SINGLE EVENT EFFECTS
TEST REPORT

Test Type:	Heavy ion
Test facility:	REF, TAMU, College station, Tx, USA
Test Date:	November 2014
Part Type:	IPP50R140CP
Part Description:	CoolMOS Power Transistor
Part Manufacturer:	Infineon

ESA contract n° 4000105495/12/NL/SFe dated 27/2/2012

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DOCUMENTATION CHANGE NOTICE

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SEE TEST REPORT

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 Glossary

DUT: Device under test.

Fluence (of particle radiation incident on a surface): The total amount of particle radiant energy incident on a surface in a given period of time, divided by the area of the surface.
In this document, Fluence is expressed in ions per cm2.

Flux: The time rate of flow of particle radiant energy incident on a surface, divided by the area of that surface.
In this document, Flux is expressed in ions per cm2*s.

Single-Event Effect (SEE): Any measurable or observable change in state or performance of a microelectronic device, component, subsystem, or system (digital or analog) resulting from a single energetic particle strike.
Single-event effects include single-event upset (SEU), multiple-bit upset (MBU), multiple-cell upset (MCU), single-event functional interrupt (SEFI), single-event latch-up (SEL), single-event gate rupture (SEGR), single-event burnout (SEB).

Single-Event Gate rupture (power mosfet) (SEGR): An event in which a single energetic-particle strike results in a breakdown and subsequent conducting path through the gate oxide of a MOSFET.

Sijngle-Event Burnout (SEB): An event in which a single energetic-particle strike induces a localized high-current state in a device, resulting in a catastrophic failure. SEB can be destructive and the use ofa protection limiting current resistor in serie with the drain supply allows for getting non destructive SEB during testing.

Error cross-section: the number of errors per unit fluence. For device error cross-section, the dimensions are cm2 per device. For bit error cross-section, the dimensions are cm2 per bit.

Tilt angle: tilt angle, rotation axis of the DUT board is perpendicular to the beam axis; roll angle, board rotation axis is parallel to the beam axis
Weibull fit: $F(x) = A\,(1- \exp\{-[(x-x_0)/W]^s\})$ with:

> x = effective LET in MeV/(mg/cm^2);
> F(x) = SEE cross-section in cm^2;
> A = limiting or plateau cross-section;
> x_0 = onset parameter, such that F(x) = 0 for $x < x_0$;
> W = width parameter;
> s = a dimensionless exponent.

Error bars: error bars are computed using a confidence level of 95% and a beam flux uncertainty of +/- 10% as recommended by Single Event Effects Test method and Guidelines ESA/SCC basic specification No 25100.

2 Introduction

This report presents the results of Heavy Ions test program carried out on IPP50R140CP part type from Infineon. IPP50R140CP samples were used for heavy ions testing at REF, TAMU, College station, Tx, USA.
This work was performed for ESA under ESA contract n° 4000105495/12/NL/SFe dated 27/2/2012.

3 Applicable and Reference Documents

3.1 Applicable Documents

AD-1. Hirex proposal « Test Methods, Requirements, and Guidelines for Evaluation of Radiation Sensitivity of Analog to Digital Converters (ADC), Digital to Analog Converters (DAC) and Vertical Power MOSFETs» HRX/PRO/3624 Issue 01 /2011/10/12.

AD-2. IPP50R140CP, Infineon datasheet, Rev. 2.0 2007-11-06.

3.2 Reference Documents

RD-1. Single Event Effects Test method and Guidelines ESA/SCC basic specification No 25100.

4 DEVICE INFORMATION

4.1 Device description

IPP50R140CP is a CoolMOS Power Transistor.

Part type:	IPP50R140CP
Manufacturer:	Infineon
Manufacturer lot number:	-
Datecode:	1109
Package:	TO-220
Top marking:	5R140P logo HAA109
Die dimensions:	4069µ x 5563µ

