National Aeronautics and Space Administration

Single-event Effect Report for EPC Series eGaN FETs: Comparison of EPC1000 and EPC2000 series devices for destructive SEE

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1.0 EXECUTIVE SUMMARY

Recent testing of the EPC1000 series Efficient Power Conversion Corporation (eGaN) FETs has shown sensitivity to single-event effects (SEE) that are destructive. These effects are most likely the failure of the very thin gate structure in HEMT architecture. EPC has recently changed the doping of the substrate to improve the performance and the SEE response. This testing compares the SEE response of both devices. Generation 2 (Gen2) has increase the doping of the substrate over Gen1, which decreases charge collection efficiency in silicon. Table 1.0-1 shows the overall results.

Table 1.0-1. The voltage at which SEE occurs (Vsee) for two generations of two device.

Rated V_{ds} [V]	Gen 1 V_{SEE} [V]	Gen 1 V_{SOA} [V]	Gen 2 V_{SEE} [V]	Gen 2 V_{SOA} [V]
40	40	30	40	30
200	40	30	80	60

2.0 PURPOSE

The purpose of this testing was to compare two different versions of eGaN FET from EPC for radiation effects from heavy ions. The devices were tested for SEE as well as investigated for any reduction in SOA from heavy ion irradiation.

3.0 TEST SAMPLES

The DUT listed in Table 3.0-1 were acquired commercially and stored under flight ESD conditions per D-57732.

Table 3.0-1. List of devices that were tested.

Manufacturer	Part Number	VDS rating (max) [V]	Channel	LDC	Package
EPC	EPC1012	200	N	NA	Custom
EPC	EPC2012	200	N	NA	Custom
EPC	EPC1014	40	N	NA	Custom
EPC	EPC2014	40	N	NA	Custom

4.0 PROCEDURE/SETUP

The general test procedure was in accordance with “The Test Guideline for Single Event Gate Rupture (SEGR) of Power MOSFETs” [JPL Publication 08-10 2/08]. Parts were serialized (if not already done), with controls marked prominently to distinguish them from test samples. Exposures were performed at ambient laboratory temperature. Since the packages from EPC were atypical, the DUTS had to be remounted in a dead-bug configuration for ion testing and testing with the ATE. Devices were verified to be functional after mounting on the test carrier, as shown in Figure 5.0-1. The equipment used in this effort is listed in Table 5.0-1.

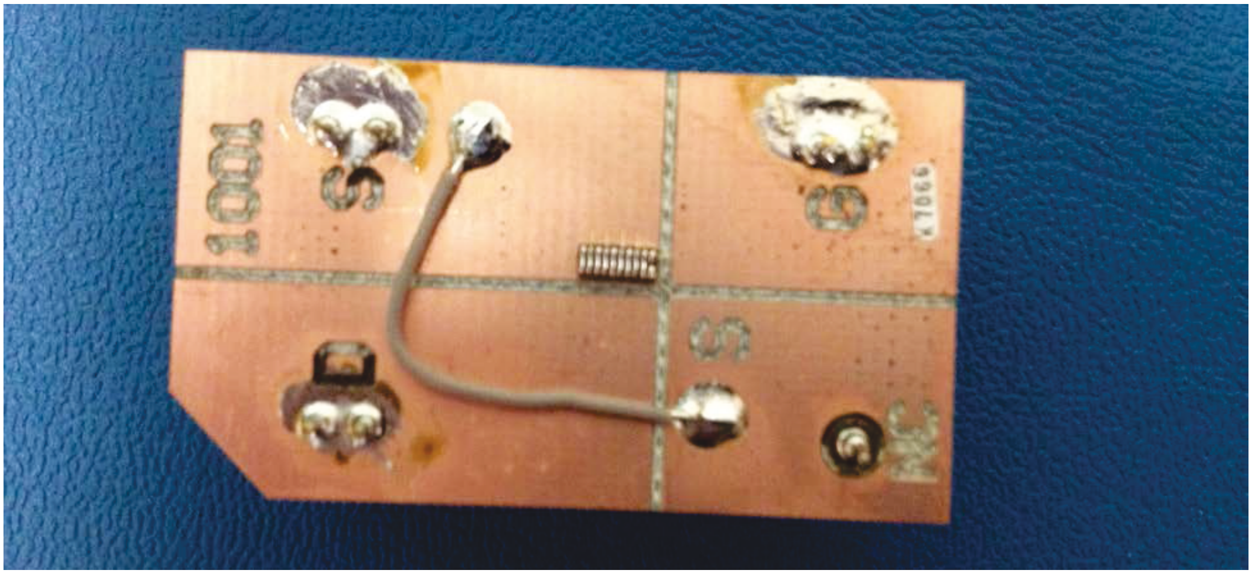

Figure 4.0-1. Dose testing carrier.

Table 4.0-1. Equipment used in this effort.

