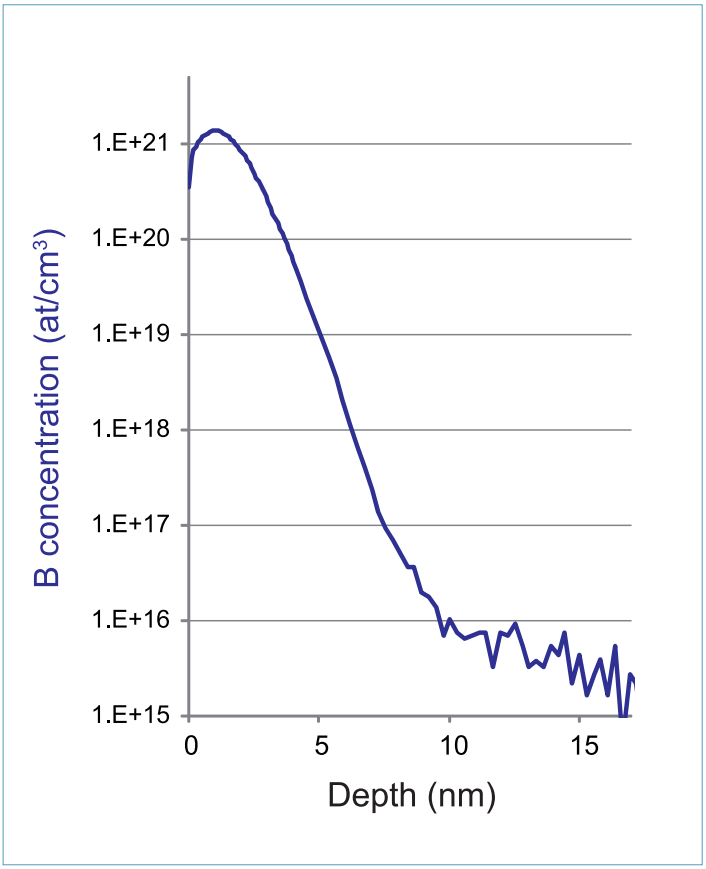
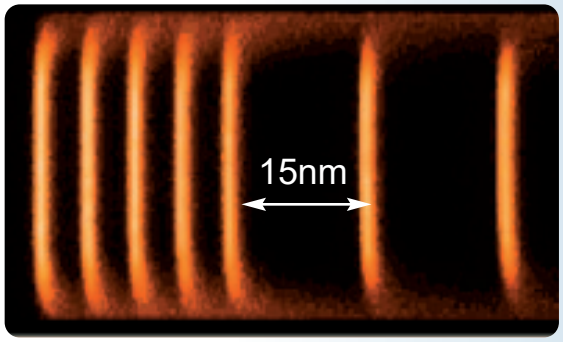
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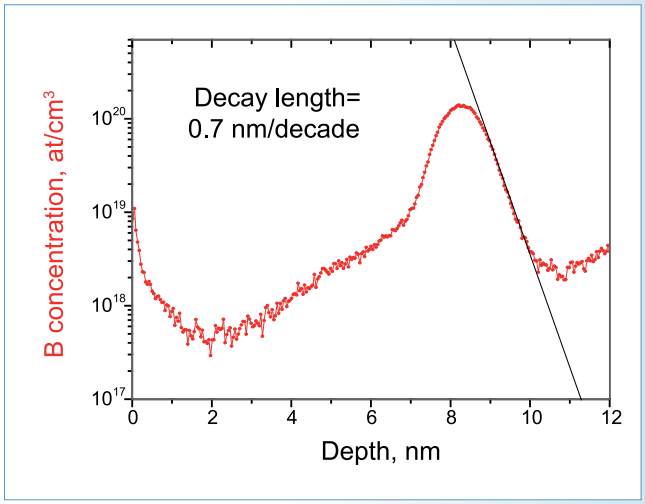
APPLICATION NOTE #SIMS-007

EXLIE SIMS

Thin Film Metrology and Ultra Shallow Implant Monitoring with EXtreme Low Impact Energy







High throughput profiling at sub-nanometer depth resolution with the IMS Wf/SC Ultra

The IMS Wf & SC Ultra:

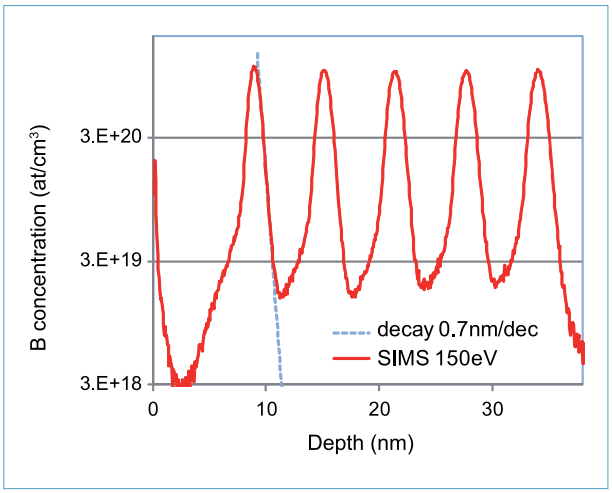
EXtreme Low Impact Energy to ensure high resolution depth profiling.

