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Characterization of CMS High Granularity Calorimeter Silicon Sensors

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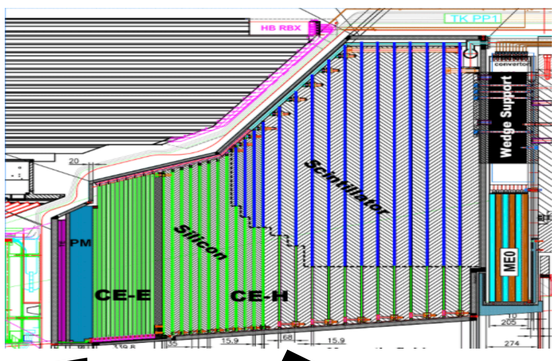
Challenges for detector design at High HL - LHC

- Two major challenges for detectors:
  1. Unprecedented radiation dosage:
     - Doses up to ~2 MGy
     - Mitigated by radiation hard detector materials and readout
  2. High Pile-up:
     - Up to ~200 pile-up per event
     - Mitigated by high granularity detectors and precise timing

High Granularity Calorimeter (HGCal)

- Endcaps cannot withstand HL-LHC conditions
- Must be replaced by HGCal
- Sampling calorimeter
- 600 m^2 of Silicon (~6 million channels)
- 500 m^2 of Scintillator (~400 thousand channels)



Electromagnetic section (CE-E)

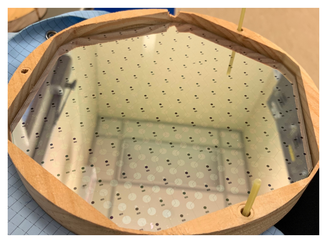
- 28 sampling layers
- Active elements: Silicon
- Absorber: Lead, Copper-Tungstate, Copper

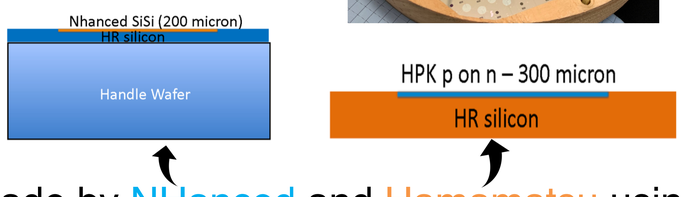
Hadronic Section (CE-H)

- 22 sampling layers
- Active elements: silicon (Layers 1-8) and silicon and scintillator (Layers 9-22)
- Absorber: stainless steel

