Status of ITC-irst activities in RD50

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Outline

Materials/Pad Detectors

• Pre-irradiated silicon - INFN Padova and Institute for Nuclear Research of NASU, Kiev;
• Detectors on MCz, Cz and Epitaxial silicon - SMART collaboration: INFN of Bari, Firenze, Padova, Perugia, Pisa and Trieste;

New detectors

• Thin Detectors - INFN of Firenze and Padova;
• 3-D detectors - Glasgow and CNM Barcelona.
Pre-irradiated material

Layout
- BaBar detector masks (single side)
- Diode + test structure

Silicon
- Fz <100> n-type 6 k\(\Omega\)
- MCz <111> n-type Okmetic >500\(\Omega\)

Pre-irradiation
- Pre-irradiation by fast neutrons at Kiev reactor, fluence \(10^{17}\) n/cm\(^2\)
- Annealing at a temperature of 850°C
- Polishing, lapping

Process
- Fz material = standard Irst (LTO, sintering@420°C)
- MCz material = No LTO and sintering @380°C.

In partnership with Kiev and INFN Padova
## Electrical Characterization

<table>
<thead>
<tr>
<th>Type</th>
<th>n</th>
<th>$V_{dep}$ (V)</th>
<th>$N_{eff}$ (10$^{11}$ cm$^{-3}$)</th>
<th>$\rho$ (kΩcm)</th>
<th>$j_D$ (µA/cm$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fz</td>
<td>1</td>
<td>reference</td>
<td>60</td>
<td>6</td>
<td>7.7</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Pre-irradiated</td>
<td>75–115</td>
<td>8–12</td>
<td>4–6</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td>70–110</td>
<td>7–11</td>
<td>4–7</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
<td>65–110</td>
<td>6.5–11</td>
<td>4–7</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td></td>
<td>70–95</td>
<td>7–9.5</td>
<td>5–6.5</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td></td>
<td>60–125</td>
<td>6–12.5</td>
<td>4–8</td>
</tr>
<tr>
<td>MCz</td>
<td>1</td>
<td>reference</td>
<td>450</td>
<td>85</td>
<td>0.55</td>
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<tr>
<td></td>
<td>1</td>
<td>Pre-irradiated</td>
<td>800</td>
<td>150</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td>490–730</td>
<td>90–140</td>
<td>0.33–0.5</td>
</tr>
</tbody>
</table>

Data from INFN Padova

In partnership with Kiev and INFN Padova
activities in progress:

diodes have been tested on wafer and cut

now:

Irradiation by:

1. 24 GeV protons at CERN;
2. Fast neutrons at Kiev and Lubljana Research Reactor;
3. 58 MeV Li ions at LNL INFN Tandem Padova.

In partnership with Kiev and INFN Padova
Run SMART

SMART collaboration: INFN groups of Firenze, Pisa, Trieste, Bari, Padova, Perugia and ITC-irst

- Test structure: diode, MOS, gated diodes, resistor, etc.
- Microstrip detectors AC coupled, poly-resistor biased

In partnership with SMART collaboration
SMART layout

5 + 5 Microstrip detectors per wafer
AC coupled, poly-resistors biased

External dimension of about 6x47mm

<table>
<thead>
<tr>
<th>Pitch</th>
<th>Implant Width</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>100</td>
<td>15</td>
<td>25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Width/pitch</th>
<th>Field Plate</th>
</tr>
</thead>
<tbody>
<tr>
<td>15/50</td>
<td>2</td>
</tr>
<tr>
<td>25/100</td>
<td>4</td>
</tr>
</tbody>
</table>
In partnership with SMART collaboration

**SMART layout**

**Square Diode**
- Area 13.6 mm²
- DIE 6x6mm
- Multiguard structure

27 per wafer

**Circular Diode**
- Area 4 mm²
- DIE 4x4mm
- Multiguard structure

10 per wafer
SMART layout

Test Structure
MOS capacitor (Poly)
Gated Diode, Capacitors, resistors, ..
DIE 6x6mm

9 per wafer

Test Structure
Diode area 4 mm2, double GR
MOS capacitor (Metal)
DIE 6x6mm

13 per wafer
Run SMART

Process
• STANDARD (LTO as passivation layer, sintering @ 420 °C)
• NO passivation, sintering @ 380 °C or @ 350 °C

Silicon
• Fz n-type 6 kΩ-cm <111>
• MCz n-type > 500 Ω-cm <100>
• Cz n-type > 900 Ω-cm <100>
• Epi ITME (50 and 75 mm 0.02 Ω-cm)

Process Status
• Process just completed

In partnership with SMART collaboration
New Detectors

• Thin Detectors
  in collab. With INFN of Firenze and Padova.

• 3-D detectors
  in collab. With Glasgow and CNM Barcelona.
Thin Detectors

- Standard process (single side)
- Silicon wet etching (TMAH Si <100>)
- From 300 μm to 50 μm

![Thin Diodes Image](image)

**Graph:**

- THICK DIODE
  - 100 μm DIODE
  - 50 μm DIODE
- square diodes (1.9 mm²)

**Graph Details:**

- **Y-axis:** $1/C^2$ [1/pF²]
- **X-axis:** Rev. Bias [V]

![Graph Image](image)
Irradiation with Li ions: depletion voltage and \( N_{\text{eff}} \)

\[
\begin{align*}
V_{\text{dep}} (V) & \approx 6 V \\
\Phi (58\text{ MeV Li/cm}^2) & \approx 6 \times 10^{12} \\
N_{\text{eff}} (\text{cm}^{-3}) & \approx 2 \times 10^{12}
\end{align*}
\]

