National Aeronautics and Space Administration

Single-Event Gate Rupture and Single-Event Burnout Test Results Performed on Hi-Rel Fuji Power MOSFETs: 2SK4217, 2SK4152, 2SK4155, and 2SK4158

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Executive Summary

Several newly available Hi-Rel total dose hardened power metal-oxide-semiconductor field-effect transistors (MOSFETs) manufactured by Fuji Electric Device Technology Co. Ltd (FDT) in conjunction with the Japan Aerospace Exploration Agency (JAXA) were tested for single-event gate rupture (SEGR) and single-event burnout (SEB). The safe-operating area (SOA) of the 2SK4217 (a 100 V rated device), 2SK4152 (130 V), 2SK4155 (200 V), and 2SK4158 (250 V) MOSFETs were tested with silver (Ag) and xenon (Xe) ions having incident linear energy transfers (LETs) of 42.2 and 53.1 MeV cm^2/mg, respectively. Test results show these devices are comparable to currently available total dose hardened technology.

It is recommended that reliability testing be undertaken for these device types, i.e., infant mortality, lifetime testing and dose-history effects on SEGR/SEB. The resulting information could be valuable information for spacecraft designers.

TABLE OF CONTENTS

1. Introduction

The metal-oxide-semiconductor field-effect transistor (MOSFET) is the most widely used transistor onboard a spacecraft. The MOSFET is typically employed in digital and analog circuits. It is a device designed to route or switch electrical power and is typically utilized to regulate high voltages and currents, i.e., from hundreds to several thousand volts (V) and up to a hundred amperes (A). On board a spacecraft, power MOSFETs are used as part of a multiplex bus architecture, where microcontrollers and or actuators are used for initiating a predetermined set of events, i.e., deploying a parachute, firing retrorockets, etc. Devices like power MOSFETs are sensitive to heavy ion irradiation and can fail catastrophically as a result of single-event gate rupture (SEGR), or single-event burnout (SEB). Manufacturers design radiation-hardened power MOSFETs for space applications. These radiation-hardened devices are not impervious to SEGR or SEB, but rather can succumb to them at a much larger linear energy transfer (LET) than their non-radiation hardened counterparts.

Over the last two decades, spacecraft designers have seen a reduction in the number of manufacturers that produce radiation-hardened power MOSFETs. In 1994, Nichols et al. [1] indicated that out of the eight manufacturers whose power MOSFETs were tested by the radiation community at large, only three were producing radiation-hardened power MOSFETs. In the mid-1990s [2–3] that number had decreased to only two, and in recent years only one manufacturer has produced for Hi-Rel space applications.

Recently, Fuji Electric Device Technology Co. Ltd (FDT) in conjunction with the Japan Aerospace Exploration Agency (JAXA) developed a radiation-hardened n-channel power MOSFET. The voltage ratings for these devices range from 100 V to 500 V. The technology was presented at the 17th Microelectronics Workshop in 2004 and has undergone Qualification Testing (QT) in accordance with JAXA requirements [4]. Some data has been presented as in [5], but data tested to an acceptable NASA standard has yet to be presented. In this study, we present data taken according to the current NASA test standards [6]. The devices tested are the 2SK4217 (a 100 V rated device), 2SK4152 (130 V), 2SK4155 (200 V), and 2SK4158 (250 V) radiation-hardened power MOSFETs (100 krad).

This document is organized as follows: Section 1 provides an introduction; Section 2 discusses the single-event effects (SEE) beam parameters, device characterization, selected test vehicle, experimental setup, bias conditions during irradiation, failure condition, and error analysis; Section 3 describes the results, the safe-operating area (SOA), the observed failure modes (OFM), two examples, and a brief observation on the general trend; Section 4 presents and describes the conclusion, discussion, and recommendation of the study; Section 5 contains the raw data, i.e., graphs and figures; and Section 6 contains the references.

2. Test Methodology

2.1 SEE Beam Parameters

All SEE tests were conducted in accordance with reference [6]. All devices were tested at the Texas A&M University (TAMU) Cyclotron Facility. The ions selected for the experiment had a range greater than the thickness of the epitaxial layer of all test devices (>107 µm in silicon). The ions used were silver (Ag) and xenon (Xe) with an ion energy of 15 MeV/amu. The incident LET of the ion-beam post-aramic film and column of air was determined by TAMU and can be found at the following website: http://cyclotron.tamu.edu/ref/beams.php. For each irradiation, the device under test (DUT) was exposed to $\sim 1\times10^5$ ions/cm^2 at a flux of $\sim 1\times10^4$ ions/cm^2 per second; thus, each irradiation run lasted ~10 seconds.

2.2 Device Characterization Prior to Irradaition

Prior to any irradiation, the devices were electrically characterized using a Tektronix 371b curve tracer. Three types of non-destructive electrical measurements were performed on all devices: threshold voltage (Vth), transconductance (gm), and breakdown voltage (BV_{DSS}). If any of these parameters were observed to not reflect typical transistor operation, the part was excluded from the test population. None were excluded. Table 1 summarizes the results of all electrical measurements performed at JPL, prior to SEE testing, and by Fuji/JAXA, prior to shipping to JPL. In the table, the average electrical measurement is shown along with the standard deviation. The JPL and JAXA measurements differ in the pass/fail definition and test ranges used. For example, the current limit that defined breakdown voltage was set by JPL to 24 µA and by JAXA to 1 mA. The value of Table 1 is that the devices were statistically in family and thus none were damaged during transit.

Table 1. Pre-irradiation electrical measurements performed by JPL and Fuji for the devices used in this study.

Device (Voltage, Amperage)	Gm (S) Mean ± SD	Vth (V) Mean ± SD	R_{DS}(on) (mΩ)	BV_{DSS} (V) Mean ± SD	Tested at JPL or Fuji
2SK4217 (100 V, 42 A)	21.63 ± 1.20*	6.27 ± 0.36**	N/A	93.47 ± 0.52***	JPL
2SK4152 (130 V, 42 A)	22.14 ± 1.40*	6.43 ± 0.40**	N/A	147.72 ± 0.63***	JPL
2SK4155 (200 V, 42 A)	21.36 ± 1.60*	6.39 ± 0.33**	N/A	212.02 ± 0.78***	JPL
2SK4158 (250 V, 42 A)	21.11 ± 1.70*	6.21 ± 0.31**	N/A	266.90 ± 0.92***	JPL
2SK4217 (100 V, 42 A)	8.29 ± 0.60†	4.06 ± 0.17††	11†††	103.74 ± 0.27††††	Fuji
2SK4152 (130 V, 42 A)	19.90 ± 0.59†	4.19 ± 0.14††	15†††	147.20 ± 0.65††††	Fuji
2SK4155 (200 V, 42 A)	19.24 ± 0.76†	4.16 ± 0.12††	23†††	212.58 ± 0.80††††	Fuji
2SK4158 (250 V, 42 A)	19.64 ± 0.98†	4.12 ± 0.11††	33†††	267.89 ± 1.06††††	Fuji

* Vds = 6.5 V and Id = 10 A. ** Vds = 5 V and Id = 1 mA. *** Id = 24 µA.
† Vds = 25 V and Id = 2 1A. †† Vds = 5 V and Id = 1 mA. ††† I_D = 50% of rated I_D, V_{GS} = 12 V and †††† Id = 1 mA.

2.3 Selected Test Vehicle

The tested devices were packaged in the SMD-2 configuration with a die size of one block per one unit, i.e., 1/1. The block can be split into one, two, or four units. Splitting the block into one or more units effectively results in lowering the current capability of the fabricated device and increasing the maximum-on resistance (R_{DS}(on)) for a given voltage rating (Table 1).

Figure 1 shows the pre-irradiation measurements performed at JPL on all the devices (shown by device type). The series of graphs in Figure 1 show the transfer curve for each device type. The transconductance and threshold voltage were determined by the transfer curve. The error bars represent the standard deviation within the tested population, and are caused by a large part-to-part variation within each device type. Temperature was not monitored during these measurements. However, the threshold voltage and transconductance (slope of curves) were consistent between parts.

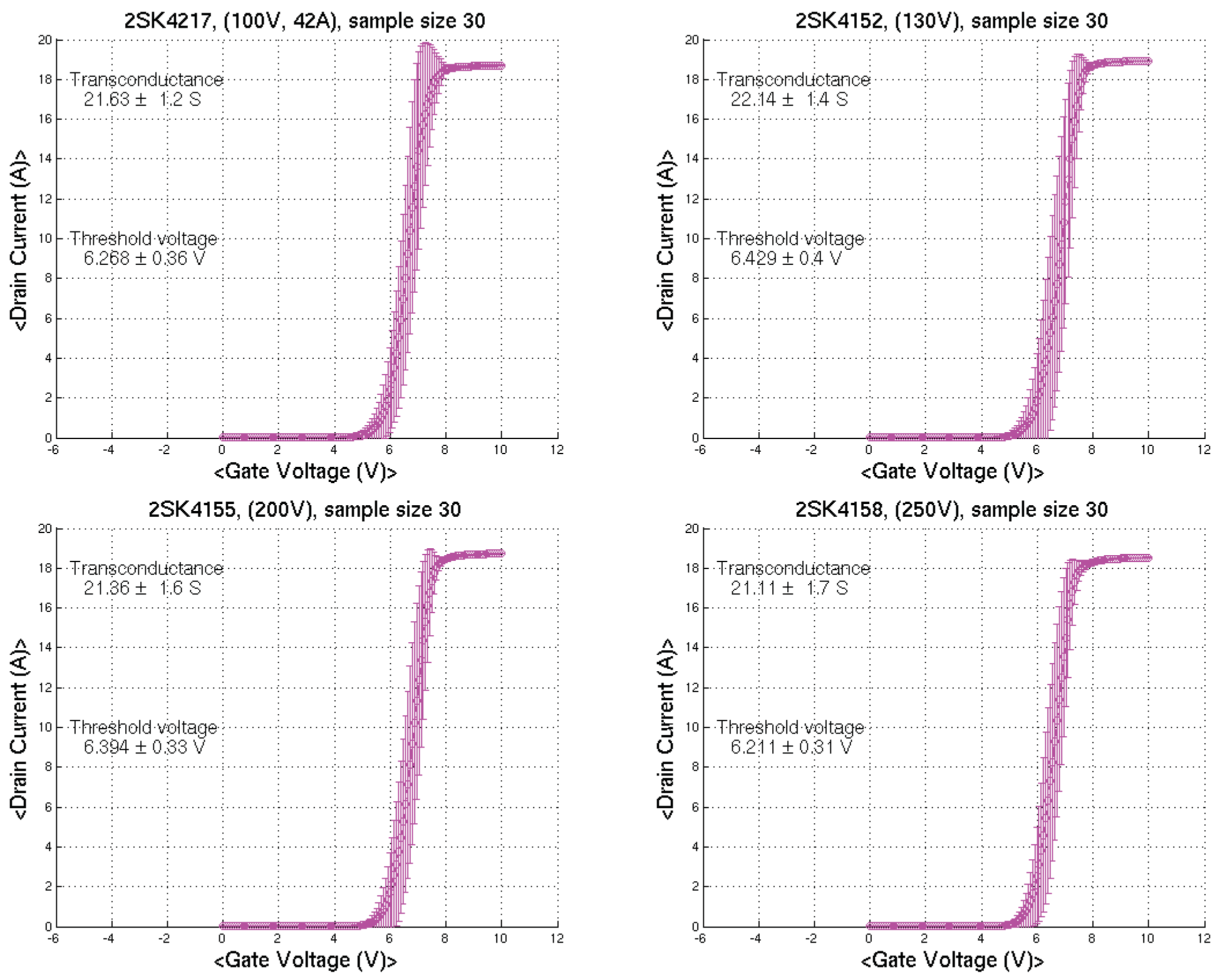


Figure 1. Pre-irradiation electrical measurements (i.e., transconductance and threshold voltage for each device type).

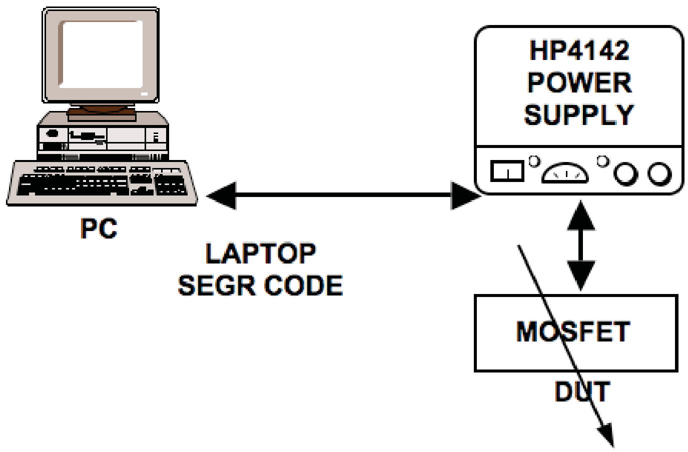


Figure 2. Schematic of experimental setup.

2.4 Experimental Setup

Figure 2 shows the schematic of the experimental setup used during the SEE testing. All devices were biased and measured with the HP4142B Modular DC Source/Monitor Unit (SMU) connected to a personal computer (PC) via a general-purpose instrument bus (GPIB). The current and voltage changes were measured at approximately 100 ms increments; the maximum current resolution of the SMU was 1 nA. Background noise in a virgin device typically had an amplitude of 60 nA. The manufacturer sent the devices without packaging for SEE testing.

2.4.1 Bias Conditions During Irradiation

During heavy ion exposure, test devices were continuously monitored for leakage currents through the gate, source, and drain terminals at a constant gate-to-source voltage (V_{GS}) and a constant drain-to-source voltage (V_{DS}). Between irradiations, the device was biased to ensure that no latent damage had occurred, but only at the previously irradiated bias, which is a variance from [6]. If the DUT was still operational, the voltage was increased and the device was irradiated again. Bias conditions during irradiation consisted of V_{GS} held constant, with V_{DS} incremented at each exposure until catastrophic failure.

2.4.2 Failure Condition

SEGR was defined as the drain-to-source voltage at which the current from gate-to-drain or gate-to-source permanently exceeded 1 µA; this variable is called Vcrit. The mean SEGR voltage value was determined by computing the arithmetic average of the "last pass" voltage and the voltage at "failure." Since the definition of the SEGR voltage is the average voltage at which the DUT exhibited an SEE and the voltage of the previous irradiation, a valid data point is one where the DUT exhibited no failures (SEGR or SEB) for at least one complete irradiation run. One type of SEGR occurs when the gate and drain currents exceed 1 µA; the source current is not altered by the catastrophic event, i.e., the large current is from gate to drain. SEGR can also manifest itself as high gate and source currents that exceed 1 µA, while the drain stays intact. SEB, on the other hand, exhibits a high source to drain current. The functionality of the gate is retained following the event. However, current control is no longer possible as the properties of the semiconductor have been damaged.

2.4.3 Error Bars

The voltage steps (system resolution, SR) were chosen to be 5% of the device voltage rating. The error bars associated with each data point on the safe-operating area (SOA) curve were computed by taking the square root of the sum of the squares of the uncertainty in each measurement (SR) and the standard deviation (SD) of all measurements on multiple device samples performed at the specific V_{DS} and V_{GS} bias condition.

2.4.4 Part Inventory

In order to map out the entire SOA of a power MOSFET for a given LET, many devices had to be tested destructively. Thirty parts per device type were available for testing. The parts were divided into two equal groups for each LET. Each group was subdivided into four groups of three parts. The four groups of three parts were used to test the following bias (V_{GS}) conditions: 0 V, −5 V, −10 V, and−15 V. Six parts were kept in reserve. Thus, a strategy was formulated whereby we could maximize the amount of information that could be acquired from the viable parts.

3. Results

Overall, the radiation response of these devices yielded comparable SEE responses as currently available total ionizing dose (TID)-hardened power MOSFETs. Device electrical characterization performed prior to irradiation yielded a part-to-part variation of less than 10% (see Section 4.1). SEE variability, defined as part-to-part variation under identical test conditions, ranged from 0% to ~41% (see Section 4.1). The greatest SEE variability was observed for the 53.1 MeV cm^2/mg incident ion.

Figure 3 is a strip chart of a typical SEGR event. The gate current is shown in blue, drain current in green, and source current in red. For this run, the gate-to-source voltage (V_{GS}) was held constant at −15 V, while the drain-to-source voltage (V_{DS}) was increased between irradiations by 5% of the device voltage rating, in this case 5 V. The black dashed line represents V_{DS} and its value can be read on the secondary Y-axis. As an example, according to the data, the last clean pass (without a failure) was when V_{DS} was set at 30 V and SEGR occurred at 35 V. Thus, the data point that is plotted on the SOA curve is V_{DS} = 32.5 V ± 2.5 V with a V_{GS} = −15 V.

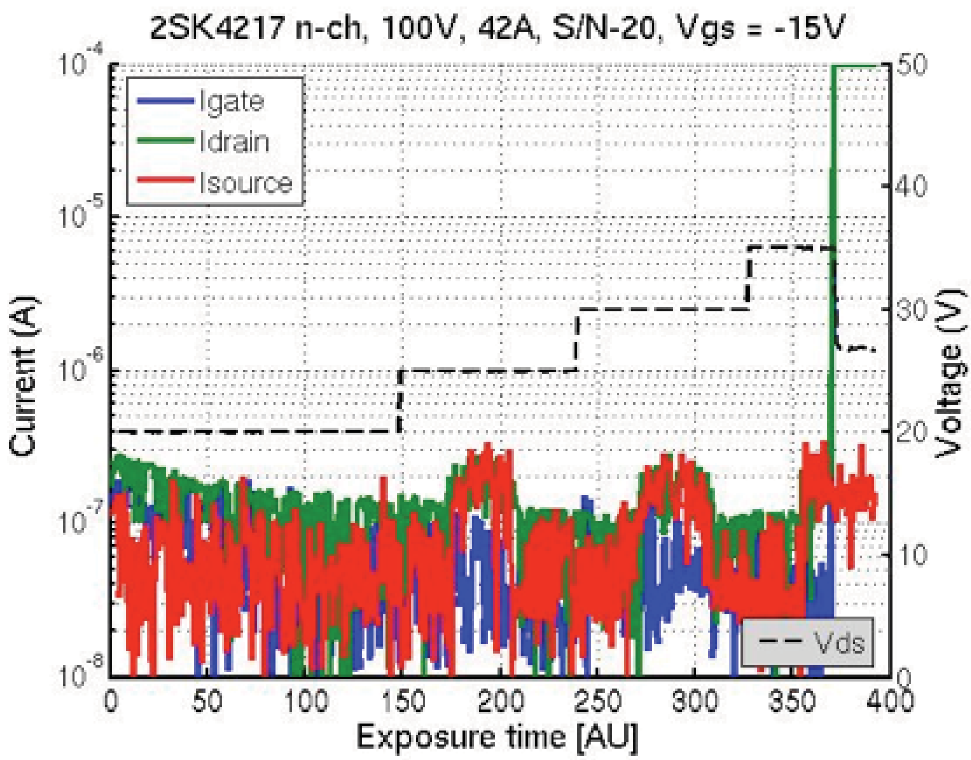


Figure 3. In-situ measurement of the 2SK4217 (100 V) device showing gate rupture. The black line is V_{DS} and uses the scale on the right.

