First measurements of Semi3D diodes before and after irradiation

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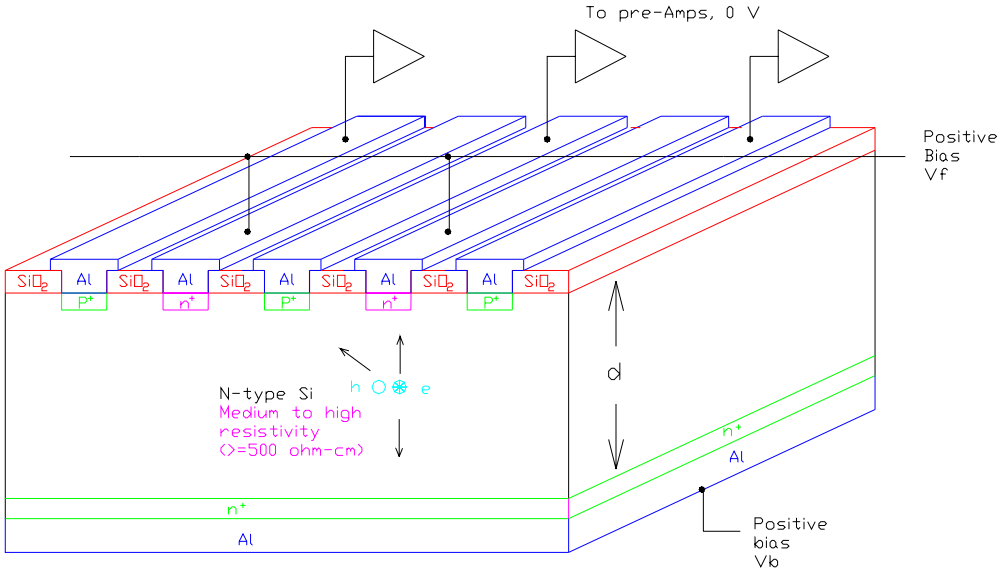
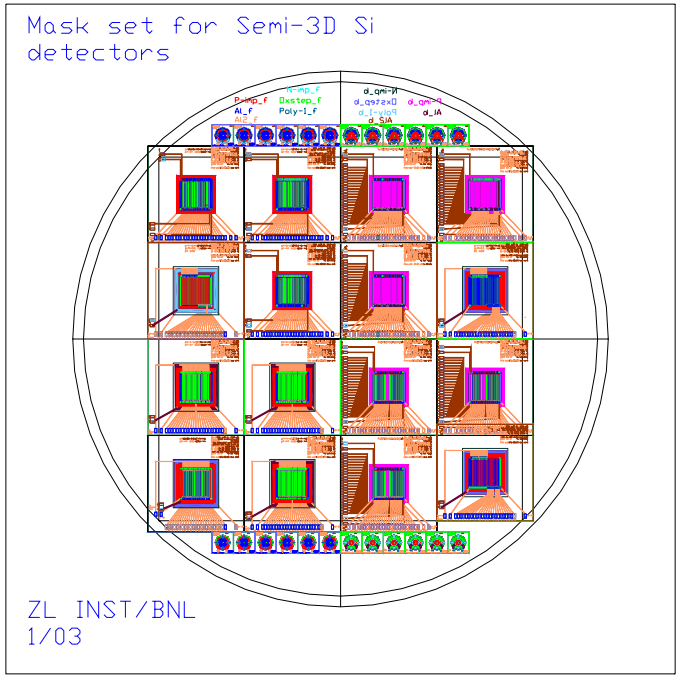
Semi 3D

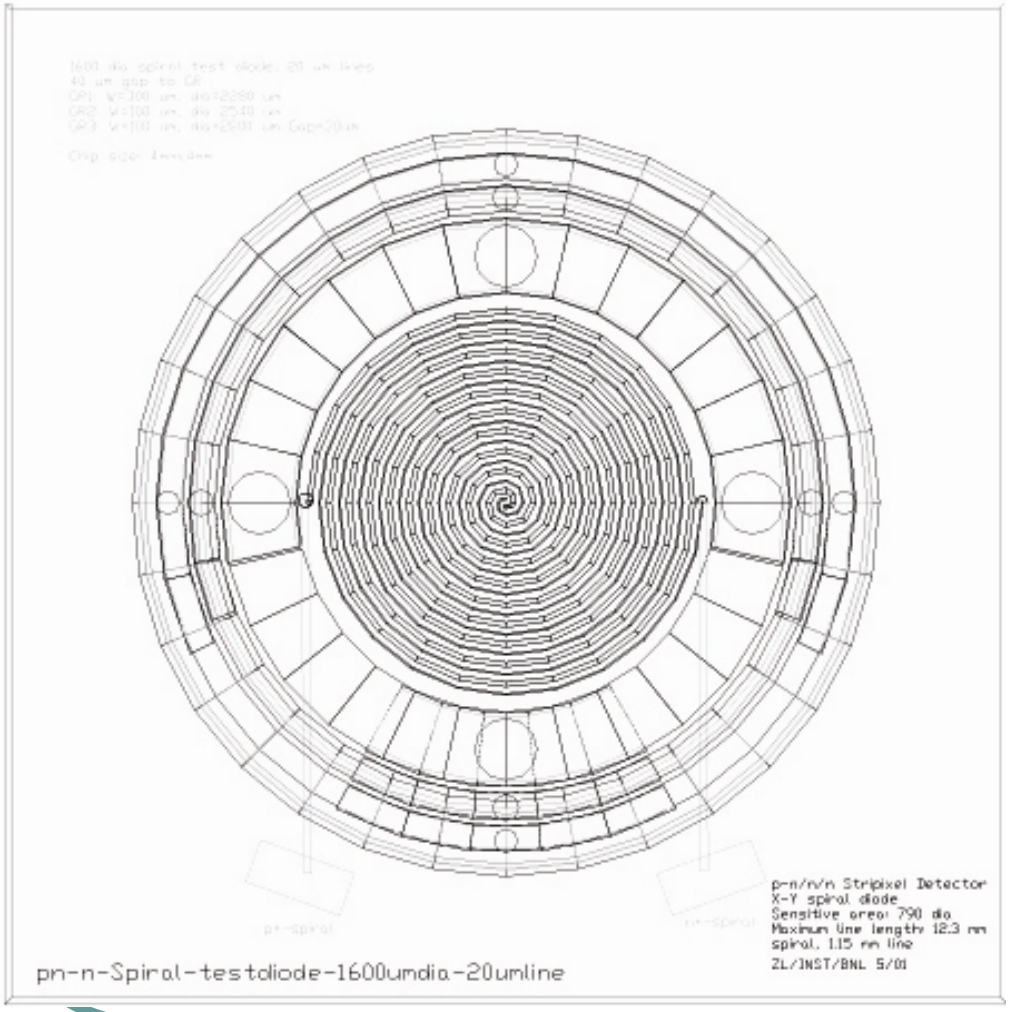
- **Planar technology**
- **V_{fd} may be reduced by a factor of 2-4 since sensors deplete from both sides and laterally**
- **Low resistivity Si (100 Ωcm) may be used (no SCSI up to 10^{15} n/cm^2)**
- **Better power balance possible**
- **Usable for both strip detectors (SSD) an pixel detectors (SPD)**



