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.

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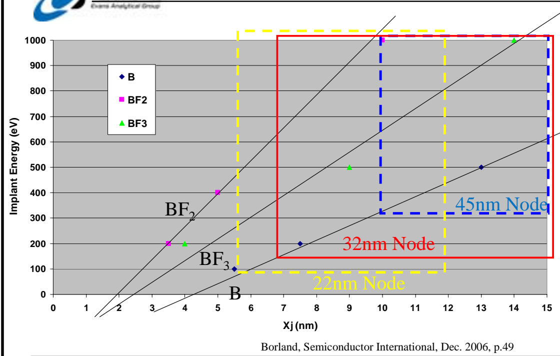
Implant Energy Versus Xj



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

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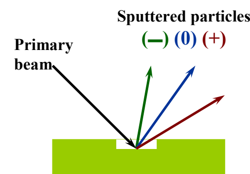
Basic Sputter Process



- 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*)

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Boron

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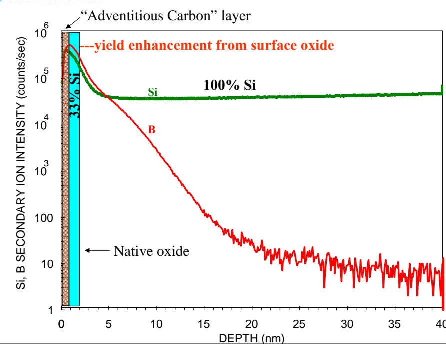
500eV B Implant Analyzed Without O_2 Flooding



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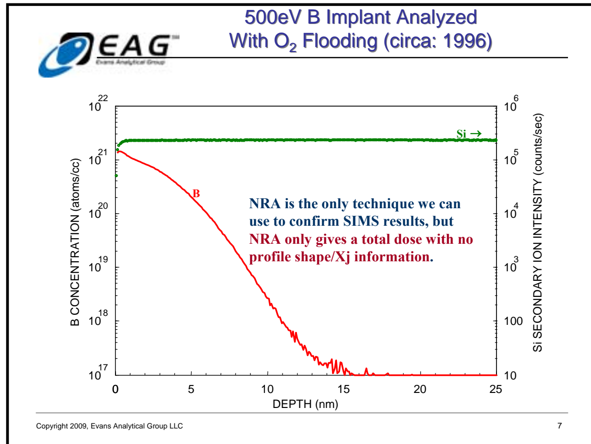

