A INNOVATIVE NEUTRON DOSEMETER

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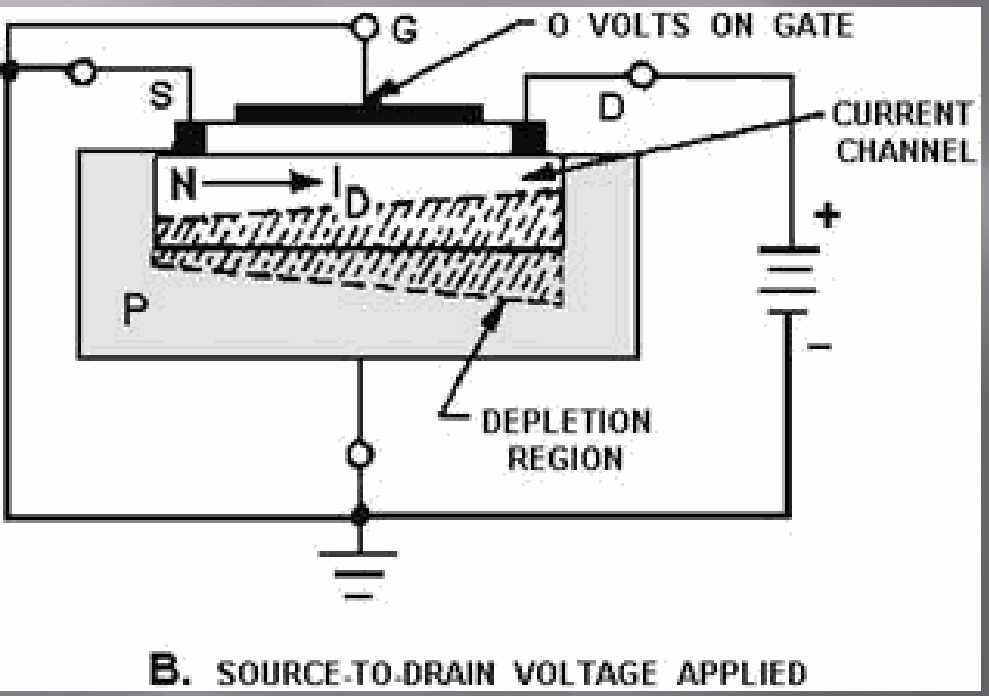
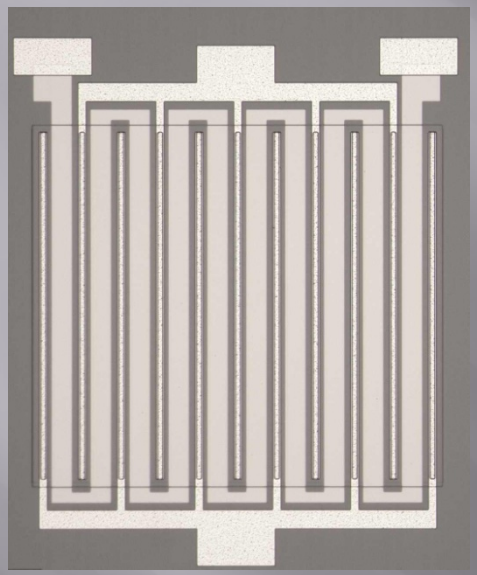
Depletion-mode MOSFETs



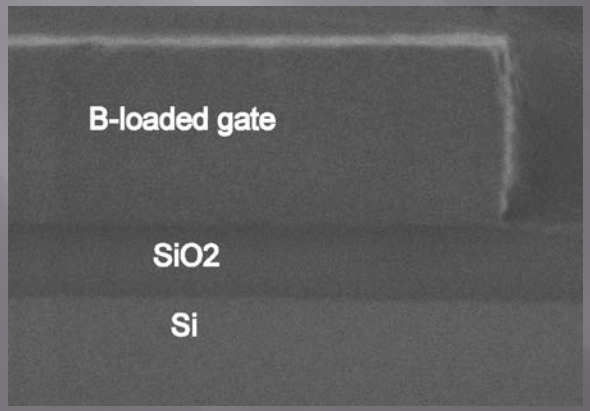
The *depletion-mode* MOSFET devices, are less commonly used than the standard *enhancement-mode* devices already irradiated in the previous experiments.