Z. Li et al, NIM<u>A478</u> (2002) 303-310.

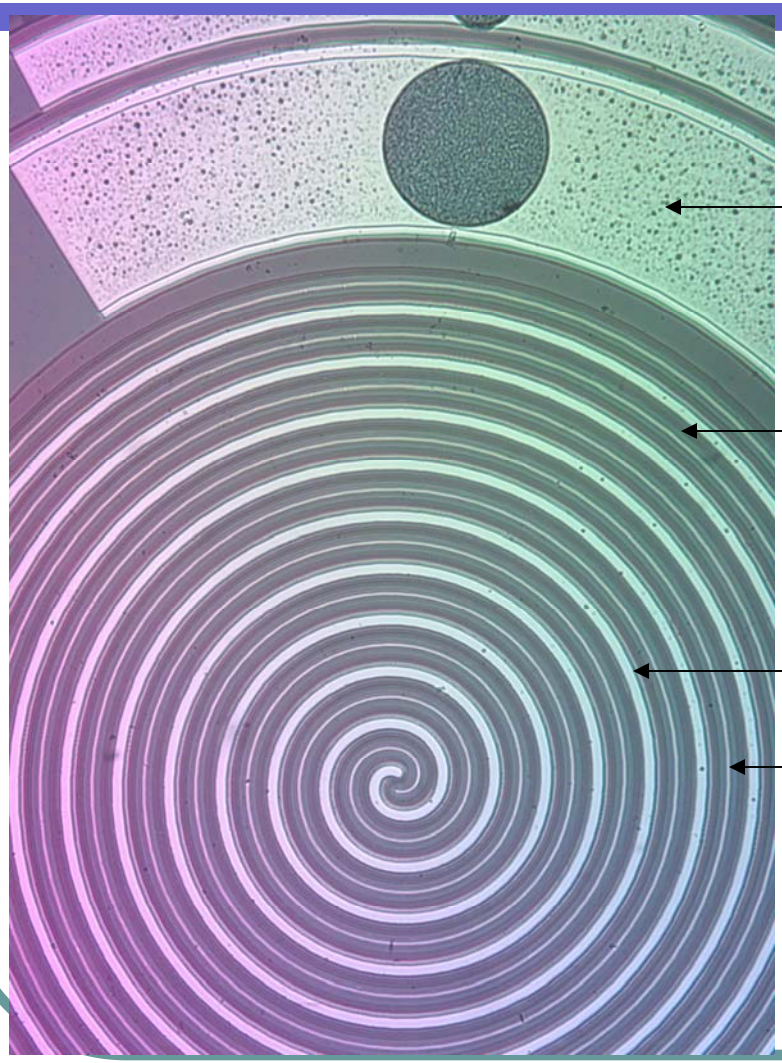


Semi-3D diodes



- **N bulk**
- **Sensitive area :**
  - **1.6 mm spiral diameter**
- **Thickness :**
  - **260 μm**
- **Resistivity :**
  - **4 KΩ cm**
- **Three electrodes on the front:**
  - **P-spiral**
  - **N-Spiral**
  - **GR**
- **One Electrode on the back:**
  - **N-contact**