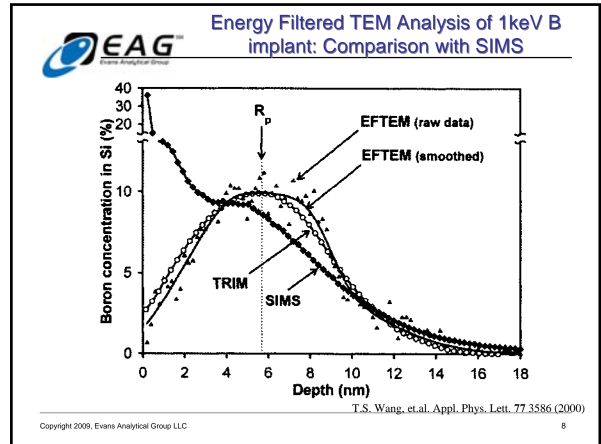

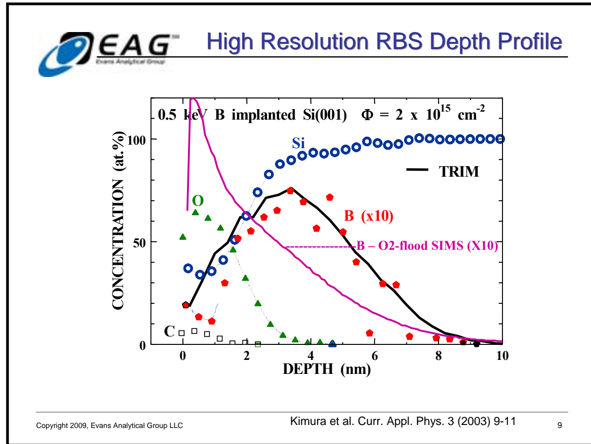

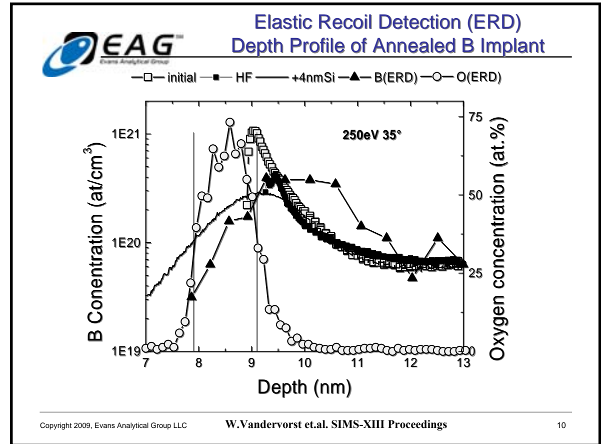

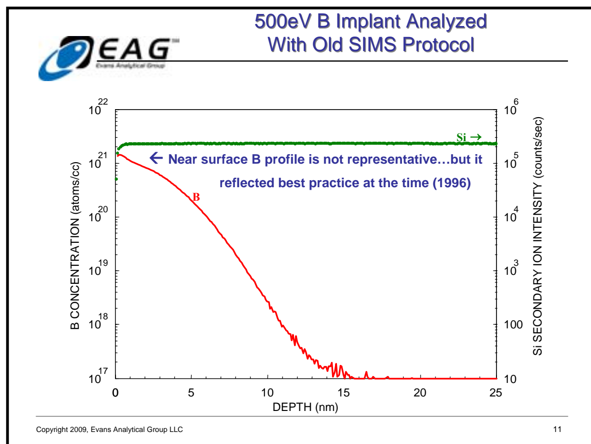

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PCOR-SIMS^{SM}

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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)

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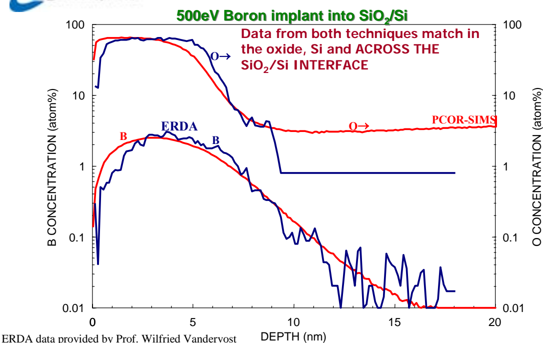
PCOR-SIMS℠ and Elastic Recoil Detection Analysis (ERDA) data comparison



ERDA data provided by Prof. Wilfried Vandervost

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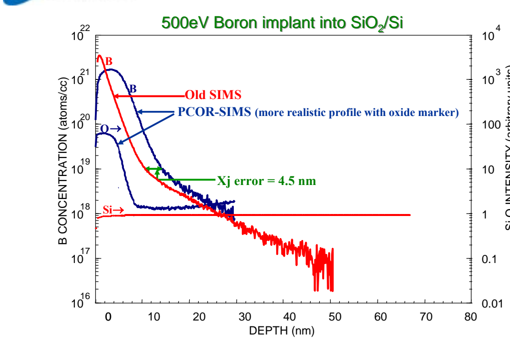
PCOR-SIMS℠ and Old SIMS Protocol comparison of as-implanted sample



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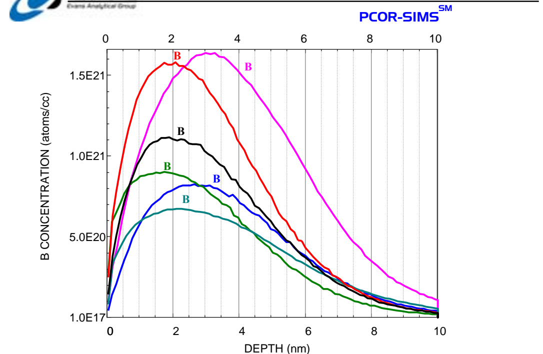
500eV B ion implantation comparison