3.1 Safe-Operating Area (SOA)

Figures 4a through 4d show the SOA curves of the four Hi-Rel Fuji devices tested. Not surprisingly, the larger LET reduced the SOA. The Vcrit value decreases as gate-to-source bias decreases, which is typical of non-SEE hardened parts. These results are comparable to similar devices tested in previous studies [7]. No significant anomalies were seen in any of the test data; however, the frequency of latent damage events (that is, SEGR events that result in gate leakage currents below the SEGR definition) was observed to be higher than previous data [8].

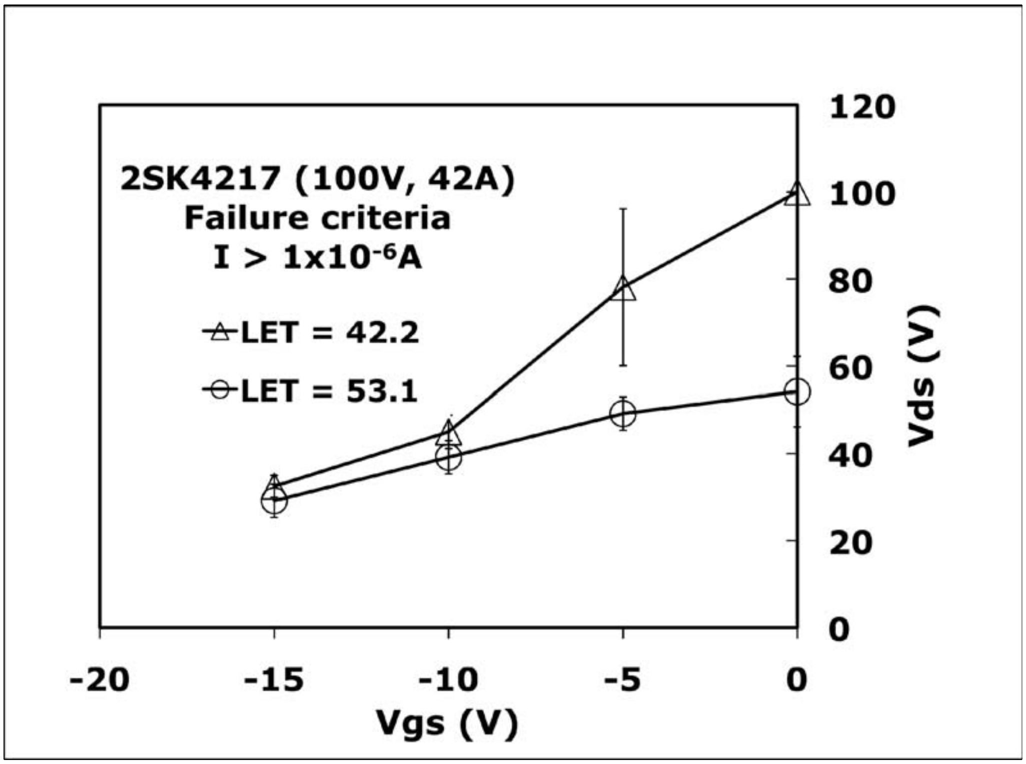


Figure 4a. SOA curves for the 2SK4217 (100 V) radiation-hardened power MOSFET tested using long-range ions with incident LETs of 42.2 and 53.1 MeV cm^2/mg.

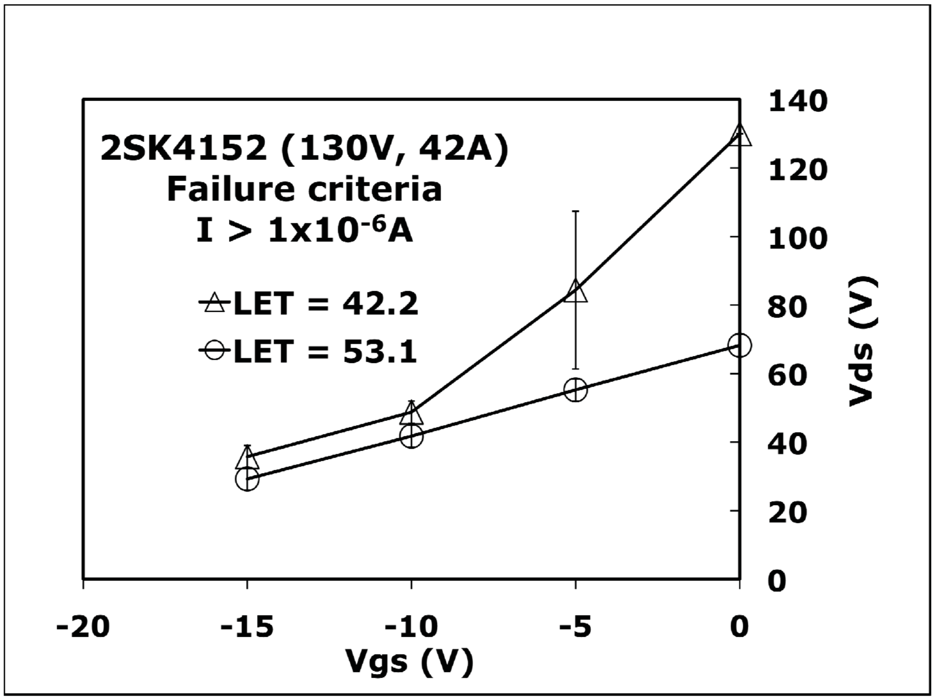


Figure 4b. SOA curves for the 2SK4152 (130 V) radiation-hardened power MOSFET tested using long-range ions with incident LETs of 42.2 and 53.1 MeV cm^2/mg.

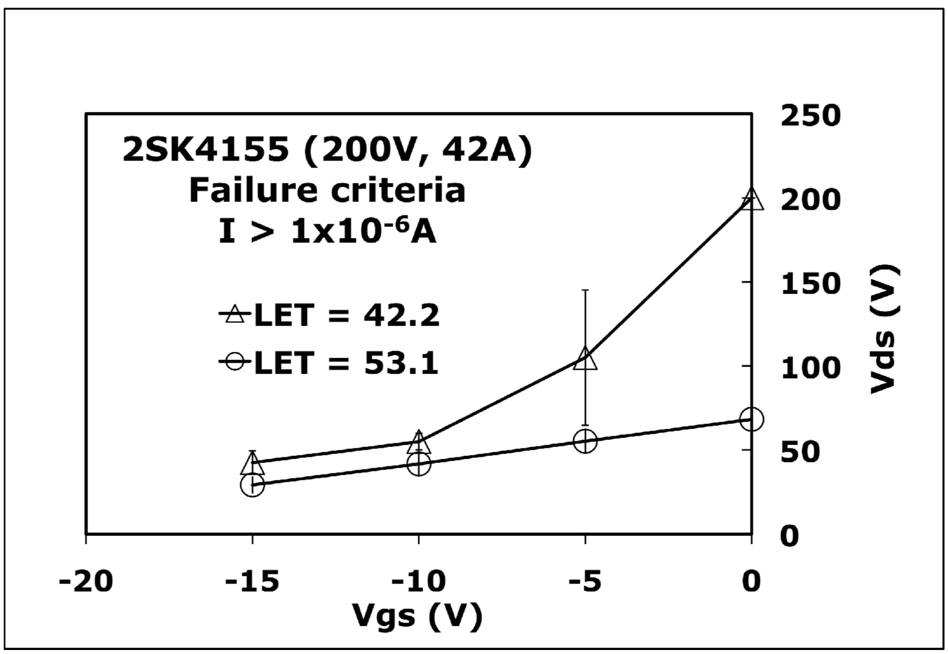


Figure 4c. SOA curves for the 2SK4155 (200 V) radiation-hardened power MOSFET tested using long-range ions with incident LETs of 42.2 and 53.1 MeV cm^2/mg.

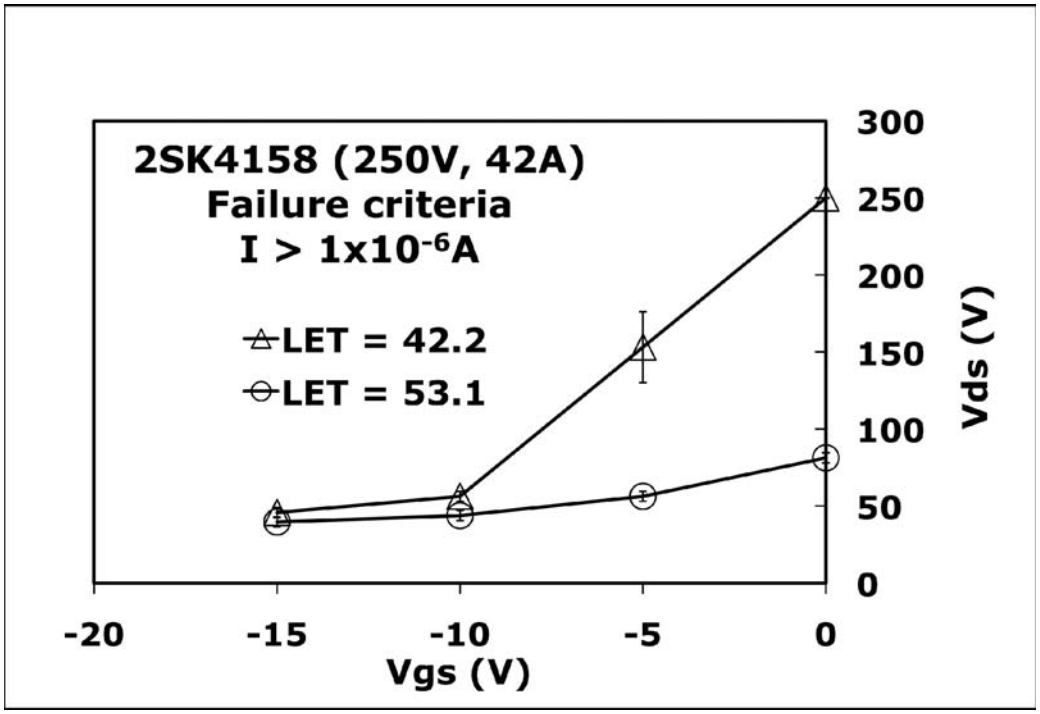


Figure 4d. SOA curves for the 2SK4158 (250 V) radiation-hardened power MOSFET tested using long-range ions with incident LETs of 42.2 and 53.1 MeV cm^2/mg.

3.2 Normalized Observed Failure Mode

In order to depict the relative frequency of SEB and SEGR, plots of the event frequency are shown in 3D format. These plots allow for analysis of what SEE type dominates for various operation conditions, and for investigation of how the SOA depends on the operation mode. These plots, which are similar to Schmoo plots, are valuable in evaluating new technologies like these. For example, when designing an SEB resistant circuit, knowing which operation conditions are likely to enhance SEB or SEGR, can be easily be determined from Figure 5.

Figure 5 plots the normalized failure modes (SEGR, SEB, and SEGR+SEB) that were observed for each of the tested device types for a range of bias conditions and incident LETs. The SEGR+SEB failure mode is not an arithmetic superposition of SEGR and SEB, but rather a failure where SEGR and SEB occur simultaneously. The left column in Figure 5 displays plots for silver ions, and the right column displays plots for xenon ions. The X- and Y-axis correspond to the applied bias conditions (V_{GS} and V_{DS}) seen on the SOA curves. Error bars are shown in the V_{DS} (Y-axis) only. The Z-axis represents the normalized observed failure modes (in percent) for the sampled devices at the applied V_{GS} and V_{DS} bias. The Z-axis represents the normalized observed failure modes (in percent) for the sampled devices at the applied V_{GS} and V_{DS} bias.

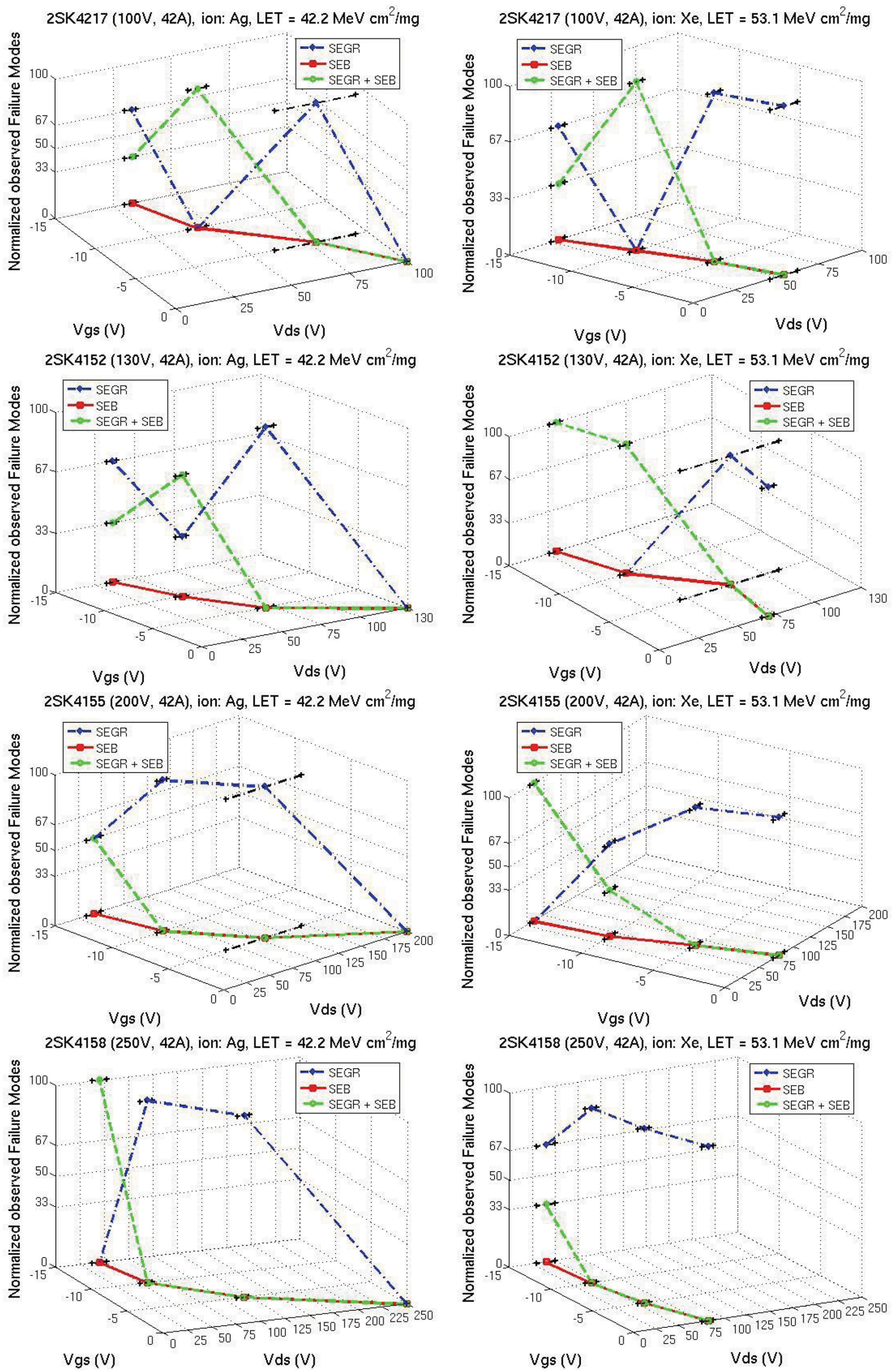


Figure 5. Normalized observed failure modes for all tested device types as a function of bias conditions and incident LET; plots for silver ions (*left column*) and plots for xenon ions (*right column*).

3.2.1 *Example 1, No Failure below V_{DS} Rating When V_{GS} = 0V*

The first example highlights the condition where the device did not experience a failure below its rated voltage (V_{DS}) when V_{GS} was set to zero. On the top left plot of Figure 5 (2SK4217, LET = 42.2 MeV cm^2/mg), V_{DS} was systematically increased from zero volts up to the rated voltage (100 V) and no SEGR or SEB or a combination of SEGR and SEB (SEGR+SEB) were observed. Thus, the percent of failure as a result of SEGR or SEB or SEGR+SEB was zero. As V_{GS} was decreased, we observed the onset of various failure modes. At V_{GS} of −5.0 V, all of the devices failed below the rated voltage with a clear signature of SEGR. The failures occurred for V_{DS} between 60.5 V and 94.5 V. At V_{GS} of −10.0 V, none of the devices failed through SEGR, but rather through SEGR+SEB. At V_{GS} of −15.0 V, 67% of the devices failed through SEGR and 33% via SEGR+SEB. These failures occurred for V_{DS} between 30.0 V and 35.0 V. SEB was never observed as a single failure mode, instead it was always found in conjunction with SEGR, i.e., SEGR+SEB.

3.2.2 *Example 2, Failure Below V_{DS} Rating When V_{GS} = 0V*

The second example highlights the condition where the device experiences a failure well below its rated voltage when V_{GS} was set to zero. On the top right plot of Figure 5 (2SK4217, LET = 53.1 MeV cm^2/mg), at V_{GS} of 0 V, all of the devices failed below the rated voltage with a clear signature of SEGR. The failures occurred for V_{DS} between 45.5 V and 53.0 V. As V_{GS} was decreased, we observed the onset of the SEGR+SEB failure mode. At V_{GS} of −10 V all of the devices failed through SEGR+SEB. These failures occurred for V_{DS} between 35.4 V and 43.0 V. At V_{GS} of −15.0 V, 67% of the devices failed through SEGR and 33% via SEGR+SEB. These failures occurred for V_{DS} between 25.4 V and 33.0 V. SEB was never observed as a single failure mode, instead it was always found in conjunction with SEGR, i.e., SEGR+SEB.

3.3 General Trends

Figure 5 displays some obvious trends. All of the devices were immune to SEE at V_{GS} = 0.0 V when tested with silver ions (LET = 42.2 MeV cm^2/mg). SEGR and SEGR+SEB failure modes were more likely to occur for both Ag and Xe ions when V_{GS} was set below 0 V. As mentioned previously, SEB was never observed as a single failure mode, but rather in concert with SEGR, i.e., SEGR+SEB.

Another observed trend revealed that failed devices irradiated while under relatively low bias conditions (V_{GS} = 0 V and −5 V) were found to still be partially operational; that is, the devices were leaky (I_G ~10 μA). This trend was not observed for devices irradiated under V_{GS} values of −10 V and −15 V.

4. Conclusion

SEGR and SEB test results of the Fuji power MOSFETs that have emerged onto the catalog of available devices show that these devices yield comparable SEE responses as power MOSFETs devices that are TID hardened.

4.1 Discussion

Following electrical characterization, we defined part-to-part variability as the quotient between the standard deviation and mean value, e.g., (SD)/(mean electrical value). Table 2 shows the results. Electrical variability was below 10% for all device types tested.