Unit	Function	Make	Calibration	JPL SN
HP4156	Parametric ATE	Agilent	20091219	TDB
HP4142	SEE ATE	Agilent	20111013	887633
Laptop	SEE control PC	Toshiba	NA	2220673

4.1 Electrical Tests

Electrical tests were performed in accordance with “The Test Guideline for Single Event Gate Rupture (SEGR) of Power MOSFETs” [JPL Publication 08-10 2/08]. All devices were verified to work by testing with a HP4156. The transfer and characteristic curves of each device were acquired to a maximum current of 10 mA on any terminal of the device.

4.2 Failure Criteria

Failure criteria were classified in accordance with “The Test Guideline for Single Event Gate Rupture (SEGR) of Power MOSFETs” [PL Publication 08-10 2/08]. However, any change in device parameters was noted for this exploratory effort.

4.3 Setup

Failure criteria were classified in accordance with “The Test Guideline for Single Event Gate Rupture (SEGR) of Power MOSFETs” [PL Publication 08-10 2/08]. Figure 4.3-1 shows the setup used in this experiment. An HP4142 forced the voltage and read a current with three independent SMUs. The background current on the board with no DUT was recorded to be ~0.5 nA in each device location.

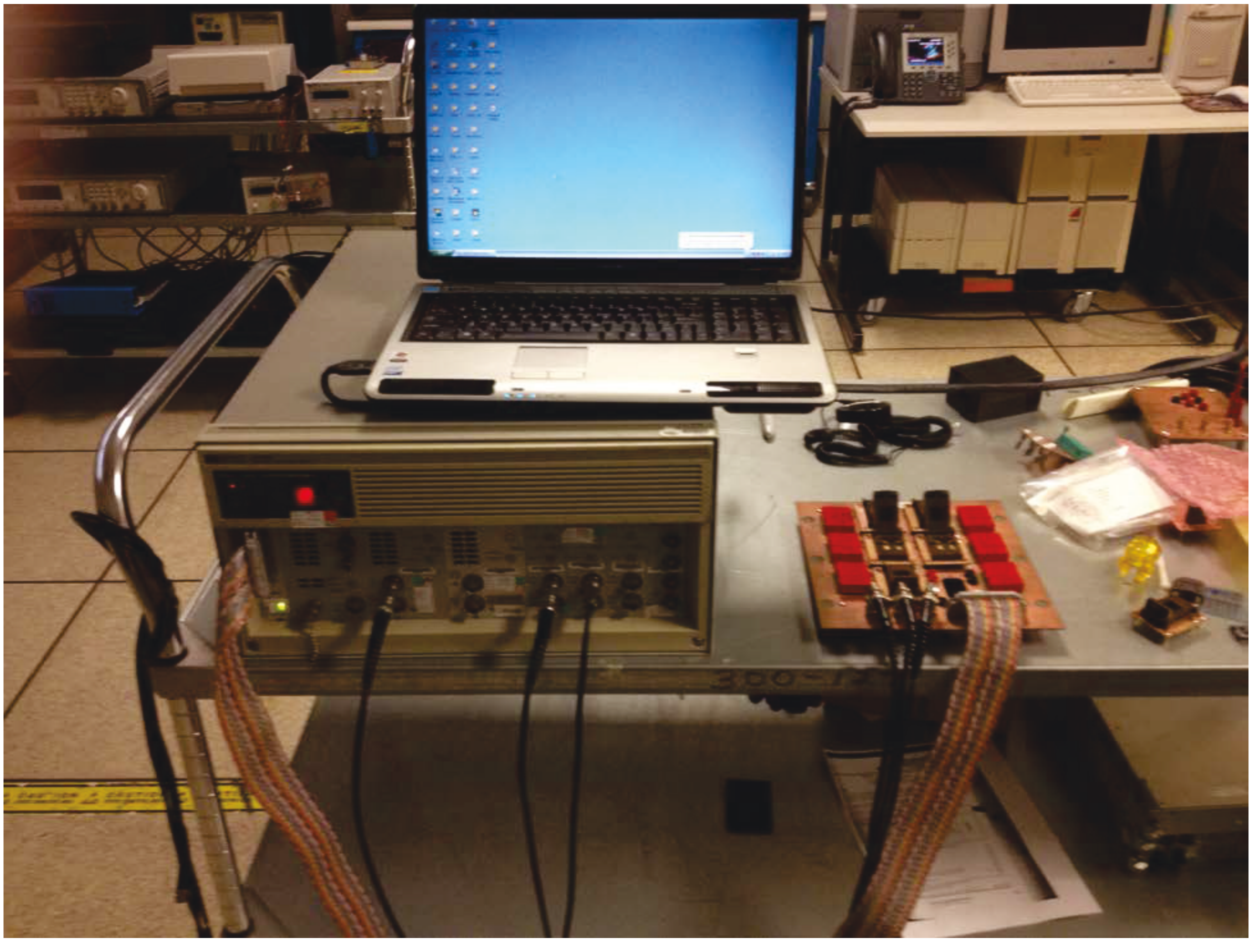

Figure 4.3-1. Setup used for SEE testing. The entire system is transported to a heavy ion site.

