MCz and thin silicon studies

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MCz Introduction

- Particle detectors have historical used FZ

- Several new SI materials are under investigation for SLHC motivated by the increased radiation hardness of oxygenated silicon

FZ crystal growth

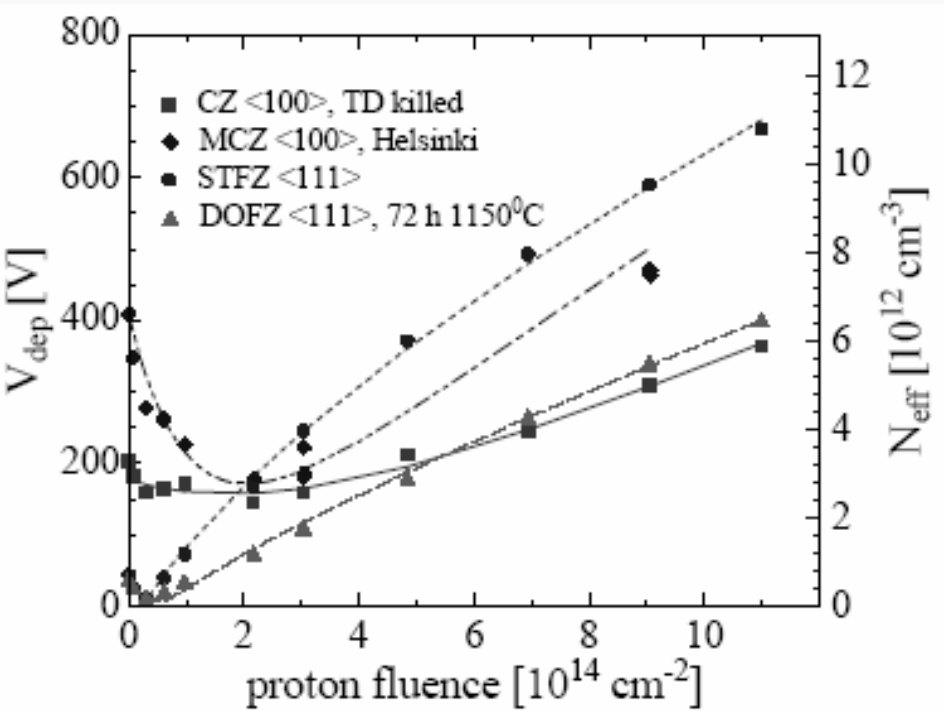
- Oxygen Concentration $<5 \times 10^{16}$
- high resistivity
- costly

CZ crystal growth

- high oxygen concentration ($\sim 10^{17}$-10^{18} cm^{-3})
- less expensive
- low resistivity range

MCz Introduction

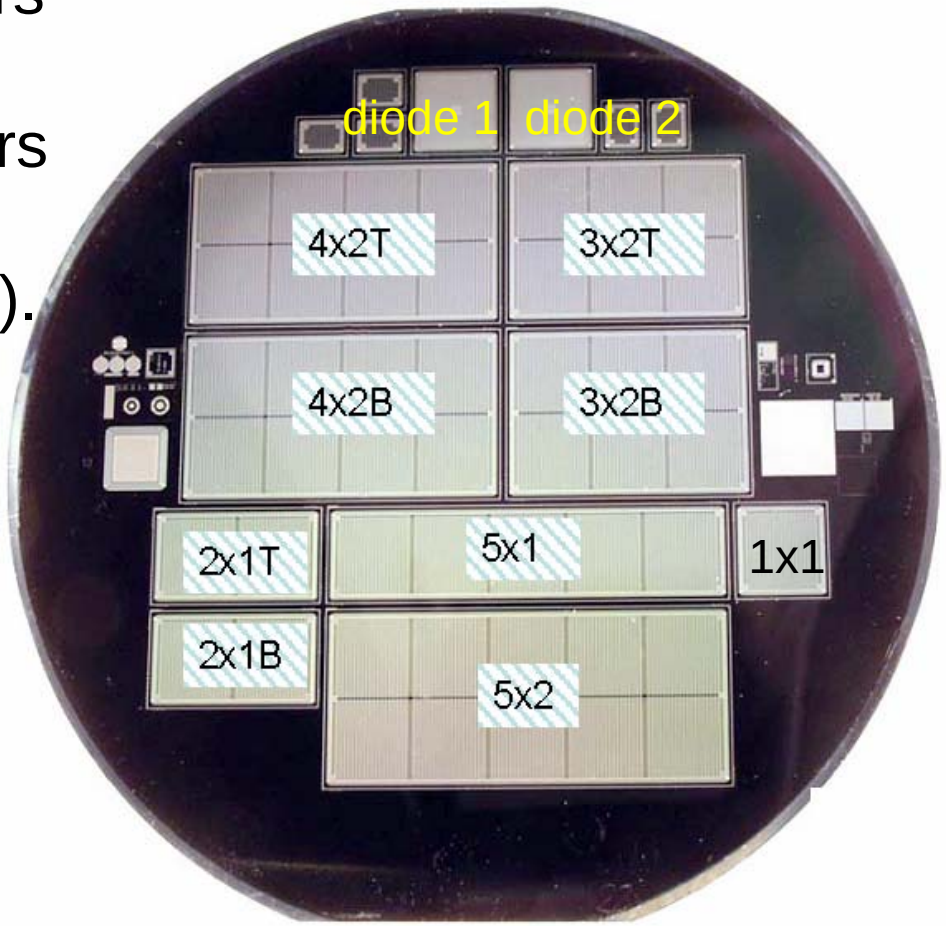
- Cz and MCz silicon show no type inversion for charged hadrons. Verified for Cz by TCT measurements, more studies needed for MCz
- Donors generations overcompensate acceptor generation in high fluence



Wafer info and layout

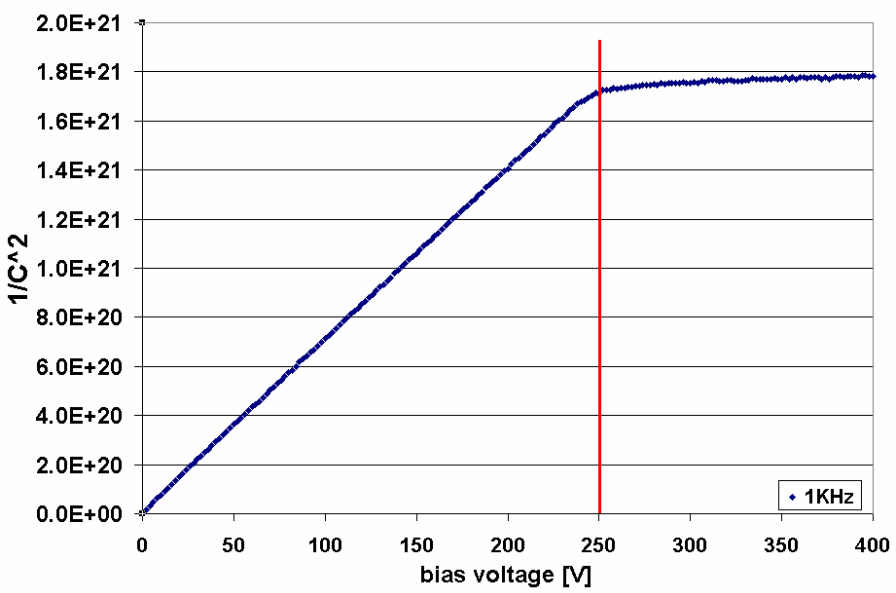
5 Magnetic Czochralski wafers were processed by SINTEF (along with 15 standard wafers for preproduction of the USCMS forward pixel project).