Semi-3D diodes with p-stops



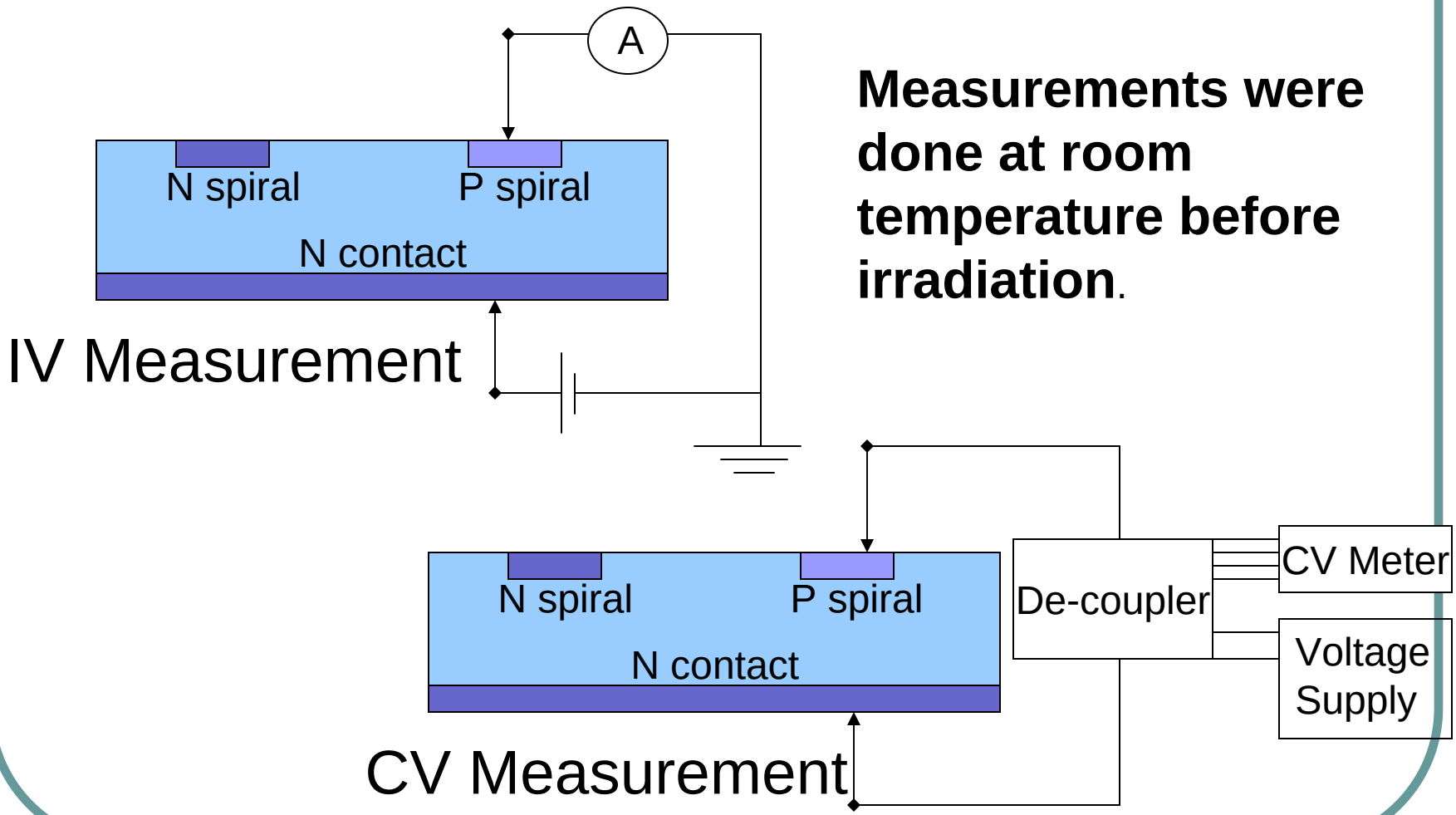
Guard Ring

Channel Stopper – P implant between P and N spiral

P Spiral

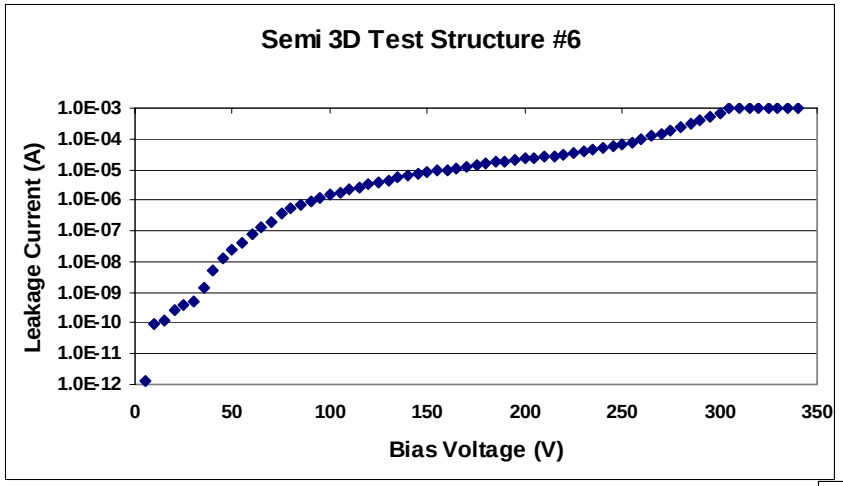
N Spiral

Schematics of measurements before Irradiation



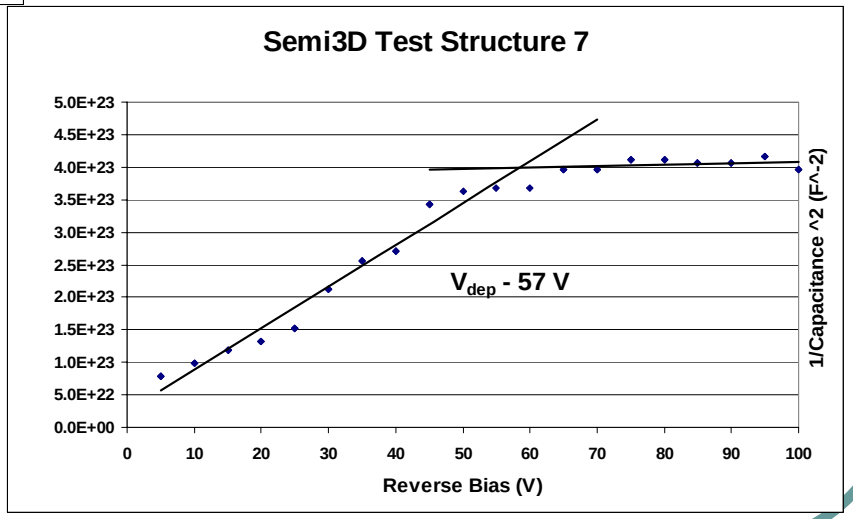
Measurements were done at room temperature before irradiation.

