NEPP Electronic Technology Workshop
June 11-12, 2012

National Aeronautics
and Space Administration

Destructive Single-Event Failures in Schottky Diodes

Megan C. Casey[1], Robert A. Gigliuto[2], Jean-Marie Lauenstein[1], Edward P. Wilcox[2], Anthony M. Phan[2], Hak Kim[2], Dakai Chen[1], and Kenneth A. LaBel[1]

1. NASA Goddard Space Flight Center, Code 561
2. MEI Technology Inc.

To be presented by Megan Casey at the NASA Electronic Parts and Packaging Program (NEPP) Electronics Technology Workshop (ETW), NASA Goddard Space Flight Center in Greenbelt, MD, June 11-12, 2013 and published on nepp.nasa.gov.

List of Acronyms

- EEE Parts – Electrical, electronic, and electromechanical parts
- EEE-INST-002 – Instructions for EEE Parts Selection, Screening, Qualification, and Derating
- GSFC – Goddard Space Flight Center
- 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

Outline

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- **Test Results**
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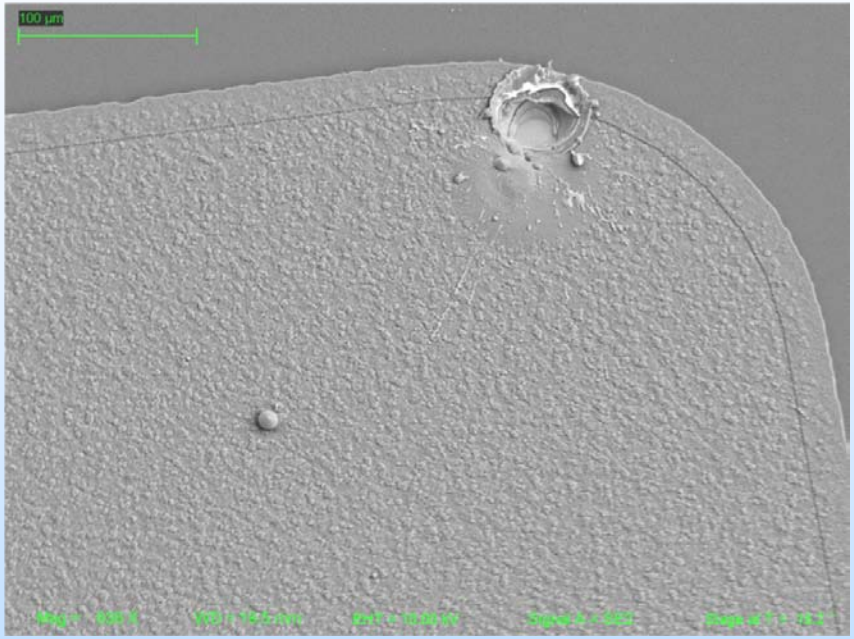
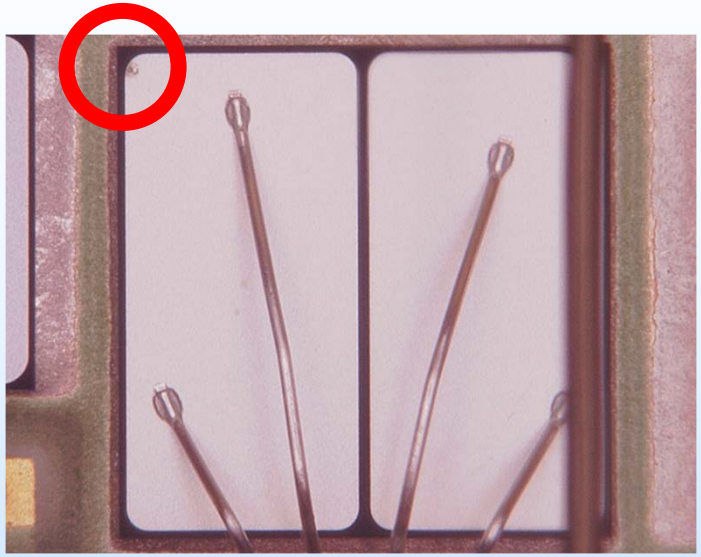
  - **Sensitron SD125SB45A**
  - **STMicroelectronics STPS20100**
- **Conclusions**



