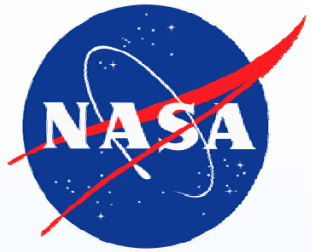
National Aeronautics and Space Administration



Destructive Single-Event Failures in Schottky Diodes

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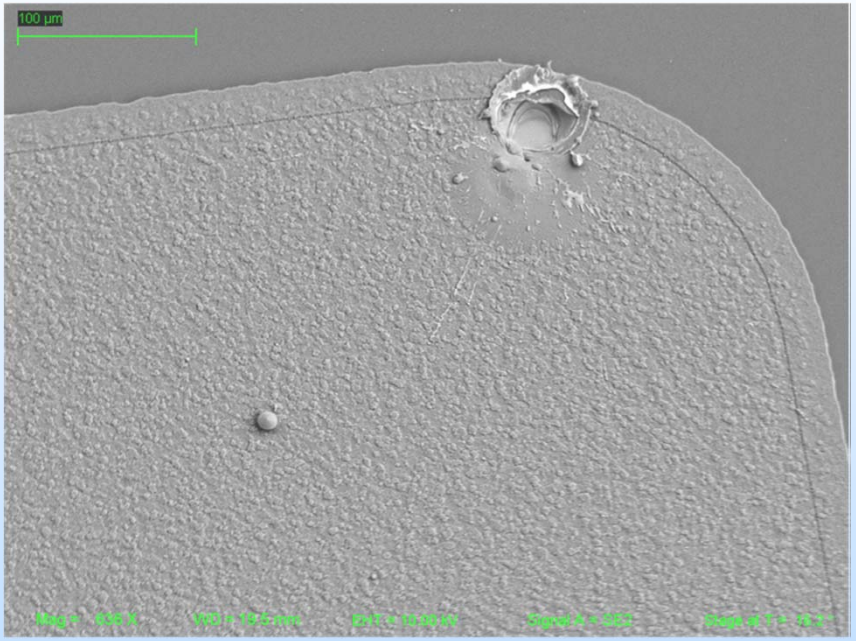


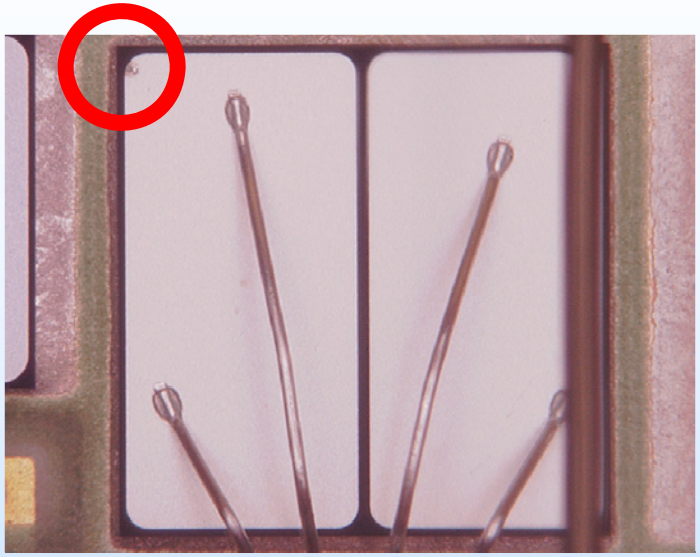
M. V. O'Bryan, *et al.*, *IEEE REDW*, 2012.

List of Acronyms

Acronym	Definition	Acronym	Definition
EEE Parts	Electrical, electronic, and electromechanical parts	MOSFET	Metal oxide semiconductor field effect transistor
EEE-INST-002	Instructions for EEE Parts Selection, Screening, Qualification, and Derating	NEPP	NASA Electronic Parts and Packaging Program
GSFC	Goddard Space Flight Center	NSREC	Nuclear and Space Radiation Effects Conference
IEEE	Institute for Electrical and Electronics Engineers	REDW	Radiation Effects Data Workshop
I_R	Reverse current	SEE	Single-event effects
IR	International Rectifier	TAMU	Texas A&M University Radiation Effects Facility
LBNL	Lawrence Berkeley National Laboratory's Berkeley Accelerator Effects Facility	V_R	Reverse voltage
LET	Linear energy transfer	V_F	Forward Voltage

