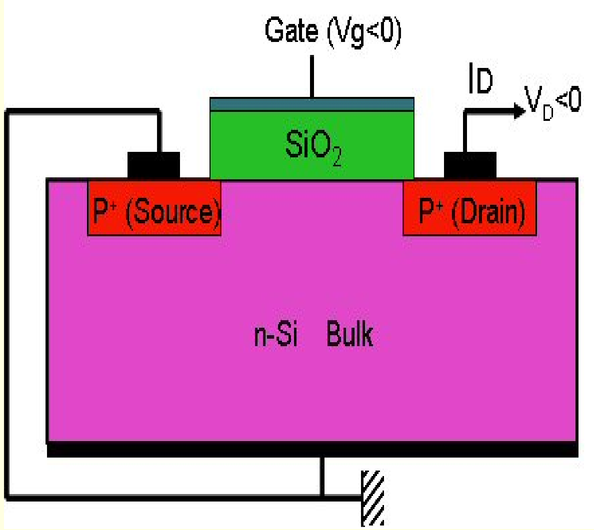
Electronic Dosimeter for Space Applications based on MOSFET Technology

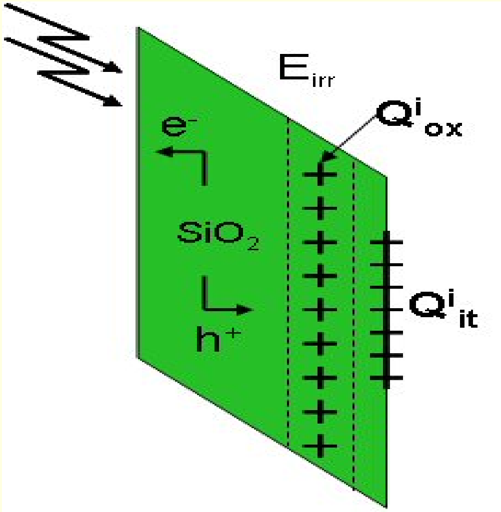
T. Laopoulos[1], S. Siskos[1], V. Konstantakos[1], T. Asaniotis[1], G. Sarrabayrouse[2], M. Zamani[3], M. Fragopoulou[3], S. Stoulos[3], E. Benton[4], Y. Uchihori[5], D. O'Sullivan[6]

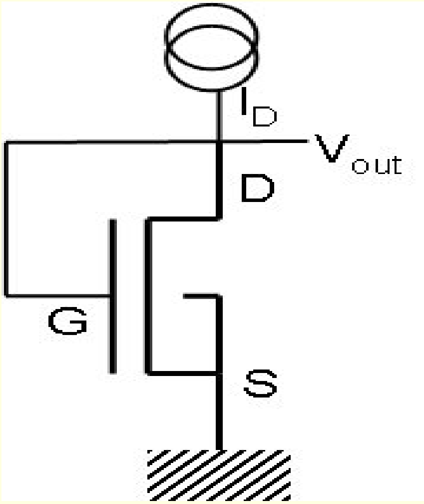
[1] School of Physics, Electronics and Computers Section Aristotle University of Thessaloniki, 541 24, Greece
[2]CNRS; LAAS; 7 avenue du colonel Roche, F-31077 Toulouse, France
[3] School of Physics, Nuclear and Elementary Particle Section, Aristotle University of Thessaloniki, 541 24, Greece
[4]Department of Physics, Oklahoma State University, Stillwater, OK 74078-3072, USA
[5]National Institute of Radiological Sciences, Radiation Measurement Research Section, Chiba 263-8555, Japan
[6]Dublin Institute for Advanced studies, 5 Merrion Square, Dublin 2, Ireland

The MOSFET used in the present study has been developed at LAAS (CNRS), Toulouse, France in corporation to Electronics Laboratory, School of Physics, AUTH, Greece. Introducing an innovative technology with very thick SiO_2 insulator the sensitivity of the device has been enhanced.