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

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, 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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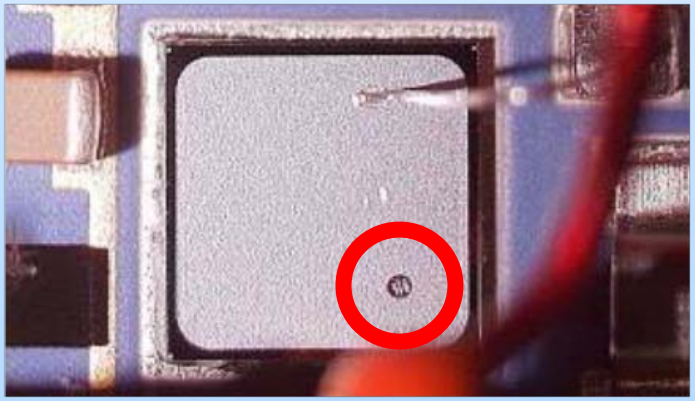

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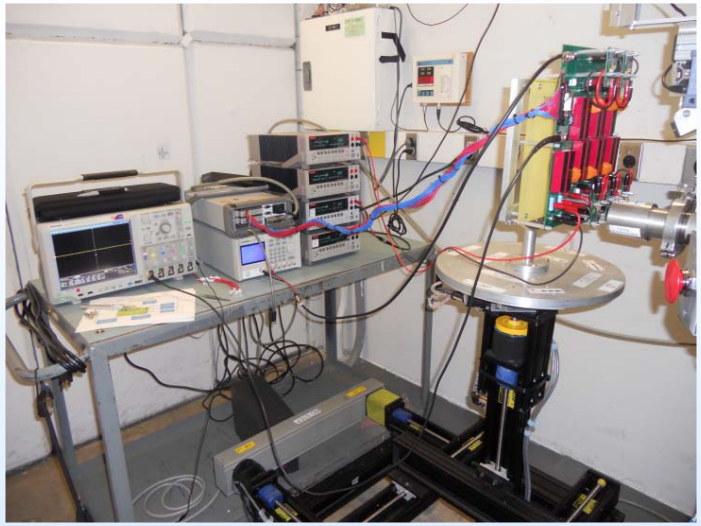
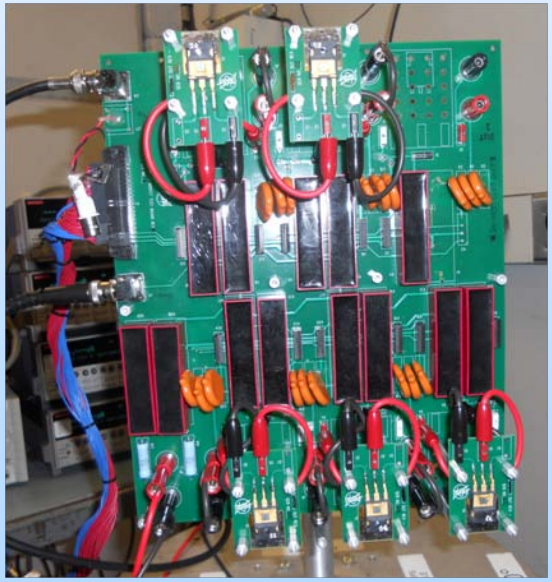
Parts Tested and Test Set-Up

- **Diodes Tested**
  - **ON Semiconductor MBR20200CT**
    - **Dual 200 V, 20 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, 20 A Schottky diode**
    - **3 diodes were irradiated**
- **Test Set-Up**
  - **Experiments were conducted using GSFC High-Voltage Power MOSFET Motherboard**





