National Aeronautics and Space Administration

Single-Event Effect Report for EPC Series eGaN FETs: EPC1001, EPC1010, EPC1014, EPC1012

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NASA Electronic Parts and Packaging (NEPP) Program
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TABLE OF CONTENTS

1.0 EXECUTIVE SUMMARY

Heavy ion testing of newly available GaN FETs from EPC were tested in March of 2012 at TAM. The EPC1010, EPC1001, EPC1012, and EPC1014 were tested for general radiation response from gold and xenon ions. Overall the devices showed radiation degradation commensurate with breakdown in isolation oxides, and similar testing by EPC and Microsemi agrees with these data. These devices were the first generation production run of the device called Gen1. Gen2 parts are scheduled for later in the third quarter of FY2012.

2.0 PURPOSE

The purpose of this testing was to characterize the newly available eGaN FET from EPC for radiation effects from heavy ions. The devices were tested for Single-Event Effect, such as Single-Event Gate Rupture (SEGR), as well as investigated for any reduction in SOA from irradiation. Dose effects from the heavy ions were also investigated.

3.0 TEST SAMPLES

The DUT listed in Table I were acquired commercially and stored under flight ESD conditions per D-57732. Since these devices were so small and the package was atypical for SEE testing, the parts had to be irradiated through the solder bumps in a dead-bug configuration. Figure 2.1 shows the various devices acquired, as prepared for a focused ion beam (FIB) analysis. An EPC1014 was selected for FIB analysis to test the feasibility of irradiation through the solder bumps. Figure 2.2 shows the pin-out of this configuration and a 25x SEM micrograph before FIB cutting. Figures 2.4–2.7, show the results of the FIB and SEM scanning. The solder varies in thickness, but it is never larger than 50 um, so ions at TAMU could easily penetrate the entire transistor volume. Figures 2.8 and 2.9 show the results of an element map done to evaluate the properties of the DUT, identify the sensitive SEE and dose volumes, and aid in future modeling efforts. All these data allowed for the ions at TAMU to adequately irradiate the device; however, an ion transport analysis would have to be done to fully describe the experimental ion conditions.

Table 3-1. List of devices that were tested.

Manufacturer	Part Number	VDS rating (max) [V]	Channel	LDC	Package
EPC	EPC1012	200	N	NA	Custom
EPC	EPC1014	40	N	NA	Custom
EPC	EPC1001	100	N	NA	Custom
EPC	EPC1010	200	N	NA	Custom

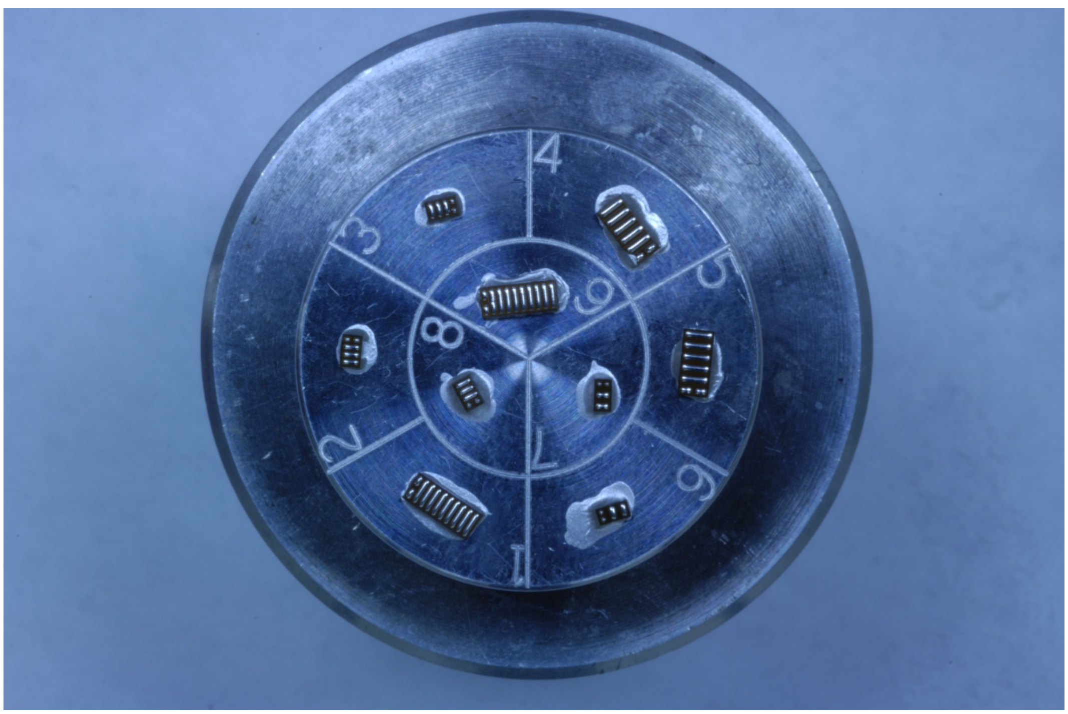

Figure 3-1. Picture of the EPC DUTs. All the available EPC devices are shown.

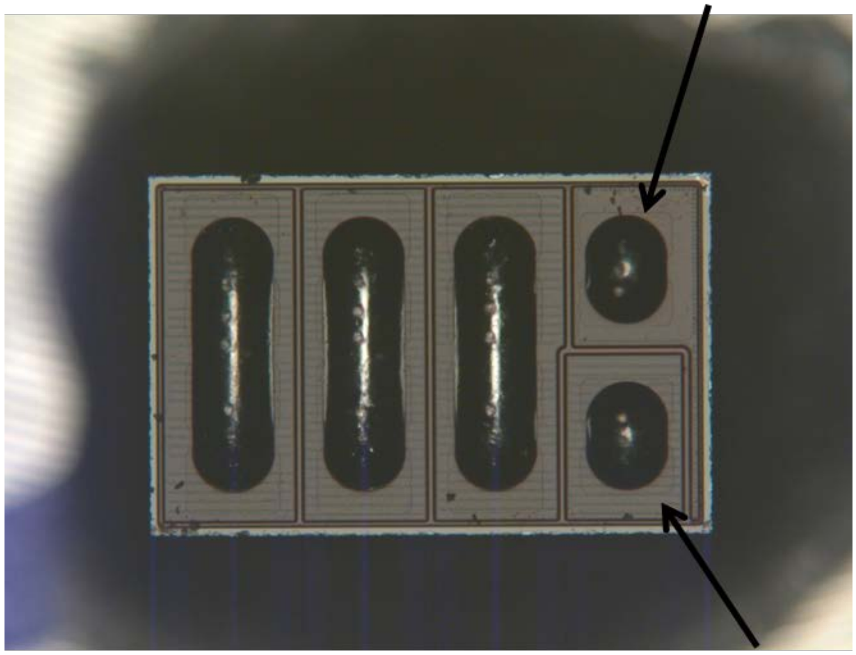

Figure 3-2. Picture of the EPC1014.

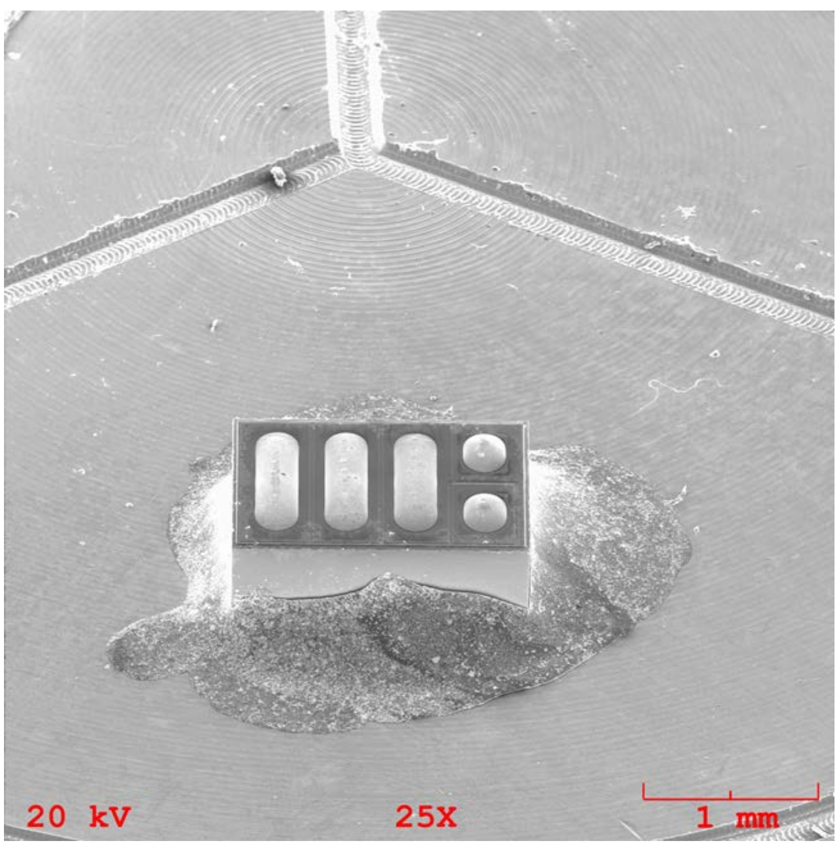

Figure 3-3. SEM on the EPC1014 prior to FIB.

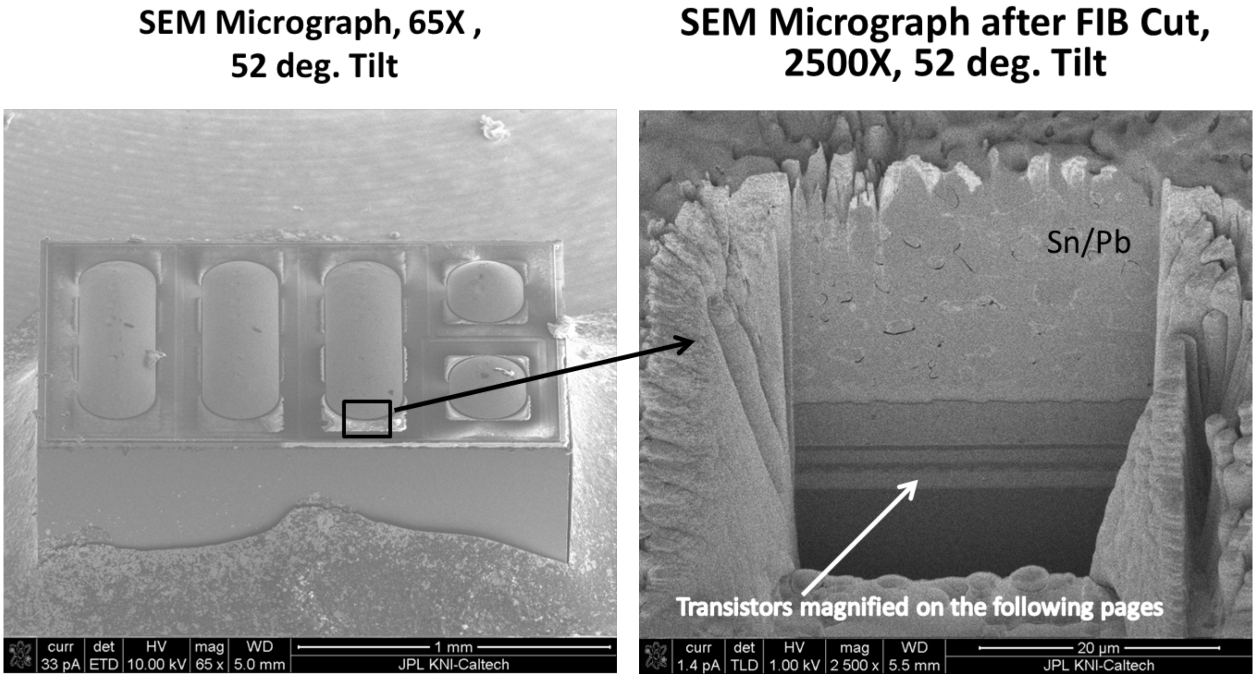

Figure 3-4. EPC1014 before and after FIB.

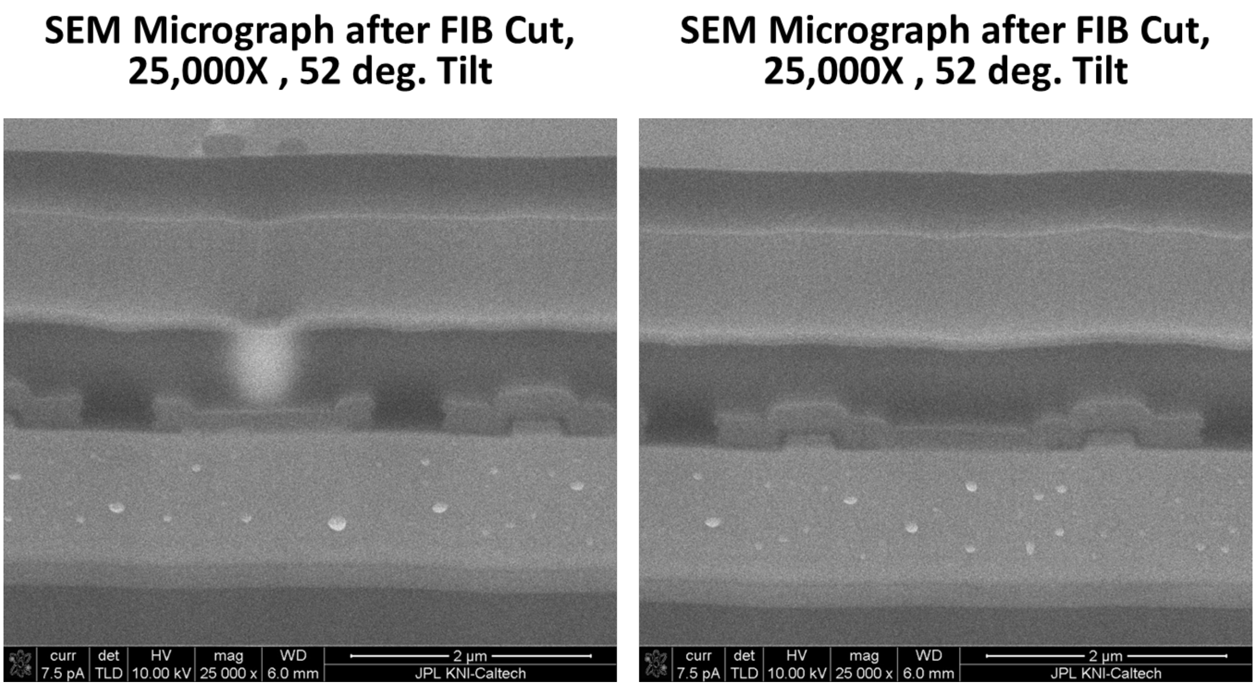

Figure 3-5. SEM of the active areas of the DUT (Note the tungsten plug on the left).