SEE variability was computed as described above. The SEE variability is tabulated in Table 3 for the tested device types as a function of incident ion LET and bias condition. In Table 3, the grey highlighted area denotes SEE variability in excess of 10% (arbitrarily cutoff). Note that for the explored bias space (from V_{GS} of 0 V to –15 V), SEE variability increased with LET for a given device type. For example, for the 2SK4217 device irradiated with Ag ions, the number of boxes whose SEE variability exceeded 10% was 1. While, under Xe irradiation, the number of grey boxes with SEE variability of over 10% was 2. The reason behind the increase of SEE variability with LET is presently not clear and may need to be investigated in the future.

4.2 Recommendation

It is recommended that reliability testing be undertaken for these device types, i.e., infant mortality, lifetime testing, and dose-history effects on SEGR/SEB. Results from those experiments would provide a wealth of valuable information to spacecraft designers.

Table 2. Part-to-part variability results, calculation based on electrical measurements conducted at JPL prior to SEE testing.

Device (Voltage, Amperage)	Threshold Voltage Variability between Parts (%)	Transconductance Variability between Parts (%)
2SK4217 (100 V, 42 A)	6.3	5.5
2SK4152 (130 V, 42 A)	6.3	6.3
2SK4155 (200 V, 42 A)	5.2	7.5
2SK4158 (250 V, 42 A)	4.8	8.1

Table 3. SEE part-to-part variability results, calculations based on heavy ion irradiations (SEE measurements) conducted at Texas A&M Cyclotron Facility.

Device (Voltage, Amperage)	LET (Ag) = 42.2 MeV cm^2/mg				LET (Xe) = 53.1 MeV cm^2/mg			
	V_{GS} = 0 V	V_{GS} = -5 V	V_{GS} = -10 V	V_{GS} = -15 V	V_{GS} = 0 V	V_{GS} = -5 V	V_{GS} = -10 V	V_{GS} = -15 V
2SK4217 (100 V, 42 A)	0.0%	23.1%	8.5%	7.7%	14.8%	7.8%	9.8%	13.1%
2SK4152 (130 V, 42 A)	0.0%	27.3%	6.7%	9.1%	4.7%	5.9%	7.8%	11.1%
2SK4155 (200 V, 42 A)	0.0%	38.4%	9.1%	16.6%	10.8%	12.4%	18.3%	14.3%
2SK4158 (250 V, 42 A)	0.0%	37.7%	11.1%	14.8%	7.7%	11.1%	14.3%	24.1%

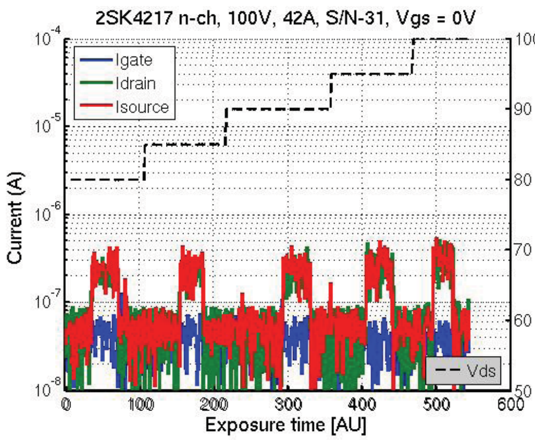
5. Rawdata (In-Situ)

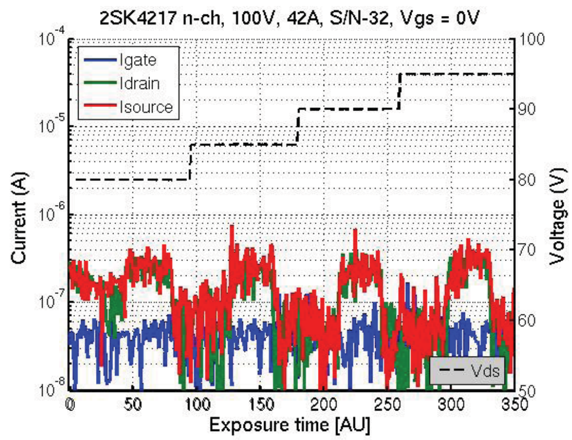
Data acquired during all irradiations are listed here by device type and bias condition.

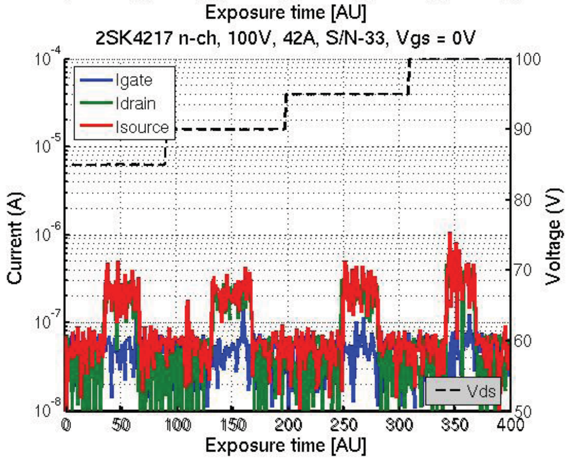
5.1 Beam Parameters

Two types of energetic heavy ions were used to acquire the data in this section—silver (Ag) ions with beam energy of 1289 MeV, with an incident LET of 42.2 MeV cm^2/mg, and a range in silicon (Si) of 119.3 µm; and xenon (Xe) ions with beam energy of 1366 MeV, with an incident LET of 53.1 MeV cm^2/mg, and a range in Si of 107.7 µm. During all irradiations, the fluence step was maintained at ~1×10^5 ions/cm^2.

5.1.1 2SK4217 (100 V, 42 A), Ag ion, bias condition V_{GS} =0 V:



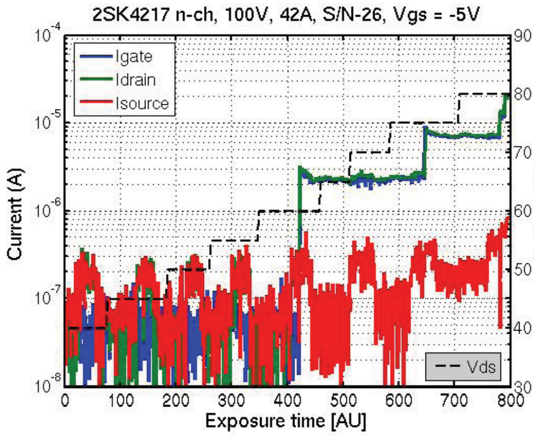


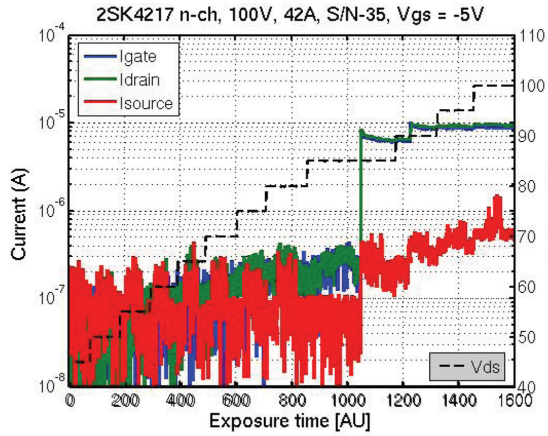


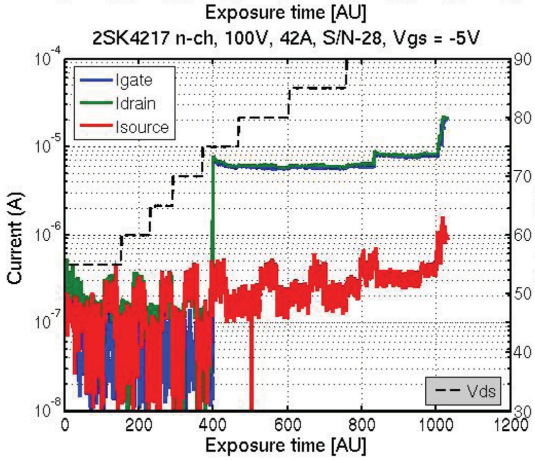
S/N	Failure Criteria 1: I_G >1 µA V_{DS} (V) Pass	Failure Criteria 1: Failed	Failure Criteria 2: I_G >10 µA V_{DS} (V) Pass	Failure Criteria 2: Failed	Failure Mode: SEGR or SEB
31	100.00	No failure	100.00	No failure	No failure
32	100.00	No failure	100.00	No failure	No failure
33	100.00	No failure	100.00	No failure	No failure

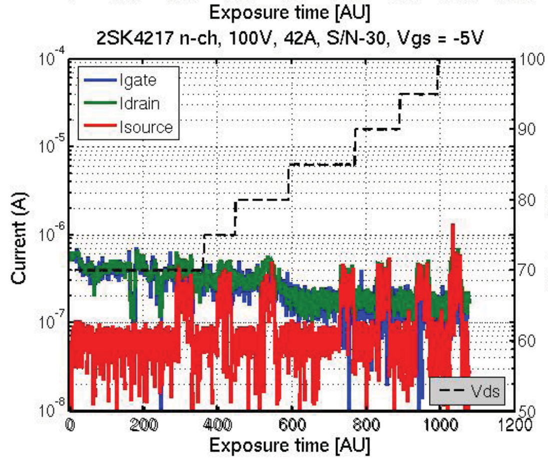
Plot Point(s)			
Failure Criteria 1: I_G > 1µA	V_{GS} (V) = 0.00	V_{DS} (V) = 100.00	Error bar (V) = ± 0.00
Failure Criteria 2: I_G > 10µA	V_{GS} (V) = 0.00	V_{DS} (V) = 100.00	Error bar (V) = ± 0.00

5.1.2 2SK4217 (100 V, 42 A), Ag ion, bias condition V_{GS} = –5 V:



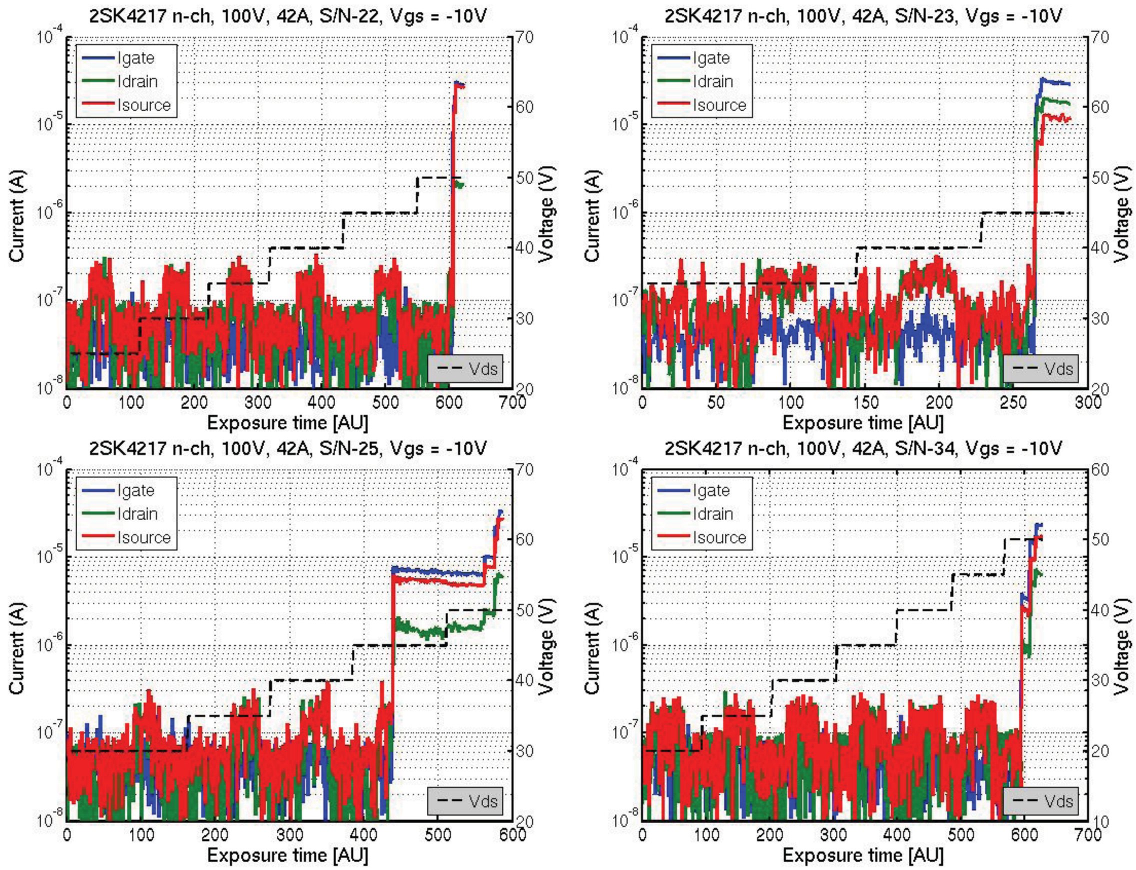






S/N	Failure Criteria 1: I_G >1 µA V_{DS} (V)		Failure Criteria 2: I_G >10 µA V_{DS} (V)		Failure Mode: SEGR or SEB
	Pass	Failed	Pass	Failed	
26	55.00	60.00	75.00	80.00	SEGR
35	80.00	85.00	95.00	100.00	SEGR
28	70.00	75.00	90.00	95.00	SEGR
30	100.00	No failure	100.00	No failure	No failure
Plot Point(s)					
Failure Criteria 1: I_G > 1 µA		V_{GS} (V) = –5.00	V_{DS} (V) = 78.13	Error bar (V) = ± 18.01	
Failure Criteria 2: I_G > 10 µA		V_{GS} (V) = –5.00	V_{DS} (V) = 91.88	Error bar (V) = ± 10.08	

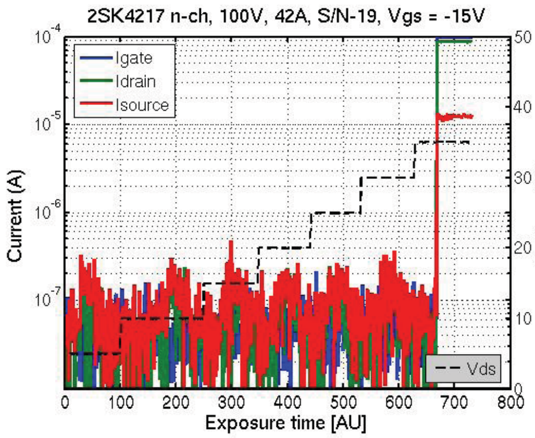
5.1.3 2SK4217 (100 V, 42 A), Ag ion, bias condition V_{GS} = –10 V:

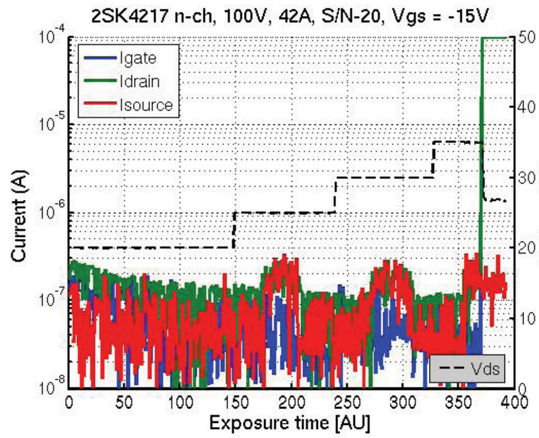


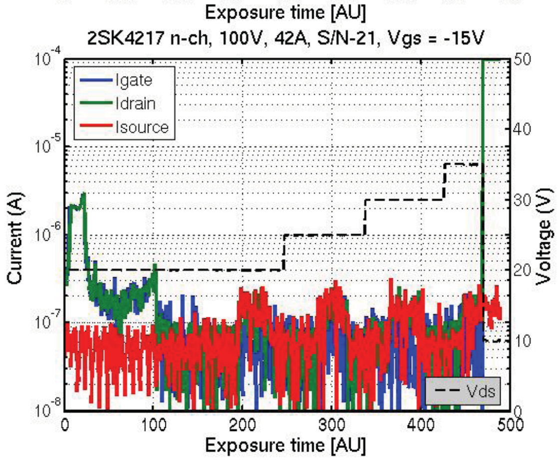
S/N	Failure Criteria 1: I_G >1 µA V_{DS} (V)		Failure Criteria 2: I_G >10 µA V_{DS} (V)		Failure Mode: SEGR or SEB
	Pass	Failed	Pass	Failed	
22	45.00	50.00	45.00	50.00	SEGR & SEB
23	40.00	45.00	40.00	45.00	SEGR & SEB
25	40.00	45.00	45.00	50.00	SEGR & SEB
34	45.00	50.00	45.00	50.00	SEGR & SEB

Plot Point(s)			
Failure Criteria 1: I_G > 1 µA	V_{GS} (V) = –10.00	V_{DS} (V) = 45.00	Error bar (V) = ± 3.82
Failure Criteria 2: I_G > 10 µA	V_{GS} (V) = –10.00	V_{DS} (V) = 46.25	Error bar (V) = ± 3.54

5.1.4 *2SK4217 (100 V, 42 A), Ag ion, bias condition $V_{GS} = -15$ V:*

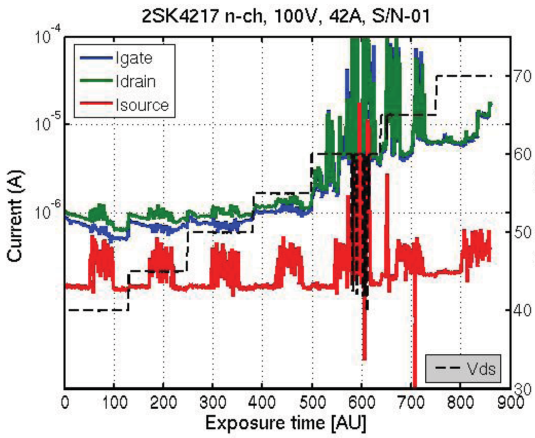


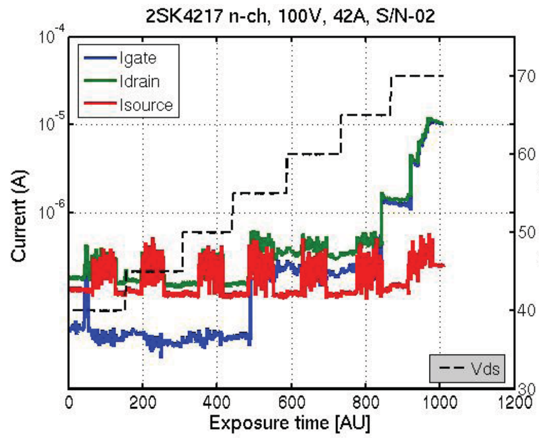


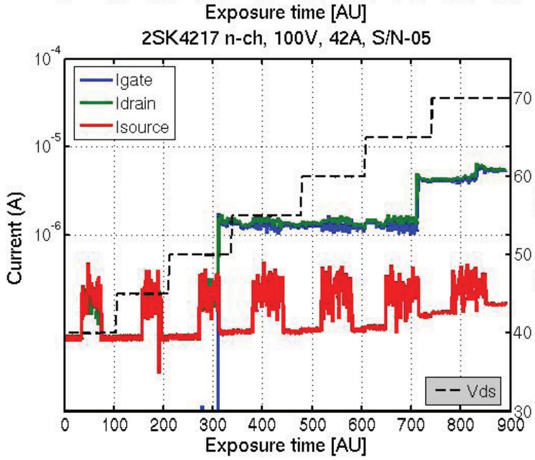


S/N	Failure Criteria 1: I_G >1 µA V_{DS} (V)		Failure Criteria 2: I_G >10 µA V_{DS} (V)		Failure Mode: SEGR or SEB
	Pass	**Failed**	**Pass**	**Failed**	
19	30.00	35.00	30.00	35.00	SEGR & SEB
20	30.00	35.00	30.00	35.00	SEGR
21	30.00	35.00	30.00	35.00	SEGR
Plot Point(s)					
Failure Criteria 1: I_G >1 µA	V_{GS} (V) = –15.00	V_{DS} (V) = 32.50	Error bar (V) = ± 2.50		
Failure Criteria 2: I_G >10 µA	V_{GS} (V) = –15.00	V_{DS} (V) = 32.50	Error bar (V) = ± 2.50		

