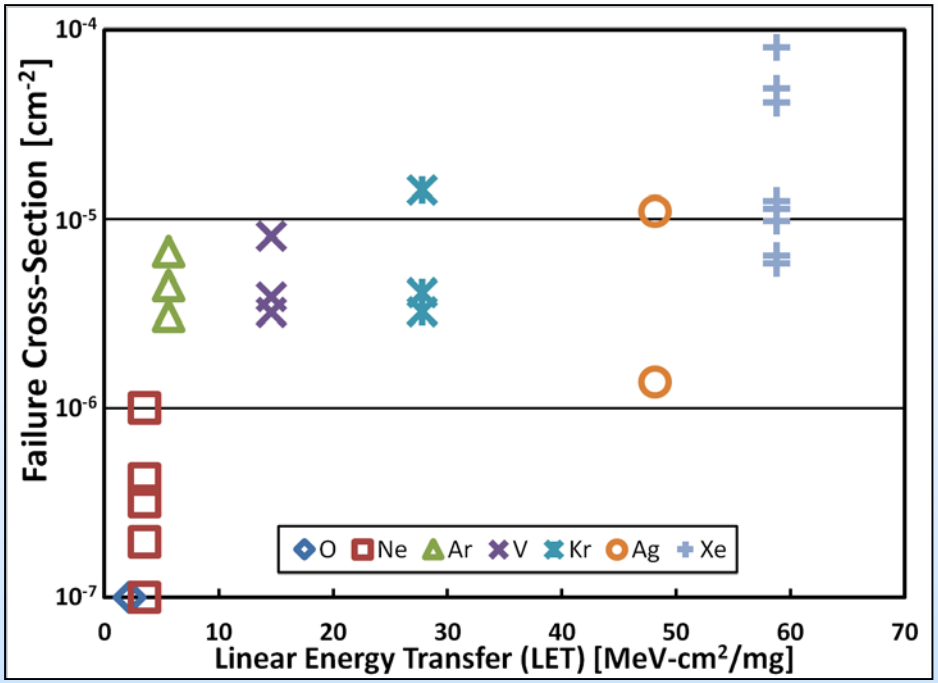
Test Results
ON Semiconductor MBR20200CT





- All parts were only found to be susceptible when reverse biased
- EEE-INST-002 states that all diodes should be derated to 75% of rated voltage, so in theory, these diodes could be used up to a voltage of 150 V
- When irradiated with 508 MeV V, failed at voltages greater than 150 V
- When irradiated with 1032 MeV Kr, failed below derated voltage threshold

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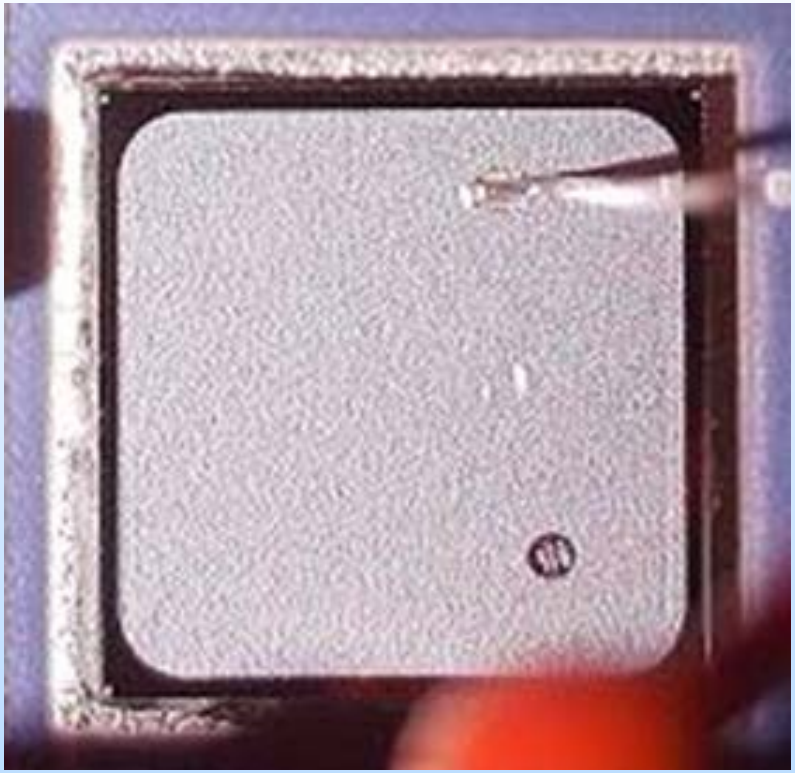
Test Results
Sensitron SD125SB45A

- Schottky diodes were irradiated with 1232 MeV Xe (LET = 58.8 MeV-cm^2/mg) at LBNL and with 2076 MeV Ta (LET = 77.3 MeV-cm^2/mg) at TAMU
  - No failures were observed with either ion, including at full rated voltage of 45 V
- Failure in the MTR28515 may be due to something other than burnout in the diode
  - Location of the failure was not along the guard ring in the DC-DC converter test
  - No failures observed in these parts independent of the converter



