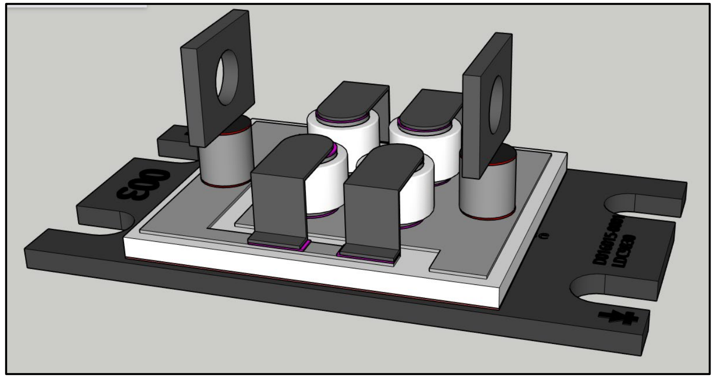


A Discussion of the Failure of a Quad Diode Module and Efforts to Assure the Flight Spares

Presented by: Jay Brusse/SSAI, Inc. work performed for NASA Goddard

With contributions from Chris Iannello/NASA KSC, Lyudmyla Ochs/NASA GSFC,
Benny Damron/Jacobs work performed for NASA MSFC, Kinn Roopwah/Boeing work performed for NASA JSC,
Henning Leidecker/NASA GSFC, Curt Tallman/Boeing work performed for NASA JSC,
Oscar Gonzalez/National Institute of Aerospace work performed for NASA LaRC, Robert Hodson/NASA LaRC

ISS BCDU FI On-Orbit Failure Investigation Team

EEE Parts Sub-Team

To Be Presented at the NEPP Electronics Technologies Workshop, June 13-16, 2022

Acronyms

Acronym	Definition
BCDU	Battery Charge Discharge Unit
BVR	Reverse Breakdown Voltage
CT X-ray	Computed Tomography X-ray
DPA	Destructive Physical Analysis
EDS	Energy Dispersive X-ray Spectroscopy
EEE	Electronic, Electromechanical, Electromagnetic
FA	Failure Analysis
FI	Fault Isolator
HTRB	High Temperature Reverse Bias
ISS	International Space Station
LDC	Lot Date Code
NASA	National Aeronautics and Space Administration
NEPP	NASA Electronic Parts & Packaging
NESC	NASA Engineering and Safety Center
PDA	Percent Defective Allowed
Qual	Qualification
R&R	Read and Record
S/N	Serial Number
SEM	Scanning Electron Microscope
SSAI	Science Systems and Applications Incorporated
T-shock	Thermal Shock

A Brief Background For Today's Talk

- In 2019 the **International Space Station (ISS) Experienced an On Orbit Failure** involving the Fault Isolator (FI) circuit in 1 of its 28 Battery Charge Discharge Units (BCDUs)
- Telemetry pointed to a **short circuit failure of a Power Rectifier Quad Diode Module** in the FI of BCDU # 4A3
  - This diode module **(lot date code (LDC) 9830)** had been operating (in steady state reverse bias) for ~13 years at time of its failure
  - Diode module normally operates with steady state reverse bias of ~120V (*rated to 500V minimum*) until an "event" occurs that activates the FI circuit
  - FI activation transitions the diode from reverse bias to forward bias in order to isolate the fault load until the event is over
  - When the event passes, the FI is de-activated and the diode reverts to normal reverse bias conditions
  - This diode module failed immediately following/during the first "activation" of this particular FI circuit in flight
- Failure Investigation of Diode Module S/N 003 from LDC 9830
  - ISS astronauts removed the malfunctioning BCDU from service which was then returned to Earth for failure analysis
  - The failed quad diode module was sent to Hi-Rel Laboratories in Spokane, WA for failure analysis
  - **Hi-Rel Laboratories confirmed that 1 of the 4 individual diodes in this module had failed catastrophically via short circuit**
  - Destructive analyses identified:
    - ***Silver Dendrites*** **growing across the sloped edges of the mesa semiconductor die**
    - ***Voids between the diode's protective encapsulating ring and the die*** **that provided space within which dendrites formed**
  - 3 remaining diodes were electrically "OK", but destructive analysis on 1 other diode found minor voiding, but NO dendrites
- The **NASA Engineering & Safety Center (NESC) convened a EEE Parts Sub-Team** to investigate root cause and to assist with risk assessment for all of the flight diode modules (4 distinct production lots) and the flight spares (from a 5th lot)

NESC EEE Parts Sub-Team Activities

- Review Diode Module Materials/Construction and Failure Analysis on LDC 9830

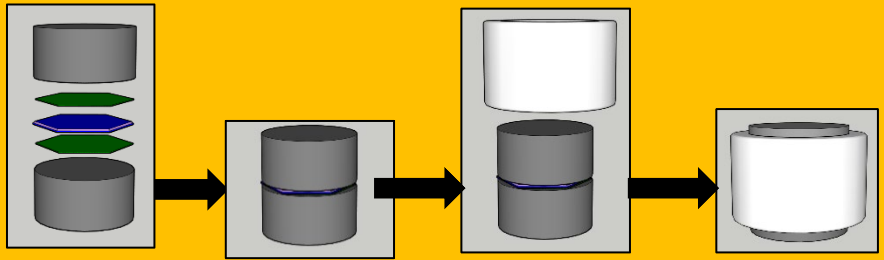
- Re-Inspect Available Diode Modules (Qual Samples, DPA Samples, Flight Spares)
  - Computed Tomography (CT) X-ray to detect “voiding” between encapsulating ring and die
  - Cross section with SEM/EDS to identify materials/construction and to inspect for voiding

- *Analyze Original Manufacturer Screening Test Data for Individual Diodes and Diode Modules*
  - *Assess each lot **parametric (in)stability***
  - *Parametric instability [especially for Reverse Breakdown Voltage (BVR)] may indicate “contamination” was present at time of production. “Contamination” is a precursor for the formation of silver dendrites*

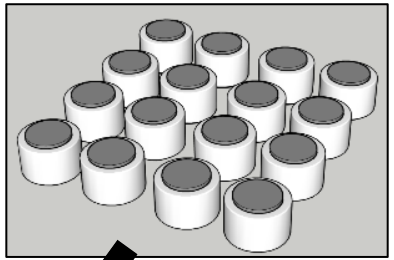
- Recommend and Perform additional inspections on Flight Spare Quad Diode Modules (LDC 0108) to add assurance prior to use in future repairs (if needed)
  - CT X-ray to detect voids (a precursor required for silver dendrite formation
  - Electrical parameter measurements

A Brief Animation to Illustrate the Individual Diode and Diode Module Construction Plus Some Insights from the Failure Analysis of Module LDC 9830 S/N 003

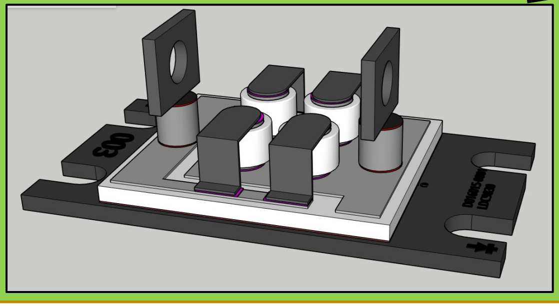
Individual Diode Build Flow



Up to Hundreds of Diodes may be produced in one lot



Diode Module



4 Diodes are used to build each Diode Module

A Theory for the Failure Mechanism of LDC 9830 is described in *"Dendritic Growth Failure of a Mesa Diode"*

P.J. Singh, et al (IBM), International Symposium on Testing and Failure Analysis (ISTFA), 1997

Abstract

The time delayed failure of a mesa diode is explained on the basis of dendritic growth on the oxide passivated diode side walls. Lead dendrites nucleated at the p$^+$ side Pb-Sn solder metallization and grew towards the n side metallization. The infinitesimal cross section area of the dendrites was not sufficient to allow them to directly affect the electrical behavior of the high voltage power diodes. However, the electric fields associated with the dendrites caused sharp band bending near the silicon-oxide interface leading to electron tunneling across the band gap at velocities high enough to cause impact ionization and ultimately the avalanche breakdown of the diode. Damage was confined to a narrow path on the diode side wall because of the limited influence of the electric field associated with the dendrite. The paper presents experimental details that led to the discovery of the dendrites. The observed failures are explained in the context of classical semiconductor physics and electrochemistry.

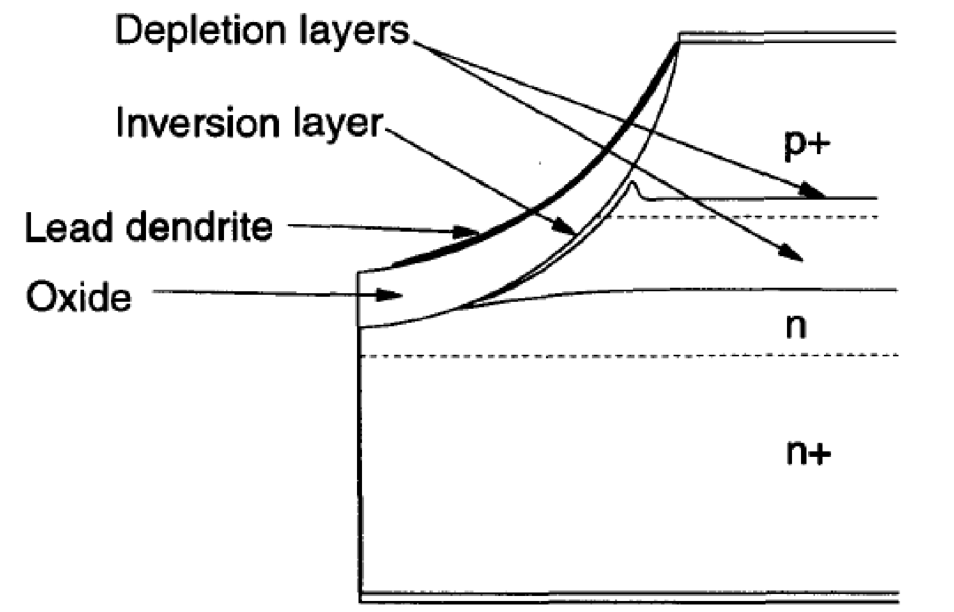


Figure 6: Contour plot of the depletion-region boundaries with a reverse bias of 350Vdc and a -350Vdc biased dendrite on the passivation oxide. Without the dendrite, the depletion region shape would be as shown in Fig. 1. Note: For illustration purposes, the inversion layer is shown much thicker than it is in reality.

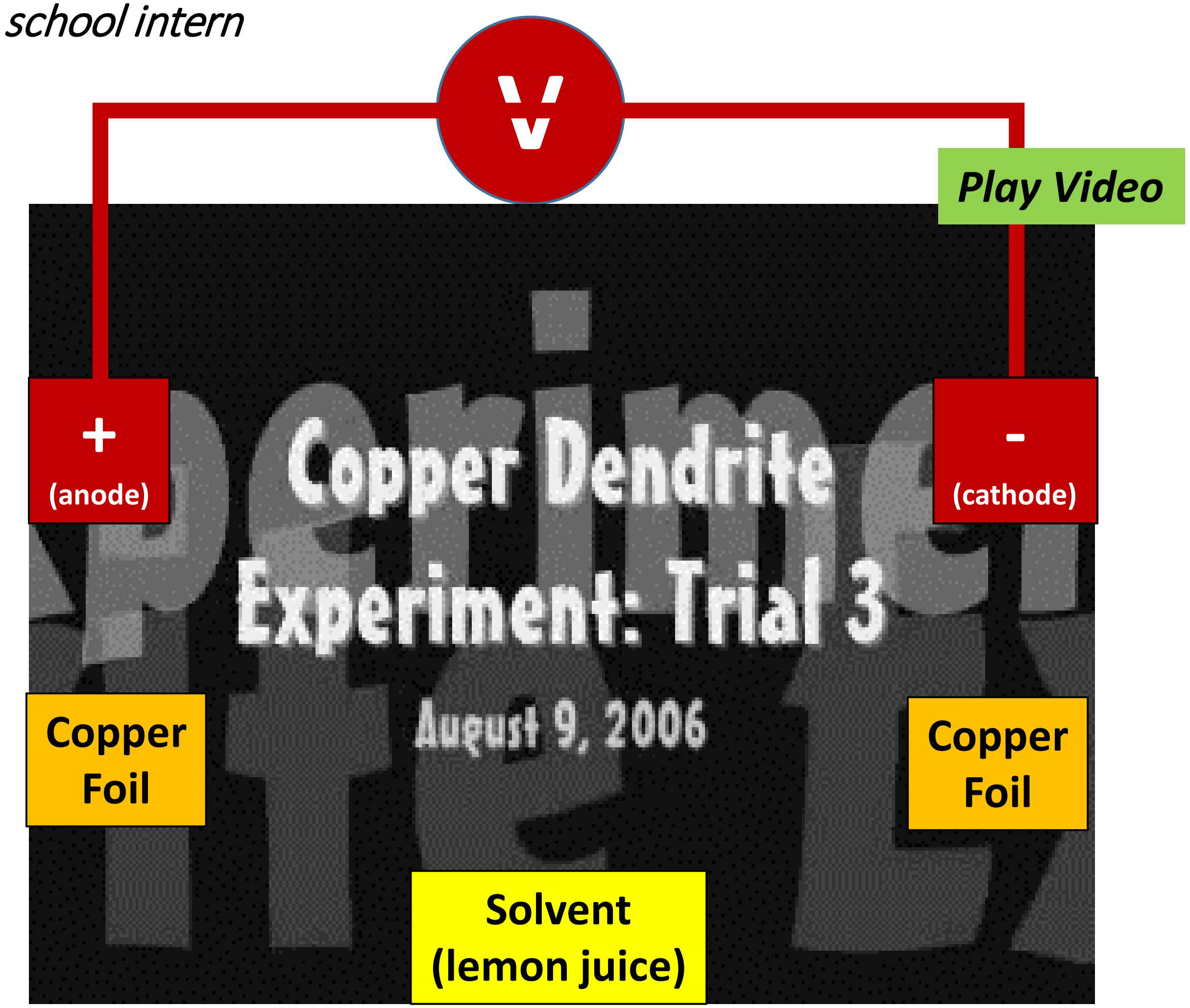
Demonstration of Metal Dendrite Formation

