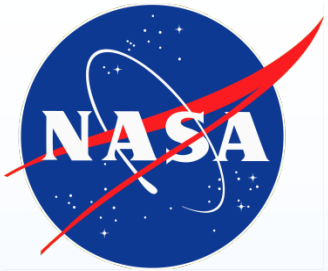

NEPP Electronic Technology Workshop
June 11-13, 2012

Observed Diode Failures in DC-DC Converters

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To be presented by Robert Gigliuto at the NASA Electronic Parts and Packaging Program (NEPP) Electronics Technology Workshop (ETW), NASA Goddard Space Flight Center in Greenbelt, MD, June 11-13, 2012 and published on nepp.nasa.gov.

History

- **During flight program testing, three tests involving DC-DC Converters have exhibited catastrophic failures from heavy ions**
  - **IR M3G2804R513R5T (customized triple output DC-DC converter, Engineering Test Unit)**
    - **Facility: Texas A&M University Cyclotron (TAMU), Test Date: September 11, 2011**
    - **Two devices failed due to destructive event in output diode**
      - **Ion: Au (LET=88.1 MeV·cm2/mg), Vin=45 V, Load = max conditions (75%/25%/25%)**
      - **Ion: Xe (LET=54.4 MeV·cm2/mg), Vin=45 V, Load = min conditions (10%/10%/10%)**
  - **IR M3G280515T (triple output DC-DC converter)**
    - **Facility: TAMU, Test Date: March 10, 2012**
    - **Three devices failed due to destructive event in output diode**
      - **Ion: Xe (LET=51.5 MeV·cm2/mg), Vin=36 V, Load = max conditions (80%/25%/25%)**
      - **Ion: Au (LET=85.4 MeV·cm2/mg), Vin=36 V, Load = max conditions (80%/25%/25%)**
      - **Ion: Au (LET=85.4 MeV·cm2/mg), Vin=28 V, Load = max conditions (80%/25%/25%)**
  - **Crane MTR28515TF/883 (triple output DC-DC converter)**
    - **Facility: TAMU, Test Date: October 12, 2011**
    - **One device failed due to destructive event in 5V output diode**
      - **Ion: Ta (LET=77.3 MeV-cm^2/mg), Vin=35 V, Load = intermediate conditions (50%/50%/10%)**

DUT Exposure Zones for M3G280515T

- **Due to beam size limitations, the DUT is shot in multiple locations to cover all potential semiconductors**

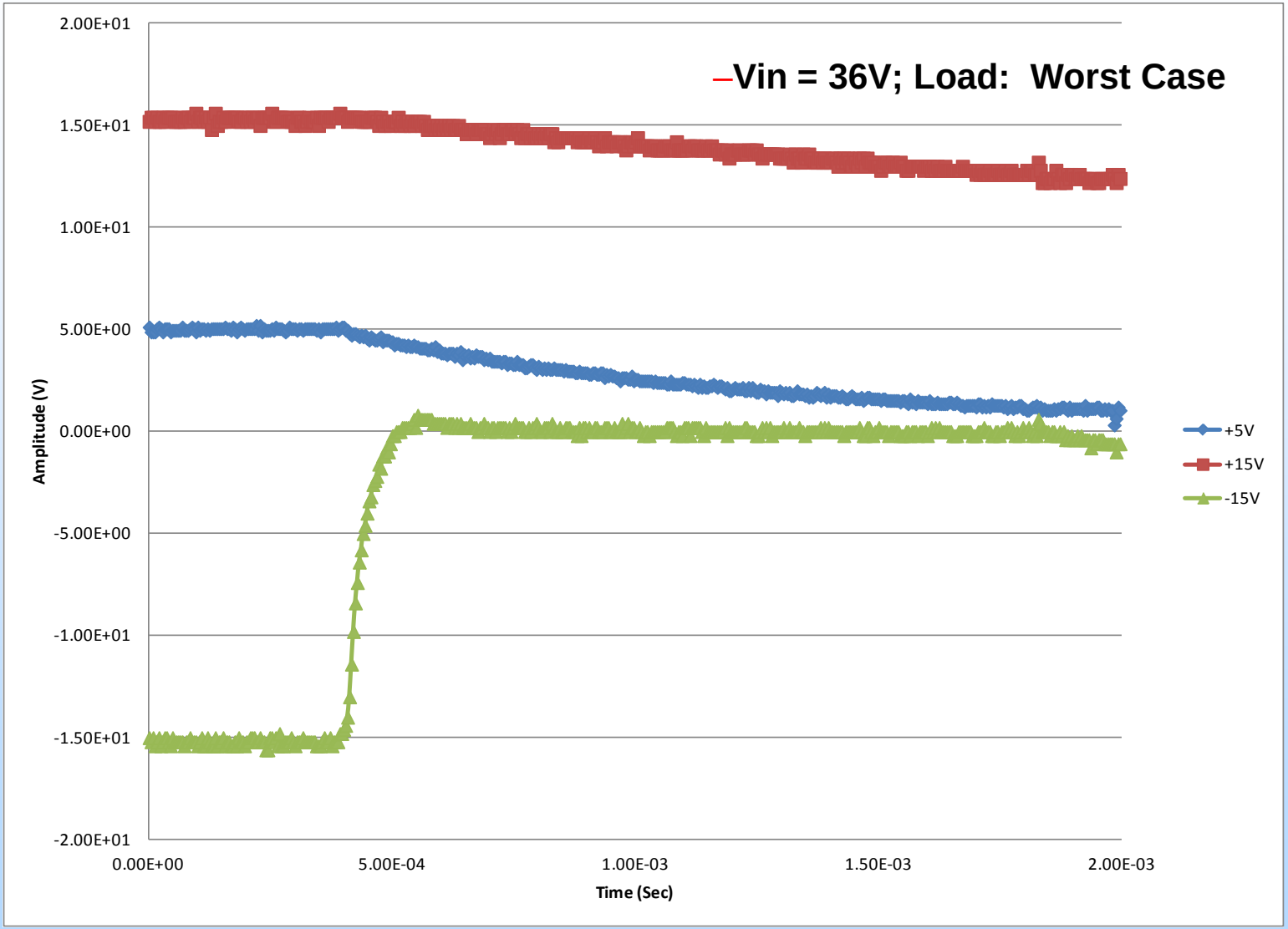
Test Summary
Texas A&M University: 10 March 2012