5.0 SOURCE REQUIREMENTS

The ion source was the TAMU cyclotron. The 25 MeV/amu beam was required to fully penetrate the substrate.

6.0 BIAS CONDITION/FIXTURES

Bias condition during the biased irradiations were in accordance with “The Test Guideline for Single Event Gate Rupture (SEGR) of Power MOSFETs” [PL Publication 08-10 2/08]. Unbiased parts were exposed in a manner that protects them against ESD.

7.0 RESULTS

Figures 7.0-1 thru 7.0-6 present the results of SEE testing at various angles for the EPC2012 and EPC1012. In all figures, green is gate current, red is V_{ds}, black is drain current. The EPC1012 is a 200 V part suspected to be worst case. Gen1 has SEE onset at 40 V (20% of rated voltage) and Gen 2 has SEE onset at 80 V (40% of rated voltage). 60 degree tilt angle irradiation shown less sensitivity to small break. But the SEE – SEDR and SET – seen at higher voltages are more pronounced. TRIM calculation showed ion Bragg peak at or beyond the active region. Figures 7.0-7 and 7.0-8 show the transfer curve for an EPC1012 and EPC2012, respectively, after similar heavy ion irradiations. Figure 7.0-9 shows the comparison in the doping of the substrate of the EPC1012 and ECP2012. The lower doping in the EPC1012 (Gen1) results in more charge collection and therefore more field distortion under the 2DEG. This would seem to be the cause of the lower V_{see} in Gen1 parts. At least three devices were tested in all conditions and Table 7.0-1 shows the lowest V_{see} of all tests. Some part-to-part variance was observed in V_{see}, but was generally within the steps size of 20 V. EPC parts with 40 V ratings were also tested, but all showed no SEE effects for any condition.

Table 7.0-1. The voltage at which SEE occurs (V_{see}) for two generations of two device.

Rated V_{ds} [V]	Gen 1 V_{SEE} [V]	Gen 1 V_{SOA} [V]	Gen 2 V_{SEE} [V]	Gen 2 V_{SOA} [V]
40	40	30	40	30
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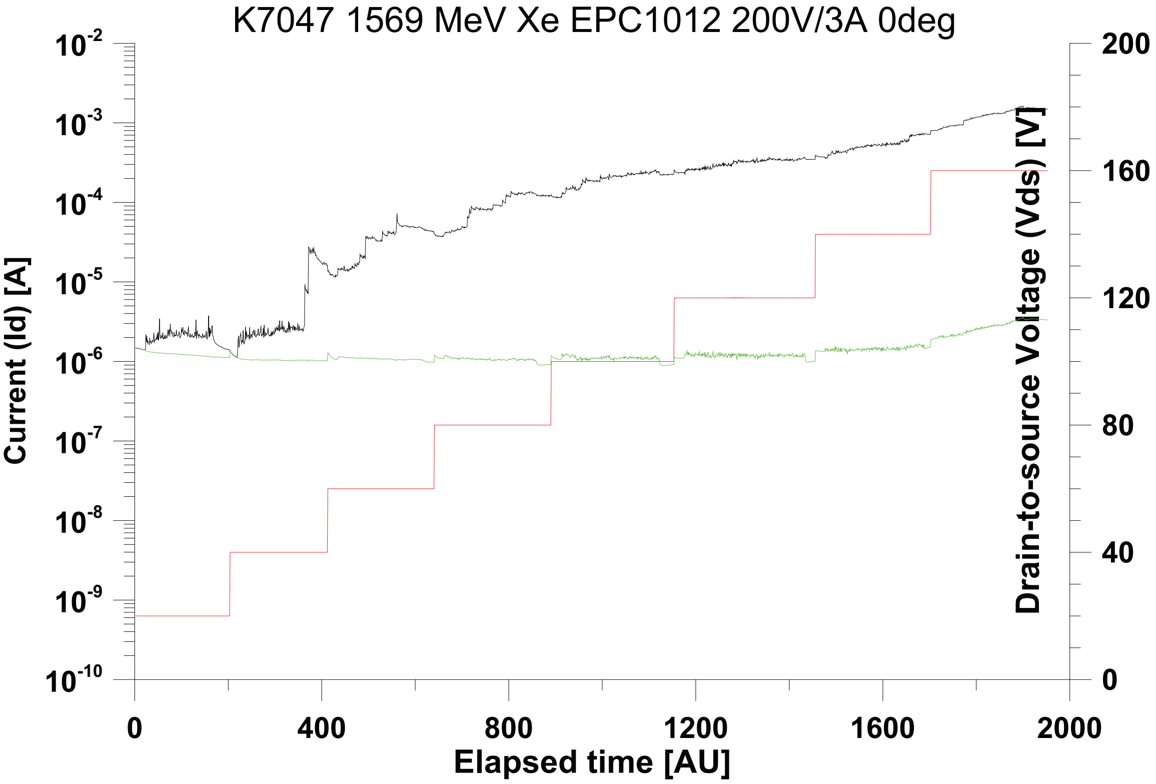


Figure 7.0-1. Heavy ion response of the EPC1012 at normal incidence. Ion flux was 2E4 cm^{-2}-s^{-1}.

