Metrology Methods for Analysis of Advanced Junctions: Advances in SIMS Characterization of Shallow B, P, As Distributions in Si

Temel Büyüklimanli, John Marino, Ihab Abdelrehim, Ming Hong Yang, Jeff Mayer, Bob Hengstebeck and Charles Magee

Acknowledgements: John Borland, Steve Walther, Dick Hockett and Wilfried Vandervorst

The "Moving Target" of ULE Implants

- Ten years ago, the ITRS Roadmap for Semiconductors listed the junction depth for the source/drain extensions of transistors as 100nm.
- Today, leading-edge chipmakers are fabricating devices with source/drain extension $X_j$ of 11nm.
- For future devices, (22nm node and beyond???), source/drain extensions are expected to be less than 7nm.
- EAG has closely monitored this progression and taken the initiative to refine its SIMS protocols to meet the ever-increasing challenges of these measurements.

![Graph: Implant Energy Versus $X_j$](image)

- **B**
- **BF$_2$**
- **BF$_3$**

- **Boron**

- 500eV B Implant Analyzed Without O$_2$ Flooding

- Yield enhancement from surface oxide
- "Adventitious Carbon" layer
- Native oxide
NRA is the only technique we can use to confirm SIMS results, but NRA only gives a total dose with no profile shape/Xj information.

Near surface B profile is not representative...but it reflected best practice at the time (1996)

PCOR-SIMS™
The EAG Difference

Point-by-Point Correction for RSF and Sputter rate changes with composition:

PCOR-SIMSSM

Accurate Concentration
Accurate Depth (Xj)
Accurate Interface definition (SiO2/Si)

500eV Boron implant into SiO2/Si

Data from both techniques match in the oxide, Si and ACROSS THE SiO2/Si INTERFACE

ERDA data provided by Prof. Wilfried Vandervorst

500eV B ion implantation comparison

500eV BF2 implant (112eV B)

2nm/decade

What about dose accuracy if B concentrations are at Atom%?
PLASMA DOPED Poly-Si

Dose measurement comparison

B CONCENTRATION (atoms/cc)

DEPTH (nm)

PCOR-SIMS

TEM of Plasma-doped Poly-Si

Annealed samples

Elastic Recoil Detection (ERD)

Depth Profile of Annealed B Implant

W. Vanderer et al. SIMS-XIII Proceedings
**PCOR-SIMS** Analysis of Annealed Sample

Boron Peaks at the Interface

---

**O2-Flood SIMS Protocol**

---

Although implanted with same energy Xj's of 1E15 and 5E14 doses are different!

No difference in Xj Between 1E15 and 5E14!!

Routine SIMS data Xj difference is due to oxide thickness difference

---

**Routine SIMS**

**Protocol Comparison**

---
**Arsenic**

3keV As implanted into 5nm Oxide Quantified using the PCOR-SIMS^®

- As (correct in SiO\(_2\) & Si)
- As (correct in SiO\(_2\))
- As (correct in Si)

**Phosphorous**

Plasma P implant

Comparison of 2kV As implant (AMAT P3i)

---Routine-SIMS (3.1E15/cm\(^2\))
---PCOR-SIMS (3.0E15/cm\(^2\))

Routine-SIMS vs. PCOR-SIMS comparison
Protocol Comparison

Comparison of 400 eV P 1E15 implant

<table>
<thead>
<tr>
<th>Depth (nm)</th>
<th>P Concentration (atoms/cc)</th>
<th>O Intensity (arbitrary units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10^17</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>10^18</td>
<td>100</td>
</tr>
<tr>
<td>10</td>
<td>10^19</td>
<td>10</td>
</tr>
<tr>
<td>15</td>
<td>10^20</td>
<td>100</td>
</tr>
</tbody>
</table>

Routine SIMS (2.0E15/cm²)

Xj@5E18=7.2nm

PCOR-SIMS_HDRSM (9.0E14/cm²)

Xj@5E18=5.6nm

PCOR-SIMS_HDRSM

MOST ADVANCED SIMS ANALYSIS PROTOCOL

106eV B implants after 1325°C anneal

Dose loss in oxide

Inactive excess B concentration

Xj measured from the oxide/Si interface

Profile abruptness

John Borland, Insight 2009