Courtesy of Anna Cyganowski/NASA GSFC Code 562 high school intern
https://nepp.nasa.gov/whisker/dendrite/

- Metal Dendrites form in fern-like patterns across a surface (x-y plane)
- Requires a solvent (“contaminant”) capable of dissolving the metal into a solution of positively charged metal ions
- Metal ions are redistributed through electromigration in the presence of an electric (E) field

1. ***M (solid) + 2H⁺ → M⁺ + H₂ (gas)*** — $M\ (solid) + 2H^+ \rightarrow M^+ + H_2\ (gas)$
2. $M^+ + E$ ***field*** — ***moves*** M^+ ***to the cathode***
3. $M^+ + e^-$ → ***M (solid) at the cathode***

M ***= metal;*** M^+ ***= metal ion;***
H^+ ***= solvent;*** e^- ***= electron***



Excerpts from Hi-Rel Laboratories Failure Analysis

Report FR-1912152 dated 12/17/19

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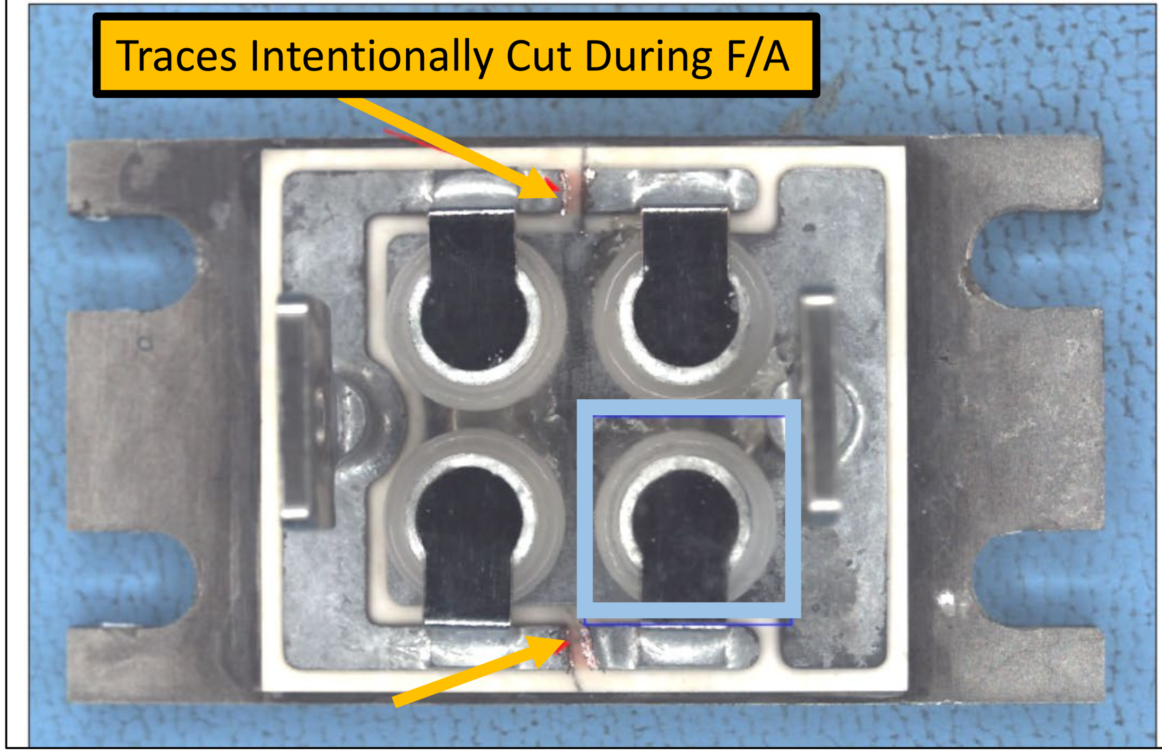
Isolation



Serial Number: Failed

Photograph of the array showing how the metal was cut to electrically isolate the failure. The blue box indicates the failed diode.

Excerpts from Hi-Rel Laboratories Failure Analysis

Report FR-1912152 dated 12/17/19

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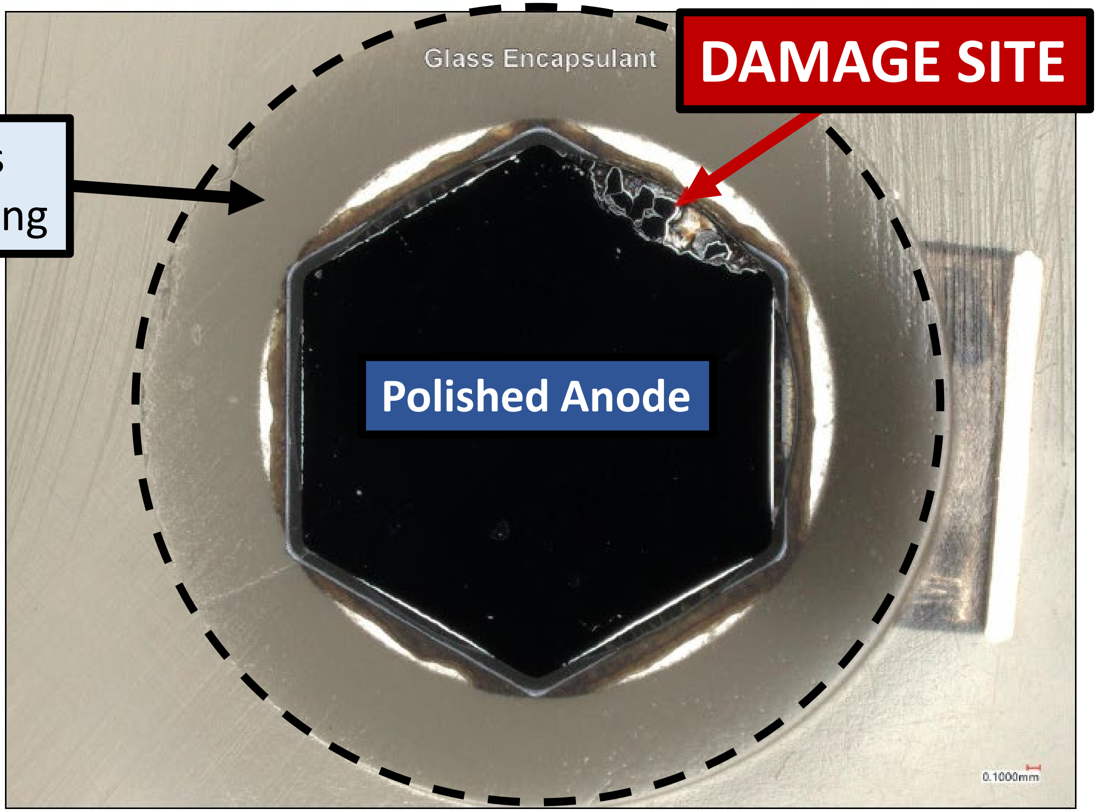
Internal Visual Inspection

Diode Cross Sectioned to Top of Die

Ceramic/Glass Encapsulating Ring



Serial Number: Failed

Overall view of the diode after planar cross section. Note the damage site.

Excerpts from Hi-Rel Laboratories Failure Analysis

Report FR-1912152 dated 12/17/19

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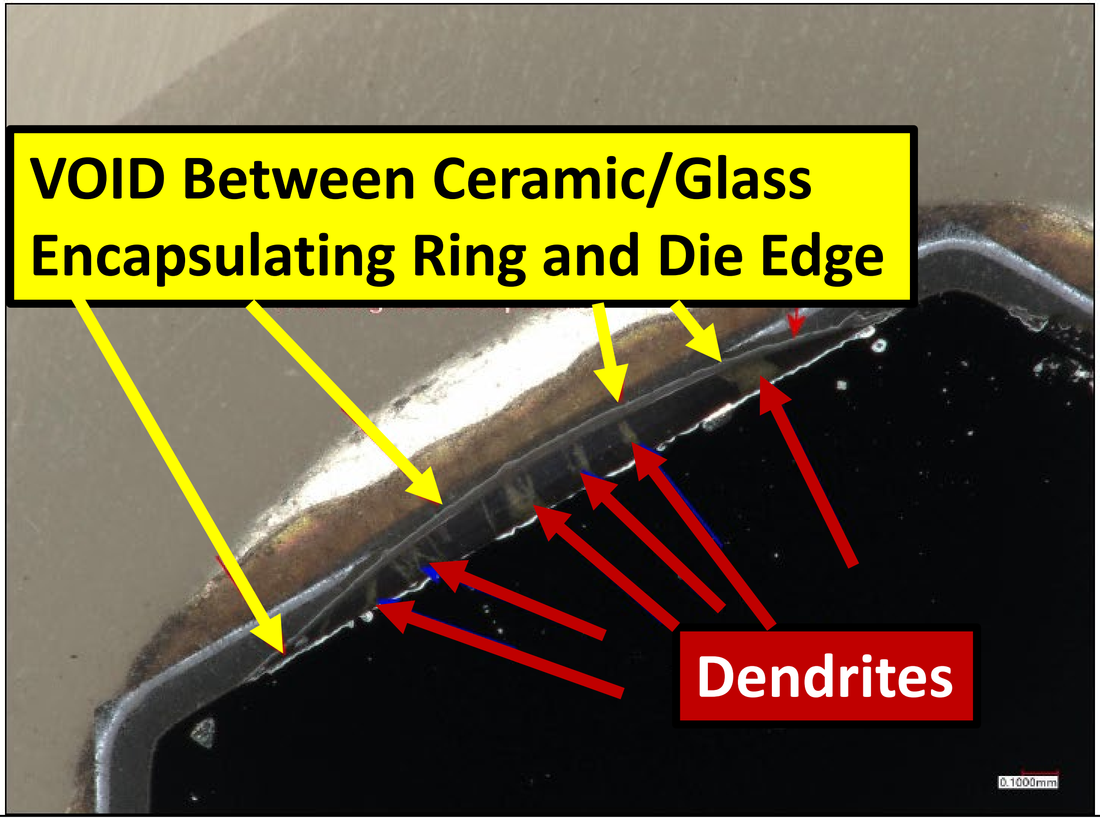
Internal Visual Inspection



Serial Number: Failed

Close up view of one edge of the die showing the void in the encapsulant and the silver dendrites.

Excerpts from Hi-Rel Laboratories Failure Analysis

Report FR-1912152 dated 12/17/19

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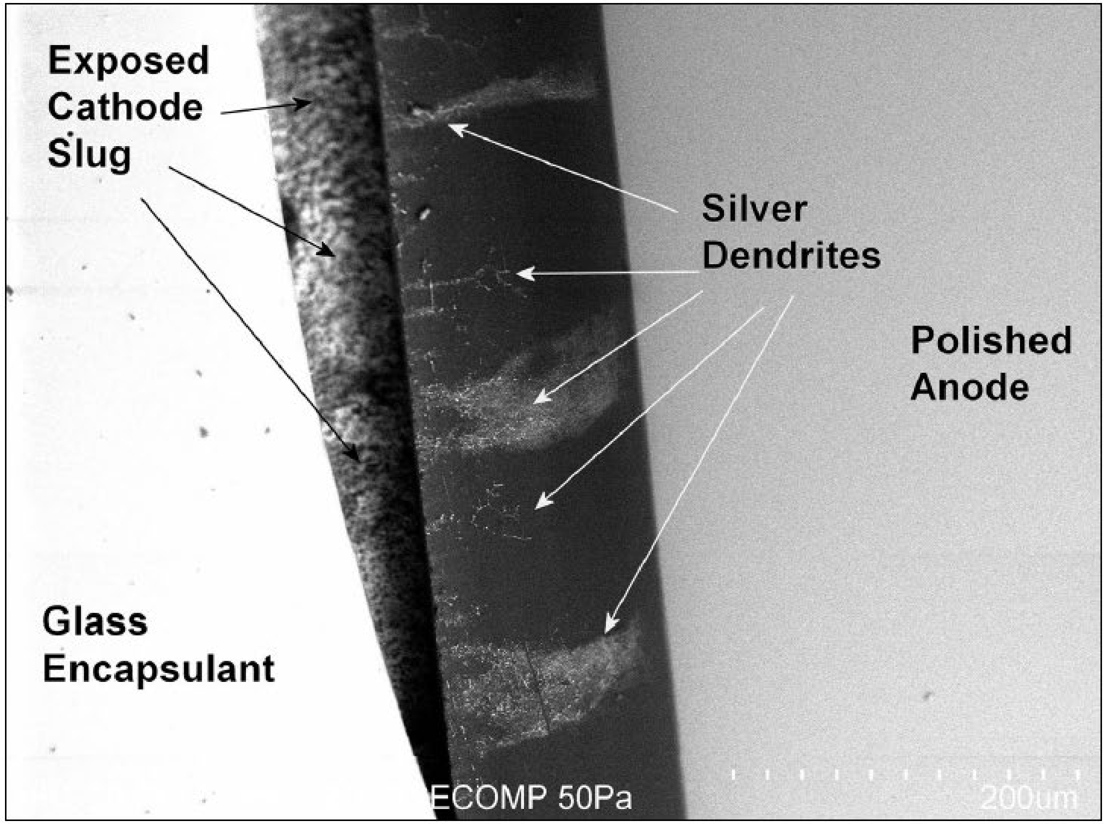
SEM/EDS Inspection



Serial Number: Failed

Close up view of one of the cavities exposing the edge of the die. Note the dendrites.