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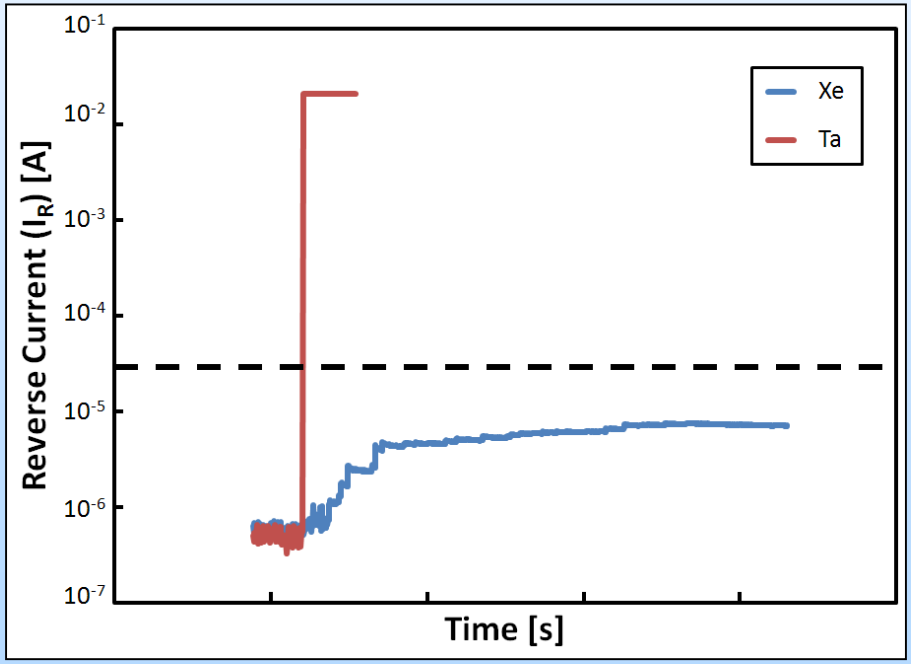
Test Results
STMicro STPS20100

- Full rated voltage (100 V) was applied during irradiation
- Current increased in steps during irradiation with Xe, but did not fail
  - May have exceeded datasheet specification for reverse current (30 µA) if fluence had been higher ($3x10^5$ particles/cm^2)
- Diode failed short as soon as the beam was turned on with Ta
  - Failure rate would be very low



Additional Parts Tested

Manufacturer	Part Number	Reverse Voltage (V)	Number of Parts Tested (#)	Xe Energy (MeV)	Xe LET (MeV-cm^2/mg)
STMicro	1N5819	45	3	1512	51.5
	STPS1045	45	3	1512	51.5
IR/Vishay	95-9951	45	3	1366	53.1
	96-1063	45	4	1366	53.1
	96-1052	60	3	1366	53.1
	95-9953	150*	1	1366	53.1
	95-9942	150	3	1366	53.1

* Part irradiated at 100 V

Path Forward

- **Recently procured 23 different Schottky diodes**
  - **Variety of manufacturers, reverse voltage ratings, and forward current ratings**
- **DUTs will be tested at LBNL June 29-July 1**
  - **12 hrs to irradiate 46 DUTs**
- **Test plans are go/no-go testing**
  - **Will irradiate with Xe at 100% of rated voltage**
    - **If pass, test two more under same conditions**
    - **If fail, test at 75%, 50%, 25%...**
  - **Intent is to identify what parameters determine failure**
  - **Derating guideline would be next step using failing parts**

Path Forward

Investigating Effect of Manufacturer

Investigating Effect of Forward Current

Investigating Effect of Reverse Voltage

Part Number	Manufacturer	Reverse Voltage	Forward Current
MBR20200CTTU	Fairchild Semiconductor	200	10
FYPF2010DNTU	Fairchild Semiconductor	100	20
MBR20100CTTU	Fairchild Semiconductor	100	10
MBR2060CT	Fairchild Semiconductor	60	20
MBR3045PT	Fairchild Semiconductor	45	30
FST30100	Microsemi	100	15
NXPS20H100CX,127	NXP Semiconductor	100	10
MBRF20100CTG	ON Semiconductor	100	10
MBR2080CTG	ON Semiconductor	80	10
MBR2060CTG	ON Semiconductor	60	10
MBR6045WTG	ON Semiconductor	45	30
MBR4045WTG	ON Semiconductor	45	20
MBRF2045CTG	ON Semiconductor	45	10
RB205T-60	Rohm Semiconductor	60	7.5
STPS60SM200CW	STMicroelectronics	200	60
STPS20200CT	STMicroelectronics	200	10
STPS30H100CT	STMicroelectronics	100	15
STPS40M60CT	STMicroelectronics	60	20
STPS4045CT	STMicroelectronics	45	20
MBR20H200CT-E3/45	Vishay Semiconductor	200	10
MBR60100CT-E3/45	Vishay Semiconductor	100	30
MBR20100CT-E3/4W	Vishay Semiconductor	100	10
VS-MBR4045WTPBF	Vishay Semiconductor	45	20

