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Radiation Tests of new European POWERMOS (HGOK)

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1 INTRODUCTION

This document reports the conditions and the results of the test campaign for the evaluation of the radiation tolerance of the discrete PowerMOS HGOK (100V, 40A, N-channel) from the manufacturer ST Microelectronics.

The purpose of this test was to evaluate total dose tolerance of this component, to investigate its suitability for being used in space applications with an accumulated dose of 100krads. This test was conducted on prototypes provided by ST.

This activity was performed by people from TEC-EPC and TEC-QC.

2 APPLICABLE DOCUMENTS

ESA/SCC Basic Specification 22900

3 REFERENCE DOCUMENTS

ST report: RHPowerMOS_ESAphase2_timeline_9sept.pdf

4 LIST OF ACRONYMS

EEE	Electrical, Electronic & Electro-Mechanical
STD	Standard
PCB	Printed Circuit Board
SP	Soldering Process
PT	Period of Test
WC	Worst Case

5 TEST SAMPLE

Samples of the HG0K device were tested (5 tested + 1 for reference). The samples were serialized before the radiation test as indicated in the following table:

PowerMOS Number	Allocation
1	bias1
2	bias1
3	bias2
4	bias2
5	bias3
6	reference

6 TESTS CONDITIONS

6.1 ESTEC Radiation Facility

The dose exposures were performed at ESA-ESTEC. The radiation facility boasts a 2000 Ci (November 2001) Co-60 gamma source. The facility consists of a control room and a radiation cell (each approximately 20 m^2) with cable feed-through enabling monitoring and control of experiments under test. Automated total dose and dose rate setting, monitoring and logging are available via HP-VEE control software running on a PC. This system may also be used for automated monitoring of experiments under test. While irradiating, dose rates are easily changed by use of a rail system installed in the radiation cell.

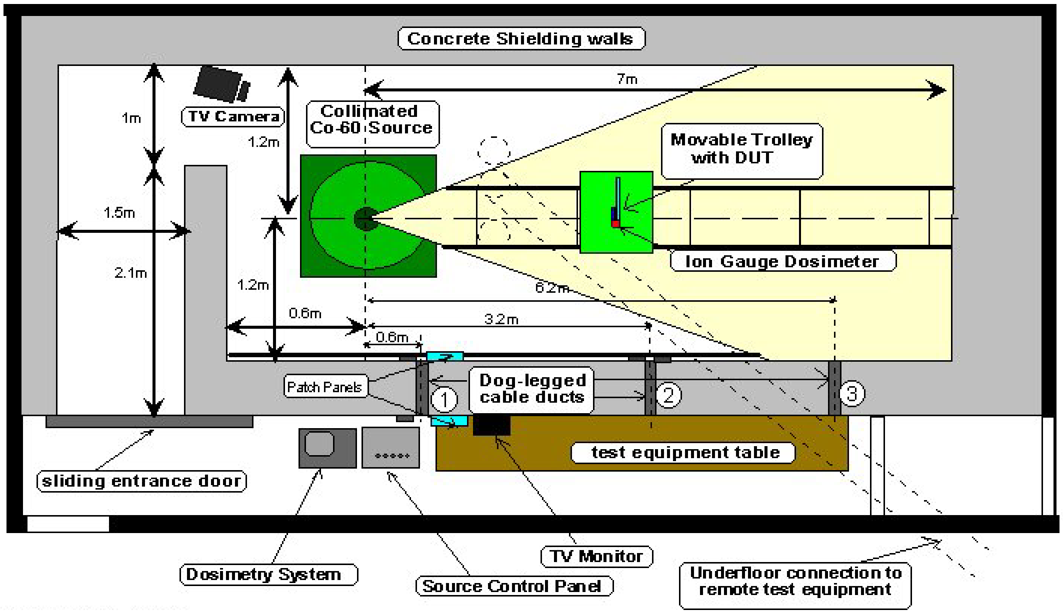

Fig1: Estec 2000 Ci Co-60 Facility

6.2 Radiation Dose

The PowerMOS were characterized before radiation and at approximately 15krads, 30krads, 45krads, 60krads and 110krads (Si). The dose rate during the radiation campaign was 12.88rads/s. At the end of the radiation phases, two annealing phases were performed. The first one was at 25degC during 24 hours, and the second one was at 100degC during 164 hours. During the radiation and annealing phases, the PowerMOS were polarised.

