P-spray implant optimization for p-type microstrip detectors
-Status of the RD50 calibration run-

C. Fleta, M. Lozano, G. Pellegrini, K. Vatter, F. Campabadal, J. M. Rafí and M. Ullán

Instituto de Microelectrónica de Barcelona
IMB-CNM (CSIC)
Spain

3th June 2005
Background

- IMB-CNM to process wafers for the Collaboration
- P-in-N and N-in-P
- Mask set designed by RD50
- Insulation between strips provided only by p-spray (no p-stops)

- Optimize the p-spray parameters before processing the RD50 wafers
  - Complete simulation process (ISE-TCAD)
    - Test run to check simulation results
  
  Wafer 1: 25 keV, $10^{12}$ cm$^{-2}$  
  Wafer 2: 25 keV, $1.4 \times 10^{12}$ cm$^{-2}$  
  Wafer 3: 25 keV, $2 \times 10^{12}$ cm$^{-2}$  
  Wafer 4: 30 keV, $10^{12}$ cm$^{-2}$  
  Wafer 5: 35 keV, $10^{12}$ cm$^{-2}$  
  Wafer 6: 45 keV, $10^{12}$ cm$^{-2}$

P-spray implant oxide thickness = 150 nm
## Simulations: I-V

<table>
<thead>
<tr>
<th>P-spray</th>
<th>B peak (cm(^{-3}))</th>
<th>B total (cm(^{-2}))</th>
<th>(V_{BD}) (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wafer 1</td>
<td>25 kev, 10(^{12}) cm(^{-2})</td>
<td>3.80(\times)10(^{15})</td>
<td>3.01(\times)10(^{11})</td>
</tr>
<tr>
<td>Wafer 2</td>
<td>25 kev, 1.4(\times)10(^{12}) cm(^{-2})</td>
<td>5.32(\times)10(^{15})</td>
<td>4.22(\times)10(^{11})</td>
</tr>
<tr>
<td>Wafer 3</td>
<td>25 kev, 2(\times)10(^{12}) cm(^{-2})</td>
<td>7.59(\times)10(^{15})</td>
<td>6.02(\times)10(^{11})</td>
</tr>
<tr>
<td>Wafer 4</td>
<td>30 kev, 10(^{12}) cm(^{-2})</td>
<td>4.13(\times)10(^{15})</td>
<td>3.56(\times)10(^{11})</td>
</tr>
<tr>
<td>Wafer 5</td>
<td>35 kev, 10(^{12}) cm(^{-2})</td>
<td>4.30(\times)10(^{15})</td>
<td>3.85(\times)10(^{11})</td>
</tr>
<tr>
<td>Wafer 6</td>
<td>45 kev, 10(^{12}) cm(^{-2})</td>
<td>4.44(\times)10(^{15})</td>
<td>4.09(\times)10(^{11})</td>
</tr>
</tbody>
</table>

- \(V_{BD}\) decreases as implanted dose increases.

![Simulated I-V](image)
Simulations: strip insulation

- Inversion layer at full depletion?

- Higher p-spray doses to avoid surface inversion on heavily irradiated devices, but $V_{BD}$ decreases
  - Compromise solution
  - Strip insulation is not the major concern in irradiated detectors
    - More complete simulations needed
Wafer characteristics

- New wafers from Siltronic
- <100>, p-type, 300 ± 15 μm
- $\rho$ (nominal) = 30 kΩ.cm, $\rho$ (measured) = 20 kΩ.cm
Fabricated devices
Electrical characterization

- Microstrips of wafers 1 to 5:
  - Very high leakage currents (mA/cm² @ 10 V)
  - Do not fulfill the requirements for radiation detectors
Electrical characterization

- **Wafer 6**
  - Leakage current $\sim \mu A/cm^2$
  - $V_{BD} > 600 V$
  - $V_{FD} = 46 \pm 5 V \rightarrow \rho = 17 \pm 2 \, k\Omega.cm$
Electrical characterization

- Verify strip insulation
  - Measurement of the resistance between two consecutive microstrips
  - Surface is clearly inverted

~250 MΩ for a N-in-P with P-stops
Oxide charge measurement

- Simulated devices: $Q_{ox} = 10^{11} \text{ cm}^{-2}$. Overestimated oxide quality?

- C-V measured in test structure (MOS capacitor)
  - Agreement with the simulated curve for $Q_{ox} = 2.5 \times 10^{10} \text{ cm}^{-2}$
  - Another reason for the bad electrical performance
Spreading resistance measurements

- Total implanted dose lower than the predicted by simulations
  - Wafer 6: 70% of the expected dose
  - Wafer 5: 9%
Second calibration run

- Higher implant energies with the lowest dose ($10^{12}$ cm$^{-2}$)
  - 45 keV (= wafer 6)
  - 60 keV
  - 75 keV
  - 90 keV

- 4 more wafers: same p-spray parameters, less thermal stress
  - Field oxide low-T deposited
Second calibration run

- Defective wafers from Siltronic
  - P-spray implant oxide thicker in some areas (irregular wafer surface)
  - Will affect the implant profile

- Could this be the reason for the bad results of the previous run?
  - Wafers from the same provider but a different batch
  - Did not detect anything unusual during the first process
Conclusions

- Calibration runs to optimize the p-spray implant parameters in N-in-P detectors
  - First run: p-spray profiles lower than expected
    - Implantation doses near the technical limit of the ion implanter. Calibration error?
    - Wrong predictions by process simulator?
    - Defective wafers?
    - ...?
  - Second run:
    - Oxide thickness not uniform due to irregular wafer surface
    - Still not finished

- What we have learnt so far...
  - Not sure of the suitability of the p-spray for heavily irradiated devices
    - Compromise between reasonable $V_{BD}$ and good strip insulation
    - More complete studies needed
  - P-spray seems to be very sensitive to fabrication details
    - Alternative technologies?