Semi-3D diodes with p-stops



IV before irradiation
The test structure has high current

CV: before irradiation diodes depletes at 57 V

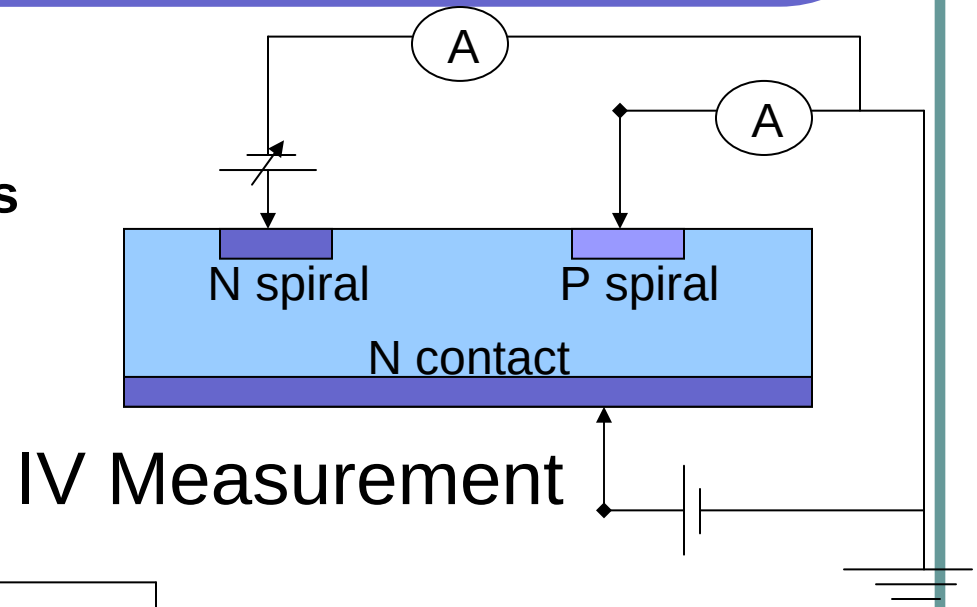


Irradiation

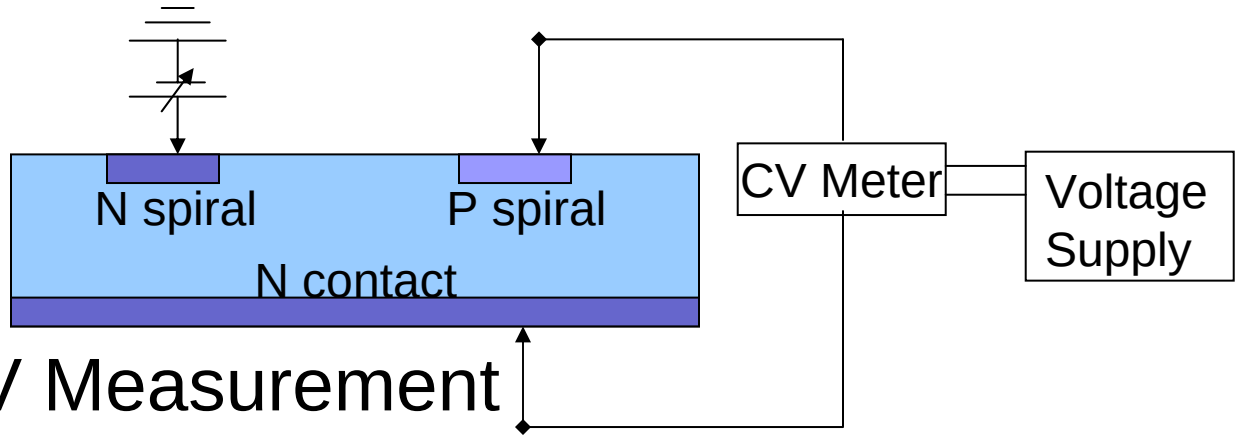
- **Irradiation carried out at CERN**
- **24 GeV Proton beam**
- **Total fluence received: 5×10^{14} n_{eq}/cm^2 and 1×10^{15} n_{eq}/cm^2**
- **Measured diode that received 5×10^{14} n_{eq}/cm^2**
- **Expected Depletion voltage ~ 370 V**

Schematic of Measurement after Irradiation

- **Vary the voltage at the N spiral. Measure depletion voltage and leakage current as a function of N spiral.**
- **Measurements were done at -10^{0}C and test structures were stored at -10^0 C.**