4.2 Sample identification

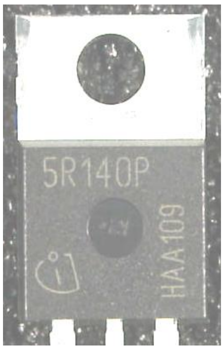


Photo 1 – Device top view

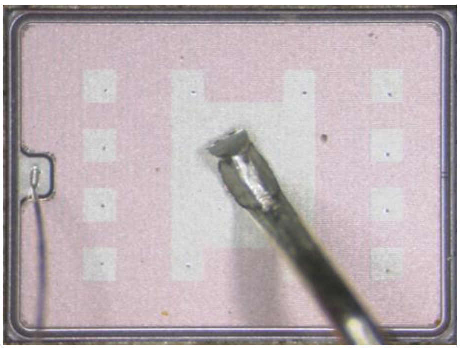


Photo 2 – Die full view

Figure 1: IPP50R140CP device identification

4.3 Sample preparation

Samples were opened by chemical etching.
Polyimide layer (6µm) was removed

4.4 Die microsection

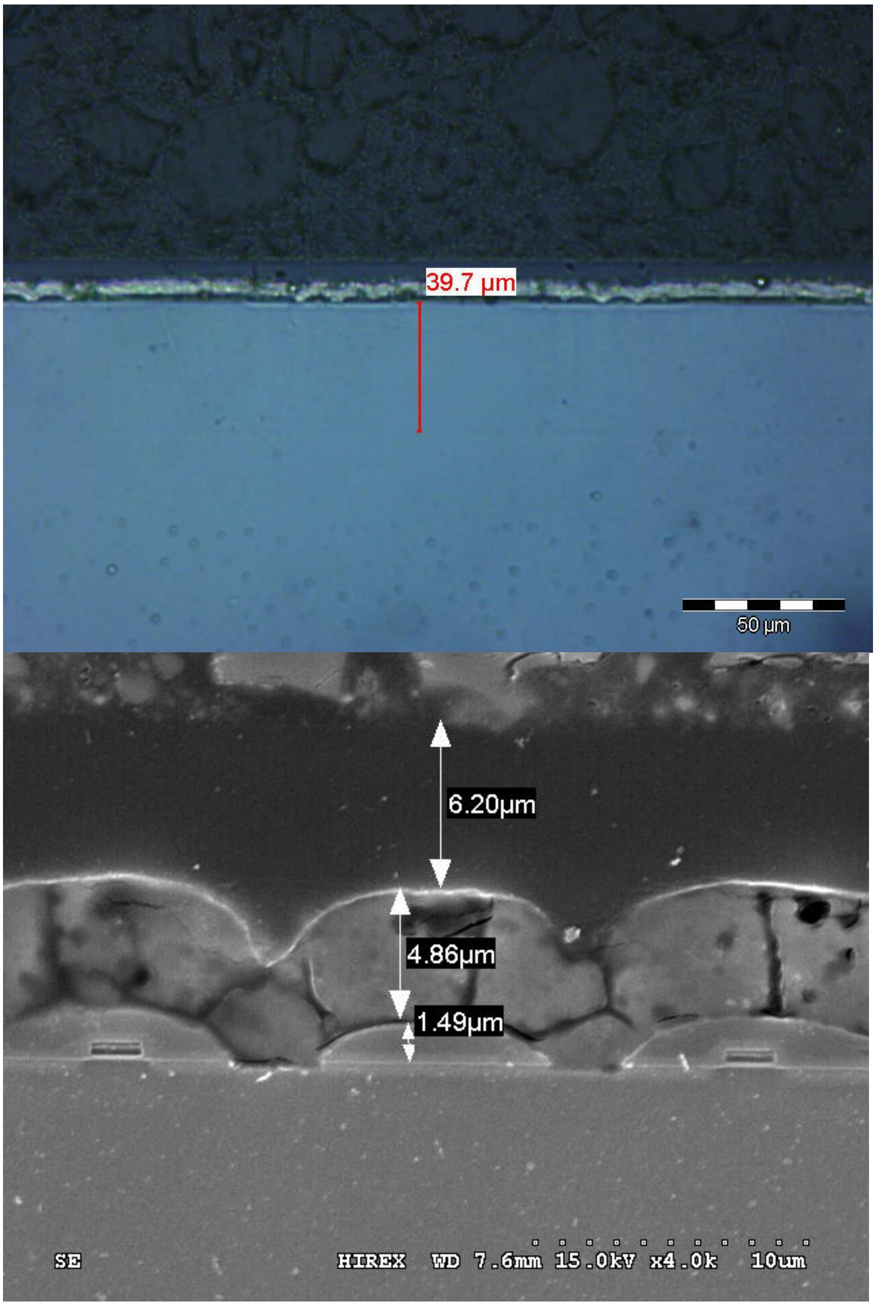


Figure 2 -IPP50R140CP die microsection

5 TAMU Facility (REF)

Test at the cyclotron accelerator was performed at Texas A & M in College Station - TX- USA.
This facility includes a special beam line dedicated to irradiation studies of semiconductor components and devices. Testing may be conducted in either 30" diameter vacuum chamber or with in-air positioning system . Both provide precise positioning in x, y, and z as well as rotations up to 60 degrees. Positioning and dosimetry are carried out by custom-made SEUSS software.

In Air Station

The in-air station is located at the end of dedicated beam-line. The station consists of a rotating platform and a removable target mounting fixture. The target positioning assembly allows the motion of the target in four directions: X, Y, Z and Theta. X and Y are the horizontal and the vertical axis in the target plane, respectively. The Z-axis is in the direction of the beam-line, with theta being the clockwise and counter-clockwise rotation about the y-axis. Target position verification is provided by the means of a CCD camera aligned with the beam path and a narrow laser beam that crosses the beam path at the center of the target chamber. The size of the exposed area is controlled by the aperture defined by a pair of remotely adjustable horizontal and vertical slits.

Vacuum Station

Vacuum station has an inside diameter of 30inch and a height 30inch.Pumping time to an operating pressure in the low 10 -4 Torr range is approximately ten minutes and the chamber vents to gaseous nitrogen in two and half minutes. Target positioning system allows X, Y, Z and Theta moving. Like for in air station, the position is checked with the means of a CCD camera.

Ion Beam

Various ion beams are available for the Radiation Effects Facility. These beams provide for a wide scope of LET with high energies for deep part penetration. Time for beam species changes will vary, but with species that have the same energy per nucleon change times is about one half hour.
Beams can be delivered with a high degree of uniformity over a 1.8" x 1.8" cross sectional area for measurements inside the vacuum chamber and 1" diameter circular cross sectional area for the in-air station. Uniformity is achieved by means of magnetic defocusing.
A degrader foil system makes it possible to set the desired beam LET value at a particular depth inside the target without changing the beam or rotating the target. The beam energy is reduced by means of a degrader system with foils having a suitable thickness and orientation with respect to the incident beam. Each foil can be inserted, withdrawn, and rotated remotely through use of computer controls.
The intensity of any beam is easily regulated over a broad range spanning several orders of magnitude in a matter of seconds. This can be done by the operator on duty at the users request.
The target exposure system is fully automated. Exposure can be set for a certain time, total accumulated fluence, or can be manually stopped at any time.