Ion	LET [MeV cm^2/mg]	DUTs Tested	Bias Voltage	Load	Exposure Zone	Fluence	SETs Observed	Destructive Events	Comments
Ag	42.2	1003005	36 V	WC	1, 2, 3, 4, 5	1.00E+07	none	none	
		1003004	36 V	WC	1, 2, 3, 4, 5	1.00E+07	none	none	
		1045035	36 V	WC	1, 2, 3, 4, 5	1.00E+07	none	none	
Xe	51.5	1045035	36 V	WC	1, 2, 3, 4, 5	1.00E+07	none	none	
		1003004	36 V	WC	1, 2, 3, 4, 5	1.00E+07	none	none	
		1045033	36 V	WC	1, 2, 3	1.00E+07	none	none	
					4	6.28E+06	none	**YES**	+15V output failed device unrecoverable after POR
		1003005	28 V	WC	4	1.00E+07	none	none	
			30 V	WC	4	1.00E+07	none	none	
			32 V	WC	4	1.00E+07	none	none	
			34 V	WC	4	1.00E+07	none	none	
			36 V	WC	4	1.00E+07	none	none	
			36 V	WC	1, 2, 3, 5	1.00E+07	none	none	
Au	85.4	1003005	36 V	WC	1, 2, 3, 5	2.00E+06	none	none	
			36 V	WC	4	3.86E+05	none	**YES**	-15V output failed device unrecoverable after POR
		1045035	36 V	WC	1, 2, 3, 5	1.00E+07	none	none	
			28 V	WC	4	1.46E+05	none	**YES**	-15V output failed device unrecoverable after POR

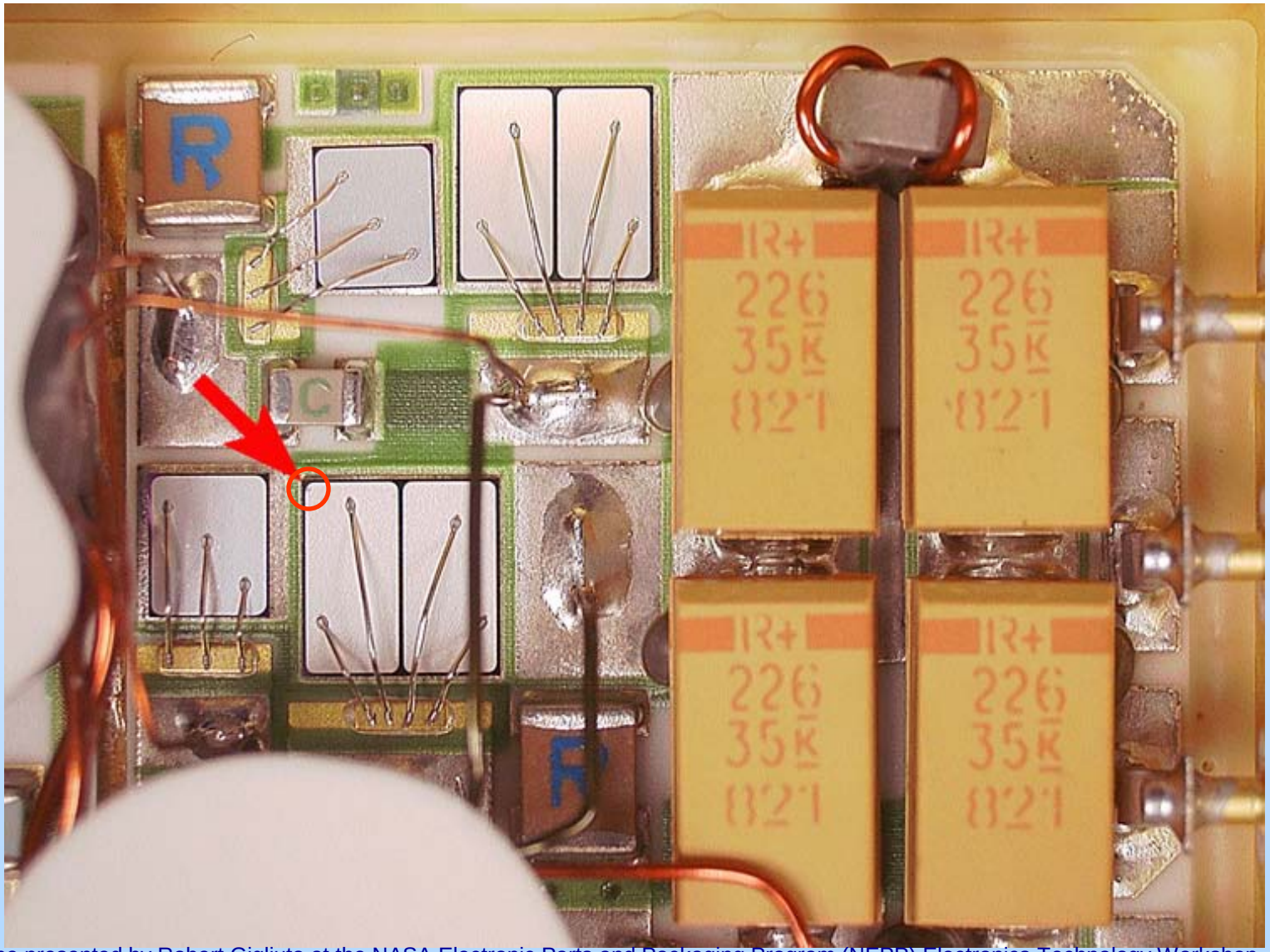
Total Ionizing Dose [rads(Si)] by DUT and Zone