5.1.5 2SK4217 (100 V, 42 A), Xe ion, bias condition V_{GS} = 0 V:

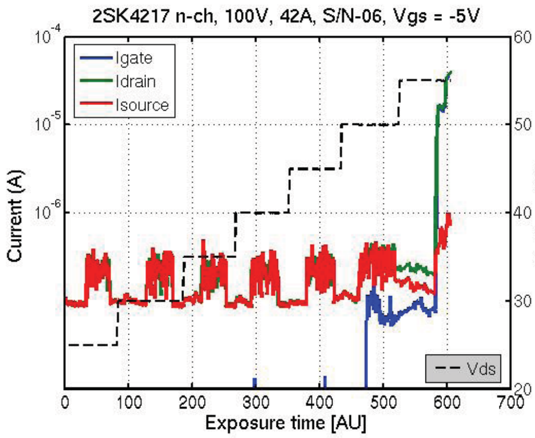


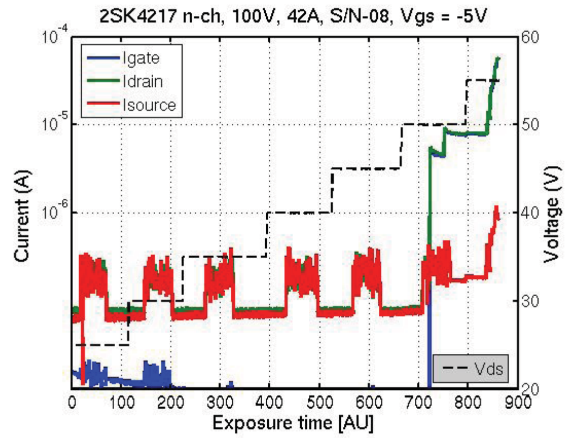


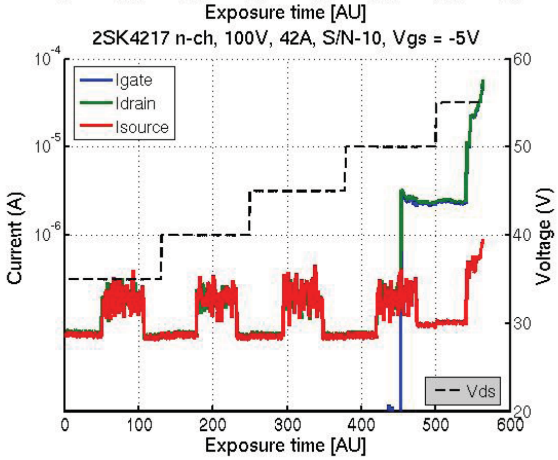


S/N	Failure Criteria 1: I_G >1 μA V_{DS} (V)		Failure Criteria 2: I_G >10 μA V_{DS} (V)		Failure Mode: SEGR or SEB
	Pass	Failed	Pass	Failed	
01	50.00	55.00	55.00	60.00	SEGR
02	60.00	65.00	65.00	70.00	SEGR
05	45.00	50.00	70.00	75.00	SEGR
Plot Point(s)					
Failure Criteria 1: I_G >1 μA		V_{GS} (V) = 0.00	V_{DS} (V) = 54.17	Error bar (V) = ± 8.04	
Failure Criteria 2: I_G >10 μA		V_{GS} (V) = 0.00	V_{DS} (V) = 65.83	Error bar (V) = ± 8.04	

5.1.6 2SK4217 (100 V, 42 A), Xe ion, bias condition V_{GS} = –5 V:



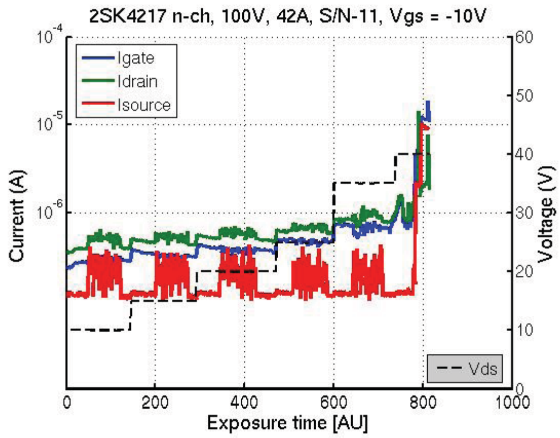


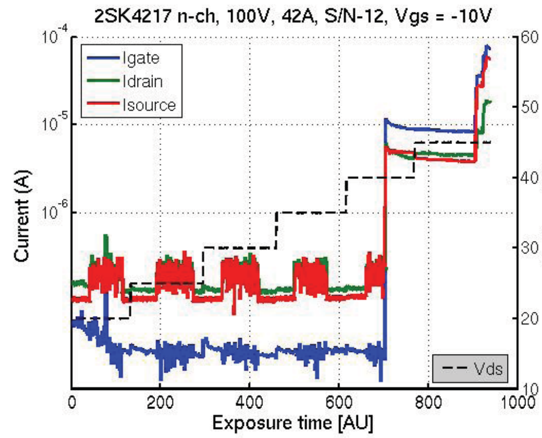


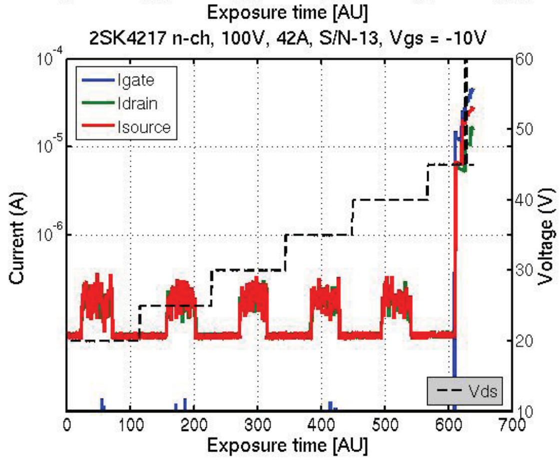
S/N	Failure Criteria 1: I_G >1 µA V_{DS} (V)		Failure Criteria 2: I_G >10 µA V_{DS} (V)		Failure Mode: SEGR or SEB
	Pass	Failed	Pass	Failed	
06	50.00	55.00	50.00	55.00	SEGR
08	45.00	50.00	50.00	55.00	SEGR
10	45.00	50.00	50.00	55.00	SEGR

Plot Point(s)			
Failure Criteria 1: I_G >1 µA	V_{GS} (V) = –5.00	V_{DS} (V) = 49.17	Error bar (V) = ± 3.82
Failure Criteria 2: I_G >10 µA	V_{GS} (V) = –5.00	V_{DS} (V) = 52.50	Error bar (V) = ± 2.50

5.1.7 *2SK4217 (100 V, 42 A), Xe ion, bias condition V_{GS} = –10 V:*

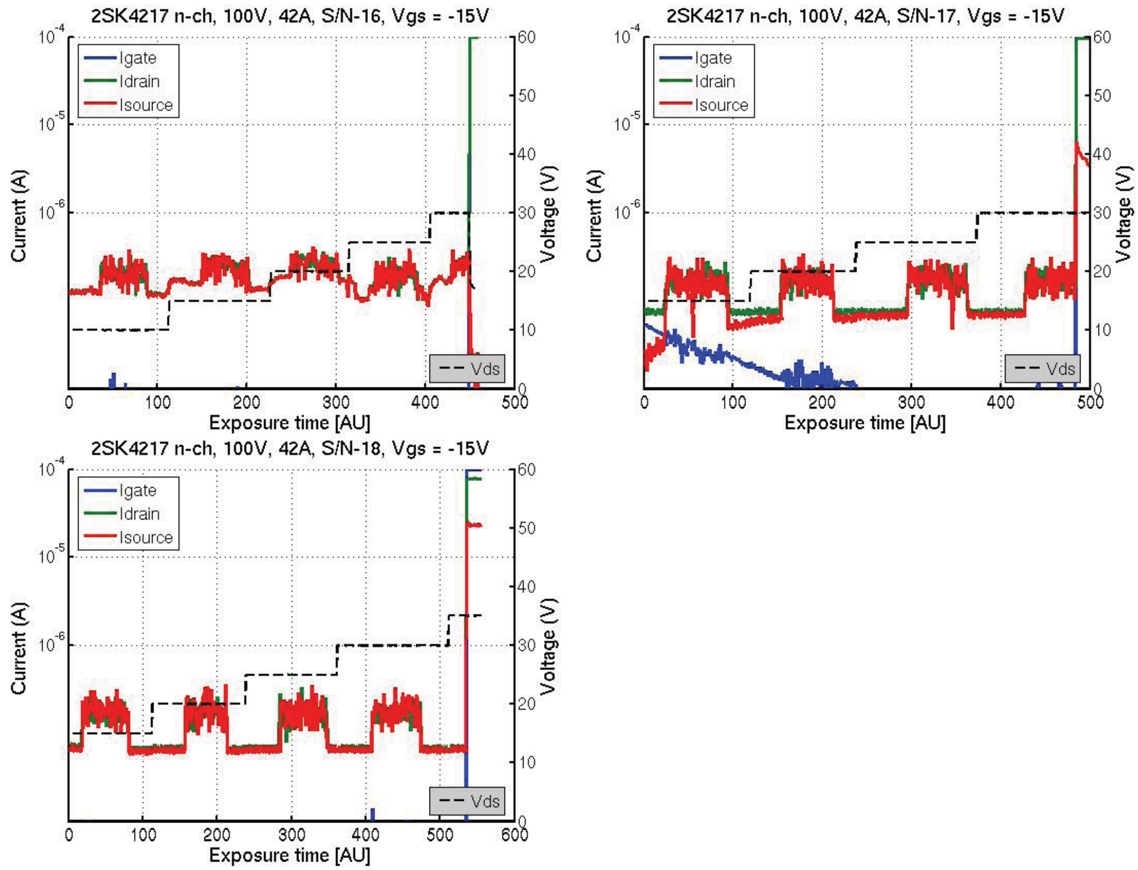






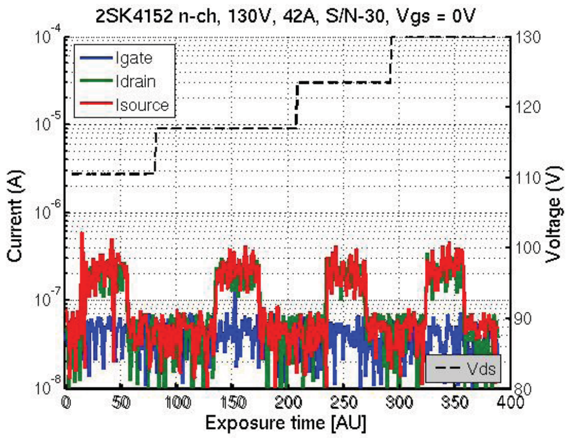
S/N	Failure Criteria 1: I_G >1 µA V_{DS} (V)		Failure Criteria 2: I_G >10 µA V_{DS} (V)		Failure Mode: SEGR or SEB
	Pass	Failed	Pass	Failed	
11	35.00	40.00	35.00	40.00	SEGR & SEB
12	35.00	40.00	35.00	40.00	SEGR & SEB
13	40.00	45.00	40.00	45.00	SEGR & SEB
Plot Point(s)					
Failure Criteria 1: I_G >1 µA		V_{GS} (V) = –10.00	V_{DS} (V) = 39.17	Error bar (V) = ± 3.82	
Failure Criteria 2: I_G >10 µA		V_{GS} (V) = –10.00	V_{DS} (V) = 39.17	Error bar (V) = ± 3.82	

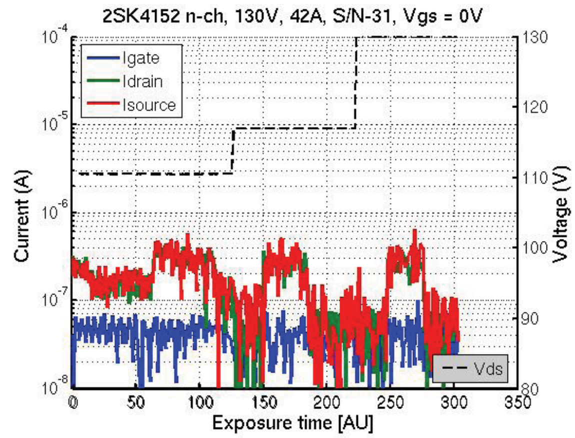
5.1.8 2SK4217 (100 V, 42 A), Xe ion, bias condition V_{GS} = –15 V:

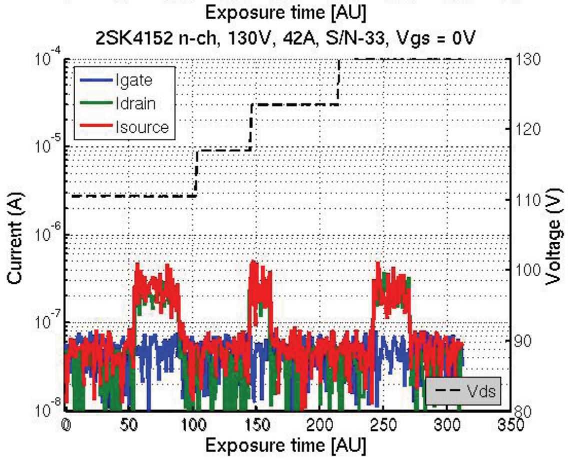


S/N	Failure Criteria 1: I_G >1 µA V_{DS} (V)		Failure Criteria 2: I_G >10 µA V_{DS} (V)		Failure Mode: SEGR or SEB
	Pass	Failed	Pass	Failed	
16	25.00	30.00	25.00	30.00	SEGR
17	25.00	30.00	25.00	30.00	SEGR & SEB
18	30.00	35.00	30.00	35.00	SEGR & SEB
Plot Point(s)					
Failure Criteria 1: I_G >1 µA		V_{GS} (V) = –15.00	V_{DS} (V) = 29.17	Error bar (V) = ± 3.82	
Failure Criteria 2: I_G >10 µA		V_{GS} (V) = –15.00	V_{DS} (V) = 29.17	Error bar (V) = ± 3.82	

5.2.1 *2SK4152 (130 V, 42 A), Ag ion, bias condition V_{GS} = 0 V:*

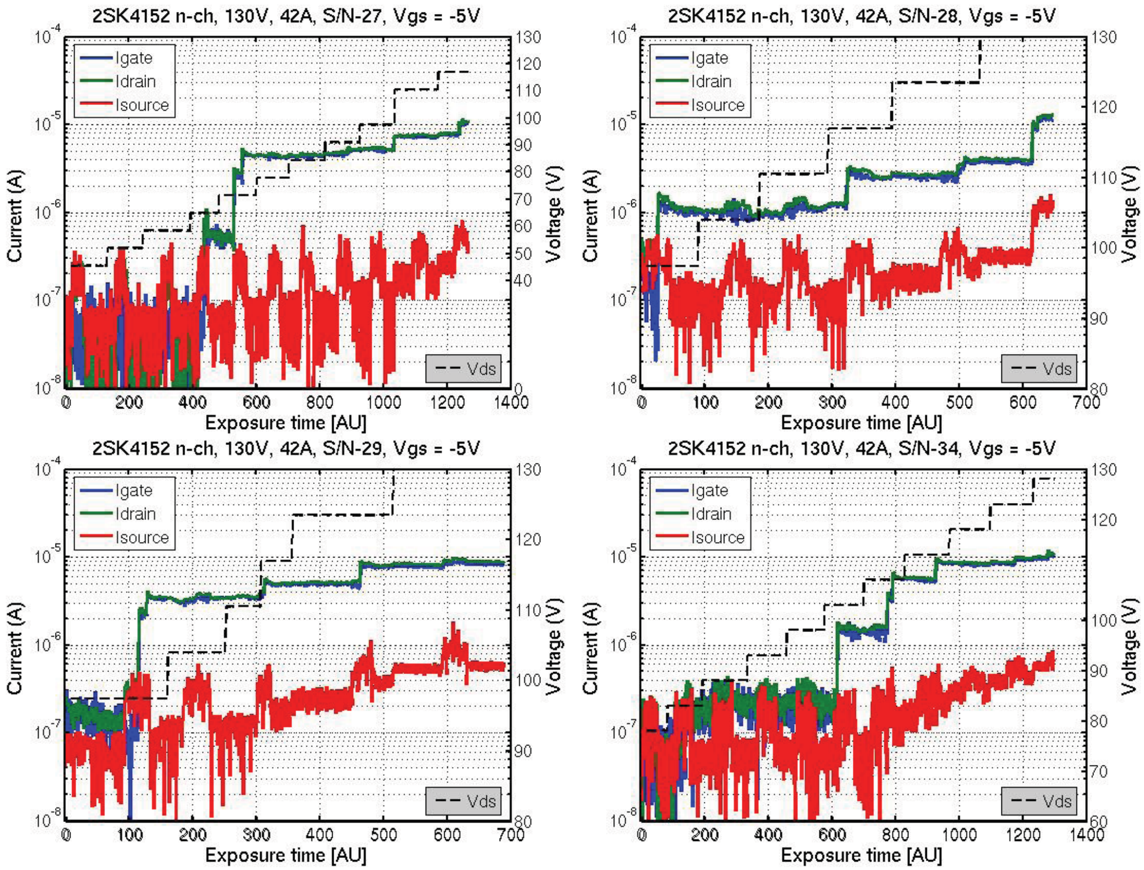






S/N	Failure Criteria 1: I_G >1 μA V_{DS} (V)		Failure Criteria 2: I_G >10 μA V_{DS} (V)		Failure Mode: SEGR or SEB
	Pass	Failed	Pass	Failed	
30	130.00	N/A	130.00	N/A	No failure
31	130.00	N/A	130.00	N/A	No failure
33	130.00	N/A	130.00	N/A	No failure
Plot Point(s)					
Failure Criteria 1: I_G >1 μA		V_{GS} (V) = 0.00	V_{DS} (V) = 130.00	Error bar (V) = ± 0.00	
Failure Criteria 2: I_G >10 μA		V_{GS} (V) = 0.00	V_{DS} (V) = 130.00	Error bar (V) = ± 0.00	