Beam Quality control

The beam uniformity and flux are determined using an array of five detectors. Each detector is made up with a plastic scintillator coupled to photo-multiplier tubes. Four of the detectors are fixed in position and set up to measure beam particle counting rates continuously at four characteristic points 1.64 inches (4.71 mm) away from the beam axis. The fifth scintillator can be optionally put in to measure the beam particle counting rate right at the beam axis. The sensitive area of each detector is defined by a 0.1 cm^2 aperture, while the intrinsic efficiency is 100% for all practical purposes. The beam uniformity parameter (ranging from 0 to 100%), the axial gain (%), and the beam flux (in particles/cm^2/s) are determined by the control software based on the detector counting rates. The results are displayed and updated once every second.

Dosimetry

The current TAMU Cyclotron dosimetry system and procedures were used.

Figure 3 shows the TAMU facility different beam lines. K500 (88”) cyclotron is used to inject beam in Radiation Effects Facility (REF) cave.

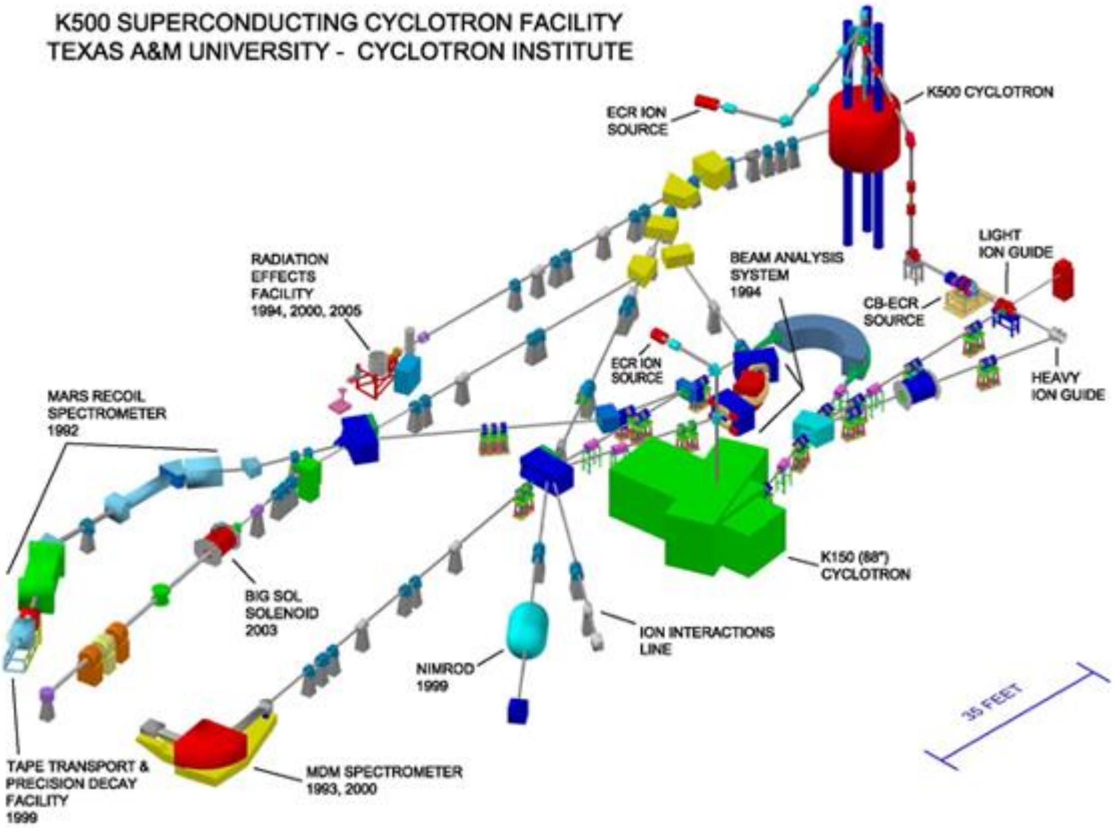


Figure 3 – TAMU facility beam lines (http://cyclotron.tamu.edu/facilities.html)

6 Test Set-up

The test set-up is composed of 4 main parts as shown in the following Figure 4 :

- DUTs board
- Set of Agilent Source Monitor Units (HP4142)
- V5 ASERT test board mounted with a 400 Msps digitizer
- A laptop running a Graphical User Interface