The annex one summarizes the radiation and annealing phases.

6.3 *Electrical Bias during radiation and annealing*

During exposures dedicated test board was used. The test board allowed biasing the devices in accordance with the electrical circuit provided in Figures 2, 3 and 4. Three types of bias were applied to the PowerMOS. Two PowerMOS (ref.: M1 and M2) were polarised with the bias #1. Two other PowerMOS (ref.: M3 and M4) were polarised with the bias #2 and one PowerMOS (ref.: M5) was polarised with the bias #3. The PowerMOS M6 was kept as reference and was not stressed.

Bias #1:
Vgs=0V, Vds=80V

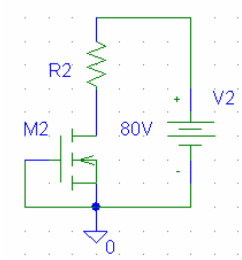

Fig2: Bias 1 applied to the two PowerMOS M1 and M2

Bias #2:
Vgs=12V, Vds=0V

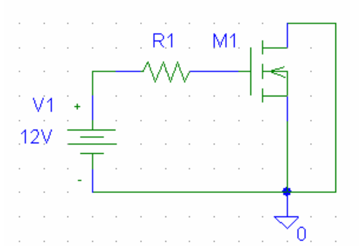

Fig3: Bias 2 applied to the two PowerMOS M3 and M4

Bias #3:
Vgs=Vds=0V

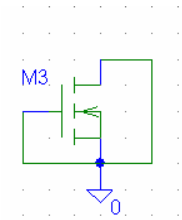

Fig4: Bias 3 applied to the PowerMOS M5

7 ELECTRICAL CONDITIONS FOR CHARACTERISATION

7.1 RDSon

Rdson is the equivalent resistance between the drain and the source of a PowerMOS, when it conducts. It is one of the most important parameter for the users of PowerMOS. The lower is the RDSon, the lower will be the conduction losses in the PowerMOS.

To measure the RDSon of a PowerMOS, the standard following conditions were applied to the PowerMOS:

- VGS signal:
  - RDSon can be measured only when the PowerMOS conducts. The PowerMOS tested is an N channel. The voltage between the gate and the source VGSon was 12V. A low frequency generator (LFG) commanded the POWERMOS.
  - It is known that RDSon is a function of the temperature. To keep the temperature constant, the pulse width (ON time) of Vgs was in the order of 300us and the Duty cycle was lower than 2%.

- Drain Current: RDSon was measured at 40A. A precise shunt was used to measure the drain current.

The schematic of the set-up to measure RDSon is the following:

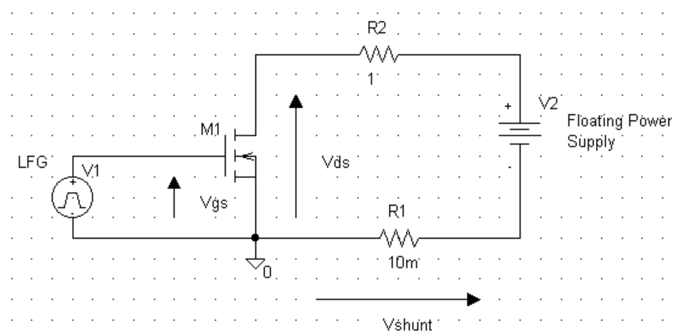

Fig5: Test set-up for the measurement of RDSon with a shunt resistor

Remark: By varying the voltage of the power supply, the drain current can be chosen. It is important to note that the power supply must be a floating power supply; otherwise the shunt won't measure the drain current.