NESC Statistical Analysis of Original Diode Manufacturer Screening Test Data Packages

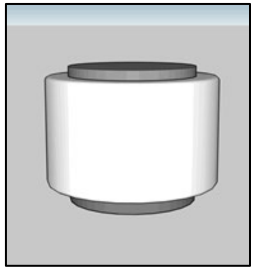
Assessing Different Lots for Parametric Instability

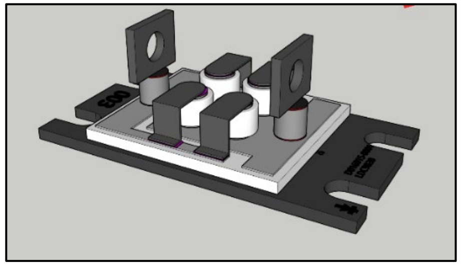
Background for the Statistical Analysis of the Diode Manufacturer’s Original Screening Data

- ISS procurement specification required the diode manufacturer to screen **individual diodes AND quad diode modules and to provide Read and Record (R&R) parametric data**
  - Modules from 5 different production LDCs were procured between 1997 and 2001:
  -
    - In-Flight Module LDCs: 9719, ***9830 (on-orbit failure),*** 9906, 0031
    - Flight Spare Module LDC: ***0108***

- NESC Analysis Provided a Comparison of the 5 distinct LDCs:
  - **Diode parametric (in)stability** as seen through the course of a High Temperature Reverse Bias (HTRB) screen
    - **Reverse Breakdown Voltage (BVR)** parameter is our focus
    - *Diodes that exhibit instability in the BVR parameter may be indicative of diodes that have contamination and/or the beginning of metal dendrite formation such as observed in the on-orbit failure from LDC 9830*

Key Screening Test for Diodes
High Temperature Reverse Bias (HTRB) Burn-In





Test Condition	HTRB for Individual Diodes	HTRB for Diode Modules
V_R	400Vdc	400Vdc
Temperature (T)	**150°C**	125°C
Time (t)	**240hrs**	48 hrs
Criteria for Acceptance	• BVR, I_R, V_F, and other parameters meet limits • **ΔBVR**, ΔI_R, ΔV_F meet limits • **Lot Percent Defective Allowed (PDA) < 5%**	• BVR, I_R, V_F, and other parameters meet limits • **ΔBVR**, ΔI_R, ΔV_F meet limits • **Lot Percent Defective Allowed (PDA) < 10%**

Purpose of High Temperature Reverse Bias (HTRB)

MIL–STD–750–1A
W/CHANGE 4

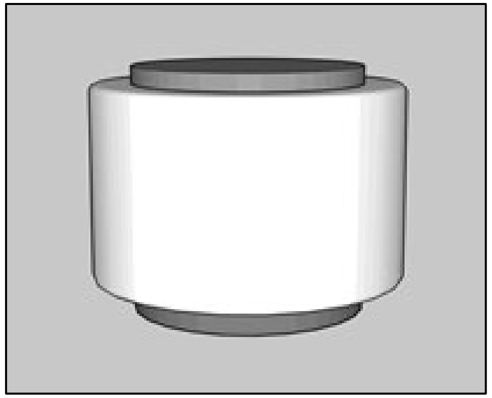
METHOD 1038.5

BURN–IN (FOR DIODES, RECTIFIERS, AND ZENERS)

1. Purpose. This test is performed to eliminate marginal semiconductor devices or those with defects resulting from manufacturing aberrations that are evidenced as time and stress dependent failures. Without the burn-in, these defective devices would be expected to result in early lifetime failures under normal use conditions. It is the intent of this test to operate the semiconductor device at specified conditions to reveal electrical failure modes that are time and stress dependent.

   a. HTRB screens for mobile ionic contaminants within the device's passivation layers. It is equally effective on most device types including diodes, rectifiers, zeners, and transient voltage suppressors.

Overall Screening Flow & Results (Pass/Fail) For Individual Diodes



LDC 9830 Individual Diode Lot is clearly the "Worst" Lot

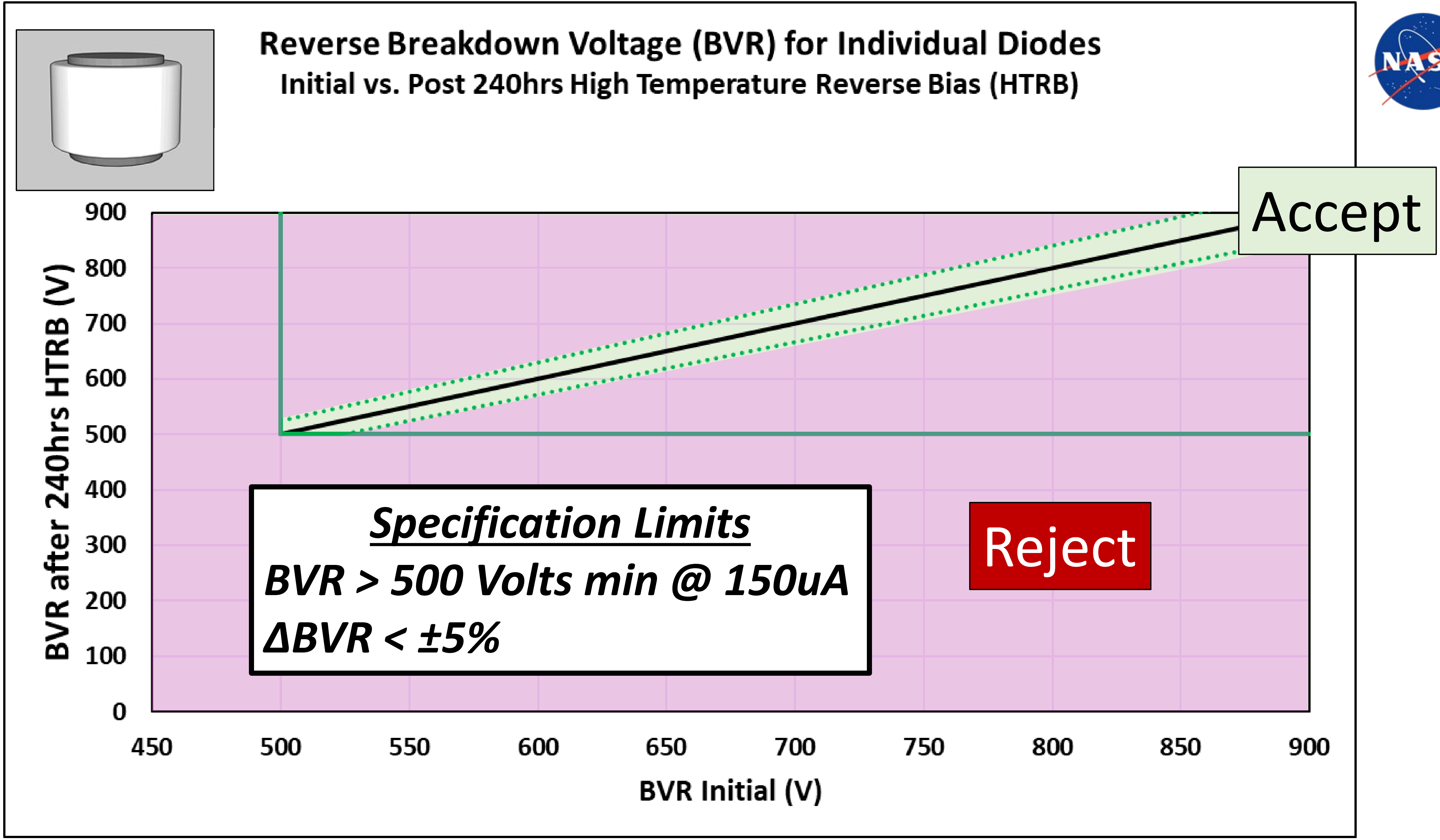
After 47% of diodes failed the 1st HTRB screen, The original manufacturer "Resubmitted" survivors to a 2nd HTRB where 1 of 53 diodes failed

Microsemi Screening Test Summary for Individual Diodes Used to Produce the ISS Power Rectifier Modules

Results below extracted from **MFR** screening test travelers provided to **ISS** as part of the original procurement data packages.

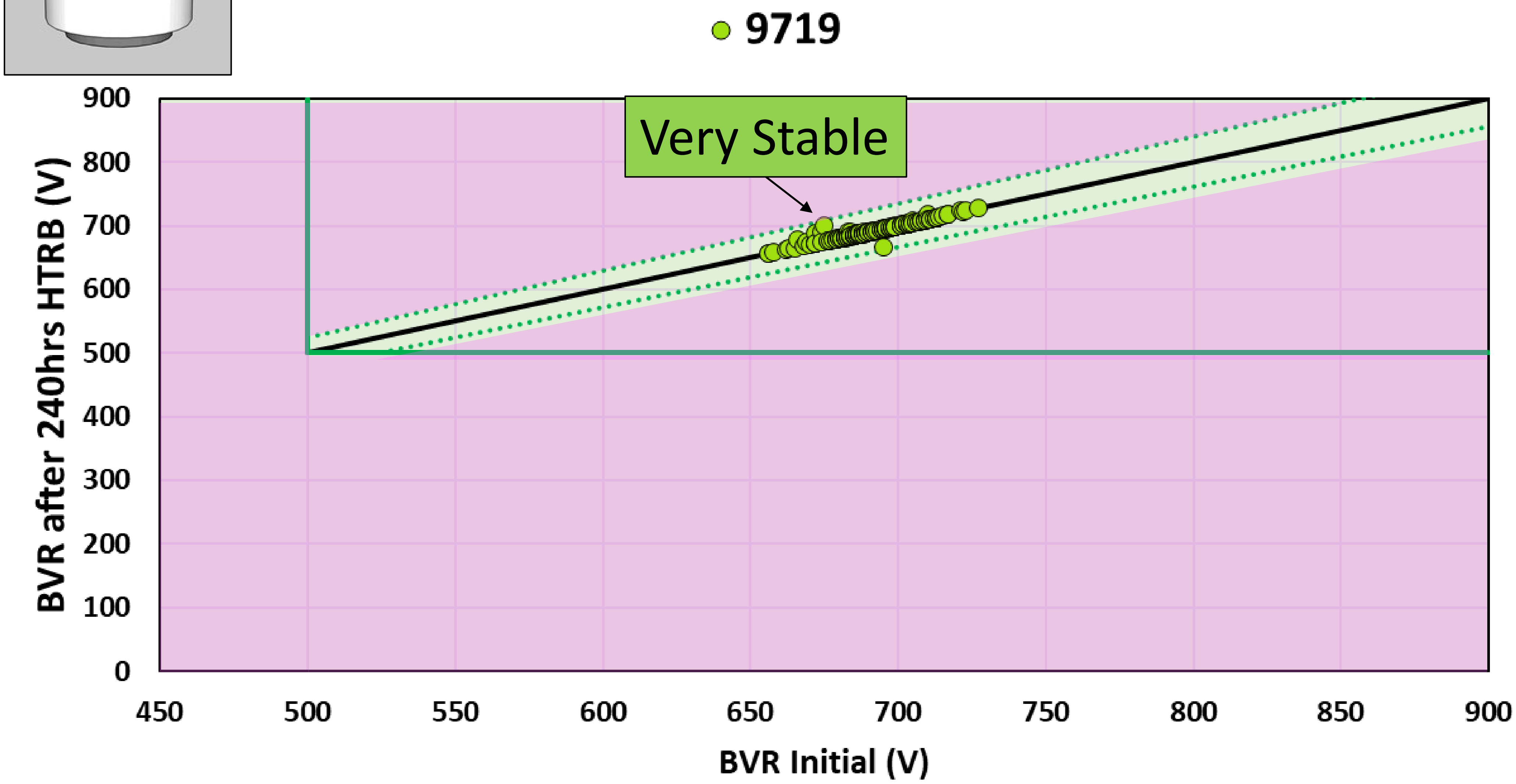
* *The same individual diode lot was used to assemble modules for BOTH LDC 0031 and 0108*