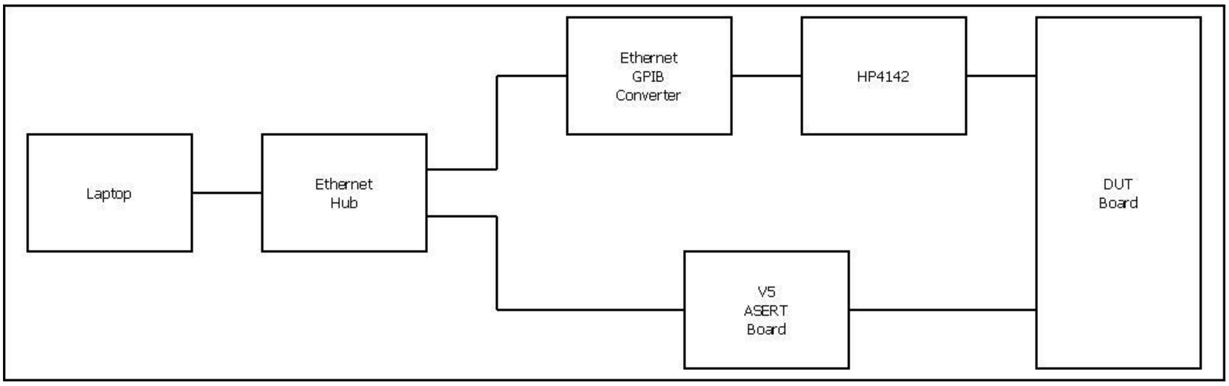


Figure 4 - Test set-up block diagram

6.1 DUTs board:

The DUTs board can hold up to 16 DUTs (2 rows by 8 columns). Each row (or line) as detailed on the Figure 5 is supplied by a set of 2 SMUs (Source Monitor Units) supplying drain and gate supplies. A drain sense is outputted from each line. A relay system allows the dynamic selection of:

- The DUT
- The bias included on the input and output conditioning systems

Input and output conditioning systems as well as DUTs are integrated on daughter boards plugged on the DUTs board.

The 2 lines are fully independent allowing the irradiation of 2 DUTs close by at the same time.

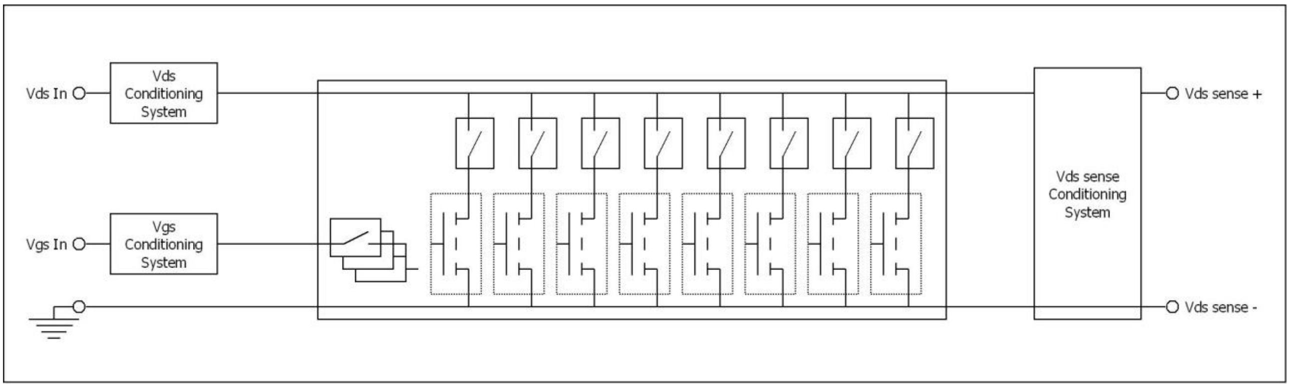


Figure 5 - DUTs board - One line schematic

The used bias is detailed on the following Figure 6.

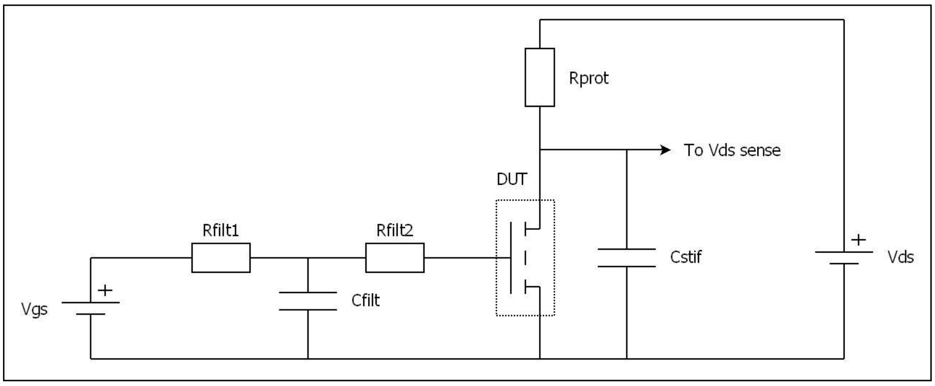


Figure 6 - Bias schematic

6.2 Agilent set of Source Monitor Units

The sourcing and monitoring of the DUT's drain and gate supplies (voltages and currents) are performed using a set of Agilent SMUs (Source Monitor Units) HP4142 featuring the following ranges:

- For the gate: HP41421B: 40µV - 100 V / 20 fA - 100 mA
- For the drain: HP41423A: 2 mV - 1000 V / 2 pA - 2 mA

This set of SMUs is controlled remotely by the Graphical User Interface through an Ethernet/GPIB converter.

6.3 V5 ASERT test board

The V5 ASERT test board is used to:

- Monitor the bias through the relay system.
- Digitize (using a 400Msps digitizer) the drain sense signal. The digitizer is configured to trig on level voltage of both channels (lines). For each test conditions, high and low thresholds are set. All events higher than the high threshold or lower than the low threshold trig the digitizer and data are plotted and recorded on the computer.

6.4 Graphical User Interface

The GUI running on the computer mainly allows the:

- Selection of the DUT
- Control of the bias
- Choice of test conditions
- Monitoring of the SMUs
- Display of currents graphs
- Management of the test sequence

6.5 Test sequence

The basic sequence used to test was the following:

- Pre run test: Initial gate stress
- Pre run test: On / Off test
- Run test: Start off test
- Run test:: exposition
  Run test: Stop off test
- Post run test: Post gate stress (PIGS)

The On / Off test is performed at the beginning of each run before the irradiation. This test is used to verify the functionality of the device.
The Off test is the test achieved during the irradiation.
Gate Stress test is carried out at the beginning and at the end of the each run. This test is used to verify the integrity of the gate. For a selected drain voltage, a voltage cycle (between the upper and lower absolute maximum ratings) is applied on the gate.

