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

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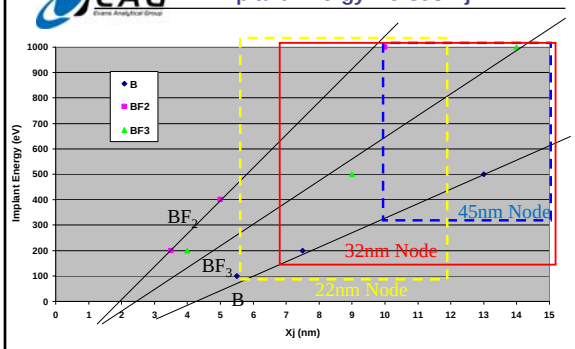
Acknowledgements: John Borland, Steve Walther, Dick Hockett and Wilfried Vandervorst

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.

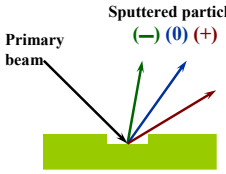
- EAG has closely monitored this progression and taken the initiative to refine its SIMS protocols to meet the ever-increasing challenges of these measurements.

Implant Energy Versus Xj



Borland, Semiconductor International, Dec. 2006, p.49

Basic Sputter Process



- **Only a few % of sputtered particles are ionized.**
- **Matrix has a strong effect on ionization probability of particles leaving the surface.**

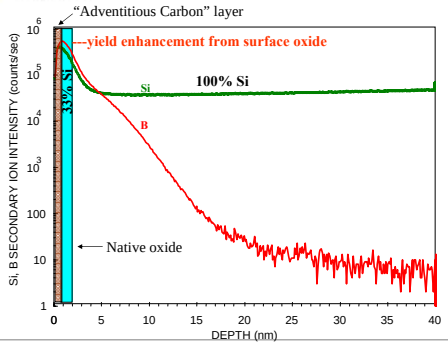
B quantification in Si

$$^{i}[B]^{Si} = \frac{RSF^{Si} \times {}^{i}I_{B}}{{}^{i}I_{Si}}$$

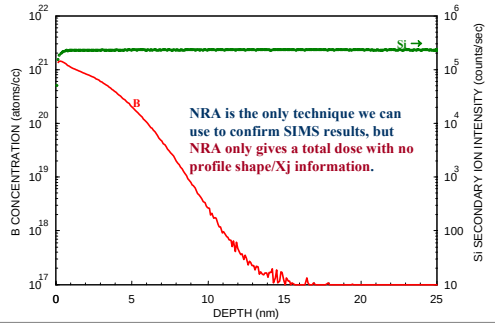
Sputter Rate = (Known depth)/(Total Analysis time)
Depth (*i*) = Sputter Rate x Time (*i*)

Boron

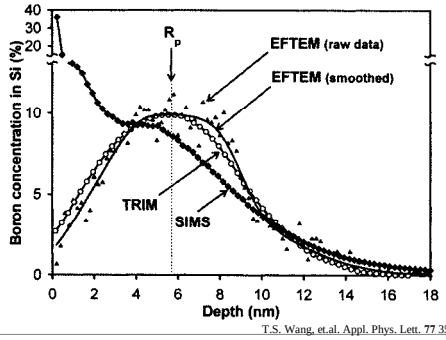
500eV B Implant Analyzed Without O_2 Flooding



500eV B Implant Analyzed With O_2 Flooding (circa: 1996)

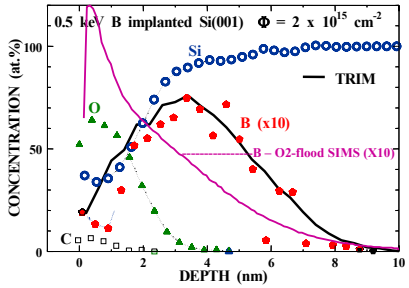


Energy Filtered TEM Analysis of 1keV B implant: Comparison with SIMS



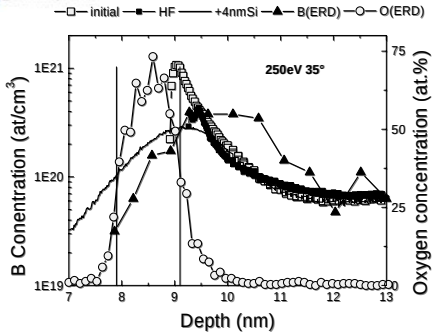
T.S. Wang, et.al. Appl. Phys. Lett. **77** 3586 (2000)