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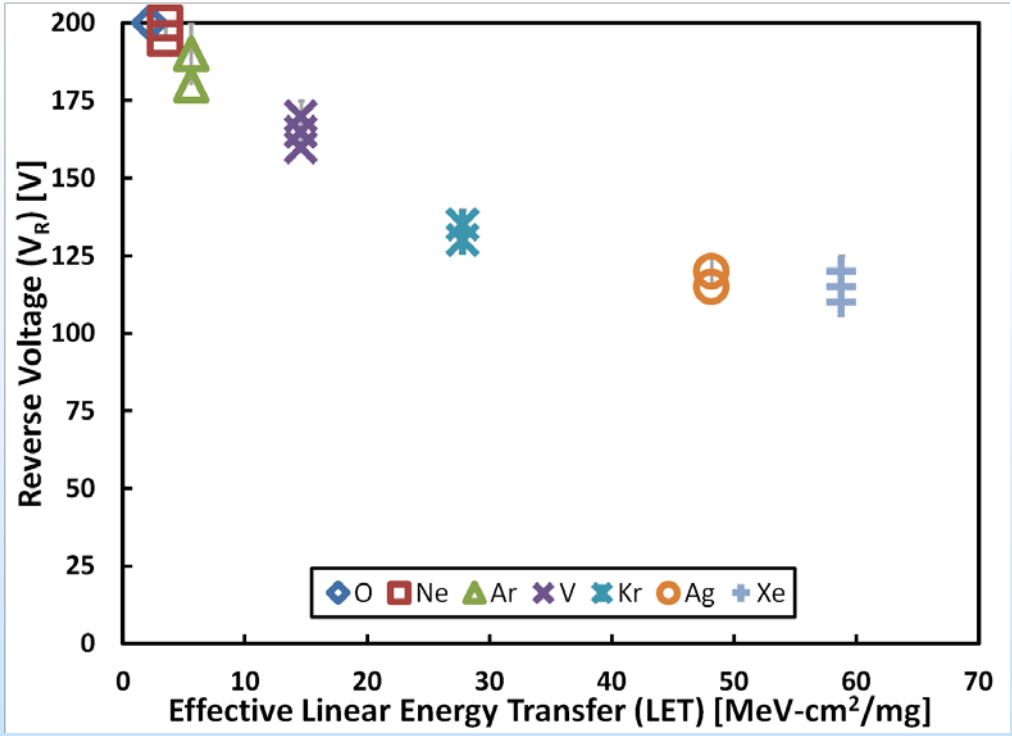
Test Facilities