7 SEE Test Results

7.1 Ions selection

The selection of the different ions and energies was performed in compliance with the following requirements:

Each device type shall be tested with at least four ion types. Two of the ion types shall have an atomic number 25 < Z < 37 (group 1). The two other ion types shall have an atomic number 45 < Z < 55 (group 2). One of the ion type belonging of each group shall be tested for at least three energies: worst-case energy (corresponding to maximum deposited charge in sensitive volume), one energy that satisfies ion range requirements of Table 2, and a high-energy (≥40 MeV/u). The calculation of the worst case energy shall be detailed in the test plan. The second ion type of each group shall be tested at one energy such as the mean LET in EPI layer is similar to mean LET in EPI corresponding to one of the selected energies with the first ion.

TABLE III
MINIMUM AND MAXIMUM ION RANGE AS A FUNCTION OF RATED V_{DS} FOR SEB TESTING OF VERTICAL POWER MOSFETS

Max rated Vds (V)	Minimum ion range (μm)	Maximum ion range (μm)
Up to 100	60	120
101 to 200	90	180
201 to 400	150	300
401 to 1000	200	400

(Table III Charge Collection in Power MOSFETs for SEB Characterisation—Evidence of Energy Effects, V. Ferlet-Cavrois *et al., IEEE TNS, VOL. 57, NO. 6, DECEMBER 2010)*

Table 1 – Ion range requirements

Copper and Kryptons ions, Cu (Z=29), Kr (Z=36), have been selected for the group 1 while Silver and Xenon, Ag(Z=47), Xe (Z=54) have been selected for the group 2.
SRIM 2013 was used to compute the critical charge deposited,energy deposited, the average LET value.
A dead layer equivalent to a sandwich of 5 µm of Aluminum, 0.4 µm of gate polysilicon and 1.1µm of silicon dioxyde noted 5(2) in detailed run results in Table 3. Epitaxy depth was set to 40 µm according to the die microsection results (see § 4.4).
The different ion beams selected are detailed in Table 2 where R correspond to the silicon surface level below the dead layer. TAMU interface is based on SRIM 2005 computations and then some minor differences have been observed with SRIM 2013 computations. Table 2 identifies also the beam selected during the test slot.

SRIM 2013 computation						TAMU beam selection				
Ion	Q	R	LET at R	E at R	Mean_LET	Cocktail	Energy	degrader	Eff. LET	y14w48
	pC	µm	MeV/(mg/cm²)	MeV	MeV/(mg/cm²)		MeV		MeV/(mg/cm²)	
Kr_wc	16.3525	56	37.74	458.8	39.65	**15MeV**	**459**	**yes**	36.2	y
Kr high	6.2896	567	15.01	2996.2	15.25	**40MeV**	**2996**	**no**	14.6	
Kr	9.9096	214	23.03	1519.1	24.03	**25MeV**	**1519**	**yes**	23.1	y
Cu	9.9401	97	21.89	600.8	24.1	**15MeV**	**601**	**yes**	22	y
Xe_wc	27.9575	66	65.14	884.3	67.8	**15MeV**	**884**	**yes**	58.6	y
Xe	19.5044	195	45.27	2492.2	47.3	**25MeV**	**2492**	**yes**	42.6	
Ag	19.3956	116	43.76	1316.7	47.03	**15MeV**	**1319**	**no**	41.8	y
Ag	20.096	107	45.13	1223.8	48.73	**15MeV**				

Table 2 – Ion beam setting

7.2 Run tests

All tests were performed in air and at room temperature.

Resistor protection was set to 10kOms.
The detailed list of runs performed at TAMU during the two test campains is provided in Table 3.
One or two samples can be tested at the same time with same or different test biasing conditions

Figure 1 shows Example of the data recorded for each dut under test and each test run.
In this figure, one can observe the initial get stress followed by on/off condition then under off condition, beam is started until the desired fluence, then when run is stopped, a post gate stress is performed.
Please note that Igs current plot can exhibit a scale factor (1e-9 in the present case)
The recorded sebs are identified by a blue triangle which are detected using 15.4 V threshold value (50 tester LSBs, 1 LSB=307 mV)
All data recorded for the different runs and duts are provided in a companion document ref. HRX/SEE/438-appendix issue1.

Figure 8 shows the envelop of the non destructive SEBs (same run as Figure 1).