Introduction: Destructive Failures in DC-DC Converters

- **At 2012 NSREC, M. V. O'Bryan et al. highlighted 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 funding, the diodes were independently irradiated to identify and understand the failure mechanism, and the severity of the potential impact to NASA missions**



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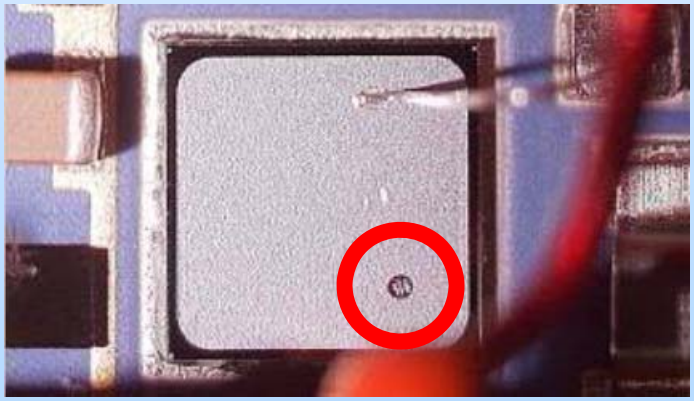

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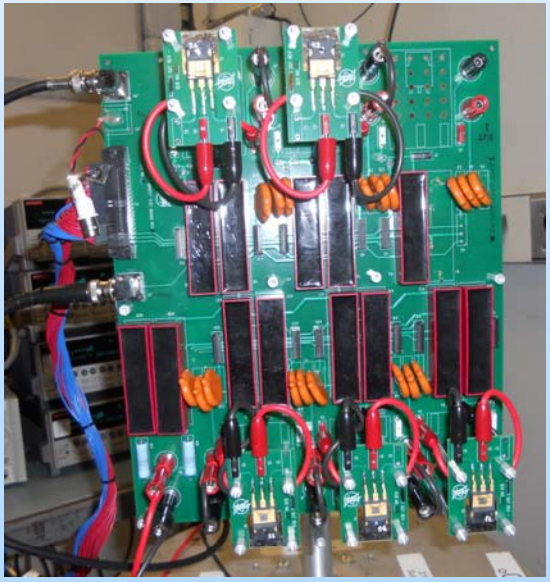
Parts Tested and Test Set-Up

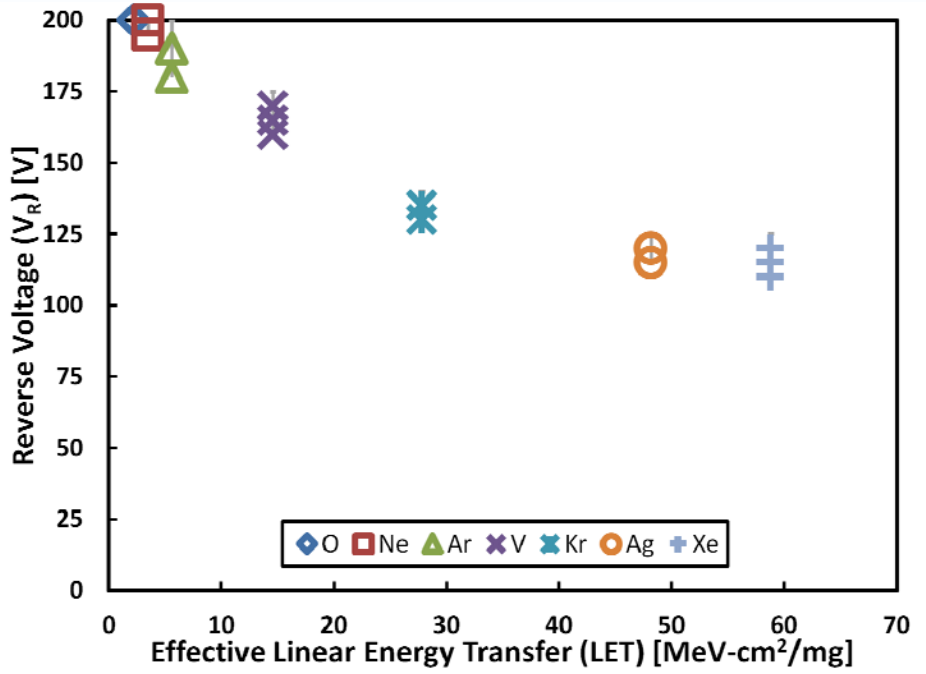
- **Diodes Tested**
  - **ON Semiconductor MBR20200CT**
    - **Dual 200 V, 20 A Schottky diode**
    - **45 diodes were irradiated**
  - **Equivalent to Sensitron SD125SB45A**
    - **45 V, 15 A Schottky diode**
    - **7 diodes were irradiated**
  - **STMicroelectronics STPS20100**
    - **Dual 100 V, 20 A Schottky diode**
    - **3 diodes were irradiated**
- **Test Set-Up**
  - **Experiments were conducted using GSFC High-Voltage Power MOSFET Motherboard**