- n-type substrate with <100> direction
- Thickness ~ 300 µm
- Two diodes and 9 sensors per wafer
- resistivity
  3~4KΩcm (standard)
  1~1.5KΩcm (MCZ)

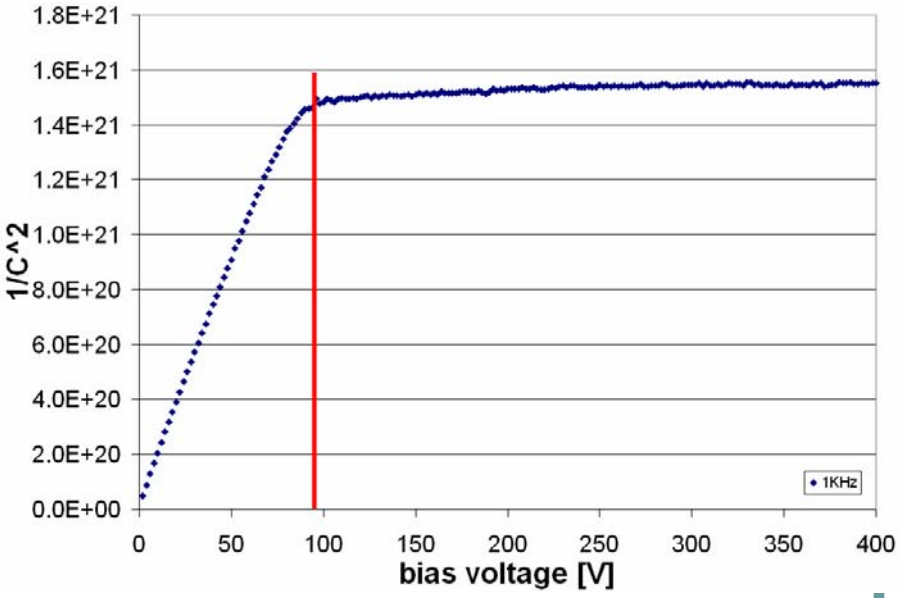


CV curves

MCZ diode



Standard diode



Depletion voltage : ~250V (MCZ)

90~100V (standard)

Yield Analysis

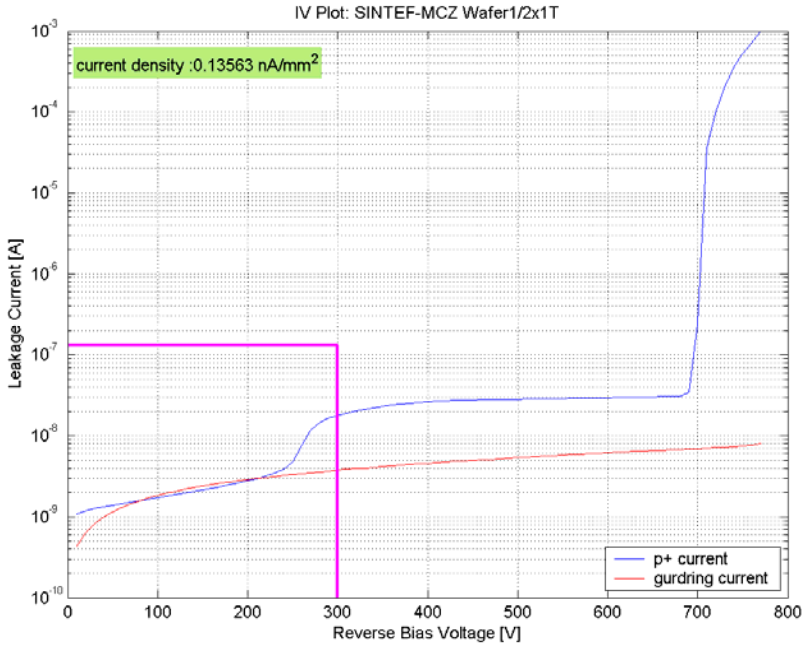
Selection specification

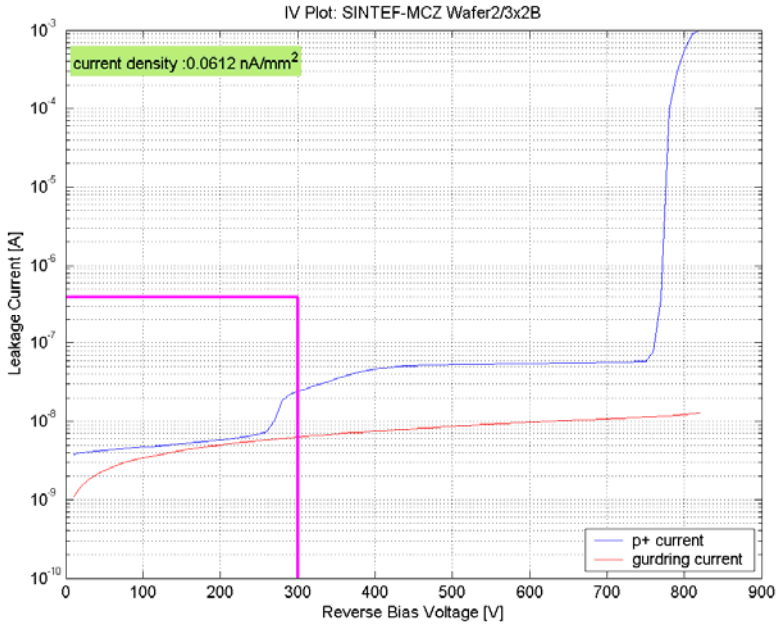
A sensor is considered “good” if it satisfies all the criteria listed below:

- $V_{breakdown}$ > 300 V
- Current density of active area: I < 1nA/mm^2
- Guard ring current < 10 times of active area current

IV examples (Good)

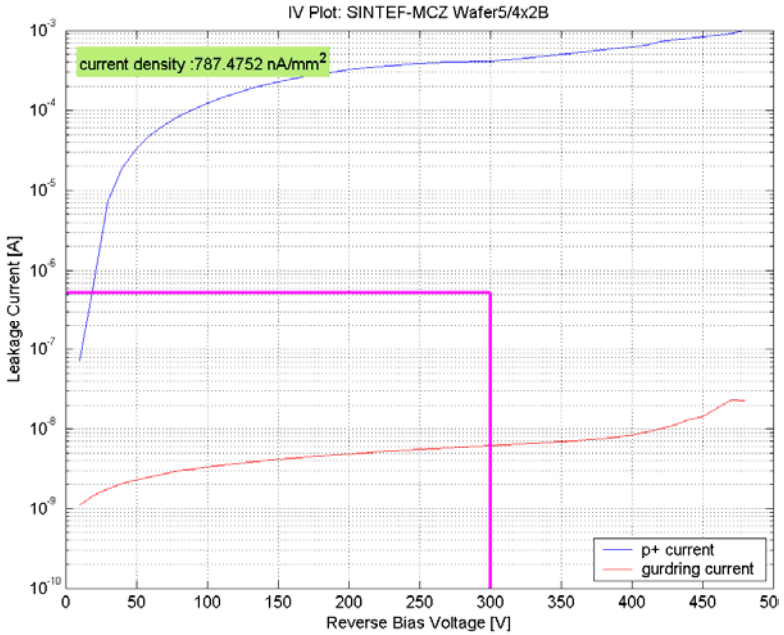
Plots show breakdown behavior at 700 ~800V

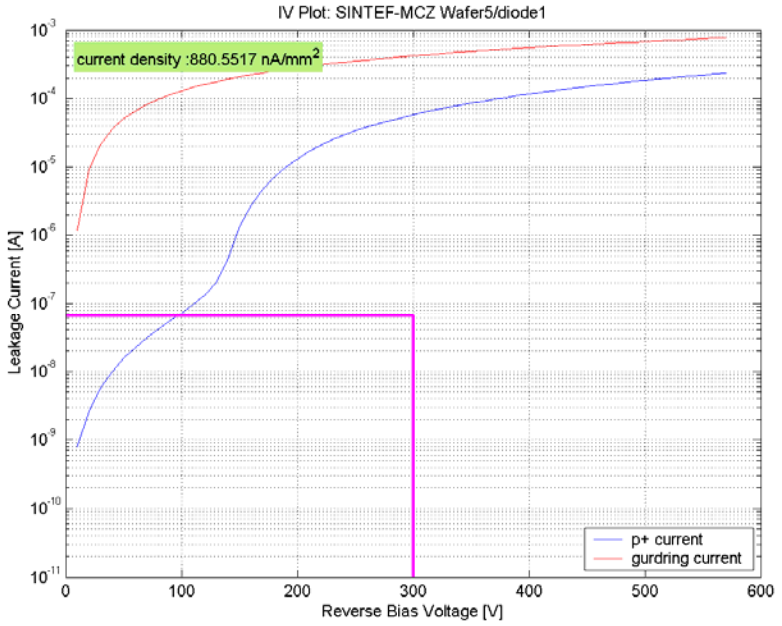




IV examples (Bad)