High Resolution RBS Depth Profile



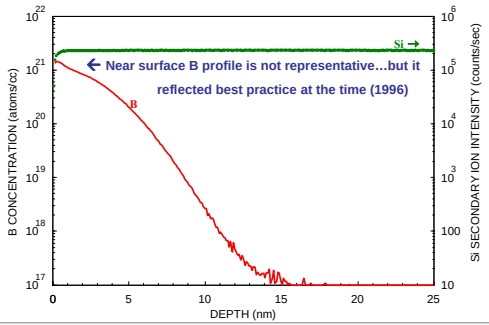
Kimura et al. Curr. Appl. Phys. 3 (2003) 9-11

Elastic Recoil Detection (ERD) Depth Profile of Annealed B Implant



W.Vandervorst et.al. SIMS-XIII Proceedings

500eV B Implant Analyzed With Old SIMS Protocol



PCOR-SIMS℠

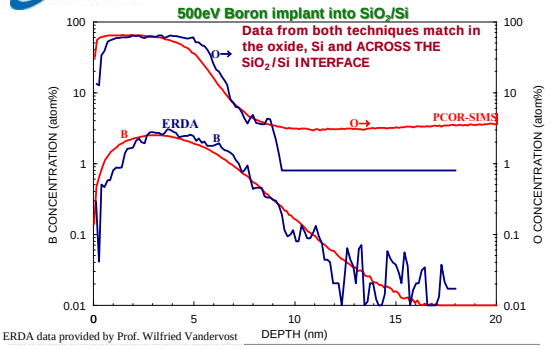
The EAG Difference

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

PCOR-SIMS℠

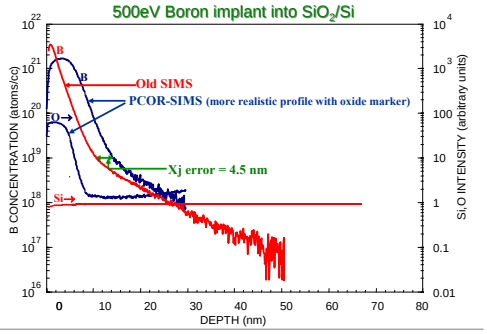
Accurate Concentration
Accurate Depth (Xj)
Accurate Interface definition (SiO2/Si)

PCOR-SIMS℠ and Elastic Recoil Detection Analysis (ERDA) data comparison

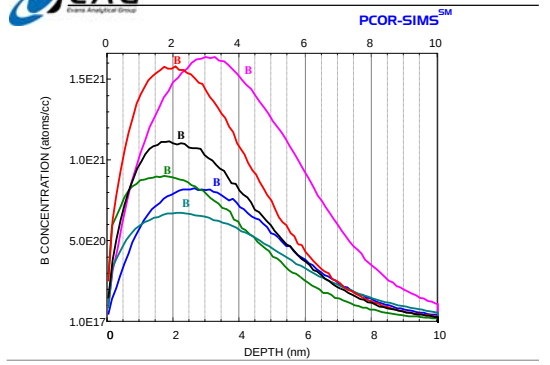


ERDA data provided by Prof. Wilfried Vandervost

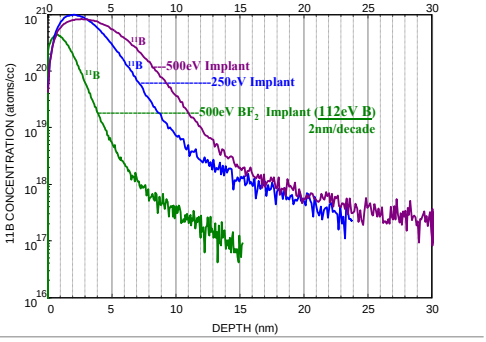
PCOR-SIMS℠ and Old SIMS Protocol comparison of as-implanted sample



500eV B ion implantation comparison

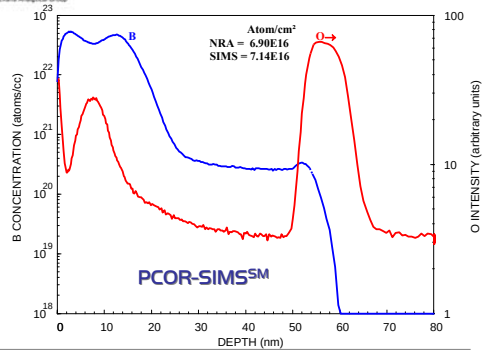


Ion Implant Energy Comparison Using PCOR-SIMS℠ Protocol

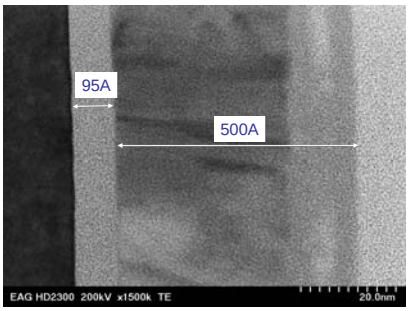


What about dose accuracy if B concentrations are at Atom%?