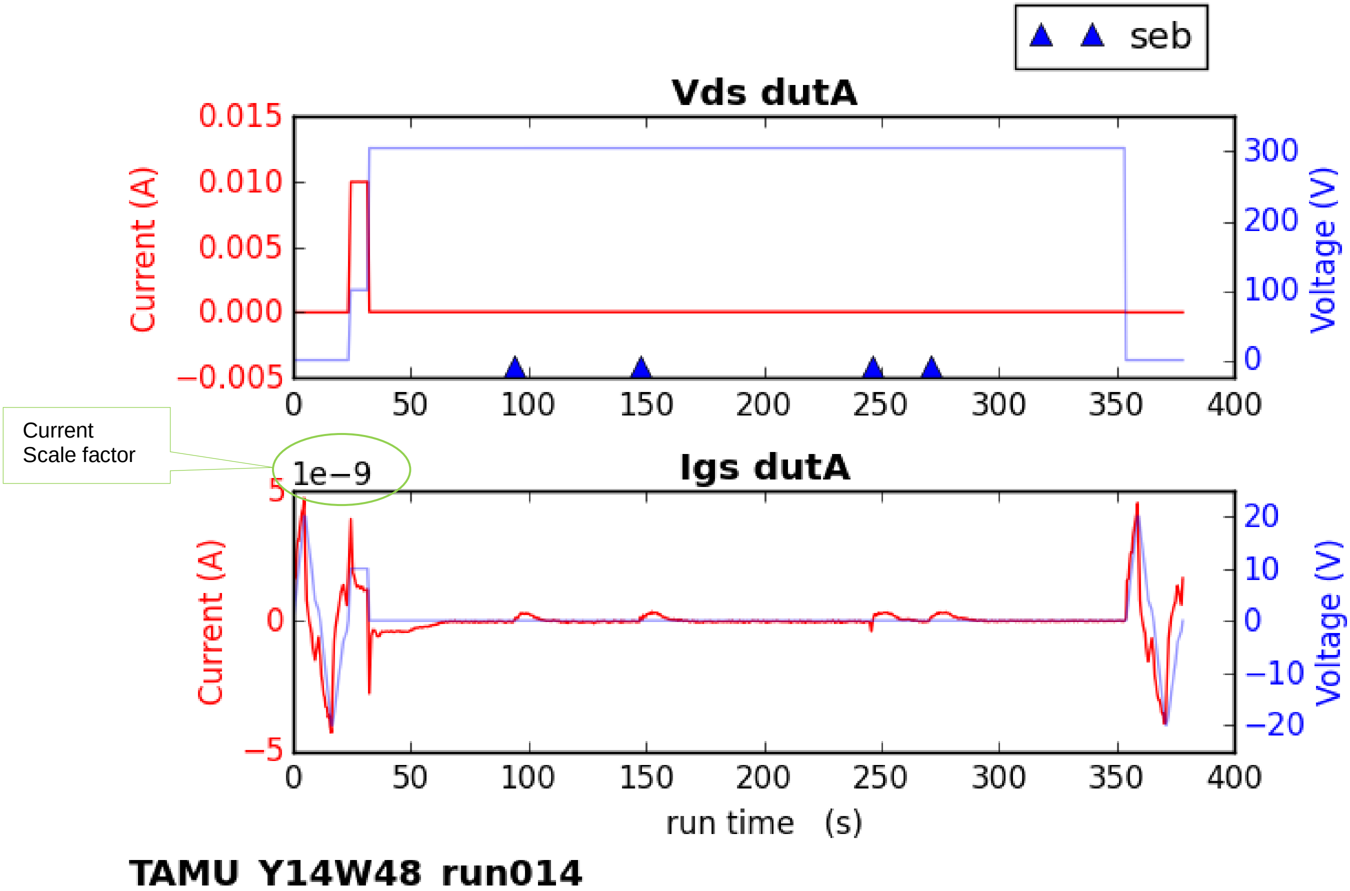
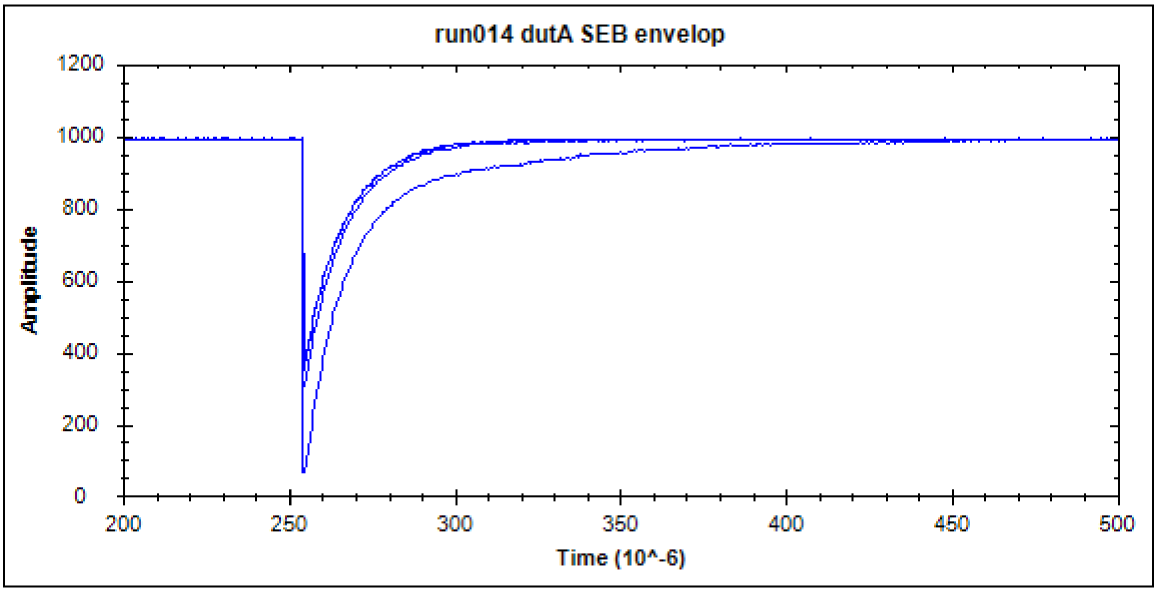


Figure 7 – Example of the data recorded for each dut under test and each test run.