DUT S/N	1	2	3	4	5	D/C
1003005	1.78E+04	1.78E+04	1.77E+04	4.86E+04	1.78E+04	0943
1003004	2.33E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	0943
1045035	2.87E+04	2.87E+04	2.87E+04	1.52E+04	2.87E+04	1036
1045033	8.26E+03	8.26E+03	8.26E+03	5.18E+03	0.00E+00	1036

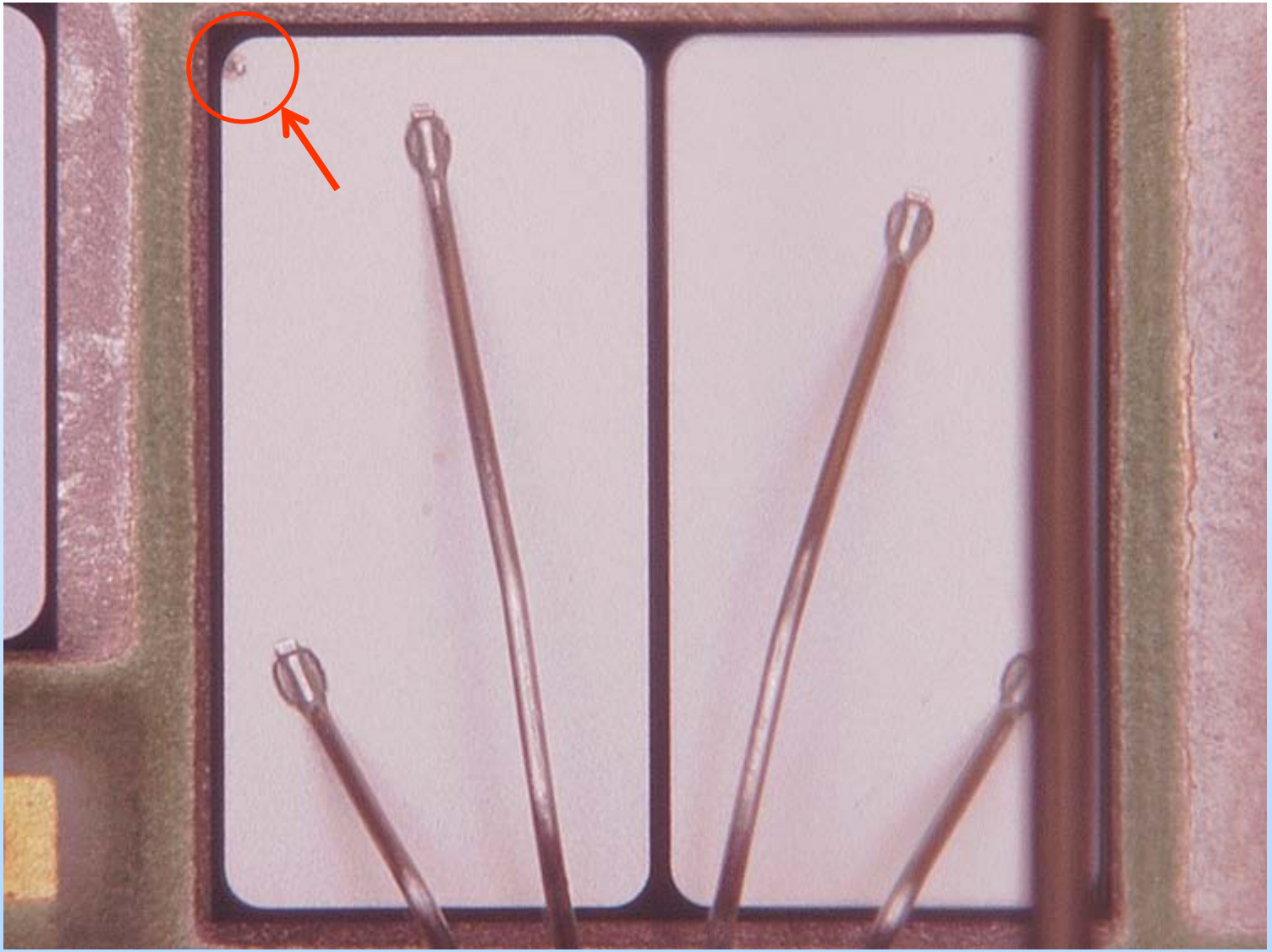
M3G280515T Destructive Event
S/N 1003005, Shot 83; Ion: Au; Location: Zone 4