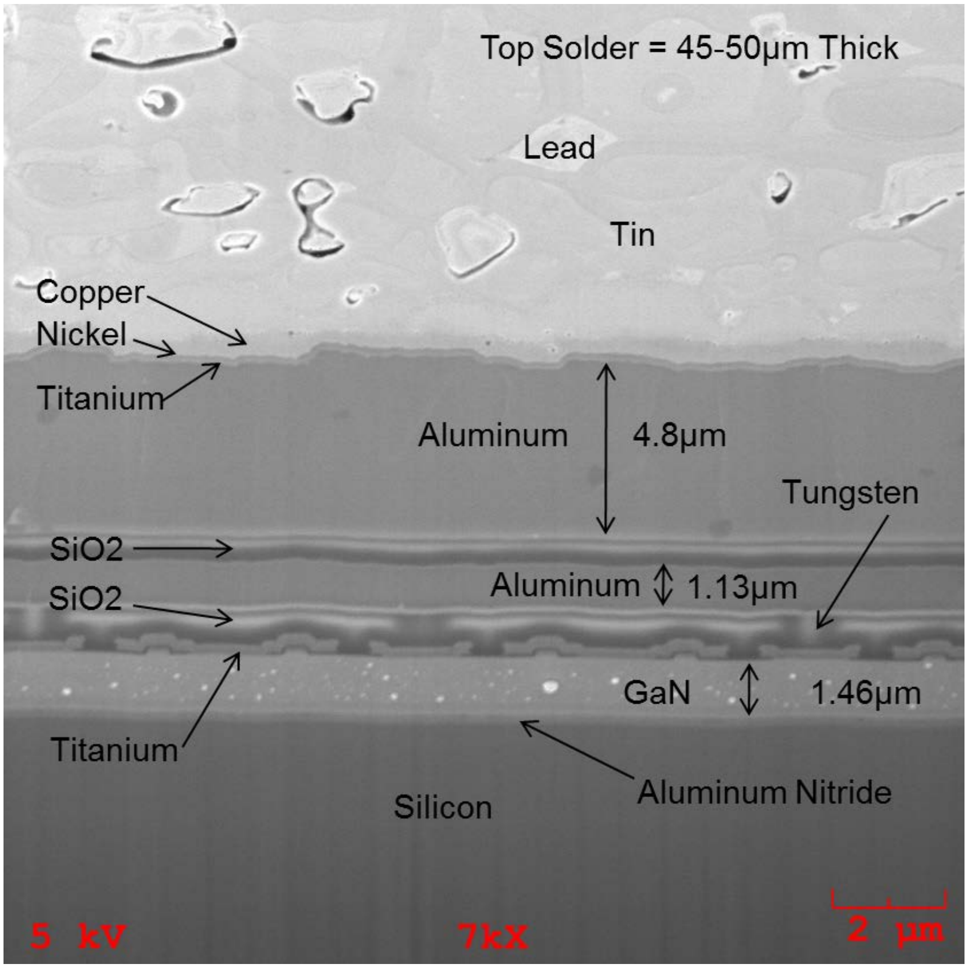

Figure 3-6. Analysis of the areas in the device.

SEM Micrograph after Mechanical cross-section, 50KX

SEM Micrograph after Mechanical cross-section, 50KX with Lateral dimensions

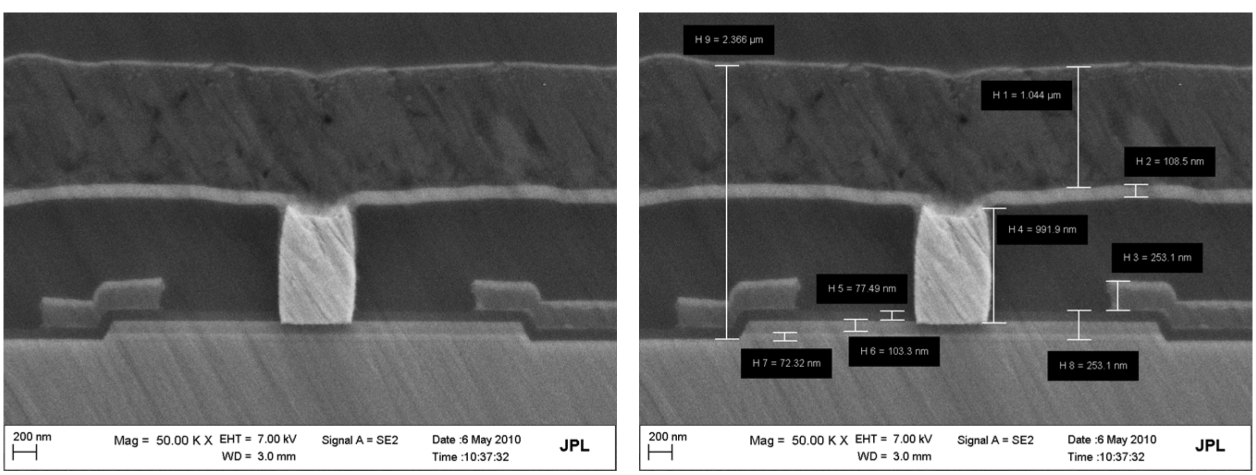

Figure 3-7. Analysis of the tungsten plug.

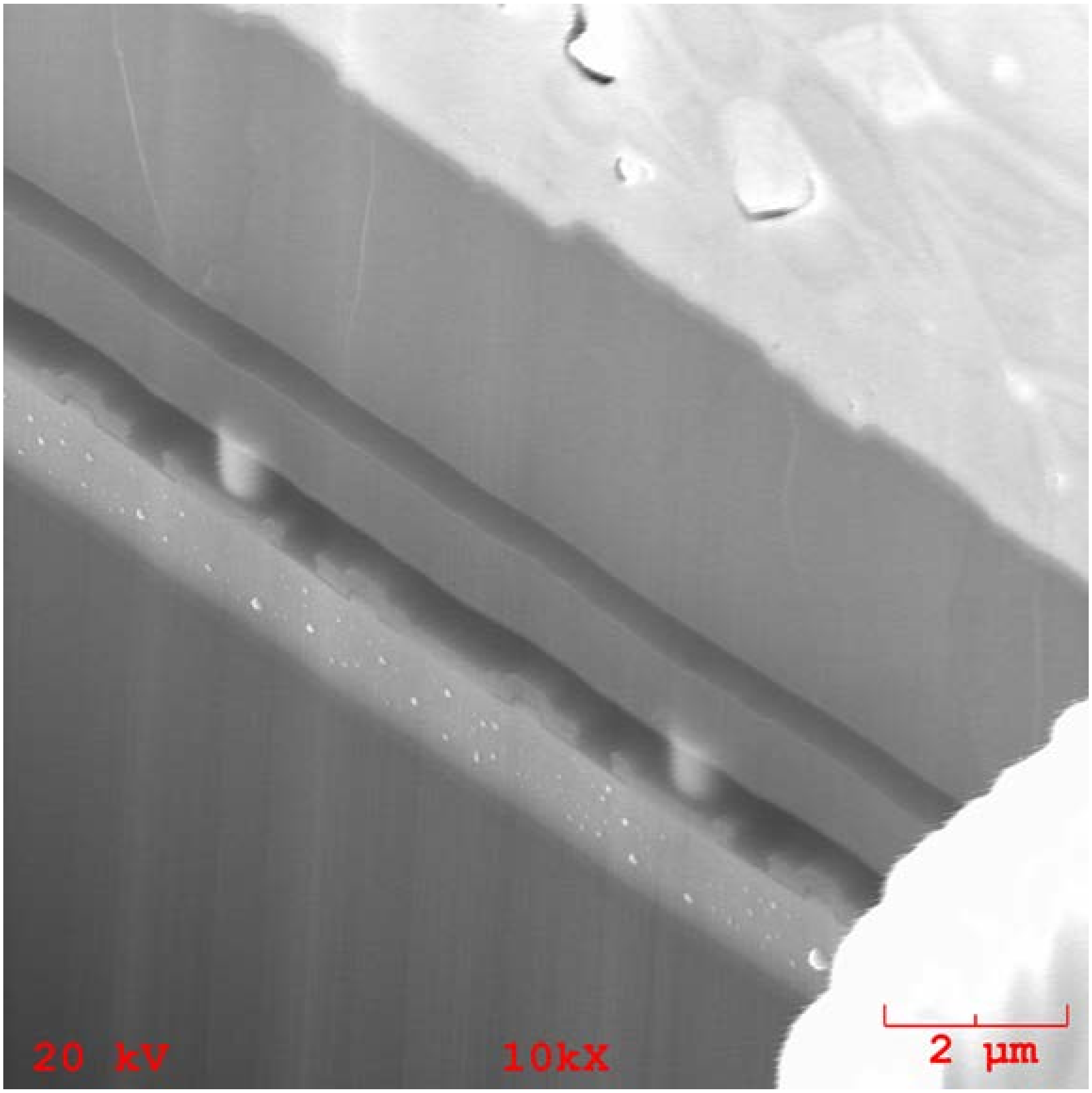

Figure 3-8. SEM of the device for the element map.

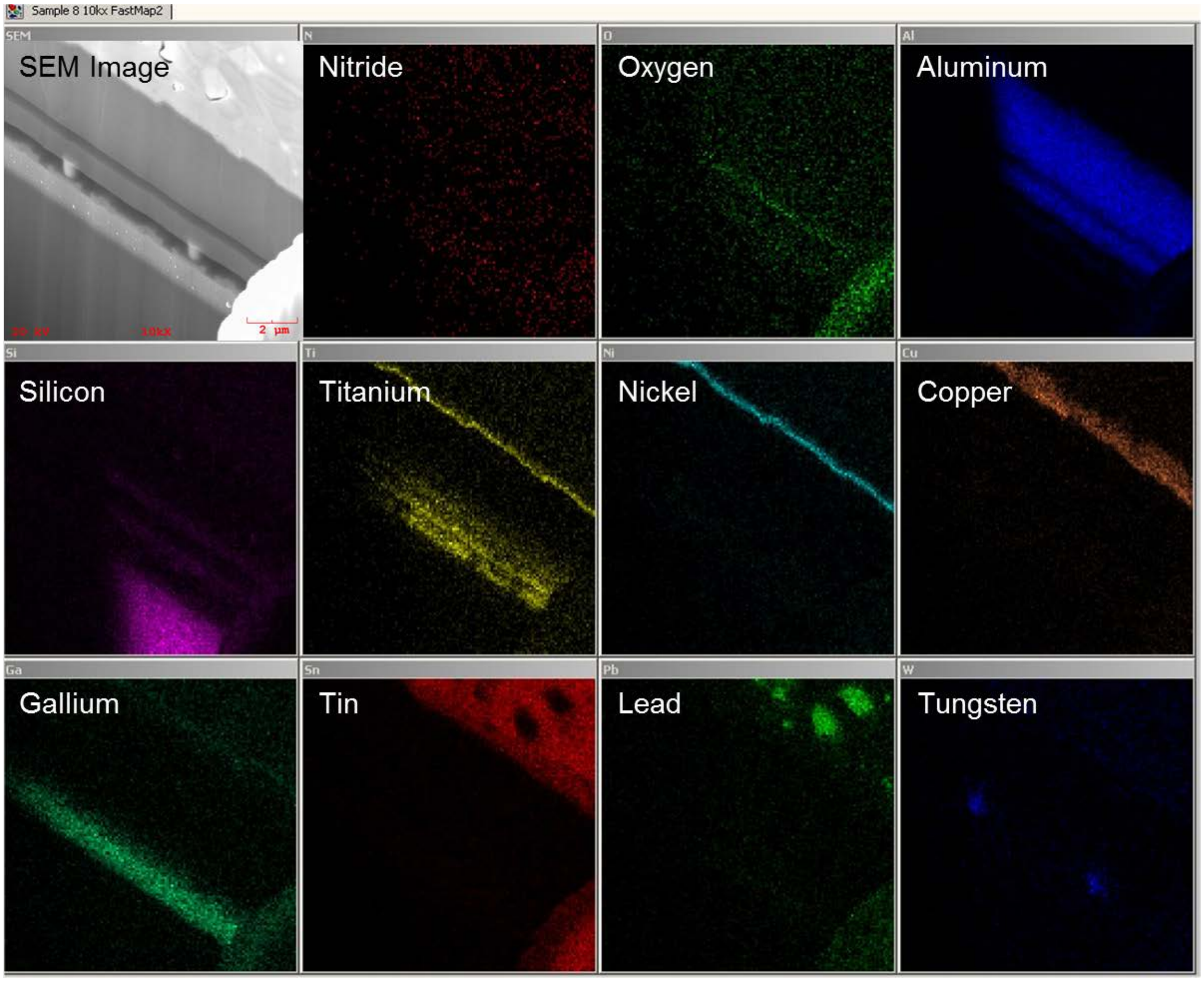

Figure 3-9. Element map of the device.

4.0 GENERAL

All DUTs were divided into four (4) groups of 3 (three) for SEGR testing, as shown in Table II. For each irradiation, an EPC1001, EPC1010, EPC1014, and EPC1012 were tested. But in the last test, two of the EPC1001 were tested to investigate an effect.

Table 3-1. List of devices that were tested.

Group	Quantity	Gate Bias [V]	Angle	Ion/Energy /MeV	LET [Mev.cm^2/mg]	Comment
1	1 of each	0	0	Au	~35	
2	1 of each	0	0	Xe	~35	
3	12 of EPC1001, 1 of EPC1014, and 1 of EPC1012	0	60	Xe	~35	Only tilt angle.

5.0 PROCEDURE/SETUP

The general test procedure adhered to "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, see Fig. 4.1. The equipment used in this effort is listed in Table III.

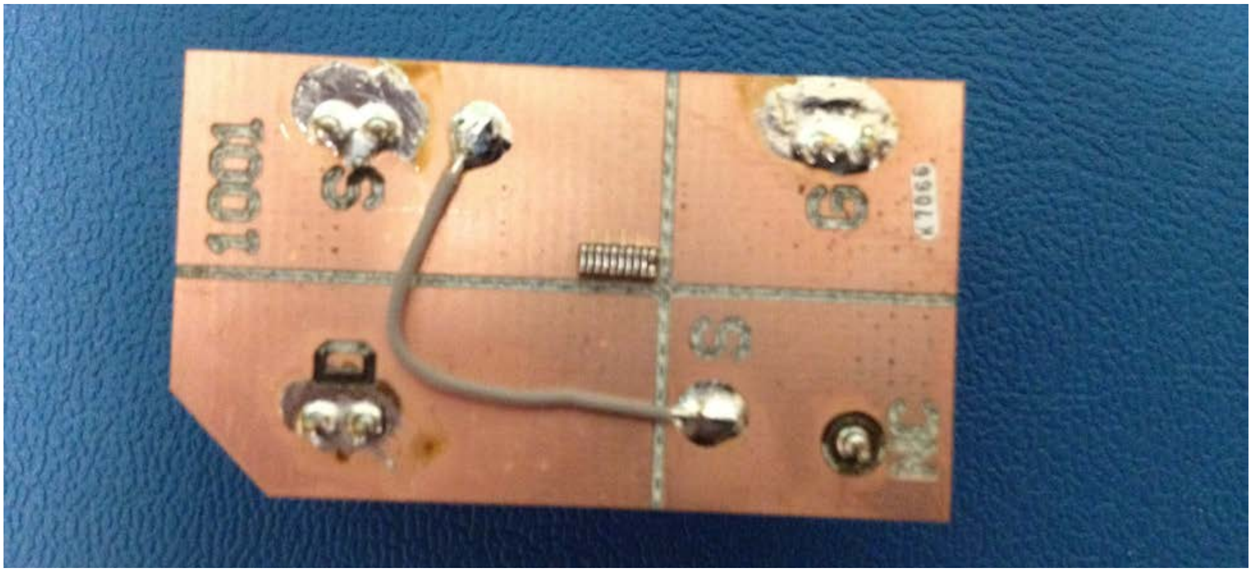

Figure 5-1. Dose testing carrier.

Table 5-1. 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

5.1 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.

5.2 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.

5.3 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.

