The sensitivity of a new type p-MOSFET dosemeter to high energy protons

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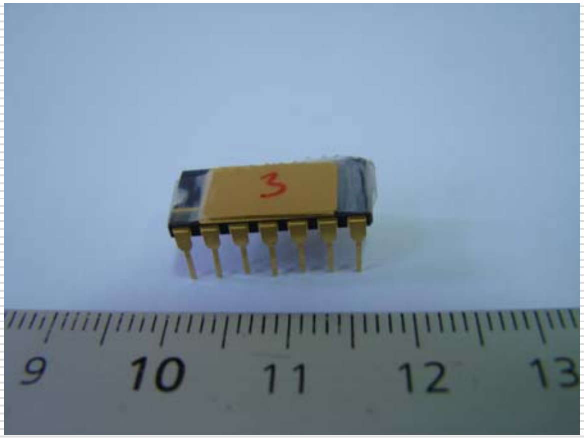
p-MOSFET dosemeters

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

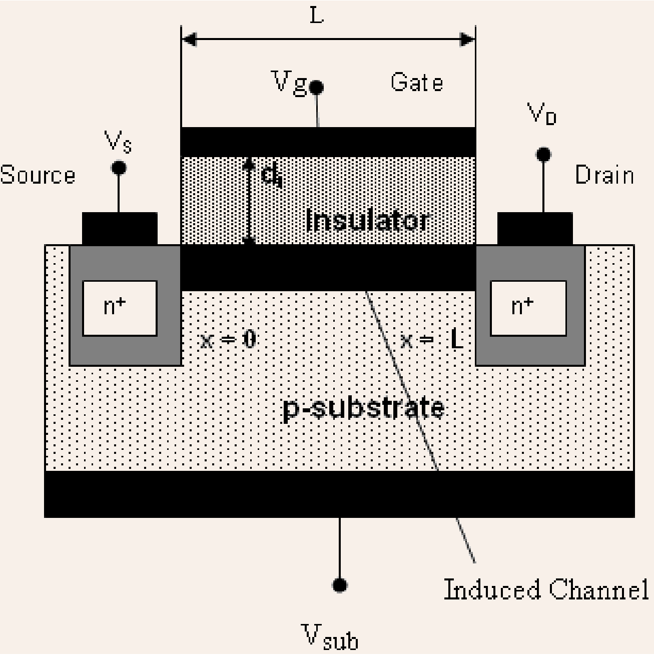
The dimensions of the dosemeter:

1 mm x 1mm

During irradiation the transistors were 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.



Dose measurements with the new p-MOSFET dosemeters



- New type of p-MOSFETs were irradiated by high energy protons.
- They have 1.6 μm thick gate insulator and they have been developed at LAAS-CNRS Laboratory Toulouse.
- The irradiations were performed at HIMAC accelerator, at the frame of **ICCHIBAN** collaboration.
- When ionizing radiation passes through the gate oxide in a MOSFET, electron-holes pairs are generated.

The response of p-MOSFET Dosemeters

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

  a) the incident particle type and energy,

  b) the ionizing particle penetration into the oxide,

  c) the absorbed dose,

  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 were experimentally determined. Parameter b was found to be close to the 1 so

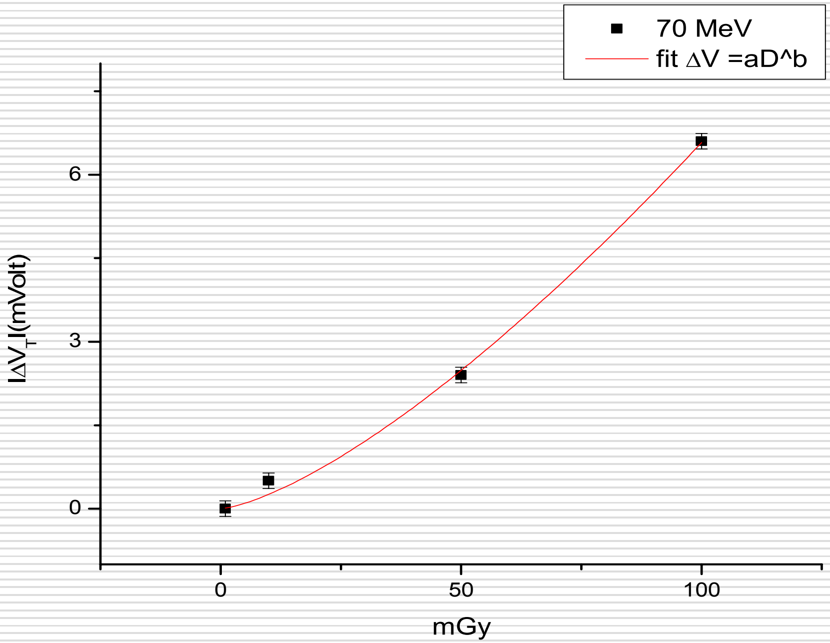
  the response of the MOSFETs was expressed by parameter a