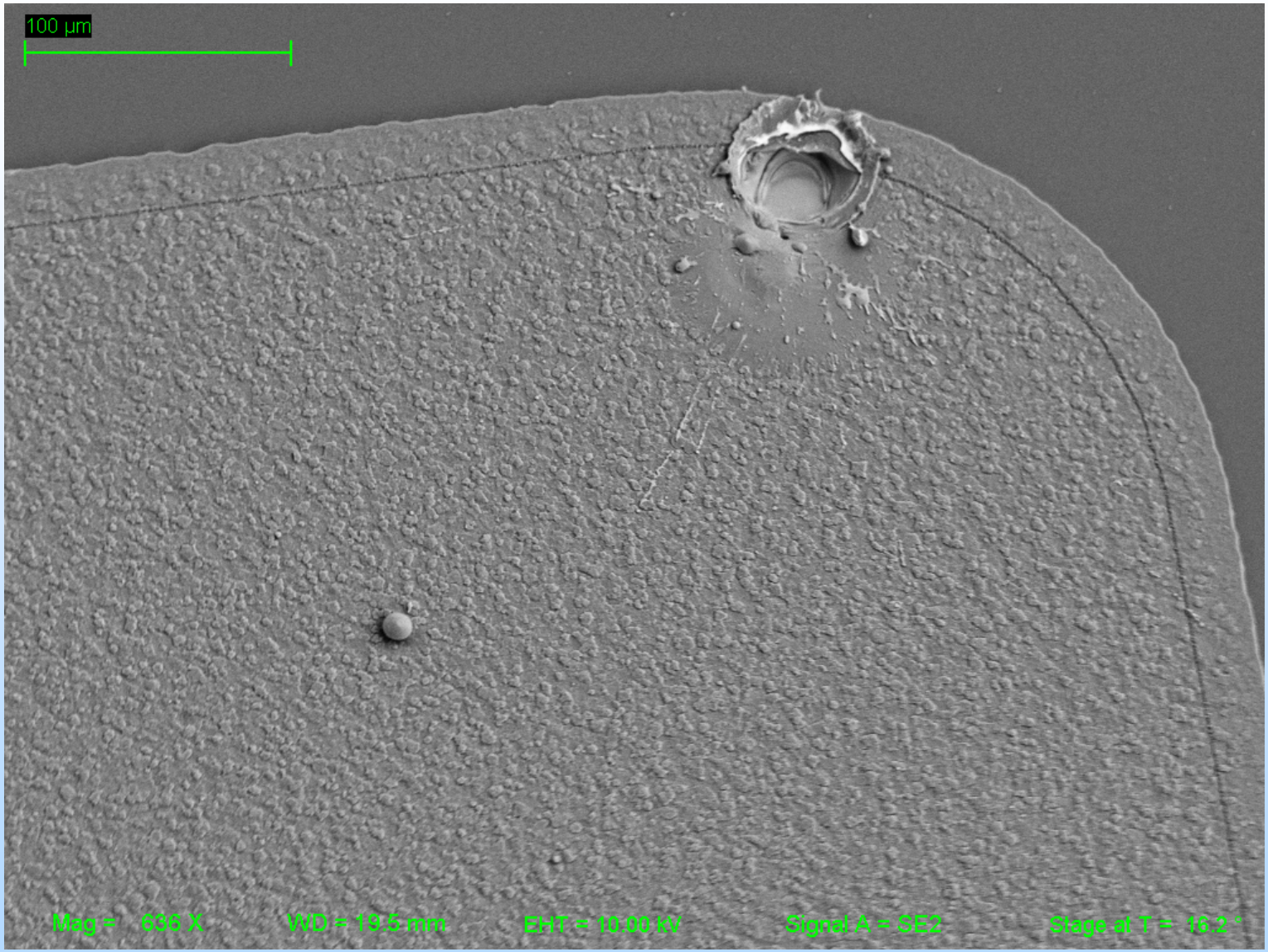
M3G280515T S/N 1003005
On Semi; MBRC20200 Schottky Diode (Au; Vin=36V)