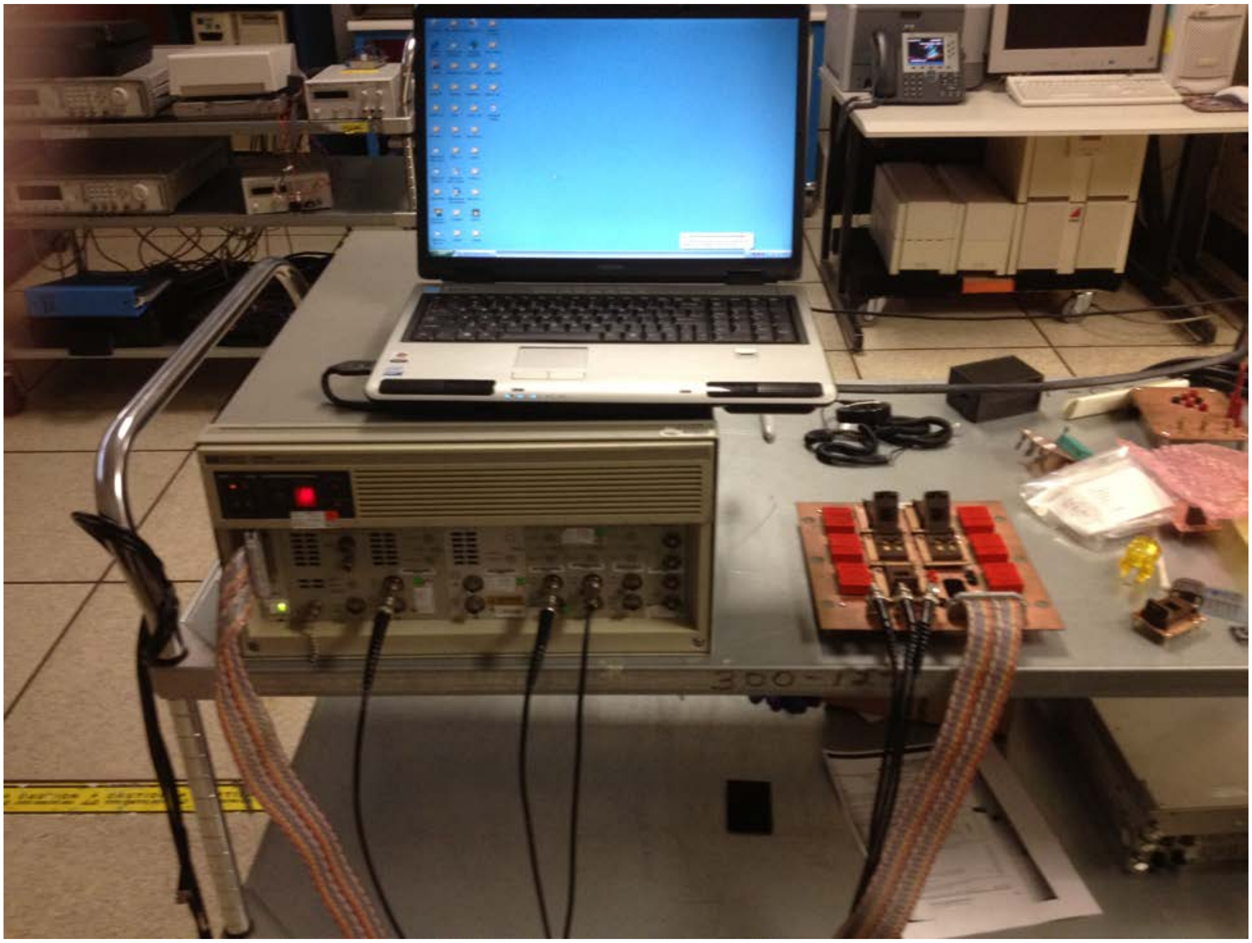

Fig. 5.3-1. Setup used for SEE testing. The entire system is transported to a heavy ion site.

6.0 SOURCE REQUIREMENTS

The ion source was the TAMU cyclotron.

7.0 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.

8.0 RESULTS

Results from testing the twelve devices are listed in Table IV. Parts showed dose damage with the following trends:

1. At normal incidence, the higher LET gold ion did more damage than xenon. This was expected.
2. Devices with lower voltage rating were less susceptible to dose damage. This was also expected.
3. Devices irradiated at 60 degrees showed little degradation.
4. Devices irradiated at 60 degrees showed catastrophic SEE with no dose damage precursors.

The dose degradation affected the following measured parameters: IDSS, Vth, and gm. The results are presented in the following figures.

Fig. 9.1 and 9.2 present part K7063, EPC1001.

Fig. 9.3 and 9.4 present part K7058, EPC1010.

Fig. 9.5 and 9.6 present part K7053, EPC1012.

Fig. 9.7 and 9.8 present part K7048, EPC1014.

Fig. 9.9 and 9.10 present part K7044, EPC1001.

Fig. 9.11 and 9.12 present part K7045, EPC1010.

Fig. 9.13 and 9.14 present part K7046, EPC1014. Despite no drain leakage, the Vth and Gm are affected.

Fig. 9.15 and 9.16 present part K7047, EPC1012.

Fig. 9.17 and 9.18 present part K7064, EPC1001. Despite no drain leakage, the Vth and Gm are affected.

Fig. 9.19 and 9.20 present part K7049, EPC1014. Despite no drain leakage, the Vth and Gm are affected.

Fig. 9.21 and 9.22 present part K7065, EPC1001. Despite no drain leakage, the Vth and Gm are affected.

Fig. 9.23 and 9.24 present part K7054, EPC1012. Despite no drain leakage, the Vth and Gm are affected. These data were taken at aggressive voltage steps to conserve machine time. The SEE results may overestimate the effect

Table 8-1. Top-level results of the initial EPC testing.

	2342 MeV Au	1569 MeV Xe	1569 MeV Xe
EPC1012	K7053	K7047	K7054
	Current leakage with dose	Current leakage with dose	No dose degradation
	No SEE	No SEE	SEGR
EPC1001	K7063	K7044	K7064
	Current leakage with dose	Current leakage with dose	None
	No SEE	No SEE	SEGR
EPC1010	K7058	K7045	NA
	Current leakage with dose	Current leakage with dose	NA
	No SEE	No SEE	NA
EPC1014	K7048	K7046	K7049
	Slight drain degradation	No dose degradation	No dose degradation
	No SEE	No SEE	No SEE

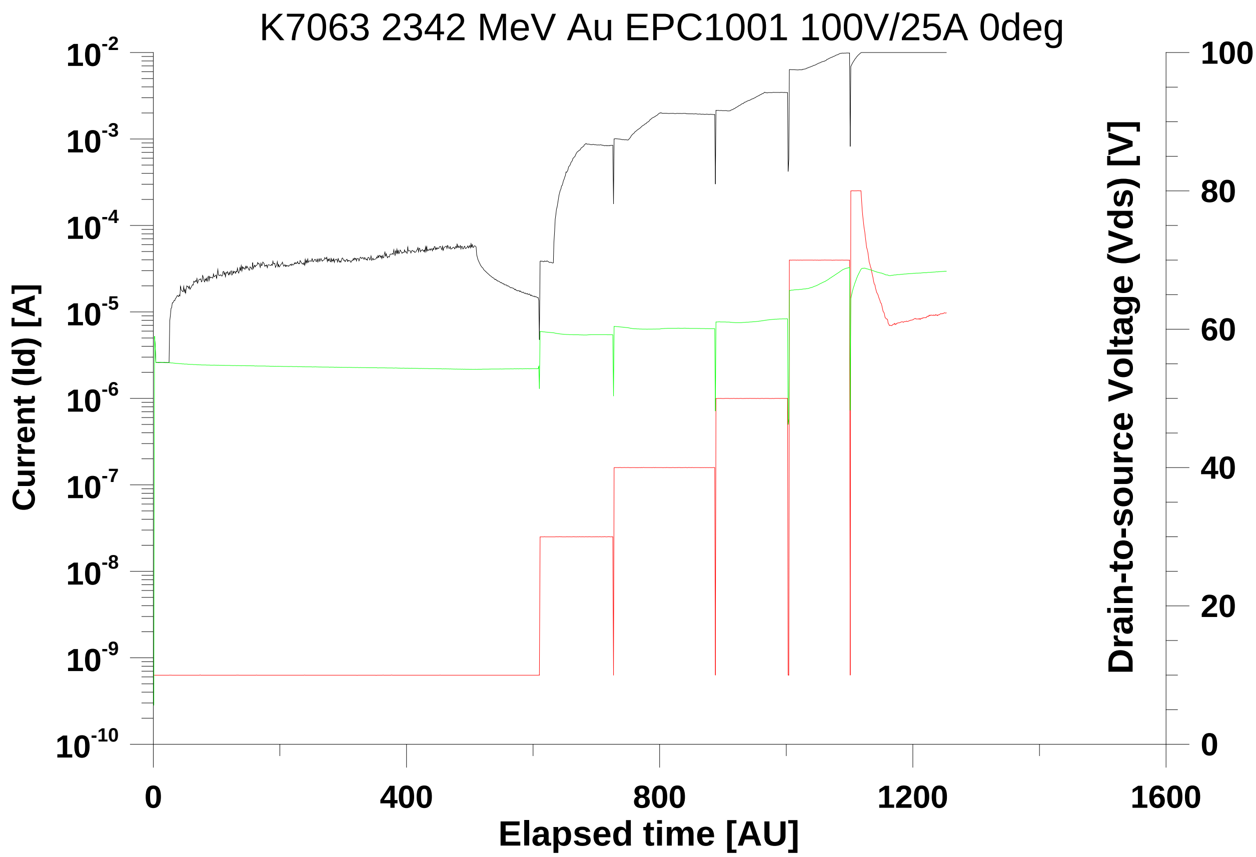

Figure 1.1-1. Heavy ion response of the EPC1001, K7063. Ion flux was 1E5 cm^{-2}-s^{-1}. The first irradiation was 1E7 cm^{-2}, the rest were for 1E6 cm^{-2}. Red line is drain voltage; gate voltage is zero volts. Black line is drain current and green line is gate current.

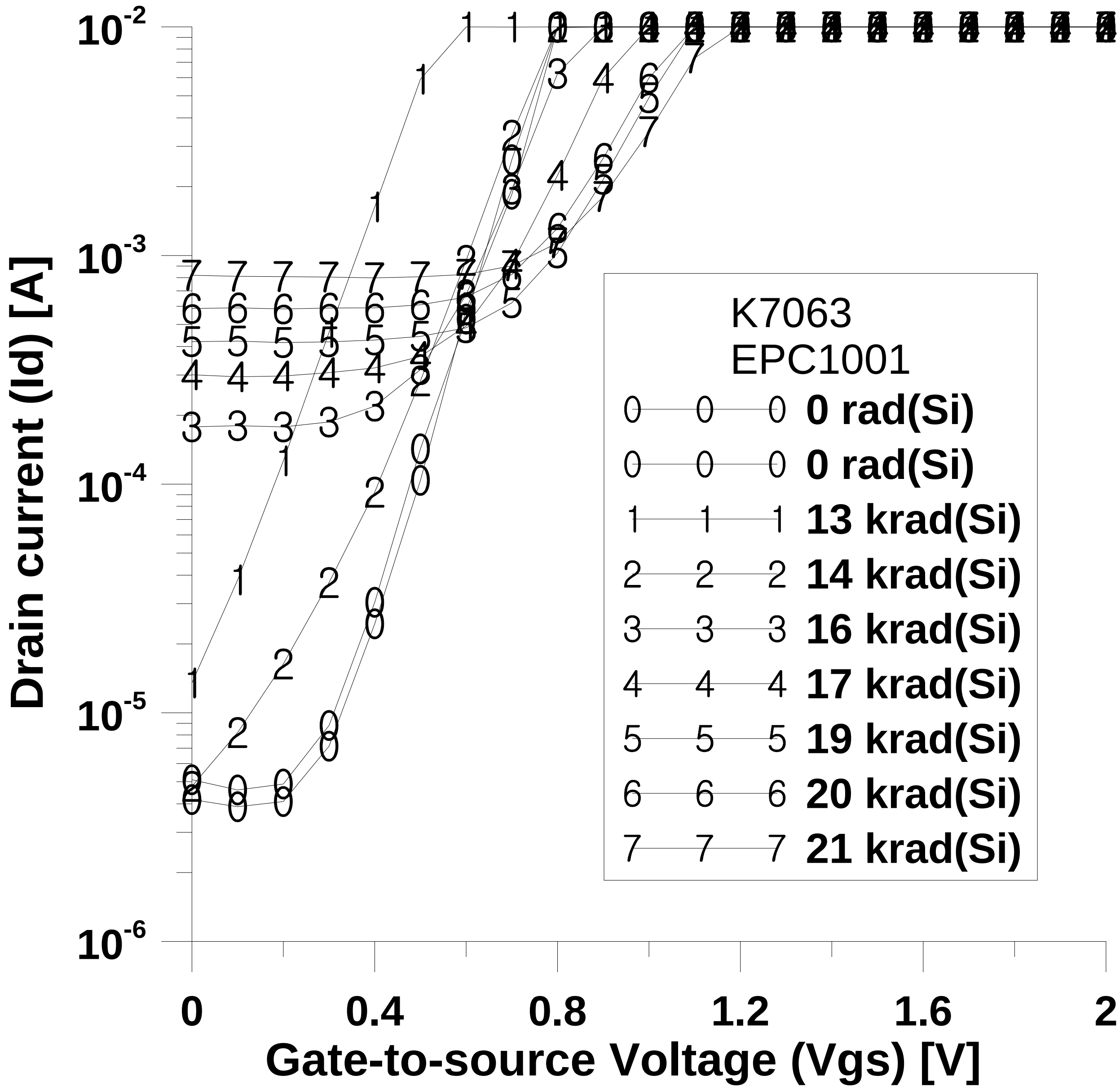

Figure 1.1-1. Effect of heavy ion radiation on the transfer curve of part K7063. Drain voltage was 10 V.

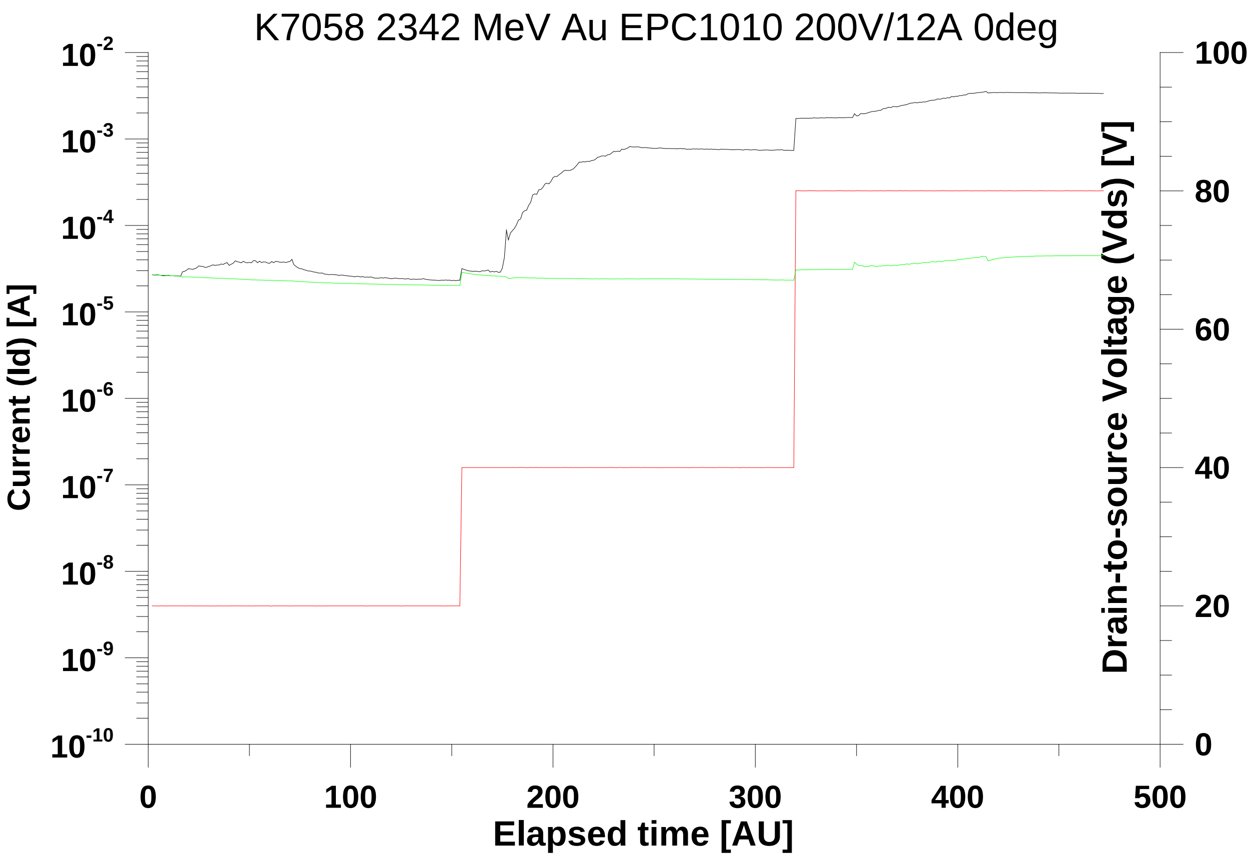

Figure 1.1-1. Heavy ion response of the EPC1010 200V/12A. Ion flux was 1E5 cm^{-2}-s^{-1}. Red line is drain voltage; gate voltage is zero volts. Black line is drain current and green line is gate current.