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

Top view of the dosemeter



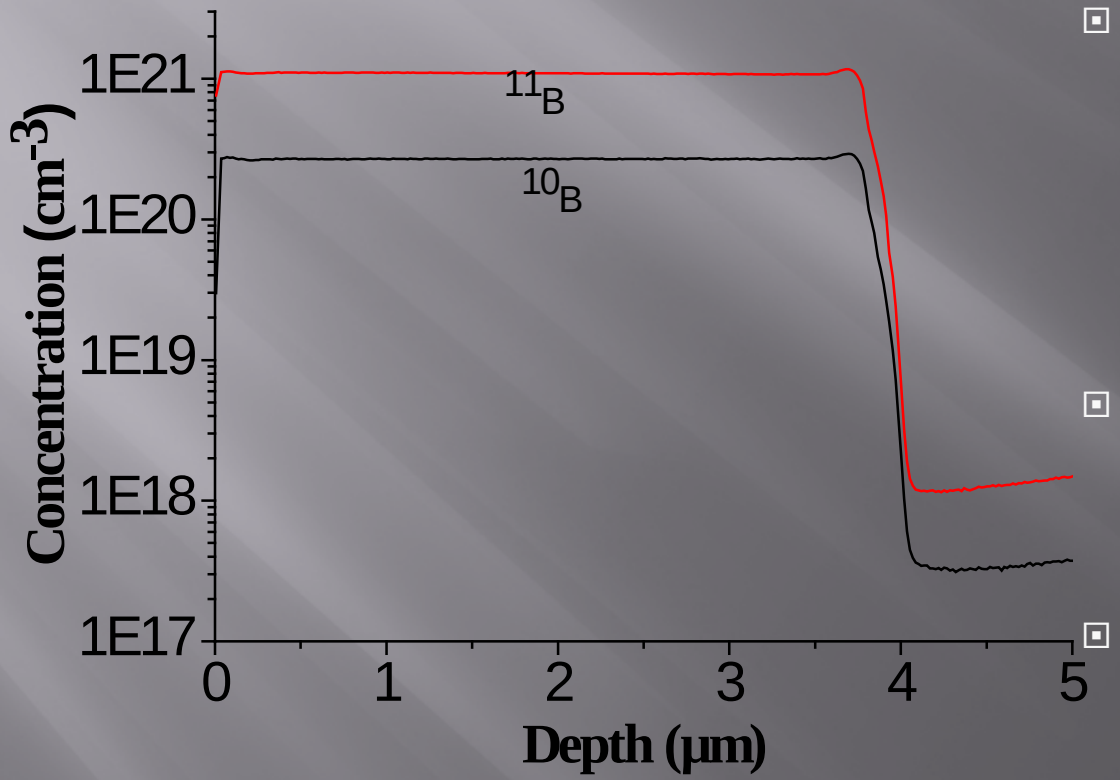
- The serpentine represents the boron-loaded gate/converter with a very large area (4.7 10^5 μm^2) in order to reduce the electronic noise (+/- 50 µV). The picture shows the converter is fully integrated to the device. The overall dimension of the device is 1.1 mm X 1.4 mm.