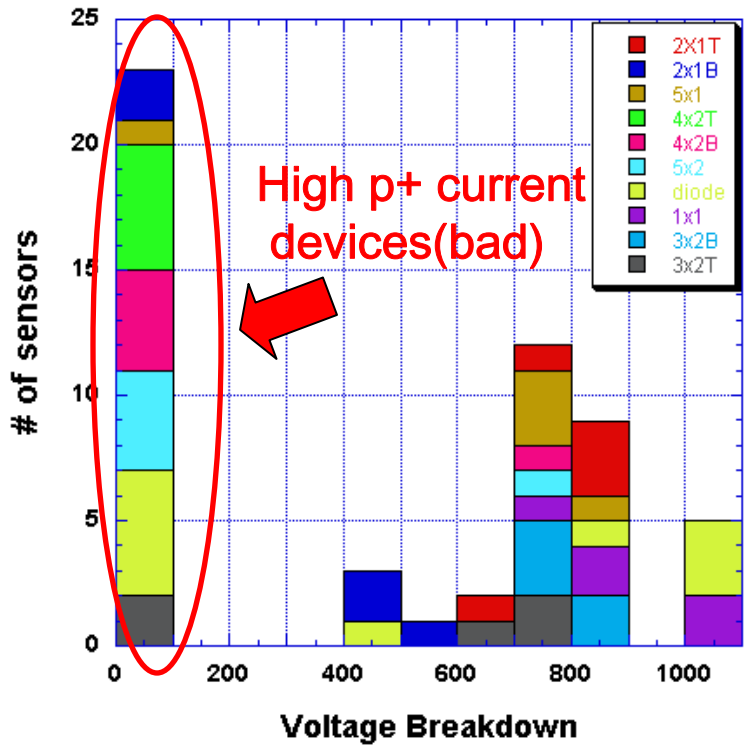
Half of devices fail specification due to high p+ current or high guard ring current at low bias voltage.



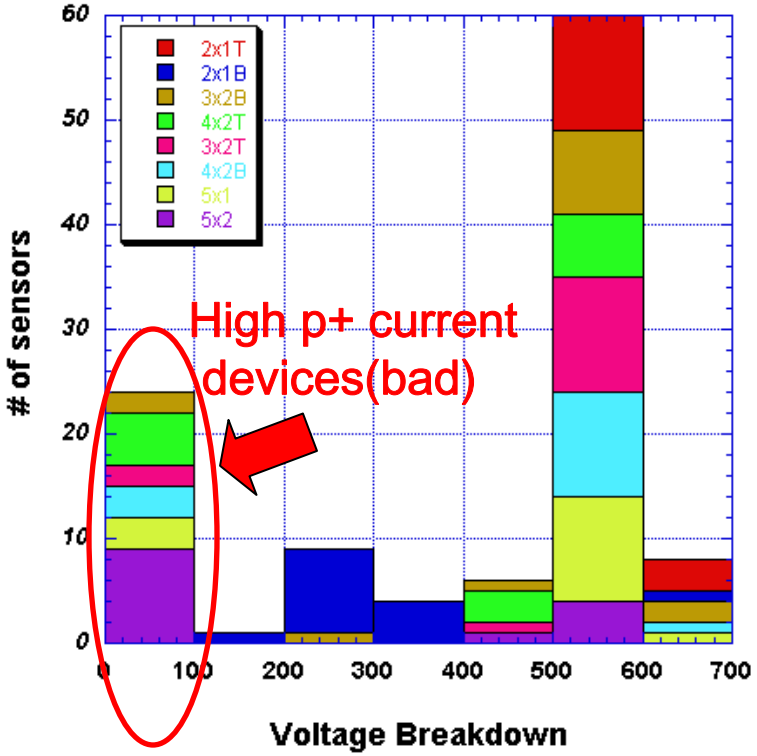


Voltage breakdown distribution

MCZ wafers



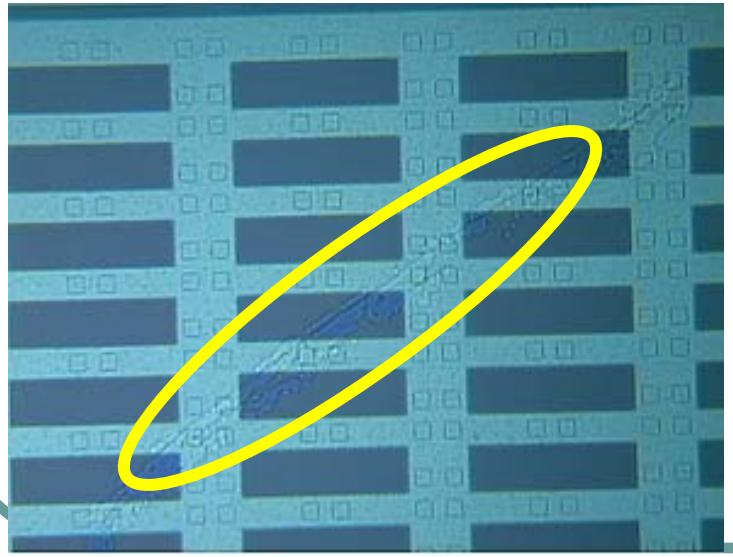
standard wafers

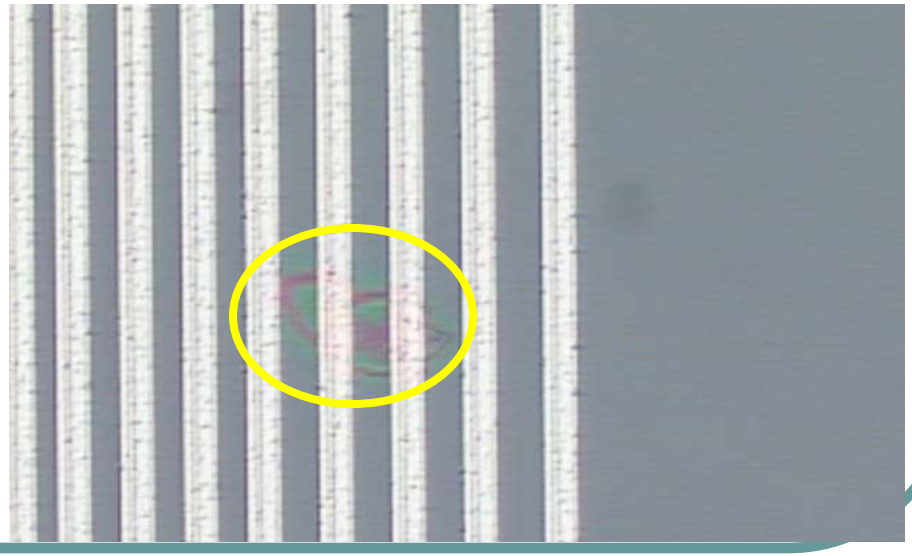


Average breakdown voltage of only good sensors is ~740V for MCZ and ~520V for standard.

IV problem

- Symptoms (electrical) and SiO_2 thickness measurements on the p-side are consistent with n^+ implant spots in the middle of the p^+ implanted area. This implies a resistive behavior during IV measurement (n^+-n-n^+)
- These defects appear to cause high p+/gr current





Summary MCz sensors

- 45 devices from 5 MCZ wafer have been characterized.
- Photolithographic defects need to be resolved.
- The average depletion voltage for MCZ sensors is about 250V and the average breakdown voltage is between 700~800V.
- FZ growth crystal(standard) and MCZ growth crystal are comparable in terms of DC characterization.
- Irradiation needs to be done
- Plan to connect sensors to electronics and perform laser and beam test studies

Thin silicon

- Thin strip detectors with a thickness of 150 μm, 200 μm and 300 μm have been fabricated with Micron Semiconductor L.t.d. (UK).
- Design is very similar to CDF L00 detector
- Design spec:
  - Single-sided AC coupled p-on-n microstrip detectors with 128 readout strips.
  - Floating intermediate strips are interleaved to the readout strips in order to enhance the position resolution.
  - The readout (implanted) pitch is 50 μm (25 μm).
  - The active area is surrounded by a 10 guard ring structure to enhance high voltage operation.