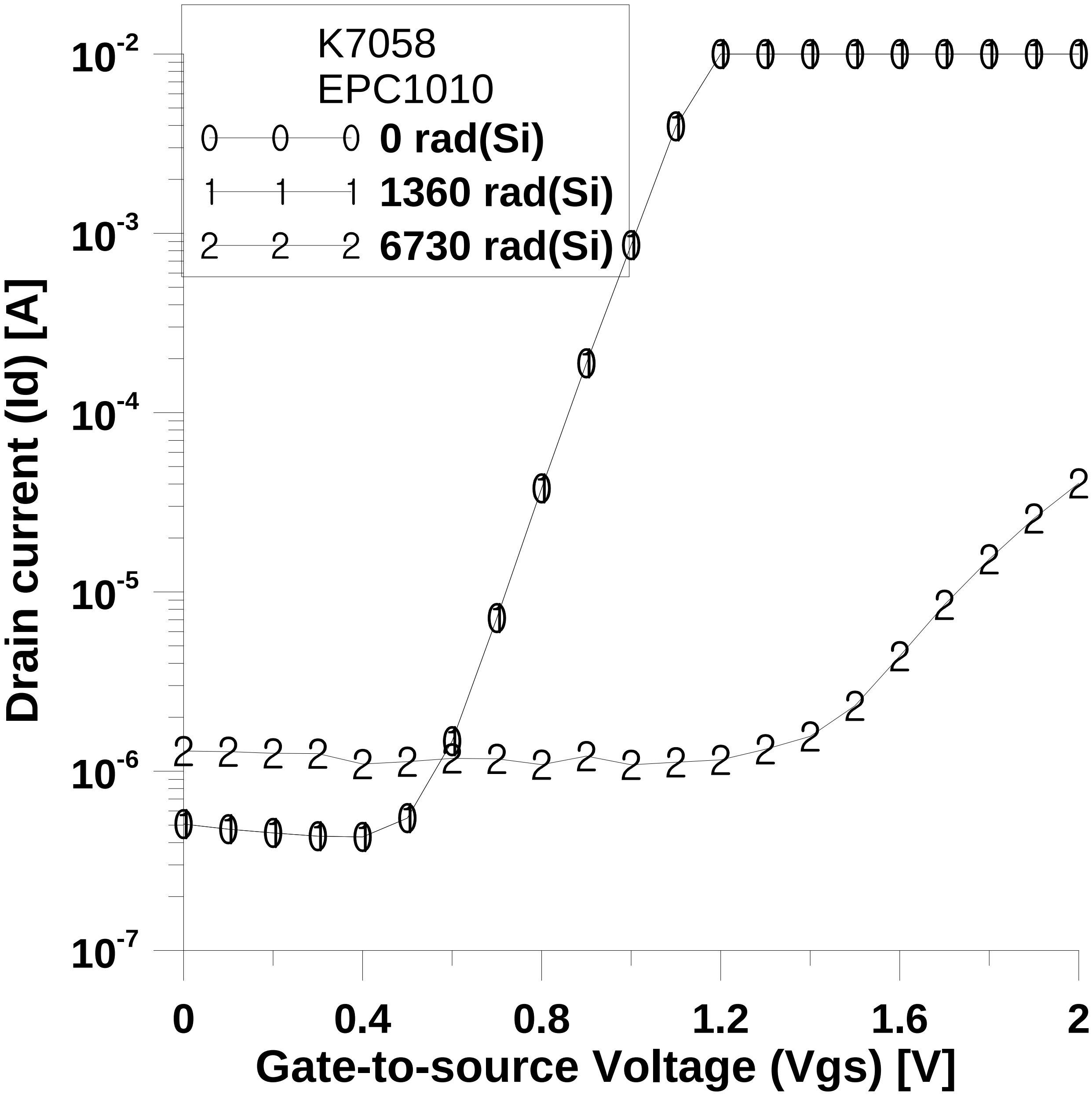

Figure 1.1-1. Effect of heavy ion radiation on the transfer curve K7058. Drain voltage was 10 V.

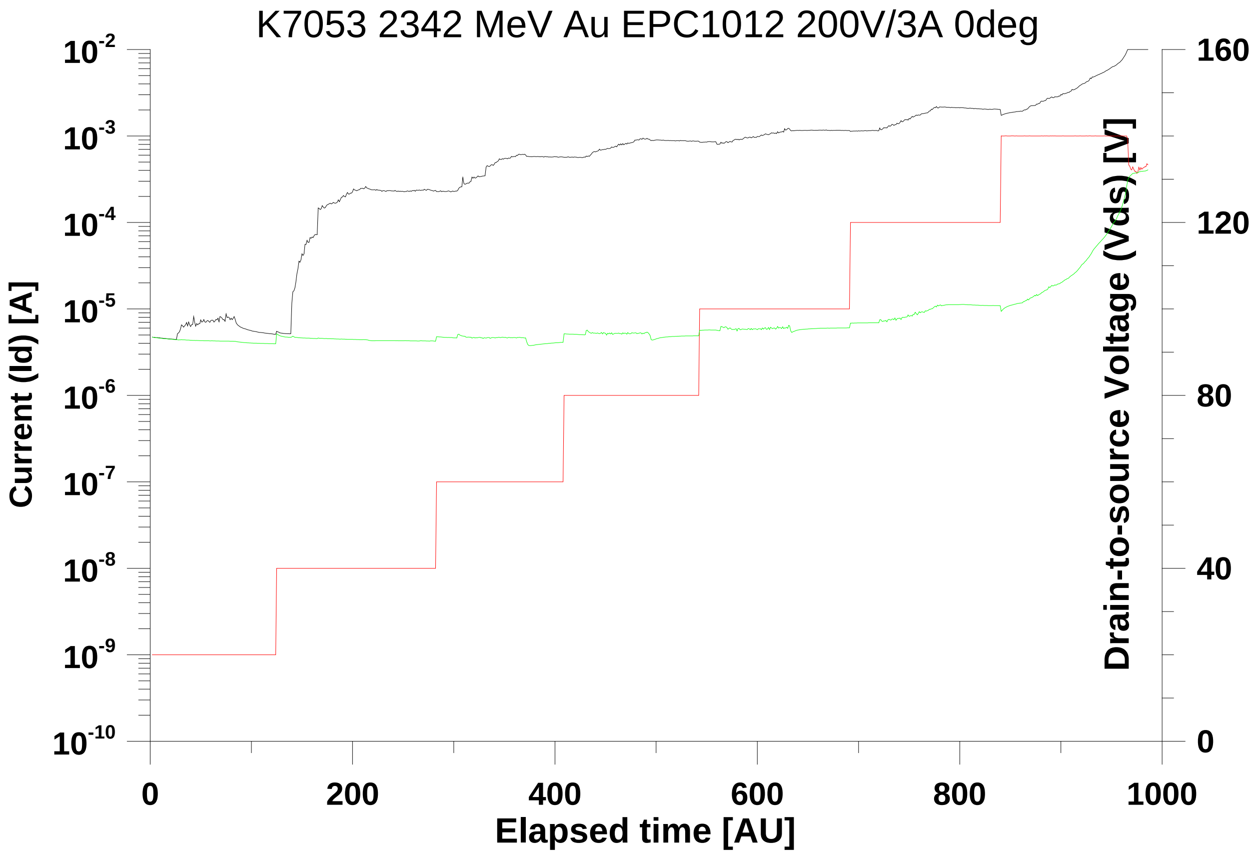

Figure 1.1-1. Heavy ion response of the EPC1012 200V/3A. Ion flux was 1E5 cm^{-2}-s^{-1}. Red line is drain voltage; gate voltage is zero volts. Black line is drain current and green line is gate current.

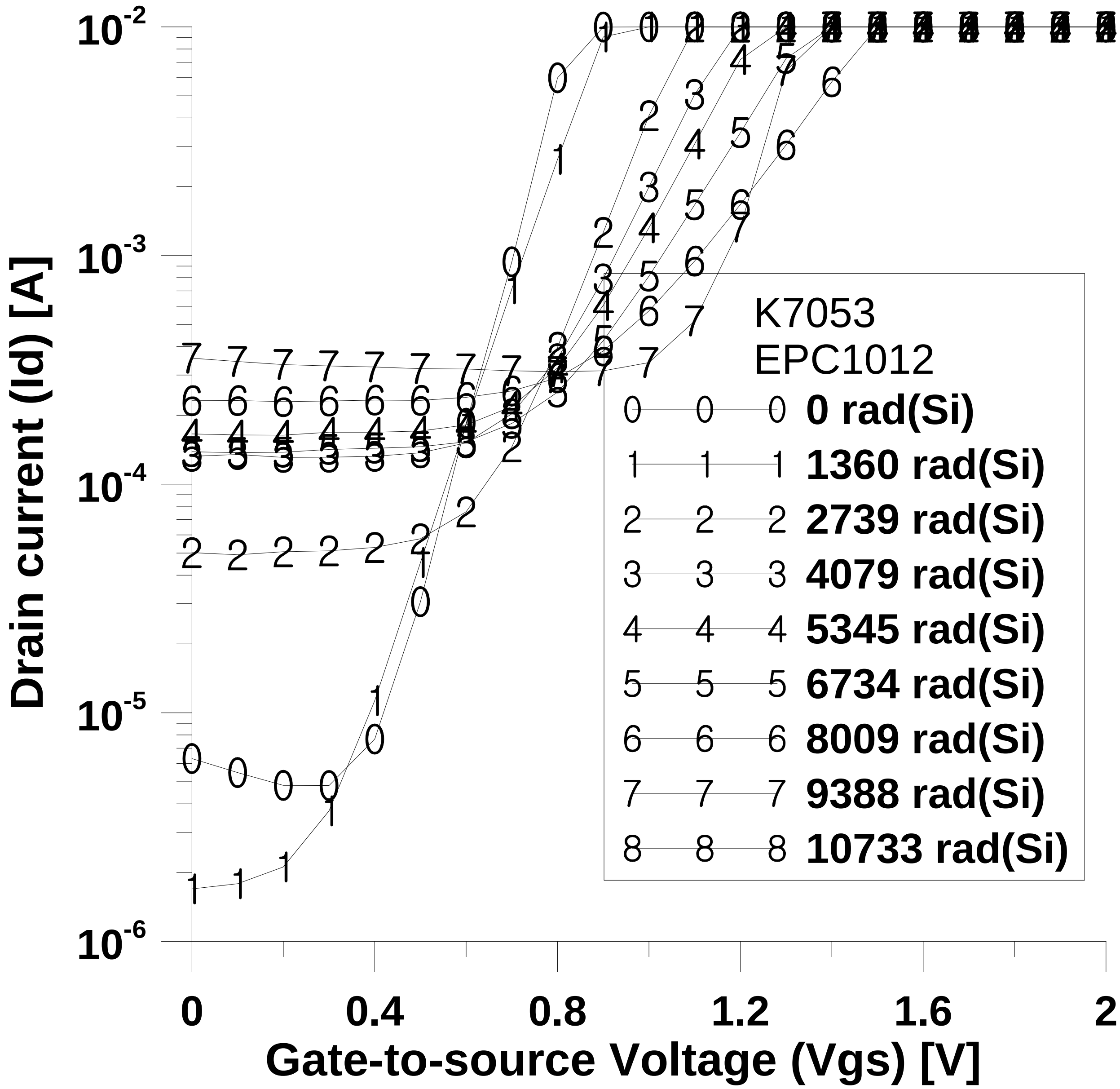

Figure 1.1-1. Effect of heavy ion radiation on the transfer curve K7053. Drain voltage was 10 V.

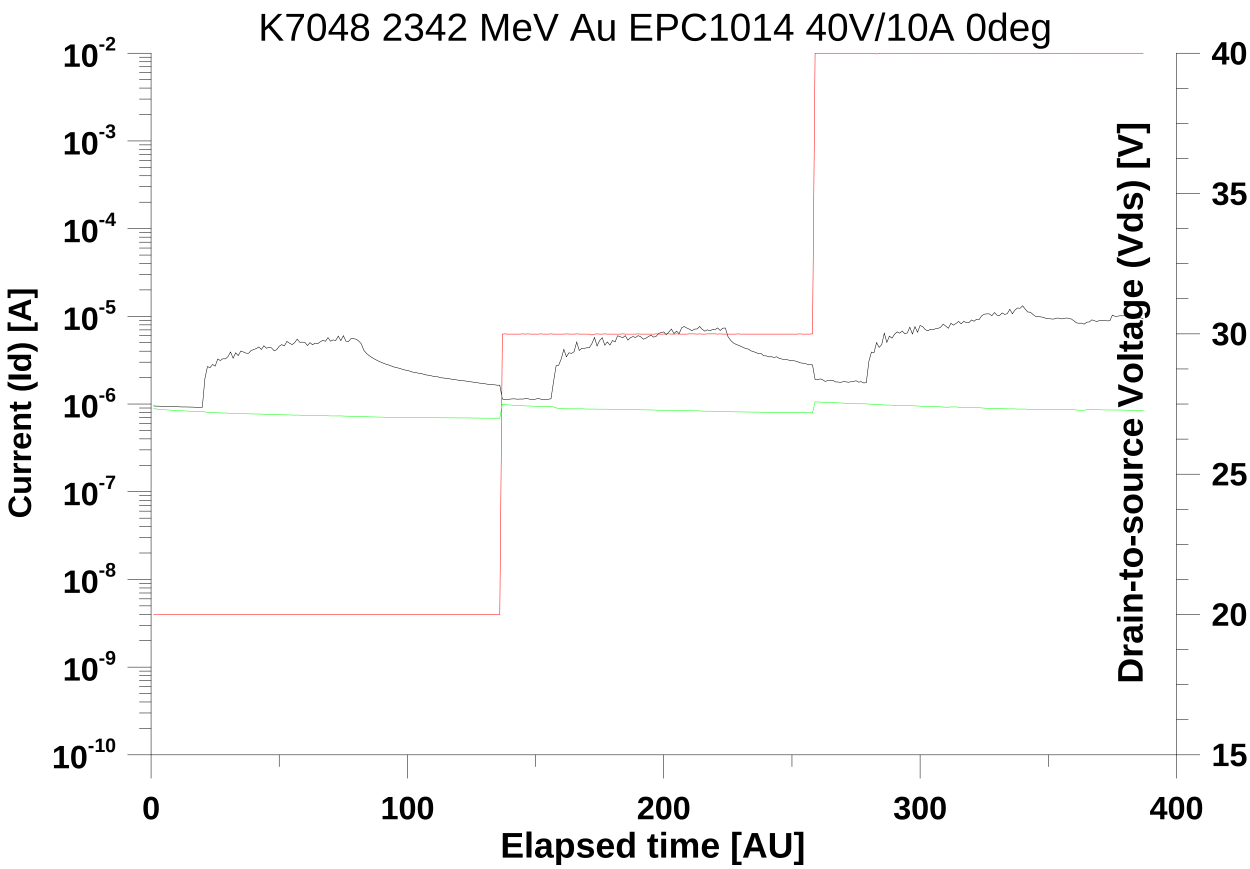

Figure 1.1-1. Heavy ion response of the EPC1014 40V/10A. Ion flux was 1E5 cm^{-2}-s^{-1}. Red line is drain voltage; gate voltage is zero volts. Black line is drain current and green line is gate current.