PRINCIPLE OF OPERATION







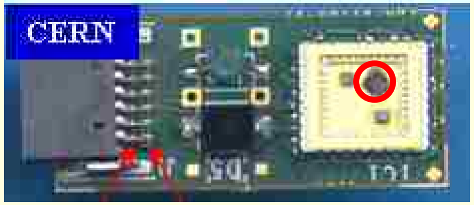
$\Delta V\ out = f(D_{ox}, Process, V_{irr}, Dose, E, dE/dx)$

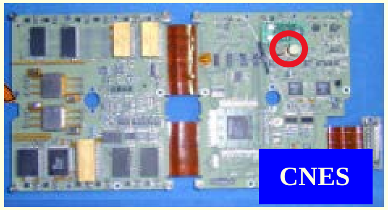
The MOSFET transistors are developed following a process designed for improving both sensitivity to radiation dose and stability. They can operate biased as a real time dosemeter and unbiased as a passive dosemeter with high performance.

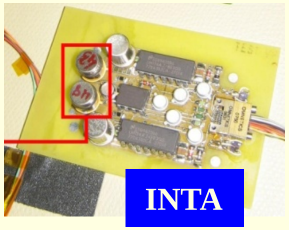
STUDIES OF LAAS DOSIMETERS IN PASSIVE MODE

Process optimisation: Oxide, Metal, semiconductor doping level
Influence of temperature variation, Fading: Dox, T
Read time instabilities, Noise
Stacking of several transistors
Sensitivity to photons, electrons, protons, neutrons
Neutron dosimeter with Lithium and Boron converters
Dosimeter reader and measurement sequence

APPLICATIONS OF LAAS DOSIMETERS



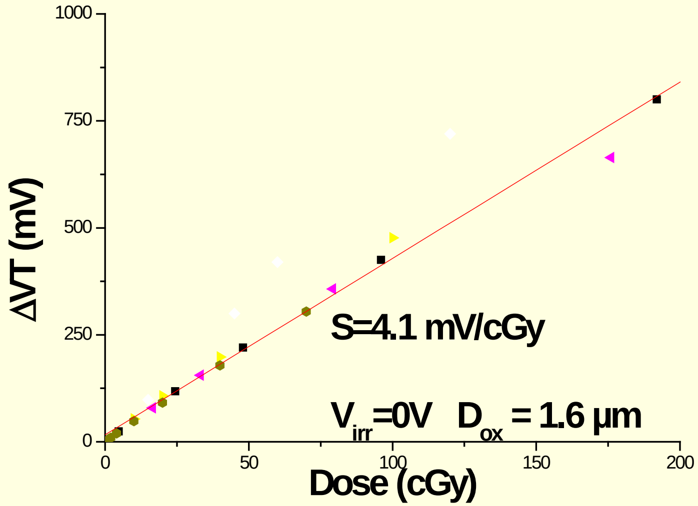


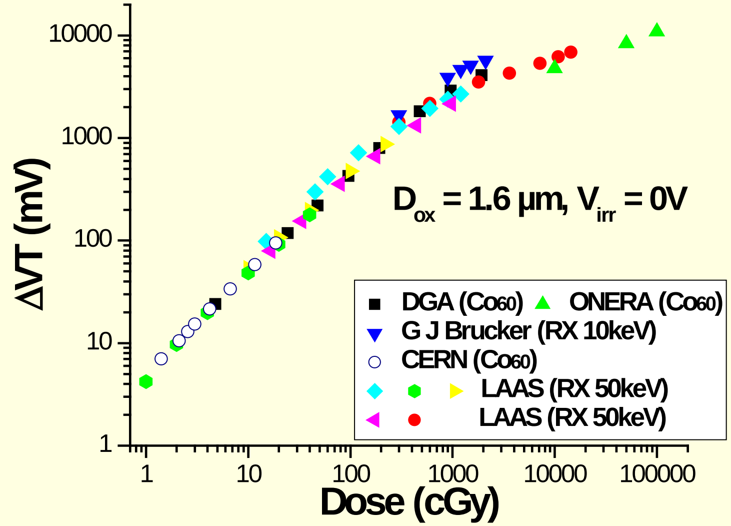


High energy physics	**CERN-LHC**: RADMON system
Space	**CNES**: SPOT4, ISS, JASON, SAC-D **INTA**: OPTOS
Military	**MGPI**: SOR T Tactical dosimetry system
Medicine	**TRAD**: DOSI-SECURE in vivo radiotherapy