7.2 Total Gate Charge

The total gate charge is important for the power-conditioning engineer. This parameter gives an idea of the size of the driver that will be used to command the PowerMOS.

To measure the total gate charge of the PowerMOS, the standard following conditions were applied:

- The drain current ID of the tested PowerMOS has to be constant. Usually a second PowerMOS in series with the tested PowerMOS is used to limit the current. The drain current is equal to the maximum continuous drain current. In our case the drain current was the maximum continuous drain current, ie: 40A.
- The gate current of the tested PowerMOS has to be constant. A pulse current of a few mA is generally injected in the gate of the tested PowerMOS. The amplitude of this pulse current has to be known before the test to be able to calculate the total gate charge. Before and after the Gate Charge measurements, the amplitude of the pulse was measured, by replacing the PowerMOS by a precise resistor (5k).
- As for RDSon, the duty cycle of the current pulse has to be lower than 2% and the pulse width in the order of a few hundred of us.
- The test voltage VDS of the PowerMOS is set to 50% of BVDss (in our case BVDss is 100V).

The schematic of the set-up to measure the total gate charge of the PowerMOS is the following:

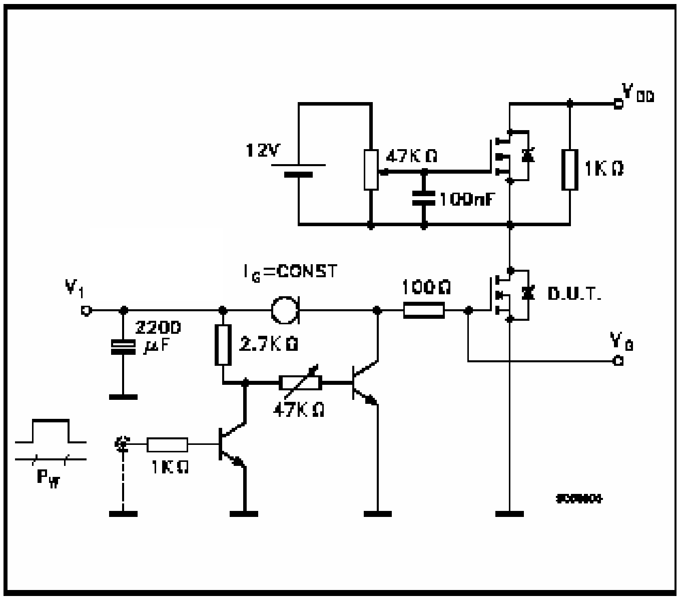

Fig6: Test set-up for the measurement of the total gate charge QG

7.3 Threshold voltage

During the measurements of the threshold voltage, VDS was equal to VGS. The Drain current Id was fixed at 250uA.

7.4 Leakage Currents (IDSS and IGSS)

To measure IDSS, VGS was fixed at 0V and VDS at 80V.
To measure IGSS, VDS was fixed at 0V, and VGS at +/-14V

7.5 Breakdown Voltage

To measure the breakdown voltage BVDSS, the drain current was fixed at 250uA and VGS at 0V.

8 INSTRUMENTS USED

8.1 Instruments used for the RDSon and the total Gate Charge measurements

To measure the different voltages a Tektronix TDS 3034B scope was used. The current was measured with a current probe Tektronix TCP202. A pulse/function generator Hewlett-Plackard 8111A, 20MHz was also used to create the gate current pulse.

8.2 Instruments used for the Leakage Currents, BVDss, VGSth measurements

A dedicated instrument to characterize PowerMOS was used to these parameters. The reference of this instrument is SZ M3000, Universal Test System (QC laboratory).