Amplitude is measured in tester LSBs (1 LSB correspond to 307mV)

Figure 8 – SEBs recorded during y14w48 run014 (see Figure 7)

7.3 Discussion

For silver ion, a wrong dead layer definition was used and beam energy at silicon surface would rather be 1220MeV with a deposited critical charge Q of 20.1 pC.
Test was successful with Group1 ion but SEGR occurrence at lower Vds did not allow for the characterization of SEb Vds threshold with Group2 ions.

Ion group	Ion	Ion, LET	Computed charge in critical volume Q (pC)	Test slot	SEB threshold (V)
Group 1	Kr High energy	Kr, 14.6	1.24	y13w35	around 32
		Kr, 14.6	1.24	y14w26	between 28 and 30
	Kr_wc	kr, 40.4	3.37	y13w35	between 27.5 and 28.5
	Kr	Kr, 27.8	2.37	y13w35	between 30 and 35
	Cu	Cu, 29.2	2.59	y14w26	around 31
Group 2	Xe_wc	Xe, 62.1	5.71	y14w26	between 24 and 25
		Xe, 62.1	5.71	y14w48	between 23 and 24
	Xe	Xe, 50.8	4.60	y13w35	Above 27.5 on 2 samples around 25 on 1 sample
		Xe, 51.9	4.71	y14w26	between 23 and 24
	Ag	Ag, 50.9	4.71	y14w26	between 23 and 24
		Ag, 50.9	4.71	y14w48	around 24

test campaign	medium	run_number	Facility_run_number	board_id	dut_part_id	Selected_beam cocktail MeV/u	Ion		roll	tilt	Al_thickness(mil)	Number_of_layers(file)	Beam_energy(MeV)	Eff._LET(MeVcm2/mg)	Eff._range(um)	Eff._fluence(ions/cm2)	Dose(rad)	run_duration live_time	Aver._flux(ions/(cm2s))	Vgs	vds	seb	SEGR	comment
y14w48	air	1	43	A	up	15	Cu		0	0	1.086	5(2)	601	22	97.4	3.01E+05	106	382.55	786	0	125	0	√	-
y14w48	air	2	44	A	up	15	Cu		0	0	1.086	5(2)	601	22	97.4	3.00E+05	106	255.967	1170	0	150	0	√	-
y14w48	air	3	45	A	up	15	Cu		0	0	1.086	5(2)	601	22	97.4	3.00E+05	106	206.933	1450	0	175	0	√	-
y14w48	air	4	46	A	up	15	Cu		0	0	1.086	5(2)	601	22	97.4	3.01E+05	106	183.15	1640	0	200	0	√	-
y14w48	air	6	47	A	up	15	Cu		0	0	1.086	5(2)	601	22	97.4	3.00E+05	106	206.55	1450	0	225	0	√	-
y14w48	air	7	48	A	up	15	Cu		0	0	1.086	5(2)	601	22	97.4	3.00E+05	106	212.5	1410	0	250	0	√	-
y14w48	air	8	49	A	up	15	Cu		0	0	1.086	5(2)	601	22	97.4	3.00E+05	106	202.45	1480	0	275	0	√	-
y14w48	air	9	50	A	up	15	Cu		0	0	1.086	5(2)	601	22	97.4	3.00E+05	106	184.883	1620	0	300	0	√	-
y14w48	air	10	51	A	up	15	Cu		0	0	1.086	5(2)	601	22	97.4	3.00E+05	106	189.217	1590	0	325	74	√	-
y14w48	air	11	52	A	up	15	Cu		0	0	1.086	5(2)	601	22	97.4	3.00E+05	106	194.483	1540	0	315	12	√	-
y14w48	air	12	53	A	up	15	Cu		0	0	1.086	5(2)	601	22	97.4	3.00E+05	106	315.583	951	0	310	4	√	-
y14w48	air	13	54	A	up	15	Cu		0	0	1.086	5(2)	601	22	97.4	3.00E+05	106	218.083	1370	0	305	0	√	-
y14w48	air	14	55	B	up	15	Cu		0	0	1.086	5(2)	601	22	97.4	3.00E+05	106	222.567	1350	0	305	4	√	-
y14w48	air	15	56	B	up	15	Cu		0	0	1.086	5(2)	601	22	97.4	3.00E+05	106	273.517	1100	0	300	1	√	-
y14w48	air	16	57	C	up	15	Cu		0	0	1.086	5(2)	601	22	97.4	3.00E+05	106	285.467	1050	0	300	0	√	-
y14w48	air	17	58	C	up	15	Cu		0	0	1.086	5(2)	601	22	97.4	3.00E+05	106	307.35	975	0	305	1	√	-
y14w48	air	18	59	C	up	15	Kr		0	0	2.343	5(2)	494	35.5	59.8	1.36E+04	7.74	10.4	1310	0	300	54	√	-
y14w48	air	19	60	C	up	15	Kr		0	0	2.489	5(2)	459	36.2	55.6	1.67E+04	9.66	11.8167	1410	0	290	50	√	1 very small seb
y14w48	air	20	61	C	up	15	Kr		0	0	2.489	5(2)	459	36.2	55.6	2.01E+04	11.7	14.65	1370	0	280	6	√	-
y14w48	air	21	62	C	up	15	Kr		0	0	2.489	5(2)	459	36.2	55.6	3.00E+05	174	206.883	1450	0	270	9	√	-
y14w48	air	22	63	C	up	15	Kr		0	0	2.489	5(2)	459	36.2	55.6	3.01E+05	174	195.7	1540	0	260	0	√	-
y14w48	air	23	64	C	up	15	Kr		0	0	2.489	5(2)	459	36.2	55.6	3.00E+05	174	189.2	1590	0	265	2	√	-
y14w48	air	24	65	B	up	15	Kr		0	0	2.489	5(2)	459	36.2	55.6	3.00E+05	174	198.733	1510	0	265	74	√	-
y14w48	air	25	66	B	up	15	Kr		0	0	2.489	5(2)	459	36.2	55.6	3.00E+05	174	202.383	1480	0	260	10	√	-
y14w48	air	26	67	B	up	15	Kr		0	0	2.489	5(2)	459	36.2	55.6	2.99E+05	173	205.05	1460	0	255	2	√	-