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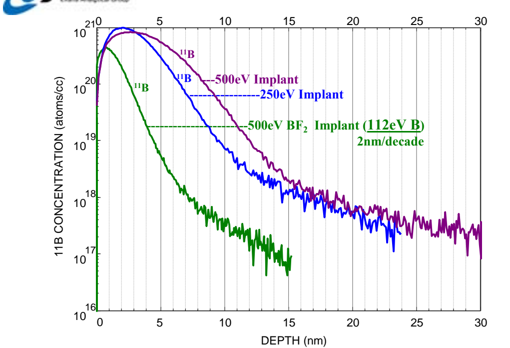
Ion Implant Energy Comparison Using PCOR-SIMS℠ Protocol



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

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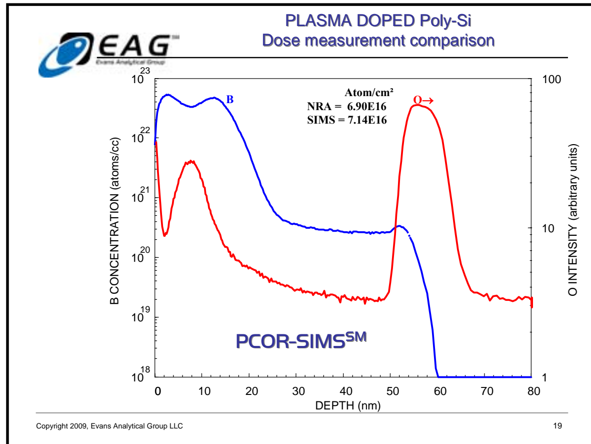

