A STUDY OF THE RESPONSE OF DEPLETED TYPE p-MOSFETs TO PHOTON AND ELECTRON DOSE

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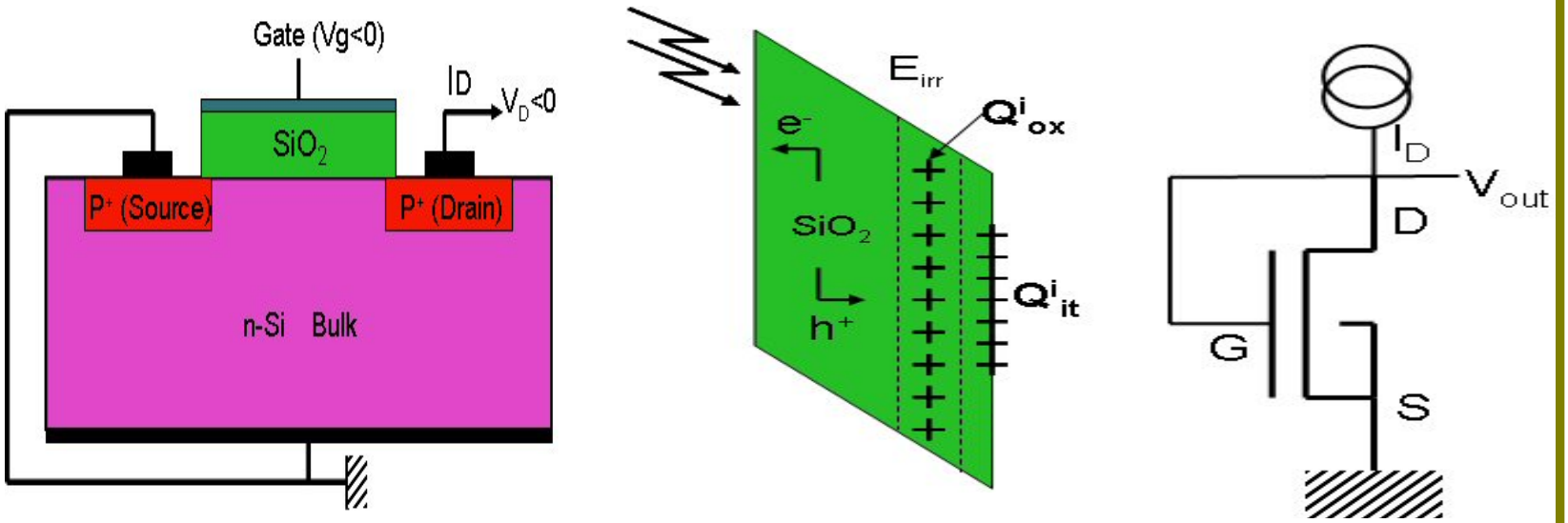
THE MOSFET USED IN THE PRESENT STUDY HAS BEEN DEVELOPED AT LAAS (CNRS), TOULOUSE, FRANCE IN CORPORATION TO ELECTRONICS LABORATORY, SCHOOL OF PHYSICS, AUTH, GREECE. *INTRODUCING AN INNOVATIVE TECHNOLOGY WITH VERY THICK SIO_2 INSULATOR THE SENSITIVITY OF THE DEVICE HAS BEEN ENHANCED.*