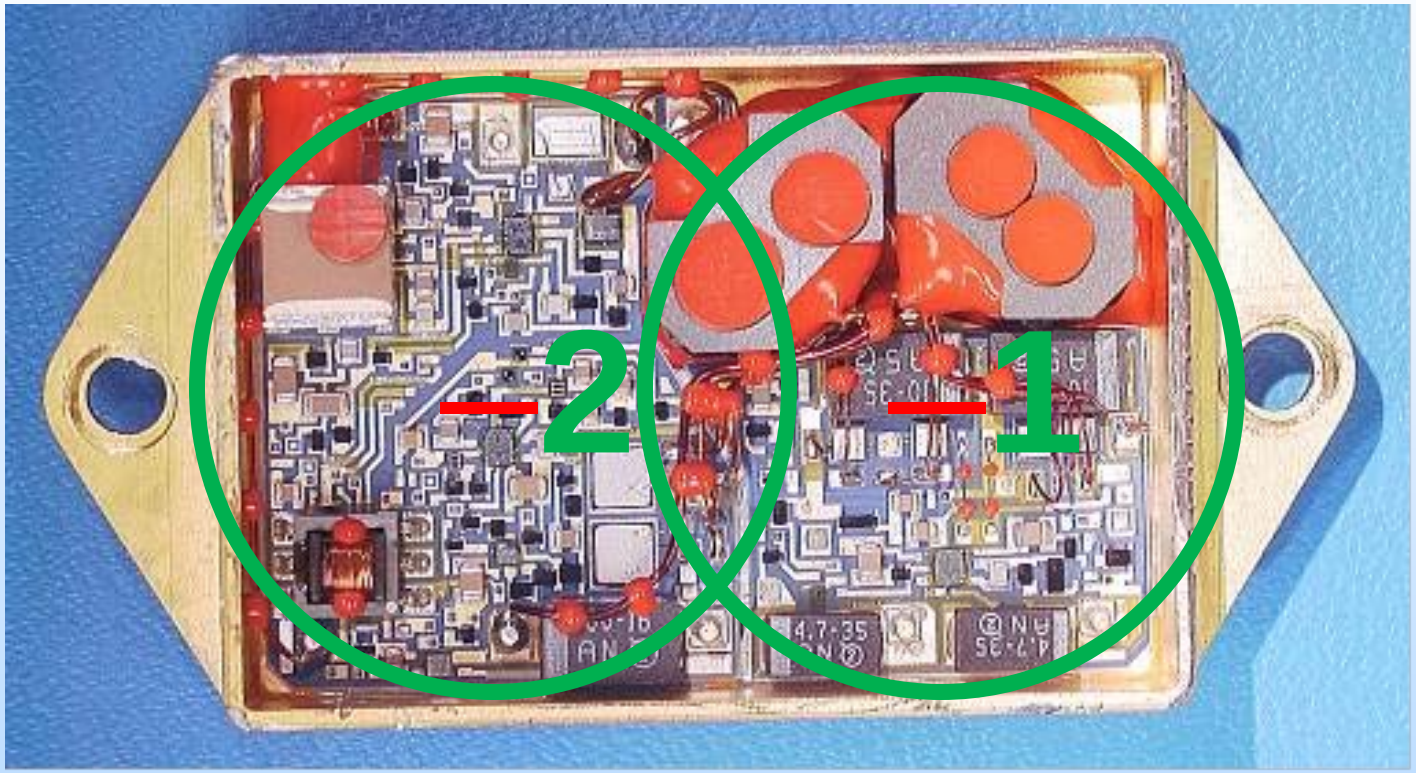
M3G280515T S/N 1003005
On Semi; MBRC20200 Schottky Diode (Au; Vin=36V)



M3G280515T S/N 1003005
On Semi; MBRC20200 Schottky Diode (Au; Vin=36V)



DUT Exposure Zones for MTR28515T



- **Due to beam size limitations, the DUT was roughly divided in half resulting in two exposure locations**

