

IRHC9Ax120 - SEE Test Report

SEE Test – R9, 100V, N-channel MOSFET, Die size 1.7 - VIH

About this document

Scope and purpose

This document describes the heavy-ion Single Event Effects (SEE) radiation tests and results for International Rectifier HiRel Products, Inc. 100V, R9, Die Size 1.7, N-channel power MOSFET. The part numbers validated based on these tests are: IRHNM9A7120, IRHNM9A3120, IRHNM9A7120SCS, IRHNM9A3120SCS, IRHNM9A7120, JANSR2N7651U8C, IRHNM9A3120, JANSF2N7651U8C.

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Intended audience.

This document is intended for customers seeking to understand the radiation tests performed on power MOSFETs.

Summary of results

IRHC9Ax120 devices were irradiated to heavy-ion Single Event Effect (SEE) using the ion source K500 Cyclotron at Texas A&M University (TAMU). Irradiation was performed at a target fluence of 3×10^5 ions/cm² and a flux of 2×10^4 ions/cm²/s. The ion beam parameters utilized during testing, along with the corresponding SEE performance results, are summarized in figure 1. The product performance demonstrates its suitability for use in space applications.

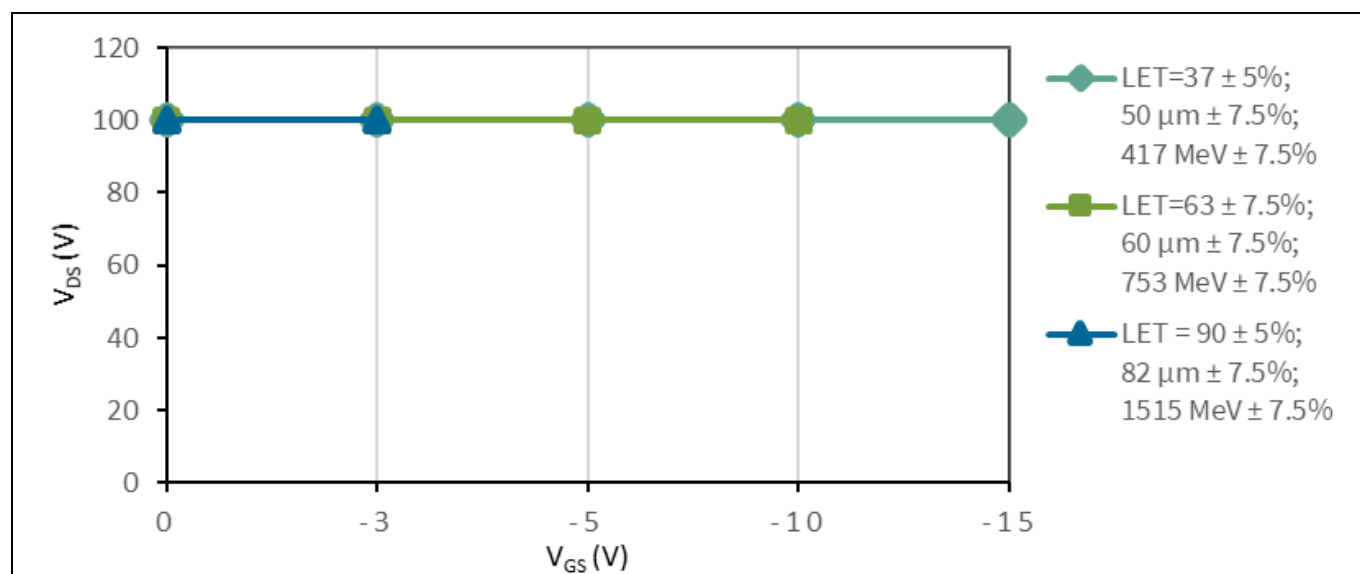


Figure 1 Typical SEE-SOA of IRHC9Ax120

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Device Description

1 Device Description

The IRHC9Ax120 is an N-Channel rad hard MOSFET for space applications. The MOSFET is designed using the R9 technology platform. The device is a Superjunction technology MOSFET and is intended for use in applications such as DC-DC converter, motor drives, etc. It is rated at 100V BV_{DSS} and the dimension of bare die is approximately 3.050mm x 3.048mm. The 100V design architecture has been qualified for the given die size.