cross-section of the converter

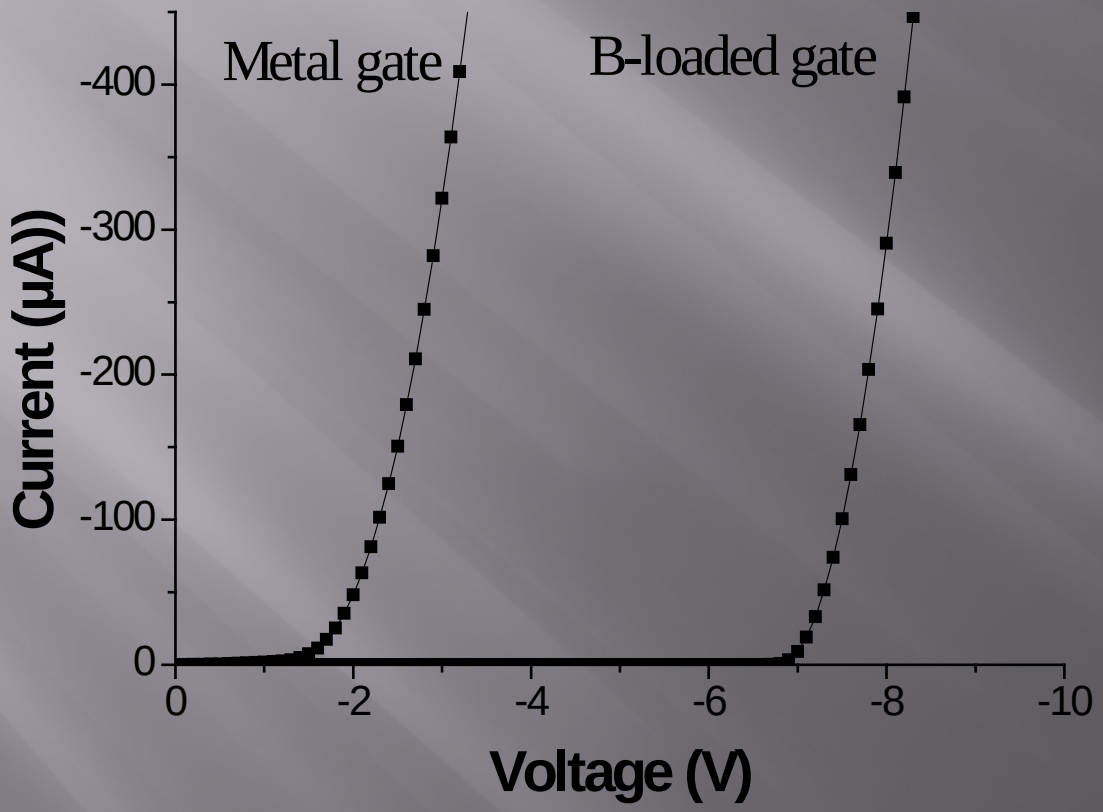
The converter is 3.74 µm thick and its homogeneity (Scanning electron Microscopy)