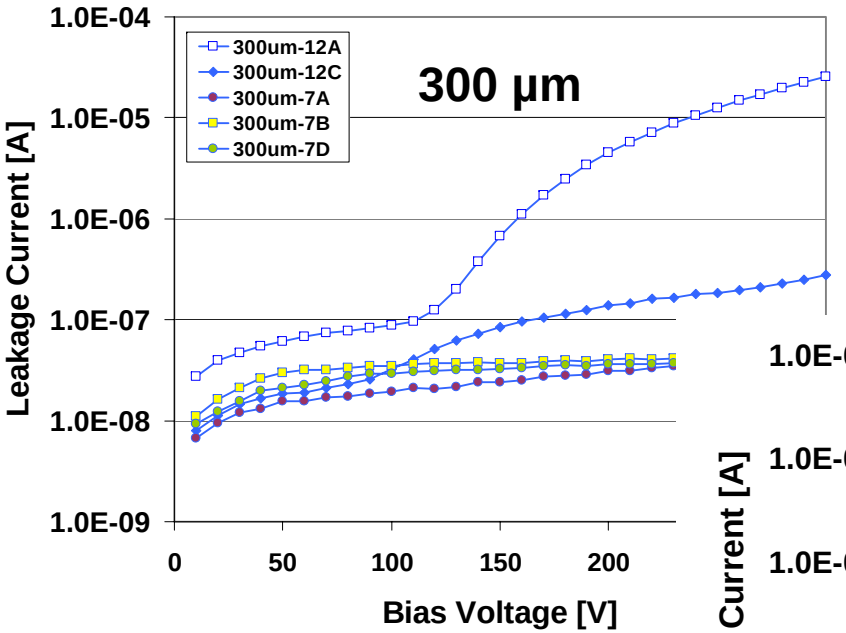
Measurements on thin silicon

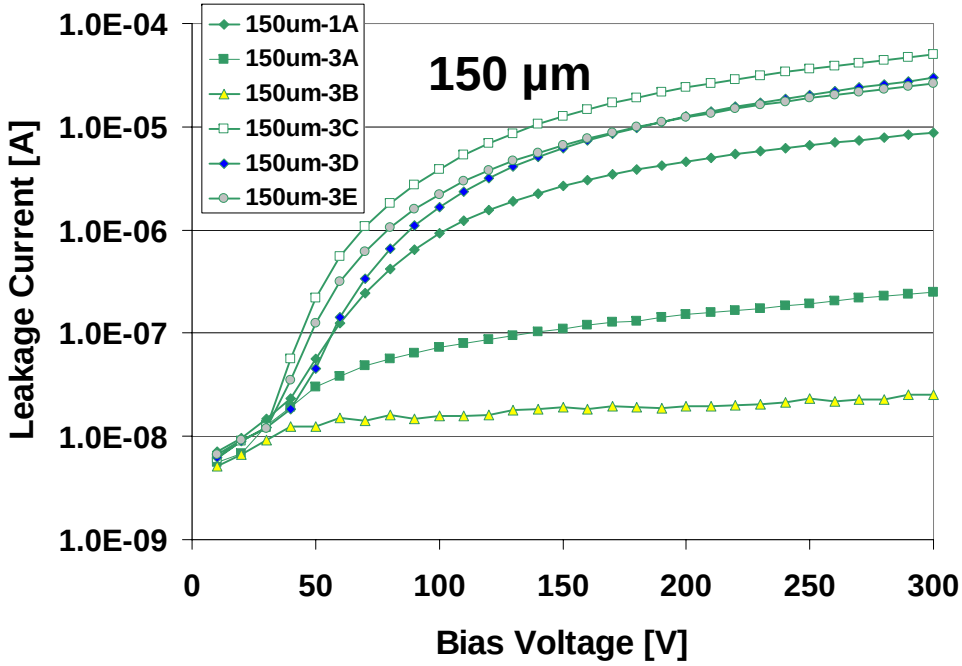
- I-V curve: Total leakage current was measured up to 1000V bias at a step of 10V
- C-V curve: Total capacitance was measured as a function of bias voltage.
- AC scan: Coupling capacitance.
- DC scan: The leakage current of individual strips.
- Inter-strip Resistance: Resistance between neighboring DC pads
- Poly-silicon Resistance: Resistance between DC pad and bias ring.

Irradiation

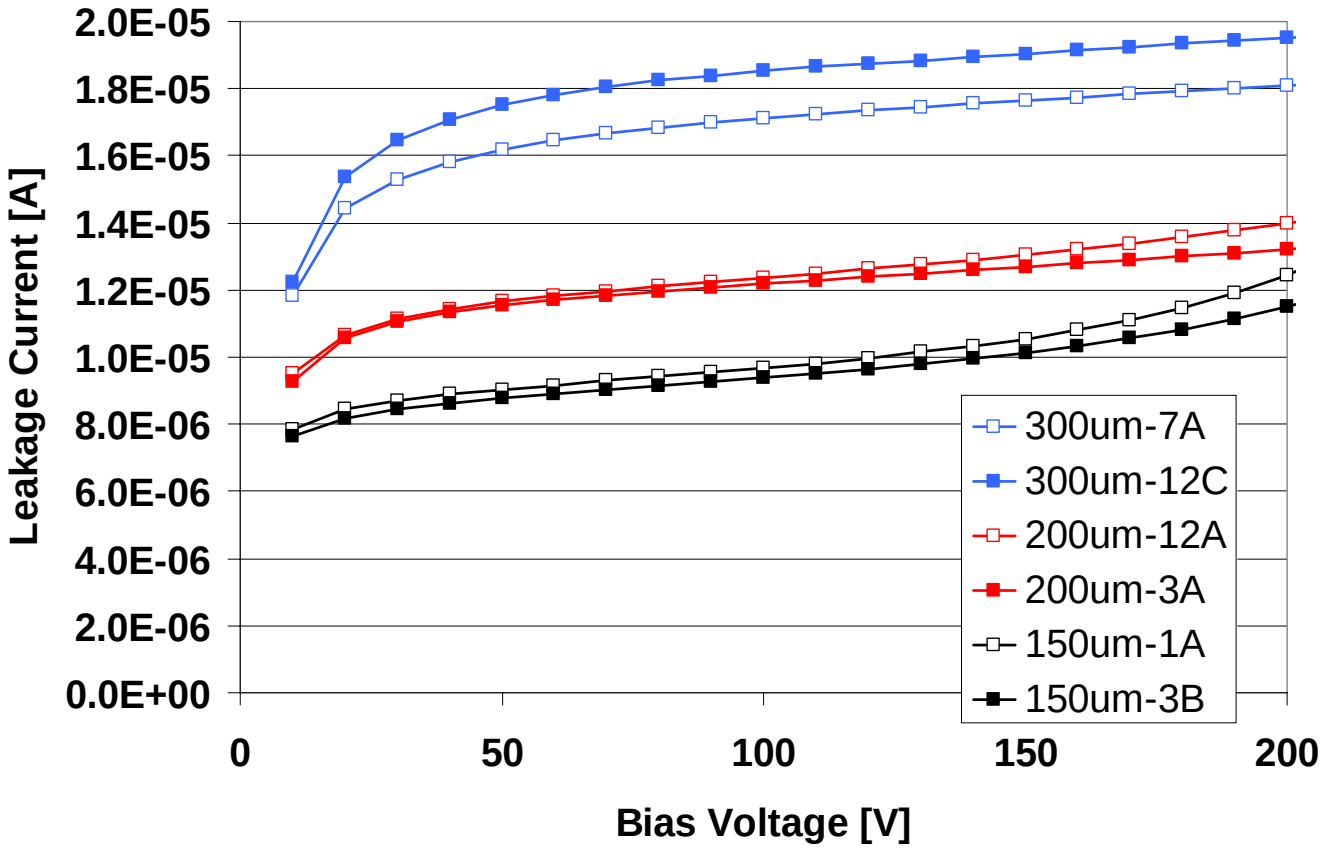
- 6 sensors were irradiation at IUCF with fluence of 1×10^{14} 1-MeV n_{eq} /cm^2
- 2 sensors per each thickness