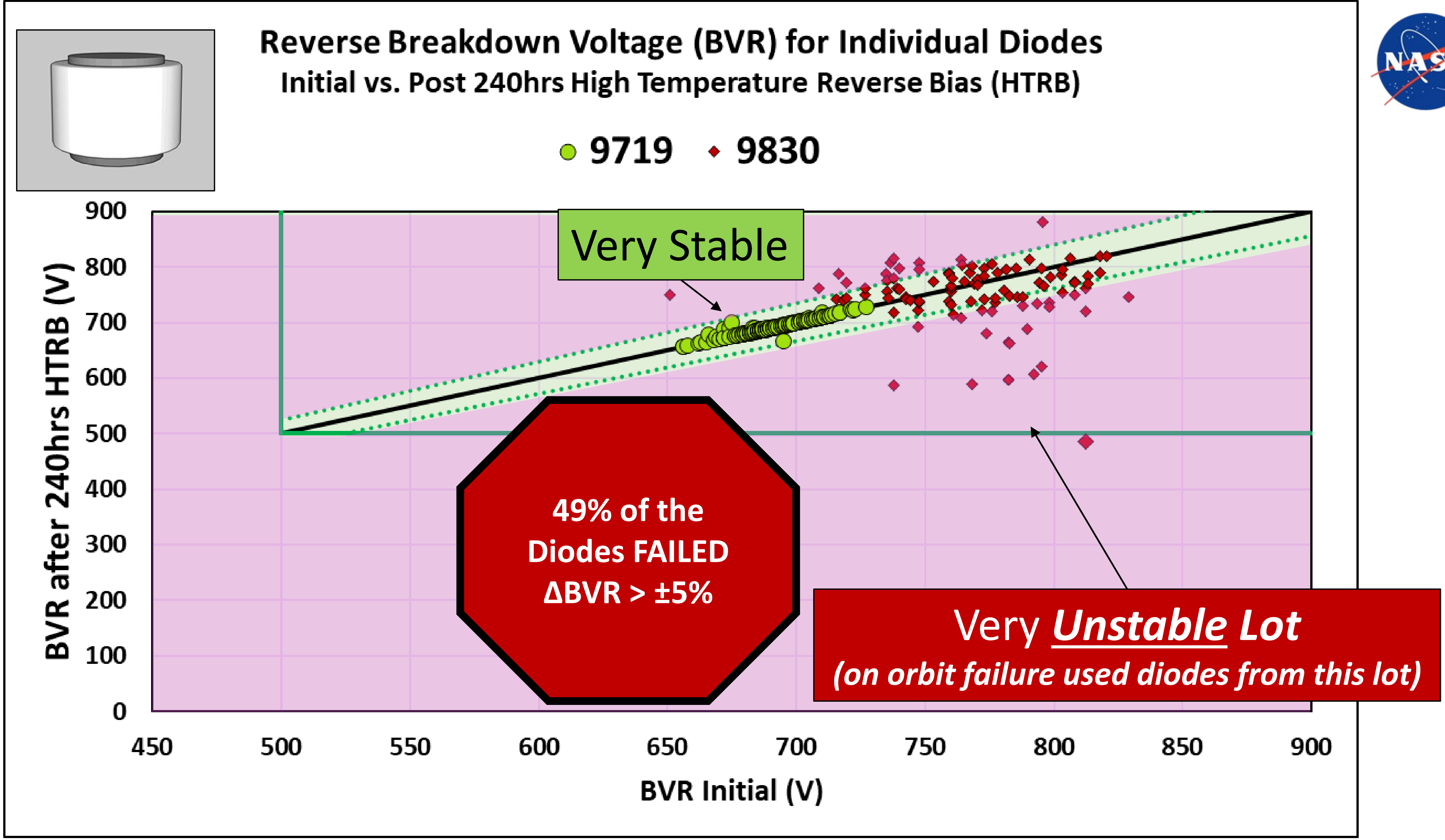
	Screening Results for INDIVIDUAL DIODES Used in Modules with the following LDCs											
Module Lot Date Code -->	***9830***			***'9719***			***9906***			****0031 / 0108***		
Individual Diode Screening Test Flow | V	*Qty*	*Acc*	*Rej*	*Qty*	*Acc*	*Rej*	*Qty*	*Acc*	*Rej*	*Qty*	*Acc*	*Rej*
Initial Electrical (I_R, V_{BR}, V_{F1}, V_{F2}, V_{F3})	100	100	0	178	178	0	139	135	4	303	303	0
High Temperature Reverse Bias (HTRB) 400V; T = 150°C	100			178			135			303		
Post 48 hrs HTRB Electricals (I_R, V_{BR}, V_{F1}, V_{F2}, V_{F3})				178	177	1						
Scope Display				177	176	1						
Post 240 hrs HTRB Electricals (I_R, V_{BR}, V_{F1}, V_{F2}, V_{F3})	100	98	2	176	174	2	135	130	5	303	300	3
Post 240 hrs HTRB Deltas (ΔI_R, ΔV_{BR}, ΔV_{F1})	98	53	45	174	174	0	130	129	1	300	289	11
Post 240 hrs Percent Defective (Lot Percent Defective Allowed < 5%)			47.0%			2.3%			4.4%			4.6%
Scope Display							129	129	0	289	289	0
Post 480 hrs HTRB Electricals (I_R, V_{BR}, V_{F1}, V_{F2}, V_{F3})	53	53	0									
Post 480 hrs HTRB Deltas (ΔI_R, ΔV_{BR}, ΔV_{F1})	53	52	1									
Post 480 hrs Percent Defective (Lot Percent Defective Allowed < 5%)			1.9%									
Scope Display	52	51	1									
Totals		*51*	*49*		*174*	*4*		*129*	*10*		*289*	*14*
Overall Diode Lot Rejection Rate through Screening	*49.0%*			*2.2%*			*7.2%*			*4.6%*		


Reverse Breakdown Voltage (BVR) for Individual Diodes
Initial vs. Post 240hrs High Temperature Reverse Bias (HTRB)
Accept
Reject
Specification Limits
BVR > 500 Volts min @ 150uA
ΔBVR < ±5%
BVR after 240hrs HTRB (V)
0
100
200
300
400
500
600
700
800
900
450
500
550
600
650
700
750
800
850
900
BVR Initial (V)

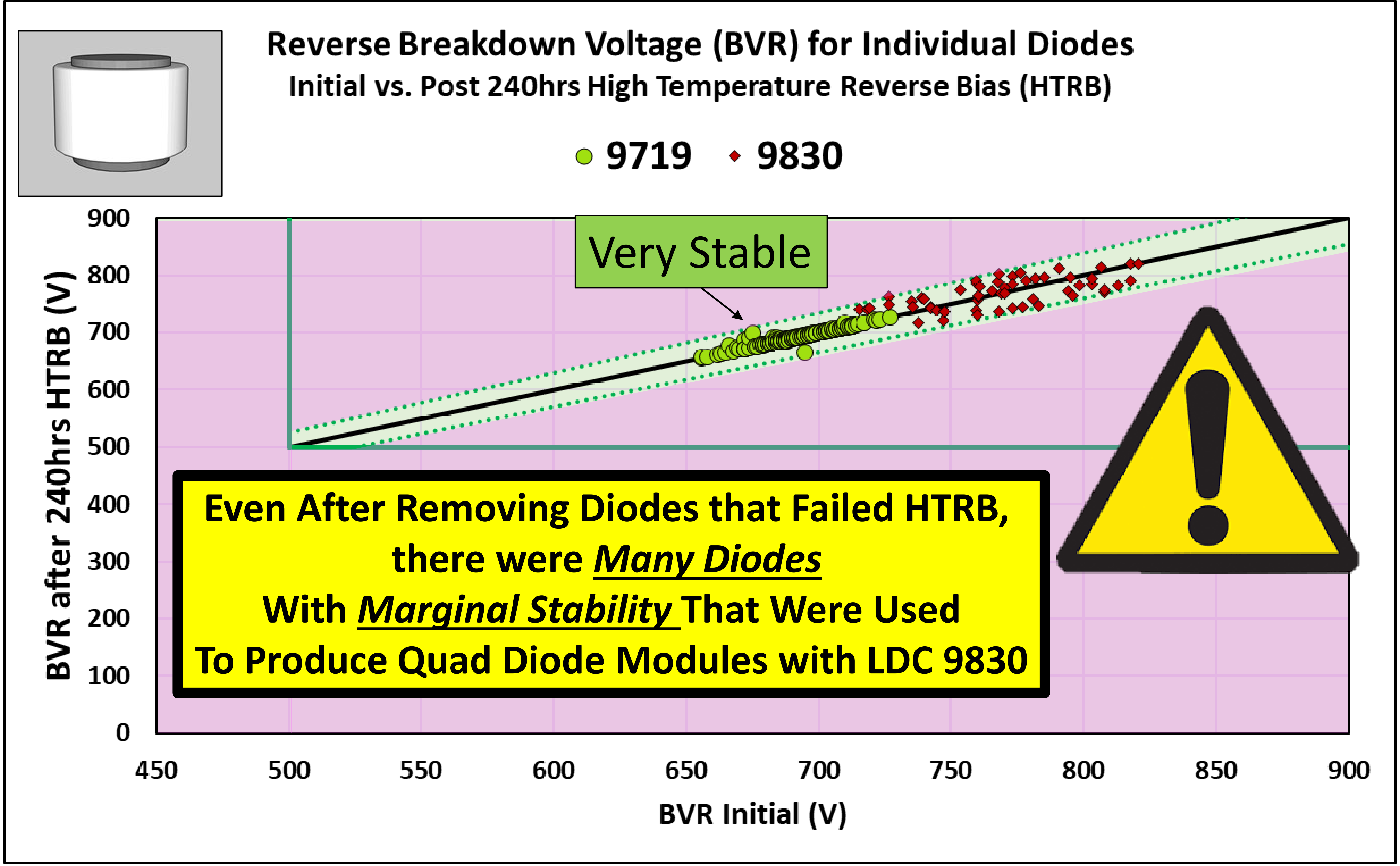
Reverse Breakdown Voltage (BVR) for Individual Diodes

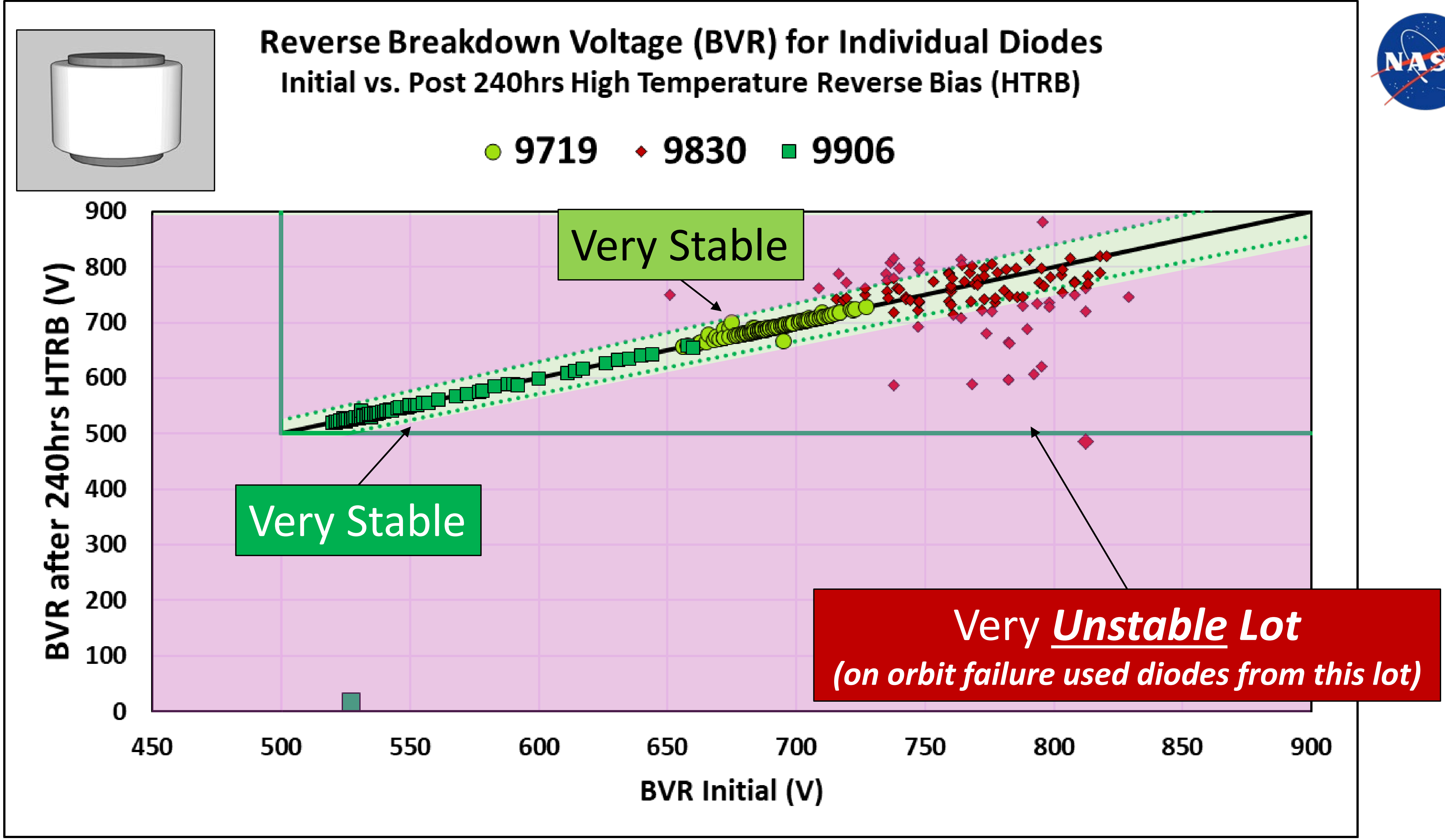
Initial vs. Post 240hrs High Temperature Reverse Bias (HTRB)



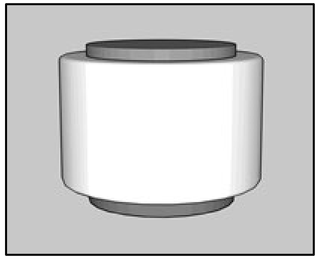


Reverse Breakdown Voltage (BVR) for Individual Diodes
Initial vs. Post 240hrs High Temperature Reverse Bias (HTRB)
9719
9830
Very Stable
49% of the Diodes FAILED ΔBVR > ±5%
Very Unstable Lot
(on orbit failure used diodes from this lot)
BVR after 240hrs HTRB (V)
BVR Initial (V)
0
100
200
300
400
500
600
700
800
900
450
500
550
600
650
700
750
800
850
900