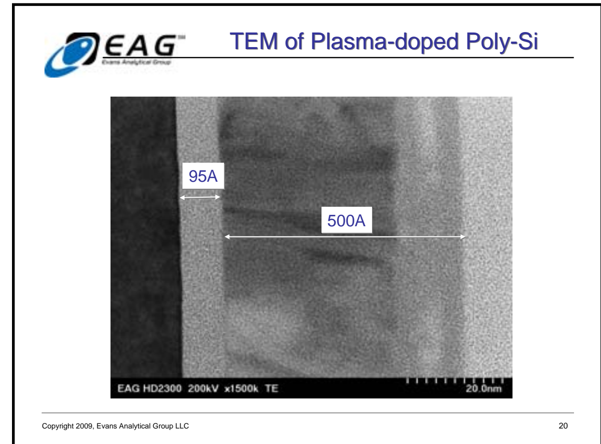

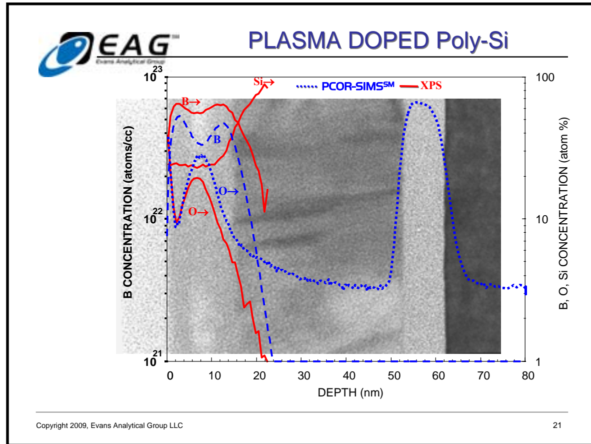

Annealed samples

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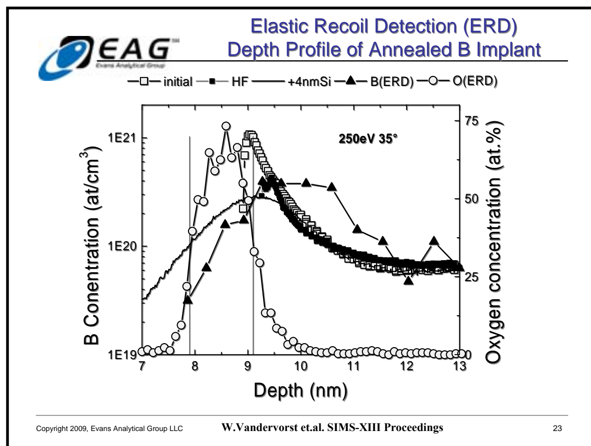
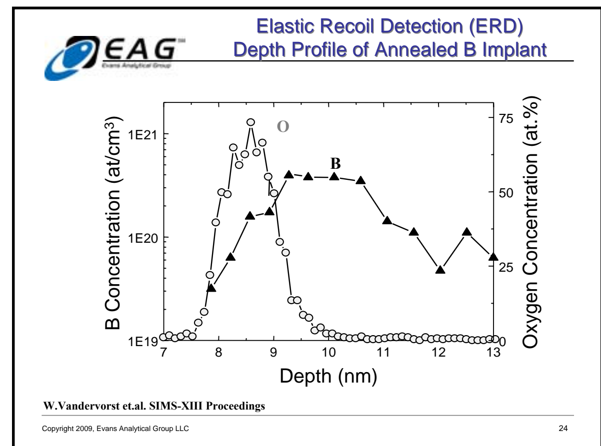
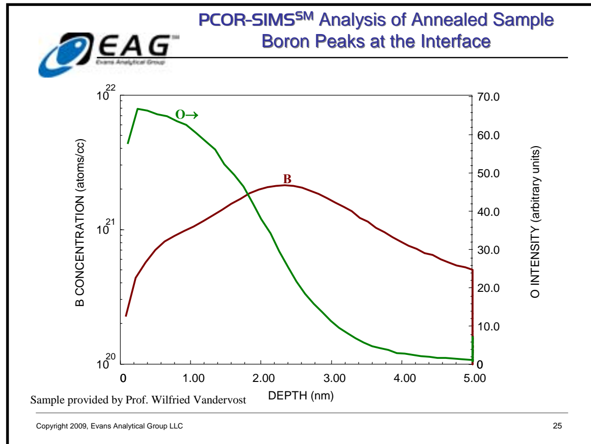




PCOR-SIMS^{SM} Analysis of Annealed Sample
Boron Peaks at the Interface



Sample provided by Prof. Wilfried Vandervost

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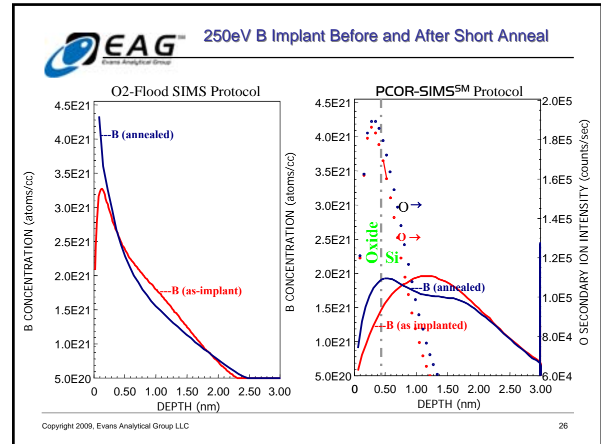
250eV B Implant Before and After Short Anneal