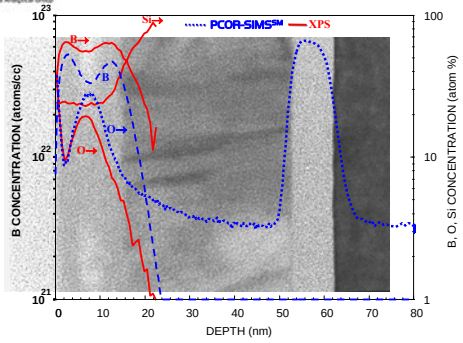
PLASMA DOPED Poly-Si
Dose measurement comparison



TEM of Plasma-doped Poly-Si

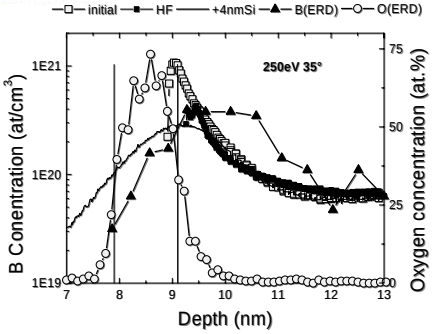


PLASMA DOPED Poly-Si



Annealed samples

Elastic Recoil Detection (ERD)
Depth Profile of Annealed B Implant



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Elastic Recoil Detection (ERD)
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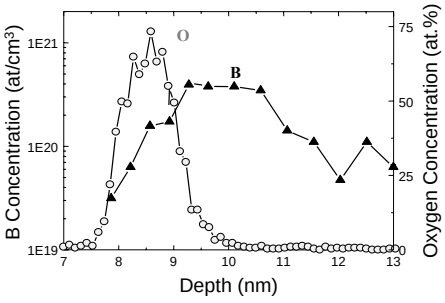

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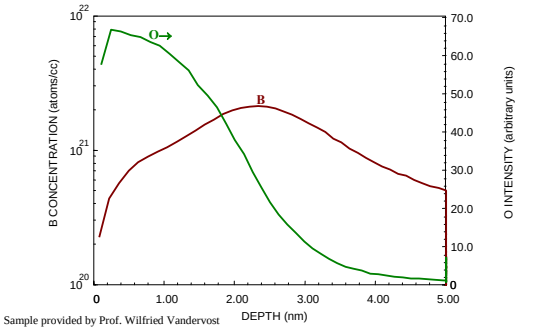
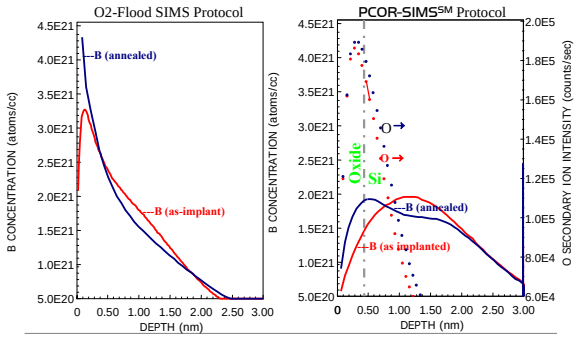
PCOR-SIMS℠ Analysis of Annealed Sample Boron Peaks at the Interface