Table 1 Device Characteristics

Device	Generation	Channel	BV_{DSS}	$I_{D(max)}^{[1]}$	$R_{DS(on)}^{[1]}$	$Q_{g(max)}^{[1]}$	Die Size	Package
IRHNM9A7120 IRHNM9A7120SCS	R9	N	100V	23A	55mΩ	23nC	3.050x3.048 (mmxmm)	SMD-0.2 Metal Lid
IRHNM9A3120 IRHNM9A3120SCS	R9	N	100V	23A	55mΩ	23nC	3.050x3.048 (mmxmm)	SMD-0.2 Metal Lid
IRHNMC9A7120 JANSR2N7651U8C	R9	N	100V	23A	55mΩ	23nC	3.050x3.048 (mmxmm)	SMD-0.2 Ceramic Lid
IRHNMC9A3120 JANSF2N7651U8C	R9	N	100V	23A	55mΩ	23nC	3.050x3.048 (mmxmm)	SMD-0.2 Ceramic Lid

1.1 Reference Documents

Datasheet: [IRHNM9A7120](#), [IRHNM9A3120](#), [IRHNM9A7120SCS](#), [IRHNM9A3120SCS](#), [IRHNMC9A7120](#), [JANSR2N7651U8C](#), [IRHNMC9A3120](#), [JANSF2N7651U8C](#).

Standard(s): MIL-PRF-19500 - TM1080, JESD57A.

IR HiRel Radiation Test Methodology: [B119-I1318-V1-7600-NA-EC](#)

1.2 Device Preparations

All test samples were subjected to electrical characterization to verify nominal performance across key parameters, including BV_{DSS} , $V_{GS(th)}$, $R_{DS(ON)}$, V_{SD} , I_{DSS} , I_{GSS} (shown in Table 3) prior to arrival at the radiation testing facility. The samples were assembled in TO-3 packages using aluminum wire bonding and left without a lid, ensuring direct exposure of the die surface to the heavy-ion beam during irradiation testing.

^[1]Refer to datasheet for test conditions and typical values

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Single-Event Effects (SEE Overview)

2 Single-Event Effects (SEE) Test Overview

2.1 Test Objectives

The goal of this SEE testing is to establish that the IRHC9Ax120 material is capable of withstanding exposure to various heavy ions and determine the threshold LET (linear energy transfer) required to cause a single ion-induced failure under bias conditions. Heavy-ion radiation tests for SEE characterization were performed at Cyclotron Institute, Texas A&M University using the K500 Superconducting Cyclotron.

Table 2 Overview of SEE tests – Worst-Case Beam Conditions

Run No.	Ion	Air gap [cm]	Beam Energy [MeV]	LET [MeV·cm ² /mg]	Range [μm]	Fluence [ions/cm ²]	Test Date	Wafer Lot (SEEID)
761 – 771 772 – 784	⁸⁴ Kr	1.5	417	38.5	51.5	3x10 ⁵	September, 2023	VE323503.1 (68A) VE323502.1 (69A)
615 – 622 623 – 630	¹²⁹ Xe	1.5	809	66.0	61.1	3x10 ⁵	July, 2023	VE323503.1 (68A) VE323502.1 (69A)
56 – 63 64 – 75	¹⁹⁷ Au	1.5	1425	90.5	80.1	3x10 ⁵	July, 2023	VE323503.1 (68A) VE323502.1 (69A)

Table 2 highlights the test overview indicating run number, ion species, air gap between the beam and DUT, beam energy, LET in Si, range in Si, fluence, test date and wafer lot number. These Worst-Case beam conditions were defined by the ion Bragg peak being in close proximity to the Epi-Substrate interface.

IR HiRel confirms the sensitive area of the transistor is exposed to a LET higher than:

- 90.5 MeV·cm²/mg using a ¹⁹⁷Au ion species
- 66.0 MeV·cm²/mg using a ¹²⁹Xe ion species
- 38.5 MeV·cm²/mg using a ⁸⁴Kr ion species

2.2 Test Setup

During the heavy-ion exposure, test samples were measured using a LabVIEW graphical user interface (GUI) custom-developed by IR HiRel. The GUI controls a DAQ to turn on and off relays that allow to select the DUT for heavy-ion exposure on a multisite board, also, it controls the power supplies that deliver regulated biases for V_{GS} and V_{DS}. Additional information regarding test setup can be found in the *IR HiRel Radiation Test Methodology*.