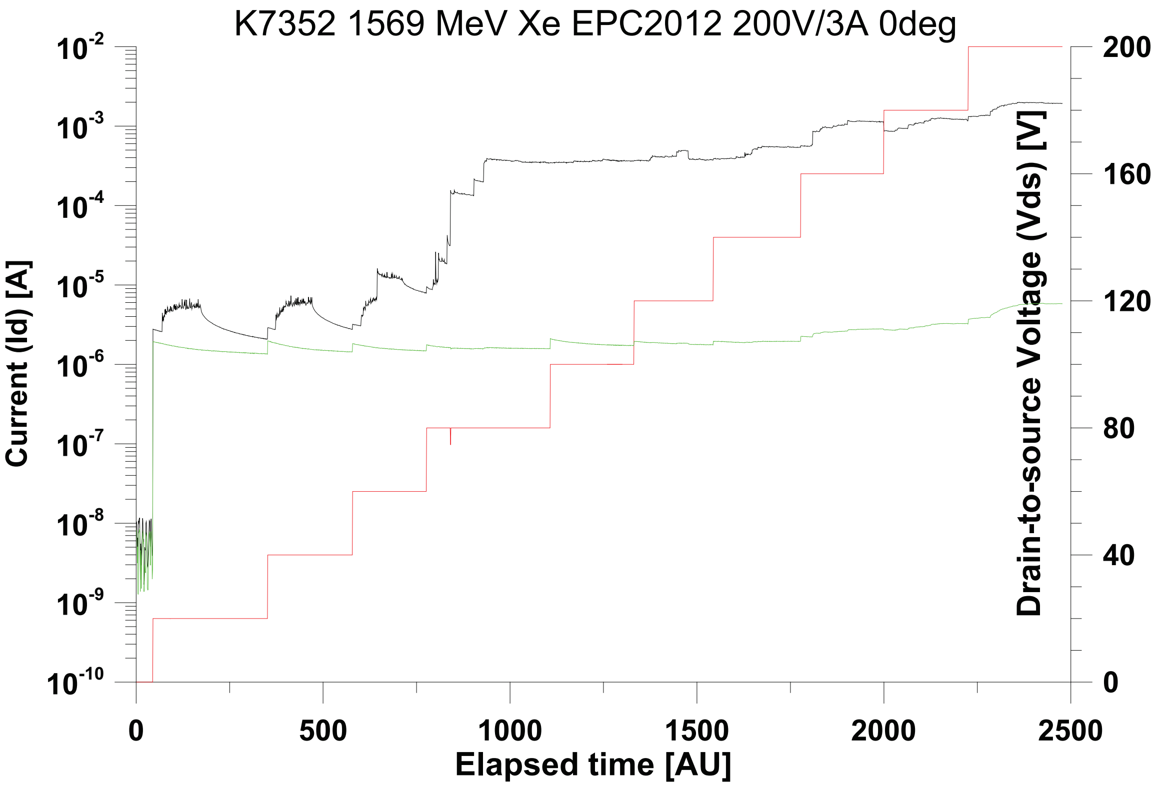


Figure 7.0-2. Heavy ion response of the EPC2012 at normal incidence. Ion flux was 2E4 cm^{-2}-s^{-1}.