PRINCIPLE OF OPERATION



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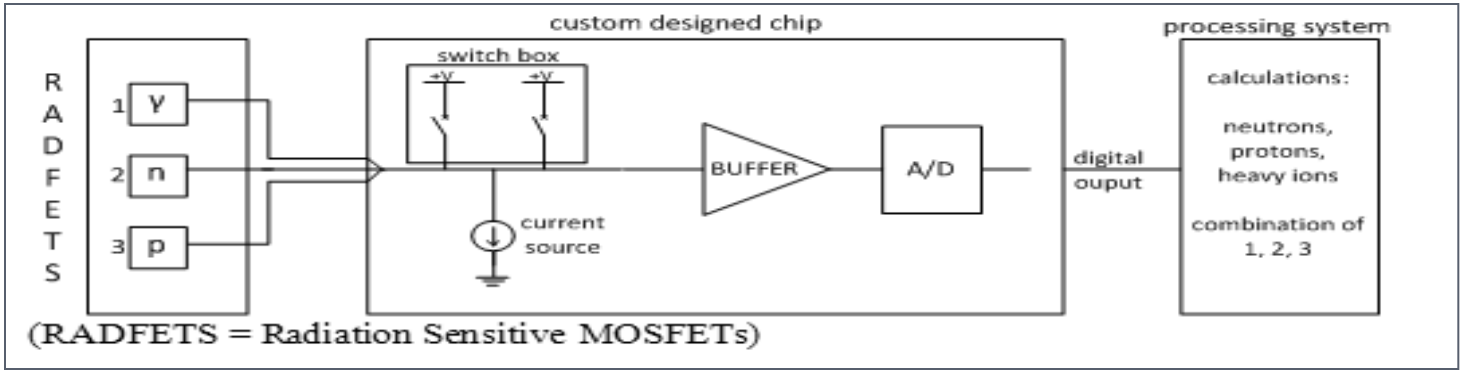
$\Delta V_{out} = f(D_{ox}, \text{Process}, V_{irr}, \text{Dose}, E, dE/dx)$

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 of the order of 100 μV.

A block diagram of the complete system is shown bellow:



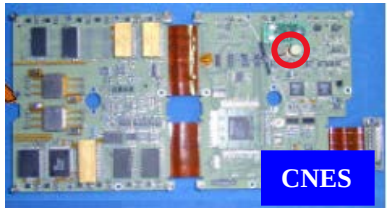
A number of circuits have been integrated in one chip. The chip has been fabricated with an appropriate technology offered by EUROPRACTICE organization and tested experimentally at the Electronics and Computer Laboratory of the University of Thessaloniki.

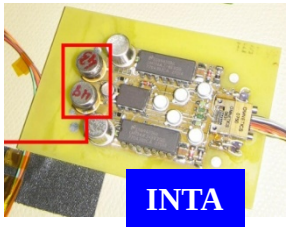
THE p-MOSFET TRANSISTORS ARE DEVELOPED FOLLOWING A PROCESS DESIGNED FOR IMPROVING BOTH SENSITIVITY TO RADIATION DOSE AND STABILITY. THE p-MOSFET CAN OPERATE AS A REAL TIME DOSEMETER AND AS A PASSIVE DOSEMETER WITH HIGH PERFORMANCE.

STUDIES OF LAAS DOSIMETERS

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

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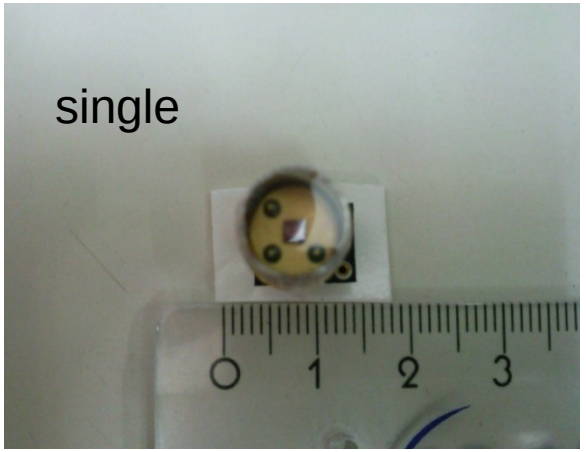
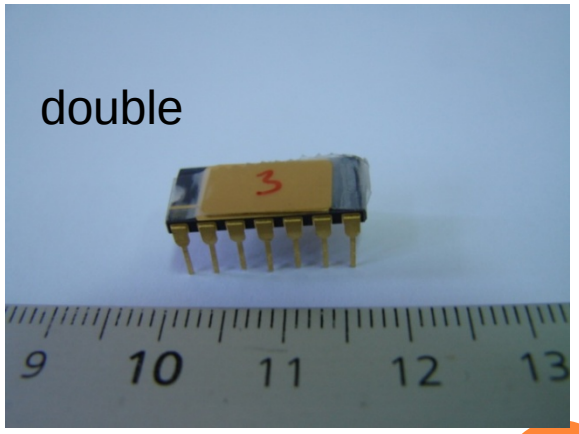
THE p-MOSFET DOSEMETER

Pictures of the Metal-Oxide-Semiconductor Field Effect Transistor, depleted p-MOSFET dosimeter, manufactured at LAAS-CNRS Laboratory, Toulouse France.