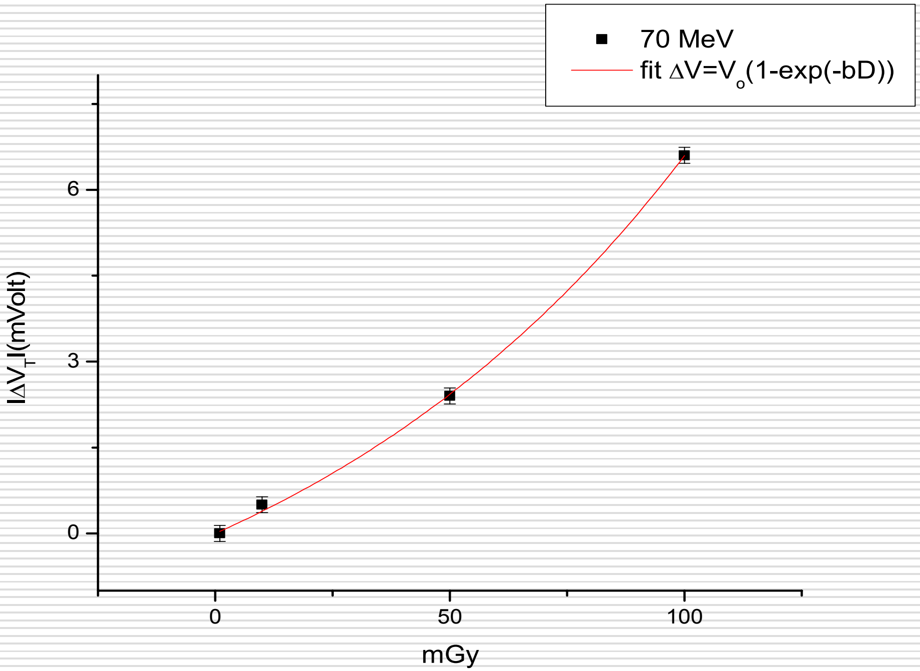
- In passive mode, according to literature, the expected response is sub-linear and the general behavior is modeled by the equation:

$$\Delta V_T = V_o \left(1- exp^{-bD} \right)$$

- Our results were fitted by both equations and although the irradiations were passive, the response of the MOSFET dosemeters in high energy protons is supra-linear.

Results from irradiation by 70 MeV protons





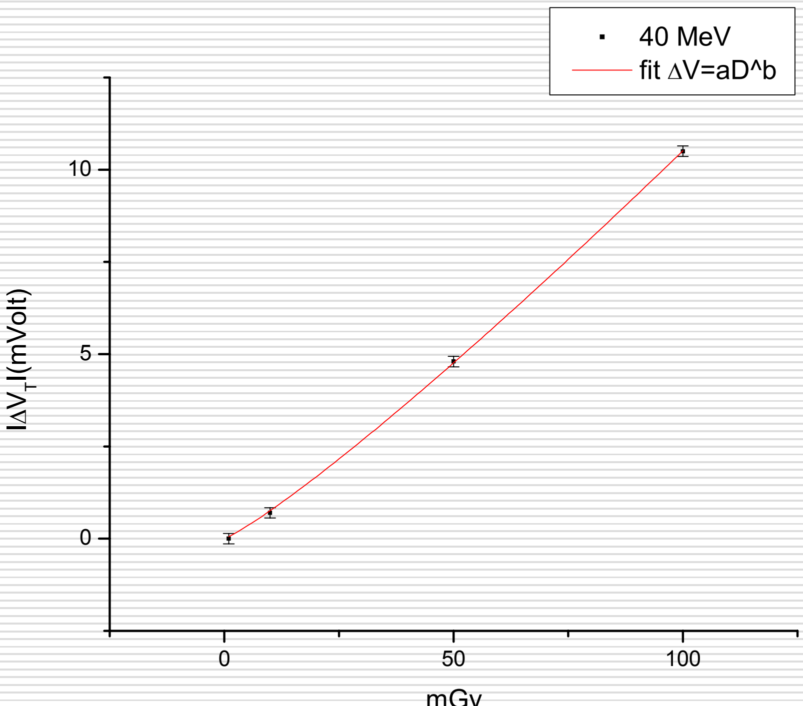
ΔV_T = (**0.010** ±0.004) • **D** $^{1.41 \pm 0.08}$

