New Approaches to HEP Sensors at CiS
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Bias rail alternatives

- **proposed solution**

  • idea: implementation of „fuses“
    • very thin metal traces on top of the final passivation
    • sensor test with short-cutted pixel matrix

  Removal of fuses afterwards:
  • very short etching step
  • laser
  • melting by applying high currents
Bias rail alternatives

- dummy fuse tests

- first tests of “burning” fuses successful
- but: problems with thickness of metal layer
  - 25, 50, 150, 300 nm thickness
  - too thin for needle: sometimes metal melted/scratched contact point
  - no issue though: pads were only for proof of principle
- additional test on prototype (2nd wafer run): wet etching!
Bias rail alternatives

- etching tests: FIB analysis

Metal rail (fuse) clearly visible

Fuse etched away

Twice the etching time of "etched"
Bias rail alternatives

Etching tests: results

- Etching successful
- Very promising: even with significant over etching acceptable
- With new layout promising cheap alternative
- More reproducible and cleaner than burning out (as expected)
Bias rail alternatives

- sensor wafer run: variants

- Bias rail over bump openings
- Bias rail opposite of bump openings (same position as punch through in conventional FE-I4)
- With pads for needle prober access
Bias rail alternatives

**summary**

- Burning tests with dummy wafer run expectedly not very reliable
- Etching tests very promising: reproducible results with low risk of failure
- Sensor wafer run being finished this week

Outlook:
- Initial characterization: is temporary metal suitable for IV-measurements?
- Flip chipping with FEs and glass wafer dummies
- Tests with x-ray source
Active edges

- reduction of inactive sensor edge by doping of side walls
- several parameters are varied
  - p- and n-type bulk
  - sensor thickness (300 & 100µm)
  - three side wall doping methods
  - trench widths
- numerous edge designs had been simulated
  - most promising ones were implemented in the layout
Active edges

- ICP trench etching step was challenging
- didn’t have much experience up to now
- dummy trials to adjust etching parameters
- optimized the etching homogeneity at the wafer edge
- most of the side walls look fine
Active edges

Photomicrographs of a wafer run showing optimization of trench geometry.
Active edges

**L** wafer run: CV measurements

<table>
<thead>
<tr>
<th></th>
<th>Thickness [µm]</th>
<th>$V_{\text{depl}}$ [V] Calcul.</th>
<th>$V_{\text{depl}}$ [V] measured</th>
<th>$V_{\text{op}}$ [V]</th>
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</thead>
<tbody>
<tr>
<td>p-Type</td>
<td>300</td>
<td>&lt;190</td>
<td>130</td>
<td>170</td>
</tr>
<tr>
<td>p-Type</td>
<td>100</td>
<td>&lt;21</td>
<td>&lt;20</td>
<td>50</td>
</tr>
<tr>
<td>n-Type</td>
<td>320</td>
<td>70...115</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>n-Type</td>
<td>100</td>
<td>7...11</td>
<td>&lt;20</td>
<td>50</td>
</tr>
</tbody>
</table>

- Measured $V_{\text{depl}}$ fit to calculated values
- Thick wafers $V_{\text{depl}}$ up to 130V
- Thinned wafers $V_{\text{depl}}$ as low as 20V
Active edges

\[ \text{wafer run: IV measurements} \]

- Random selection, measured manually
- Excellent results
- No breakthroughs under 200V for most diodes

- Systematic automatic measurement
- Inconsistencies between curves
- Majority of sensors break through at \(~80...120V\)

- Manual Cross-Check
- Early breakthroughs remain
- Assumption: sensors were affected/damaged irreversibly by automatic prober
Active edges

L wafer run: implantation variants

Leakage currents @ 70V

- No significant differences between 4QI and PIII
- BBr$_3$: Faktor 10 (p-type) ... 5 (n-type) smaller
- Matches doping profiles
- Otherwise substrate material more influence
- n-type material of inferior quality?
Active edges

Summary

- Technological development & processing of active edge sensors successful
- Even after obviously damaged (by automatic prober), thinned sensors have excellent yield with up to 90% for $d_e=50\mu m$
- Significant reduction in yield only for $d_e=30\mu m$
- No disadvantages with thinned sensors
- Implantation Variants:
  - **4QI**: Reliable and reproducible, no disadvantages with larger angles
  - **PIII**: IV results good, doubts concerning doping profiles (susceptible to mechanical defects?)
  - **BBBr$_3$**: many advantages in principle (high and deep doping, lower leakage currents)
Trench detectors and 3D

new project sneak peak

3D-sensor process
Planar „trench detector“ process

Aim: establish 3D-sensor processing at CiS while developing a versatile prototyping technique for variable geometries
Summary

CiS is developing several different technologies to be able to cope with future HL-LHC challenges

• Active Edge project completed

• Alternative biasing methods for pixels: sensor wafer run to be finished

• New project: 3D processing
Backup etching tests

Metal rail (fuse) clearly visible

Fuse etched away

Twice the etching time of „etched“