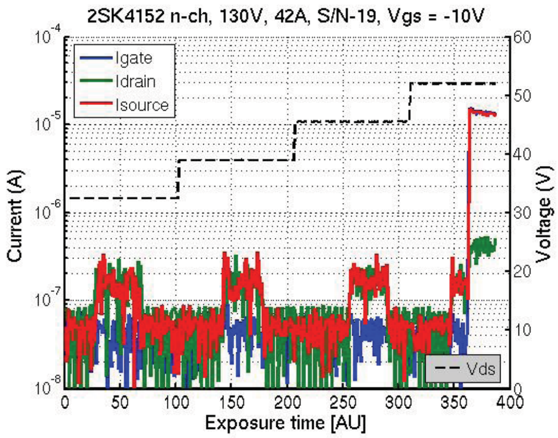
5.2.2 *2SK4152 (130 V, 42 A), Ag ion, bias condition V_{GS} = –5 V:*

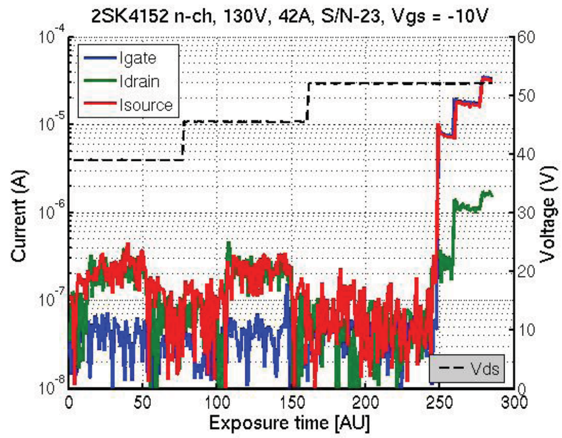


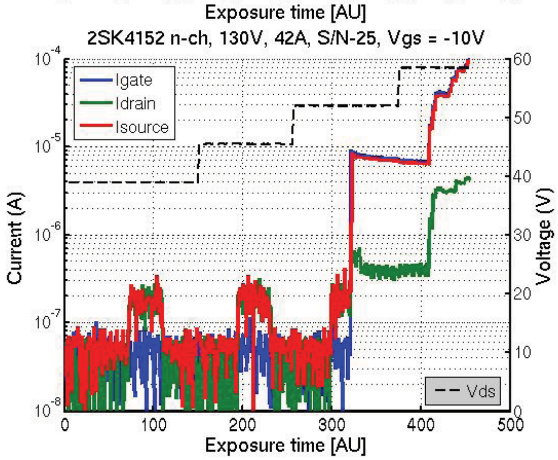
S/N	Failure Criteria 1: I_G >1 µA V_{DS} (V)		Failure Criteria 2: I_G >10 µA V_{DS} (V)		Failure Mode: SEGR or SEB
	Pass	Failed	Pass	Failed	
27	65.00	71.50	110.50	117.00	SEGR
28	N/A	N/A	123.50	130.00	SEGR
29	N/A	N/A	123.50	130.00	SEGR
34	98.00	103.00	121.50	128.00	SEGR

Plot Point(s)			
Failure Criteria 1: I_G >1 µA	V_{GS} (V) = –5.00	V_{DS} (V) = 84.38	Error bar (V) = ± 23.05
Failure Criteria 2: I_G >10 µA	V_{GS} (V) = –5.00	V_{DS} (V) = 123.00	Error bar (V) = ± 7.04

5.2.3 2SK4152 (130 V, 42 A), Ag ion, bias condition V_{GS} = –10 V:



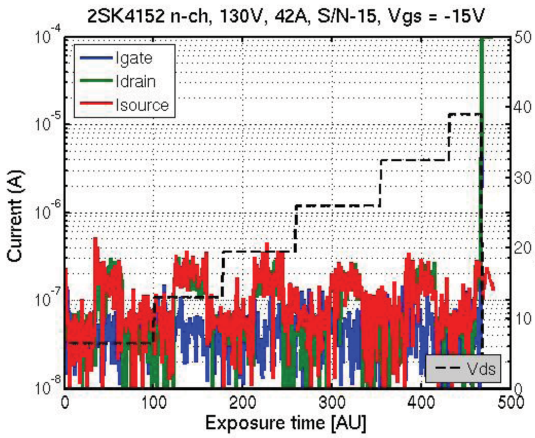


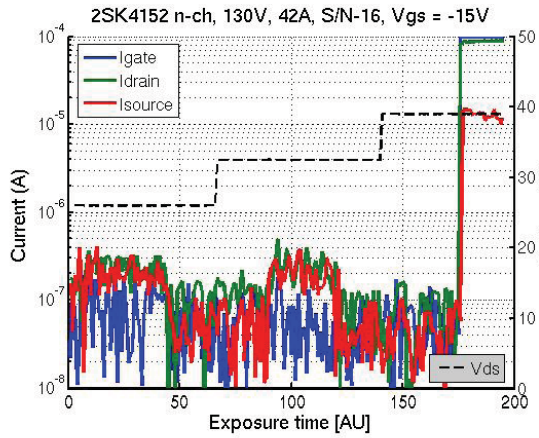


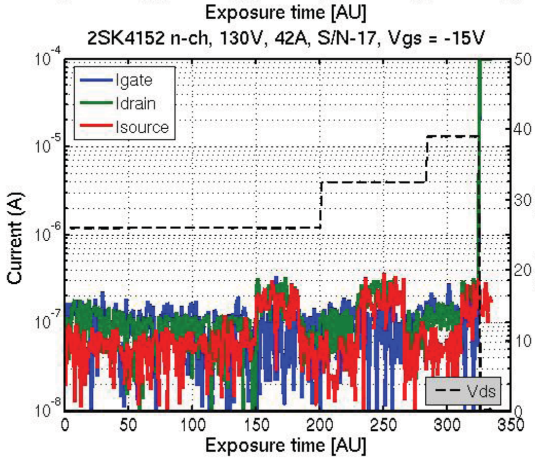
S/N	Failure Criteria 1: I_G >1 μA V_{DS} (V)		Failure Criteria 2: I_G >10 μA V_{DS} (V)		Failure Mode: SEGR or SEB
	Pass	Failed	Pass	Failed	
19	45.50	52.00	45.50	52.00	SEGR
23	45.50	52.00	45.50	52.00	SEGR & SEB
25	45.50	52.00	52.00	58.50	SEGR & SEB

Plot Point(s)			
Failure Criteria 1: I_G >1 μA	V_{GS} (V) = –10.00	V_{DS} (V) = 48.75	Error bar (V) = ± 3.25
Failure Criteria 2: I_G >10 μA	V_{GS} (V) = –10.00	V_{DS} (V) = 50.92	Error bar (V) = ± 4.96

5.2.4 2SK4152 (130 V, 42 A), Ag ion, bias condition V_{GS} = –15 V:

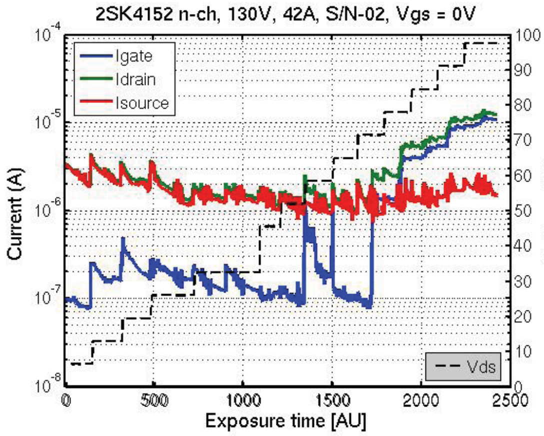


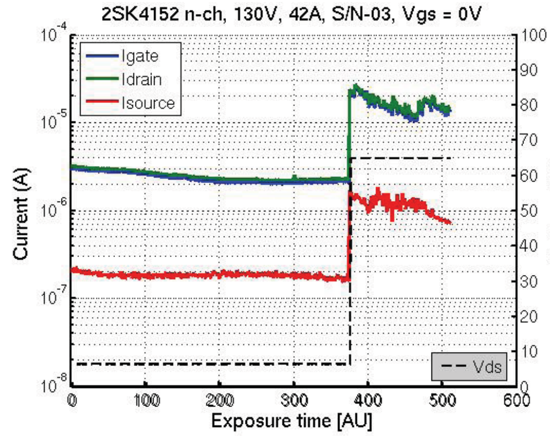


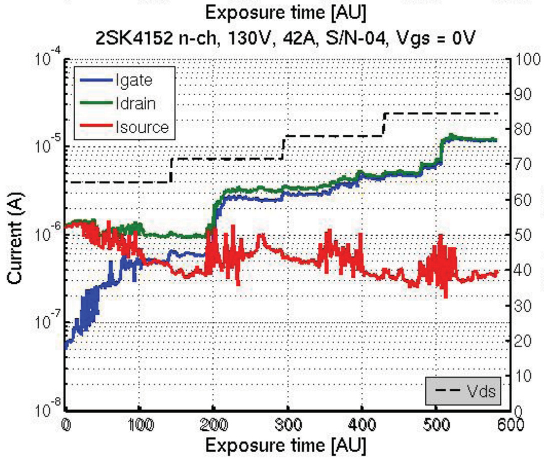


S/N	Failure Criteria 1: I_G >1 µA V_{DS} (V)		Failure Criteria 2: I_G >10 µA V_{DS} (V)		Failure Mode: SEGR or SEB
	Pass	Failed	Pass	Failed	
15	32.50	39.00	32.50	39.00	SEGR
16	32.50	39.00	32.50	39.00	SEGR & SEB
17	32.50	39.00	32.50	39.00	SEGR
Plot Point(s)					
Failure Criteria 1: I_G >1 µA		V_{GS} (V) = –15.00	V_{DS} (V) = 35.75		Error bar (V) = ± 3.25
Failure Criteria 2: I_G >10 µA		V_{GS} (V) = –15.00	V_{DS} (V) = 35.75		Error bar (V) = ± 3.25

5.2.5 2SK4152 (130 V, 42 A), Xe ion, bias condition V_{GS} = 0 V:



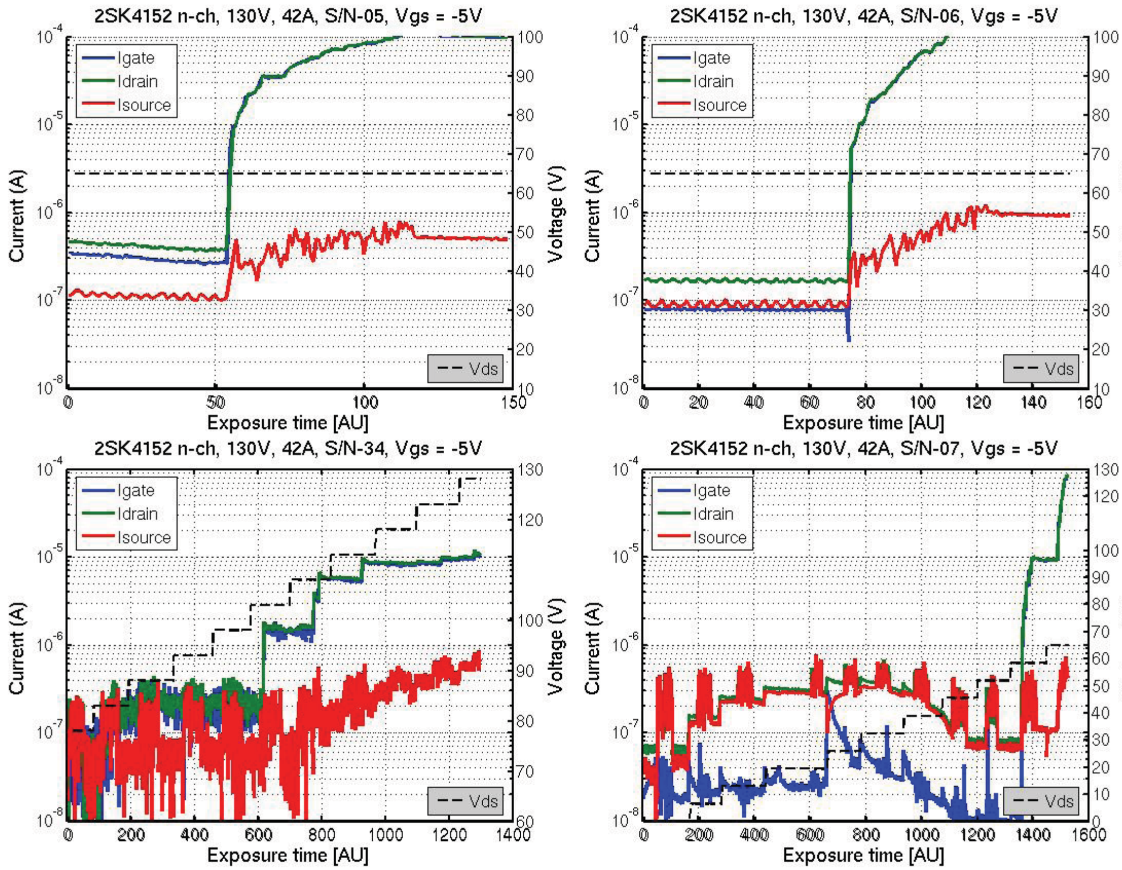




S/N	Failure Criteria 1: I_G >1 µA V_{DS} (V)		Failure Criteria 2: I_G >10 µA V_{DS} (V)		Failure Mode: SEGR or SEB
	Pass	Failed	Pass	Failed	
02	65.00	71.50	91.00	97.5	SEGR
03	N/A	N/A	6.60	65.00	SEGR
04	65.00	71.50	78.00	84.50	SEGR

Plot Point(s)			
Failure Criteria 1: I_G >1 µA	V_{GS} (V) = 0.00	V_{DS} (V) = 68.25	Error bar (V) = ± 3.25
Failure Criteria 2: I_G >10 µA	V_{GS} (V) = 0.00	V_{DS} (V) = 70.42	Error bar (V) = ± 30.86

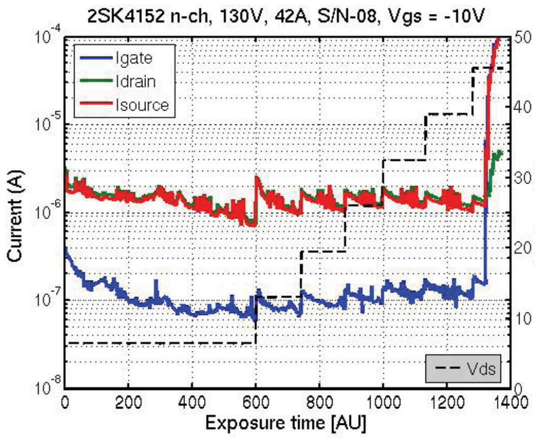
5.2.6 2SK4152 (130 V, 42 A), Xe ion, bias condition $V_{GS} = -5$ V:

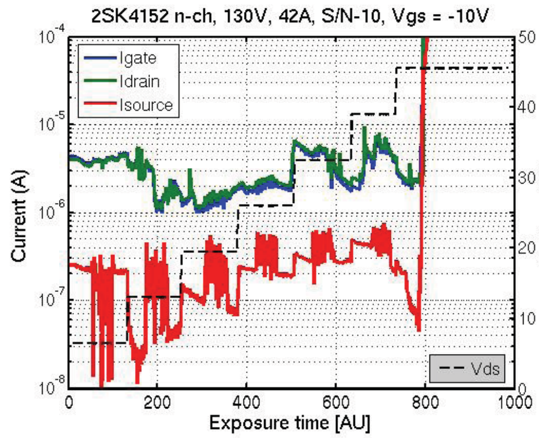


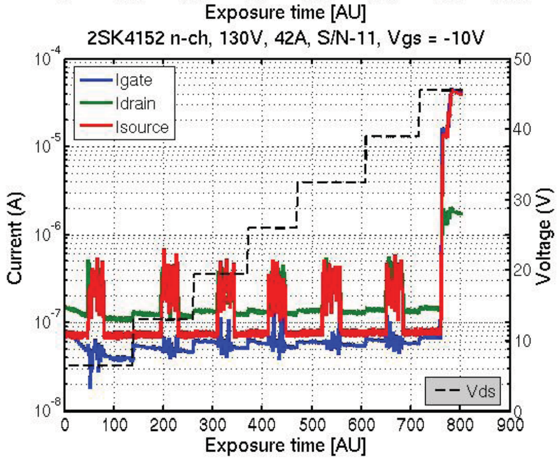
S/N	Failure Criteria 1: I_G >1 µA V_{DS} (V)		Failure Criteria 2: I_G >10 µA V_{DS} (V)		Failure Mode: SEGR or SEB
	Pass	Failed	Pass	Failed	
05	N/A	N/A	N/A	N/A	SEGR
06	N/A	N/A	N/A	N/A	SEGR
34	98.00	103.00	123.00	128.00	SEGR
07	52.00	58.50	58.50	65.00	SEGR

Plot Point(s)			
Failure Criteria 1: I_G >1 µA	V_{GS} (V) = –5.00	V_{DS} (V) = 77.50	Error bar (V) = ± 31.63
Failure Criteria 2: I_G >10 µA	V_{GS} (V) = –5.00	V_{DS} (V) = 93.25	Error bar (V) = ± 22.33

5.2.7 2SK4152 (130 V, 42 A), Xe ion, bias condition V_{GS} = –10 V:



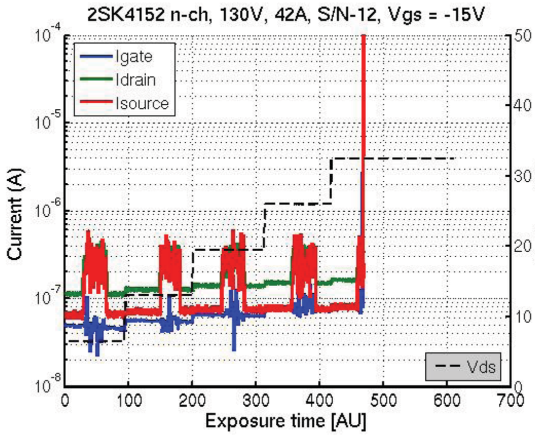


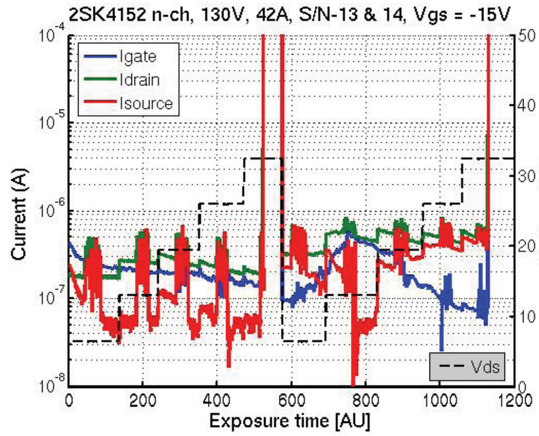


S/N	Failure Criteria 1: I_G >1 µA V_{DS} (V)		Failure Criteria 2: I_G >10 µA V_{DS} (V)		Failure Mode: SEGR or SEB
	Pass	Failed	Pass	Failed	
08	38.00	45.50	38.00	45.50	SEGR & SEB
10	N/A	N/A	38.00	45.50	SEGR & SEB
11	38.00	45.50	38.00	45.50	SEGR & SEB