Data from INFN Section of Padova
Thin silicon diode irradiation: leakage current

<table>
<thead>
<tr>
<th>Radiation source</th>
<th>Devices</th>
<th>Radiation Fluence</th>
<th>(\alpha) after 4 min at 80°C (A/cm)</th>
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</thead>
<tbody>
<tr>
<td>This experiment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>58 MeV Li</td>
<td>IRST (FZ) 300 µm</td>
<td>0-1.02 \times 10^{13} Li/cm²</td>
<td>(223±10)×10^{-17} A/cm</td>
</tr>
<tr>
<td>58 MeV Li</td>
<td>IRST (FZ) 100 µm</td>
<td>0-1.83 \times 10^{13} Li/cm²</td>
<td>(132±1)×10^{-17} A/cm</td>
</tr>
<tr>
<td>58 MeV Li</td>
<td>IRST (FZ) 50 µm</td>
<td>0-1.83 \times 10^{13} Li/cm²</td>
<td>(106±2)×10^{-17} A/cm</td>
</tr>
<tr>
<td>Other experiments</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>58 MeV Li</td>
<td>ST (FZ) 300 um</td>
<td>0-0.52 \times 10^{13} Li/cm²</td>
<td>(206±2)×10^{-17} A/cm</td>
</tr>
<tr>
<td></td>
<td>CNM (FZ) 280 um</td>
<td></td>
<td></td>
</tr>
<tr>
<td>58 MeV Li</td>
<td>Hamburg (Epi) 50 µm</td>
<td>0-2.12 \times 10^{13} Li/cm²</td>
<td>(114±5)×10^{-17} A/cm</td>
</tr>
<tr>
<td>1 MeV neutrons</td>
<td></td>
<td></td>
<td>4.56×10^{-17} A/cm</td>
</tr>
</tbody>
</table>

Data from INFN Padova
Thin silicon diode: future activity

- Irradiation by 24 GeV protons at CERN:
  \( \Phi = 10^{15} \text{ p/cm}^2 - 10^{16} \text{ p/cm}^2 \) (7-28 May 2004)

- Irradiation by 58 MeV Li ions at Padova:
  \( \Phi = 8 \times 10^{13} \text{ Li/cm}^2 - 16 \times 10^{13} \text{ Li/cm}^2 \) (23 May 2004)

- Comparison of the damage induced by 24 GeV protons and 58 MeV Li ions in diodes with different thickness (50\(\mu\)m - 100\(\mu\)m - 300\(\mu\)m):
  - depletion voltage;
  - leakage current density at full depletion;
  - CCE;
  - annealing characteristics.
**CCE - Florence set-up**

- It is a low noise charge integrator with
  - shaping factor = 2.4 µsec
  - ENC = (280 + 5.6C/pF)e-

- It is optimized for single channel detectors

Data from C. Tosi, E. Focardi, M. Bruzzi (INFN Firenze)
Devices under test: single diode - single guard ring

<table>
<thead>
<tr>
<th>non irradiated diodes</th>
<th>50µm</th>
<th>100µm</th>
<th>300µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.9 mm²</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>3.5 mm²</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Diodes irradiated with Li ions at 58MeV and $10^{13}$ cm⁻²
Annealing at 80°C for 4 min

<table>
<thead>
<tr>
<th>Li⁺ irradiated Diodes</th>
<th>50µm</th>
<th>100µm</th>
<th>300µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.9 mm²</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
3-D detector

- Mask: Glasgow
- CNM Barcelona: deep-trench
- Irst: process

In partnership with Glasgow and Barcelona
3-D poly and TEOS deposition

<table>
<thead>
<tr>
<th></th>
<th>Surface</th>
<th>Top</th>
<th>Bottom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poly</td>
<td>1.05µm</td>
<td>0.8µm</td>
<td>0.7µm</td>
</tr>
<tr>
<td>TEOS</td>
<td>0.96µm</td>
<td>0.7µm</td>
<td>0.6µm</td>
</tr>
</tbody>
</table>

In partnership with Glasgow and Barcelona
Metal deposition

Aluminium sputtering

Aluminium is deposited up to the first 20-30 µm

In partnership with Glasgow and Barcelona
3-D photoresist definition

Hole
- diameter 5µm
- distance 5µm

Optical Microscope

SEM picture

In partnership with Glasgow and Barcelona
3-D photoresist definition

In partnership with Glasgow and Barcelona
First results on MCz silicon at Irst

Process:
1. standard Irst process for detector realization (sintering @ 420°C)
2. no LTO deposition (sintering at 380°C)

<table>
<thead>
<tr>
<th>Process</th>
<th>Fz &lt;111&gt; n-type 6 Kohm</th>
<th>MCz &lt;100&gt; n-type &gt;0.5 Kohm</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDV (V)</td>
<td>23.2</td>
<td>&gt; 1700 estimated</td>
</tr>
<tr>
<td></td>
<td>23.9</td>
<td>367 - 450</td>
</tr>
<tr>
<td>$Q_{ox}$ (1/cm²)</td>
<td>1.56E+11</td>
<td>3.40E+11</td>
</tr>
<tr>
<td></td>
<td>2.68E+10</td>
<td>4.63E+10</td>
</tr>
<tr>
<td>$I$ @ 100V (nA/cm²)</td>
<td>0.50</td>
<td>2.67</td>
</tr>
<tr>
<td></td>
<td>0.97</td>
<td>0.78</td>
</tr>
<tr>
<td>$s_0$ (cm/sec.)</td>
<td>0.9</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>0.4</td>
<td>0.7</td>
</tr>
</tbody>
</table>

In partnership with SMART collaboration