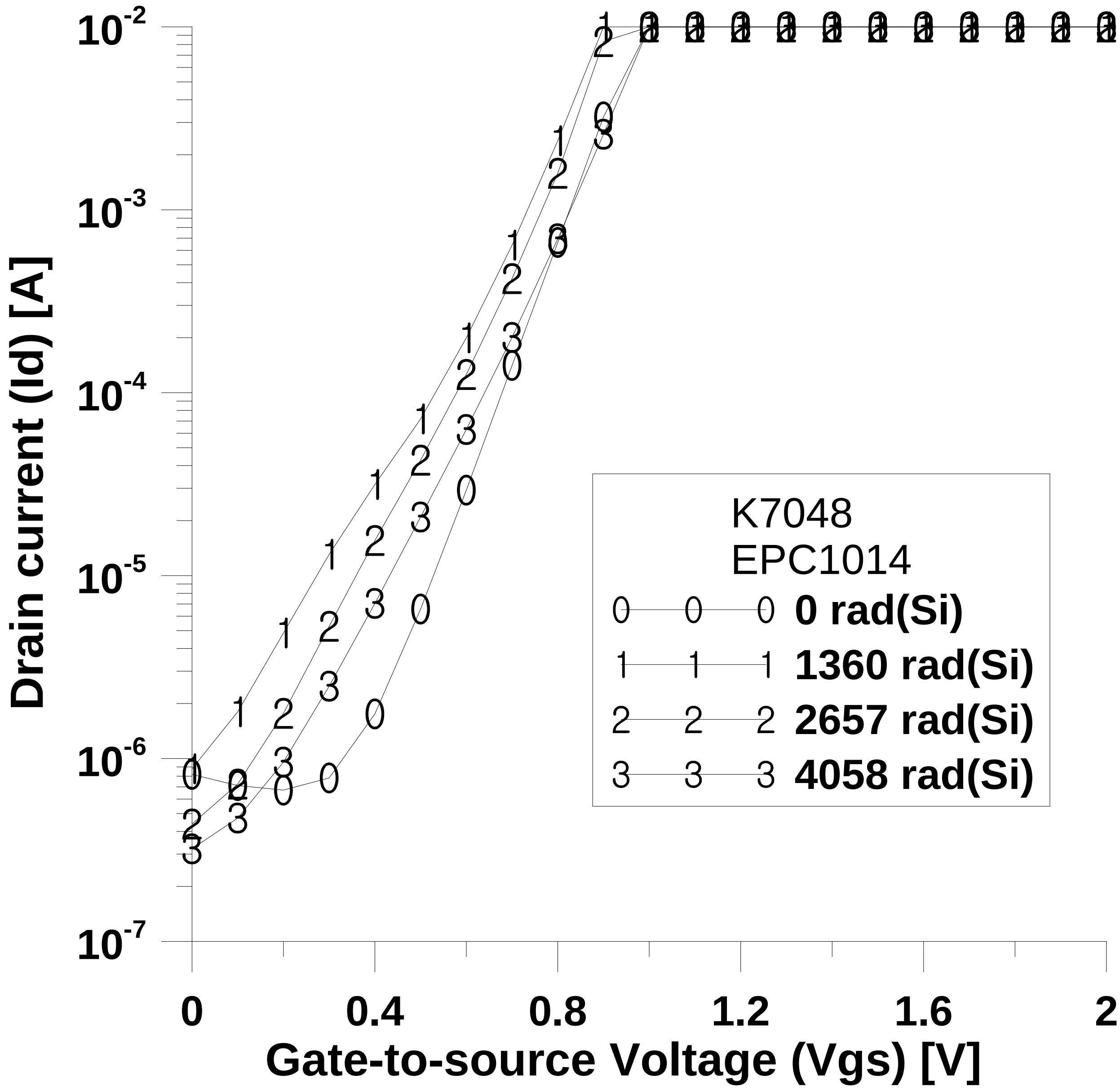

Figure 1.1-1. Effect of heavy ion radiation on the transfer curve K7048. Drain voltage was 10 V.

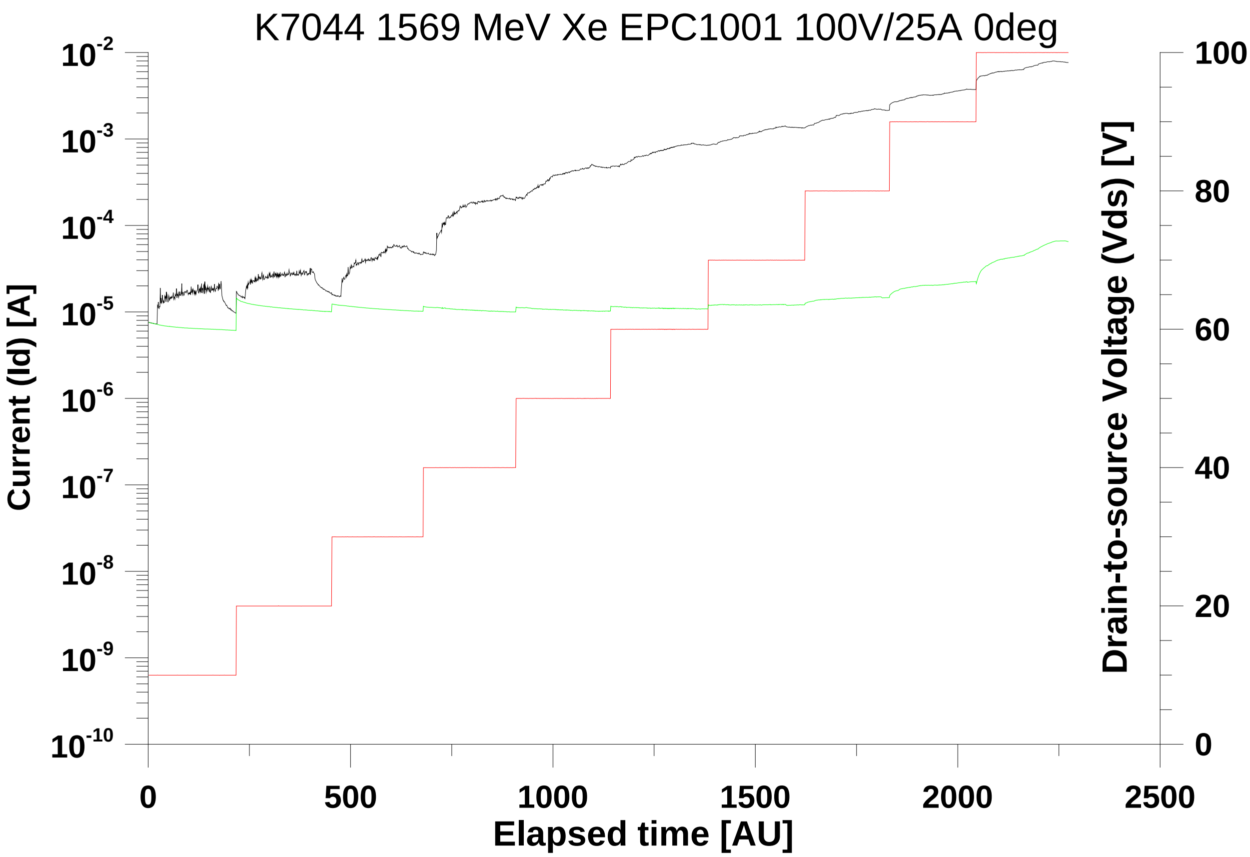

Figure 1.1-1. Heavy ion response of the EPC1001 100V/25A. Ion flux was 3E4 cm^{-2}-s^{-1}. Red line is drain voltage; gate voltage is zero volts. Black line is drain current and green line is gate current.

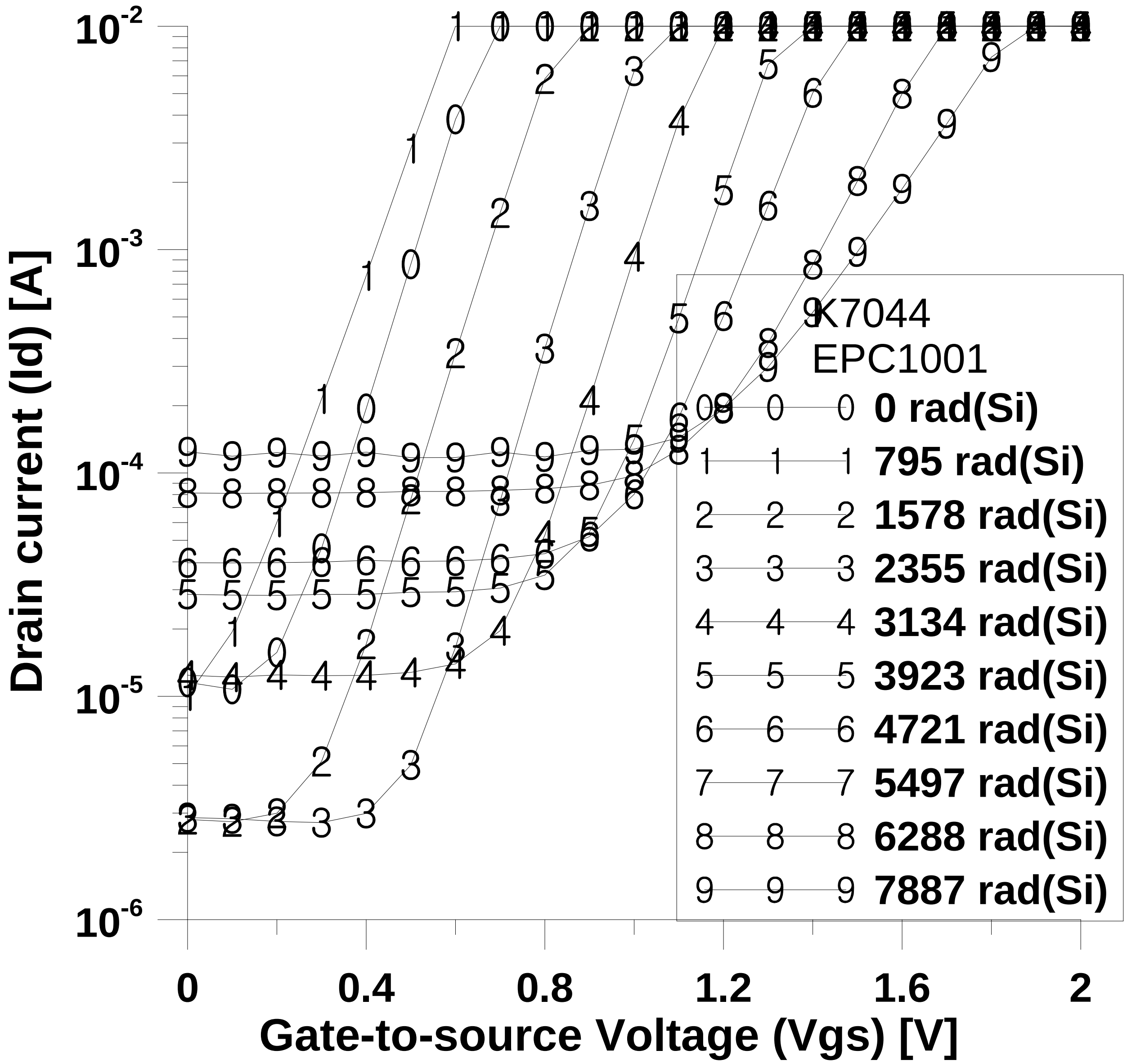

Figure 1.1-1. Effect of heavy ion radiation on the transfer curve K7044. Drain voltage was 10 V.

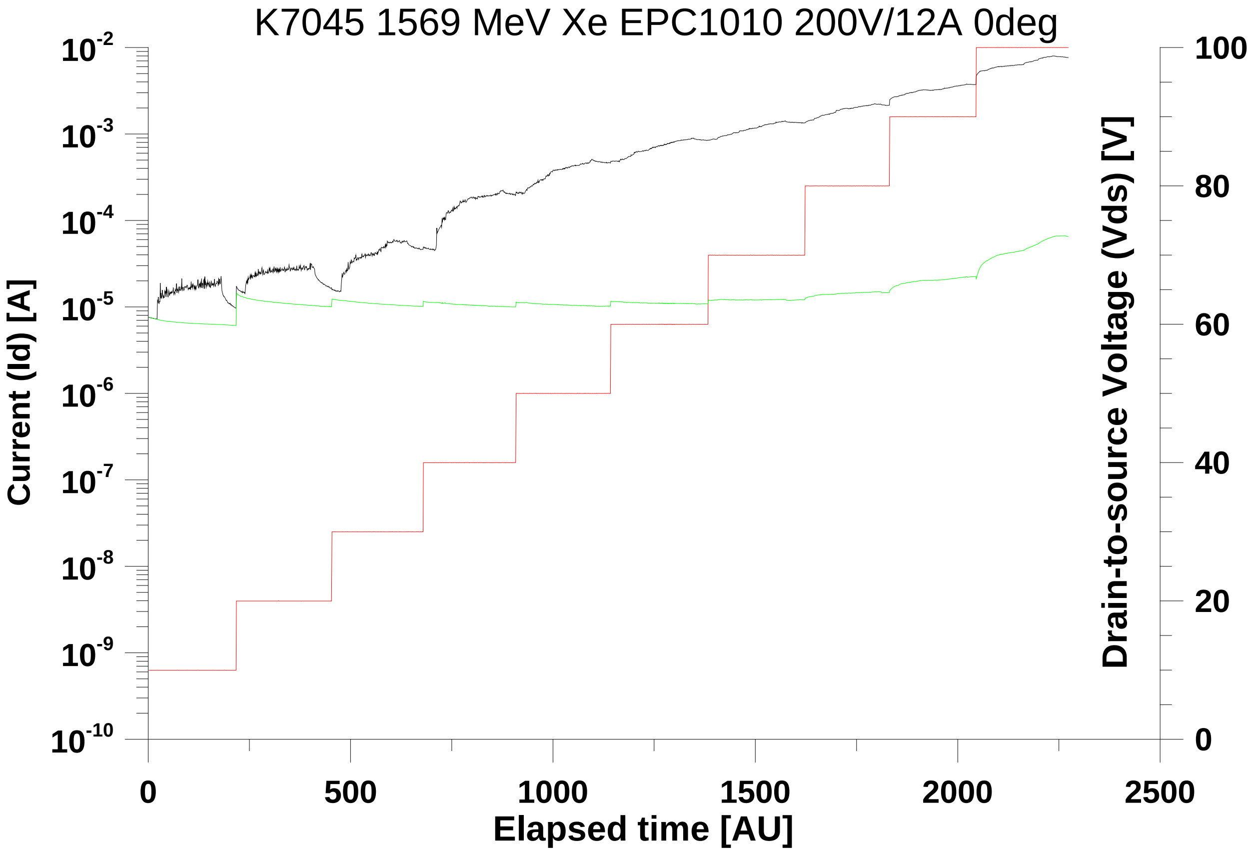

Figure 1.1-1. Heavy ion response of the EPC1010 200V/12A. Ion flux was 3E4 cm^{-2}-s^{-1}. Red line is drain voltage; gate voltage is zero volts. Black line is drain current and green line is gate current.