Plot Point(s)			
Failure Criteria 1: I_G >1 µA	V_{GS} (V) = –5.00	V_{DS} (V) = 41.75	Error bar (V) = ± 3.25
Failure Criteria 2: I_G >10 µA	V_{GS} (V) = –5.00	V_{DS} (V) = 41.75	Error bar (V) = ± 3.25

5.2.8 2SK4152 (130 V, 42 A), Xe ion, bias condition V_{GS} = –15 V:

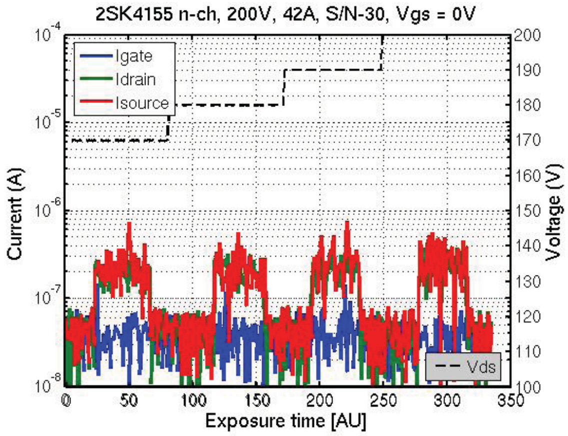


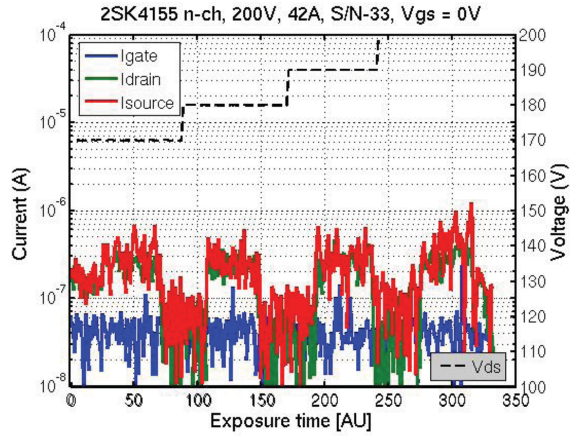


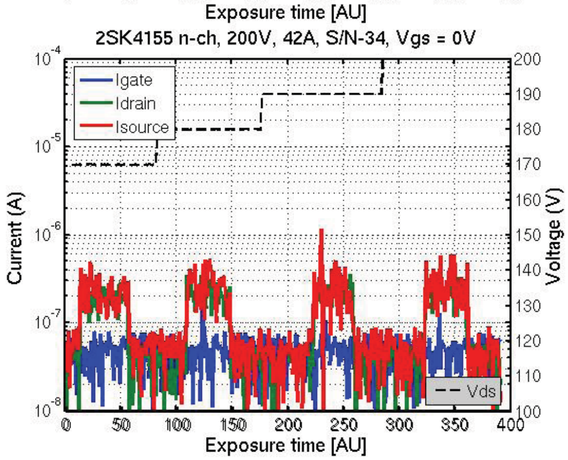
S/N	Failure Criteria 1: I_G >1 µA V_{DS} (V) Pass	Failure Criteria 1: I_G >1 µA V_{DS} (V) Failed	Failure Criteria 2: I_G >10 µA V_{DS} (V) Pass	Failure Criteria 2: I_G >10 µA V_{DS} (V) Failed	Failure Mode: SEGR or SEB
12	26.00	32.50	26.00	32.50	SEGR & SEB
13	26.00	32.50	26.00	32.50	SEGR & SEB
14	26.00	32.50	26.00	32.50	SEGR & SEB

Plot Point(s)			
Failure Criteria 1: I_G >1 µA	V_{GS} (V) = –15.00	V_{DS} (V) = 29.25	Error bar (V) = ± 3.25
Failure Criteria 2: I_G >10 µA	V_{GS} (V) = –15.00	V_{DS} (V) = 29.25	Error bar (V) = ± 3.25

5.3.1 2SK4155 (200 V, 42 A) Ag ion, bias condition V_{GS} = 0 V:

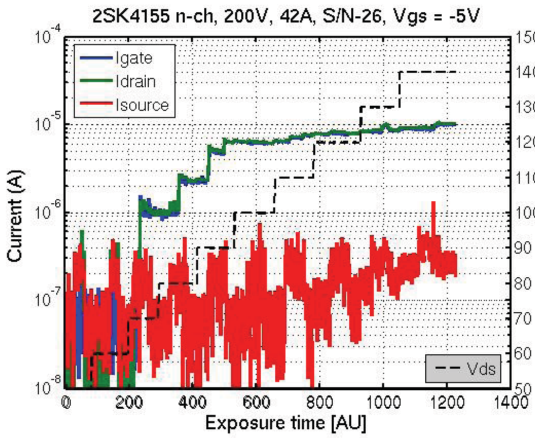


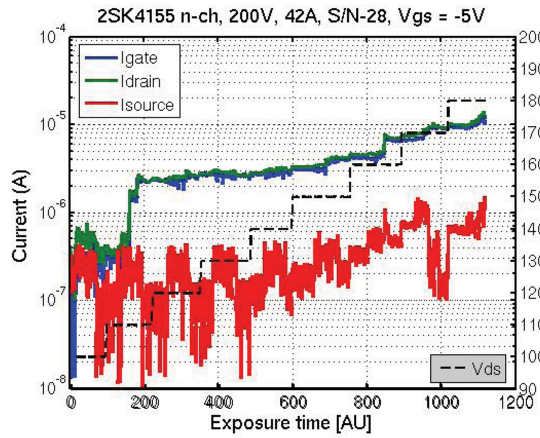


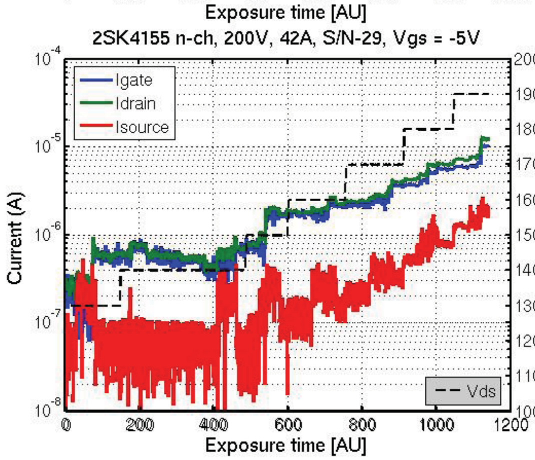


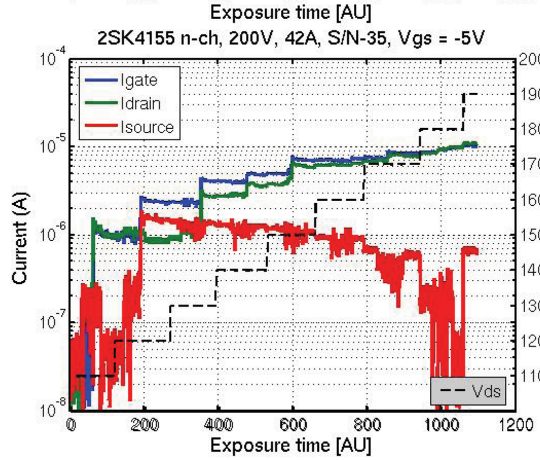
S/N	Failure Criteria 1: I_G >1 µA V_{DS} (V)		Failure Criteria 2: I_G >10 µA V_{DS} (V)		Failure Mode: SEGR or SEB
	Pass	Failed	Pass	Failed	
30	200.00	N/A	200.00	N/A	No failure
33	200.00	N/A	200.00	N/A	No failure
34	200.00	N/A	200.00	N/A	No failure
Plot Point(s)					
Failure Criteria 1: I_G >1 µA		V_{GS} (V) = 0.00	V_{DS} (V) = 200.00	Error bar (V) = ± 0.00	
Failure Criteria 2: I_G >10 µA		V_{GS} (V) = 0.00	V_{DS} (V) = 200.00	Error bar (V) = ± 0.00	

5.3.2 2SK4155 (200 V, 42 A) Ag ion, bias condition V_{GS} = –5 V:



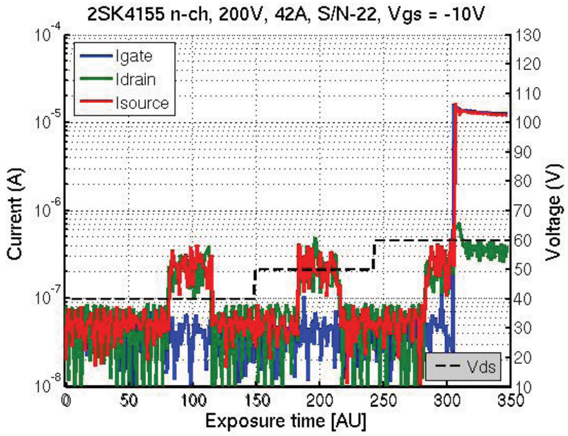


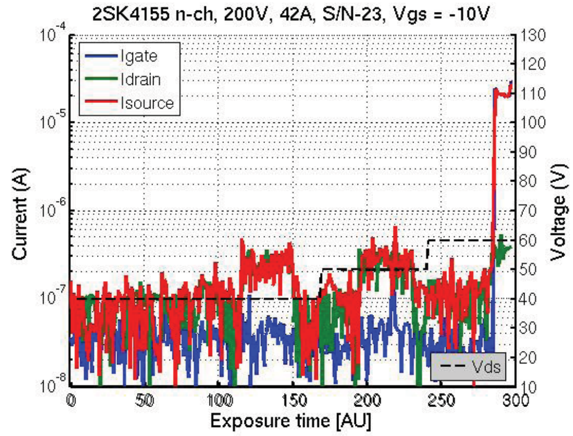


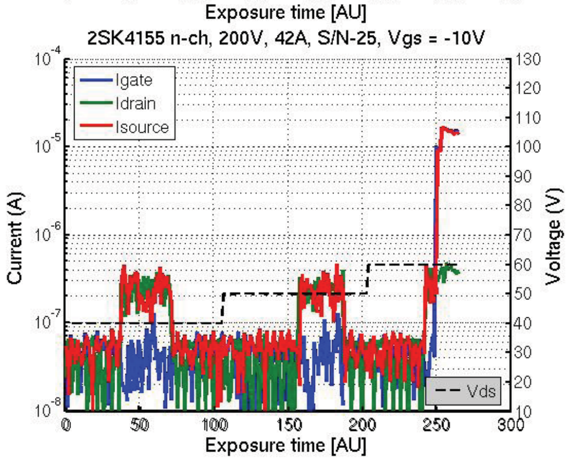


S/N	Failure Criteria 1: I_G >1 µA V_{DS} (V)		Failure Criteria 2: I_G >10 µA V_{DS} (V)		Failure Mode: SEGR or SEB
	Pass	Failed	Pass	Failed	
26	60.00	70.00	130.00	140.00	SEGR
28	100.00	110.00	170.00	180.00	SEGR
29	140.00	150.00	180.00	190.00	SEGR
35	N/A	110.00	180.00	190.00	SEGR
Plot Point(s)					
Failure Criteria 1: I_G >1 µA		V_{GS} (V) = –5.00	V_{DS} (V) = 105.00	Error bar (V) = ± 40.31	
Failure Criteria 2: I_G >10 µA		V_{GS} (V) = –5.00	V_{DS} (V) = 170.00	Error bar (V) = ± 24.32	

5.3.3 2SK4155 (200 V, 42 A) Ag ion, bias condition V_{GS} = –10 V:



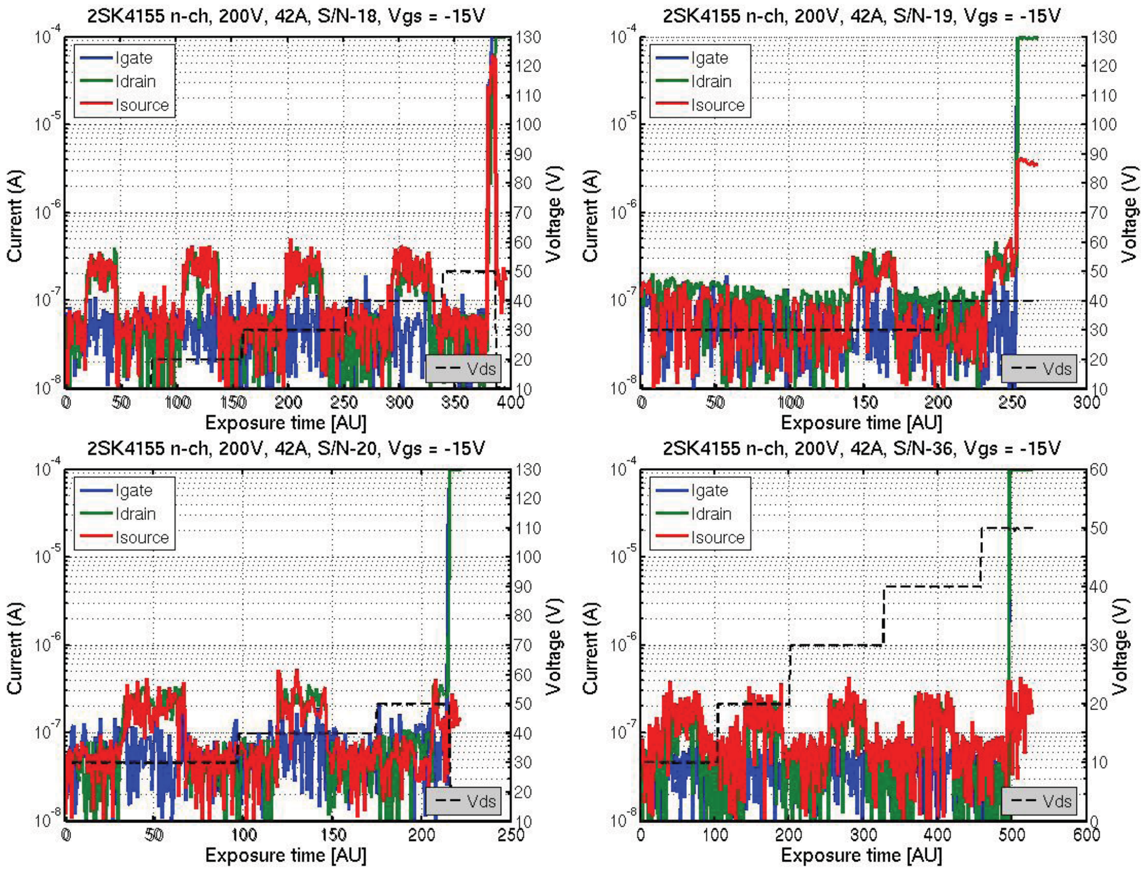




S/N	Failure Criteria 1: I_G >1 μA V_{DS} (V)		Failure Criteria 2: I_G >10 μA V_{DS} (V)		Failure Mode: SEGR or SEB
	Pass	Failed	Pass	Failed	
22	50.00	60.00	50.00	60.00	SEGR
23	50.00	60.00	50.00	60.00	SEGR
25	50.00	60.00	50.00	60.00	SEGR

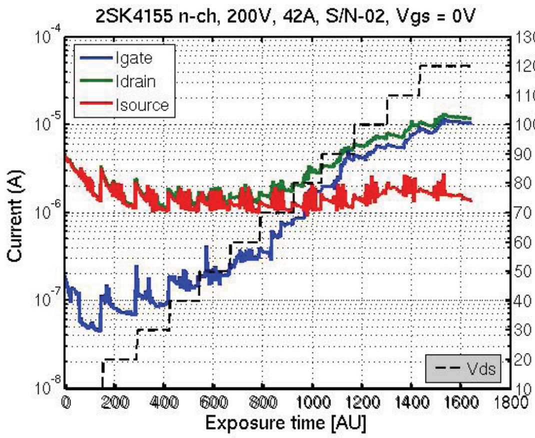
Plot Point(s)			
Failure Criteria 1: I_G >1 μA	V_{GS} (V) = –10.00	V_{DS} (V) = 55.00	Error bar (V) = ± 5.00
Failure Criteria 2: I_G >10 μA	V_{GS} (V) = –10.00	V_{DS} (V) = 55.00	Error bar (V) = ± 5.00

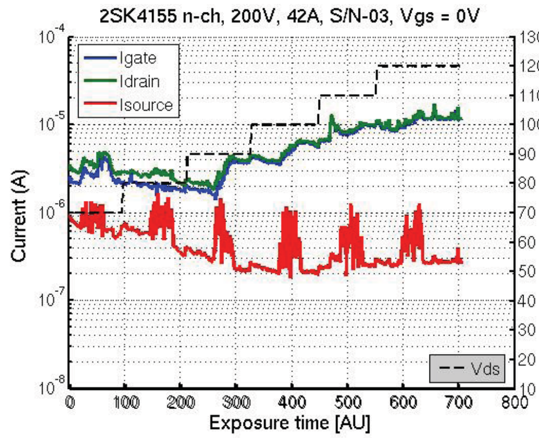
5.3.4 2SK4155 (200 V, 42 A) Ag ion, bias condition V_{GS} = –15 V:

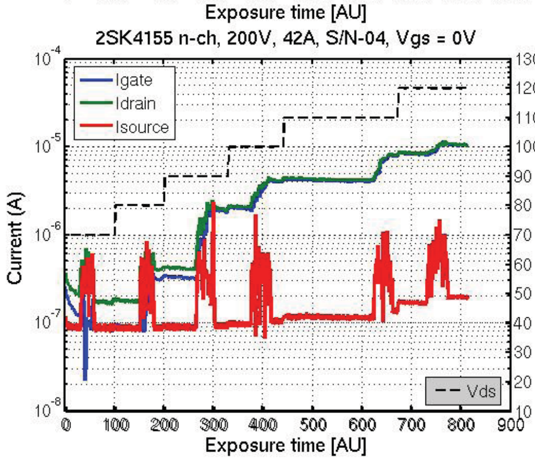


S/N	Failure Criteria 1: I_G >1 µA V_{DS} (V) Pass	Failure Criteria 1: I_G >1 µA V_{DS} (V) Failed	Failure Criteria 2: I_G >10 µA V_{DS} (V) Pass	Failure Criteria 2: I_G >10 µA V_{DS} (V) Failed	Failure Mode: SEGR or SEB
18	40.00	50.00	40.00	50.00	SEGR & SEB
19	30.00	40.00	30.00	40.00	SEGR & SEB
20	40.00	50.00	40.00	50.00	SEGR
36	40.00	50.00	40.00	50.00	SEGR
Plot Point(s)					
Failure Criteria 1: I_G >1 µA		V_{GS} (V) = –15.00	V_{DS} (V) = 42.50	Error bar (V) = ± 7.07	
Failure Criteria 2: I_G >10 µA		V_{GS} (V) = –15.00	V_{DS} (V) = 42.50	Error bar (V) = ± 7.07	

5.3.5 2SK4155 (200 V, 42 A) Xe ion, bias condition V_{GS} = 0 V:



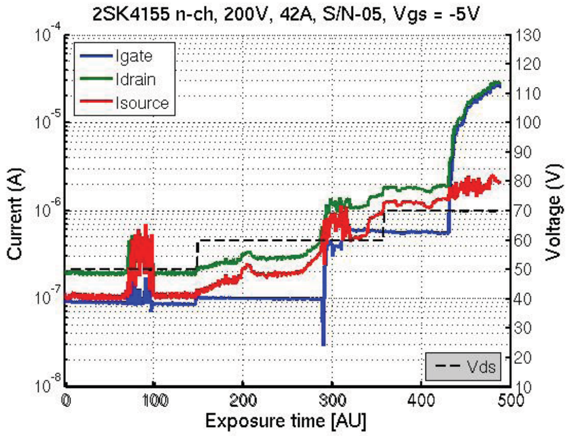


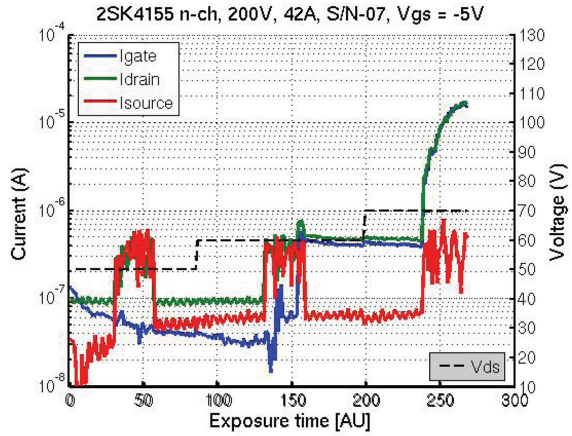


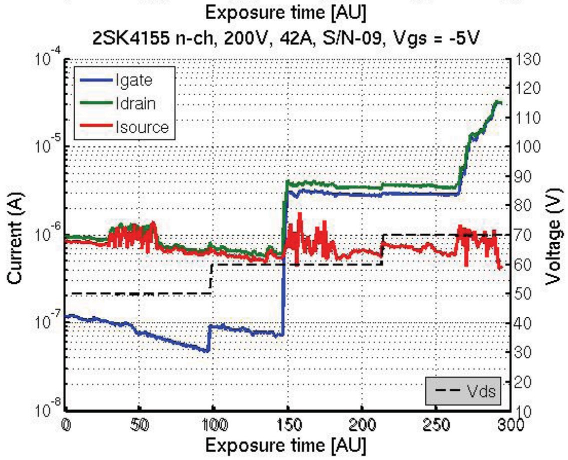
S/N	Failure Criteria 1: I_G >1 µA V_{DS} (V)		Failure Criteria 2: I_G >10 µA V_{DS} (V)		Failure Mode: SEGR or SEB
	Pass	Failed	Pass	Failed	
02	70.00	80.00	110.00	120.00	SEGR
03	N/A	N/A	100.00	110.00	SEGR
04	80.00	90.00	110.00	120.00	SEGR

Plot Point(s)			
Failure Criteria 1: I_G >1 µA	V_{GS} (V) = 0.00	V_{DS} (V) = 80.00	Error bar (V) = ± 8.66
Failure Criteria 2: I_G >10 µA	V_{GS} (V) = 0.00	V_{DS} (V) = 111.67	Error bar (V) = ± 7.64

5.3.6 2SK4155 (200 V, 42 A) Xe ion, bias condition V_{GS} = –5 V:



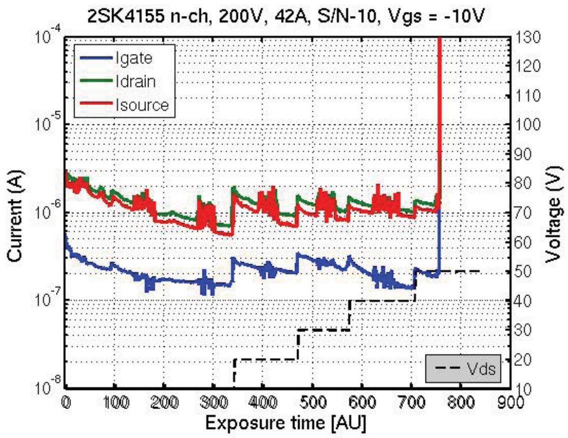


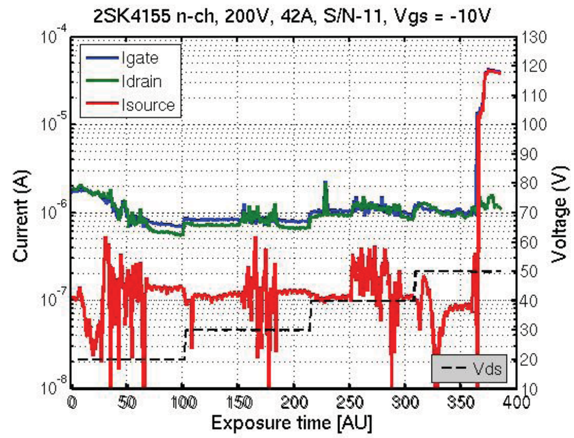


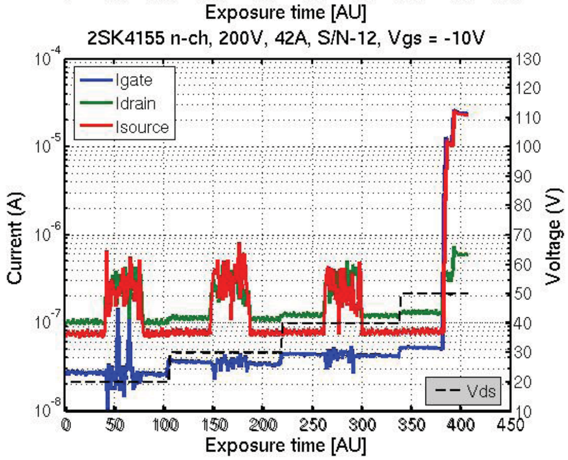
S/N	Failure Criteria 1: I_G >1 µA V_{DS} (V)		Failure Criteria 2: I_G >10 µA V_{DS} (V)		Failure Mode: SEGR or SEB
	Pass	Failed	Pass	Failed	
05	60.00	70.00	60.00	70.00	SEGR
07	60.00	70.00	60.00	70.00	SEGR
09	50.00	60.00	60.00	70.00	SEGR

Plot Point(s)			
Failure Criteria 1: I_G >1 µA	V_{GS} (V) = –5.00	V_{DS} (V) = 61.67	Error bar (V) = ± 7.64
Failure Criteria 2: I_G >10 µA	V_{GS} (V) = –5.00	V_{DS} (V) = 65.00	Error bar (V) = ± 5.00

5.3.7 2SK4155 (200 V, 42 A) Xe ion, bias condition V_{GS} = –10 V:



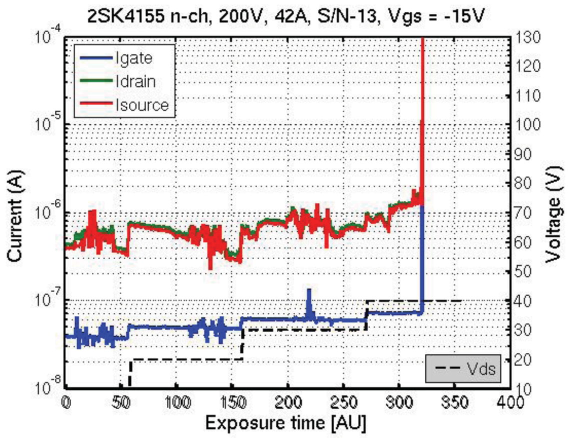


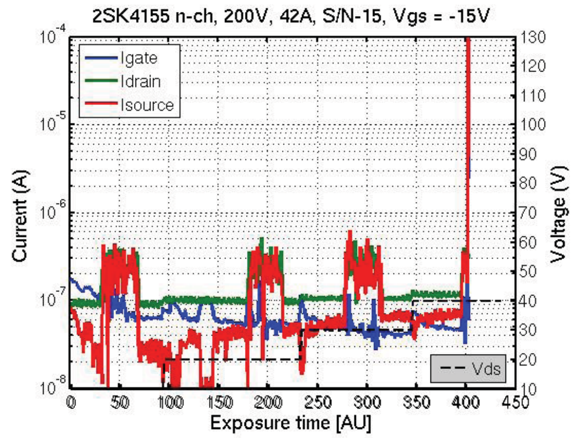


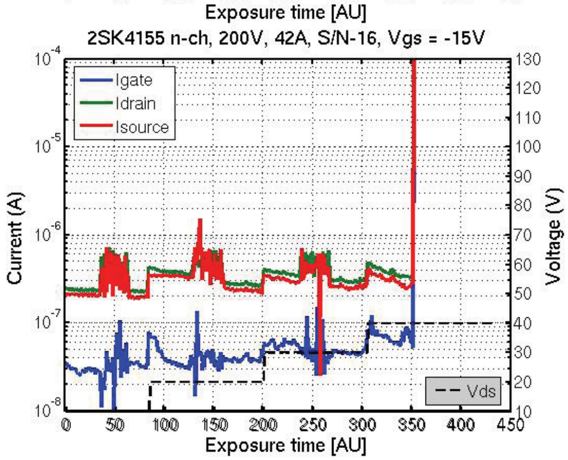
S/N	Failure Criteria 1: I_G >1 µA V_{DS} (V)		Failure Criteria 2: I_G >10 µA V_{DS} (V)		Failure Mode: SEGR or SEB
	Pass	Failed	Pass	Failed	
10	40.00	50.00	40.00	50.00	SEGR & SEB
11	30.00	40.00	40.00	50.00	SEGR
12	40.00	50.00	40.00	50.00	SEGR

Plot Point(s)			
Failure Criteria 1: I_G >1 µA	V_{GS} (V) = –10.00	V_{DS} (V) = 41.67	Error bar (V) = ± 7.64
Failure Criteria 2: I_G >10 µA	V_{GS} (V) = –10.00	V_{DS} (V) = 45.00	Error bar (V) = ± 5.00

5.3.8 *2SK4155 (200 V, 42 A) Xe ion, bias condition V_{GS} = –15 V:*



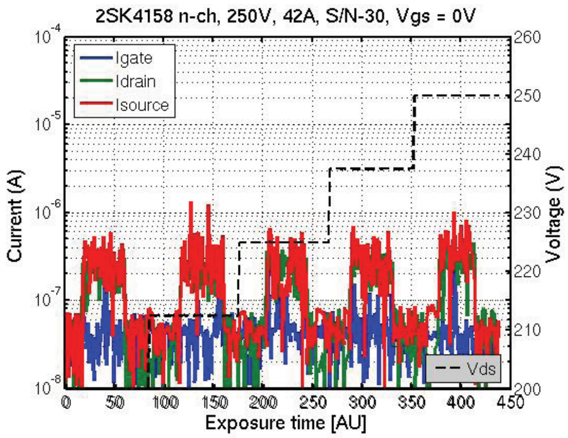


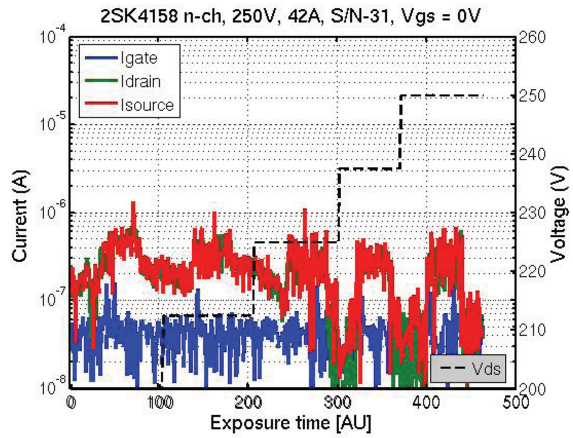


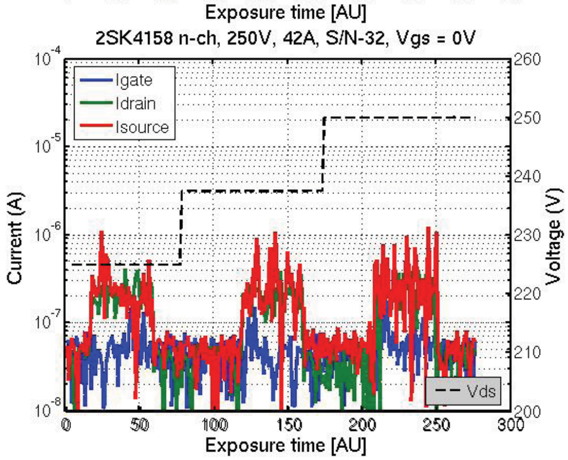
S/N	Failure Criteria 1: I_G >1 μA V_{DS} (V)		Failure Criteria 2: I_G >10 μA V_{DS} (V)		Failure Mode: SEGR or SEB
	Pass	Failed	Pass	Failed	
13	30.00	40.00	30.00	40.00	SEGR & SEB
15	30.00	40.00	30.00	40.00	SEGR & SEB
16	30.00	40.00	30.00	40.00	SEGR & SEB

Plot Point(s)			
Failure Criteria 1: I_G >1 μA	V_{GS} (V) = –15.00	V_{DS} (V) = 35.00	Error bar (V) = ± 5.00
Failure Criteria 2: I_G >10 μA	V_{GS} (V) = –15.00	V_{DS} (V) = 35.00	Error bar (V) = ± 5.00

5.4.1 2SK4158 (250 V, 42 A) Ag ion, bias condition V_{GS} = 0 V:



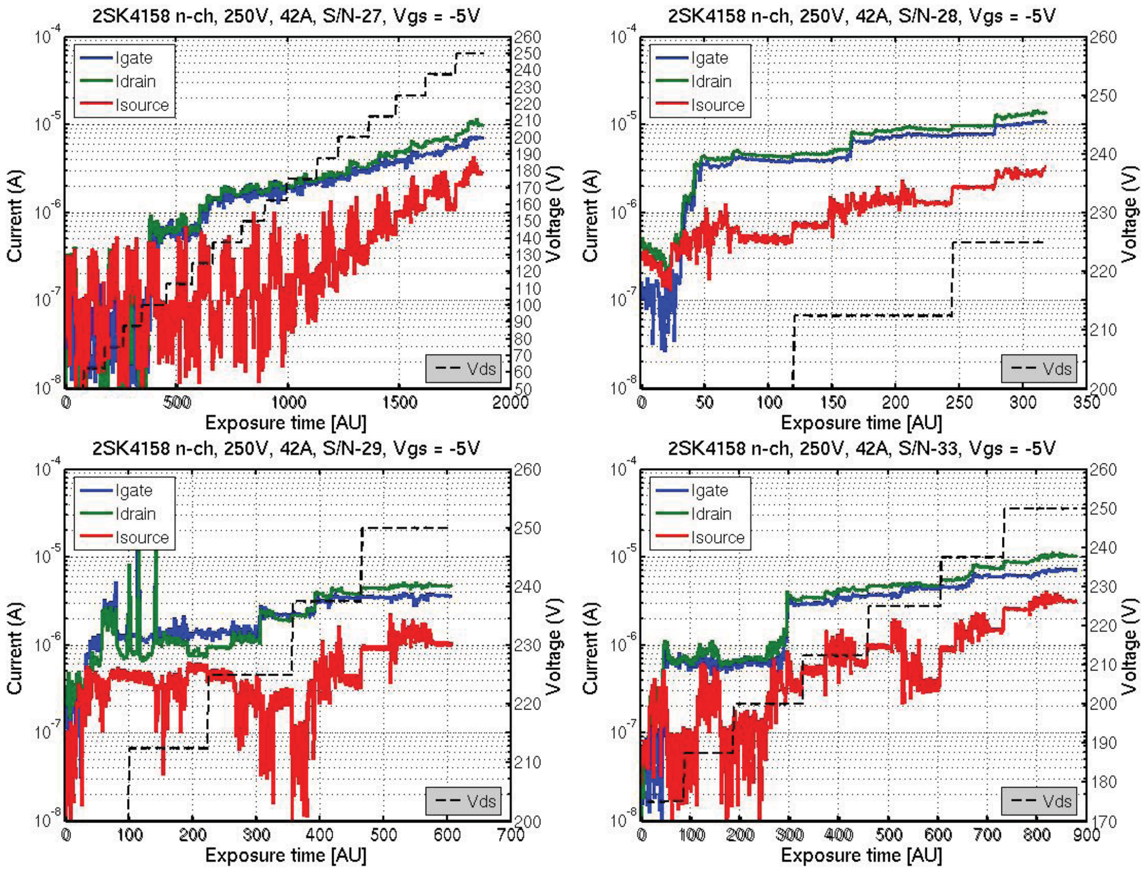




S/N	Failure Criteria 1: I_G >1 µA V_{DS} (V)		Failure Criteria 2: I_G >10 µA V_{DS} (V)		Failure Mode: SEGR or SEB
	Pass	Failed	Pass	Failed	
30	250.00	N/A	250.00	N/A	No failure
31	250.00	N/A	250.00	N/A	No failure
32	250.00	N/A	250.00	N/A	No failure

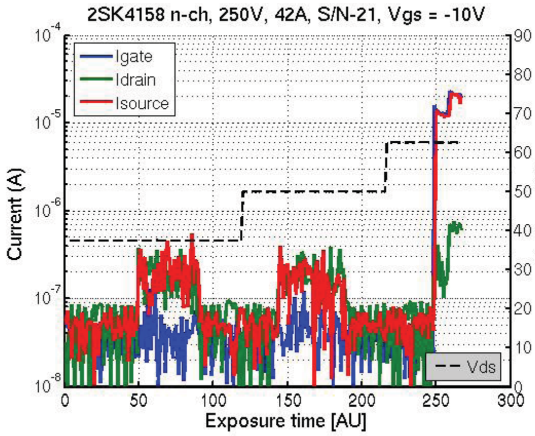
Plot Point(s)			
Failure Criteria 1: I_G >1 µA	V_{GS} (V) = 0.00	V_{DS} (V) = 250.00	Error bar (V) = ± 0.00
Failure Criteria 2: I_G >10 µA	V_{GS} (V) = 0.00	V_{DS} (V) = 250.00	Error bar (V) = ± 0.00

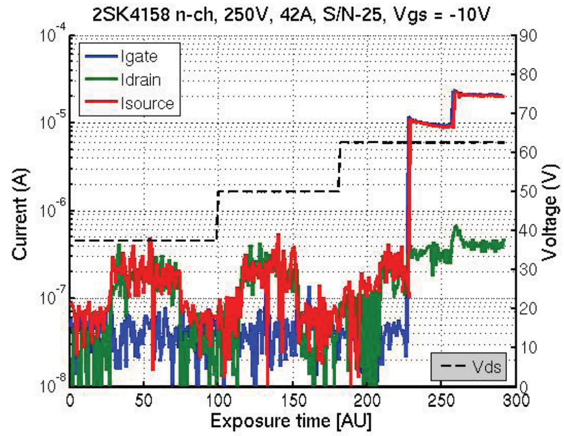
5.4.2 2SK4158 (250 V, 42 A) Ag ion, bias condition V_{GS} = –5 V:

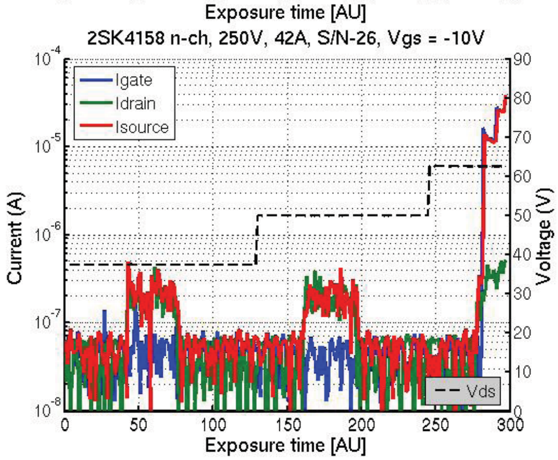


S/N	Failure Criteria 1: I_G >1 µA V_{DS} (V)		Failure Criteria 2: I_G >10 µA V_{DS} (V)		Failure Mode: SEGR or SEB
	Pass	Failed	Pass	Failed	
27	100.00	125.00	250.00	N/A	SEGR
28	N/A	N/A	212.50	225.00	SEGR
29	N/A	N/A	250.00	N/A	No failure
33	187.50	200.00	250.00	N/A	SEGR
Plot Point(s)					
Failure Criteria 1: I_G >1 µA		V_{GS} (V) = –5.00	V_{DS} (V) = 153.13	Error bar (V) = ± 57.79	
Failure Criteria 2: I_G >10 µA		V_{GS} (V) = –5.00	V_{DS} (V) = 242.19	Error bar (V) = ± 16.83	

5.4.3 2SK4158 (250 V, 42 A) Ag ion, bias condition V_{GS} = –10 V:

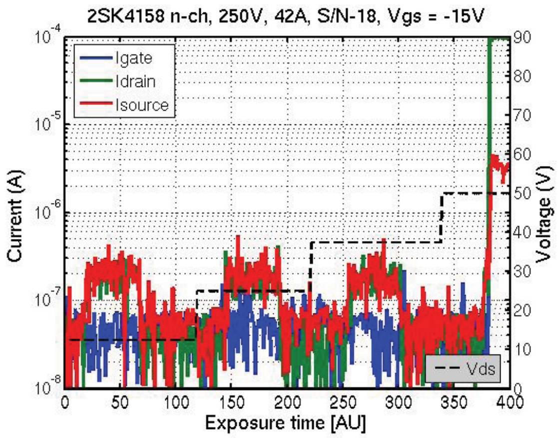


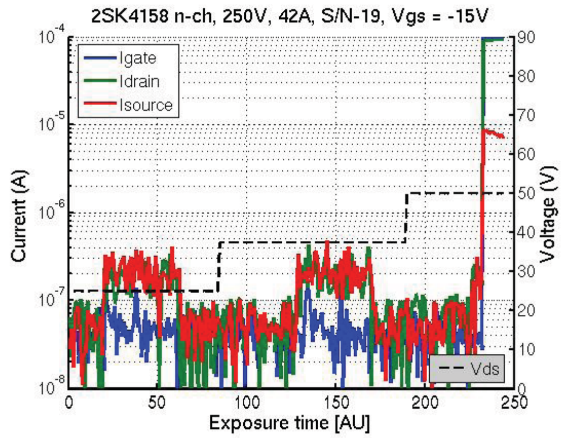


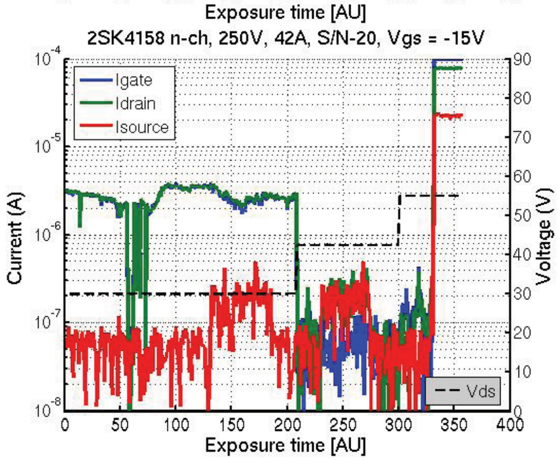


S/N	Failure Criteria 1: I_G >1 µA V_{DS} (V)		Failure Criteria 2: I_G >10 µA V_{DS} (V)		Failure Mode: SEGR or SEB
	Pass	Failed	Pass	Failed	
21	50.00	62.50	50.00	62.50	SEGR
25	50.00	62.50	50.00	62.50	SEGR
26	50.00	62.50	50.00	62.50	SEGR
Plot Point(s)					
Failure Criteria 1: I_G >1 µA		V_{GS} (V) = –10.00	V_{DS} (V) = 56.25	Error bar (V) = ± 6.25	
Failure Criteria 2: I_G >10 µA		V_{GS} (V) = –10.00	V_{DS} (V) = 56.25	Error bar (V) = ± 6.25	

5.4.4 2SK4158 (250 V, 42 A) Ag ion, bias condition $V_{GS} = -15$ V:



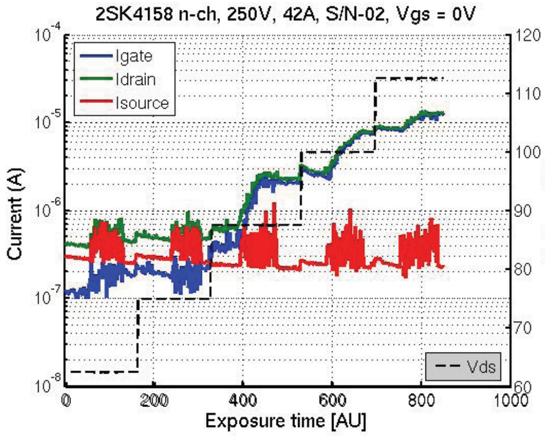


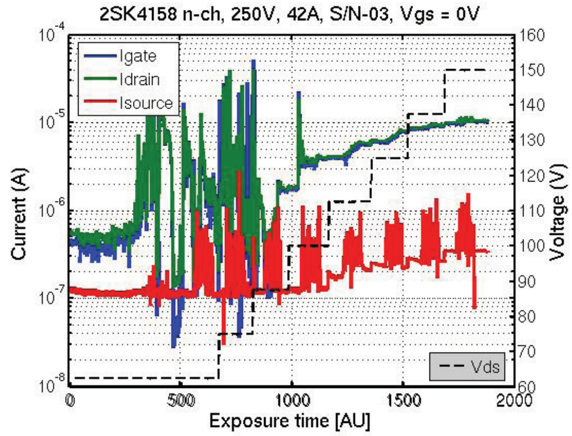


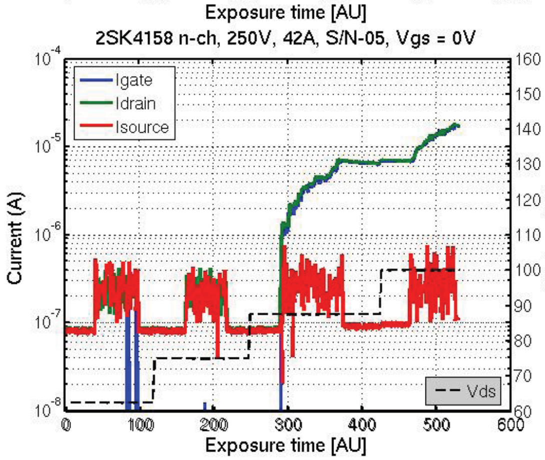
S/N	Failure Criteria 1: I_G >1 µA V_{DS} (V) Pass	Failure Criteria 1: I_G >1 µA V_{DS} (V) Failed	Failure Criteria 2: I_G >10 µA V_{DS} (V) Pass	Failure Criteria 2: I_G >10 µA V_{DS} (V) Failed	Failure Mode: SEGR or SEB
18	38.50	50.00	38.50	50.00	SEGR & SEB
19	38.50	50.00	38.50	50.00	SEGR & SEB
20	42.50	55.00	42.50	55.00	SEGR & SEB

Plot Point(s)			
Failure Criteria 1: I_G >1 µA	V_{GS} (V) = –15.00	V_{DS} (V) = 45.75	Error bar (V) = ± 6.77
Failure Criteria 2: I_G >10 µA	V_{GS} (V) = –15.00	V_{DS} (V) = 45.75	Error bar (V) = ± 6.77

5.4.5 2SK4158 (250 V, 42 A) Xe ion, bias condition $V_{GS} = 0$ V:



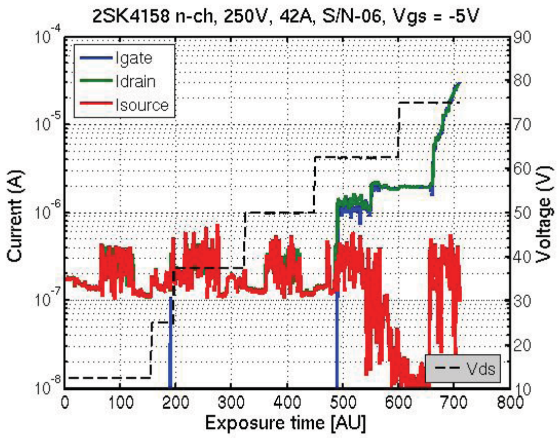


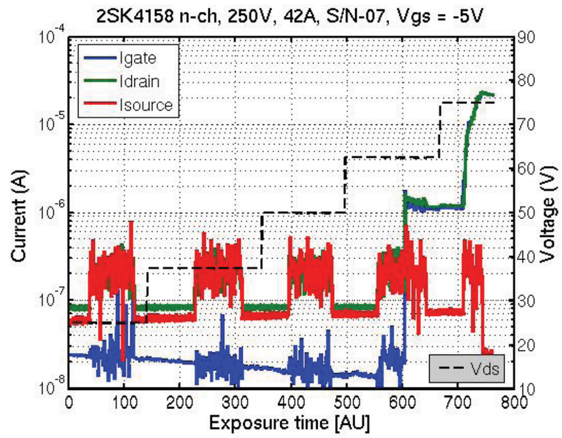


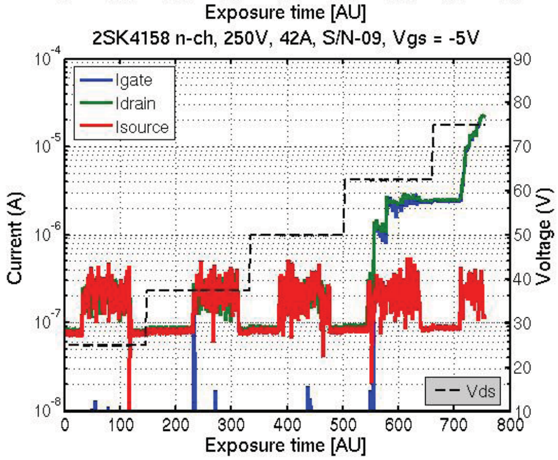
S/N	Failure Criteria 1: I_G >1 µA V_{DS} (V)		Failure Criteria 2: I_G >10 µA V_{DS} (V)		Failure Mode: SEGR or SEB
	Pass	Failed	Pass	Failed	
02	75.00	87.50	100.00	112.50	SEGR
03	N/A	N/A	137.50	150.00	SEGR
05	75.00	87.50	87.50	100.00	SEGR

Plot Point(s)			
Failure Criteria 1: I_G >1 µA	V_{GS} (V) = 0.00	V_{DS} (V) = 81.25	Error bar (V) = ± 6.25
Failure Criteria 2: I_G >10 µA	V_{GS} (V) = 0.00	V_{DS} (V) = 114.58	Error bar (V) = ± 26.76

5.4.6 2SK4158 (250 V, 42 A) Xe ion, bias condition V_{GS} = –5 V:



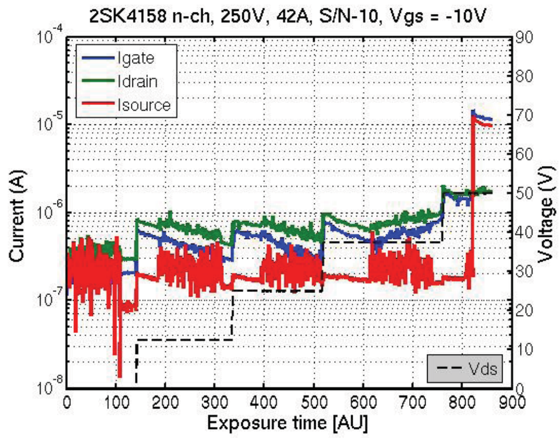


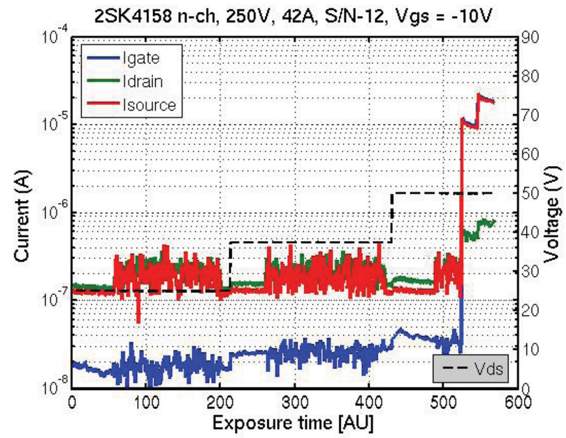


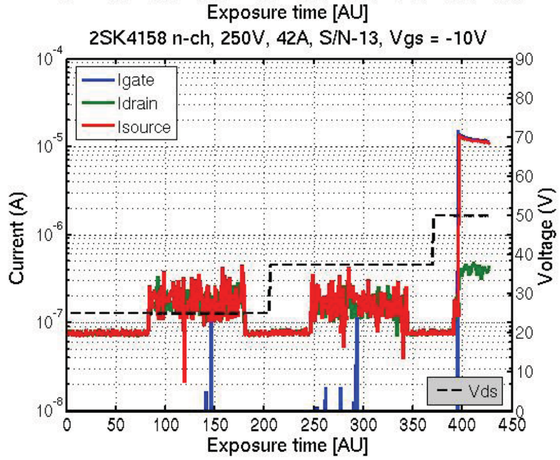
S/N	Failure Criteria 1: I_G >1 µA V_{DS} (V)		Failure Criteria 2: I_G >10 µA V_{DS} (V)		Failure Mode: SEGR or SEB
	Pass	Failed	Pass	Failed	
06	50.00	62.50	62.50	75.00	SEGR
07	50.00	62.50	62.50	75.00	SEGR
09	50.00	62.50	62.50	75.00	SEGR

Plot Point(s)			
Failure Criteria 1: I_G >1 µA	V_{GS} (V) = –5.00	V_{DS} (V) = 56.25	Error bar (V) = ± 6.25
Failure Criteria 2: I_G >10 µA	V_{GS} (V) = –5.00	V_{DS} (V) = 68.75	Error bar (V) = ± 6.25

5.4.7 2SK4158 (250 V, 42 A) Xe ion, bias condition V_{GS} = –10 V:



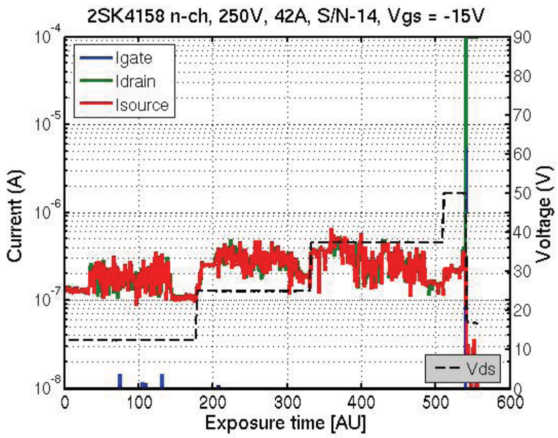


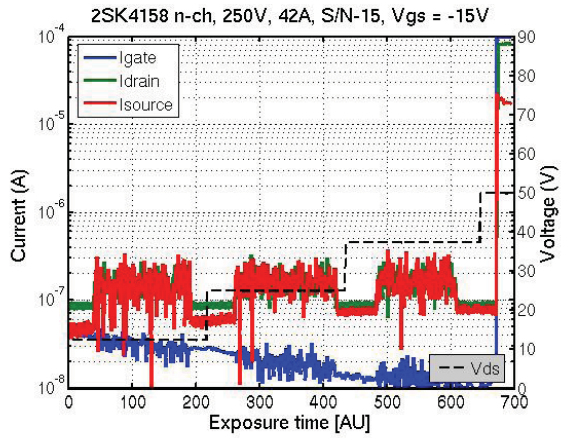


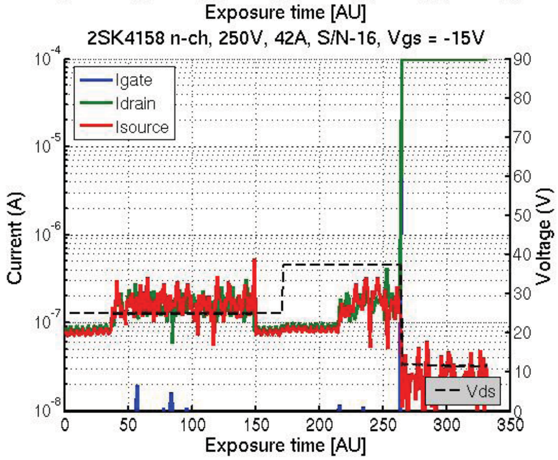
S/N	Failure Criteria 1: I_G >1 µA V_{DS} (V)		Failure Criteria 2: I_G >10 µA V_{DS} (V)		Failure Mode: SEGR or SEB
	Pass	Failed	Pass	Failed	
10	37.50	50.00	37.50	50.00	SEGR
12	37.50	50.00	37.50	50.00	SEGR
13	37.50	50.00	37.50	50.00	SEGR

Plot Point(s)			
Failure Criteria 1: I_G >1 µA	V_{GS} (V) = –10.00	V_{DS} (V) = 43.75	Error bar (V) = ± 6.25
Failure Criteria 2: I_G >10 µA	V_{GS} (V) = –10.00	V_{DS} (V) = 43.75	Error bar (V) = ± 6.25

5.4.8 2SK4158 (250 V, 42 A) Xe ion, bias condition V_{GS} = –15 V:







S/N	Failure Criteria 1: I_G >1 μA V_{DS} (V)		Failure Criteria 2: I_G >10 μA V_{DS} (V)		Failure Mode: SEGR or SEB
	Pass	Failed	Pass	Failed	
14	37.50	50.00	37.50	50.00	SEGR
15	37.50	50.00	37.50	50.00	SEGR & SEB
16	25.00	37.50	25.00	37.50	SEGR

Plot Point(s)			
Failure Criteria 1: I_G >1 μA	V_{GS} (V) = –15.00	V_{DS} (V) = 39.58	Error bar (V) = ± 9.55
Failure Criteria 2: I_G >10 μA	V_{GS} (V) = –15.00	V_{DS} (V) = 39.58	Error bar (V) = ± 9.55

6. References

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