test campaign	medium	run_number	Facility_run_number	board_id	dut_part_id	Selected_beam cocktail MeV/u	Ion		roll	tilt	Al_thickness(mil)	Number_of_layers(file)	Beam_energy(MeV)	Eff._LET(MeVcm2/mg)	Eff._range(um)	Eff._fluence(ions/cm2)	Dose(rad)	run_duration live_time	Aver._flux(ions/(cm2s))	Vgs	vds	seb	SEGR	comment
y14w48	air	27	68	B	up	15	Kr		0	0	2.489	5(2)	459	36.2	55.6	3.00E+05	174	188.1	1590	0	250	0	√	-
y14w48	air	28	69	A	up	15	Kr		0	0	2.489	5(2)	459	36.2	55.6	3.00E+05	174	183.6	1630	0	260	5	√	-
y14w48	air	29	70	A	up	15	Kr		0	0	2.489	5(2)	459	36.2	55.6	3.00E+05	174	191.433	1570	0	255	2	√	-
y14w48	air	30	71	A	up	15	Kr		0	0	2.489	5(2)	459	36.2	55.6	3.00E+05	174	192.7	1550	0	250	0	√	-
y14w48	air	31	76	A	up	15	Xe		0	0	1.477	5(2)	884	58.3	70.3	1.85E+04	17.3	13.0667	1420	0	260	72		Ids increase during exposure and fail post gate stress
y14w48	air	45	79	B	up	15	Xe		0	0	1.477	5(2)	884	58.3	70.3	2.67E+04	25	34.0167	786	0	230	25		fail initial gate stress
y14w48	air	46	80	C	up	15	Xe		0	0	1.477	5(2)	884	58.3	70.3	3.04E+04	28.4	16.85	1800	0	230	31		Ids increase during exposure and fail post gate stress
y14w48	air	47	81	D	up	15	Xe		0	0	1.477	5(2)	884	58.3	70.3	2.99E+05	279	186.15	1610	0	150	0		fail post gate stress
y14w48	air	48	82	D	up	15	Xe		0	0	1.477	5(2)	884	58.3	70.3	1.95E+05	182	118.517	1650	0	170	0		dut dead during previous run
y14w48	air	49	83	E	up	15	Xe		0	0	1.477	5(2)	884	58.3	70.3	3.01E+05	281	209.483	1430	0	100	0		fail post gate stress
y14w48	air	50	84	E	up	15	Xe		0	0	1.477	5(2)	884	58.3	70.3	3.00E+05	280	215.733	1390	0	120	0		dut dead during previous run
y14w48	air	52	85	F	up	15	Xe		0	0	1.477	5(2)	884	58.3	70.3	3.00E+05	281	244.217	1230	0	50	0	√	
y14w48	air	53	86	F	up	15	Xe		0	0	1.477	5(2)	884	58.3	70.3	3.00E+05	280	253.433	1180	0	80	0		fail post gate stress
y14w48	air	54	86	F	up	15	Xe		0	0	1.477	5(2)	884	58.3	70.3	3.00E+05	280	253.433	1180	0	?	0		dut dead during previous run
y14w48	air	101	131	G	up	15	Ag		0	0	0	air_25mm	1319	41.8	122.3	3.00E+05	201	225.15	1330	0	60	0	√	-
y14w48	air	102	132	G	up	15	Ag		0	0	0	air_25mm	1319	41.8	122.3	3.00E+05	201	232.717	1290	0	80	0	√	-
y14w48	air	104	133	G	up	15	Ag		0	0	0	air_25mm	1319	41.8	122.3	3.09E+05	207	263.317	1170	0	up to 250	10	√	Vds searching...
y14w48	air	105	134	G	up	15	Ag		0	0	0	air_25mm	1319	41.8	122.3	3.00E+05	201	272.467	1100	0	250	47		fail post gate stress
y14w48	air	107	135	H	up	15	Ag		0	0	0	air_25mm	1319	41.8	122.3	8.19E+04	54.9	79.8167	1030	0	240	1		ids degradation (10µA) at 134s, fail post gate stress
y14w48	air	110	137	G	down	25	Kr		0	0	2.523	5(2)	1519	23.1	217.3	1.81E+05	66.8	174.9	1030	0		3	√	Vds searching..., seu at 310, not at 300
y14w48	air	111	138	G	down	25	Kr		0	0	2.523	5(2)	1519	23.1	217.3	3.00E+05	111	288.017	1040	0	300	7	√	-
y14w48	air	112	139	G	down	25	Kr		0	0	2.523	5(2)	1519	23.1	217.3	3.00E+05	111	281.533	1060	0	290	1	√	-
y14w48	air	113	140	H	down	25	Kr		0	0	2.523	5(2)	1519	23.1	217.3	3.00E+05	111	281.783	1070	0	290	2	√	-

Table 3 – REF, November 2014 (y14w48), IPP50R140CP, run table