9 TESTS RESULTS

No manufacturers limits shown on graphs

Tests results including tables and graphics are provided in this section for each measured parameter.
During the annealing phase 2 (100degC during 164 hours) a PowerMOS failed (M1). The causes of the failure were not identified, but a DPA was proposed to help to understand the failure. A failure during an annealing phase is extremely rare. It is important to highlight that the test card, where the PowerMOS were mounted, could have been in contact with one of the internal and conductive walls of the thermal chamber, and create a short circuit.

9.1 RDSon

Figure 7 introduces the results concerning RDSon. Usually, this parameter was not affected by the radiation dose. It is important to highlight that the PowerMOS were soldered to perform this measurement. The soldering may be the cause of the little variation of RDSon at the different level of radiation.

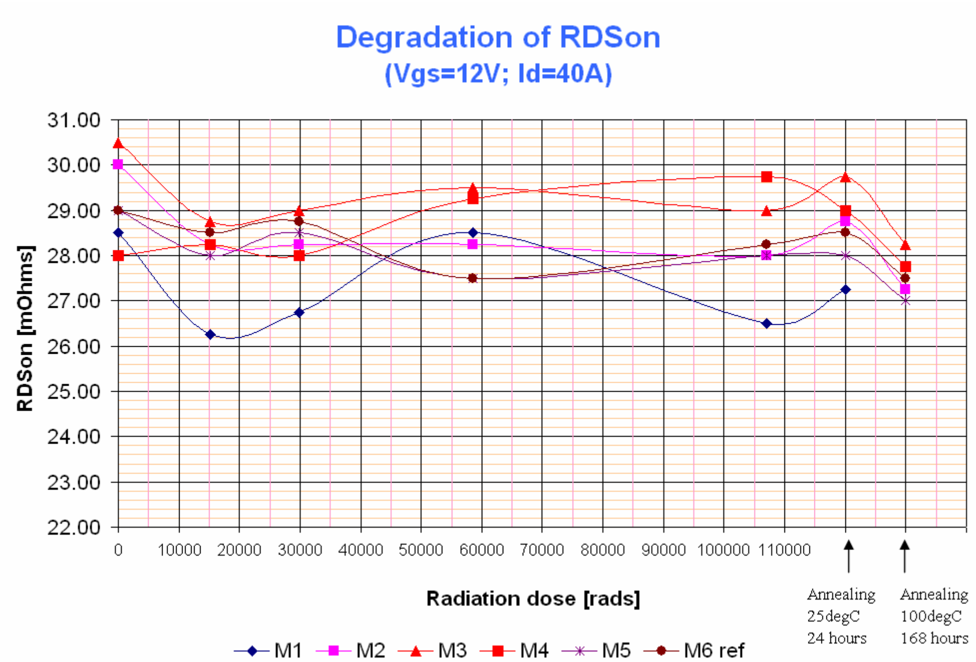

Fig.7 Degradation of RDSon during the radiation Test

9.2 Total Gate Charge

Figure 8 introduces the results concerning the Total Gate Charge. The radiation affected consistently the total gate charge. The PowerMOS biased with the bias 1 are the most affected. The total gate charge at 100krads represents an augmentation of 35% of the initial value, measured before the radiation.