Reverse Breakdown Voltage (BVR) for Individual Diodes
Initial vs. Post 240hrs High Temperature Reverse Bias (HTRB)
9719
9830
Very Stable
Even After Removing Diodes that Failed HTRB,
there were Many Diodes
With Marginal Stability That Were Used
To Produce Quad Diode Modules with LDC 9830
BVR after 240hrs HTRB (V)
BVR Initial (V)
0
100
200
300
400
500
600
700
800
900
450
500
550
600
650
700
750
800
850
900

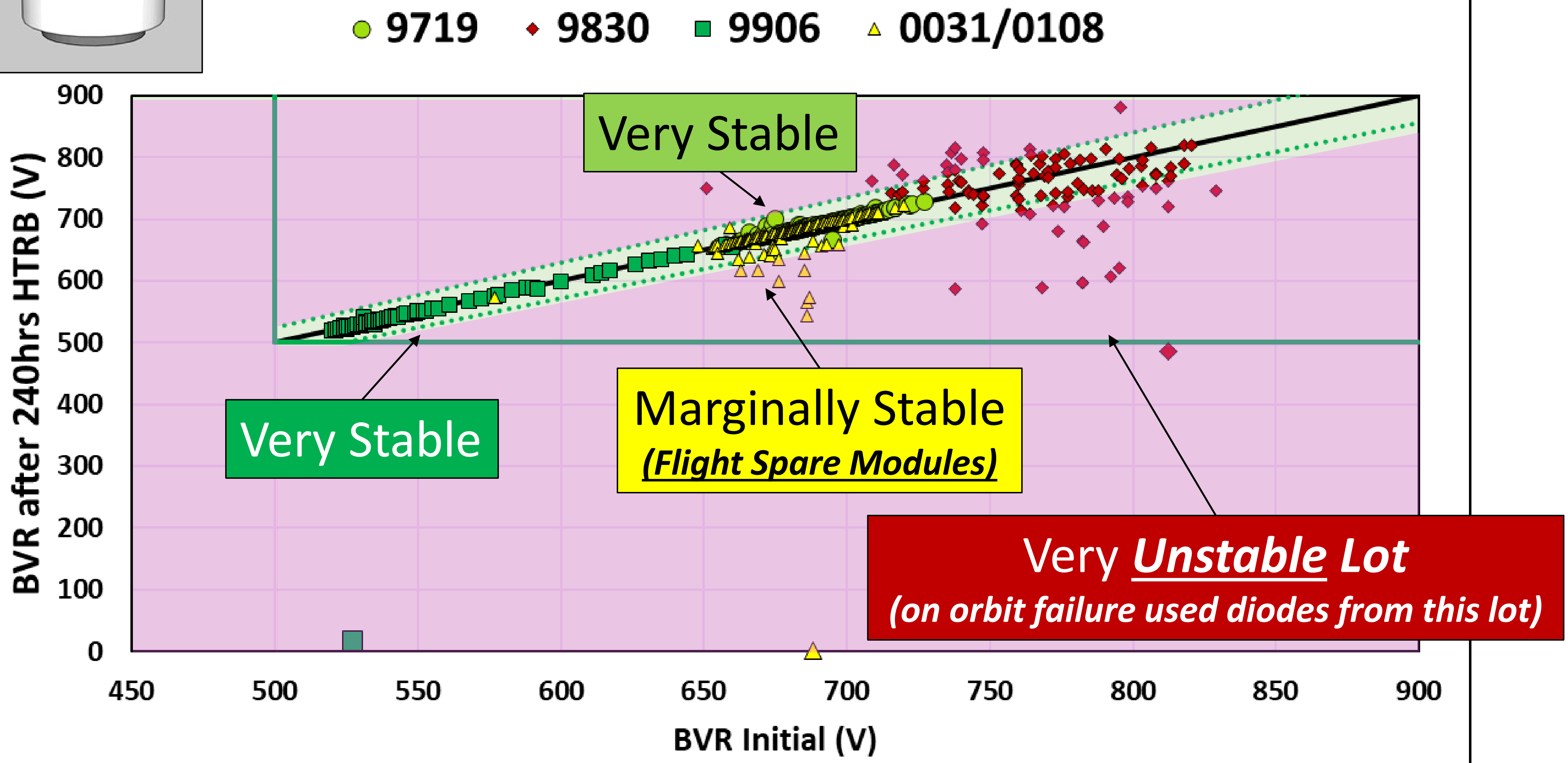


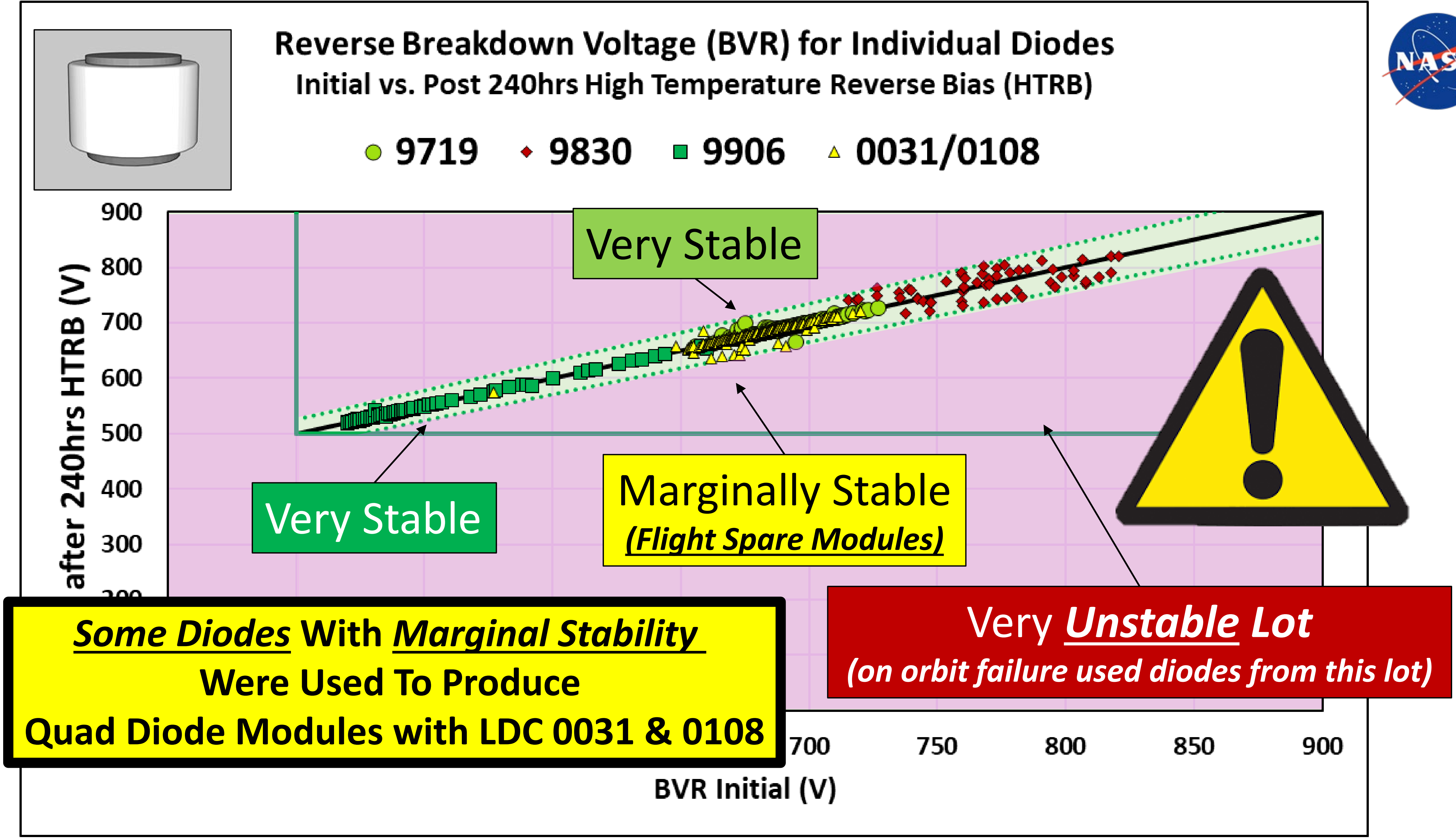
Reverse Breakdown Voltage (BVR) for Individual Diodes
Initial vs. Post 240hrs High Temperature Reverse Bias (HTRB)
9719
9830
9906
Very Stable
Very Stable
Very Unstable Lot
(on orbit failure used diodes from this lot)
BVR after 240hrs HTRB (V)
900
800
700
600
500
400
300
200
100
0
450
500
550
600
650
700
750
800
850
900
BVR Initial (V)

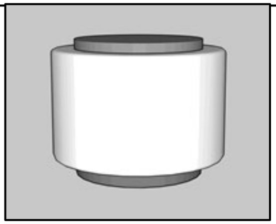


Reverse Breakdown Voltage (BVR) for Individual Diodes

Initial vs. Post 240hrs High Temperature Reverse Bias (HTRB)



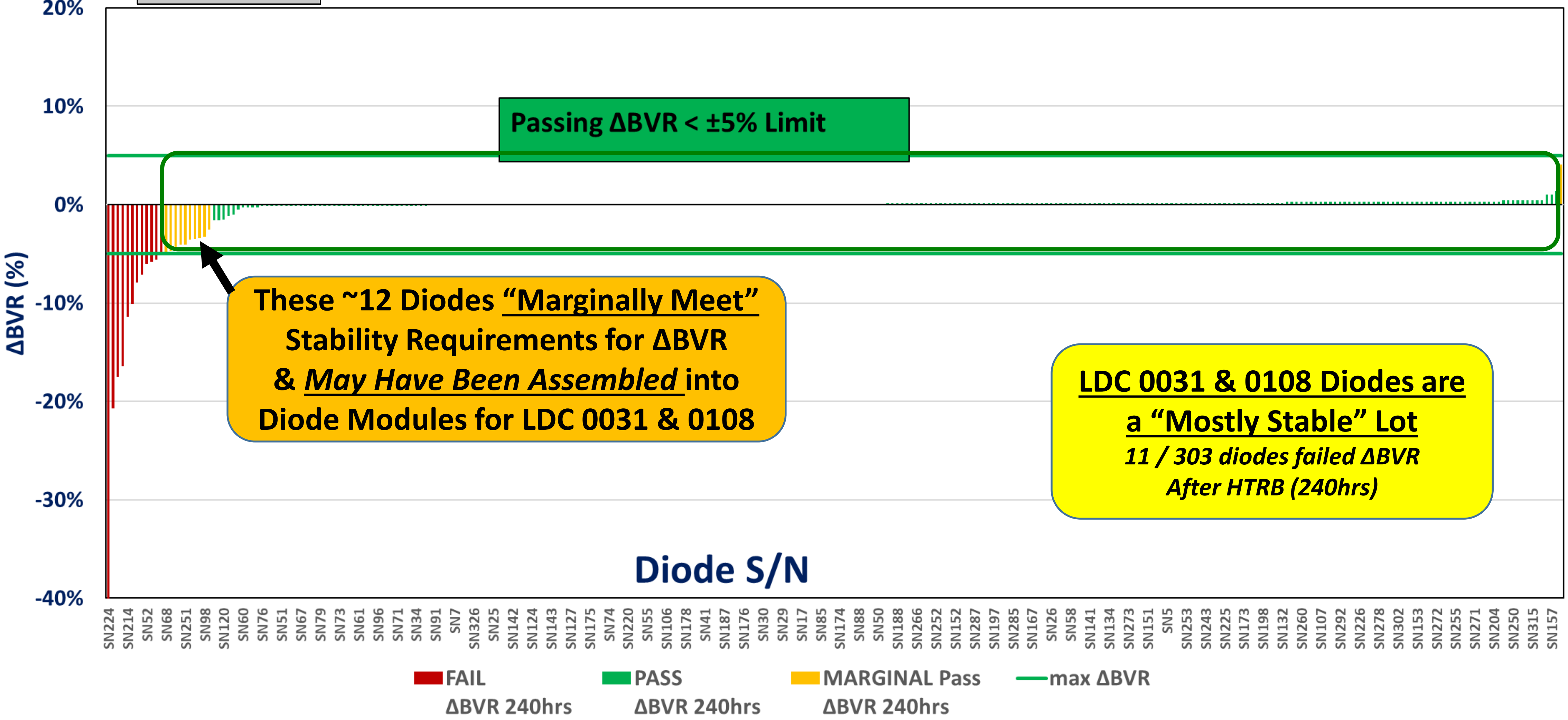

Reverse Breakdown Voltage (BVR) for Individual Diodes
Initial vs. Post 240hrs High Temperature Reverse Bias (HTRB)
9719
9830
9906
0031/0108
after 240hrs HTRB (V)
900
800
700
600
500
400
300
Very Stable
Very Stable
Marginally Stable
(Flight Spare Modules)
Some Diodes With Marginal Stability Were Used To Produce Quad Diode Modules with LDC 0031 & 0108
Very Unstable Lot
(on orbit failure used diodes from this lot)
700
750
800
850
900
BVR Initial (V)



LDC 0031 and 0108 Individual Diodes

Change in Reverse Breakdown Voltage (BVR)