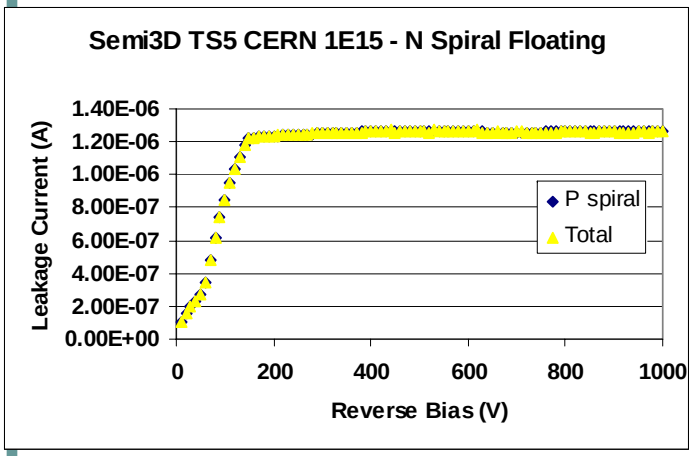


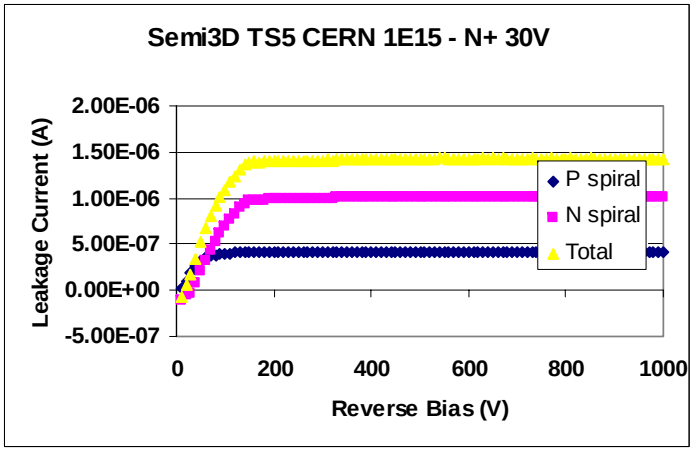
IV Measurement

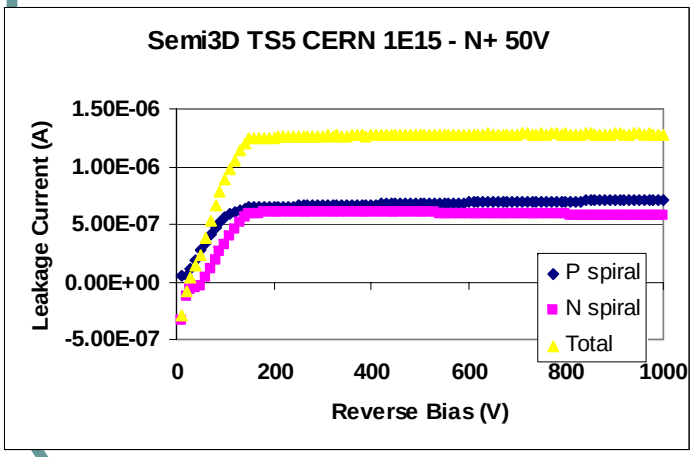


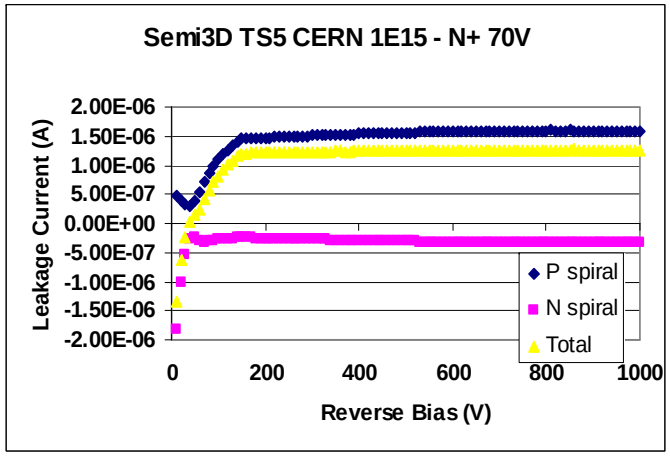
CV Measurement

IV Measurements



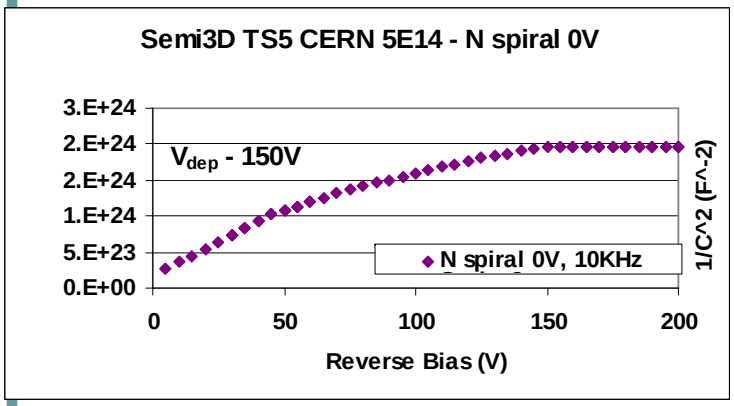


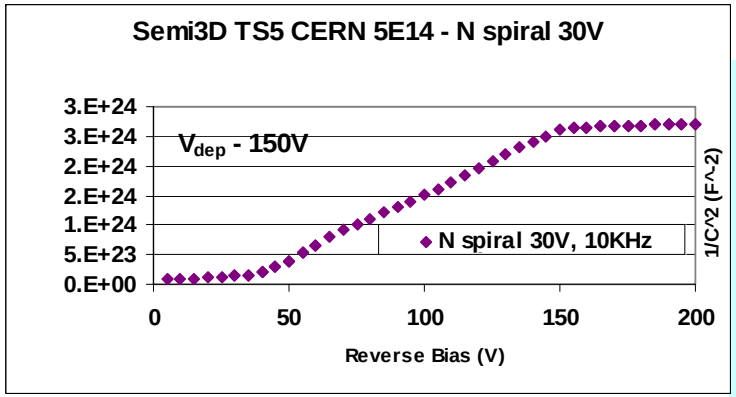


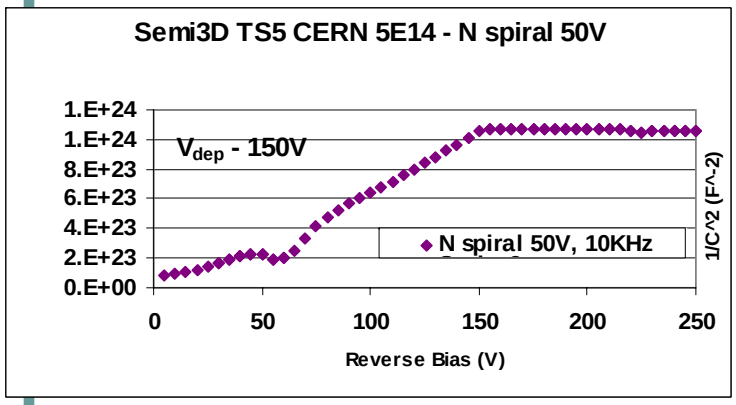


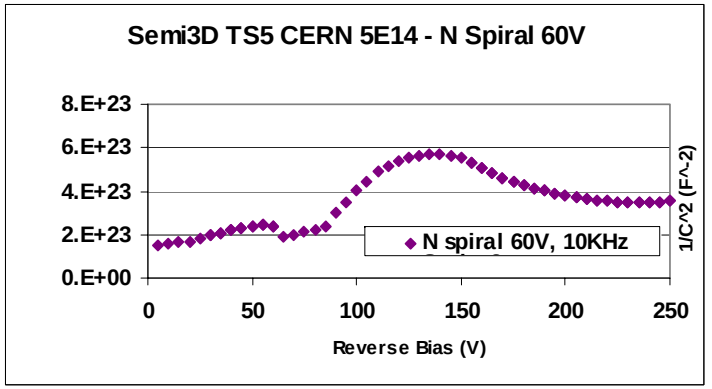
As the voltage at N spiral increases the current through the N spiral decreases and current through P spiral increases until channel current flows from P spiral to N spiral

CV measurements at 10 KHz





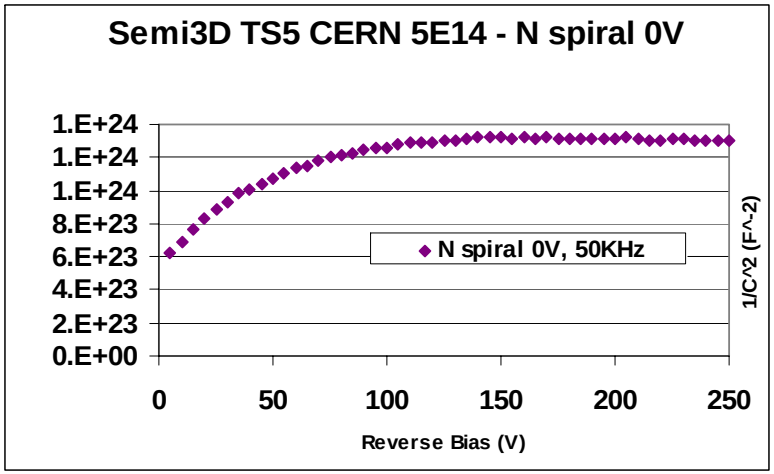


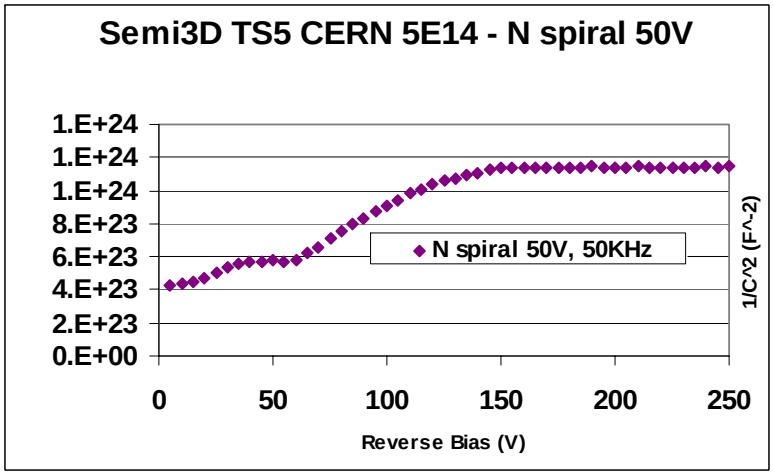


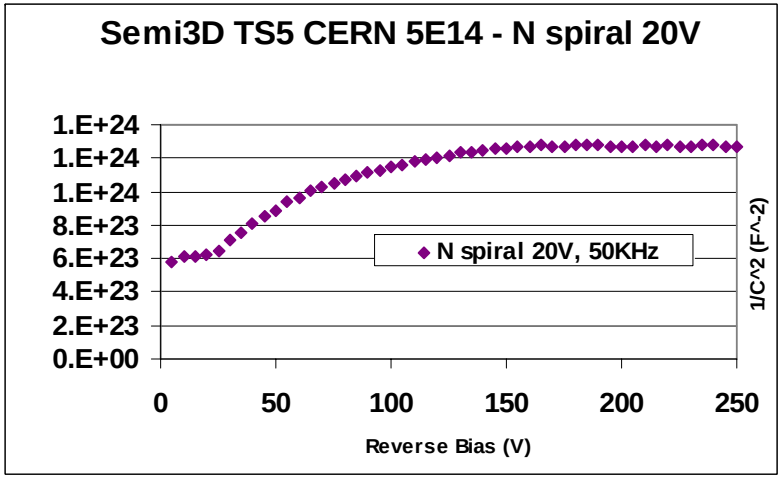
- **Voltage on N spiral doesn't effect the depletion voltage.**
- **Around 60 V the channel current between P spiral and N spiral starts flowing.**