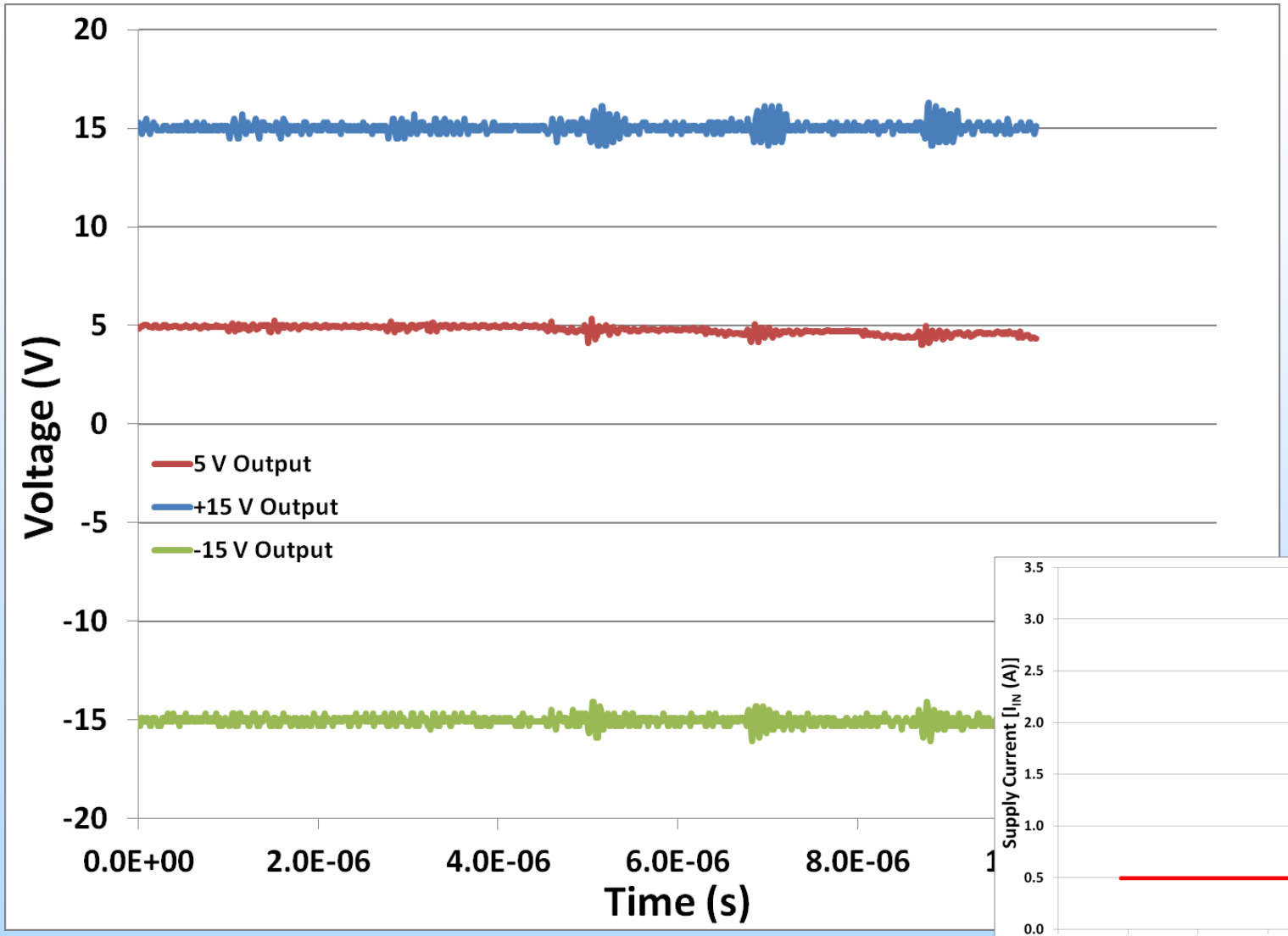
MTR28515T Test Summary

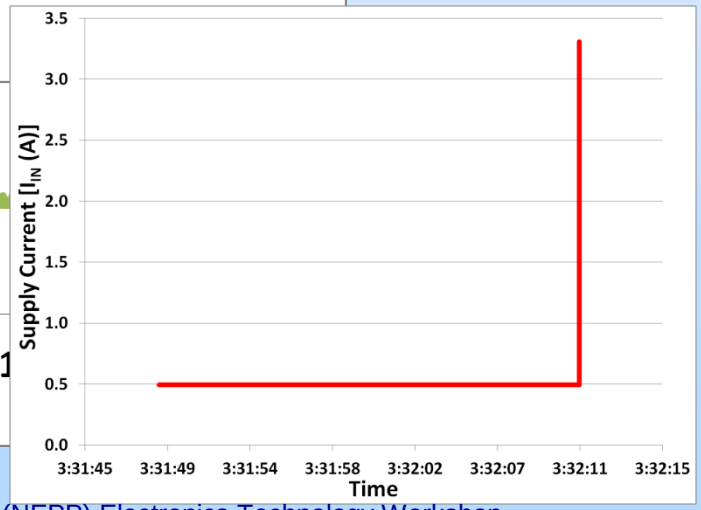
Texas A&M University: 12 October 2011

Ion	LET [MeV-cm^2/mg]	DUTs Tested	Bias Voltage	Load	Exposure Zone	Fluence	SETs Observed	Destructive Events	Comments
Ag	42.2	2	28 V	10%	1, 2	1.00E+07	none	none	
		2	28 V	50%	1, 2	1.00E+07	none	none	
		2	28 V	85%	1, 2	1.00E+07	Yes (0, 7)	none	
		2	35V	10%	1, 2	1.00E+07	none	none	
		2	35V	50%	1, 2	1.00E+07	none	none	
		2	35 V	85%	1, 2	1.00E+07	Yes (6, 55)	none	
		1	28 V	85%	1, 2	1.00E+07	Yes (0, 6)	none	
		1	35 V	85%	1, 2	1.00E+07	Yes (0, 28)	none	
Xe	51.5	3	28 V	10%	2	1.00E+07	none	none	
		3	28 V	50%	2	1.00E+07	none	none	
		3	28 V	85%	2	1.00E+07	Yes (12)	none	
		3	35 V	50%	2	1.00e+07	Yes (2)	none	
		3	35 V	85%	2	1.00E+07	Yes (25)	none	Saw increase in input current, but returned to original values
		2	28 V	85%	2	1.00E+07	Yes (1)	none	
		2	35 V	50%	2	1.00E+07	none	none	
		2	35 V	85%	2	1.00E+07	Yes (40)	none	
Ta	77.3	1	28 V	10%	2	1.00E+07	none	none	
		1	28 V	50%	2	1.00E+07	none	none	
		1	28 V	85%	2	1.00E+07	Yes (6)	none	
		1	35 V	10%	2	1.00E+07	Yes (2)	none	
		1	35 V	50%	2	1.72e+06	Yes (1)	**YES**	5 V output failed; device unrecoverable after POR