Test Criteria

3 Test Criteria

All the tests were done at normal incidence which has been determined to be the worst case for Superjunction power MOSFETs. To achieve the desired energy/penetration depth, aluminum foil degraders and adjusted air distances were used. The measurements and irradiation runs were performed at room temperature (25 °C), with average flux and fluence of 2×10^4 ions/cm²/s and 3×10^5 ions/cm², respectively. The test procedure was based on MIL-STD-750, Method 1080. For more detailed description on test methodology employed by IR HiRel, refer to the *IR HiRel Radiation Test Methodology* document.

Three passes were required for qualification (including post-electrical test) and two failures for characterization of each SEE-SOA test point. This was validated for samples from two different wafer lots. This sequence was repeated for the next ion species. The detailed logsheet for each run is provided in Sections 4.2 – 4.4. The combination of SEB-SOA and SEGR-SOA yields the SEE-SOA.

3.1 Characterization Test Bias Sequence for SEB-SOA

1. V_{GS} : 0 V
2. V_{DS} : Start at 80V. Increase in steps of 10V until $V_{DS(max)}$ or FAIL occurs

3.2 Characterization Test Bias Sequence for SEGR-SOA

1. V_{DS} : Keep V_{DS} at maximum (at which PASS value was obtained for previous test bias sequence i.e. SEB)
2. V_{GS} : Start at -1V. Decrease in steps of 1V until $V_{GS(max)}$ or FAIL occurs

3.3 Qualification Test Bias Sequence for SEB/SEGR-SOA

1. Based on the results of the characterization, product was qualified by testing three samples of each wafer to the closest passing V_{GS} and V_{DS} voltages.
2. All samples MUST pass qualified specification biases (V_{GS}/V_{DS}).

3.4 Post-Electrical Test Criteria

- Post Irradiation Gate Stress (PIGS) test: $V_{GS} = V_{GS(max)} = -20V$ at $V_{DS} = 80V$ was applied to verify the gate integrity after each irradiation run.
- Pass/Fail criteria are based on I_{DSS} , I_{GSSf} and I_{GSSr} limits (shown in Table 3)

Table 3 Electrical Parameters Limits

Parameter	Test Conditions	Limit
I_{DSS}	$V_{DS} = 100V$, $V_{GS} = 0V$	$\leq 0.95\mu A$
I_{GSSf}	$V_{GS} = 20V$, $V_{DS} = 0V$	$< 90nA$
I_{GSSr}	$V_{GS} = -20V$, $V_{DS} = 0V$	$< -90nA$
$V_{GS(th)}$	$V_{DS} = V_{GS}$, $I_D = 1.0mA$	2.05V to 3.95V
BV_{DSS}	$I_D = 1.0mA$	$\geq 101.5V$
$R_{DS(ON)}$	$V_{GS} = 12V$, $I_D = 14A$	$< 55m\Omega$
V_{SD}	$I_S = 23A$	$\leq 1.2V$

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Test Results

4 Test Results

4.1 Destructive SEB/SEGR Test Results

IRHC9Ax120 devices have been tested using the ion source K500 Cyclotron at TAMU and typical SEE-SOA for V_{DS}/V_{GS} combinations established. Each point on the graph, or insitu bias condition, has been verified by irradiating and subsequent electrical testing of a minimum of 3 devices, with no valid failures allowed.

Table 4 SEE-SOA of IRHC9Ax120 – Worst-Case Beam Conditions (TAMU)

V_{GS} (V)	V_{DS} (V)		
	LET = 38.5; 51.5 μm ; 417 MeV	LET = 66; 61.1 μm ; 809 MeV	LET = 90.5; 80.1 μm ; 1425 MeV
0	100	100	100
-5	100	100	100
-10	100	100	
-15	100	100	
-20	100		