LAAS-CNRS

Response studies on photons at passive mode

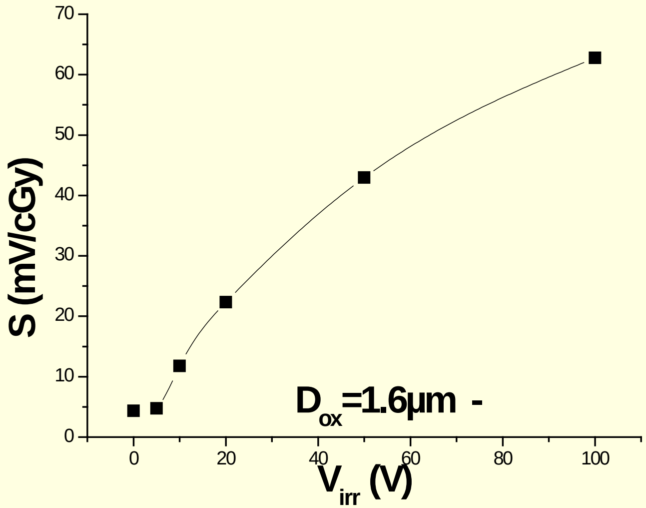


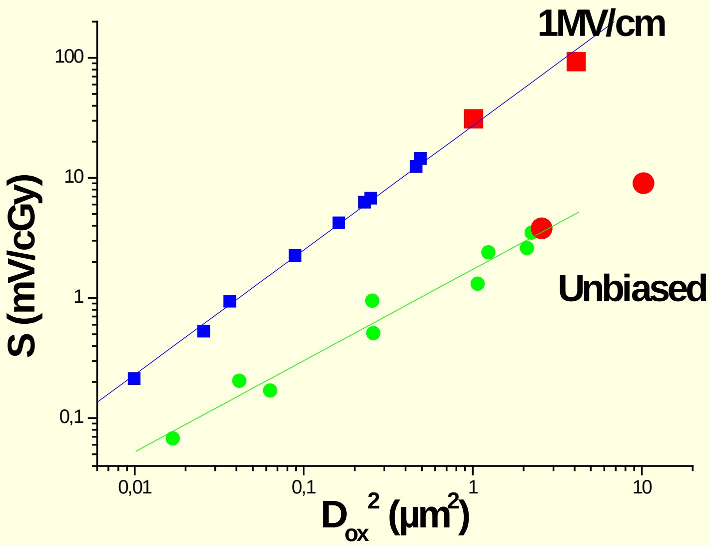


LAAS-CNRS

The response curve has a linear behavior at low doses while above 10 Gy a saturation is presented. The measured values are considerable higher than the corresponding ones reported in literature up to now