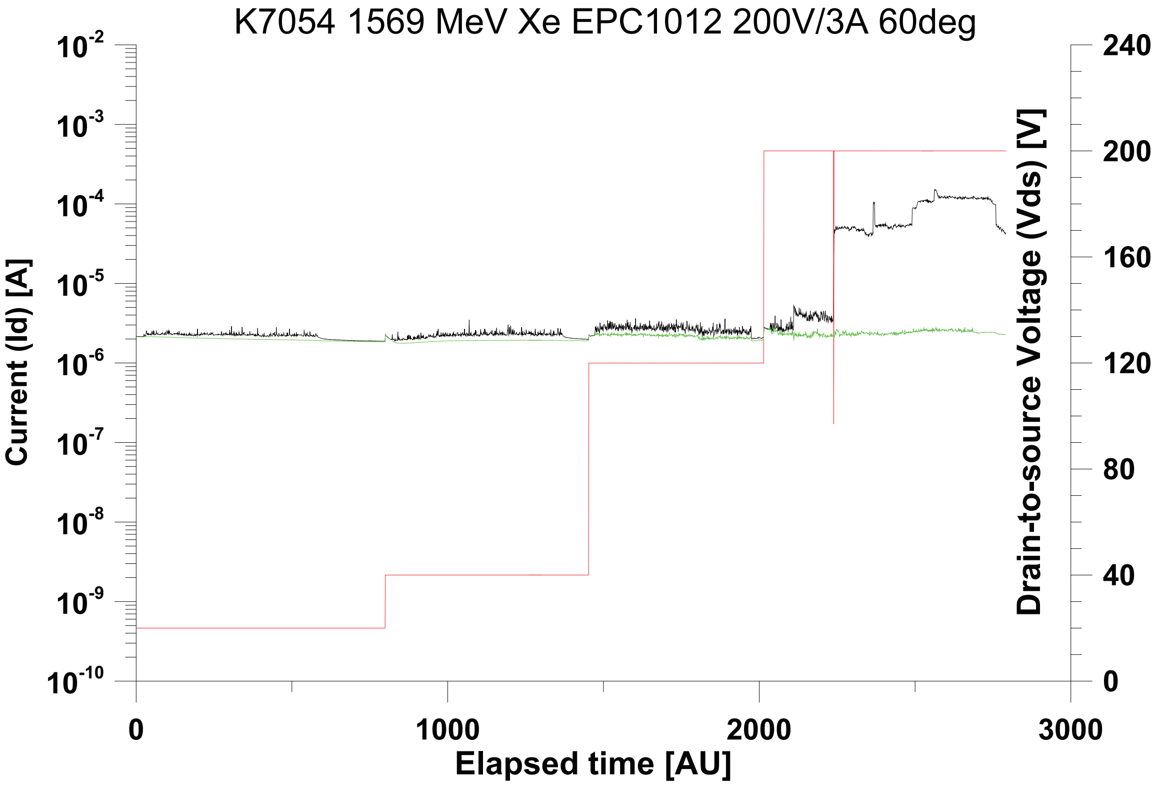


Figure 7.0-3. Heavy ion response of the EPC2012 at 60 degree tilt. Ion flux was 2E4 cm^{-2}-s^{-1}.

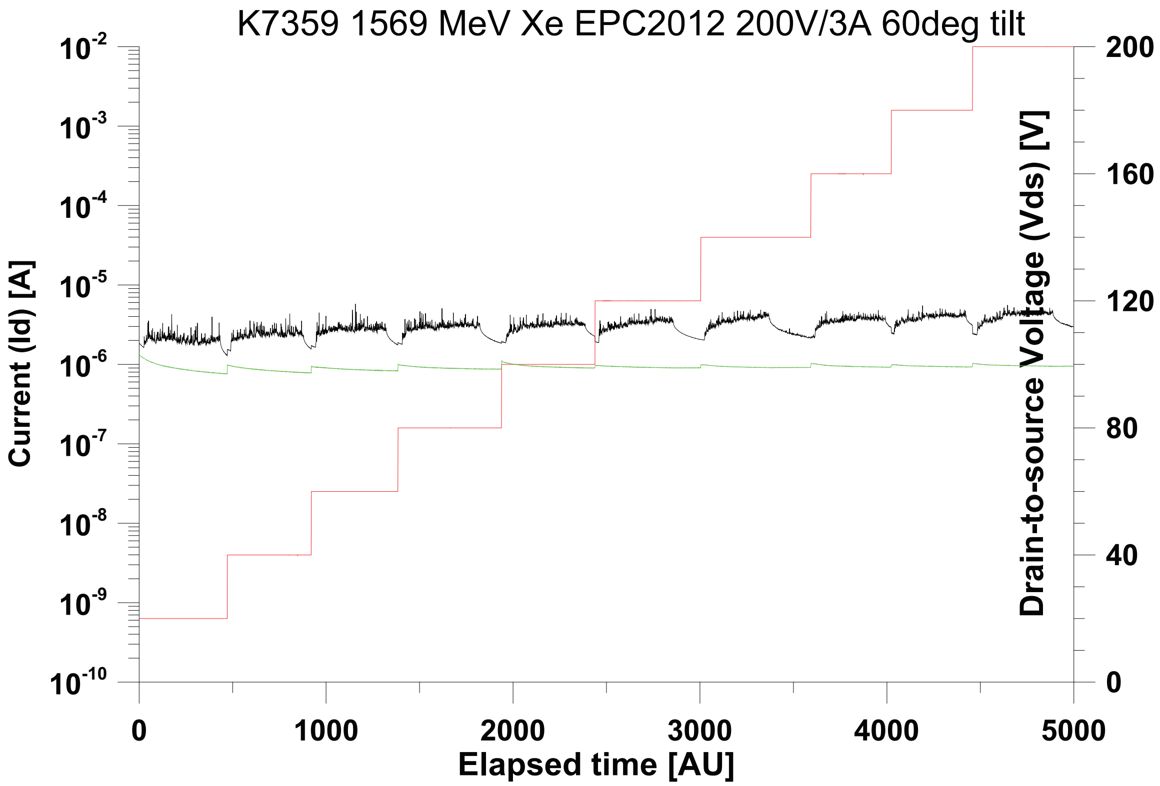


Figure 7.0-4. Heavy ion response of the EPC2012 at 60 degree tilt. Ion flux was 2E4 cm^{-2}-s^{-1}.