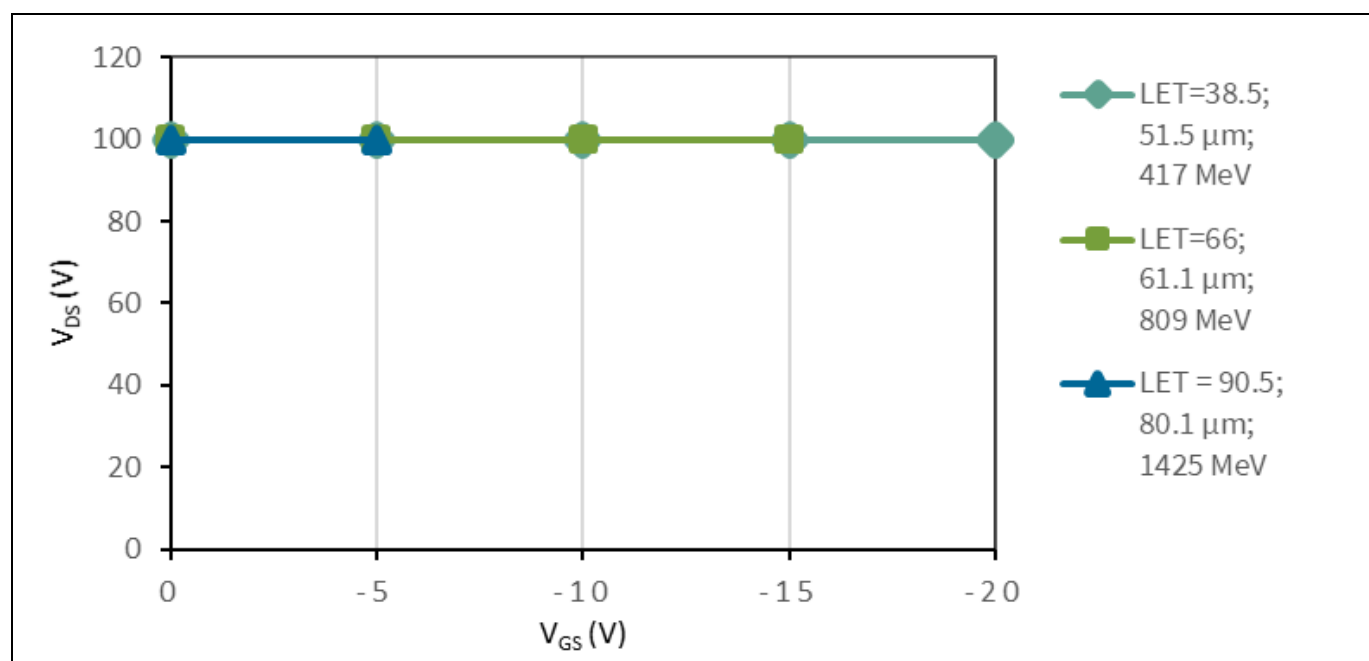


Figure 2 SEE-SOA of IRHC9Ax120 – Worst-Case Beam Conditions (TAMU)

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Test Results

4.2 ¹⁹⁷Au – SEE Run Results

Heavy-ion irradiation using ¹⁹⁷Au ion species was conducted in July 2023 at the K500 Cyclotron facility at Texas A&M University (TAMU). All tests were performed at a normal incidence with a 1.5 cm air gap between the beam window and the die surface. The beam parameters and degrader configuration were carefully selected to position the Bragg peak in close proximity to the epitaxial-substrate interface, as follows: LET = 90.5 MeV·cm²/mg, Energy = 1425 MeV, Range = 80.1 μm, Degradar = 2 mil aluminum foil, and Degradar Angle = 14.113°.

Table 5 SEE run data of IRHC9Ax120 - ¹⁹⁷Au ion species

Run No.	Wafer Lot	SEE ID	DUT Serial #	Eff. Fluence ions/cm ²	Avg. Flux ions/cm ² /s	VGS Volts	VDS Volts	Pass/Fail (subject to Post-SEE Electricals) Blank=Pass
56	VE323503.1	68A	1	2.95E+05	2.03E+04	-5	100	
57				2.91E+05	1.90E+04	-7	100	Failed
58			2	3.00E+05	2.02E+04	-5	100	
59				2.92E+05	1.95E+04	-6	100	
60				2.97E+05	1.99E+04	-7	100	
61				3.02E+05	1.97E+04	-8	100	Failed
62			3	3.00E+05	2.11E+04	-5	100	← Worst-Case Au curve spec point
63			4	3.01E+05	1.80E+04	-5	100	← Worst-Case Au curve spec point
64			5	2.95E+05	1.96E+04	-5	100	← Worst-Case Au curve spec point
65	VE323502.1	69A	1	2.89E+05	2.16E+04	-5	100	
66				3.01E+05	2.11E+04	-6	100	
67				3.06E+05	2.08E+04	-7	100	Failed
68			2	2.90E+05	2.15E+04	-5	100	
69				2.93E+05	1.99E+04	-6	100	
70				3.09E+05	1.95E+04	-7	100	
71				2.95E+05	1.99E+04	-8	100	Failed
72			3	3.08E+05	2.13E+04	-5	100	← Worst-Case Au curve spec point
73			4	2.99E+05	2.09E+04	-5	100	Invalid Wrong Socket
74				3.01E+05	2.04E+04	-5	100	← Worst-Case Au curve spec point
75			5	3.02E+05	1.97E+04	-5	100	← Worst-Case Au curve spec point

