PQC studies for HPK bulk resistivity problem

- Measurements of the depletion voltage of diodes for HPK sets with high substrate resistivity
  - constance of resistivity within a set
  - variation of resistivity across the wafer
- Comparison with the sensor depletion voltage
  - Is it possible to base the acceptance criteria on the sensor depletion voltage?
DIODE IN THE STANDARD MOON
\[d = 4.0 \text{ cm}\]

DIODE 2
\[d = 5.7 \text{ cm}\]

DIODE 3
\[d = 6.3 \text{ cm}\]

DIODE 4
\[d = 6.3 \text{ cm}\]

Active area = 3.1 cm
Active area = 5.9 cm

\[d = \text{distance from the center of the wafer}\]
DIODE IN THE STANDARD MOON
\[ d = 4.2 \text{ cm} \]

DIODE 3
\[ d = 6.3 \text{ cm} \]

DIODE 2
\[ d = 4.6 \text{ cm} \]

DIODE 4
\[ d = 6.3 \text{ cm} \]

N.B. In the IB2 wafer Diode 2 is closer to the center with respect to IB1

d = distance from the center of the wafer

Active area = 5.9 cm
Active area = 3.1 cm
Assuming a depletion depth equal to 290 m and a constant resistivity across the wafer we get the following relations:

Depletion voltage on the diode (V) (KΩ cm)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>90</td>
<td>3.25 *</td>
</tr>
<tr>
<td>100</td>
<td>2.93</td>
</tr>
</tbody>
</table>

* Present upper limit on the substrate resistivity for thin sensors
Average SET PERUGIA 23: 95.2 V
Average batch 246001: 95.5 V
Average batch 248006: 93.8 V

**Standard Moon Diode**

**CV on Diode SET PERUGIA 23 (IB2)**

- **Batch 246001**
- **Batch 248006**

- **V_depl [V]**

A. Macchiolo, Sensor Meeting, Tracker Week, 16th July 2003
Average : 88.2 V

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Standard Moon Diode

CV on Diode SET PERUGIA 30 (IB2)

Average SET Perugia 30: 80.4 V
Average Batch 312012: 87.1 V
Average Batch 312011: 93.1 V
Average Batch 248006: 69.5 V
In the IB2 wafer Diode 2 has in average a depletion voltage close to the Standard Moon diode since they have a similar distance from the center.

**Averages**

- **Standard Moon:** 110.3 V
- **Diode 2:** 106.6 V
- **Diode 3:** 93.2 V
- **Diode 4:** 91.6 V
Averages

Standard Moon: 72.4 V
Diode 2: 70.5 V
Diode 3: 62.8 V
Diode 4: 65.7 V

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Averages

Standard Moon: 85.7 V
Diode 2: 78.7 V
Diode 3: 73.7 V
Diode 4: 77.2 V

In the IB1 wafer Diode 2 has a larger distance from the center with respect to the Standard Moon diode.
Again substrates with low depletion voltage and high resistivity in the last weeks (IB2 and W3 sensors)

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Comparison between the depletion voltages on the diodes and on the sensors

A semi-analytical solution of the Poisson equation predicts:

\[ V_{\text{sensor}} = V_{\text{diode}} + 2 \frac{p}{d} f \left( \frac{w}{p} \right) \]

In the case of the IB2 sensor: \( V_{\text{sensor}} = 1.26 \text{ V}_{\text{diode}} \)

(assuming a constant resistivity across the wafer)

\[ f \left( \frac{w}{p} \right) = f(0.25) = 0.32 \]

\( w = 30 \text{ m} \) \hspace{1cm} Width of the strip p+ implant

\( p = 120 \text{ m} \) \hspace{1cm} Strip pitch

\( d = 290 \text{ m} \) \hspace{1cm} Depletion depth


A. Macchiolo, Sensor Meeting, Tracker Week, 16\textsuperscript{th} July 2003
$V_{\text{depl of sensors}}$ vs $V_{\text{depl of diodes}}$

From the fit:

$V_{\text{sensor}} = V_{\text{diode}} \times 1.49$

Average of the measurements on the sensors for each bin of the diode depletion voltage:

$V_{\text{sensor}} = 1.49 \, V_{\text{diode}}$

$V_{\text{sensor}} = 1.26 \, V_{\text{diode}}$

IB2

127 entries
**IB1 (HPK)**

Data fit

\[ V_{sensor} = 1.14 \text{ V}_\text{diode} \]

Theory

\[ V_{sensor} = 1.17 \text{ V}_\text{diode} \]

![Graph showing data and theory fit for IB1 (HPK)]

**W5A (HPK)**

Data fit

\[ V_{sensor} = 1.35 \text{ V}_\text{diode} \]

Theory

\[ V_{sensor} = 1.17 \text{ V}_\text{diode} \]

![Graph showing data and theory fit for W5A (HPK)]

Pisa 42, first IB1 set sent by HPK
OB2 (STM)

Data fit

$V_{\text{sensor}} = 1.35 \, V_{\text{diode}}$

Theory

$V_{\text{sensor}} = 1.23 \, V_{\text{diode}}$

OB1 (STM)

Data fit

$V_{\text{sensor}} = 1.50 \, V_{\text{diode}}$

Theory

$V_{\text{sensor}} = 1.15 \, V_{\text{diode}}$

198 entries

40 entries
If we want to infer the relation between the depletion voltage of the diode and of the corresponding sensor we have to accumulate much more statistics for IB1 and W1 wafers. At the moment the entries in the DB common to PQC and QTC are
40 for IB1
1 for W1

For W1-TEC and W1-TID it is difficult to disentangle the contribution of the resistivity varying across the wafer and the geometrical factor because the distance of the Standard Moon diode from the centre of the wafer is larger than the average distance for the corresponding sensor (i.e. the diode resistivity is not representative of the sensor one).