Facility	Ion	Energy (MeV)	LET at Normal Incidence (MeV-cm^2/mg)	Range in Si (µm)	Parts Tested	Angles (°)
TAMU	Ar	944	5.60	193	MBR20200CT	0
	Kr	1032	27.80	170	MBR20200CT	0
	Xe	1512	51.5	120	STPS20100	0
	Ta	2076	77.3	119	STPS20100	0
LBNL	O	183	2.19	226	MBR20200CT	0
	Ne	216	3.49	175	MBR20200CT	0
	V	508	14.59	113	MBR20200CT	0
	Ag	10	48.15	90	MBR20200CT	0, 10, 30
	Xe	1232	58.78	90	MBR20200C SD125SB45A	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 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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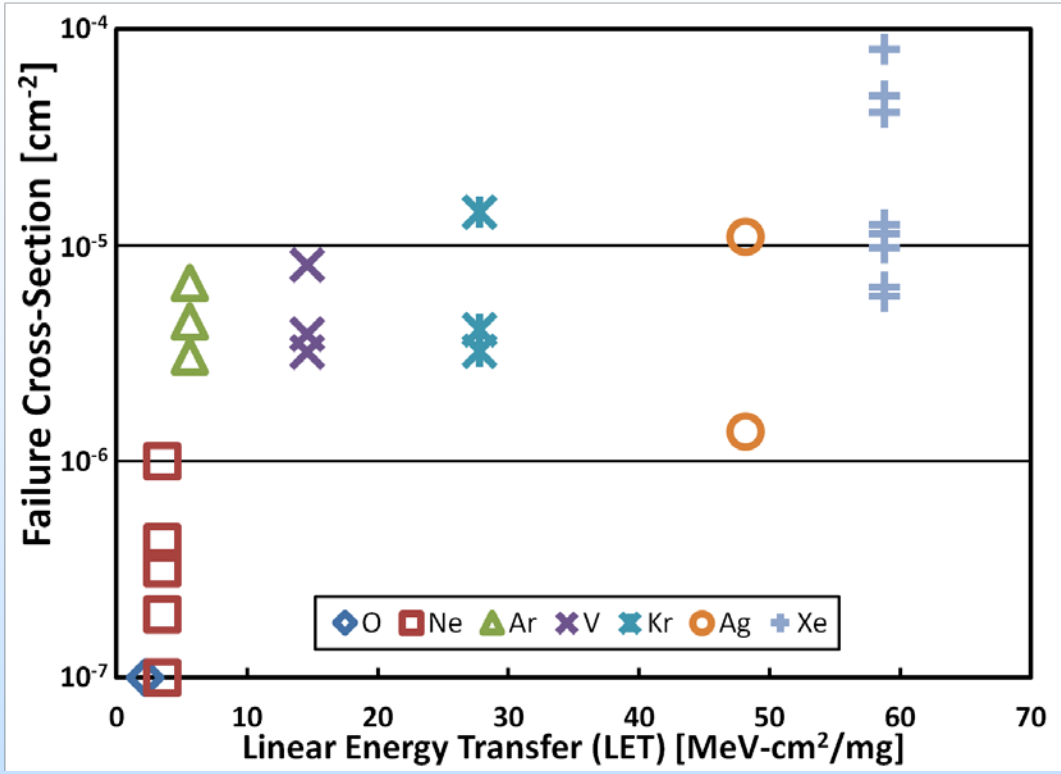
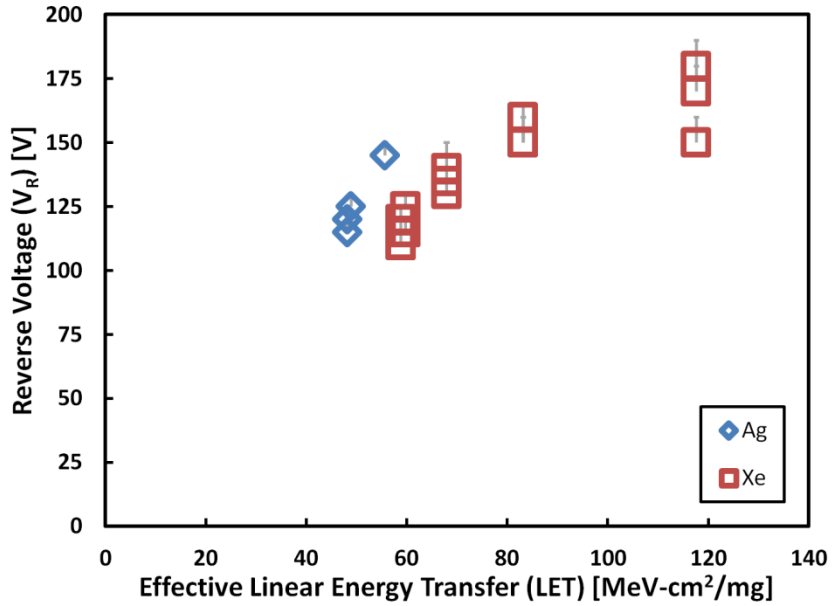
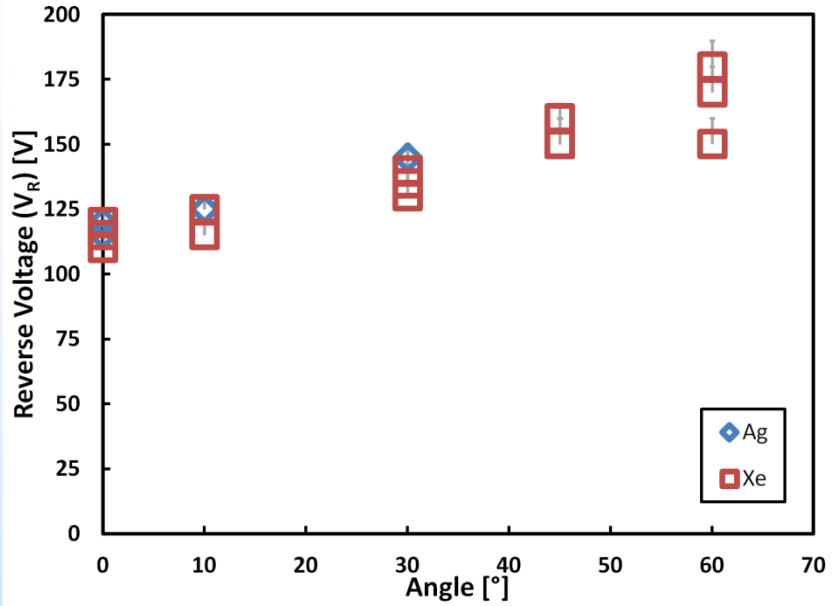
Test Results
ON Semiconductor MBR20200CT



- 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 = 2.19 MeV-cm^2/mg)
  - Failures were observed at 195 V and 200 V with 216 MeV Ne (LET = 3.49 MeV-cm^2/mg)