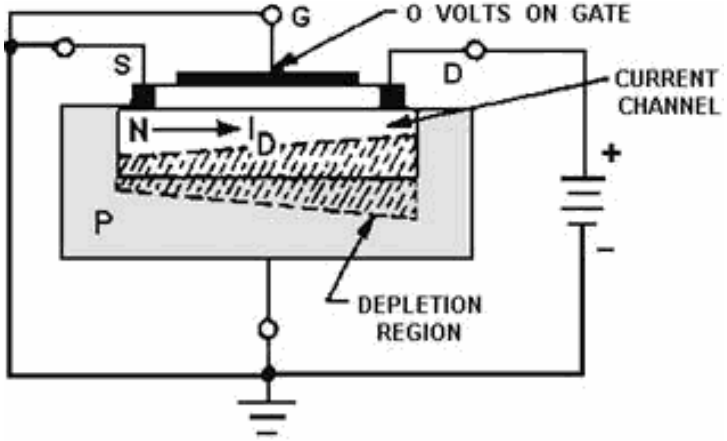
The dimensions of the dosemeter: 1 mm x 1mm

During irradiation (as a passive dosemeter) the transistor was short-circuit while during measurement the MOSFETs were diode connected (gate and drain grounded) and the source was fed by a constant current of 100 μA.





DEPLETION-TYPE MOSFETS



B. SOURCE-TO-DRAIN VOLTAGE APPLIED

The *depletion - type* MOSFET devices, are less commonly used than the standard *enhancement - type* which has been studied during previous experiments.

The *depletion -type* MOSFET devices are dopped so that a channel exists even with zero voltage from the gate to the source.

THE RESPONSE OF p-MOSFET DOSEMETERS

- The **threshold voltage** shift, ΔV_T, which is the measured quantity, depends upon:

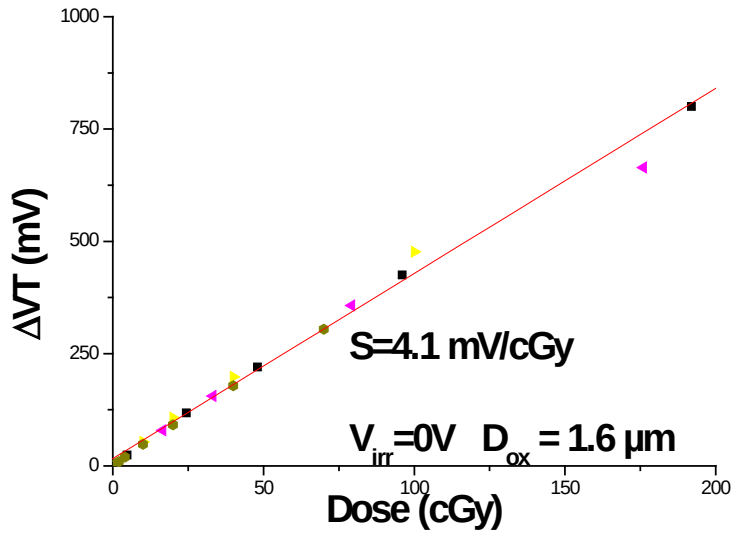
  a) the incident particle type and energy (dE/dx)
  b) the ionizing particle penetration into the oxide
  c) the absorbed dose, D,
  d) the gate bias during irradiation and
  e) the gate insulator thickness.

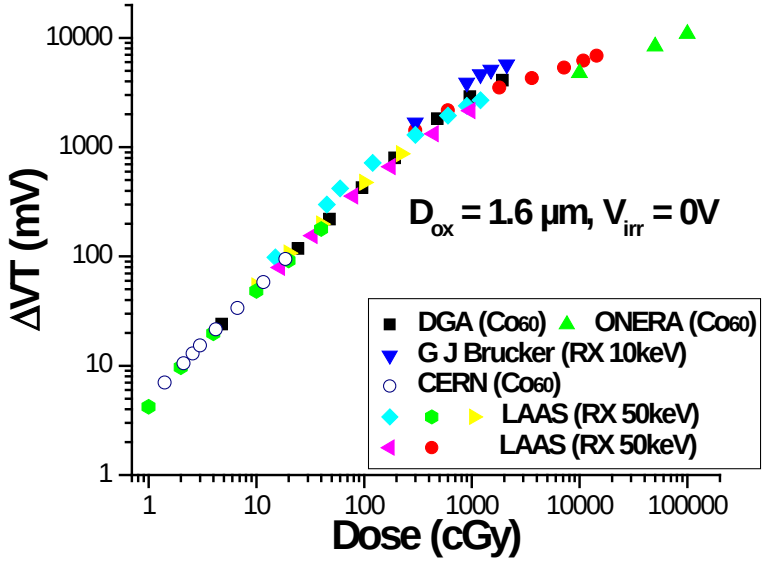
- For this exposure mode, usually called **zero bias mode**, the expected response of the voltage shift ΔV_T follows a power-law :