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100eV Boron implants

PCOR-SIMS^{SM} with High Depth Resolution

PCOR-SIMS_HDR^{SM}

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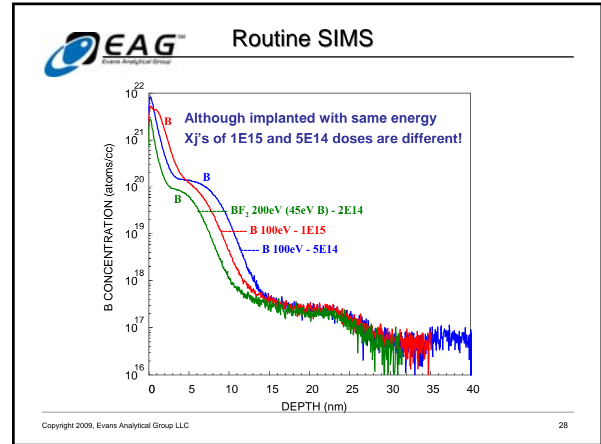
Routine SIMS



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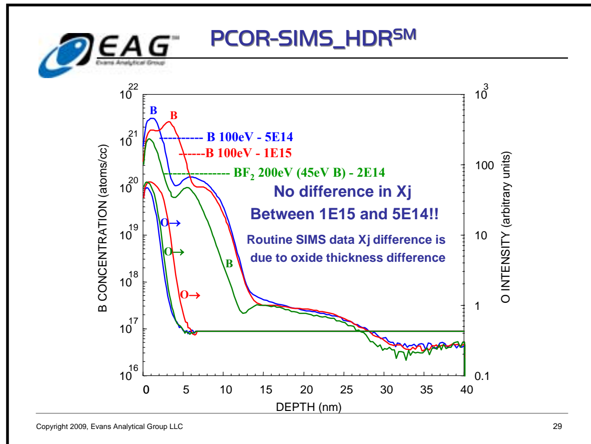
PCOR-SIMS_HDR^{SM}



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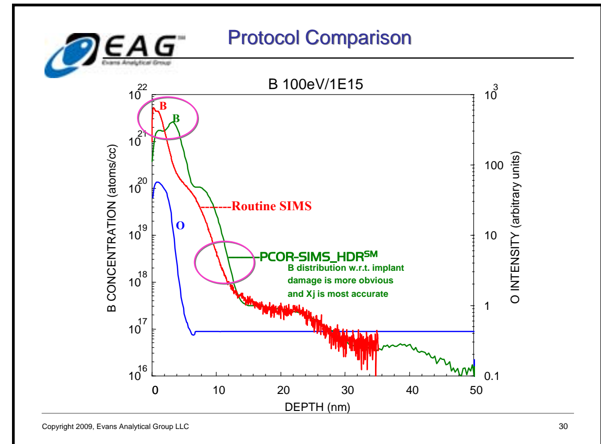
Protocol Comparison



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Arsenic

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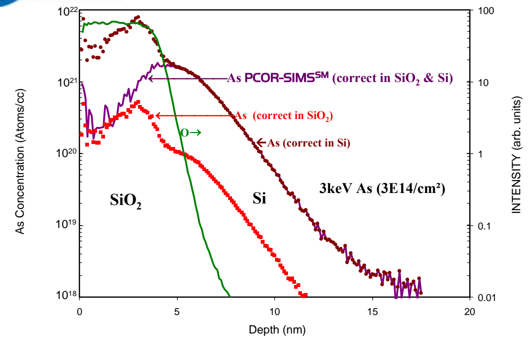
3keV As implanted into 5nm Oxide Quantified using the PCOR-SIMS℠



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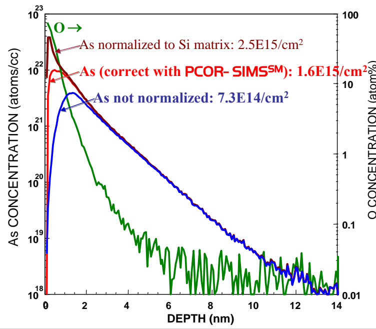
Plasma Implant Quantified Using the PCOR-SIMS℠ Protocol



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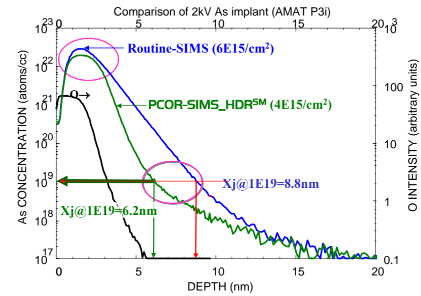
Protocol Comparison