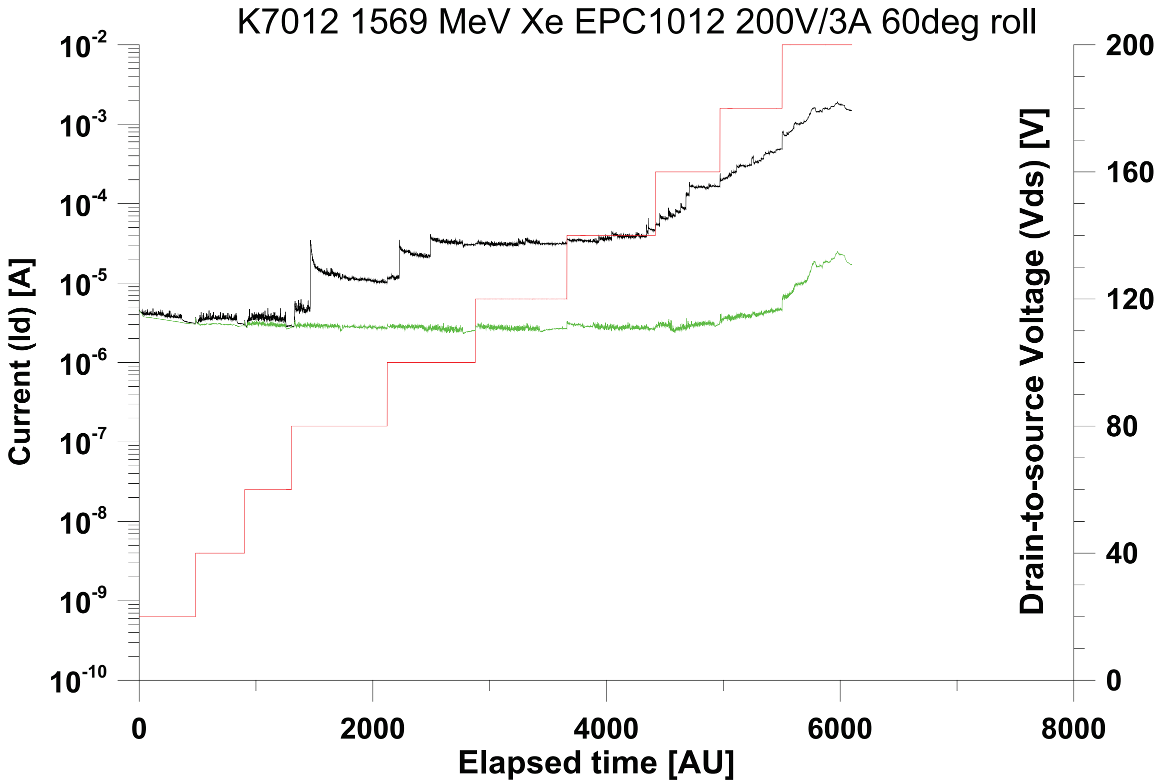


Figure 7.0-5. Heavy ion response of the EPC2012 at 60 degree roll. Ion flux was 2E4 cm^{-2}-s^{-1}.