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Test Results

4.3 ¹²⁹Xe – SEE Run Results

Heavy-ion irradiation using ¹²⁹Xe ion species was conducted in July 2023 at the K500 Cyclotron facility at Texas A&M University (TAMU). All tests were performed at a normal incidence with a 1.5 cm air gap between the beam window and the die surface. The beam parameters and degrader configuration were carefully selected to position the Bragg peak in close proximity to the epitaxial-substrate interface, as follows: LET = 66 MeV·cm²/mg, Energy = 809 MeV, Range = 61.1 μm, Degradar = 2 mil aluminum foil, and Degradar Angle = 27.838 °.

Table 6 SEE run data of IRHC9Ax120 - ¹²⁹Xe ion species

Run No.	Wafer Lot	SEE ID	DUT Serial #	Eff. Fluence ions/cm ²	Avg. Flux ions/cm ² /s	VGS Volts	VDS Volts	Pass/Fail (subject to Post-SEE Electricals) <i>Blank=Pass</i>
615	VE323503.1	68A	7	3.04E+05	2.19E+04	-15	100	
616				2.32E+05	2.17E+04	-17	100	Failed
617			8	3.06E+05	2.12E+04	-15	100	
618				2.91E+05	2.13E+04	-16	100	
619				2.37E+05	2.17E+04	-17	100	Failed
620			9	3.06E+05	2.15E+04	-15	100	← Worst-Case Xe curve spec point
621			10	2.94E+05	2.17E+04	-15	100	← Worst-Case Xe curve spec point
622			11	2.96E+05	2.14E+04	-15	100	← Worst-Case Xe curve spec point
623	VE323502.1	69A	7	2.95E+05	2.24E+04	-15	100	
624				2.93E+05	2.20E+04	-17	100	Failed
625			8	2.90E+05	2.14E+04	-15	100	
626				3.06E+05	2.08E+04	-16	100	
627				1.86E+05	2.09E+04	-17	100	Failed
628			9	3.06E+05	2.00E+04	-15	100	← Worst-Case Xe curve spec point
629			10	3.00E+05	1.92E+04	-15	100	← Worst-Case Xe curve spec point
630			11	3.00E+05	2.02E+04	-15	100	← Worst-Case Xe curve spec point

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Test Results

4.4 ⁸⁴Kr – SEE Run Results

Heavy-ion irradiation using ⁸⁴Kr ion species was conducted in September 2023 at the K500 Cyclotron facility at Texas A&M University (TAMU). All tests were performed at a normal incidence with a 1.5 cm air gap between the beam window and the die surface. The beam parameters and degrader configuration were carefully selected to position the Bragg peak in close proximity to the epitaxial-substrate interface, as follows: LET = 38.5 MeV·cm²/mg, Energy = 417 MeV, Range = 51.5 μm, Degraded = 2 mil aluminum foil, and Degraded Angle = 49.188°.

Table 7 SEE run data of IRHC9Ax120 - ⁸⁴Kr ion species

Run No.	Wafer Lot	SEE ID	DUT Serial #	Eff. Fluence ions/cm ²	Avg. Flux ions/cm ² /s	VGS Volts	VDS Volts	Pass/Fail (subject to Post-SEE Electricals) <i>Blank=Pass</i>
761	VE323503.1	68A	6	2.98E+05	2.04E+04	-20	100	
762				2.91E+05	2.15E+04	-25	100	
763				2.94E+05	2.16E+04	-27	100	Failed
764			12	2.90E+05	2.11E+04	-20	100	
765				1.64E+05	2.02E+04	-25	100	Failed
766			13	2.95E+05	2.21E+04	-20	100	
767				3.05E+05	2.15E+04	-22	100	
768				3.07E+05	2.15E+04	-24	100	Failed
769			14	3.09E+05	2.25E+04	-20	100	← Worst-Case Kr curve spec point
770			15	3.05E+05	2.21E+04	-20	100	← Worst-Case Kr curve spec point
771			16	2.93E+05	2.20E+04	-20	100	← Worst-Case Kr curve spec point
772	VE323502.1	69A	6	3.10E+05	2.17E+04	-20	100	
773				2.98E+05	2.21E+04	-22	100	
774				2.93E+05	2.22E+04	-24	100	
775				3.08E+05	2.33E+04	-25	100	
776				8.19E+04	2.02E+04	-27	100	Failed
777			12	2.88E+05	2.20E+04	-20	100	
778				3.11E+05	2.22E+04	-22	100	
779				2.97E+05	2.29E+04	-24	100	
780				2.90E+05	2.12E+04	-25	100	
781				2.48E+05	2.19E+04	-26	100	Failed
782			13	2.94E+05	2.32E+04	-20	100	← Worst-Case Kr curve spec point
783			14	3.00E+05	2.36E+04	-20	100	← Worst-Case Kr curve spec point
784			15	3.05E+05	2.07E+04	-20	100	← Worst-Case Kr curve spec point