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Phosphorous

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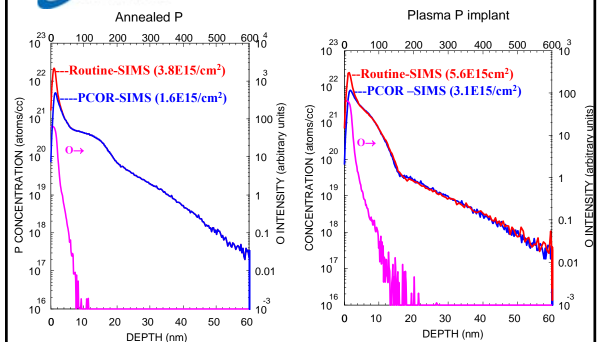
Routine-SIMS vs. PCOR-SIMS comparison



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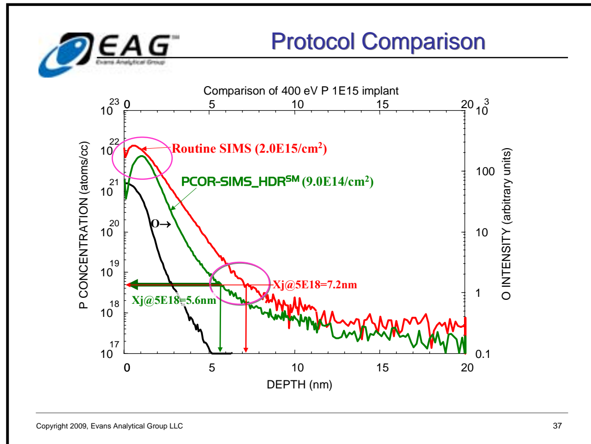
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Protocol Comparison
Comparison of 400 eV P 1E15 implant
Routine SIMS (2.0E15/cm2)
PCOR-SIMS_HDRSM (9.0E14/cm2)
O→
Xj@5E18=7.2nm
Xj@5E18=5.6nm
P CONCENTRATION (atoms/cc)
O INTENSITY (arbitrary units)
DEPTH (nm)
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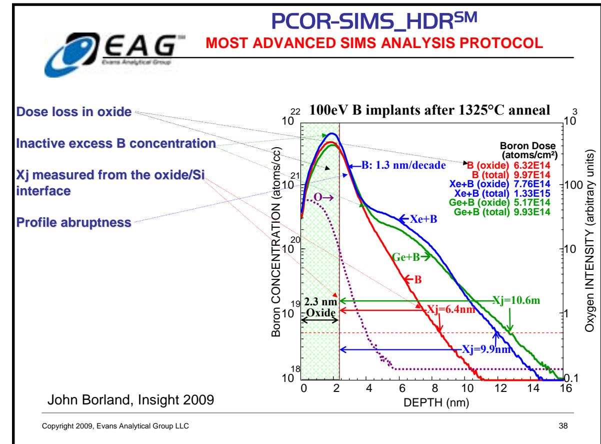
37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PCOR-SIMS_HDRSM
MOST ADVANCED SIMS ANALYSIS PROTOCOL
Dose loss in oxide
Inactive excess B concentration
Xj measured from the oxide/Si interface
Profile abruptness
100eV B implants after 1325°C anneal
B: 1.3 nm/decade
Boron Dose (atoms/cm2)
B (oxide) 6.32E14
B (total) 9.97E14
Xe+B (oxide) 7.76E14
Xe+B (total) 1.33E15
Ge+B (oxide) 5.17E14
Ge+B (total) 9.93E14
O→
Xe+B
Ge+B
B
2.3 nm Oxide
Xj=10.6m
Xj=6.4nm
Xj=9.9nm
Boron CONCENTRATION (atoms/cc)
Oxygen INTENSITY (arbitrary units)
DEPTH (nm)
John Borland, Insight 2009
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38