Sample provided by Prof. Wilfried Vandervost

250eV B Implant Before and After Short Anneal

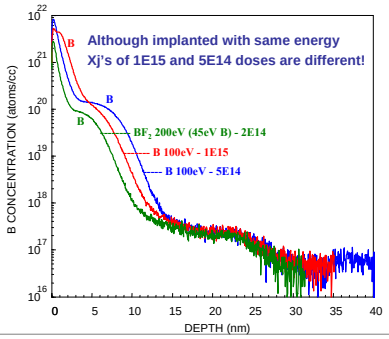


100eV Boron implants

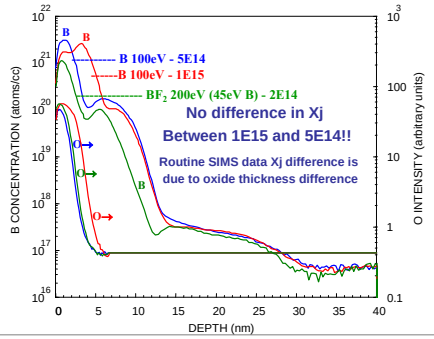
PCOR-SIMS℠ with High Depth Resolution

PCOR-SIMS_HDR℠

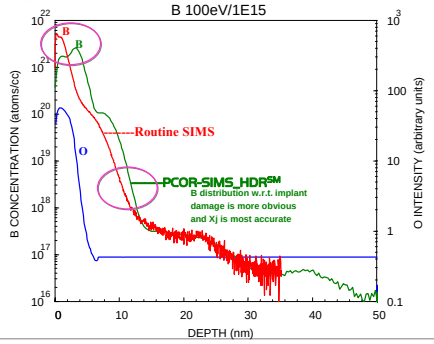
Routine SIMS



PCOR-SIMS_HDR℠

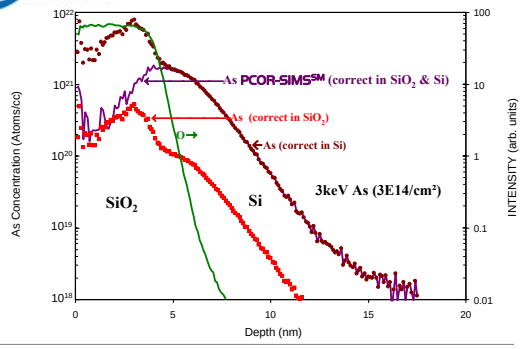


Protocol Comparison

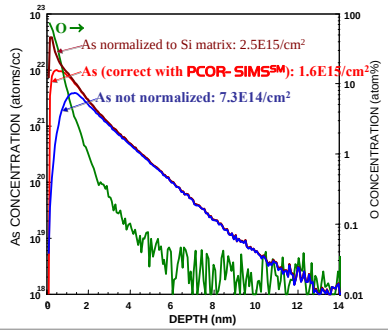


Arsenic

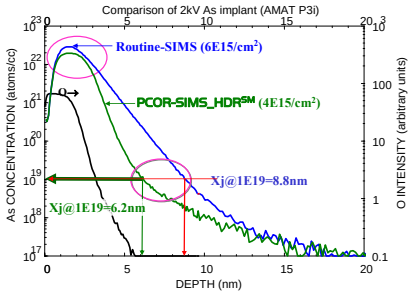
3keV As implanted into 5nm Oxide Quantified using the PCOR-SIMS℠



Plasma Implant Quantified Using the PCOR-SIMS℠ Protocol

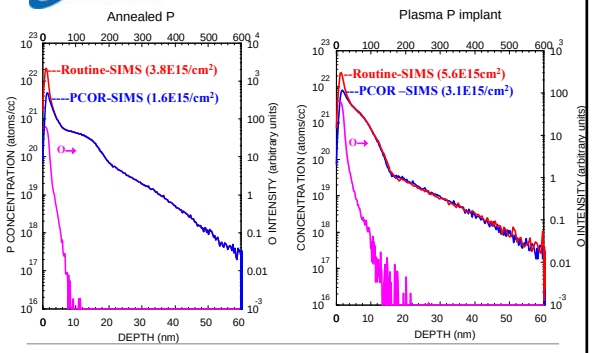


Protocol Comparison

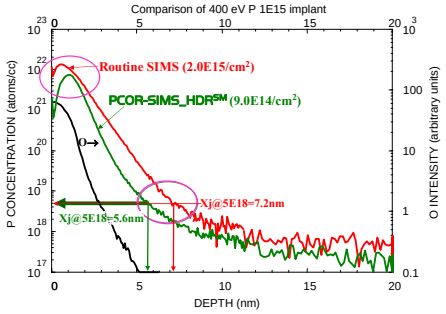


Phosphorous

Routine-SIMS vs. PCOR-SIMS comparison



Protocol Comparison



PCOR-SIMS_HDR℠

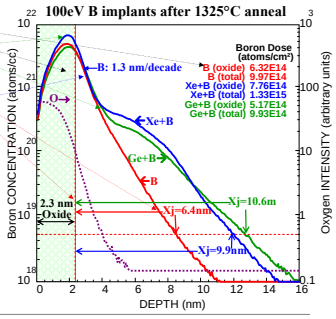
MOST ADVANCED SIMS ANALYSIS PROTOCOL

Dose loss in oxide

Inactive excess B concentration

Xj measured from the oxide/Si interface

Profile abruptness



John Borland, Insight 2009