Depletion Voltage is found by determining V where C changes by less than 1%

CV Measurements at 50 KHz

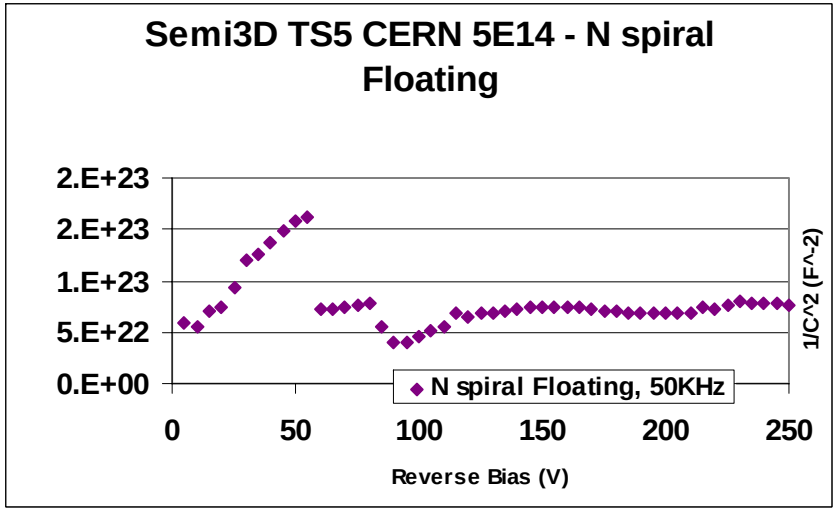


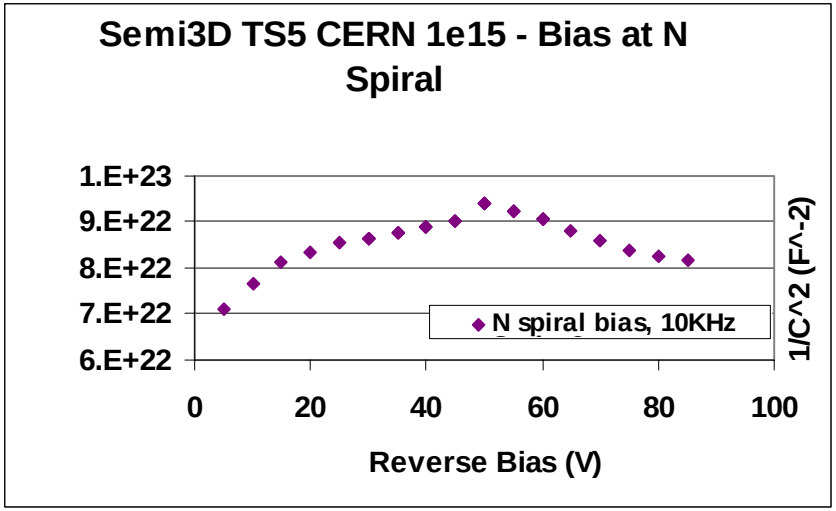




V_{dep} ~ 125 V
Depletion voltage changes slightly with voltage at N spiral.

Other Measurements (semi 3D diode with p-stops)

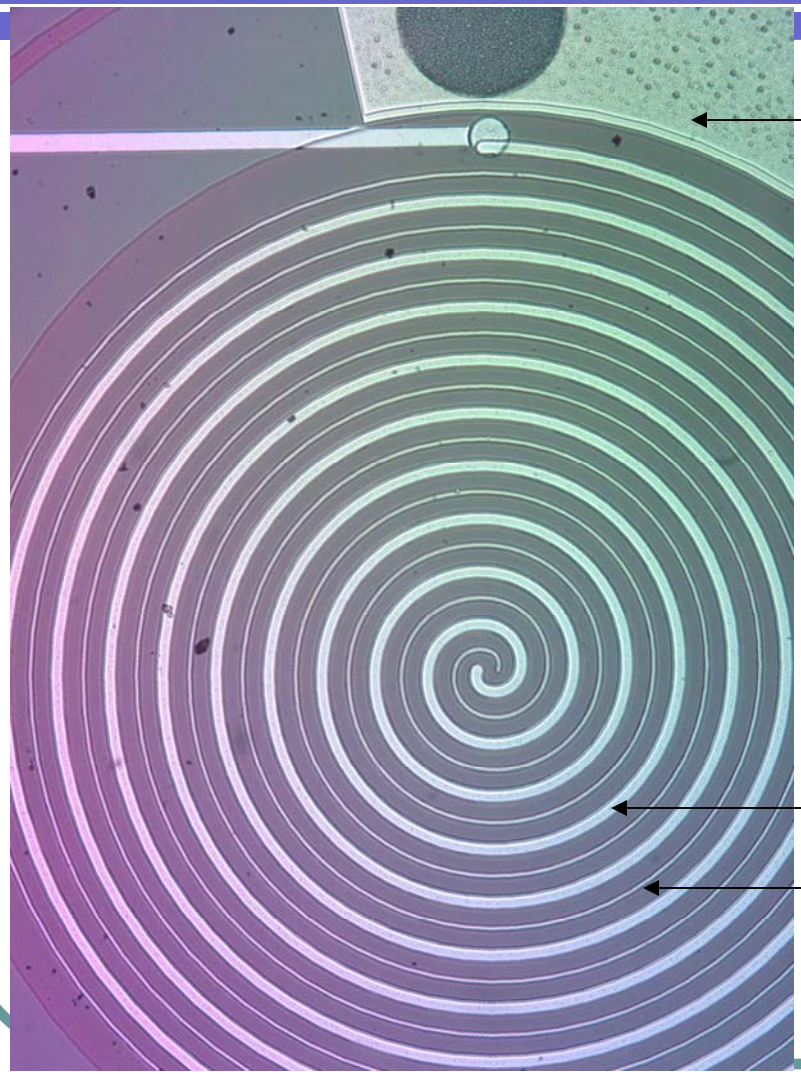




CV while N spiral was floating.

CV while bias was applied at N spiral and backside is floating. Capacitance is measured between P spiral and backside.