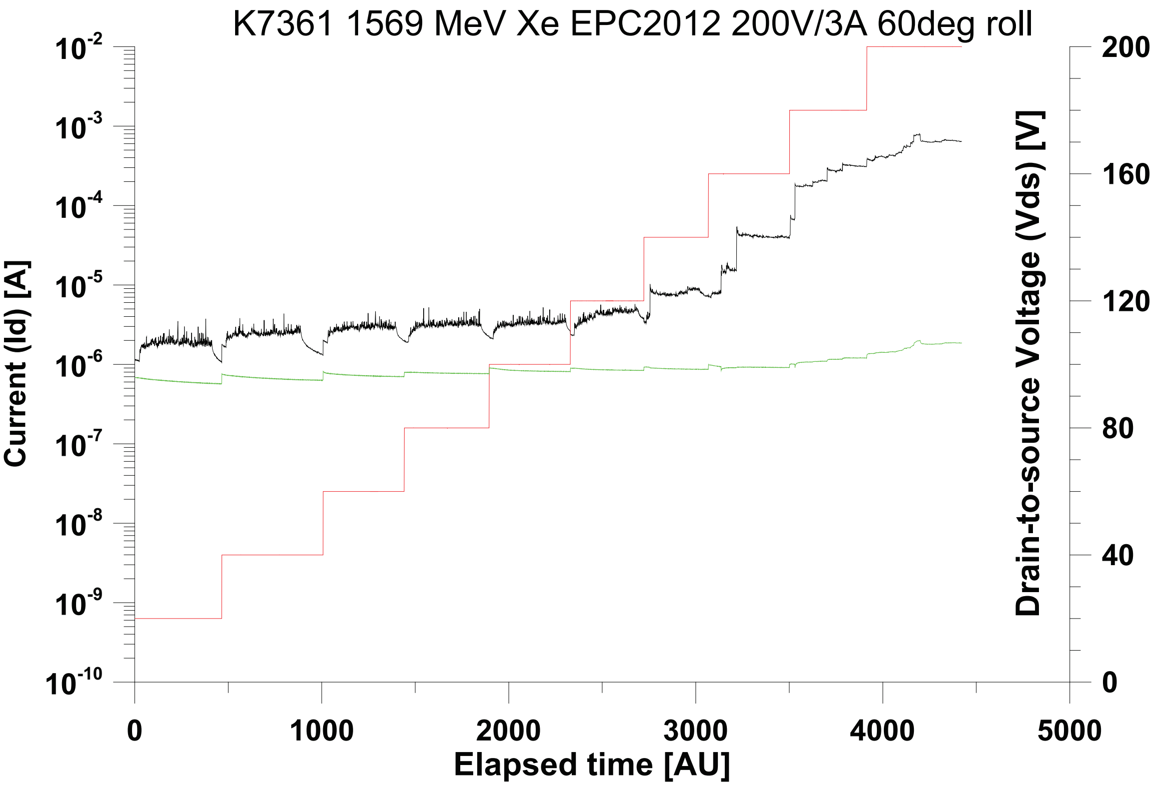


Figure 7.0-6. Heavy ion response of the EPC2012 at 60 degree roll. Ion flux was 2E4 cm^{-2}-s^{-1}.

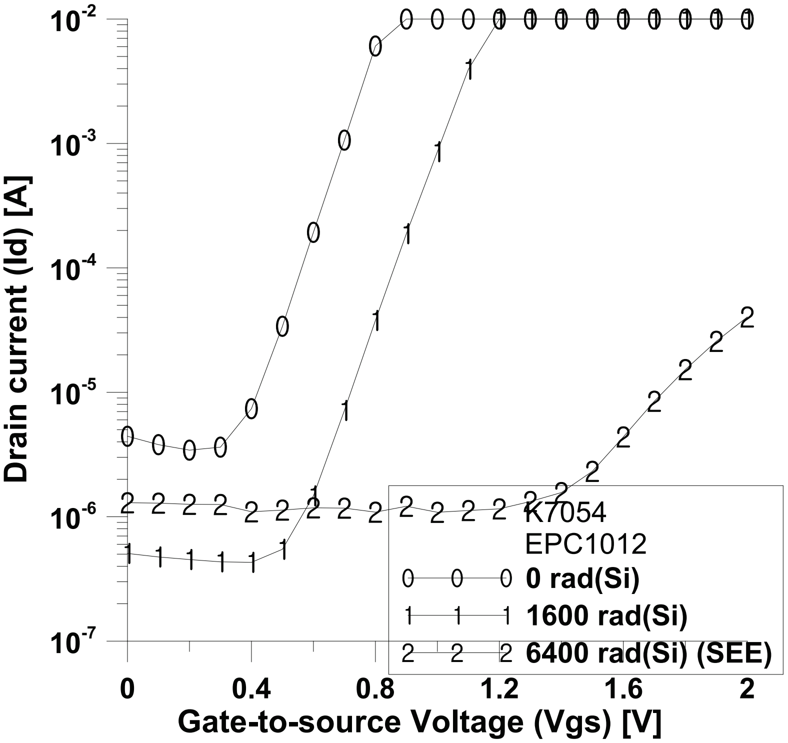


Figure 7.0-7. I-V curve after several heavy ion irradiations for an EPC1012.