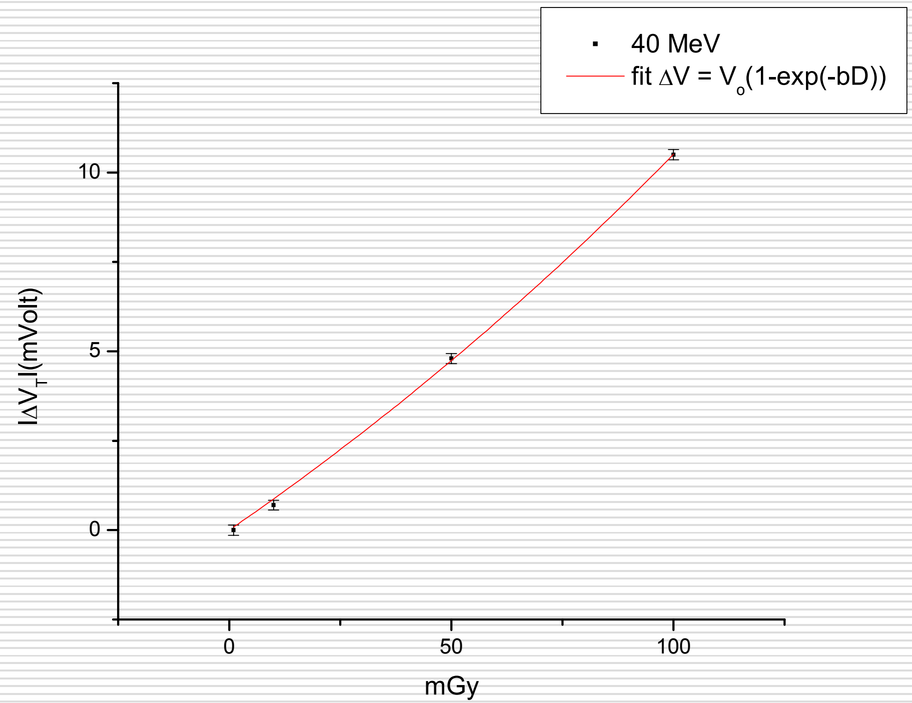
(R^2 = 99.6 %)

ΔV_T = (**-3.40** ±0.58) • **(1- Exp**$^{[(0.011 \pm 0.001)*D]}$**)**

(R^2 = 99.9 %)

Results from irradiation by 40 MeV protons





$$\Delta V_T = (\mathbf{0.055} \pm 0.005) \bullet \mathbf{D}^{\mathbf{1.14} \pm 0.02}$$

$(R^2 = 99.9\ \%)$

$$\Delta V_T = (\mathbf{-21.8} \pm 7.6) \bullet \mathbf{(1- Exp[^{(0.004 \pm 0.001)*D}])}$$