Semi 3D diode (no p-stops)



Guard Ring

NO Channel Stopper –
P implant between P and N spiral

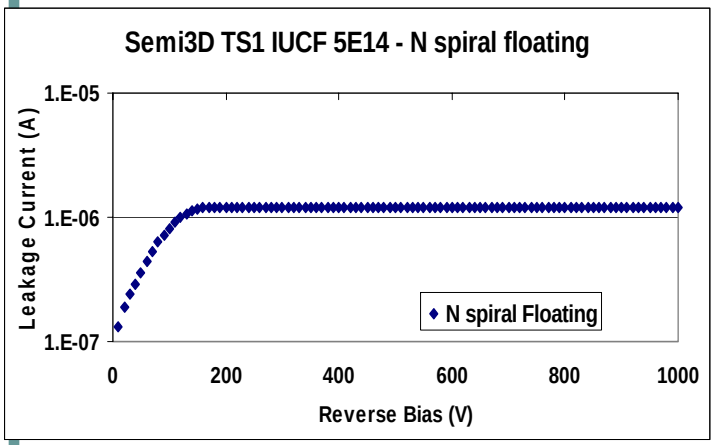
P Spiral

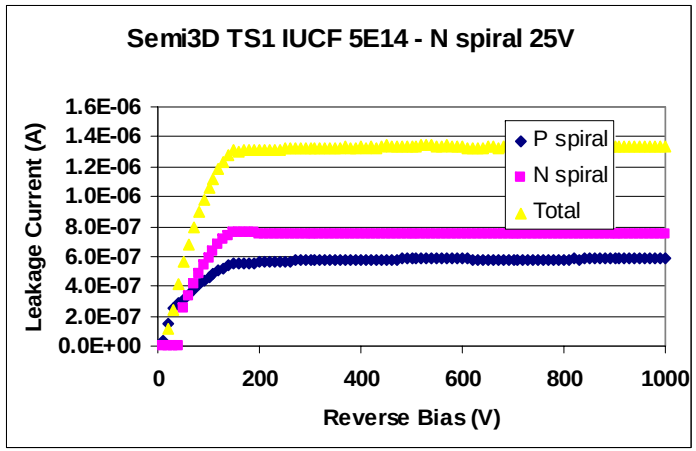
N Spiral

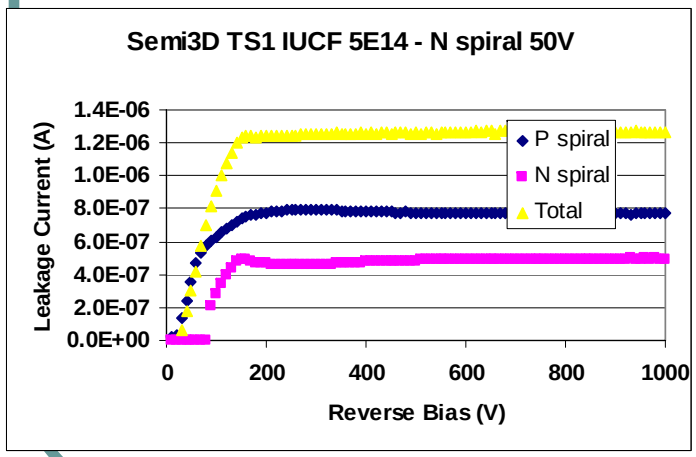
Irradiation

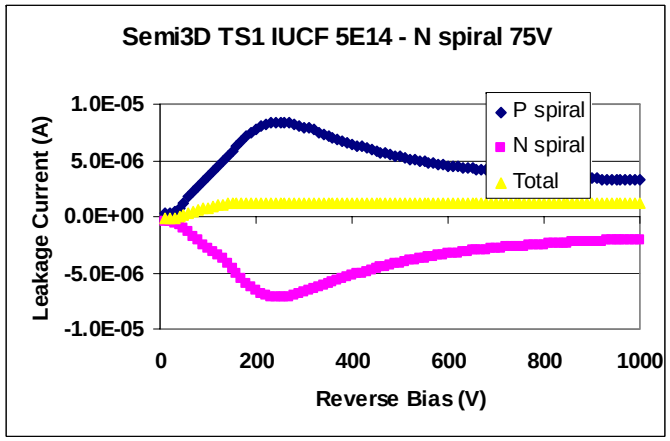
- **Irradiation carried out at Indiana University Cyclotron Facility (IUCF)**
- **200 MeV Proton beam**
- **Total fluence received: 5×10^{14} n_{eq}/cm^2**
- **Expected Depletion voltage ~ 370 V**