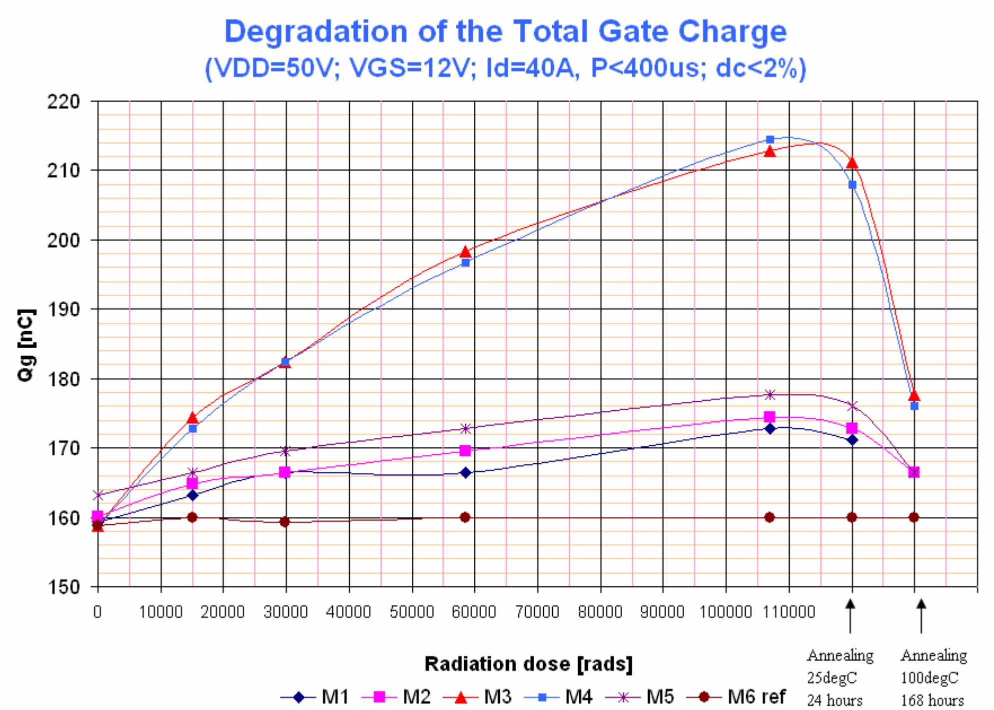

Fig.8 Degradation of the total gate charge during the radiation Test

9.3 Threshold voltage

Figure 9 introduces the results concerning the threshold voltage. The radiation affected this parameter. The PowerMOS biased with the bias 1 are the most affected. The degradation for the PowerMOS 1 and 2 at 100krads represents a diminution of about 33% of the initial value, measured before the radiation.