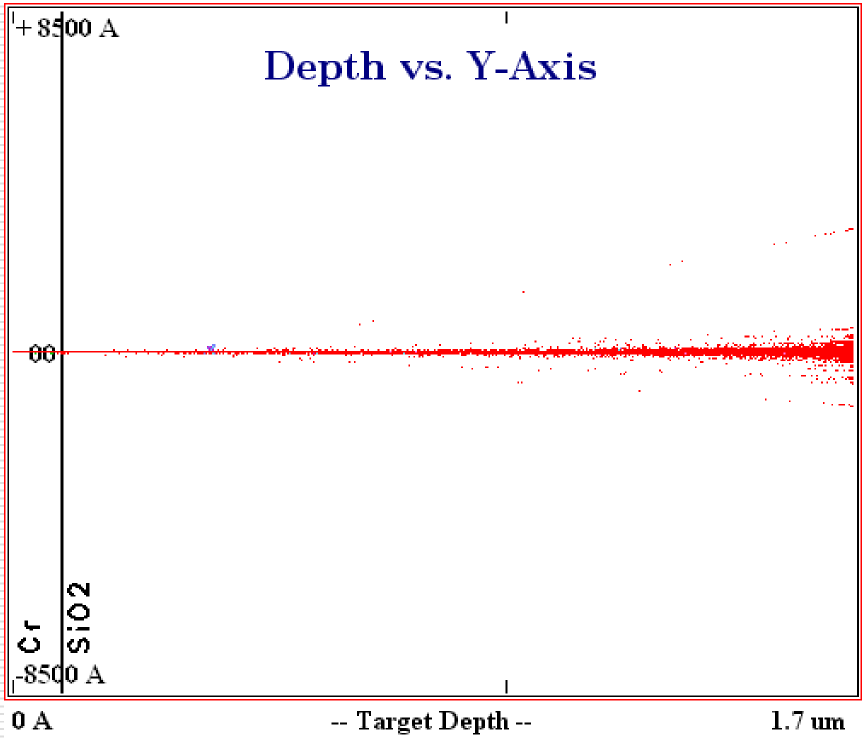
$(R^2 = 99.9\ \%)$

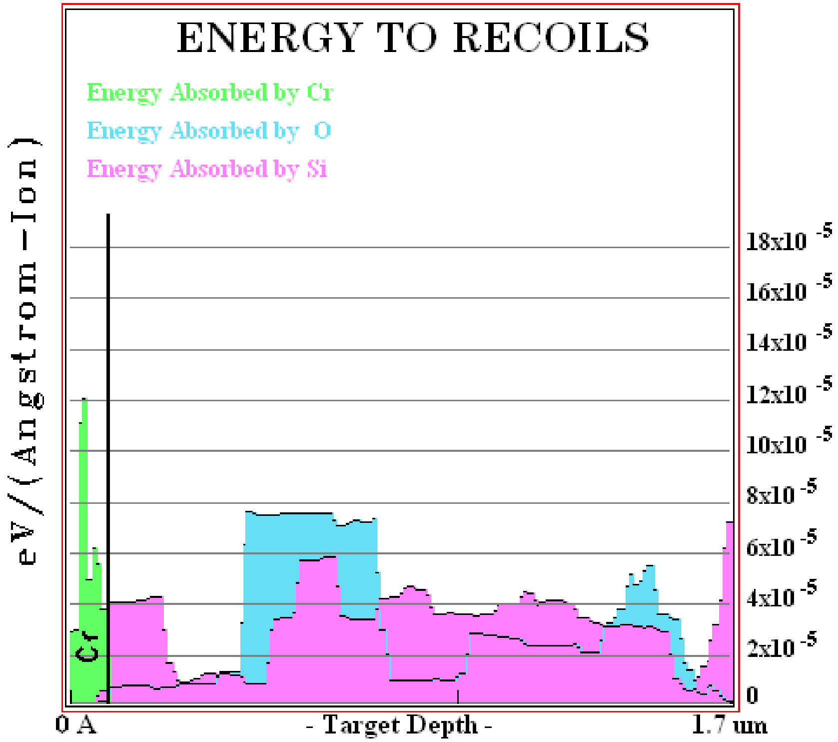
Dose estimation for **blind** experiments

According to the response calculations (using power or exponential function) the dose estimations of blind experiments are presented in the following table. In particular, blind experiment No1 of 40 MeV proton irradiation gave voltage increment at the lower detection limit, i.e. 0.4 ±0.14 (~35%) mV.

Blind	**Proton 70 MeV**	**Proton 40 MeV**
No. 1	86 ± 14 mGy	< 10 mGy
No. 2	47 ± 10 mGy	88 ± 9 mGy

Calculations using the SRIM





Comparison with calculation

Proton energy (MeV)	Calculation	Experimental**
40	3.2 10^{-19} V/ion	3.2 10^{-19} V/ion
70	1.6 10^{-19} V/ion	1.92 10^{-19} V/ion

**conversion factor from Phys. Med Biol 54 (2009) 1997—2014 for AP geometry (anterion-to posterion)

Results from current work

Proton energy (MeV)	Response (single MOSFET) mV/mGy	Response of stack (two MOSFET with Li) mV/mGy
70	0.0658 ± 0.0065	2.857 ± 0.00014
40	0.1067 ± 0.0018	2.074 ± 0.00014

Results from literature

Proton energy (MeV)	Response
115	0.036 mV/mGy [Rad. Prot. Dos. (2009) 1-15]
62	0.04 mV/mGy [Rad. Prot. Dos. (2009) 1-15]
47	0.034 mV/mGy [Rad. Prot. Dos. (2009) 1-15]
62	0.07 mV/mGy [Physica Medica (2006) Vol XXII, N.1]

Future work for heavy ions Calculations

Calculated response

Ion with Energy 100 MeV	Response V/ion
Fe	$3\ 10^{-15}$
Si	$3.2\ 10^{-16}$
C	$1.6\ 10^{-17}$
He	$9.6\ 10^{-19}$

* With Al absorber heavy ions can be separated by protons

Conclusion

- Supra-linear response of the new p-MOSFET dosemeters is observed for protons. This behavior is valid for a wide dose range.
- Their response is higher than previously reported in the literature even when a stack of a dosemeters with biased during irradiation was used.
- Their response can be increased about an order of magnitude, if a stack of two identical MOSFET dosemeters is used.
- According to calculations MOSFET dosemeters seems to present very good response to heavy ions.
- MOSFETs are promising devices for their use in space radiation dosimetry.