$$\Delta V_T = \alpha D^b$$

- Parameters a and b are experimentally determined.

RESPONSE STUDIES OF THE p-MOSFET DOSEMETERS **WITH PHOTONS**





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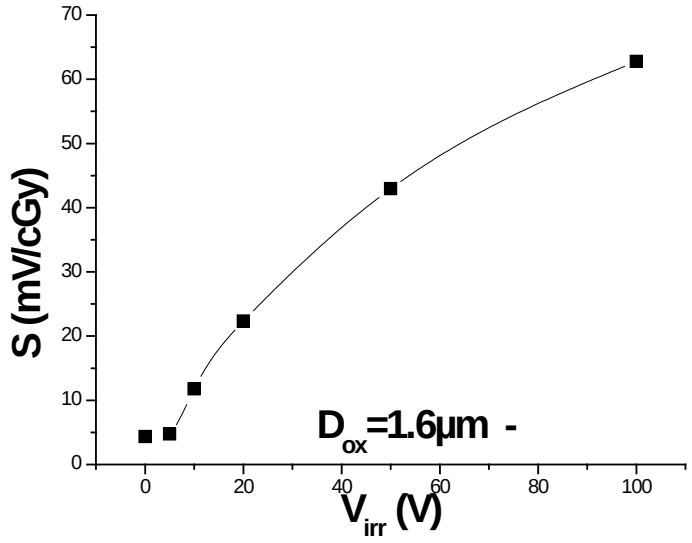
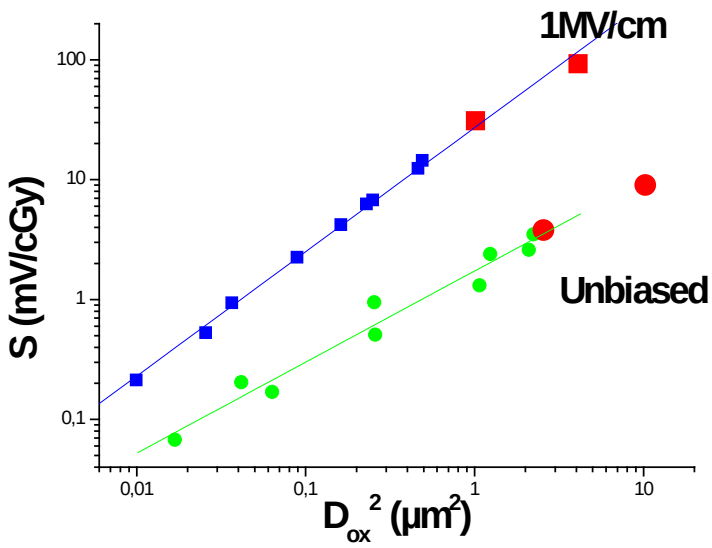
The response curve has a linear behavior up to 10 Gy where a saturation is presented. The resulted values of the response are considerable higher than the corresponding ones reported in literature up to now

RESPONSE STUDIES OF THE p-MOSFETs **WITH PHOTONs** AS A FUNCTION OF VBS





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The response is higher when a bias is applied to the source of the p-MOSFET dosemeter. A saturation is presented for applied voltage higher than 100 V.