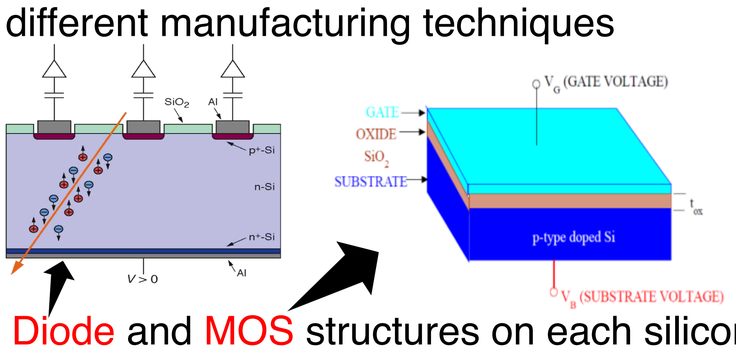
HGCal Silicon Sensors

- 8-inches in diameter and hexagonal



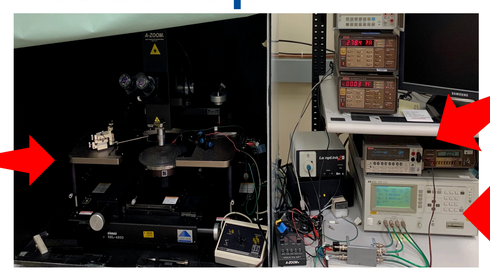


- Made by NHanced and Hamamatsu using different manufacturing techniques



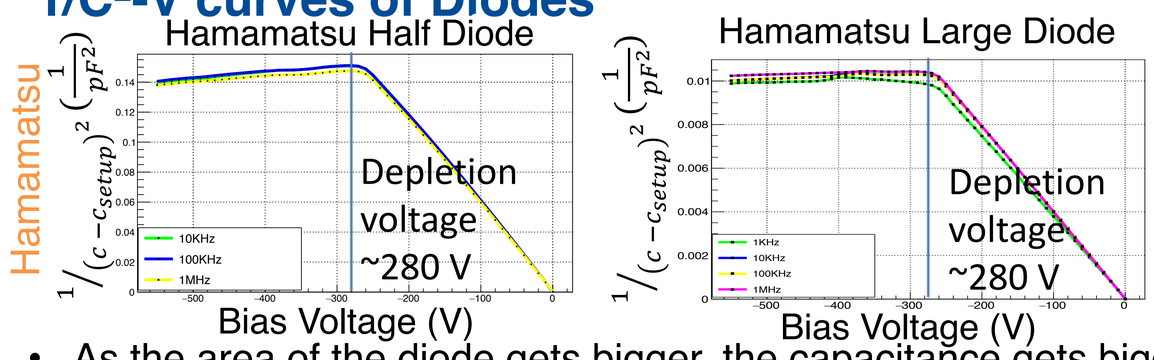
- Diode and MOS structures on each silicon sensor test structures
- This project studies the capacitance of the MOS and diode structures as a function of voltage in order to study the quality of the sensors made by these companies.

Experimental Set Up



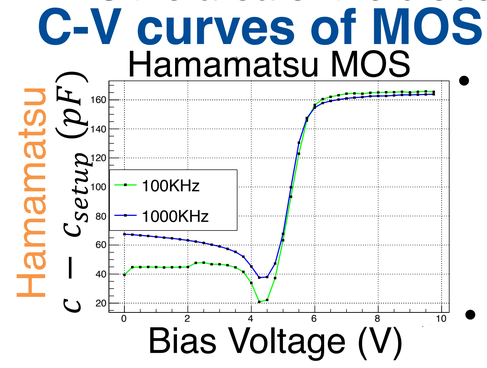
- Manual Probe Station
- Keithley 2410 1100V SourceMeter
- HP 4284A Precision LCR Meter
- Irradiation was preformed by Rhode Island Nuclear Science Center with a fluence of 7.5 x 10^{14} N_{eq}.

1/C²-V curves of Diodes



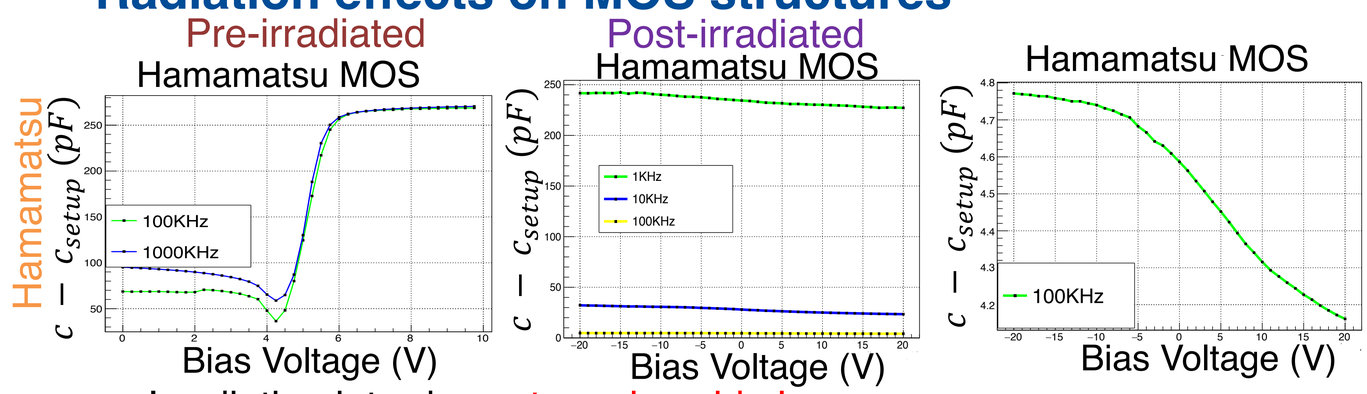
- As the area of the diode gets bigger, the capacitance gets bigger.