Test Results
ON Semiconductor MBR20200CT

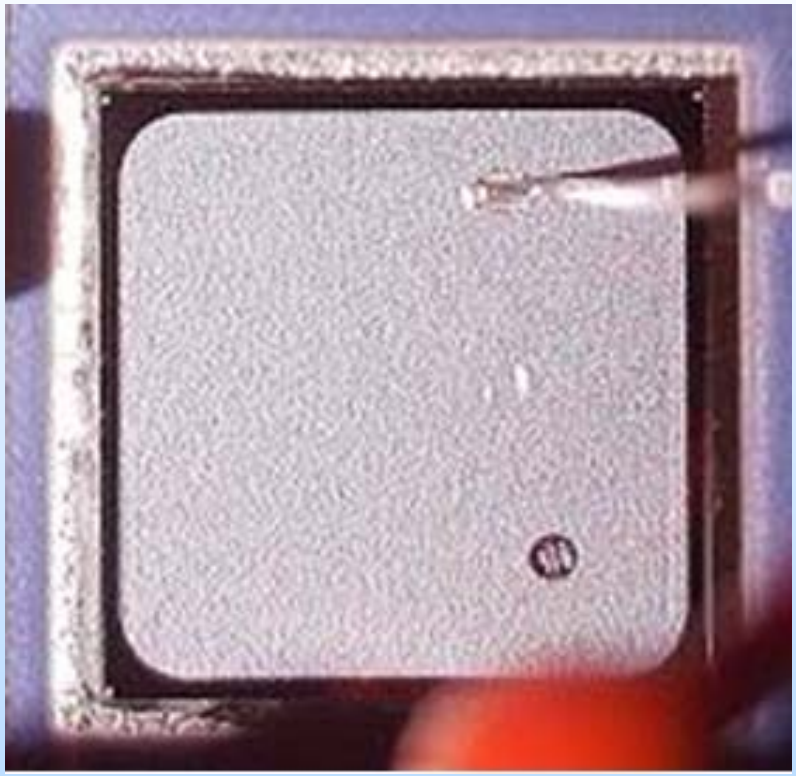




- Last passing voltage does not improve rapidly with increasing angle of incidence
- Data up to and including 45° points follow the cosine law
  - 60° points make trend appear linear

Test Results
Sensitron SD125SB45A

- Schottky diodes were irradiated with 1232 MeV Xe (LET = 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
  - Diode could not be failed independently of the converter



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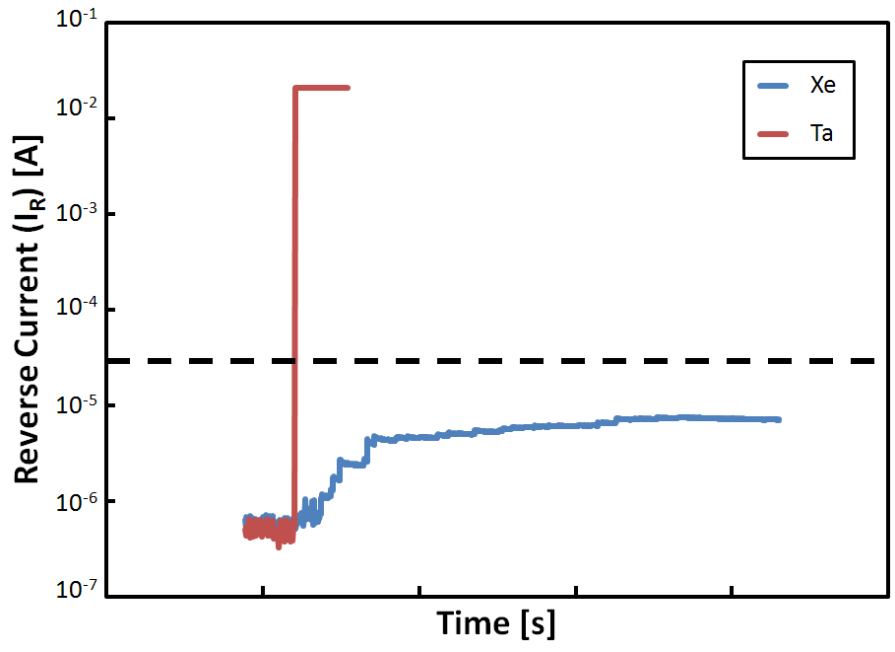
Test Results
STMicro STPS20100

- 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



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 is currently done with power MOSFETs

Path Forward

- Continue investigating Schottky diodes
  - Currently have two more types of STMicro Schottkys, five types of IR/Vishay Schottkys, and three Infineon
  - Looking for more!
- Answer open questions
  - How widespread is this problem?
  - Is there a minimum rated voltage threshold?
- More beam time scheduled at TAMU June 13-16 and LBNL June 29-July 2
- Current work will also be presented at the 2013 NSREC in San Francisco, CA