THE EXPERIMENT WITH ELECTRONS

- **The p-MOSFET devices were irradiated with electrons at the Linac of Anticancer Theageneio Hospital of Thessaloniki.**
- **The beam was collimated and had a circular shape of 4cm in diameter. It was oriented perpendicular to the SiO_2 surface.**
- **The irradiations were performed at the isocentre.**
- **The response of the device was studied at 6, 8, 10, 12 and 15 MeV electrons with a dose rate of 1 Gy/min.**
- **Measurements were taken with the device operated in real time mode.**

RESPONSE STUDIES OF THE p-MOSFET SENSOR (WITH LI) WITH ELECTRONS

OPERATION AT ACTIVE MODE

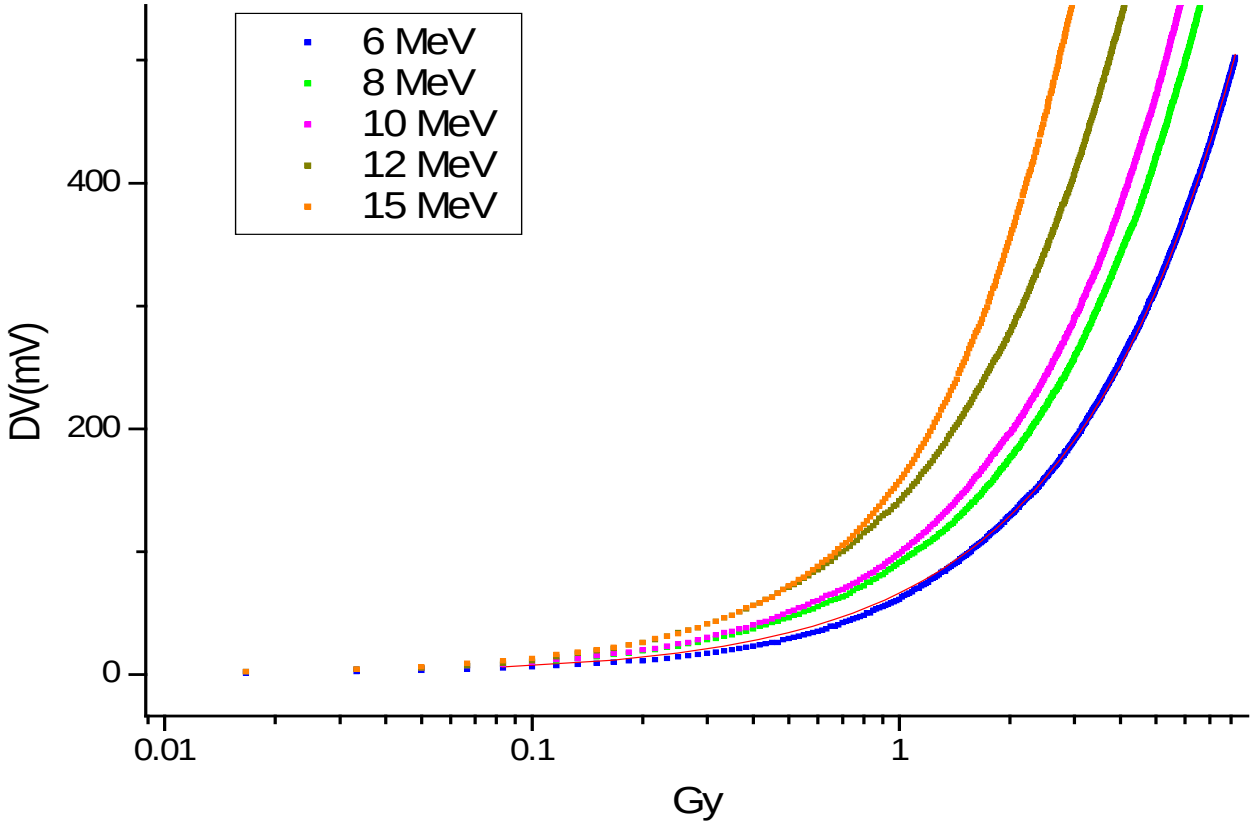
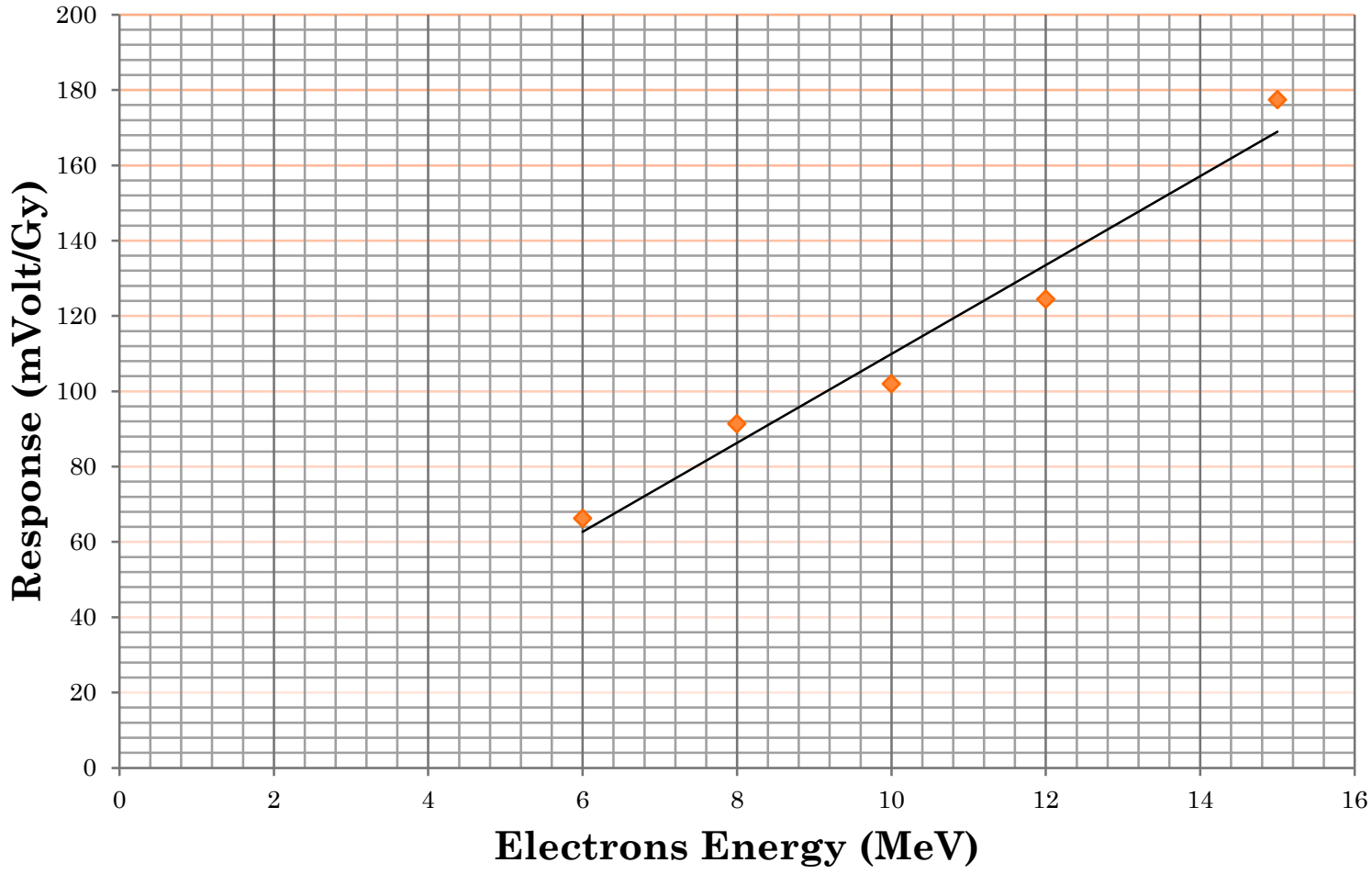