Test Facilities

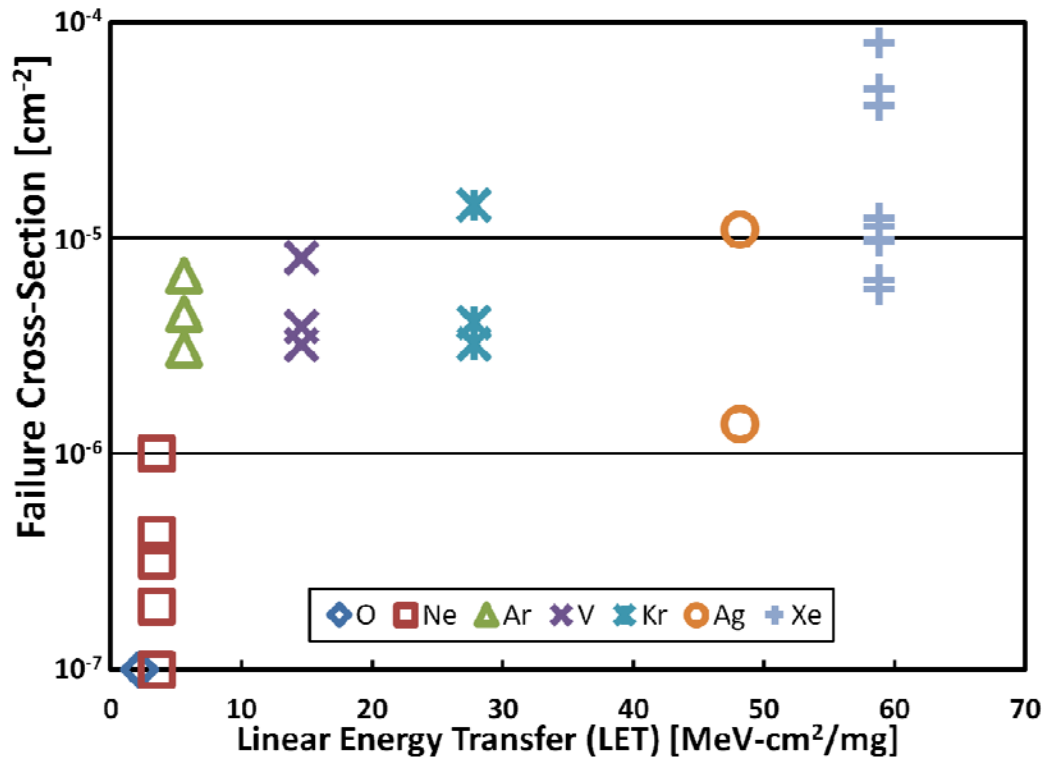
Facility	Ion	Energy (MeV)	LET at Normal Incidence (MeV-cm^2/mg)	Range in Si (µm)	Angles (°)
TAMU	Ar	944	5.60	193	0
	Kr	1032	27.80	170	0
	Xe	1512	51.5	120	0
	Ta	2076	77.3	119	0
LBNL	O	183	2.19	226	0
	Ne	216	3.49	175	0
	V	508	14.59	113	0
	Ag	10	48.15	90	0, 10, 30
	Xe	1232	58.78	90	0, 10, 30, 45, 60 0