Resutling from High Temperature Reverse Bias (HTRB) Burn-In Screening



NESC EEE Parts Sub-Team Recommendations

Rescreen Flight Spared Modules Prior to Use

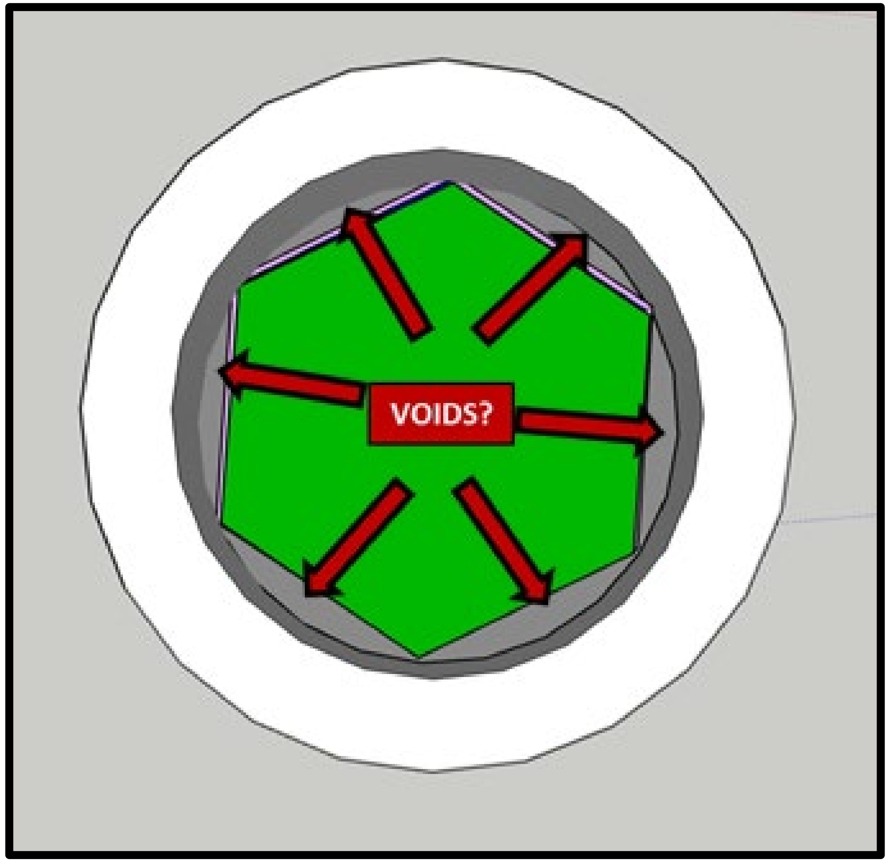
NESC EEE Parts Sub-Team Recommendations to Assure Flight Spare Modules from LDC 0108

- **<u>Prior to Use:</u>**
  Rescreen Flight Spare Modules from LDC 0108 using CT X-ray

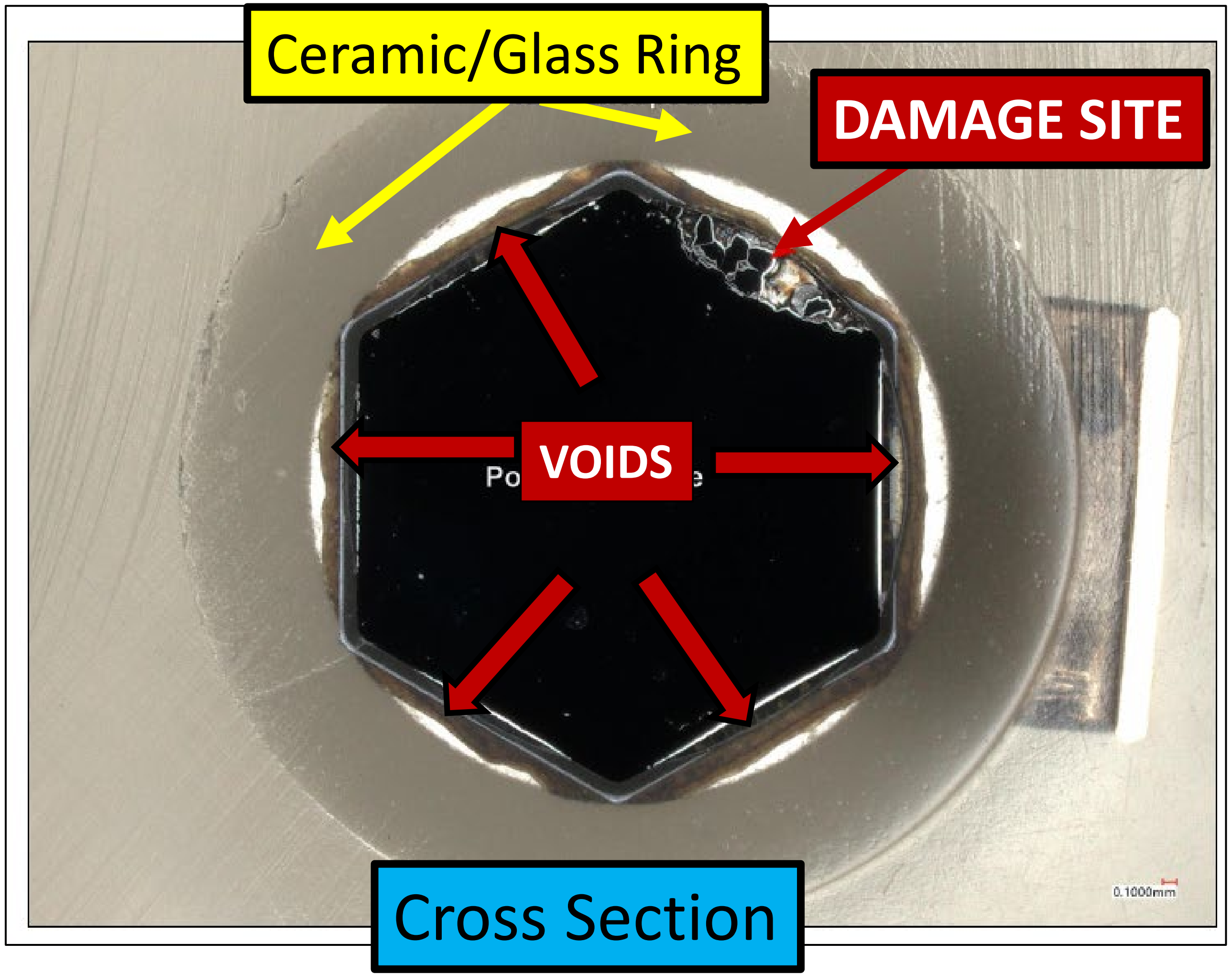
  - **Inspect for voids between ceramic/glass encapsulation and edges of die**

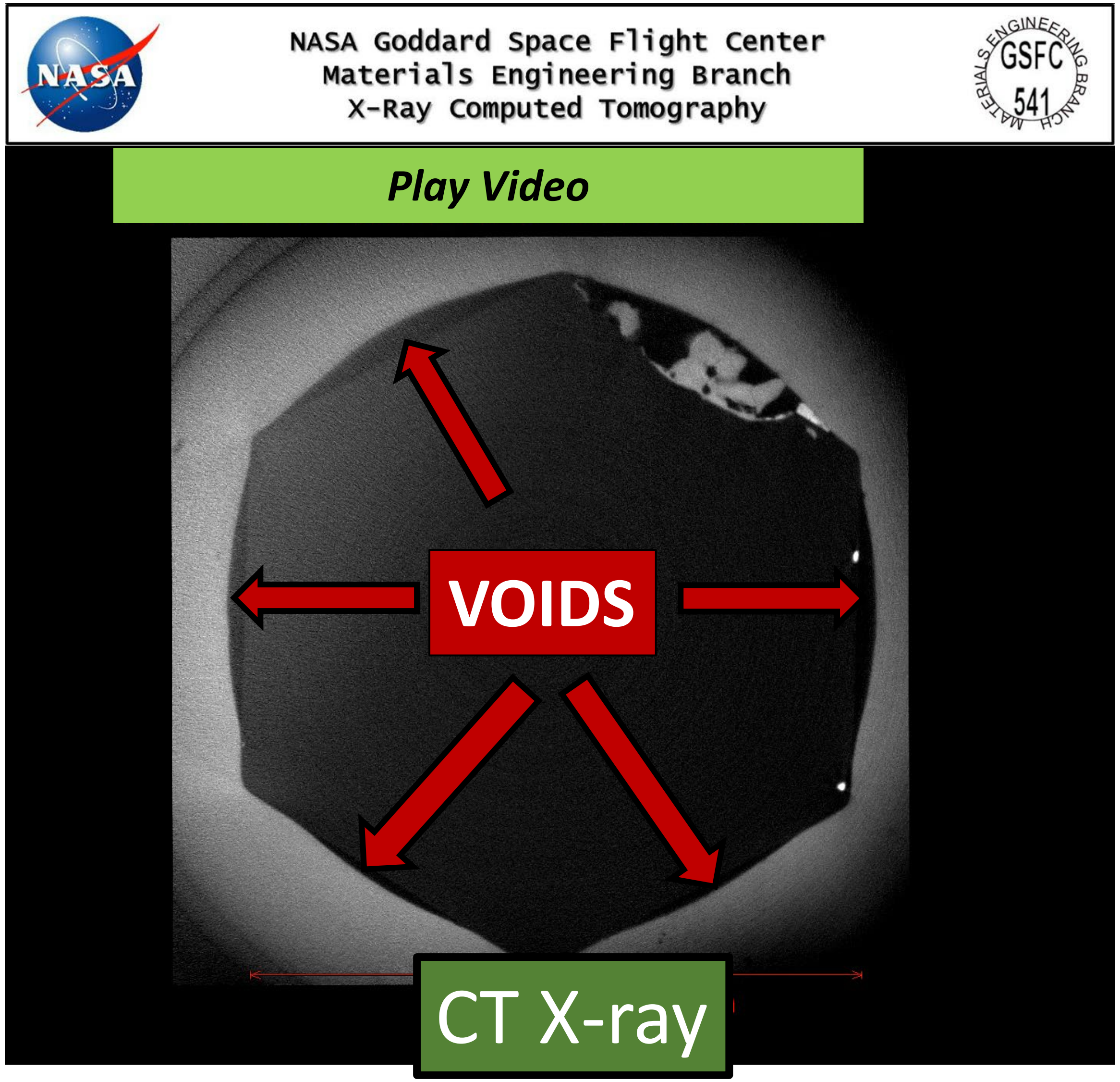
  - **Rationale:**
    V<u>oiding is a necessary precursor</u> to allow silver dendrite formation in this critical location of the diode construction

CT X-ray allows for a non-destructive, "Virtual" Cross Section



Comparison of Cross Section vs. CT X-ray Inspection of the On-Orbit FAILED Diode from LDC 9830

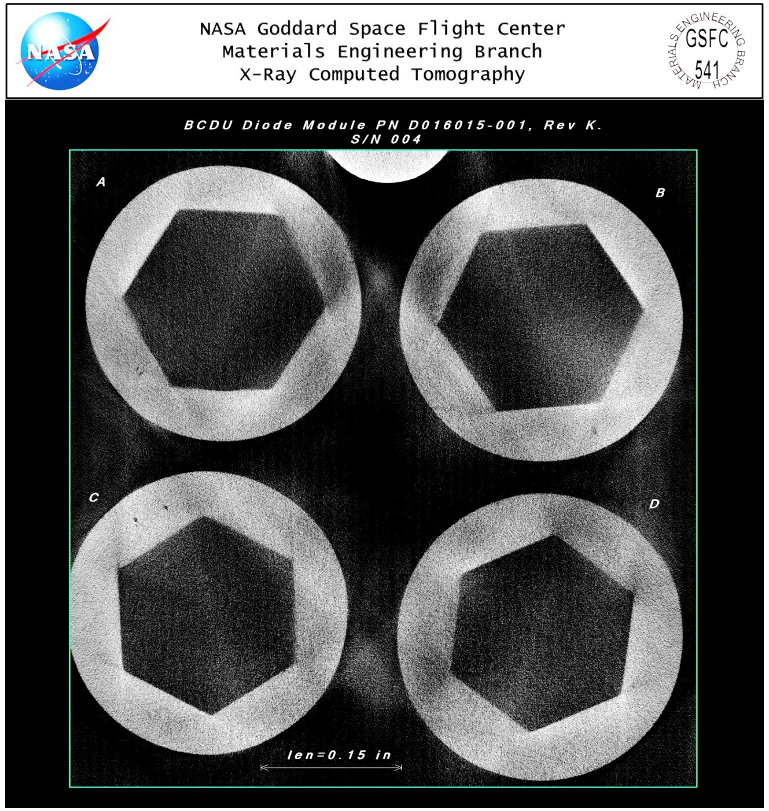




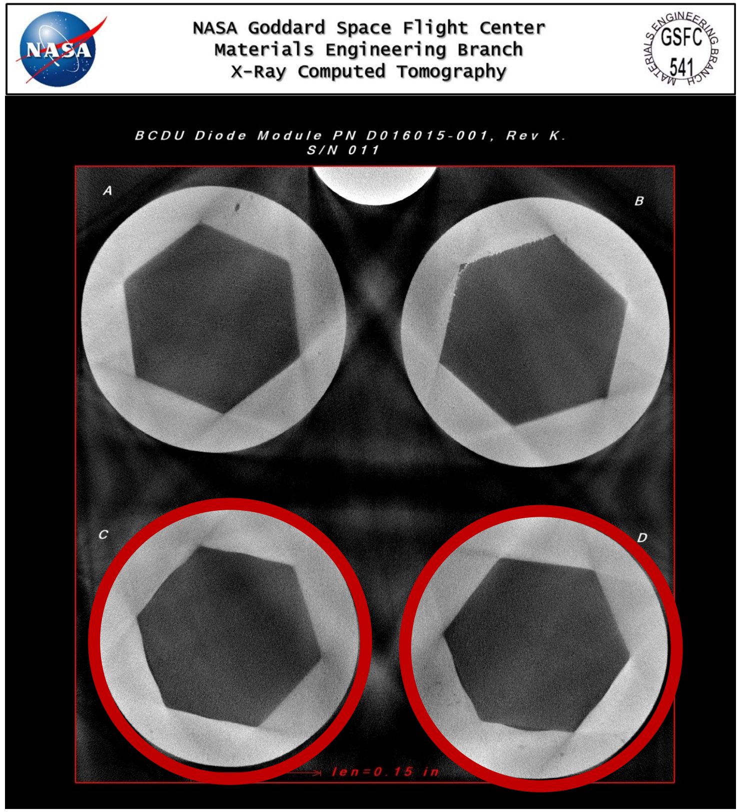
Results of Rescreening for LDC 0108

- 27 Modules from LDC 0108 Have Been Rescreened Via CT X-ray
  - **14 Pass** **NO VOIDS**
  - **13 Rejected** **VOIDS detected in 1 or more of 4 diodes in quad module**

