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Floating Gate Sensors (IC Malaga) Proposal for the sensor characterization

Abstract

This document presents a proposal for the characterization of the FG sensors to assess its main features.

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1. INTRODUCTION

This document summarizes the discussion on the Floating gate (FG) sensor, held at CERN on 17/01/2012 [1].

The meeting showed the potentiality of the sensor to measure the Total Ionizing Dose (TID) with a resolution in the order of 1 rad. The discussion of the test results of H4IRRAD highlighted the need for a more complete analysis of the Floating Gate sensor. The different issues are discussed, and the test campaigns are proposed to characterize the sensor.

2. TEST RESULTS DISCUSSION

Different values of sensitivity were found in different tests:

- ~290 Hz/rad at the Radiation Physics Laboratory (USC) at two dose rates of 100 rad/hour and 300 rad/hour;
- ~230 Hz/rad at the H4IRRAD, a CERN test area with a mixed field radiation environment, (ratio calculated with RadFet 400 nm with an uncertainty of 50%) at two dose rates of 0.7 rad/hour and 5.6 rad/hour.

Thus, a gamma calibration is needed in order to verify the sensitivity of the sensors.

Moreover, the sensor seems to saturate at a dose rate of 500 rad/hour at the USC facility. An investigation on the dose rate is necessary.

In all the previous tests, one or two sensors were tested. More samples from the same lot (at least 3) must be tested. The spread among their response will determine the sample-to sample variation.

The gamma irradiation will indicate the maximum dose rate that the sensor can stand without saturation. Then, a test campaign with proton should be foreseen to assess the difference response with different particles at different energy. The lowest available dose rate at the proton beam facility of the Paul Scherrer Institute (PSI) is ~700 rad/hour at 230 MeV.

The radiation effects on the readout electronic are to analyse too; a proton test is suggested in order to verify the hardness for TID, DD, and SEU.

Since the sensor is very sensitive to the temperature, pre-irradiation and post-irradiation thermal characterization must be foreseen.

Electrical characteristics have to be measured before and after the irradiation. Frequency resolution and noise level must be characterized.

The recharge process has to be fully characterized in radiation field. The recharge process can depend on the dose rate.

3. PROPOSAL

In this Section, a characterization strategy is proposed:

1. Gamma (Co^{60}) Calibration to assess
 - a. Sample to sample variation
 - b. Sensitivity
 - c. Dose rate dependency; highlight the maximum dose rate that the sensor can stand.
 - d. Analysis to do at the end of each run
 - i. Verify the recharge voltage
 - ii. Verify the noise levels of the frequency output and the currents
 - iii. At the restart of the run, measure the resolution of the sensor to check if it gets worse with dose
 - e. Verify the temperature effect on the irradiated samples. Ideally, a procedure to follow should be defined

The table I reports a proposal for 4 runs at the USC facility to verify the above points a-e.

Run	Time [h]	Dose rate [rad/h]	Cumulative Dose [rad]	# Samples	Recharge [V]
1	1	10	10	3	5
1	1	10	10	3	3
1	1	100	100	3	5
1	1	200	200	1	5
2	1	10	20	3	5
2	1	10	20	3	3
2	1	100	200	3	5
2	1	200	400	1	5
3	1	10	30	3	5
3	1	10	30	3	3
3	1	100	300	3	5
3	1	200	600	1	5
4	2	10	50	3	5
4	2	10	50	3	3
4	2	100	500	3	5
4	2	500 or the maximum dose rate	1600	1	5

Table 1. Proposal for a gamma test at the USC facility.

2. Proton test at PSI

- a. Effects of TID, DD, and SEU on the reading circuit (The readout circuit should be provided without the embedded sensor)
 - i. Verify the recharge voltage
 - ii. Verify the noise levels of the frequency output and the currents
 - iii. Verify the temperature effect on the irradiated samples. Ideally, a procedure to follow should be defined
- b. Energy dependency; the feasibility of this study depends on the maximum acceptable dose rate (see 1.c) (This test refers to the full circuit: readout + sensor)

3. Laboratory tests as a reference

- a. Thermal characterization for different devices from different lots. Read the frequency outputs at different temperatures. Ideally, a procedure to follow should be defined
- b. Electrical characteristics to be measured for each lot. Verify the noise levels of the frequency outputs and the currents with repeated measurements in the laboratory.
- c. Controlled recharge process. Verify if the recharge voltage is repeatable. The minimum period for the recharge should be defined.