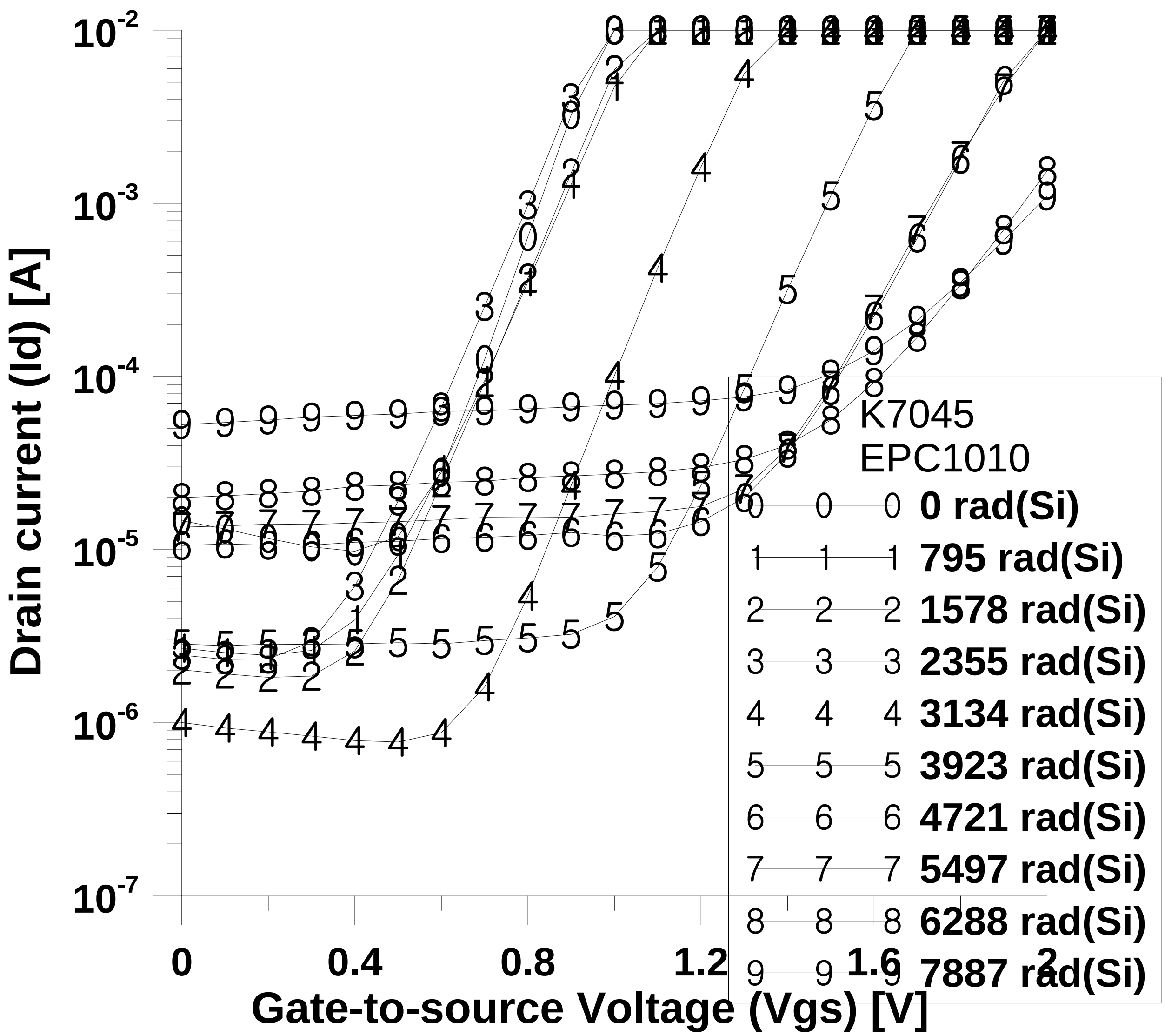

Figure 1.1-1. Effect of heavy ion radiation on the transfer curve K7045. Drain voltage was 10 V.

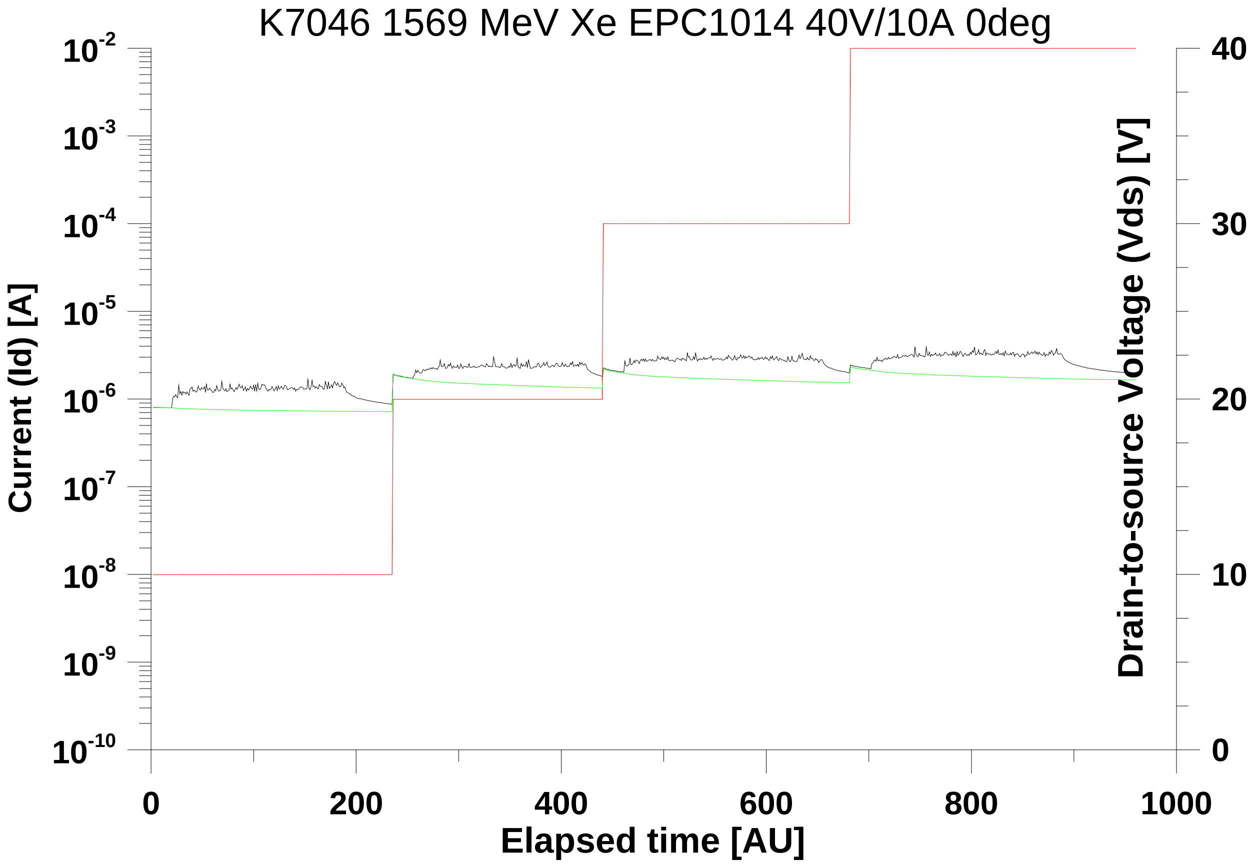

Figure 1.1-1. Heavy ion response of the EPC1014 40V/10A. Ion flux was 3E4 cm^{-2}-s^{-1}. Red line is drain voltage; gate voltage is zero volts. Black line is drain current and green line is gate current.

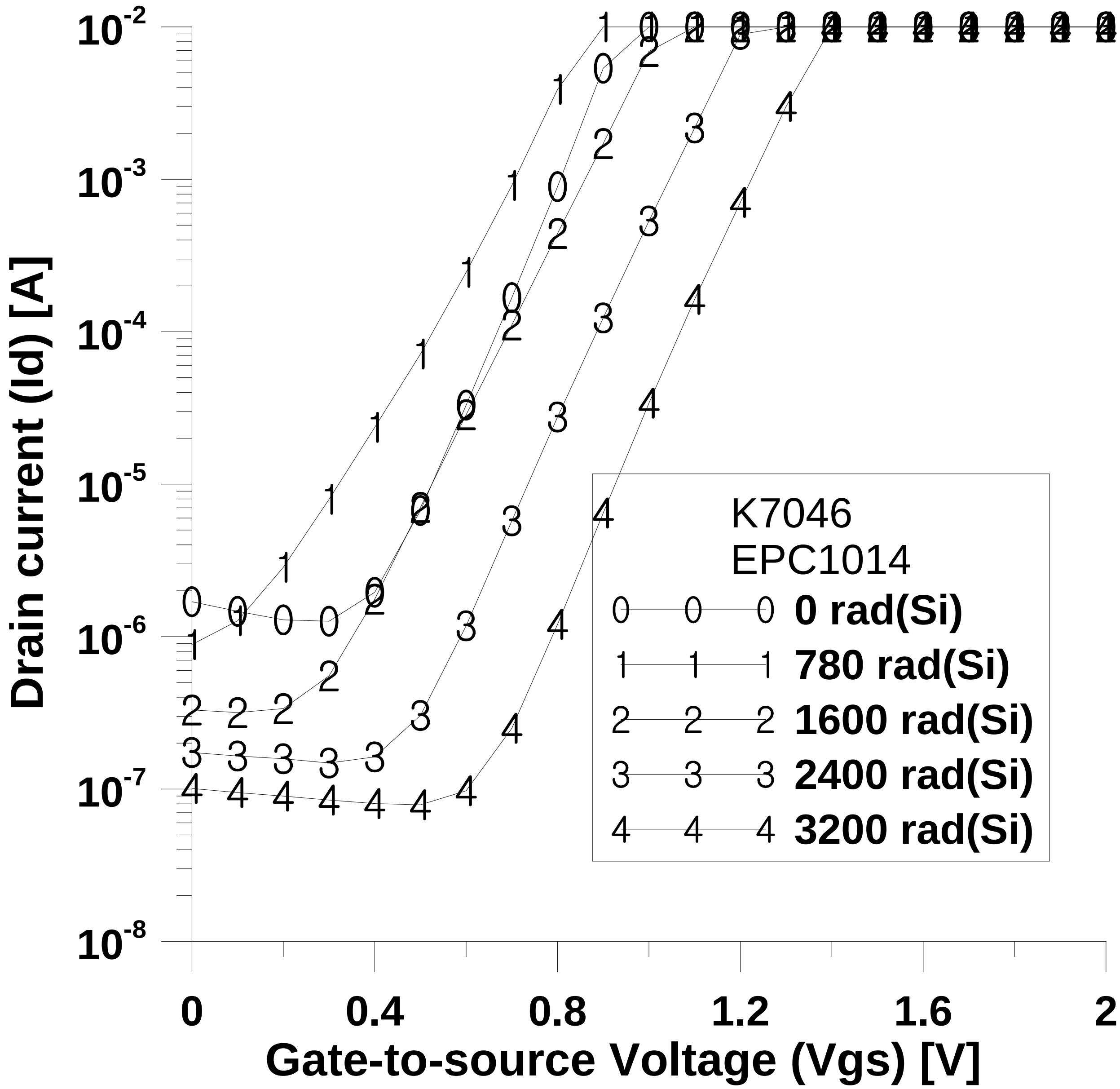

Figure 1.1-1. Effect of heavy ion radiation on the transfer curve K7046. Drain voltage was 10 V.

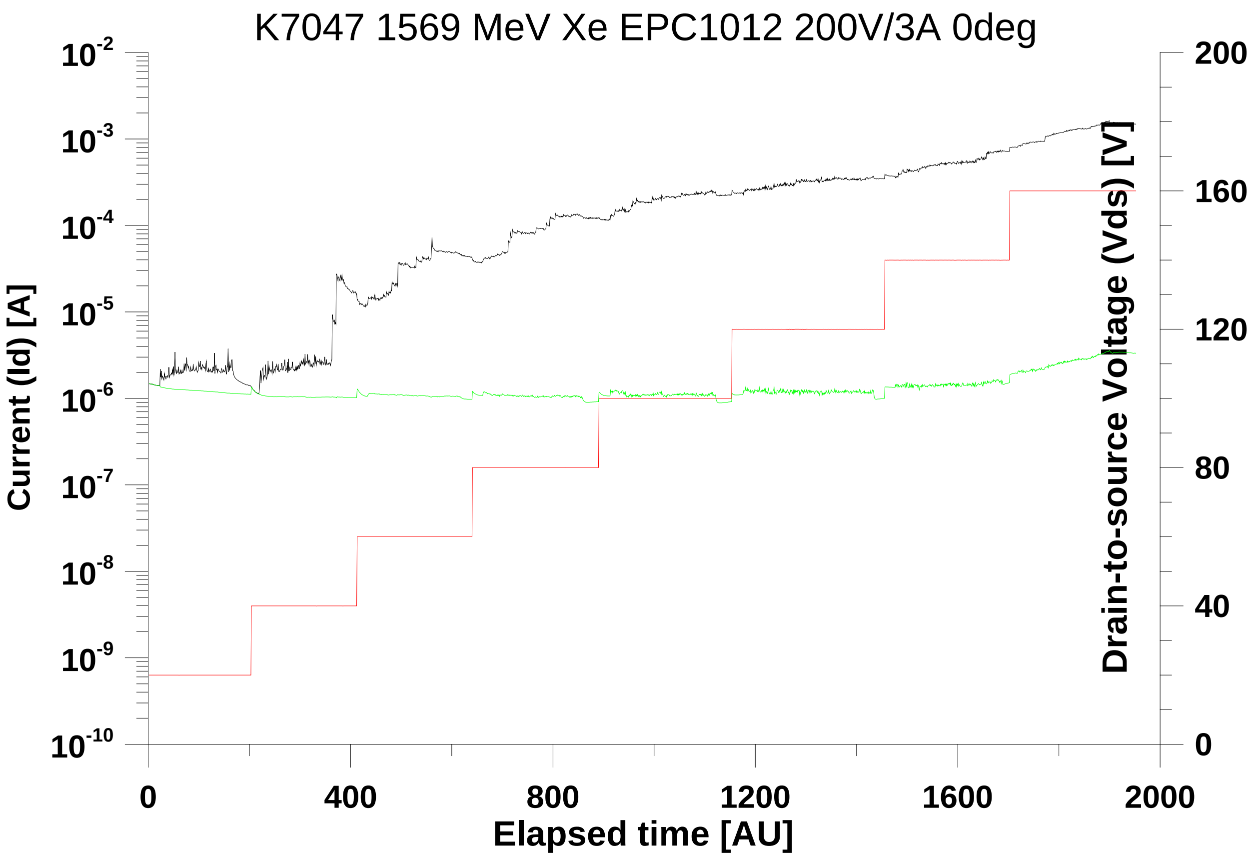

Figure 1.1-1. Heavy ion response of the EPC1012 200V/3A. Ion flux was 3E4 cm^{-2}-s^{-1}. Red line is drain voltage; gate voltage is zero volts. Black line is drain current and green line is gate current.

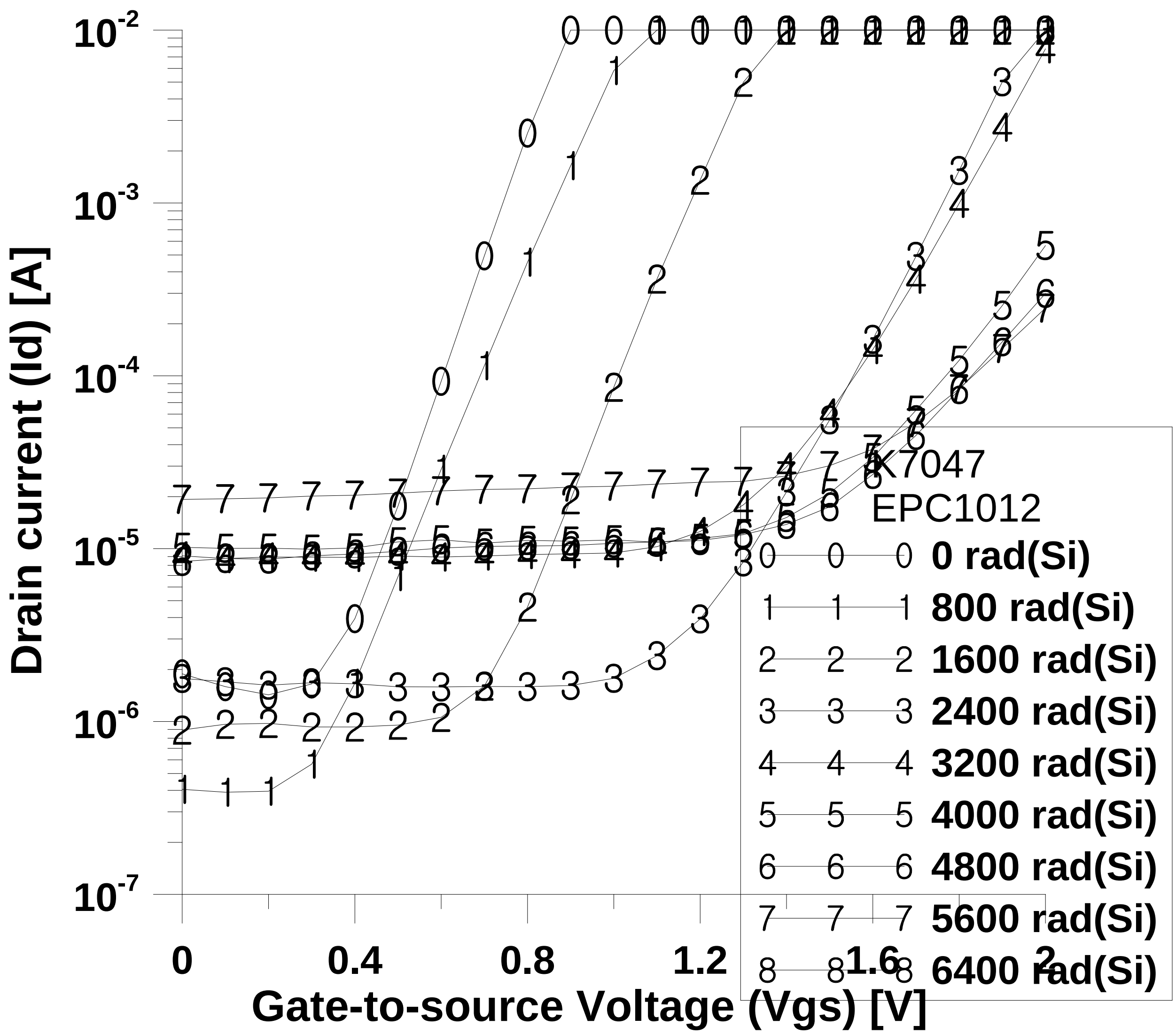

Figure 1.1-1. Effect of heavy ion radiation on the transfer curve K7047. Drain voltage was 10 V.