Test Results
ON Semiconductor MBR20200CT



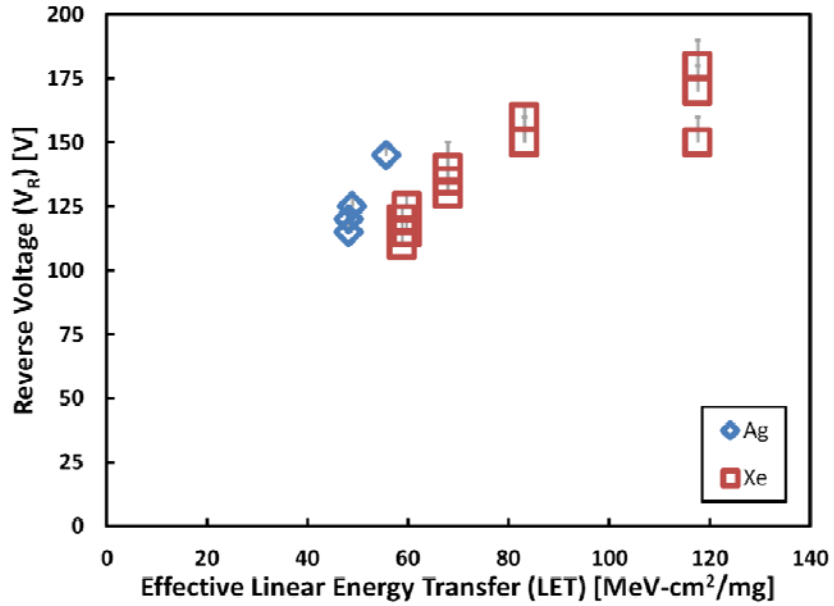
- All parts were only found to be susceptible when reverse biased
- EEE-INST-002 states that all diodes should be derated to 75% of rated voltage, so in theory, these diodes could be used up to 150 V
- When irradiated with 508 MeV V, diodes failed at voltages greater than 150 V
- When irradiated with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

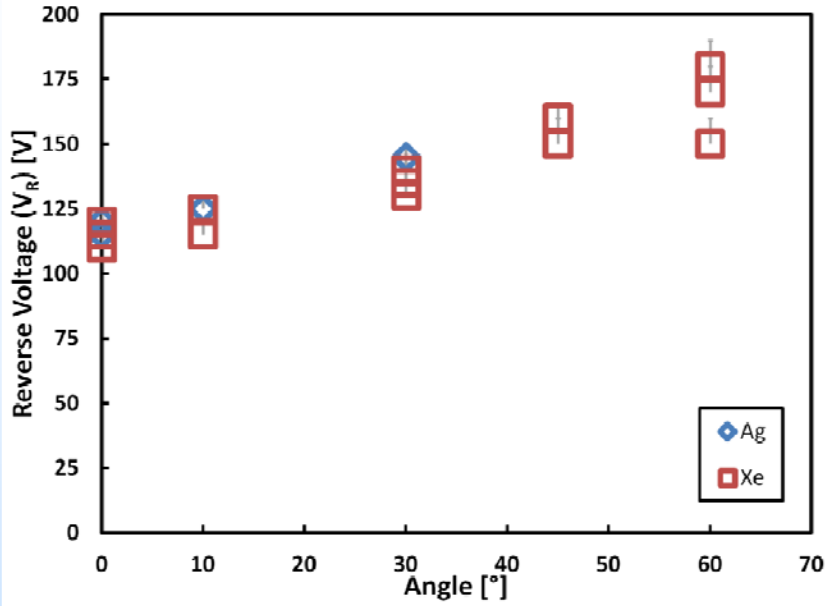
Test Results
ON Semiconductor MBR20200CT



- Difficult to accurately calculate **destructive** SEE cross-sections
- Diodes have a clear onset threshold and seem to saturate at ~1x10^{-5} cm^2
  - No failures were observed with 183 MeV O (LET = 2.2 MeV-cm^2/mg)
  - Failures were observed at 195 V and 200 V with 216 MeV Ne (LET = 3.5 MeV-cm^2/mg)