IV curves before irradiation





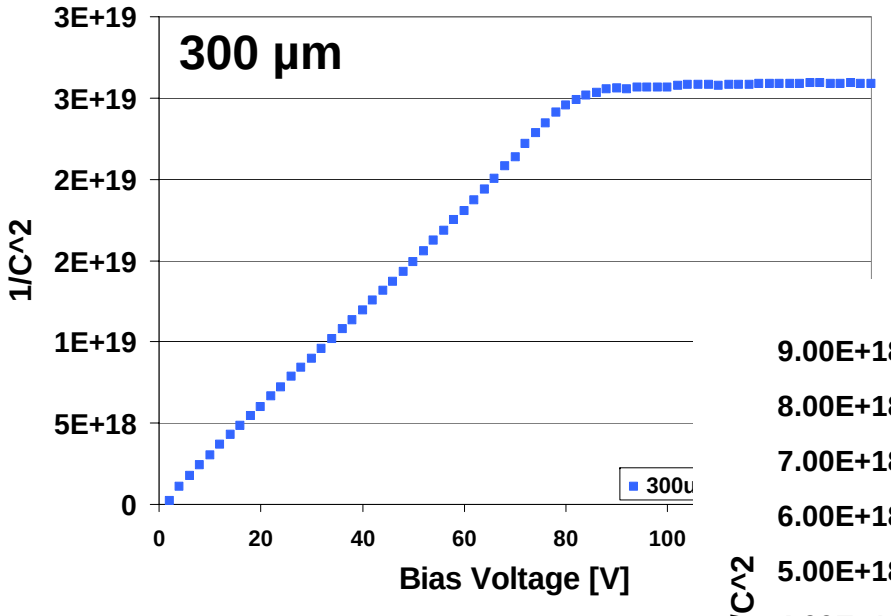
IV curves after irradiation

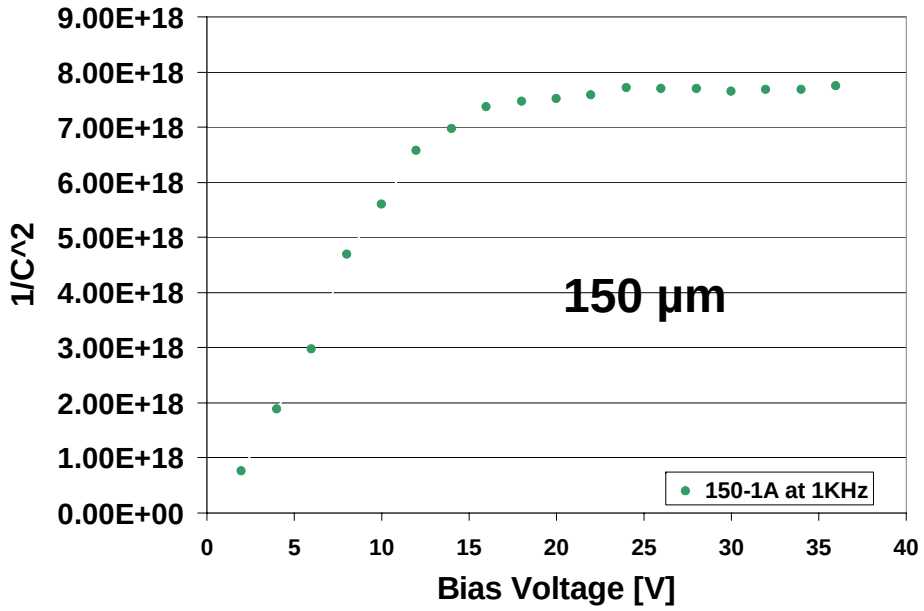


Summary: IV measurements

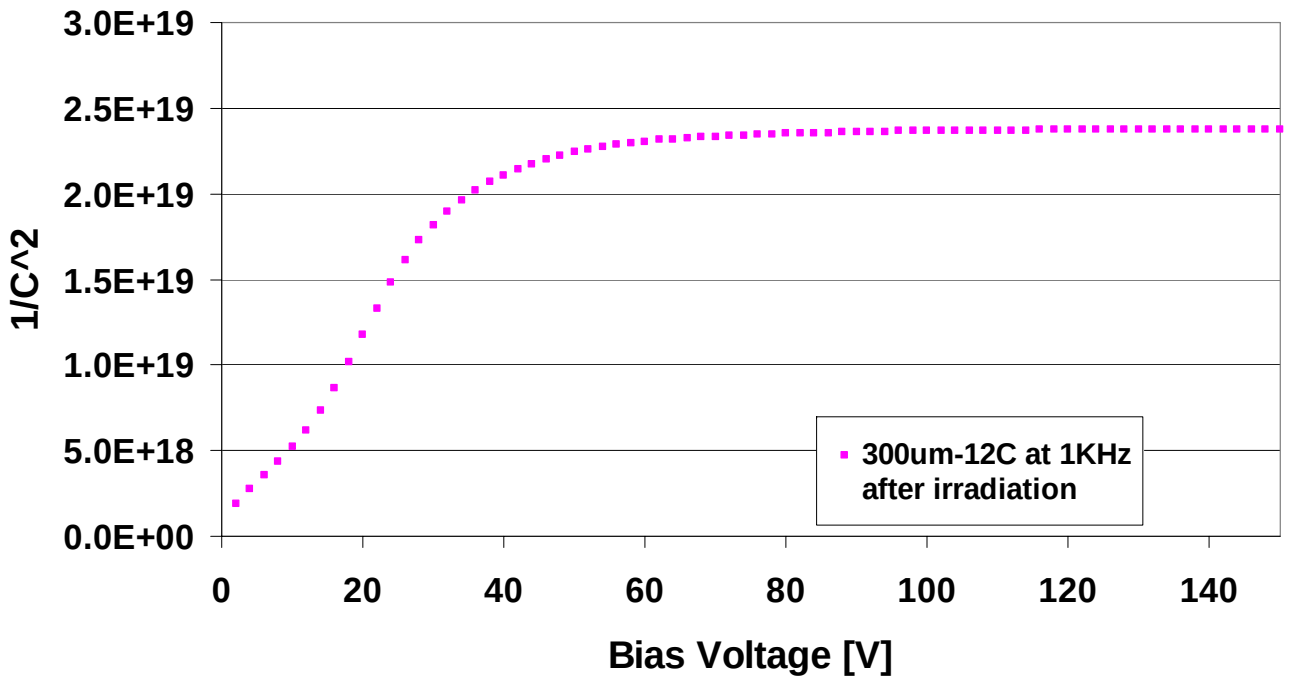
- Before irradiation there is no correlation between the leakage current and the sensor thickness. This is an indication that the surface current is dominating over the bulk current.
- After irradiation, IV characteristic shows that the leakage current is not only dominated by bulk current but clearly follows the expected linear correlation with the thickness of the sensor.