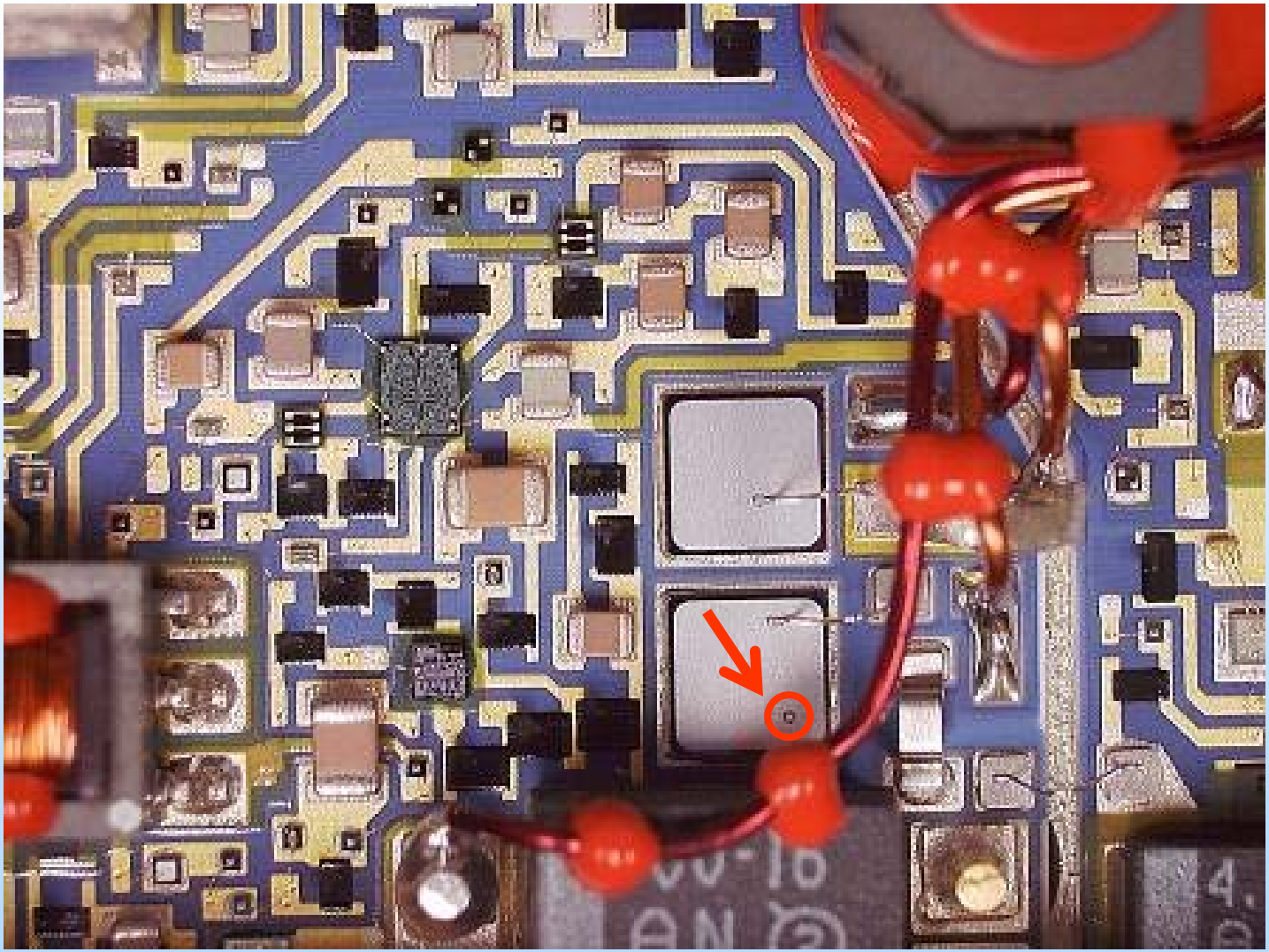
DUT S/N	Total Ionizing Dose [rad(Si)]
1	5.16e+04
2	7.64E+04
3	4.12E+04