Response studies on photons at active mode

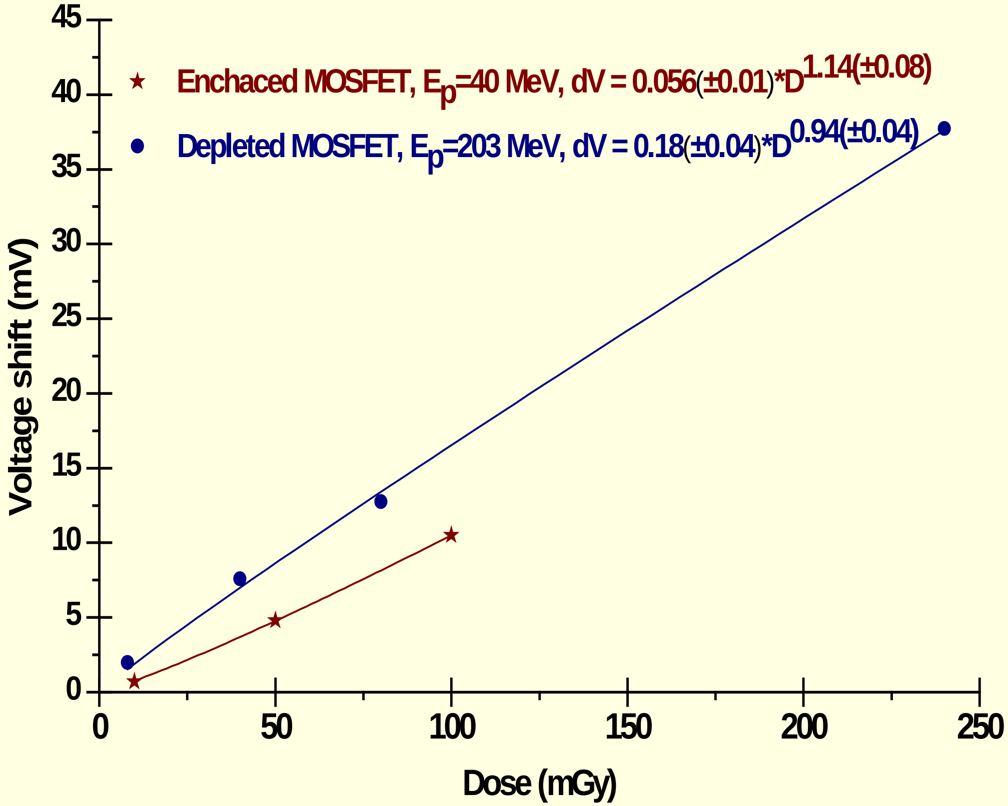




LAAS-CNRS

The response is higher (about one order of magnitude) at active mode than in passive one. A saturation is presented for applied voltage higher than 100 V.

Response studies on high-energy protons at Japanese accelerators. Two types of MOSFET, the depleted and the enhanced one have been tested, during proton irradiations at passive mode.



The response curve has an almost linear behavior. The response of the enchased sensors present a supralinear behavior while the depleted one a sub-linear.

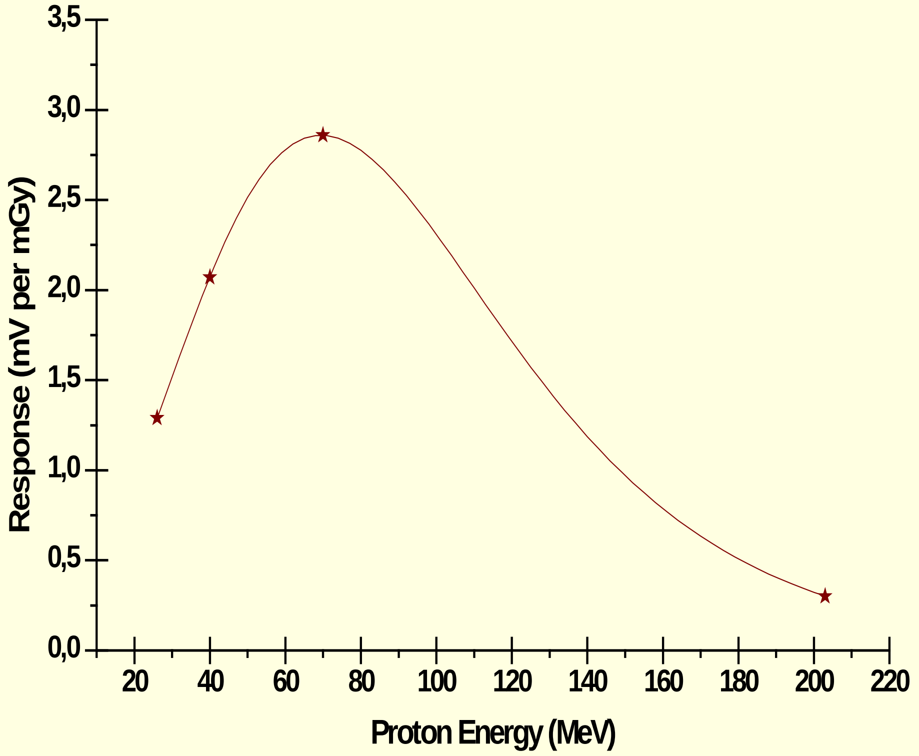
The response of depleted sensor even at high energy proton fields (E_p=203MeV), where lower energy is expected to be deposited in the sensor, is considerable higher than the enhanced one at low energy proton fields (E_p=40MeV).

一番 **ICCHIBAN Project**

Response studies using depleted MOSFET with and with out ^{6}LiF converter to protons.

According to the limited data obtained, the voltage shift measured using sensors with ^{6}LiF converter is higher than the one without ^{6}LiF converter.
Regarding to fitting the response vs dose more data is needed and so a certain conclusion could be achieved.

Response studies to protons using a stack of two depleted MOSFET with ^{6}LiF converter.



The response measured has a rapid increment up to ~70 MeV and then degreases significantly at proton energies > 200 MeV.
Using the limited date obtained up today an extreme function could be applied as follows:

$$R = A \cdot e^{[-e^{(-z)} - z + 1]}$$

$$z = \frac{x - x_c}{w}$$

A = 2.9 mV/mGy
x_c = 69 MeV and w = 41 MeV

The response to protons at energy higher than 200MeV is comparable to the response measured for fast neutrons and photons.