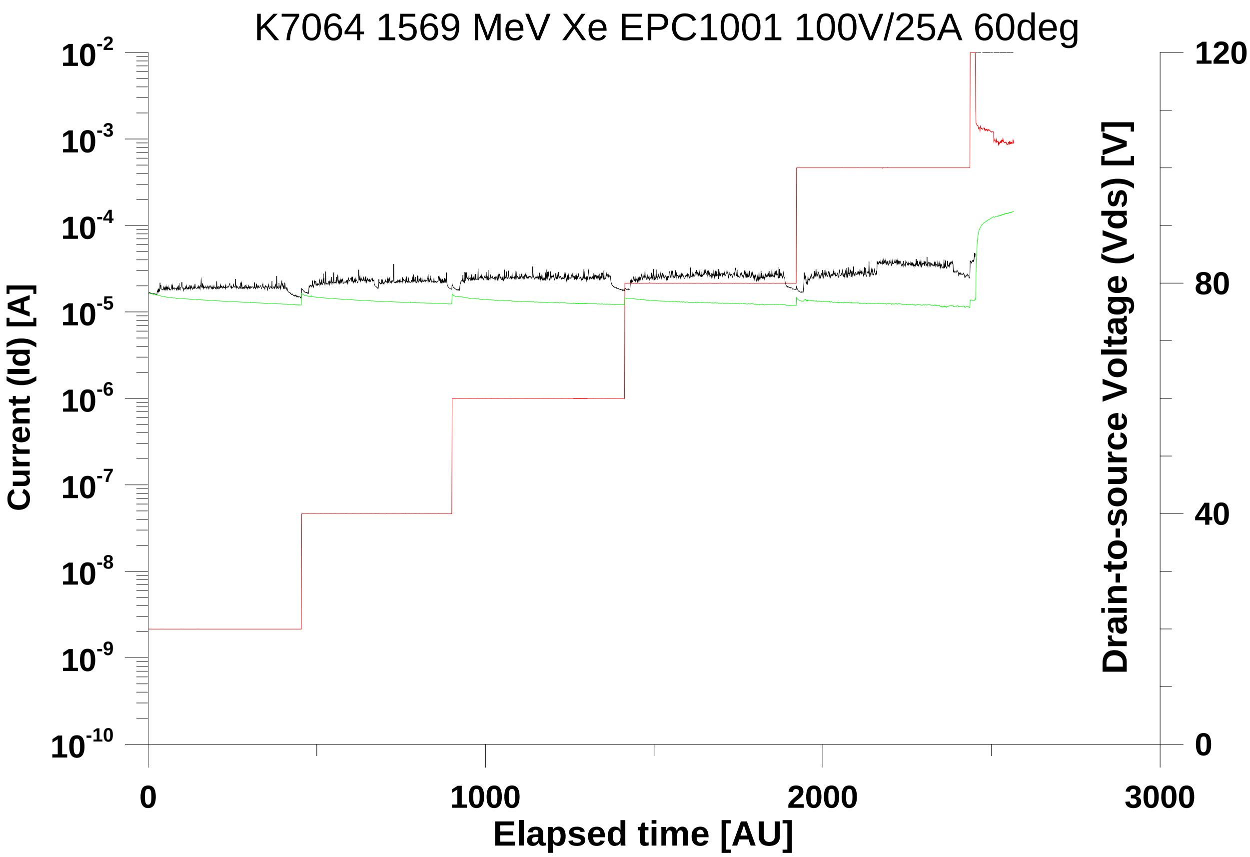

Figure 1.1-1. Heavy ion response of the EPC1001 100V/25A 60deg. Ion flux was 3E4 cm^{-2}-s^{-1}. Red line is drain voltage; gate voltage is zero volts. Black line is drain current and green line is gate current.

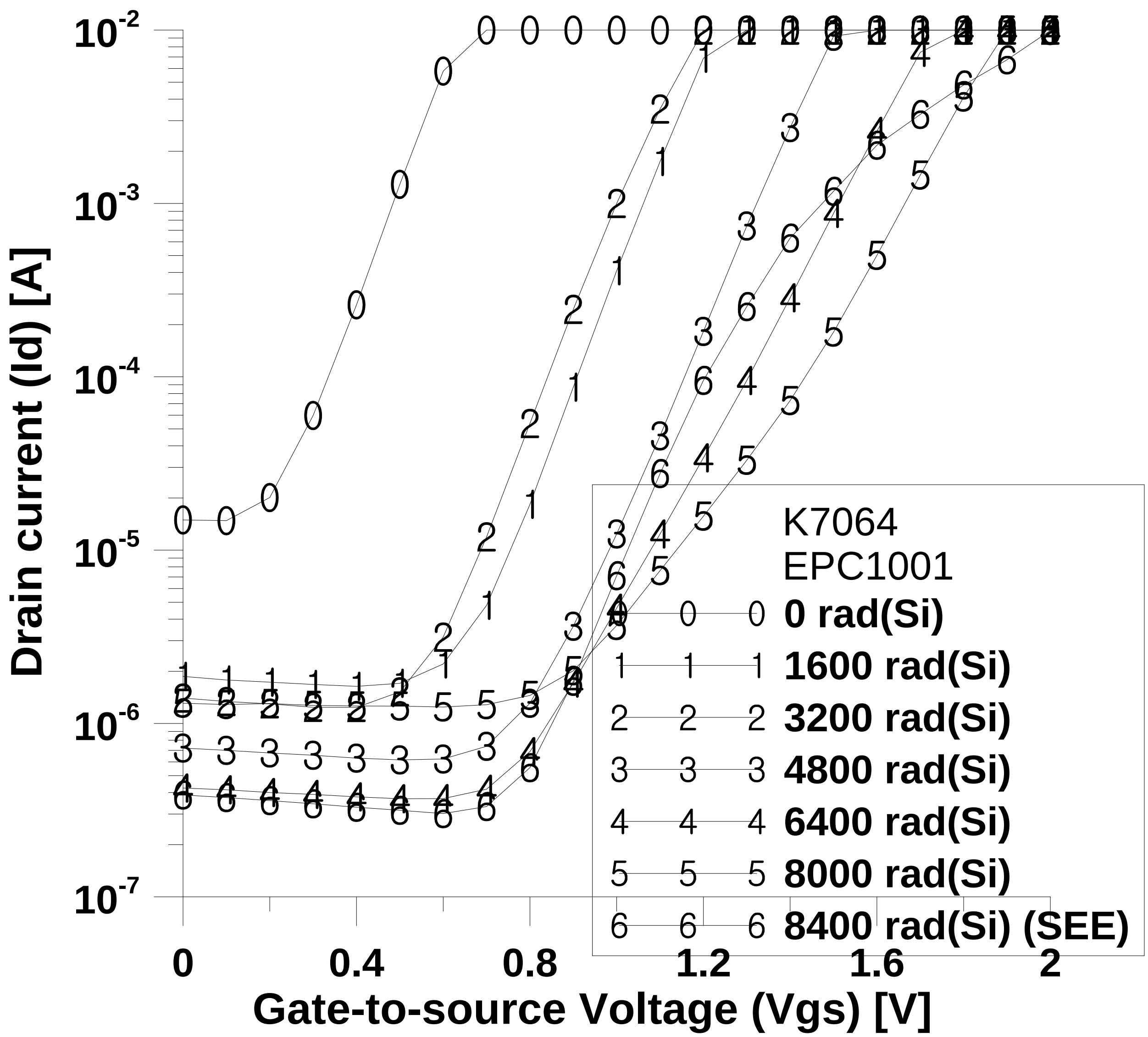

Figure 1.1-1. Effect of heavy ion radiation on the transfer curve K7064. Drain voltage was 10 V.

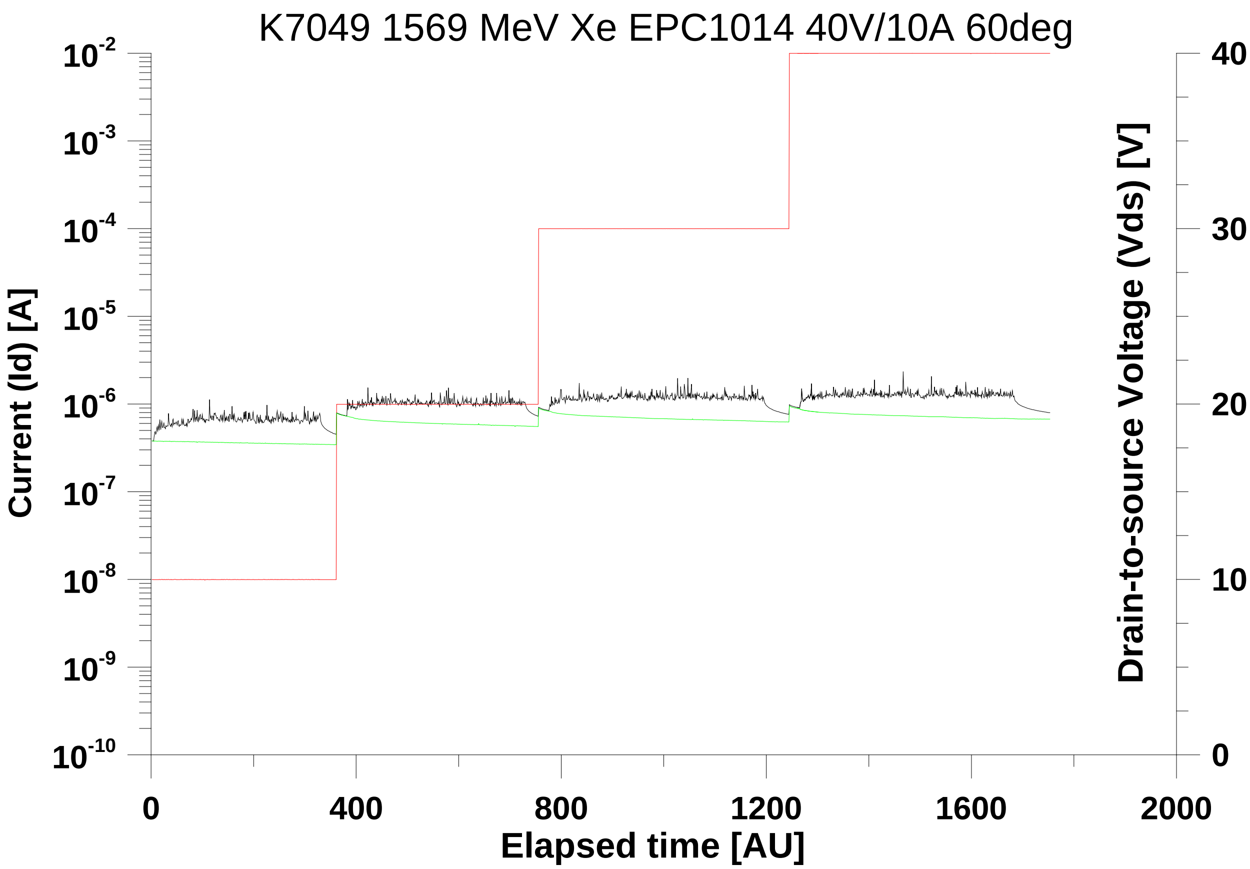

Figure 1.1-1. Heavy ion response of the EPC1014 40V/10A 60deg. Ion flux was 3E4 cm^{-2}-s^{-1}. Red line is drain voltage; gate voltage is zero volts. Black line is drain current and green line is gate current.

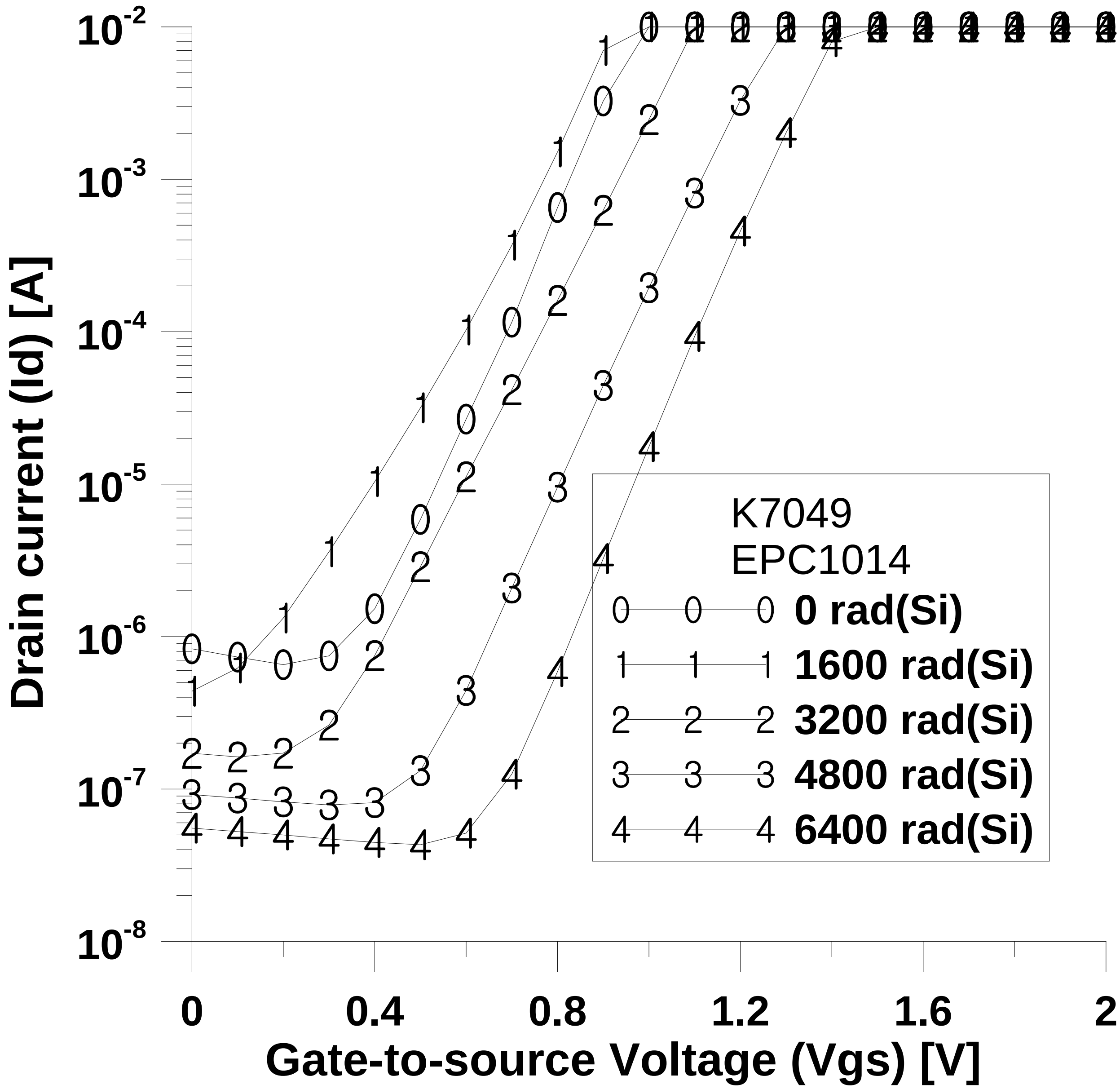

Figure 1.1-1. Effect of heavy ion radiation on the transfer curve K7049. Drain voltage was 10 V.

