Radiation hardness characterisation of HVCMOS with the Transient Current Technique

ATLAS inner tracker upgrade for the HL-LHC

The HL-LHC project aims to increase the luminosity by a factor of 10 beyond the LHC’s design value.

- Tracking detector upgrade is needed for:
  - separation of primary vertices in a busy environment
  - efficient readout
  - tolerance to high radiation doses

ATLAS will replace its Inner Detector with a full-silicon tracker (ITk) [1]. The total expected dose is studied with simulations and all the technologies are being tested in those conditions.

The Transient Current Technique has been used to characterise the performance after irradiation of HV-CMOS sensors, technology candidate for the 5th pixel layer of the new tracking system, positioned 279 mm from the collisions.

HV-CMOS and the AMS H35 Demonstrator

CMOS technology embedded in each pixel shielded by a deep n-doped well allows the possibility to operate at high voltage (HV)

Pros:
- monolithic, no bump-bonding → lower material budget
- collection by drift → radiation hardness

H35 Demo - HV-CMOS technology by AMS [2]
- 4 matrices + some non instrumented test structures
- 4 different resistivities: 20, 80, 200 and 1000 Qcm
- 250x50 µm² pixels, divided in 3 n-wells.

Test structures for TCT located at the edge of the chip 3x3 matrix with two read-out channels: central pixel and frame

Proton irradiation

- 16.7 MeV protons
- 3.6 hardness factor
- sensors irradiated mounted on boards

Dose monitored online: measurement of the beam current density on different layers of collimators

H35DEMO

The Transient Current Technique

Pulsed IR laser beam to generate electron-hole pairs with µm precision in a silicon detector.

The measurements of the charge are collected by moving the laser along the sensor edge allowing to create a 2D map of the active area.

Evolution of the depletion depth

From the 2D maps the depletion depth is measured at different bias voltages after every step of irradiation

Observations:
- similar trend for the 2 irradiation campaigns
- increase of the depletion depth due to initial acceptor removal, then slow decrease
- stronger effect for low resistivities (up to 8 times the original size!)
- more moderate for the high resistivities (~30%)

The same test structures have been characterised in [5] after neutrons irradiation

Acceptor removal effect more pronounced with protons!