CV curve before irradiation





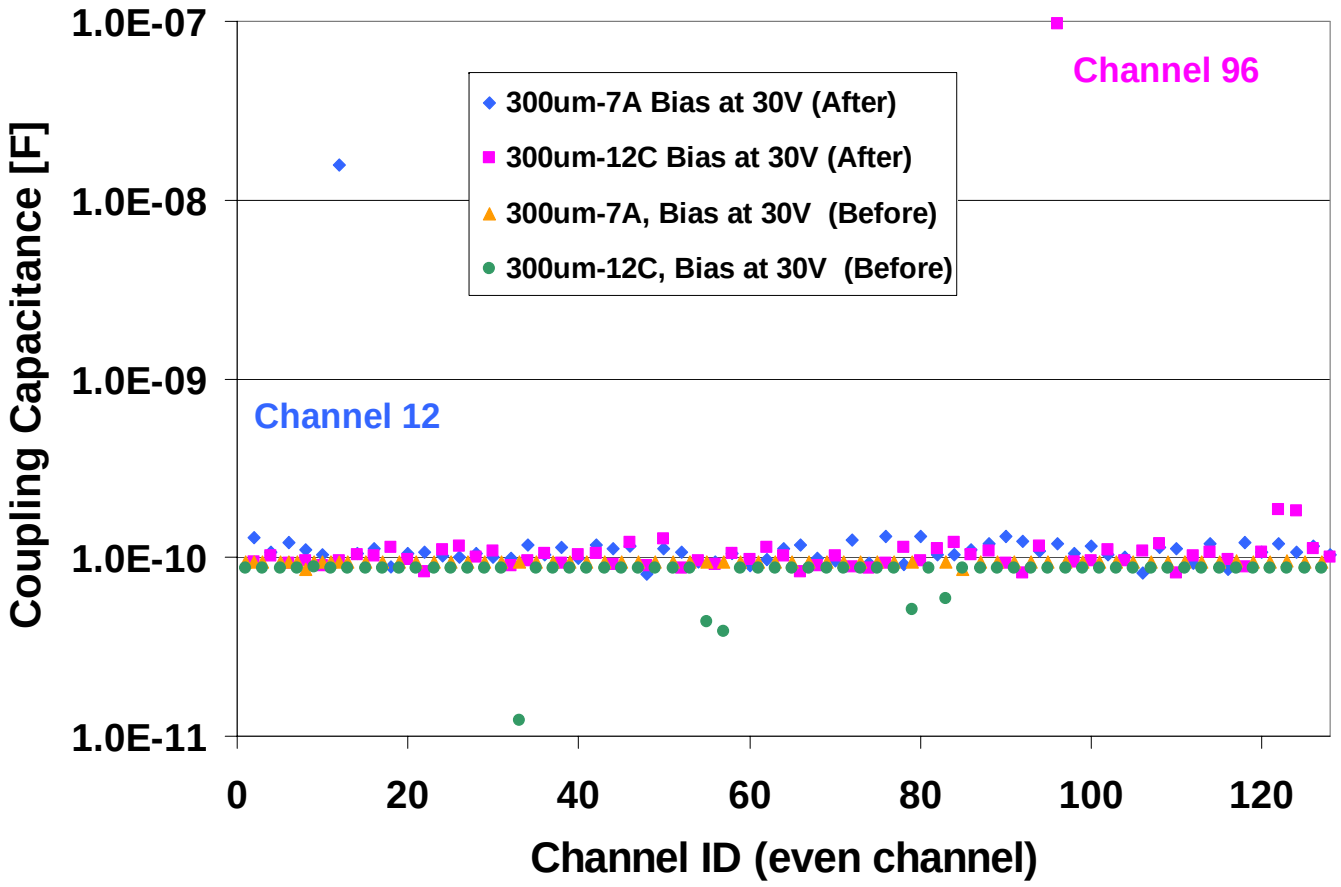
CV after irradiation



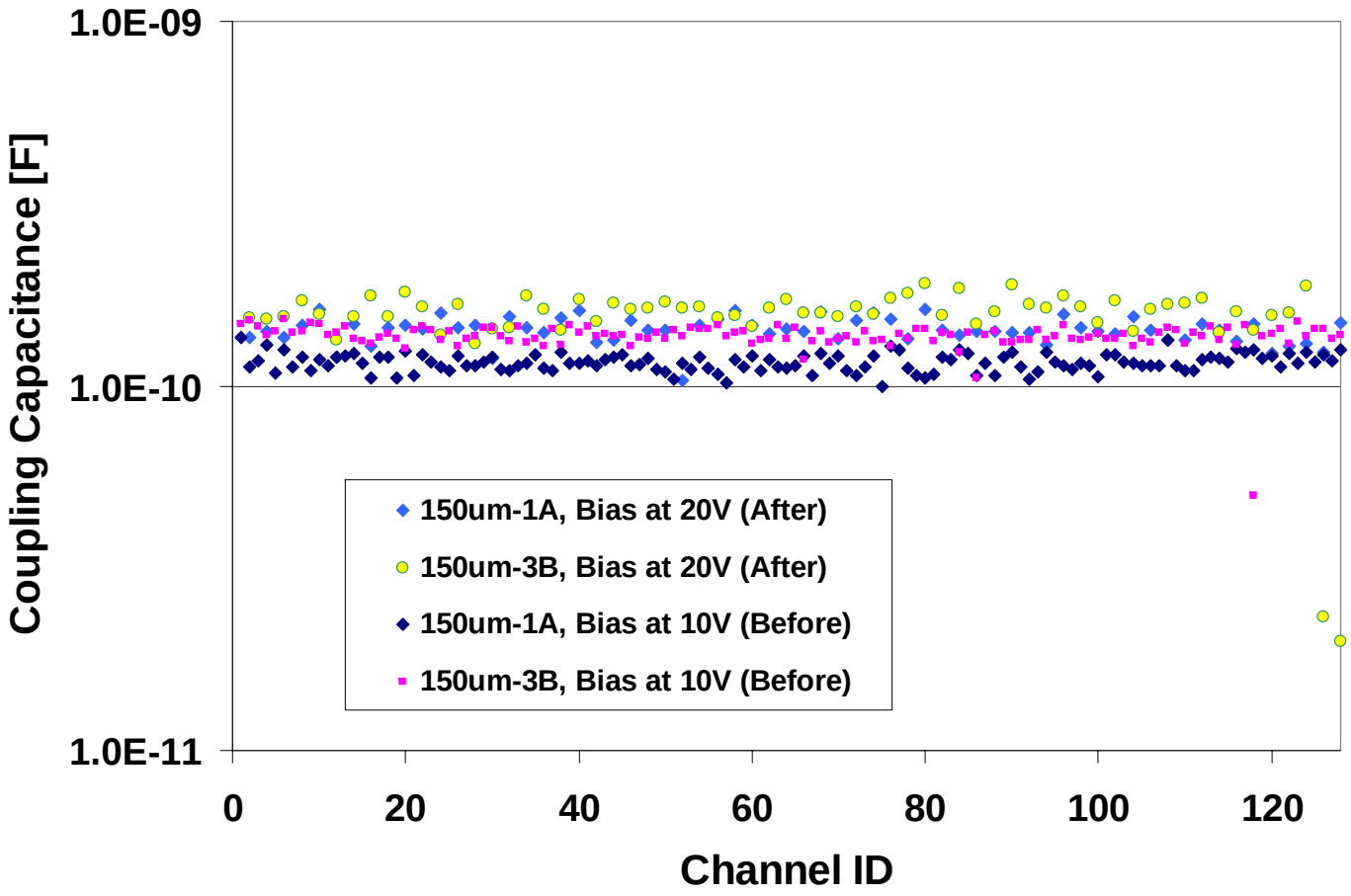
Summary: Depletion Voltage

Thickness [μm]	Un-irradiated Depletion Voltage [V]	Depletion Voltage [V] after 1E14 1MeV n_{eq}
300	80 ~ 105	25~40
200	~30	~18
150	~16	~12

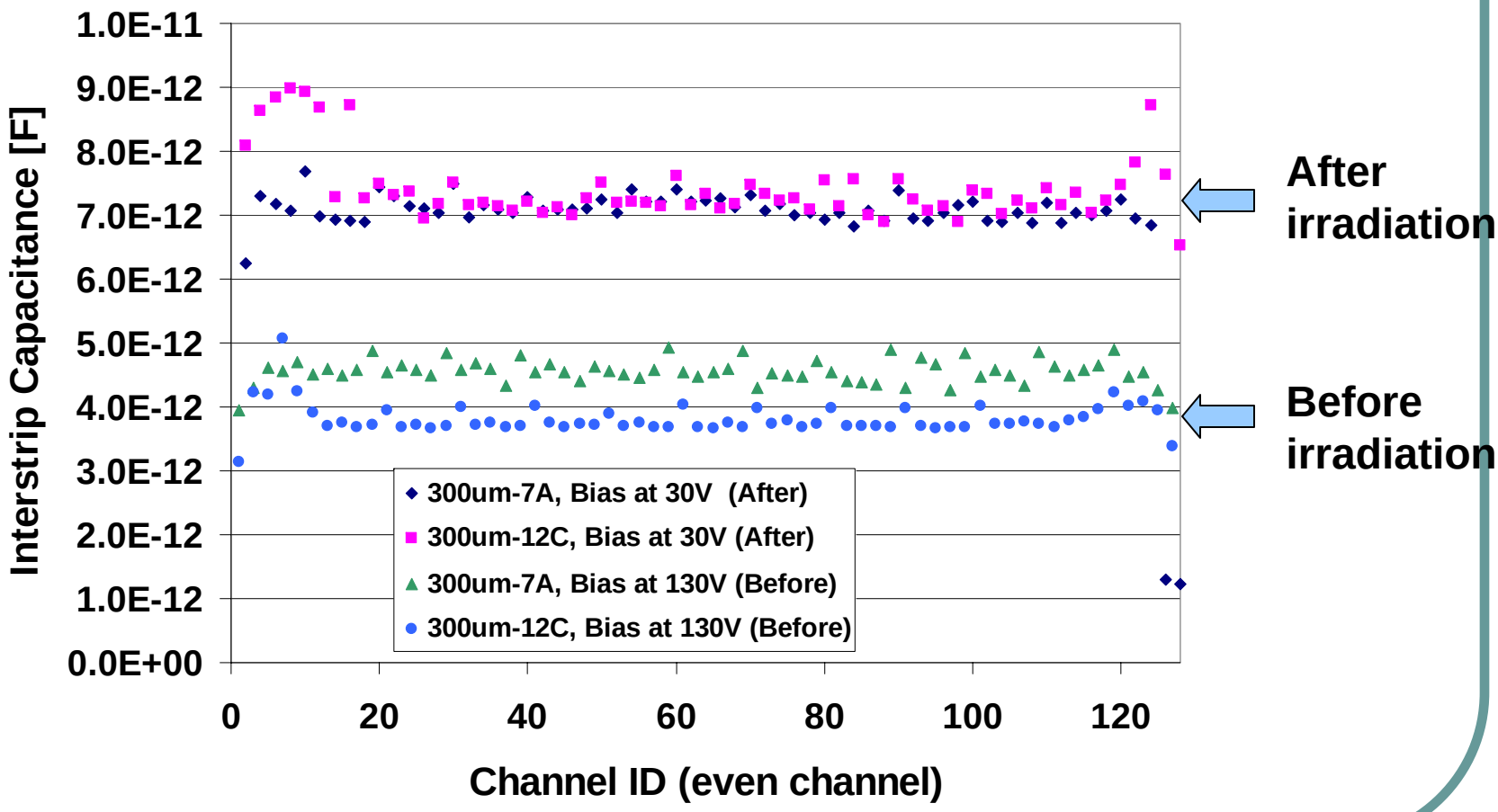
C_C comparison before& after irradiation, @100Hz, 300µm