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Conclusion

5 Conclusion

As a guardband against the possibility of fluctuating beam conditions, IR HiRel is publishing the following typical worst case SEE response specifications for final datasheet use: Typical SEE-SOA of IRHC9Ax120 – Worst-Case Beam Conditions.

Table 8 Typical SEE-SOA of IRHC9Ax120 – Worst-Case Beam Conditions

V_{GS} (V)	V_{DS} (V)		
	LET = $38.5 \pm 5\%$; $50 \mu\text{m} \pm 7.5\%$; $417 \text{ MeV} \pm 7.5\%$	LET = $63 \pm 7.5\%$; $60 \mu\text{m} \pm 7.5\%$; $809 \text{ MeV} \pm 7.5\%$	LET = $90.0 \pm 5\%$; $82 \mu\text{m} \pm 7.5\%$; $1425 \text{ MeV} \pm 7.5\%$
0	100	100	100
-3	100	100	100
-5	100	100	
-10	100	100	
-15	100		

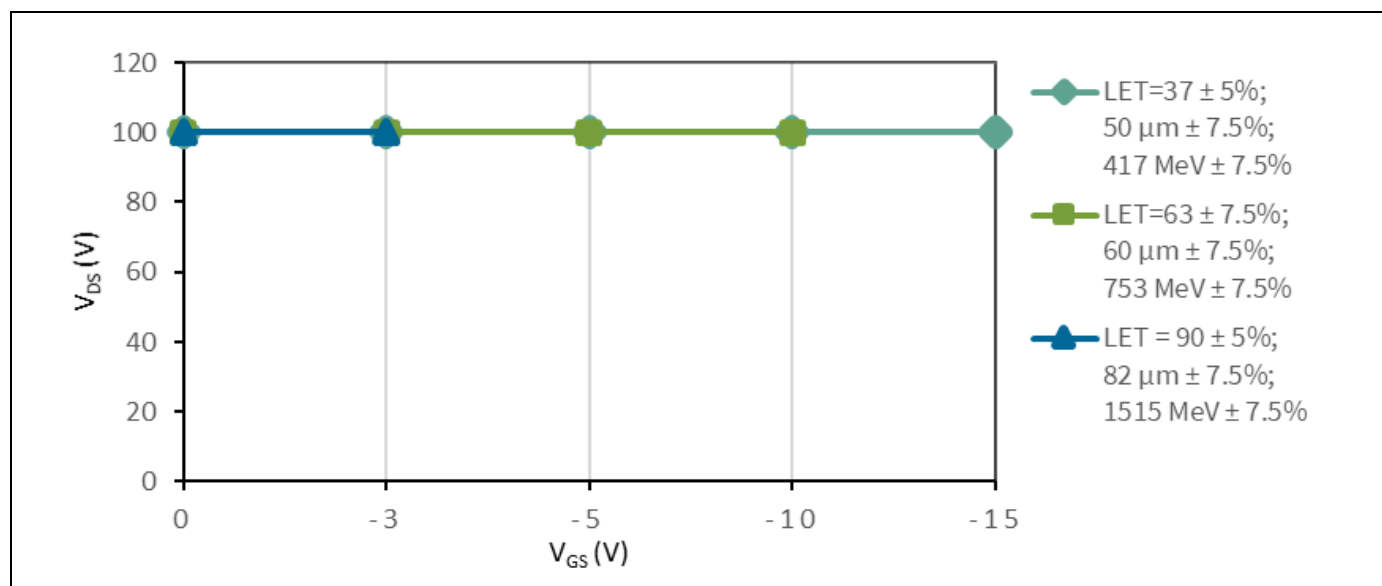


Figure 3 Typical SEE-SOA of IRHC9Ax120 – Worst-Case Beam Conditions

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Revision History

Revision History

Document version	Date of release	Description of changes
Rev A	2026/08/07	Initial released

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