ICCHIBAN Project

Response studies using a depleted MOSFET with ^{6}LiF converter to alphas and heave ions.

An irradiation to alpha particles 2.2 keV/µm has been performed as a blind at 50 mGy during ICCHIBAN irradiations.
Using the response of 70 MeV protons the results range at 47 mGy indicating that the same response could be applied to light particle like deuteron and alpha, as well.

Irradiations to heavy ions fields at 290 MeV/n C and 500 MeV/n Fe have been performed as well.
The response to 290 MeV/n C particles measured (0.13 mV/mGy) is comparable to 200 MeV protons.
In the case 500 MeV/n Fe an almost same threshold voltage shift has been observed for all doses studied. This result is due to high recombination effect occurred in the silicon oxide in these cases.

Conclusions

A dosimeter based on a depleted sensor with ^{6}LiF converter is sensitive enough to high energy protons up to 200 MeV. The sensitivity to protons is about two times higher than previously reported in literature.

The response to light charged particles like protons, deuterons and alphas with few decades of MeV energy is one order of magnitude higher than to fast neutrons, photons and protons E>200 MeV.

In case of 290 MeV/n C the response is comparable to light particles with the same energy.

In case of 500 MeV/n Fe no results have been obtained due to high recombination effect occurred. The recombination effect can be reduced if a V_{bs} is applied to the source of the MOSFET.

Perspective

The dosimeter has to be irradiated to high energy protons 100-200 MeV protons and low energy < 20 MeV.

The response to high energy light particles (deuterons and alphas) as well as to electrons is needed regarding to cover the primary spectrum of cosmic radiation.

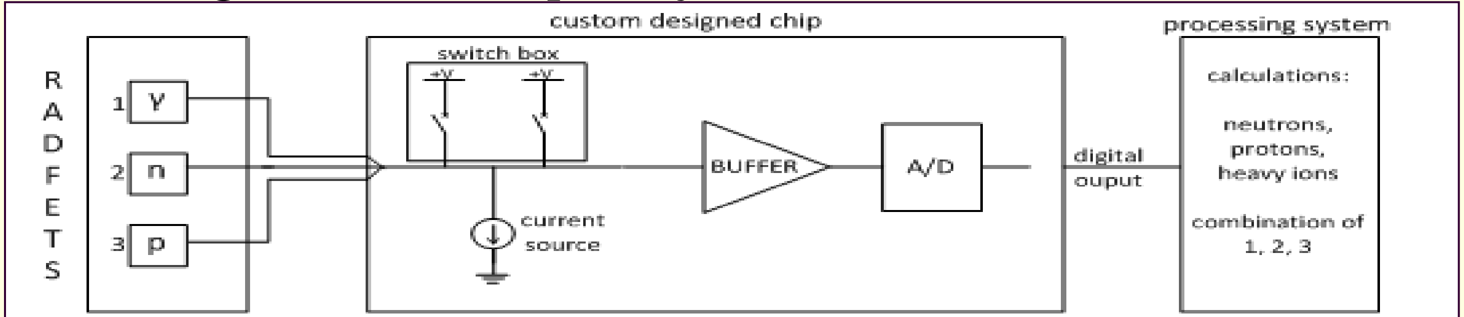
A better study on heavy ions response has to be organized including both irradiations and calculation with MCNPX and SRIM codes.

The study of the influence of a voltage applied at the source of MOSFET is required regarding to improve the response of the dosimeter and to eliminate any recombination effect occurred. Using a real time dosimeter as the one presented below this demand can be realized.

Perspective

A compact automated configuration based on a microcontroller, a memory, A/D converters and a custom designed chip to implemented all other needed functions has been designed. The high sensitivity system is being able to measure the threshold voltage shift due to radiation dose with precision at the order of 100 μV.

A block diagram of the complete system is shown bellow:



(RADFETS = Radiation Sensitive MOSFETs)

A number of circuits have been integrated in one chip. The chip has been fabricated with an appropriate technology offered by EUROPRACTICE organization and tested experimentally at the Electronics and Computer Laboratory of the University of Thessaloniki.

Perspective

Up today the real time dosimeter tested has dimensions of a portable instrumentation (20 x 15 x 10 cm) because of the battery size used.

Regarding to ensure low power consumption, low weight and low volume of the system, which is crucial for space applications, a project have been developed in order to have a dosimeter in size of smart phone that could be transfer and irradiated under any circumstances.

THANK YOU FOR YOUR ATTENTION !