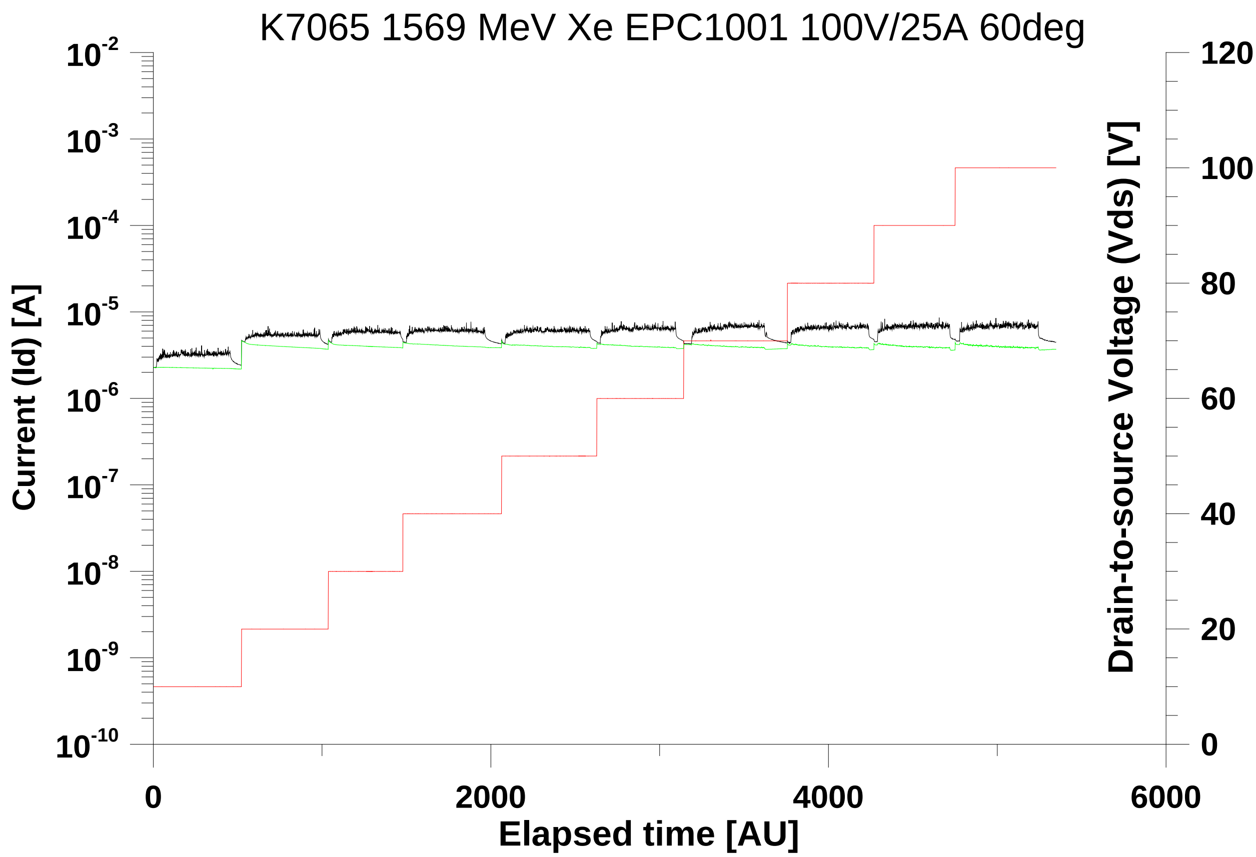

Figure 1.1-1. Heavy ion response of the EPC1001 100V/25A 60deg. Ion flux was 3E4 cm^{-2}-s^{-1}. Red line is drain voltage; gate voltage is zero volts. Black line is drain current and green line is gate current.

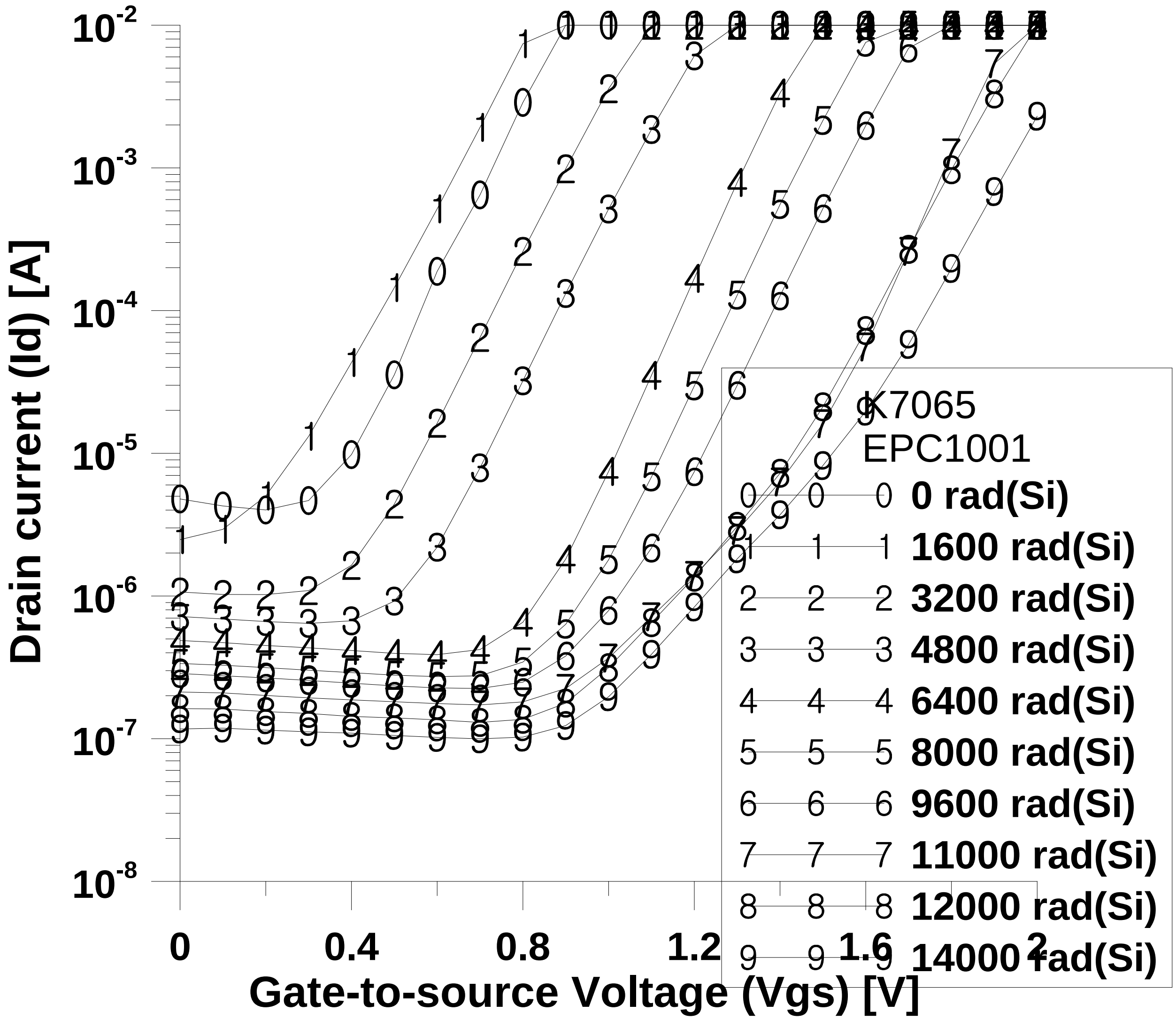

Figure 1.1-1. Effect of heavy ion radiation on the transfer curve K7065. Drain voltage was 10 V.

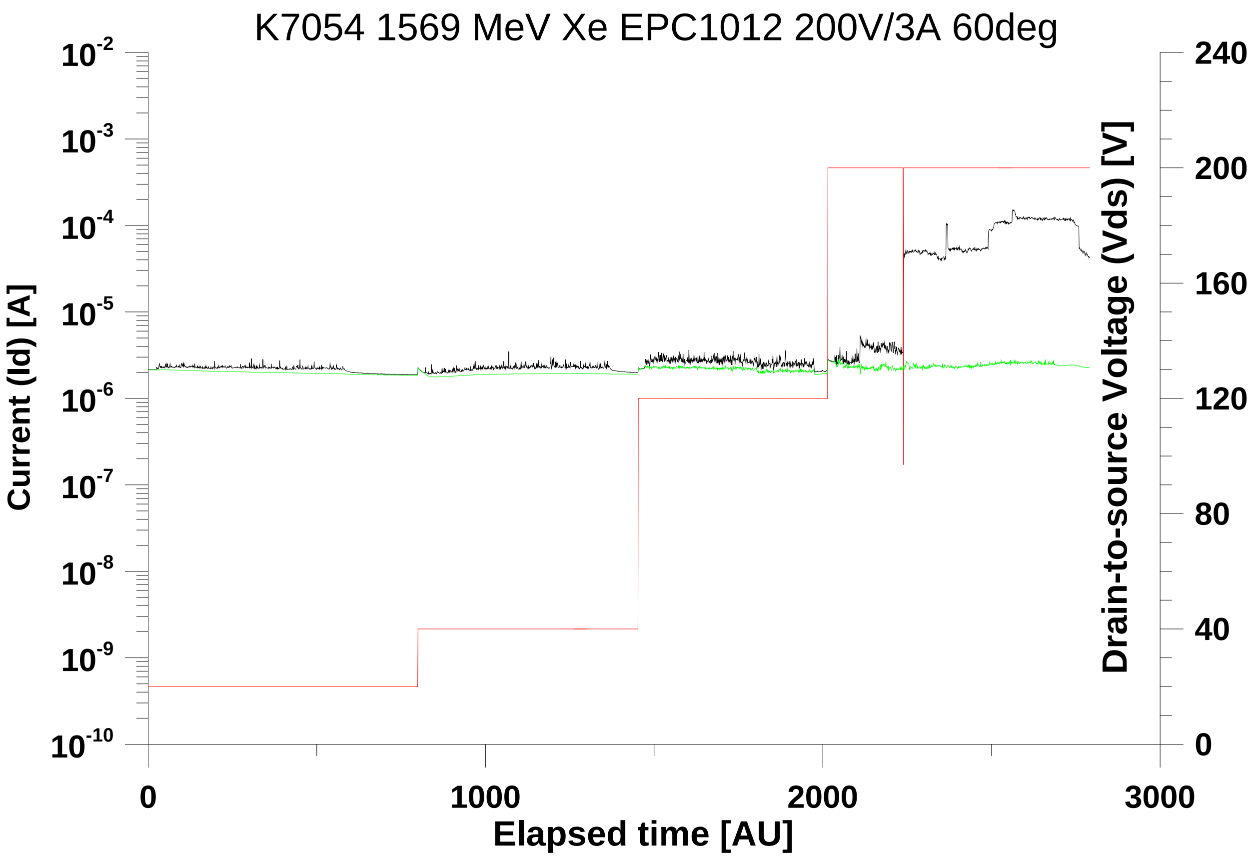

Figure 1.1-1. Heavy ion response of the EPC1012 200V/3A 60deg. Ion flux was 3E4 cm^{-2}-s^{-1}. Red line is drain voltage; gate voltage is zero volts. Black line is drain current and green line is gate current.

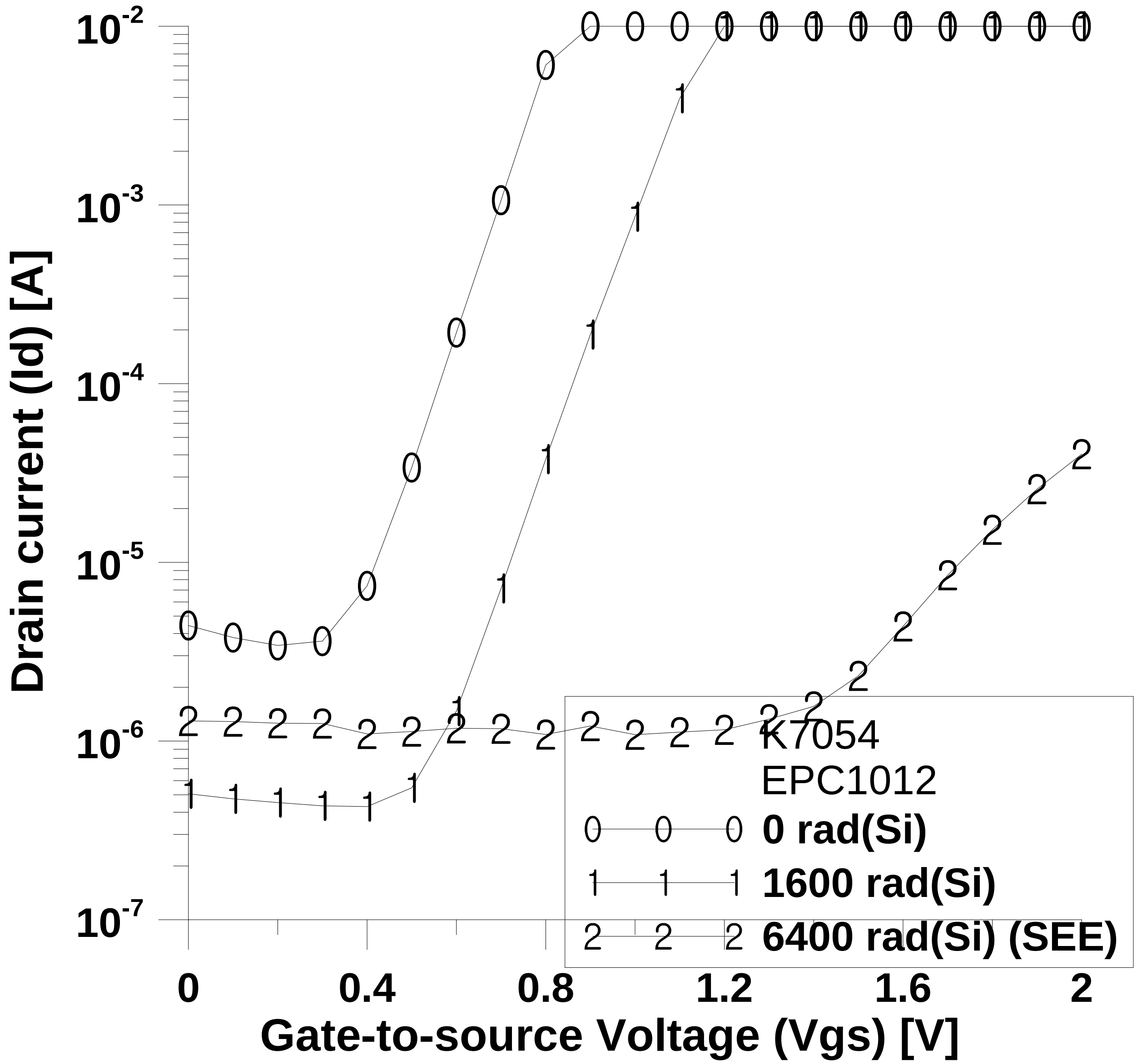

Figure 1.1-1. Effect of heavy ion radiation on the transfer curve K7054. Drain voltage was 10 V.