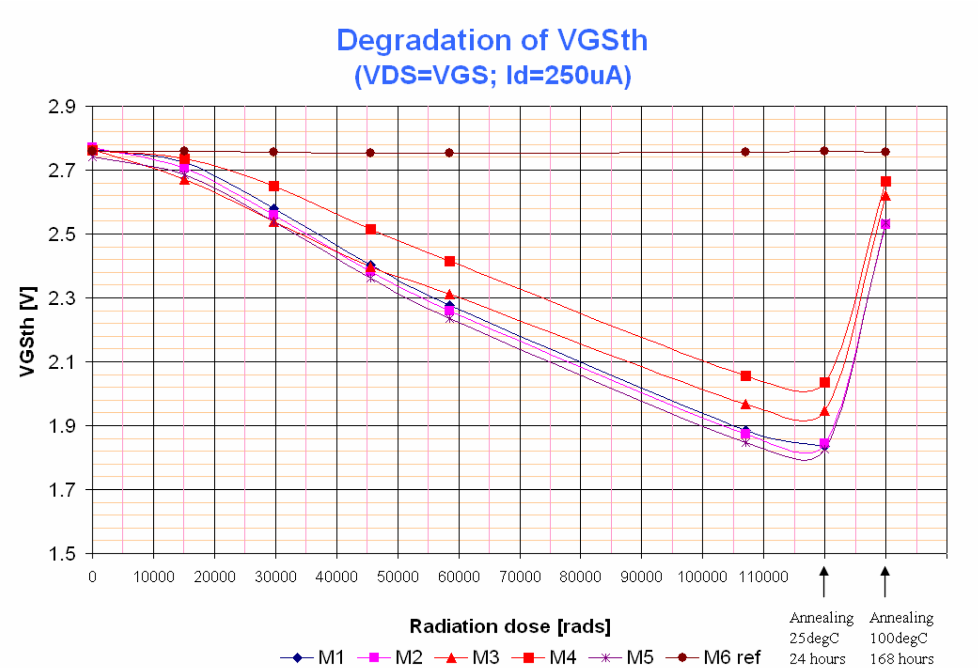

Fig.9 Degradation of the threshold voltage during the radiation Test

9.4 Leakage Currents IDSS

Figure 10 introduces the results concerning the leakage Current IDSS. The radiation affected this parameter, specially the PowerMOS M3 and 4 (bias 2), at high cumulative radiation dose. At 100krads the leakage current of these two PowerMOS (M3 and M4) reached respectively 6.5uA and 5.7uA.

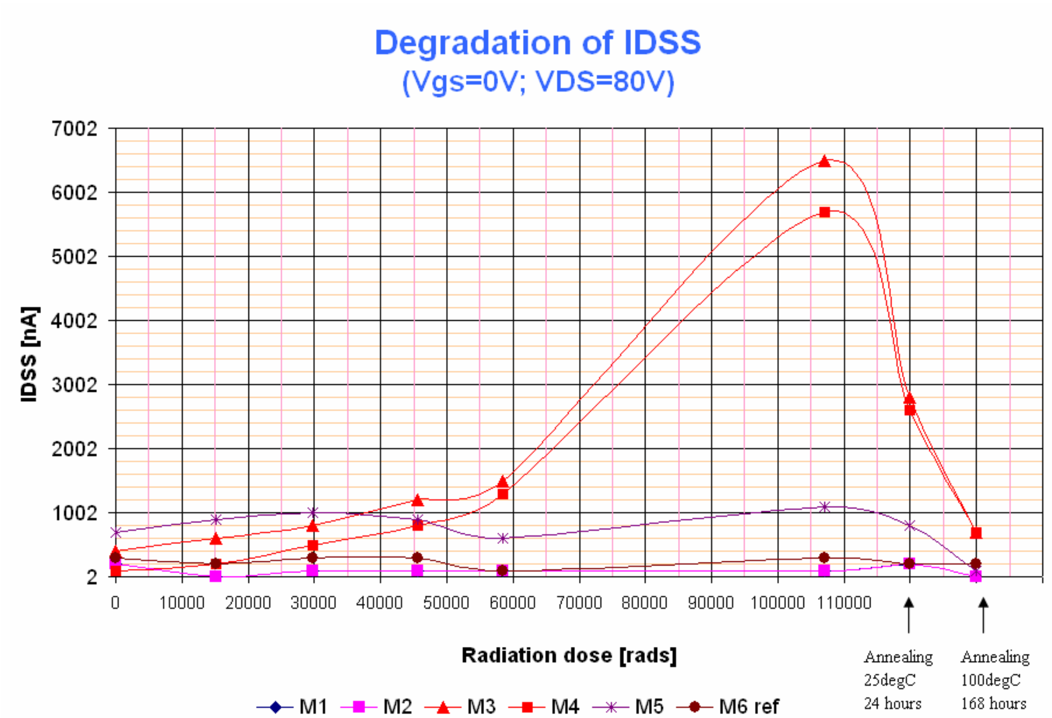

Fig.10 Degradation of the leakage Current IDSS during the radiation Test

9.5 Leakage Current IGSS with VGS=+14V

Figure 11 introduces the results concerning the leakage Current IGSS.