Number of devices for each phase:

N°	Type of test	N° of device to be tested
1	Gamma (Co60) Calibration	10 samples + 6 spares
2	Proton test at PSI	At least 6 (only readout electronic) +2 spares At least 6 (readout + sensors) + 4 spares
3	Thermal characterization	2 new devices and the DUTs of the Co60 test
4	Electrical characterization	Same as thermal characterization

Table 2. Number of devices needed for each phase.

The total number of devices to test is 34.

4. FACILITY AND TEST FORESEEN

4.1 USC GAMMA FACILITY

The facility [2] provides sample irradiation service with cobalt 60 gamma photons at different dose rates. The tests will be carried out at the laboratory irradiation room, which has the dimensions of 10 m x 6 m (Figure 1).

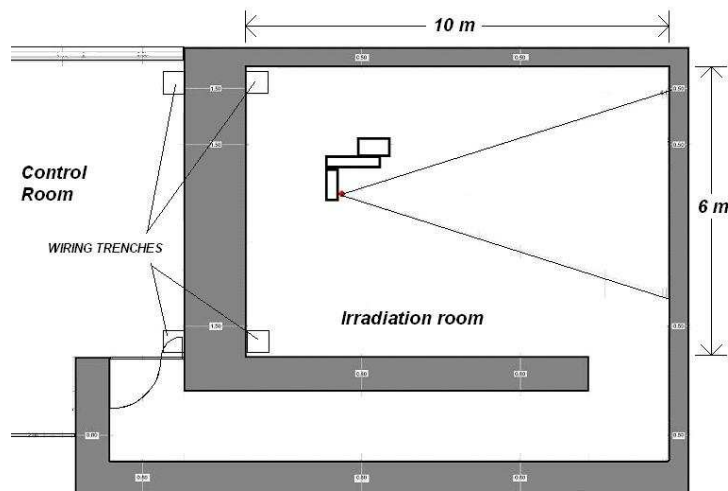


Figure 1. Irradiation facility plan.

The Co60 source can be collimated in rectangular or square shape. It is a divergent beam so irradiation area and dose rate depend on distance to source.

The dose rate absorbed in a medium $D_{med}(d)$ at a distance d is defined by:

$$D_{med}(d) = D_{med}(d_{ref}) \cdot \frac{d_{ref}^2}{d^2}$$

where $D_{med}(d_{ref})$ is known.

An ionization chamber measures exposure rate which can be converted to absorbed dose rate (air). In order to convert absorbed dose rate D_{air} to absorbed dose to medium D_{med} , the following expression must be used:

$$D_{med} = D_{air} \cdot s_{med,air}$$

where $s_{med,air}$ is the stopping power ratio between the medium and the air for the secondary electrons generated by a Co60 photon beam.

The typical available values of dose rate in Silicon are in the range 28 rad/h - 10 krad/h.

At this facility, several points discussed in Section 2 can be analyzed. In particular, this test can be retained as a calibration if no dose rate dependency is found. If more than 2 samples are tested, and they are put close to each other, a sample to sample variation can be evaluated. If other sensors are placed at different distances from the Co60 source the dose rate dependence can be pointed out.

If the sensors can be heated, a temperature characterization can be done at 0 rad and at different TID (see plan for gamma irradiation test).

The analysis of the recharge process can be done. We have to take into account that the high dose rate forces a high frequency of the recharge process. The minimum period is to define.

4.2 FRAUNHOFER GAMMA FACILITY

A Co60 gamma source is also available at the Fraunhofer facility. The dose rate goes from $1e-4$ rad/h up to 100 rad/h. The considerations made in section 3.1 apply also to this facility.

4.3 PSI PROTON TEST FACILITY

At Paul Scherrer Institute a 230 MeV of proton beam is available. The energy can range from 30 MeV up to 230 MeV. The intermediate energy can be achieved by means of copper degraders.

The irradiation spot is 5 cm with a 5 cm collimator. The 5 cm collimator is necessary in order to have good beam homogeneity.

In this facility, it is possible to verify the effects of the protons on the readout circuit. The Displacement Damage, TID and SEU effects can be evaluated.

This facility could be eventually used to understand if the energy of charged particles, such as the protons, can influence the response of the sensor.

5. REFERENCES

[1] <http://indico.cern.ch/conferenceDisplay.py?confId=228736>

[2] USC Gamma Facility, <http://www.usc.es/en/investigacion/riaidt/radiofisica/irradiacion.html>