Results - IV



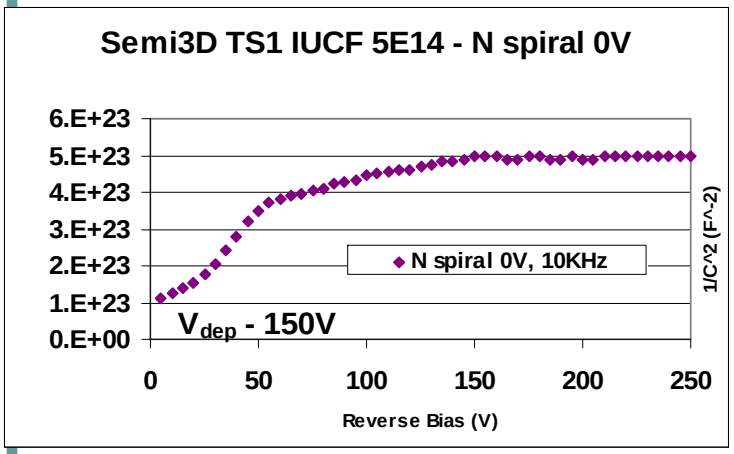


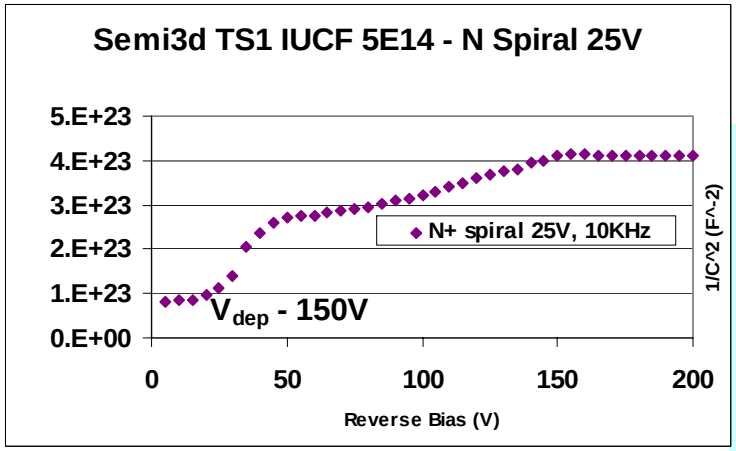


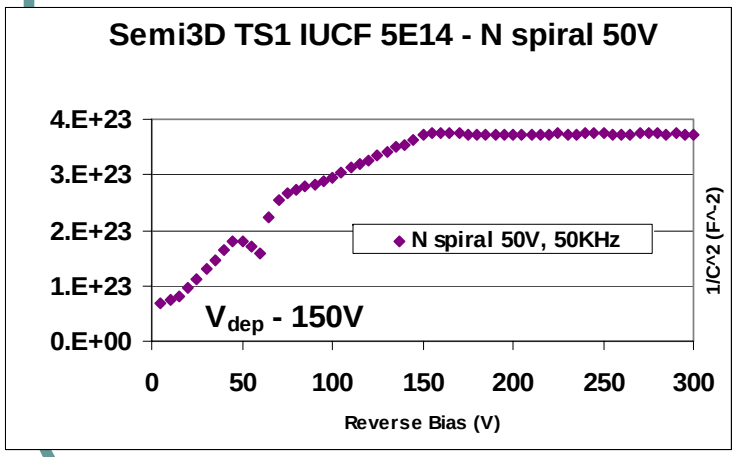


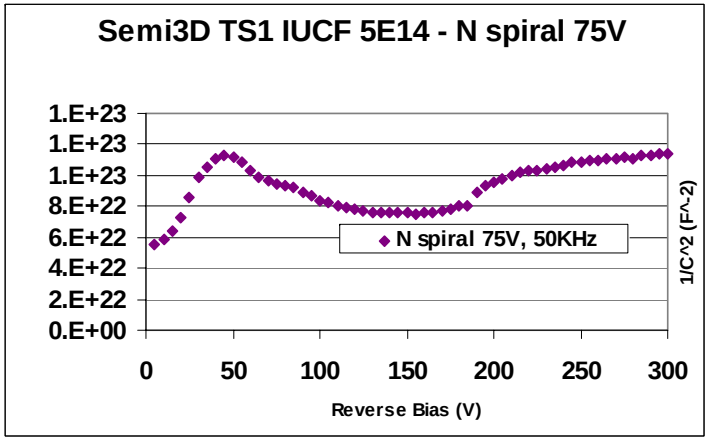
As voltage on N spiral increases the current through the N spiral decreases and current through P spiral increases until a huge channel current flows from P spiral to N spiral

CV Measurements at 10 KHz



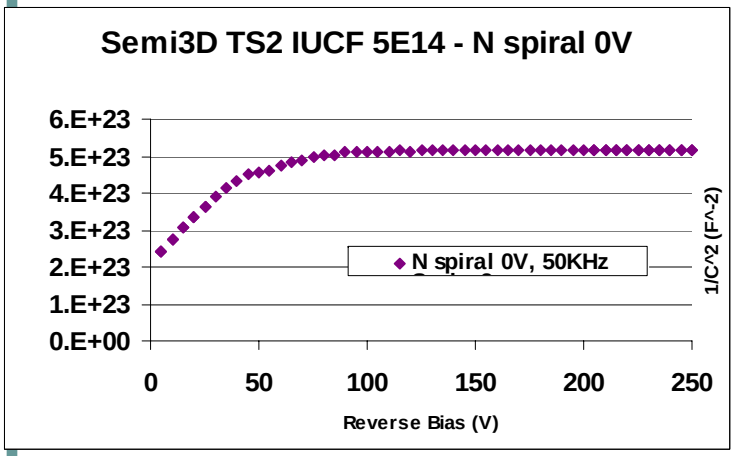


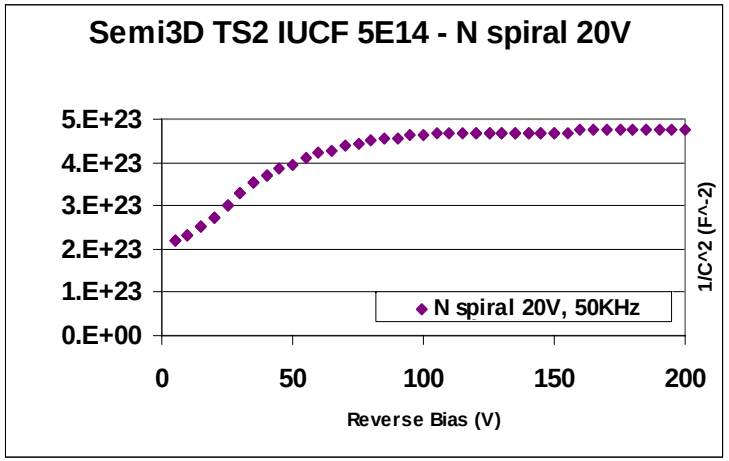


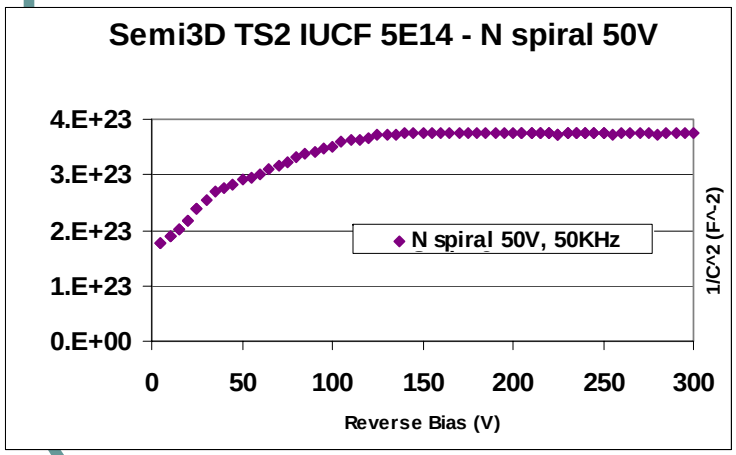


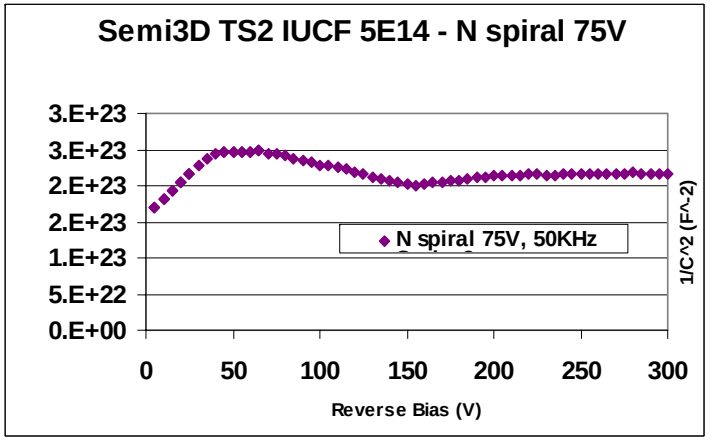
- **Depletion voltage doesn't change with voltage at N spiral.**
- **Around 70 V the channel current between P spiral and N spiral starts flowing.**

CV measurement at 50 KHz









- V_{dep} ~ 100 V
- Depletion voltage doesn't change with voltage at N spiral.
- Around 70 V the channel current between P spiral and N spiral starts flowing.

Conclusions

- First results after irradiation show that semi-3D diodes deplete at about half the expected voltage for standard silicon.
- We measure a depletion voltage of about 150 V while a standard diode would deplete at about 370 V
- More investigation needed to understand:
  - Shape of CV measurements
  - Dependency of V_{dep} on frequency
  - Depletion voltage versus voltage on the n-spiral
  - Charge collection efficiency