S/N 004 Pass – NO Voids



S/N 011 FAIL – Voids in 2 of 4 diodes



Conclusions

1. Failure Analysis Found:
   - Quad Diode Module from **LDC 9830 Failed Due to Silver Dendrites Growing Within Voids** Between Ceramic/Glass Encapsulating Ring and Die Edges in 1 of 4 Diodes
     - Voids are a necessary, though not sufficient, precursor for dendrite formation

2. Analysis of the Original Manufacturer's HTRB Burn-In Test Data for 5 LDCs Determined:
   - **LDC 9830 individual diodes are the Worst Overall Lot** due to parametric instability (ΔBVR) through HTRB Burn-In
     - Many "unstable" diodes were not screened out and were used in quad diode modules having LDC 9830
   - **LDCs 9719 & 9906 are very stable lots**
   - **LDCs 0108 & 0031 may contain a few Individual diodes with parametric instability (ΔBVR)**

3. CT X-ray inspection is an effective, non-destructive technique to inspect for voids between encapsulating ring and die edges
   - **CT X-ray has been performed on flight spare modules from LDC 0108 to provide additional assurance to restrict use of diodes with voids**

Backup

Examples of Data Package Information Provided By the Original Manufacturer

Screening Traveler Results for Individual Diodes used in LDC 9830 Modules

			PASS	REJ
DIODE ELECTRICAL TEST	04-03-98	04-03-98		
IRM1,BVR1,VFM1,VFM2,VFM3	04-03-98	04-03-98	101	0
MISSING DURING PROCESS	04-10-98	04-10-98	100	1
HTRB FOR 240 HOURS AT 150 DEGREES C. AT VR=400 Vdc	04-10-98	04-20-98	100	0
IRM1,BVR1,VFM1,VFM2,VFM3	04-20-98	04-20-98	98	2
DELTA IR1,VFM1,BVR1	04-21-98	04-21-98	53	45

PERCENT DEFECTIVE ALLOWABLE (PDA) = 10.%
ACTUAL PERCENT DEFECTIVE = 47.%
THE PRECEDING STEPS ARE POTENTIAL LOT JEOPARDY POINTS.

			PASS	REJ
HTRB FOR 240 HOURS AT 150 DEGREES C. AT VR=400 Vdc (RESUBMISSION)	05-29-98	06-08-98	53	0
DIODE ELECTRICAL TEST	06-08-98	06-08-98		
IRM1,BVR1,VFM1,VFM2,VFM3	06-08-98	06-08-98	53	0
DELTA IR1,VFM1,BVR1	06-08-98	06-08-98	52	1

PERCENT DEFECTIVE ALLOWABLE (PDA) = ~~10.%~~ 5%
ACTUAL PERCENT DEFECTIVE = 1.9%
THE PRECEDING STEPS ARE POTENTIAL LOT JEOPARDY POINTS.

R&R Parametric Data for Individual Diodes used in LDC 9830 Modules

	PRE	INTERIM	POST	PRE/INTERIM Delta	PRE/INTERIM Delta %	INTERIM/POST Delta	INTERIM/POST Delta %	
DEVICE: 1								
IRM1 - 1	330.002n	420.002n	405.000n	90.000n	27.273	-15.000n	-3.571	
BVR1 - 2	760.300	761.800	761.400		197.291m		-52.507m	
VFM1 - 3	811.500m	804.002m	807.800m	-7.500m		3.600m		
VFM2 - 4	1.233	1.218	1.218					
VFM3 - 5	1.423	1.425	1.426					
IRM2 - 6			8.582u					
VFM4 - 7			1.200					
VFM5 - 8			1.189					
TRR - 9			39.700n					
Cj - 10			175.700p					pass
DEVICE: 3								
IRM1 - 1	340.002n	420.002n	536.000n	80.000n	23.529	116.000n	27.619	
BVR1 - 2	817.900	819.600	819.300		207.849m		-36.603m	
VFM1 - 3	812.300m	804.000m	799.000m	-8.300m		-5.000m		
VFM2 - 4	1.240	1.224	1.226					
VFM3 - 5	1.431	1.426	1.432					
IRM2 - 6			18.720u					
VFM4 - 7			1.195					
VFM5 - 8			1.185					
TRR - 9			42.450n					
Cj - 10			122.500p					pass
DEVICE: 4								
IRM1 - 1	630.002n	1.180u	99.990uF	350.000n	42.169	98.810uF	8.374KF	
BVR1 - 2	782.700	661.802	9.990 F		-15.447 F		-98.490 F	
VFM1 - 3	813.900m	800.002m	9.990 F	-13.900m		9.190 F		
VFM2 - 4	1.232	1.216	9.990 F					
VFM3 - 5	1.420	1.420	9.990 F					
IRM2 - 6			9.990 F					
VFM4 - 7			9.990 F					
VFM5 - 8			9.990 F					
TRR - 9			9.990 F					
Cj - 10			9.990 F					FAIL

Measuring Reverse Breakdown Voltage (BVR)

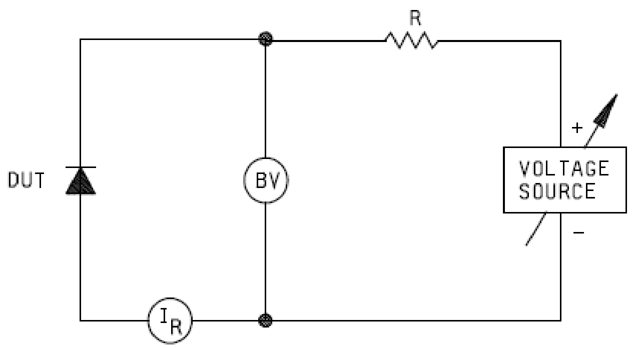
MIL–STD–750–4
w/CHANGE 3

METHOD 4021.2

BREAKDOWN VOLTAGE (DIODES)

1. Purpose. The purpose of this test method is to determine if the breakdown voltage of the semiconductor device is greater than the specified minimum limit.

2. Test circuit. The resistance R is a current-limiting resistance and is chosen to avoid excessive current flowing through the device. (See figure 4021–1).



NOTE: The ammeter shall present essentially a short-circuit to the terminals between which the current is being measured or the voltmeter readings shall be corrected for the drop across the ammeter.

FIGURE 4021–1. Test circuit for breakdown voltage (diodes).

3. Procedure. The reverse current shall be adjusted from zero until either the minimum limit for breakdown voltage or the specified test current is reached. The device is acceptable if the specified minimum limit for BV is reached before the test current reaches the specified value. If the specified test current is reached first, the device is rejected.

4. Summary. The test current (see 3) shall be specified in the applicable performance specification sheet or acquisition document:

**** P R E Page–1

Original Diode Manufacturer Test Conditions For Individual Diodes

SYMBOLS	MIN.	MAX.	COND. 1(I)	COND. 2(V)
IRM1 – 1	50.000n	40.000u	0.000p	500.000
BVR1 – 2	520.000	900.000	150.000u	0.000p

Original Diode Manufacturer Test Conditions For Quad Diode Modules

SYMBOLS	MIN.	MAX.	COND. 1(I)	COND. 2(V)
IRM1 – 1	1.000u	170.000u	0.000p	500.000
BVR1 – 2	510.000	800.000	500.000u	0.000p

"Percent Defective Allowable (PDA)" per MIL-PRF-19500 Rev L (1998)

Note – the following requirements remain unchanged in the current Rev P (2018)

E.5.2 Percent Defective Allowable (PDA). Selected electrical parameters shall be designated in the performance specification sheet for screen 11 and 13 which shall be used for the PDA calculation. These parameters may also be compared to determine whether the change during burn-in (delta) is indicative of a lot stability problem. All burn-in pre-conditioning failures, either HTRB or power burn-in, shall be counted towards the applicable PD unless the pre-conditioning is part of the manufacturer's standard flow.

MIL-PRF-19500L

APPENDIX E

E.5.2.1 JANTX and JANTXV PDA. The PDA for each inspection lot (or screening lot if the alternate flow is used) shall be 10 percent (for each burn-in) on all failures for the specified electrical parameters in steps 11 and 13a. Delta limits shall be defined in the performance specification sheets. For delta limits, the delta parameter values measured after burn-in (100 percent screening test) shall be compared with delta parameter values measured prior to that burn-in. Unless otherwise specified, inspection lots which exceed the 10 percent PDA may be resubmitted one time only to the burn-in operation failed. The PDA shall be 3 percent on the resubmitted inspection lot to each failed burn-in. If the combined burn-in PD's for the first submission exceeds 20 percent or either of the resubmitted burn-in exceed the 3 percent PDA, the entire lot shall be unacceptable for any quality level.

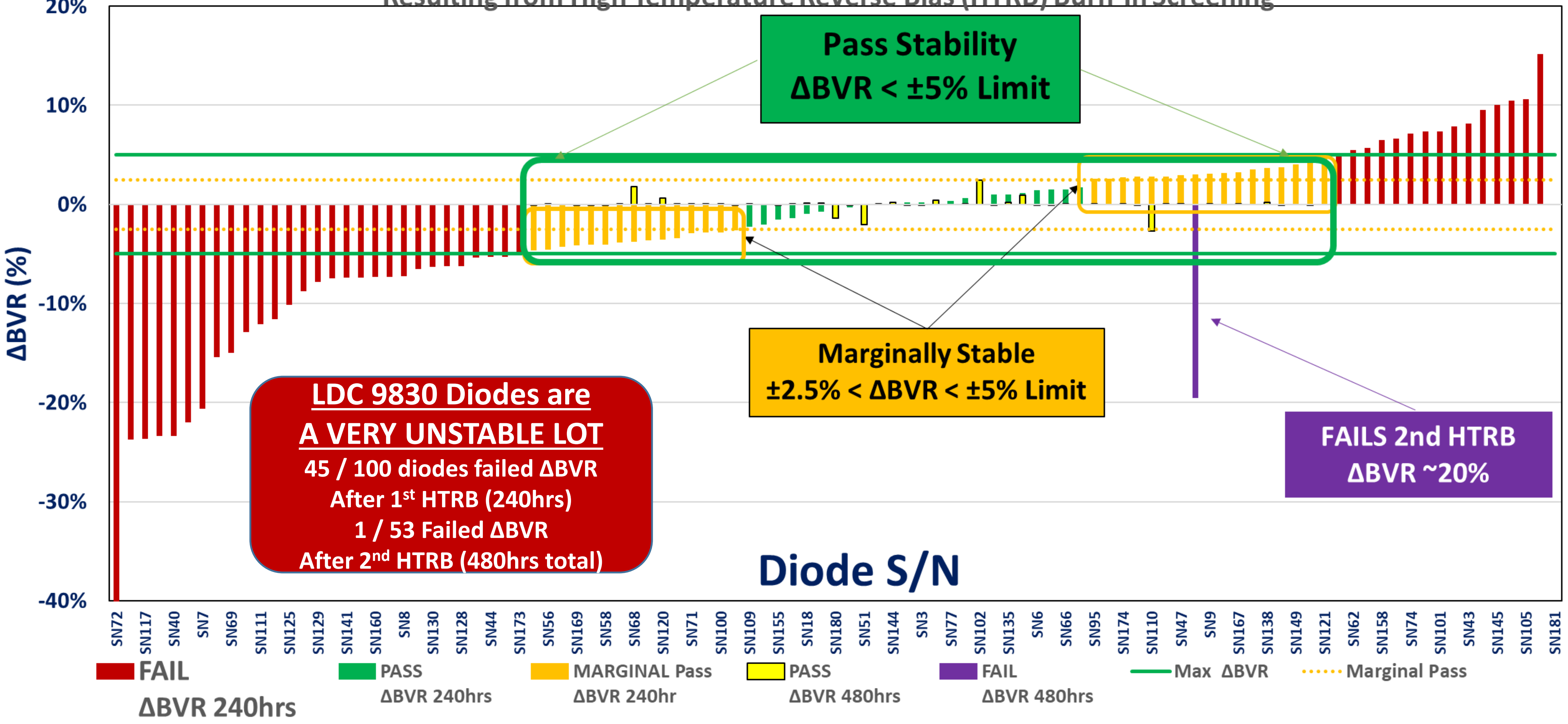
E.5.2.2 JANS PDA. The PDA for each inspection lot shall be 5 percent (for each burn-in) on all failures for specified electrical parameters in steps 11 and 13. Delta limits shall be defined in the performance specification sheets. For PDA delta limits, the delta parameter values measured after burn-in (100 percent screening test) shall be compared with delta parameter values measured prior to that burn-in. Unless otherwise specified, inspection lots which exceed the 5 percent PDA may be resubmitted one time only to the burn-in operation failed. The PDA shall be 3 percent on the resubmitted inspection lot to each failed burn-in. If the combined burn-in PD for the first submission exceeds 10 percent or either of the resubmitted burn-in exceed the 3 percent PDA, the entire inspection lot shall be unacceptable for any quality level.