SIMS profiles of ^{10}B and ^{11}B in the converter



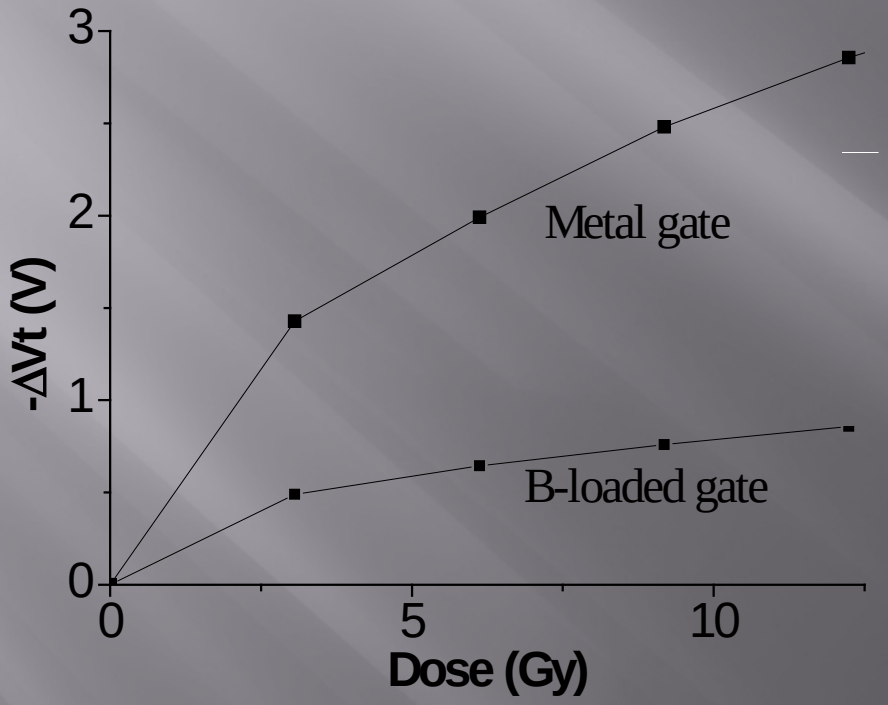
- The total boron concentration is equal to 1.3 10^{21} cm^{-3} among which about 2.6 10^{20} are in the form of the ^{10}B isotope.
- The profile appears constant across the whole layer thickness.
- The profiles were measured by Secondary Ion Mass Spectrometry

Current-voltage curves of the dosimeter



- The threshold voltage corresponding to the new gate is shifted by more than 5V compared to the metal gate case. This shift is due to a difference in the work function of the gates and more importantly to an increase of the initial fixed charge of about 7.10^{10} cm^{-2}.

Response of the dosemeter to photons



- Due to the large threshold voltage value the built-in electric field in the oxide layer is smaller. Consequently the probability to escape recombination for the generated holes is also smaller when the dosemeter is used in the unbiased mode.
- This is depicted in Figure shows a decrease of the response to a photon irradiation in comparison to the similar dosemeter with a metal gate.