C-V curves of MOS structures



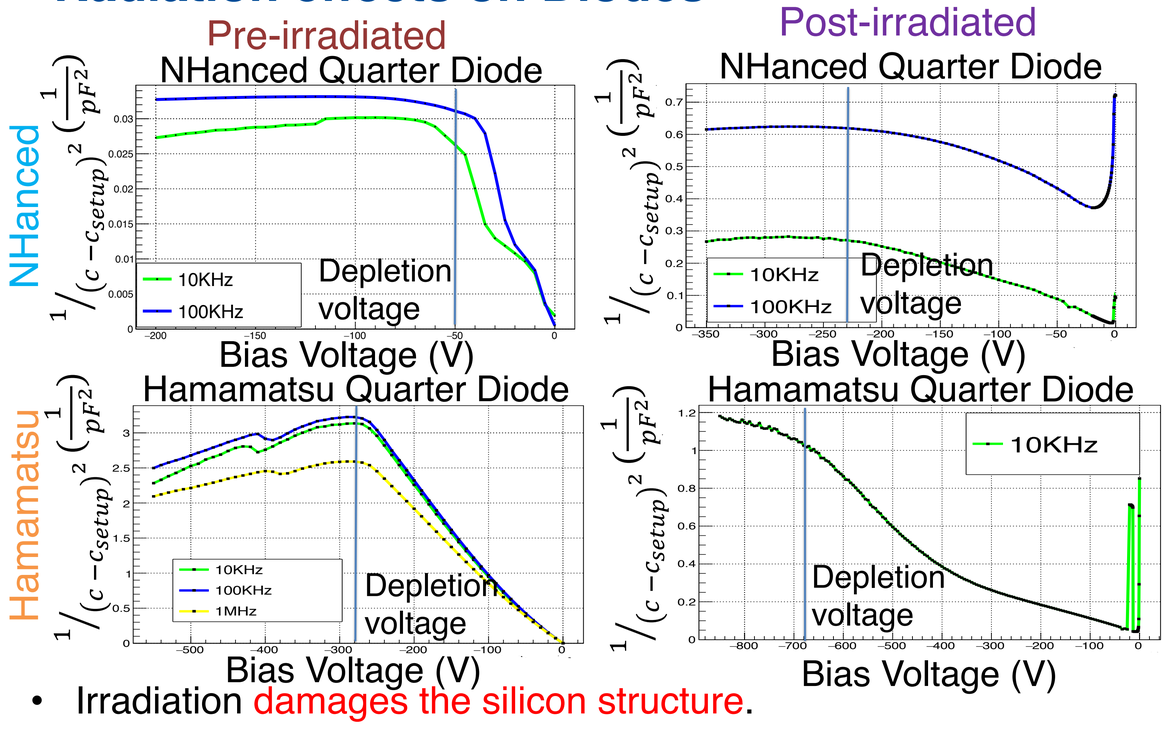
- Plots yield:
  - Oxide thickness through $T_{ox} = \frac{A \in_{ox}}{C_{ox}}$ ~720 nm
  - Flatband voltage ~6.5 V
  - Threshold voltage ~4 V
  - Effective and oxide charge ~3.46 x 10^{-8} C/cm^2
  - Doping concentration ~7.9 x 10^{13}
- Which characterize quality of the insulator
- Hamamatsu's sensors have a thick, high-quality oxide layer.

Radiation effects on MOS structures



- Irradiation introduces traps in oxide layer.
- Irradiated sensors have less defined curves and smaller ranges.

Radiation effects on Diodes



- Irradiation damages the silicon structure.
- After irradiation, the shape is less defined and the depletion voltage is higher.

Conclusions

- Hamamatsu and NHanched both experience roughly expected radiation damage.
- Hamamatsu has better oxide quality and overall performance than Nhanced.

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