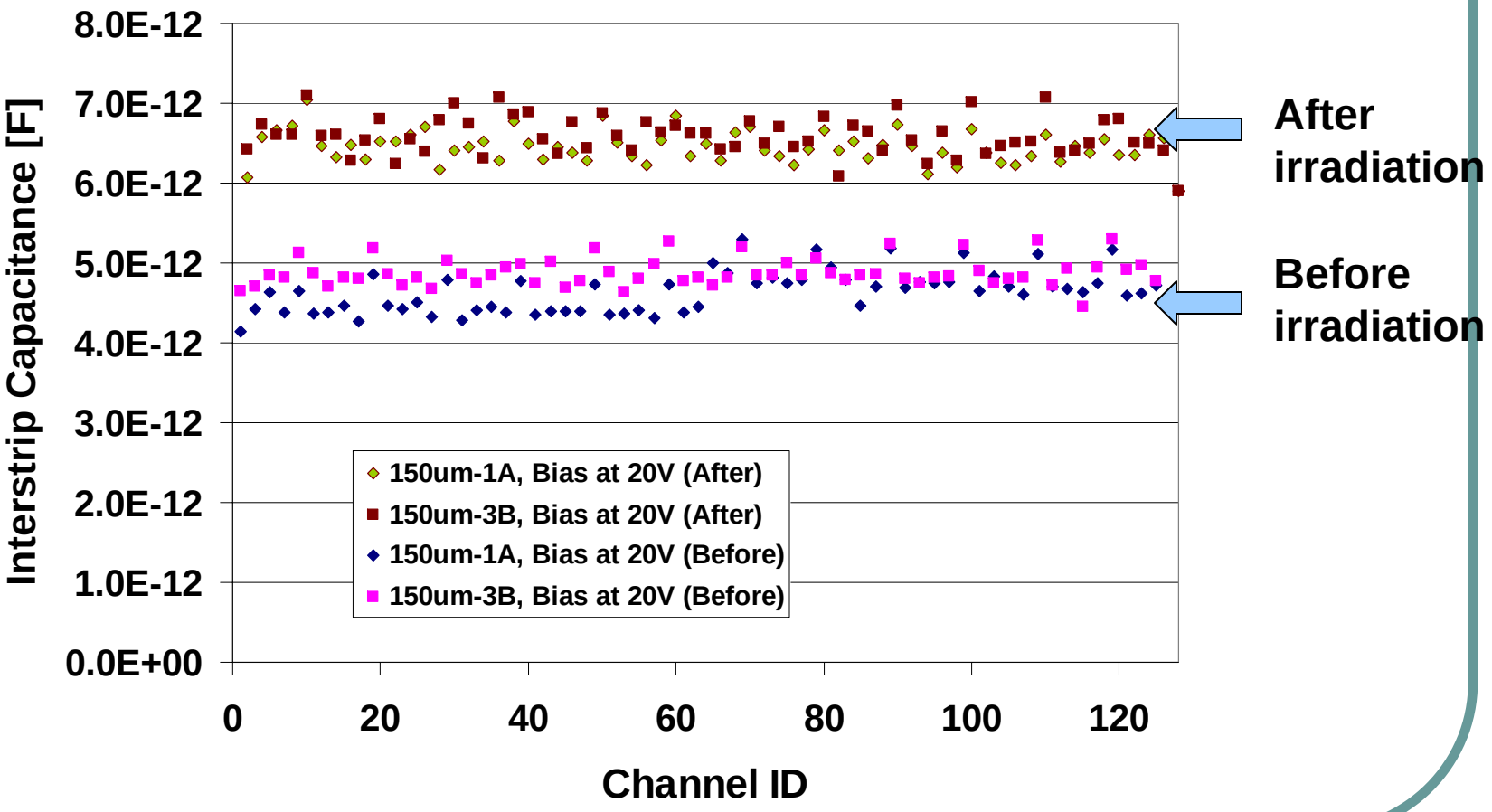
C_C comparison before& after irradiation, @100Hz, 150µm



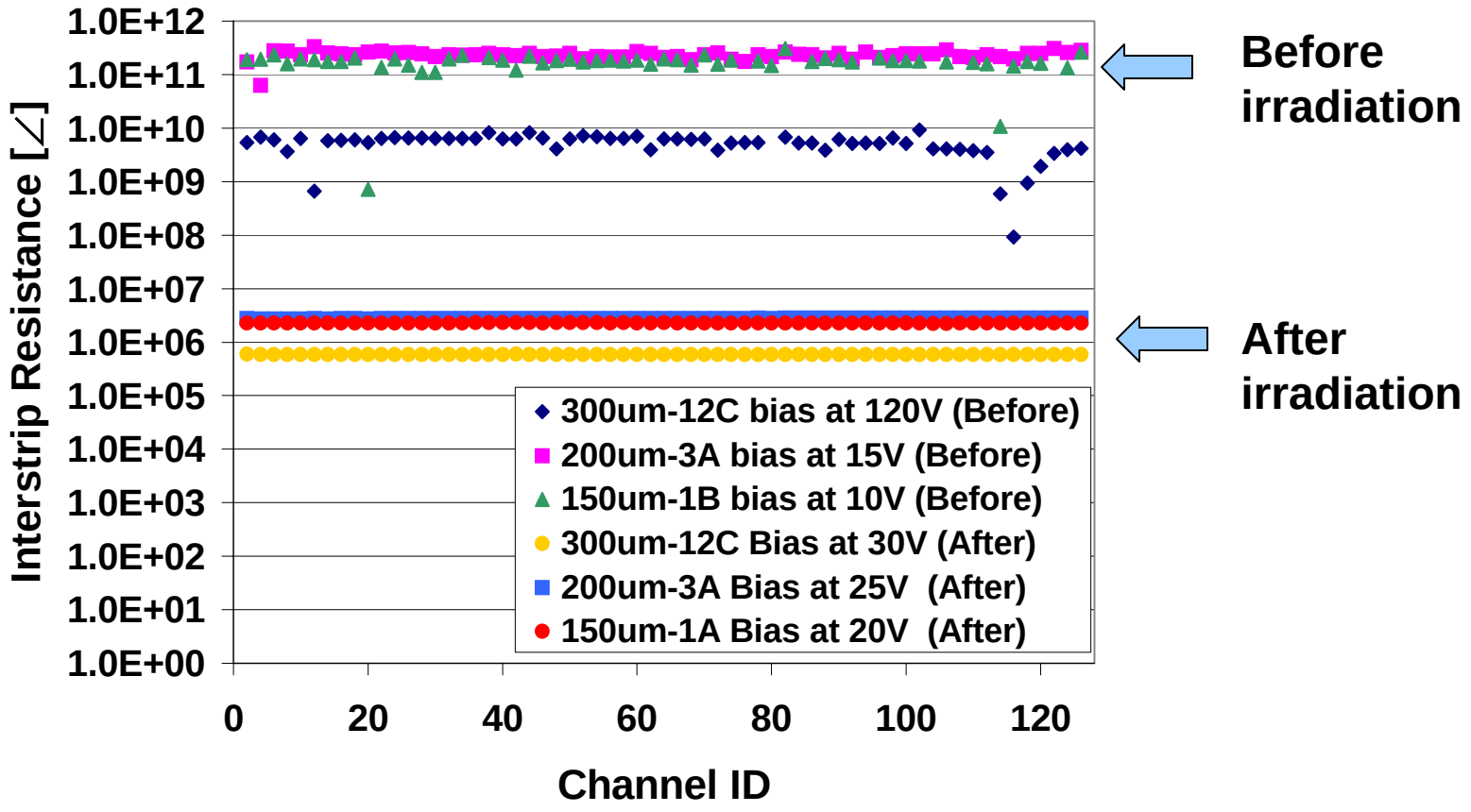
C_{is} Comparison before & after irradiation, @ 1MHz, 300µm