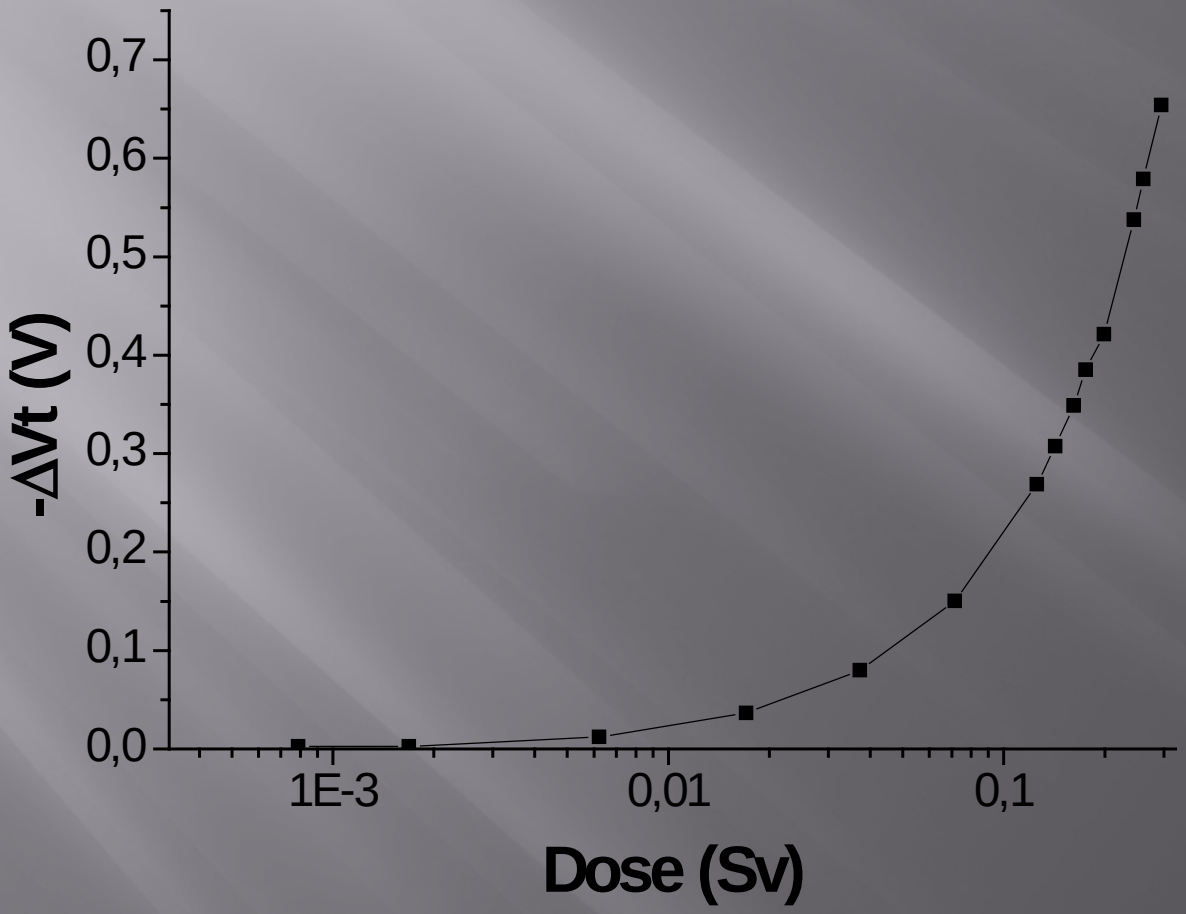
Threshold Voltage

- The **threshold voltage** shift, ΔV_T, which is the measured quantity, depends upon the incident particle type and energy, the ionizing particle penetration into the oxide, the absorbed dose, the gate bias during irradiation and the gate insulator thickness.
- In personal dosimetry an unbiased dosemeter is preferable and for that reason in these experiments the irradiated dosemeters were chosen to be unbiased.
- For this exposure mode, usually called zero bias mode, the expected response of the voltage shift ΔVth follows a power-law :

$$\Delta V_T = \alpha D^b \qquad (1)$$

- Parameters a and b were experimentally determined. Parameter b was found to be close to the unity then the response of the MOSFETs was expressed by parameter a

Thermal neutron response



- The sensitivity to neutrons is obtained thanks to a boron-loaded conversion layer deposited as the transistor gate on the gate oxide.
- Good linearity of the response
- with a sensitivity of 2.2 V/Sv for thermal neutrons

Response of B-doped dosemeter

Type of radiation	Applied current	Response (mV/mSv)	b parameter
Thermal neutrons (up to 1eV)	100 µA	2.2 ± 0.002	1.04 ± 0.001
Intermediate-fast neutrons (above 1 eV)	100 µA	0.033 ± 0.002	0.99 ± 0.002

The response of metal oxide dosemeter with LiF

Type of radiation	Applied current	Response (mV/mSv)	Response (mV/mGy)	b parameter
Thermal neutrons (up to 1eV)	100 µA	1.580 ± 0.002	8.13 ± 0.01	1.13 ± 0.001
Intermediate-fast neutrons (above 1 eV)	100 µA	0.0165 ± 0.001	0.223± 0.13	0.97 ± 0.002

Conclusion

- Simulation with MCNP5 software shows that the number of reactions generated in the converter is about a factor 2 less than in the case of the LiF converter.
- However several improvements can be made. The first one is related to the use of natural boron which contains about 20% of active ^{10}B atoms;
- using a ^{10}B enriched source during the converter deposition should give an increase of the sensitivity.
- The boron content of the layer can be increased by at least a factor 10 but this is certainly limited by the increase of the resistivity and the generation of mechanical stress during deposition.
- Also the design of the structure was certainly not optimum and the converter thickness should be increased too.