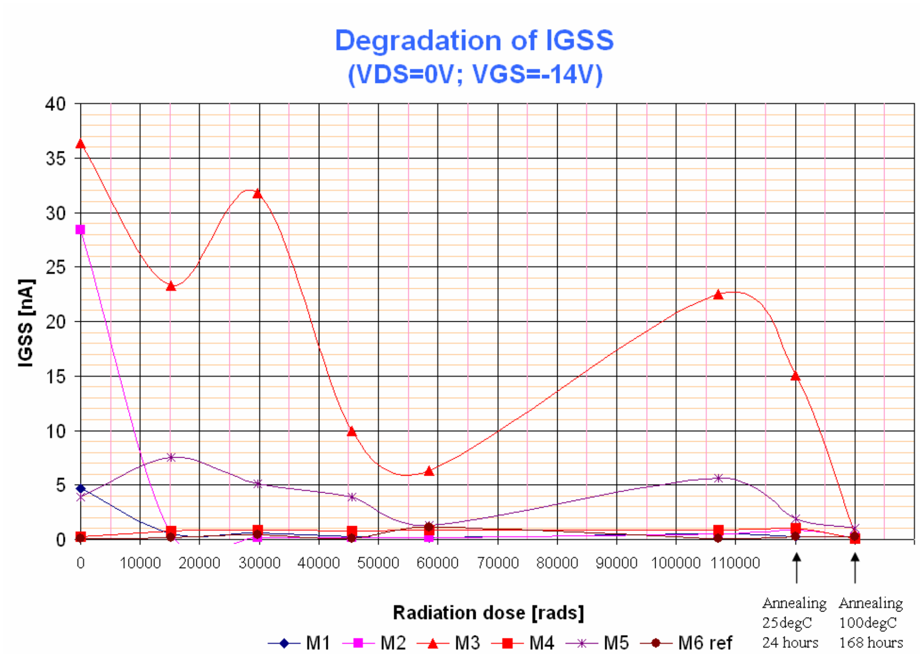

Fig.11 Degradation of the leakage Current IGSS (+) during the radiation Test

9.6 *Leakage Current IGSS with VGS=-14V*

Figure 12 introduces the results concerning the leakage Current IGSS.

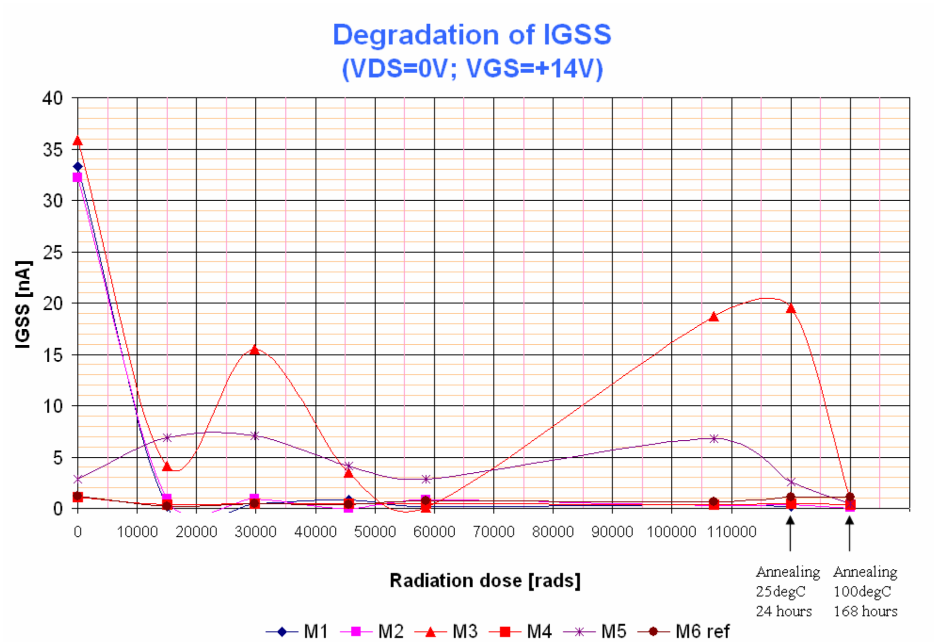

Fig.12 Degradation of the leakage Current IGSS (-) during the radiation Test

9.7 Breakdown Voltage

Figure 13 introduces the results concerning the breakdown voltage BVDSS. The radiation affected this parameter at the beginning of the radiation tests until several krads, then the parameter stabilised.
The PowerMOS M1 and M2 (bias 1) were more affected than the others.