MTR28515T Destructive Event
DUT #1, Ion: Ta, Vin = 35 V, Load: 85%, Location: 2

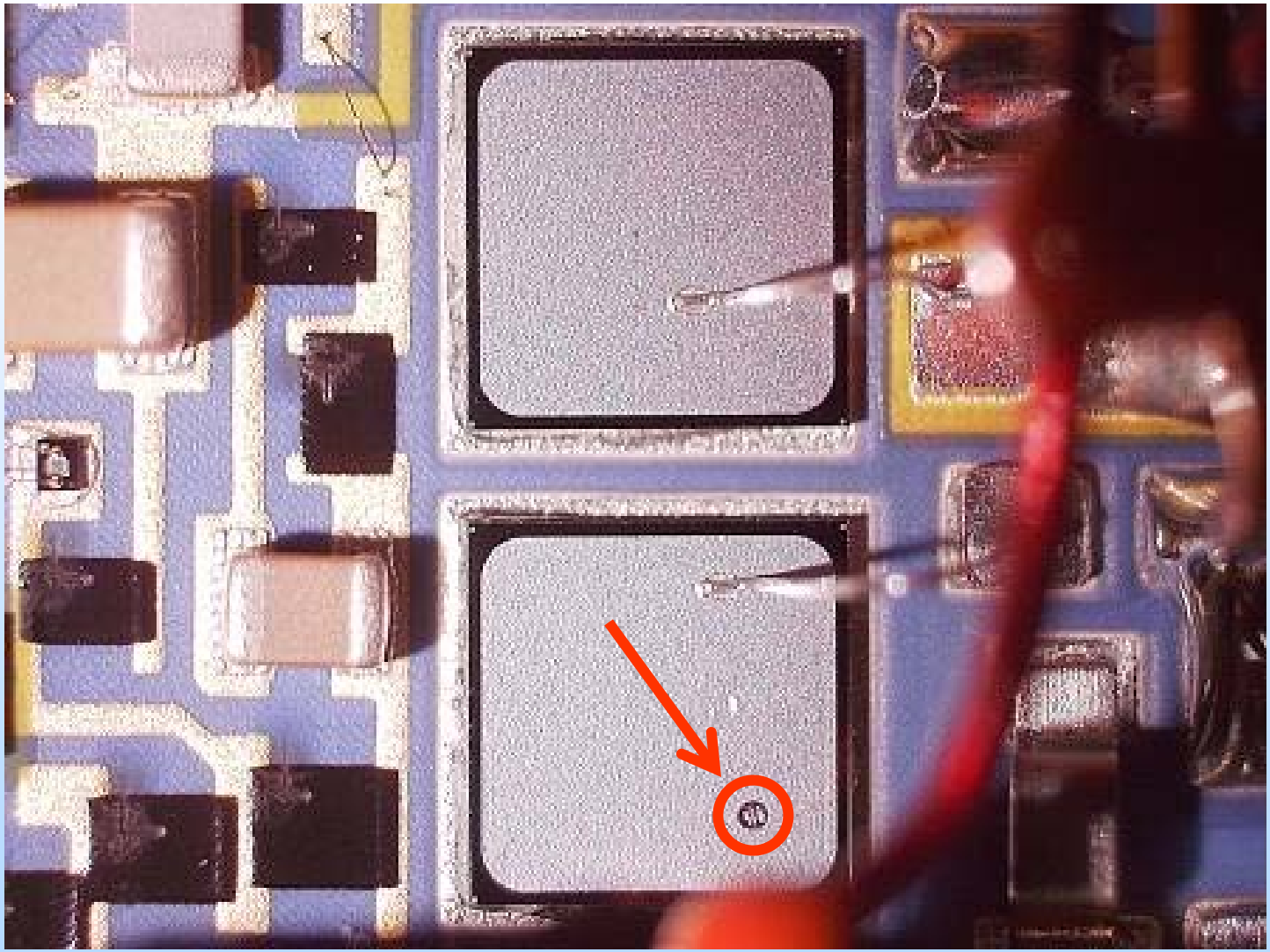




MTR28515T DUT #1
Sensitron SEN-R-668-026 Schottky Diode Failed (Ta; Vin=35V)

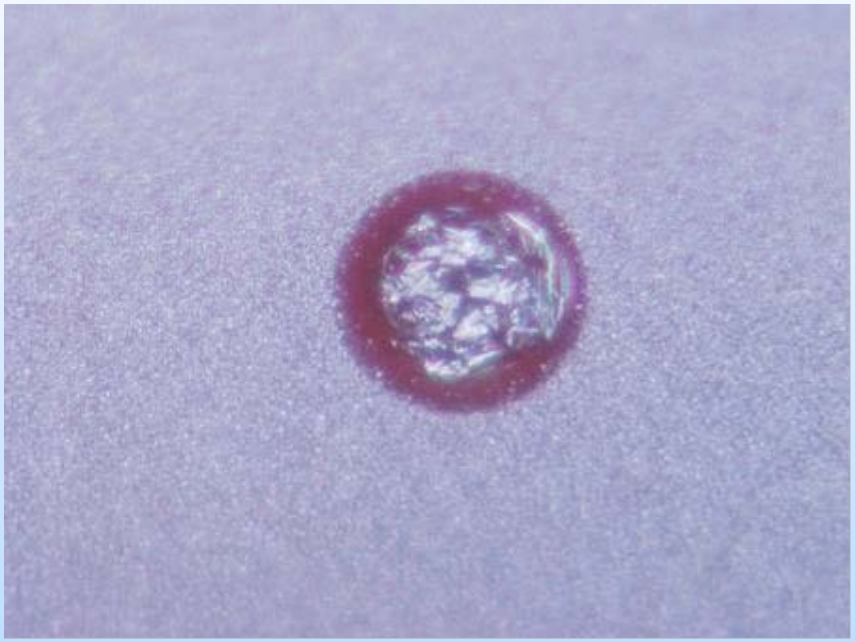


MTR28515T DUT #1
Sensitron SEN-R-668-026 Schottky Diode Failed (Ta; Vin=35V)

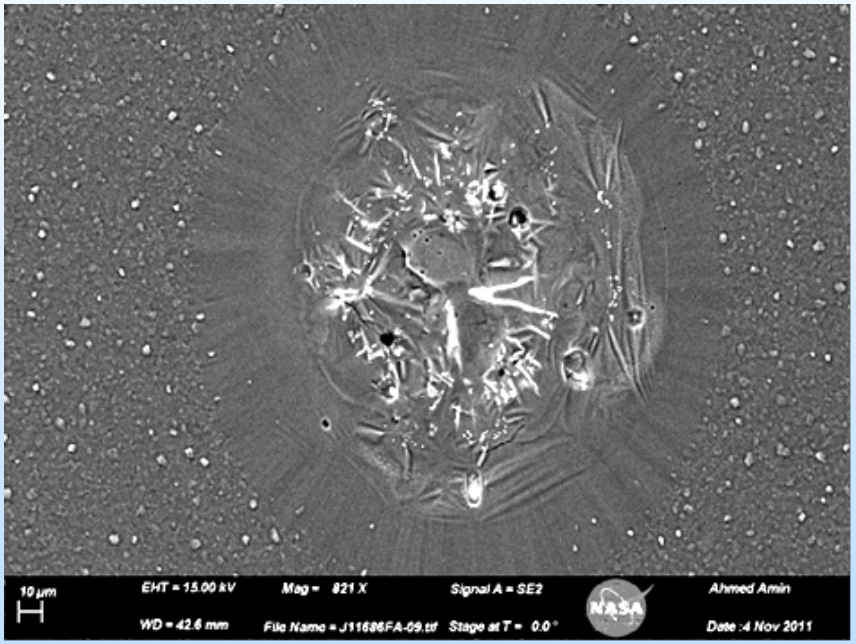


MTR28515T DUT #1
Sensitron SEN-R-668-026 Schottky Diode Failed (Ta; Vin=35V)

– Close-up Optical View of Failure



– Close-up SEM of Failure Location



Path Forward

- Test conclusions
  - The failure mechanism seems to be localized in the Schottky diodes
  - This is a new failure mechanism and shall be examined in more detail
- Upcoming tests at Lawrence Berkeley National Laboratory to verify failure mechanism (test planned for 15 May)
- NEPP test objectives are to
  - Isolate the diode and duplicate the failure without the ancillary converter circuitry
  - Determine the failure mechanism sensitivity to
    - Input voltage
    - Ion species
    - Angular exposure

Diode failure mechanism is a new single event effects phenomena under investigation