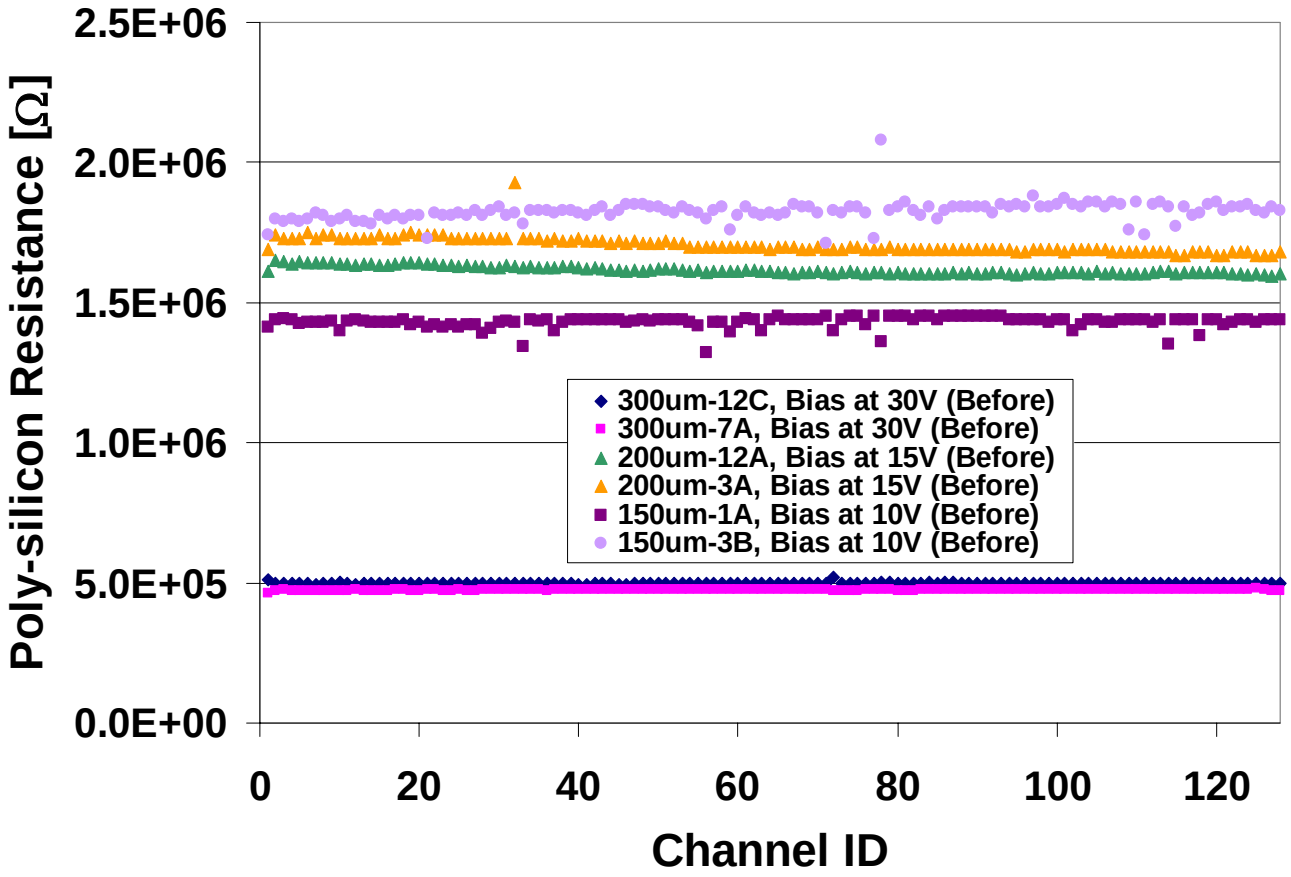
C_{is} Comparison before & after irradiation, @1MHz, 150µm



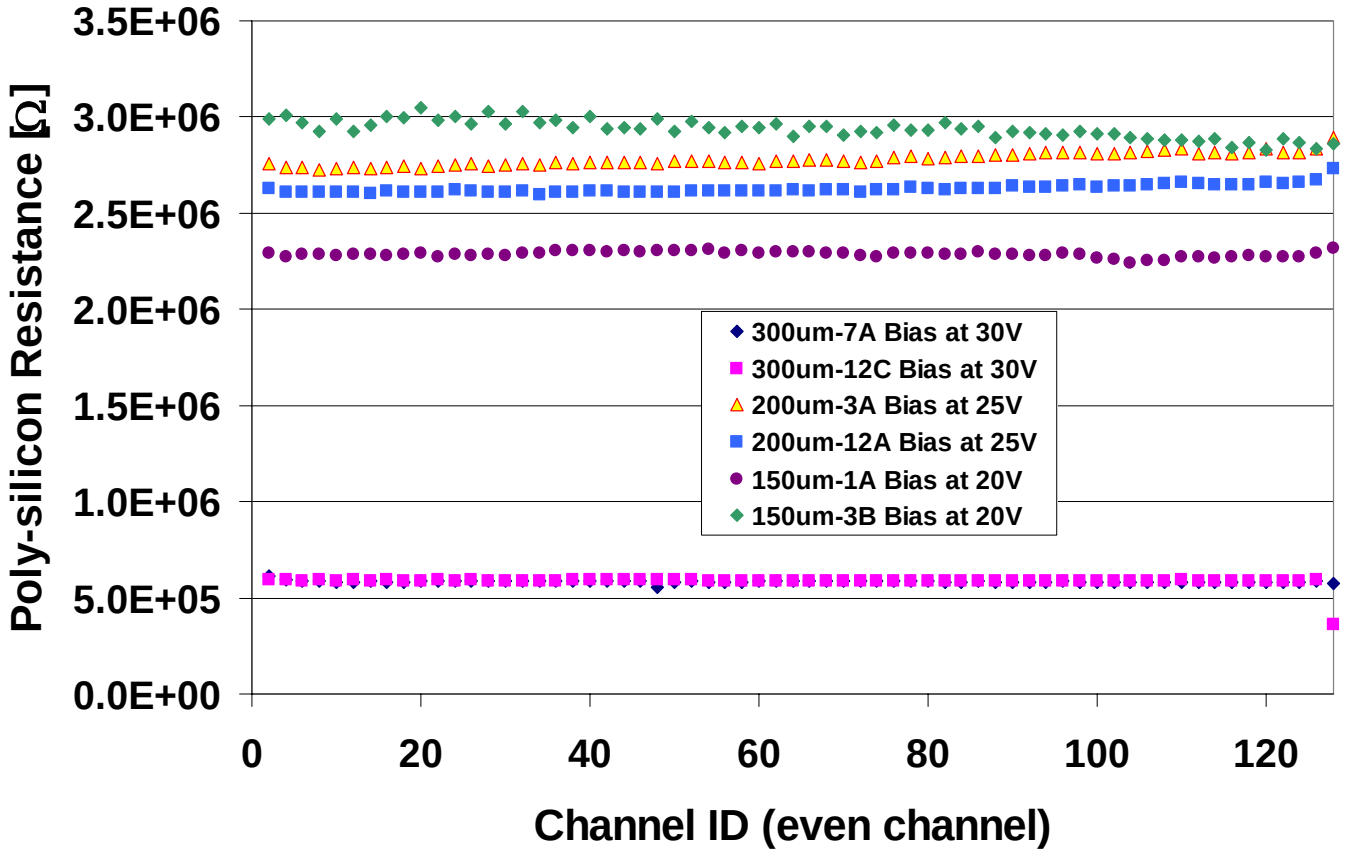
R_{is} before & after irradiation



Poly-silicon resistance before irradiation



Poly-silicon resistance at -10C after irradiation



Summary thin sensors

- Sensors with a thickness between 150 to 300 µm have been fabricated by Micron.
- Sensors were irradiated up to 1×10^{14} 1Mev n-eq/cm^2
- DC characterization before and after irradiation has been completed.
- 150 µm sensors show similar behavior as 300 µm
- Plan to connect sensors to electronics and perform laser and beam test studies to study charge collection efficiency.