Test Results
ON Semiconductor MBR20200CT

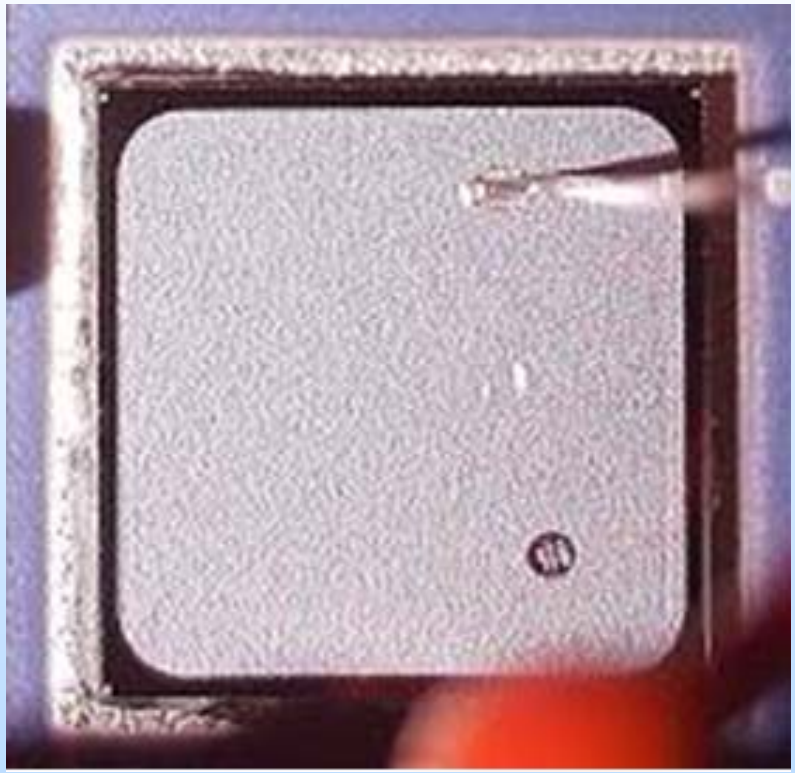




- Last passing voltage does not improve rapidly with increasing angle of incidence
- Data up to and including 45° points follow the cosine law
  - 60° points make trend appear linear

Test Results
Sensitron SD125SB45A

- Schottky diodes were irradiated with 1232 MeV Xe (LET = 59 MeV-cm^2/mg) at LBNL and with 2076 MeV Ta (LET = 77 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
  - Diode could not be failed independently of the converter



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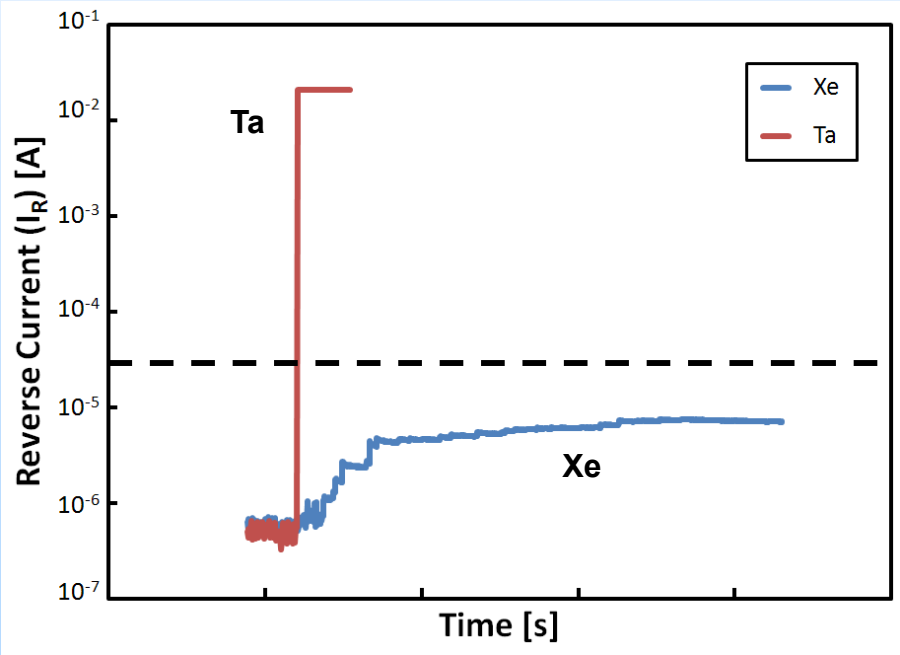
Test Results
STMicroelectronics STPS20100

- 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 ion fluence had been higher ($3x10^5$ particles/cm^2)
- Diode failed short as soon as the Ta beam was turned on
  - 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-cm²/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

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
- 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 same method is currently applied to power MOSFETs

Acknowledgments

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