Irradiation tests on standard and oxygenated ROSE diodes produced by ST Microelectronics and Sintef

Michael Moll
- CERN -

E.Fretwurst, M.Glaser, F.Lemeilleur, G.Lindstroem, A.Ruzin, J.Wuestenfeld, .... ROSE
Material / Diodes / Irradiations

- **Wacker silicon**
- **Different orientations:** $<111>$ and $<100>$
- **Different resistivities:** 1, 2 and 15 KΩcm
- **Diode producer:** ST Microelectronics - ROSE mask
- **Two batches:**
  - 1.) No oxygen enrichment ⇒ Standard diodes
  - 2.) Oxygen enrichment ⇒ Oxygenated diodes
    (30h or 60h at 1200°C)
- **Irradiation:** CERN PS 24GeV/c protons
ST Microelectronics - standard diodes

- Different orientations <111> and <100> and resistivities
- CV measurements before irradiation

![Graph showing capacitance vs. bias voltage for different diode orientations and resistivities.](graph.png)
ST Microelectronics - standard diodes

- Different resistivities and crystal orientations
- IV measurements before irradiation

Standard silicon : ST - Microelectronics test structures before irradiation

![IV measurement graph](image-url)
SIMS Measurements - standard samples

W330 - 1KΩ cm <100>

Concentration [at/cm³]

Depth [μm]

10E+18
10E+17
10E+16
10E+15

12C
16O
SIMS Measurements - standard samples
SIMS Measurements - standard samples

![SIMS Measurement Graph](image)

**W335 - 2KΩ cm <100>**

- Concentration [at/cm³]
- Depth [µm]

- 10E+18
- 10E+17
- 10E+16
- 10E+15

- 0.0
- 50.0
- 100.0
- 150.0

- 12C
- 16O

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SIMS Measurements - standard samples

![Graph](image)

W336 - 2KΩ cm <111>

Concentration [at/cm³]

Depth [µm]

- 1.0E+18
- 1.0E+17
- 1.0E+16
- 1.0E+15

12C
16O

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SIMS Measurements - standard samples
Oxygenated and Standard diodes

**Diodes produced by ST Microelectronics (Catania, Italy)**

<table>
<thead>
<tr>
<th>ID</th>
<th>Wafer</th>
<th>Silicon</th>
<th>Orientation</th>
<th>rho [KΩcm]</th>
<th>Treatment</th>
<th>SIMS [O]</th>
<th>SIMS [C]</th>
<th>IRR-scenario</th>
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<tbody>
<tr>
<td>W301-T</td>
<td>5&quot;</td>
<td>Wacker</td>
<td>&lt;111&gt;</td>
<td>1,03</td>
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<td>3,20E+15</td>
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<td>2,10E+15</td>
<td>PS-11/99 5</td>
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<td>Wacker</td>
<td>&lt;111&gt;</td>
<td>15</td>
<td>reference</td>
<td>8,60E+15</td>
<td>8,40E+15</td>
<td>PS-11/99 1</td>
</tr>
</tbody>
</table>

be careful with the ratio [O]/[C] - [C] close to or below detection limit !!!!
SIMS Measurements - oxygenated samples

Wacker <111> - ST 30/60h at 1200C

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ST Microelectronics - standard diodes

- Different resistivities and crystal orientations

![Graph showing the relationship between \( N_{\text{eff}} \) and \( \Phi_{\text{proton}} \). The graph includes data points for different crystal orientations and resistivities.]
ST Microelectronics - Standard diodes

- Different resistivities and crystal orientations
- Neutron irradiation (Ljubljana) + 4min annealing at 80°C

![Graph showing depletion voltage vs neutron flux](image)

**ST Microelectronics - Standard Silicon**

- 5K <111> W339 n
- 2K <100> W335 n
- 2K <111> W336 n
- 1K <100> W330 n
- 1K <111> W333 n
ST Microelectronics - standard diodes

- Different resistivities and crystal orientations
- \( \alpha \) - value taken at depletion voltage

\[
\begin{array}{c|c|c}
\text{Crystal Orientation} & \text{Resistivity} & \text{Data Code} \\
\hline
\langle 111 \rangle & 15 \, \text{K}\Omega \text{cm} & \text{W339} \\
\langle 111 \rangle & 1 \, \text{K}\Omega \text{cm} & \text{W333} \\
\langle 100 \rangle & 1 \, \text{K}\Omega \text{cm} & \text{W330} \\
\langle 111 \rangle & 2 \, \text{K}\Omega \text{cm} & \text{W336} \\
\langle 100 \rangle & 2 \, \text{K}\Omega \text{cm} & \text{W335} \\
\end{array}
\]
ST Microelectronics - oxygenated diodes

- Different orientations <111> and <100>

![Graph showing different orientations <111> and <100> for ST Microelectronics oxygenated diodes.]
ST Microelectronics - oxygenated diodes

- Different resistivities and crystal orientations

![Graph showing the relationship between proton dose and effective density](image-url)
Comparison: standard and oxygenated diodes

- Oxygen enriched diodes do not show a big variation in $V_{dep}$
Sintef diodes
Material / Diodes / Irradiations

- Topsil silicon
- Orientations: <100>
- Resistivity: 1KΩcm
- Diode producer: Sintef - ROSE mask
- Two batches:
  - 1.) No oxygen enrichment ⇒ Standard diodes
  - 2.) Oxygen enrichment ⇒ Oxygenated diodes
    (80h at 1150°C)
- Irradiation: CERN PS 24GeV/c protons
Sintef - standard and oxygenated diodes

- No difference between oxygenated and standard diode?
SIMS Measurements - oxygenated samples

![Graph showing T08 - 80h 1150C diffusion](image)

**Concentration [at/cm^3]**

- Orange line: 12C
- Blue line: 16O

**Depth [μm]**

- 0,0
- 50,0
- 100,0
- 150,0
- 200,0

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SIMS Measurements - standard samples

![Graph showing concentration vs. depth for T12 standard diode with two lines representing different isotopes: 12C and 16O.](image)

- Concentration [at/cm³]
- Depth [µm]

- 1.0E+18
- 1.0E+17
- 1.0E+16
- 1.0E+15

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Conclusion

• Sintef and ST Microelectronics std/oxygenated diodes tested with 24 GeV/c protons

• All oxygenated diodes found to be “radiation hard” !!
  \[\Rightarrow\] A high oxygen content \([O] > 1 \times 10^{17}\) cm\(^{-3}\) leads to “radiation hardness”.

• Strong variation of radiation hardness of “standard” diodes !
• Material with a low oxygen content \([O] \approx 1 \times 10^{16}\) cm\(^{-3}\) can be “radiation hard”
  \[\Rightarrow\] Is the ratio between O and C - concentration determining the radiation hardness of the silicon diodes ?