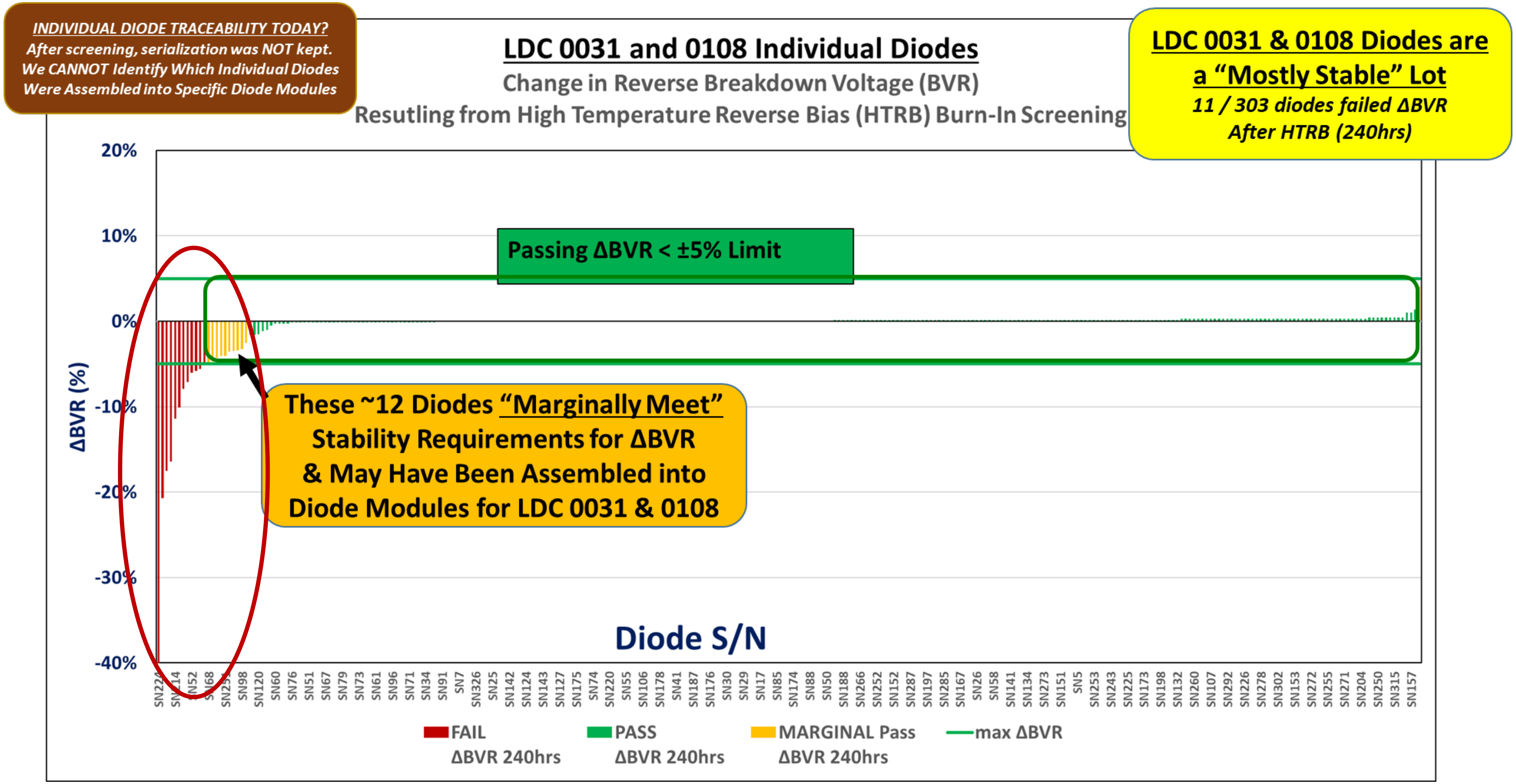
Assessment of Individual Diode Parametric (In)Stability through ***ΔBVR through HTRB Screening***

LDC 9830 Individual Diode

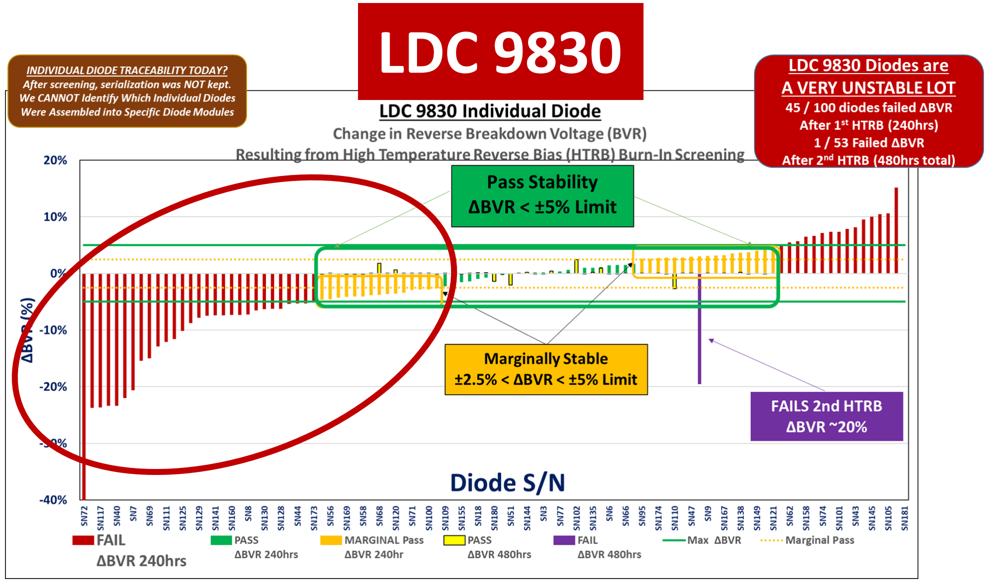
Change in Reverse Breakdown Voltage (BVR)

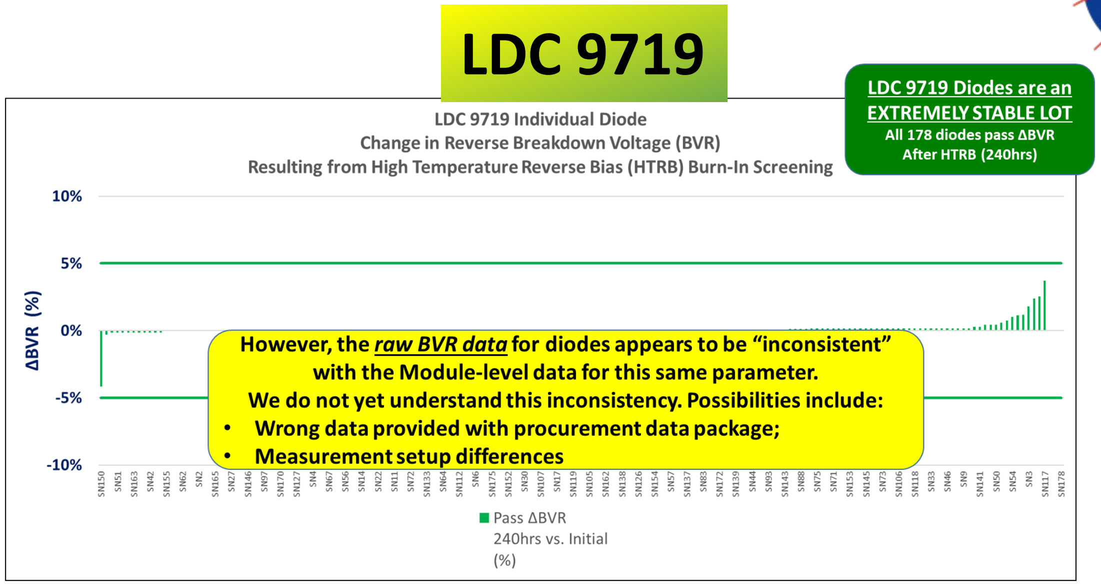
Resulting from High Temperature Reverse Bias (HTRB) Burn-In Screening

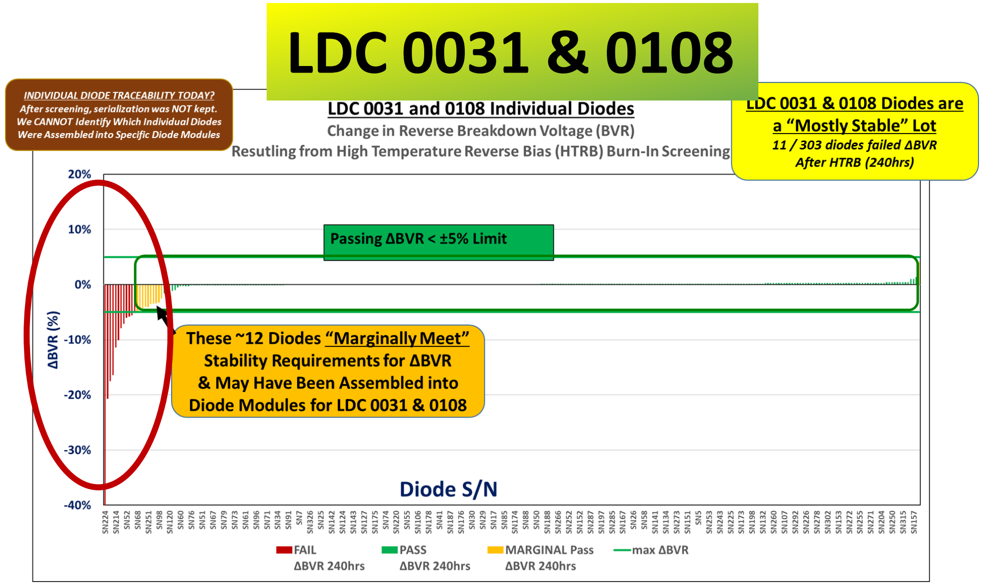


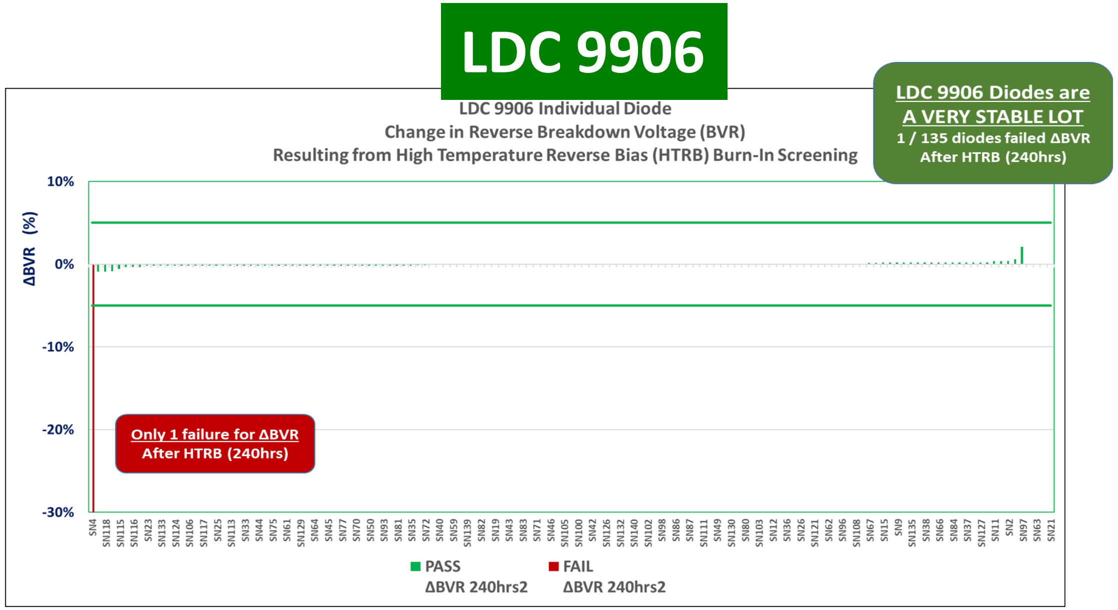

INDIVIDUAL DIODE TRACEABILITY TODAY?
After screening, serialization was NOT kept.
We CANNOT Identify Which Individual Diodes
Were Assembled into Specific Diode Modules
LDC 0031 and 0108 Individual Diodes
Change in Reverse Breakdown Voltage (BVR)
Resutling from High Temperature Reverse Bias (HTRB) Burn-In Screening
LDC 0031 & 0108 Diodes are
a "Mostly Stable" Lot
11 / 303 diodes failed ΔBVR
After HTRB (240hrs)
Passing ΔBVR < ±5% Limit
These ~12 Diodes "Marginally Meet"
Stability Requirements for ΔBVR
& May Have Been Assembled into
Diode Modules for LDC 0031 & 0108
20%
10%
0%
-10%
-20%
-30%
-40%
ΔBVR (%)
Diode S/N
FAIL ΔBVR 240hrs
PASS ΔBVR 240hrs
MARGINAL Pass ΔBVR 240hrs
max ΔBVR

All **Individual Diode Lots** Compared for ΔBVR









Cross Section of an Individual Diode

Example Showing a Diode in Which the Ceramic/Glass Encapsulating Ring is in Intimate Contact with the Edge of the Die