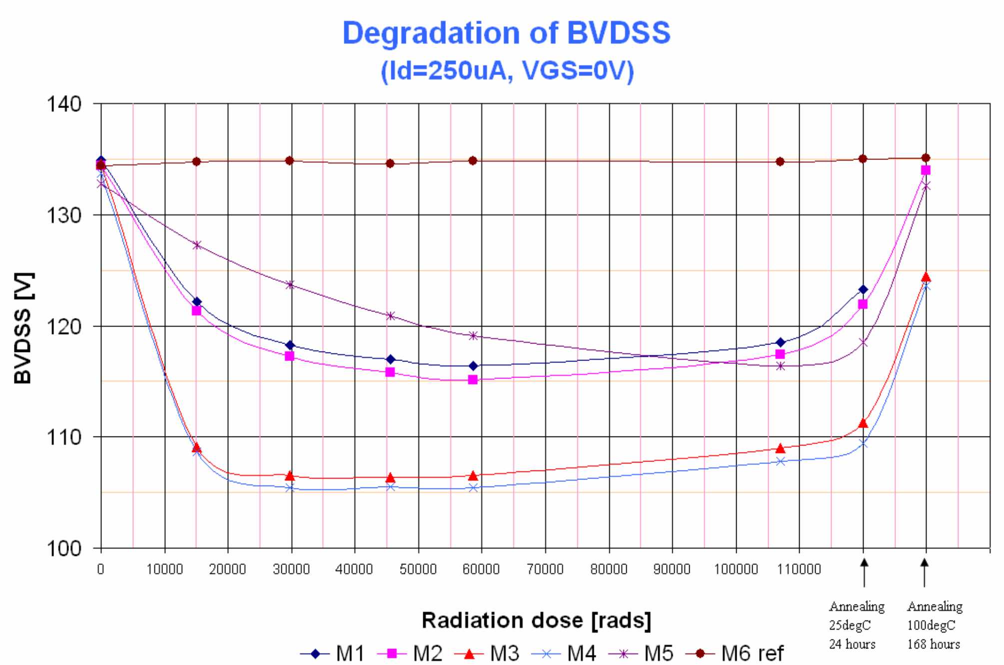

Fig.13 Degradation of the Breakdown Voltage BVDSS during the radiation Test

10 CONCLUSION

The results and conditions of the radiation test of the future European PowerMOS HGOK have been presented. One failure occurred (M1) during the second annealing phase (100degC during 164 hours). There is good reason to believe this failure is more due to a set-up problem than to a PowerMOS weakness.

RDSon was not affected by the accumulative total dose. However BVDss, VGSth, and the leakage current IDSS were degraded. Are devices within specifications at end of test ?

11 ANNEX ONE: RADIATION TEST SCHEDULE

Date	Hours	Minutes	Seconds	Radiation in H2O [rads]	Radiation in Si [rads]	Comments
						Characterization before radiation
22-Aug	11	9	34			
22-Aug	11	17	24	93.6		
						Calibration
22-Aug	11	24	53			
23-Aug	9	2	2	17653	15110	
						Characterization 1
23-Aug	13	53	26			
24-Aug	10	50	46	34791	29781	
						Characterization 2
24-Aug	14	58	48			
25-Aug	13	48	30	53254	45585	
						Characterization 3
25-Aug	14	24	17	68397	58547	
26-Aug	9	4	52			
						Characterization 4
26-Aug	12	19	58	125035	107029	
29-Aug	9	19	14			
						Characterization 5
29-Aug	12	15	0	0	0	
30-Aug	12	15	0	0	0	Annealing 25degC
						Characterization 6
30-Aug	16	45	0	0	0	
06-Sep	14	0	0	0	0	Annealing 100degC
						Characterization 7