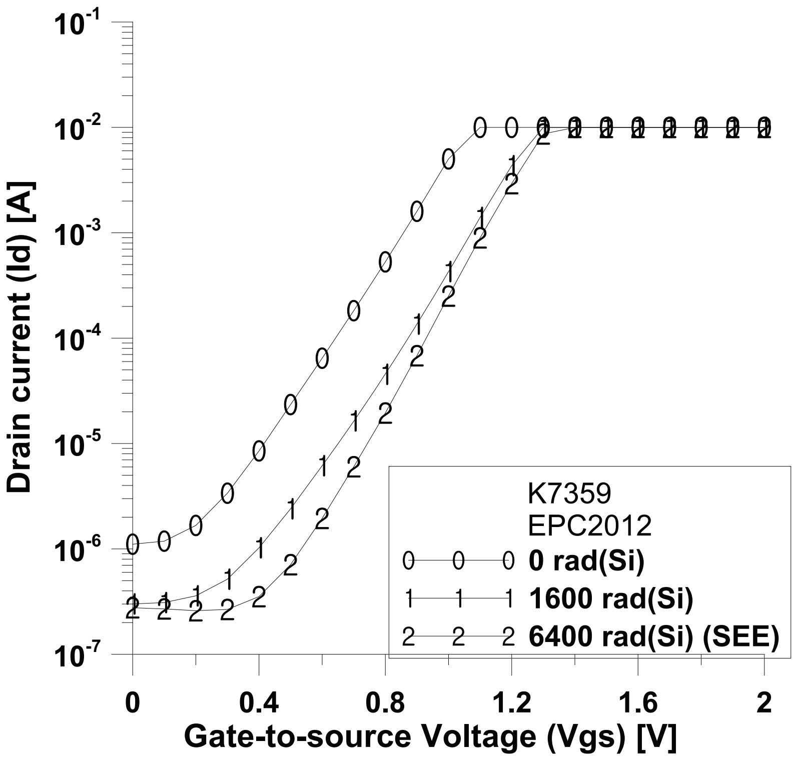
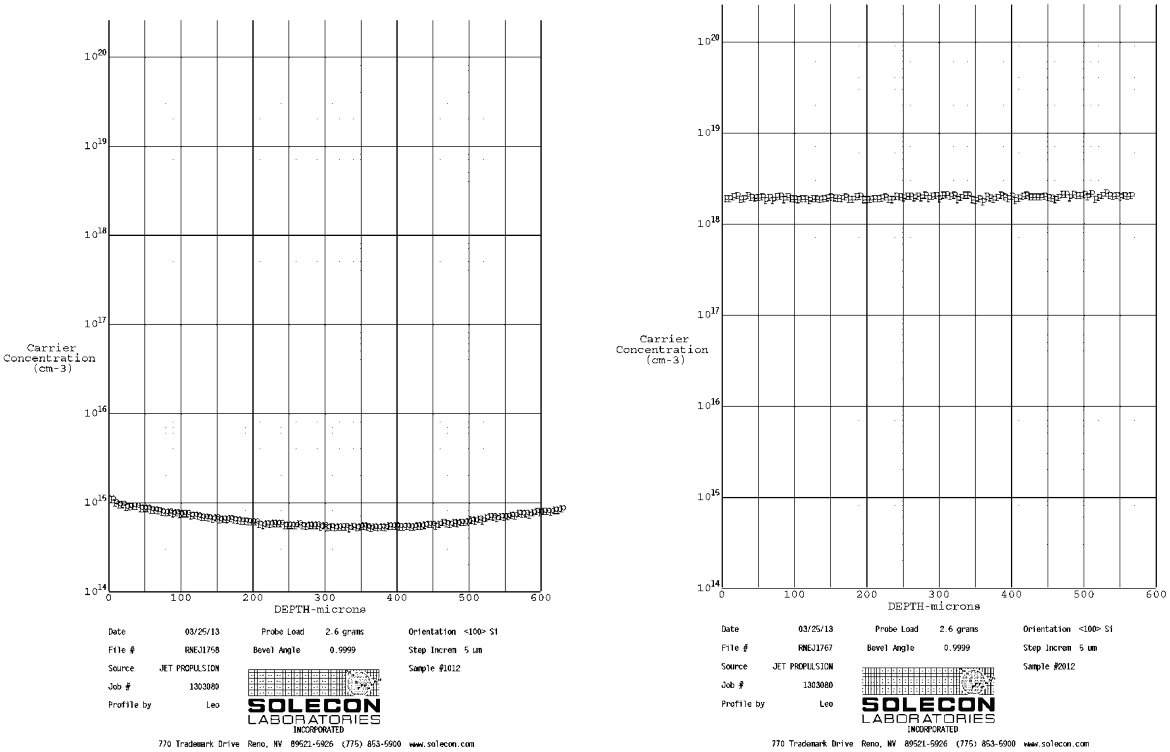


Figure 7.0-8. I-V curve after several heavy ion irradiations for an EPC2012.



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770 Trademark Drive Reno, NV 89521-5926 (775) 853-5900 www.solecon.com

Date 03/25/13
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770 Trademark Drive Reno, NV 89521-5926 (775) 853-5900 www.solecon.com

Figure 7.0-9. Spreading resistance results for the EPC1012 (left) and EPC2012 (right).

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14. ABSTRACT

Recent testing of the EPC1000 series eGaN FETs has shown sensitivity to Single Event Effects (SEE) that are destructive. These effects are most likely the failure of the very thin gate structure in HEMT architecture. EPC has recently changed the doping of the substrate to improve the performance and the SEE response. This testing compares the SEE response of both devices.

15. SUBJECT TERMS

Single-event effect, SEE, Enhanced Power Conversion, EPC, Single Event Gate Rupture, SEGR, Efficient Power Conversion Corporation, eGaN, FET, heavy ions, HEMT architecture

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