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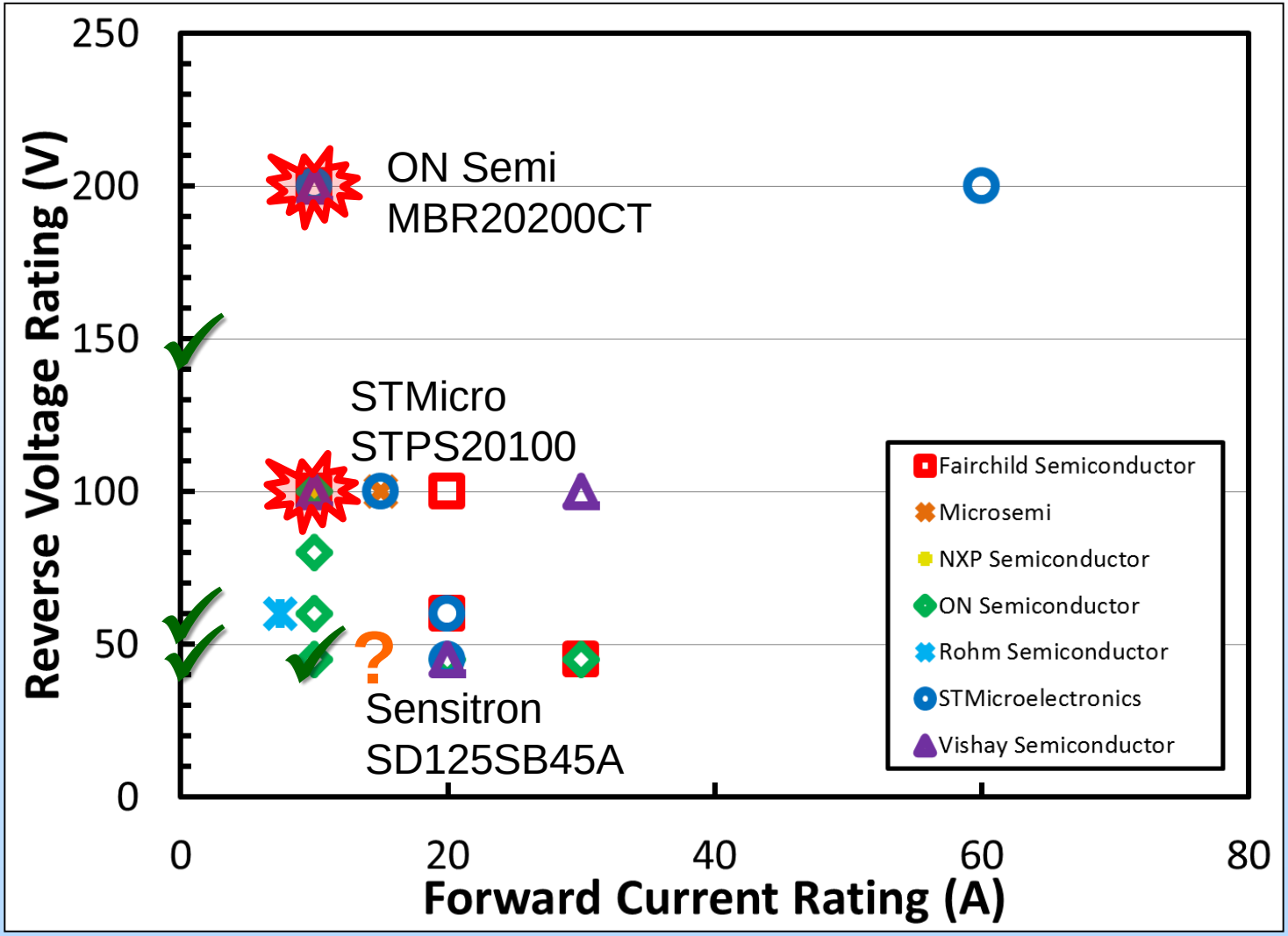

Conclusions

- We have shown that Schottky diodes are susceptible to destructive single-event effects
  - Failures only occur when diodes are reverse biased
  - Failures visible along guard ring in parts with no current limiting
- Future work will be completed to identify parameter that determines diode susceptibility
  - Manufacturer(s)? Reverse voltage? Forward Current?
- By determining the last passing voltages, a safe operating area can be derived
  - If these values are used for derating, rather than the rated voltage we can work to ensure the safety of future missions
    - This is currently done with power MOSFETs