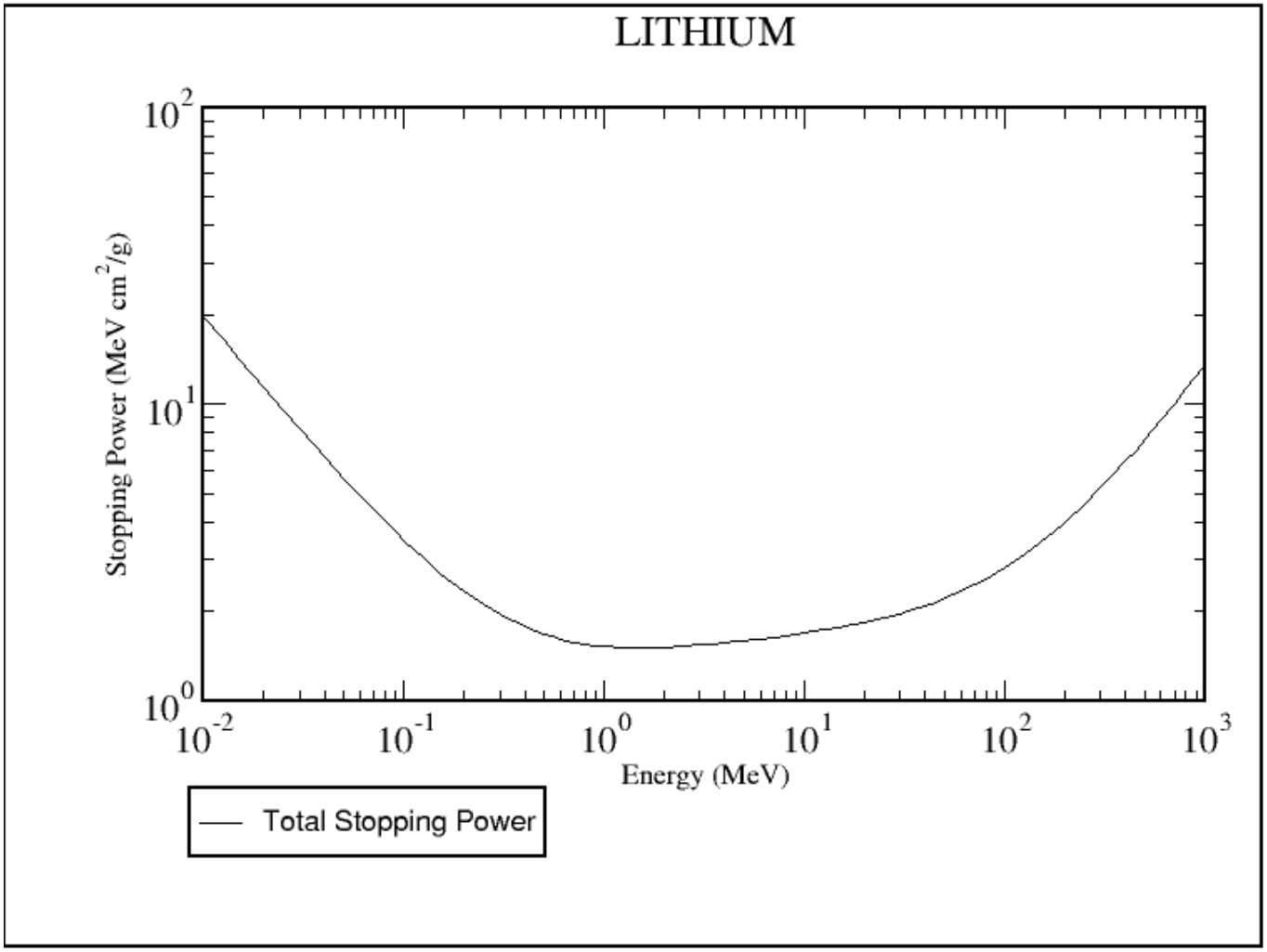
TABLE 1. THE VALUES OF THE RESPONSE AND THE DEGREE OF LINEARITY VERSUS ELECTRON DOSE

E, MeV	a, mVolt/Gy	b
6	66.20 ± 0.11	0.96 ± 0.01
8	91.36 ± 0.08	0.95 ± 0.01
10	101.93 ± 0.08	0.95 ± 0.01
12	124.43 ± 0.76	1.03± 0.02
15	177.36 ± 0.76	1.02 ± 0.03

THE RESPONSE OF THE p-MOSFETs AS A FUNCTION OF ELECTRON ENERGY



STOPPING POWER OF ELECTRONS



CONCLUSIONS

- The depleted type of p-MOSFET dosemeters present similar response to photons and electrons of few MeV energy.
- The response of these dosemeters is about 2 times higher than the response of the MOSFETs dosemeters presented in literature, which are enhancement type MOSFETs.
- This response can be increased even more, about one order of magnitude, if a biased applied in the source of the dosemeters during the irradiation
- The response of the depleted dosemeters as a function of the dose is linear for wide range of doses.
- The response of the dosemeters to electrons presents a linear behavior as a function of electron energy.
- This result is in contradiction with the results presented in literature obtained with MOSFET dosemeters of enhancement type and without any converter.