The continuous scaling down of CMOS devices pushes the limits of junction depths below the 10nm range, with a profile steepness of 1-2nm per decade, imposing severe challenges to characterization techniques. At such a scale, the SIMS technique can be used to monitor in-depth distributions of elements and dopants, provided that SIMS profiles can be measured with a **depth resolution better than 1nm per decade**.

This can only be achieved by using **very low energy primary ion bombardment**: that is, energies significantly lower than those applied so far (300-500 eV) are mandatory. There are 2 main limitations to implementing **EX**treme **L**ow **I**mpact **E**nergy (EXLIE) sputtering conditions for SIMS:

- a dramatic drop in sputter yield is observed with impact energies below 250eV,
- SIMS instruments have been optimized for operating with energies > 300eV, therefore, their primary ion columns do not deliver high current densities at lower impact energies, and only extremely low sputter rates (~0.1nm/mn) are available.

Recent innovations on the **IMS Wf** and **SC Ultra Cs^+ and O_2^+ ion sources** have **improved the primary beam density** at very low impact energies, thereby providing access to **sputter rates of several nm/min** for both Cs^+ and O_2^+ at 150eV.



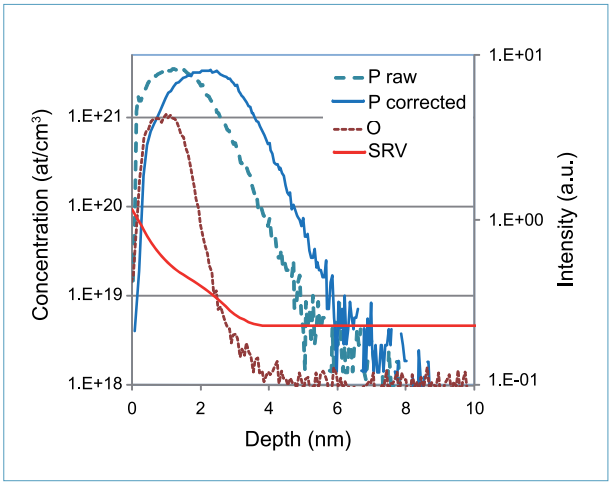
Analysis of five Boron delta-layers in epitaxial grown Si with the CAMECA IMS Wf under EXLIE conditions. The profile demonstrates that a 150eV impact energy may combine sub-nm depth resolution with the capability of measuring in-depth profiles over tens of nm.

Achieving accurate dopant quantification thanks to WinCurve's new depth scale correction feature.

Lowering the impact energy of primary ions is a required but not sufficient condition to get access to accurate dopant distribution at the near surface.

In order to improve the accuracy of the depth scale calibration, the variation of the Sputter Rate both at the surface (sputtering transient) and at the SiO_2/Si interface (matrix effect) must be taken into account. For this purpose, a concept of a **Sputter Rate Variation** (SRV) must be applied to the **depth scale calibration procedure**, consisting of a point-to-point SR correction.[1]

This depth scale correction method is implemented in a new version of the CAMECA data processing software, WinCurve. The accuracy of the resulting depth scale can be evaluated by comparing SIMS profiles obtained under different sputtering conditions (Cs^+ and O_2^+) with quantitative HR-RBS and ERDA data.

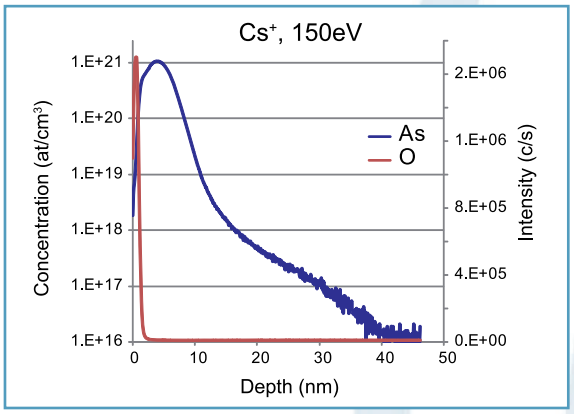


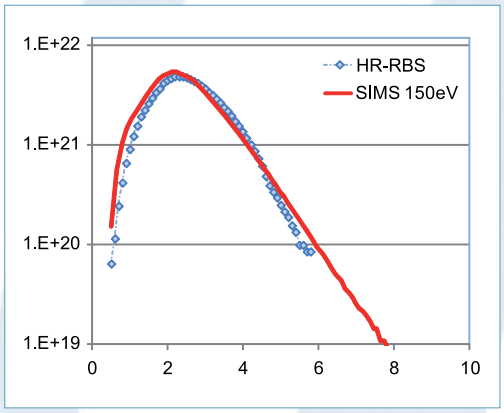
[1] *A. Merkulov et al, Advanced secondary ion mass spectroscopy quantification in the first few nanometer of B, P, and As ultra shallow implants, J. Vac. Sci. Technol. B 28, C1C48 (2010)*

The benefits of EXLIE conditions are shown for **shallow implants profiles** of As and B.

The data below show that the use of very low impact energies does not affect the dynamic range of the elements of interest, and therefore allows **accurate profile quantification**.

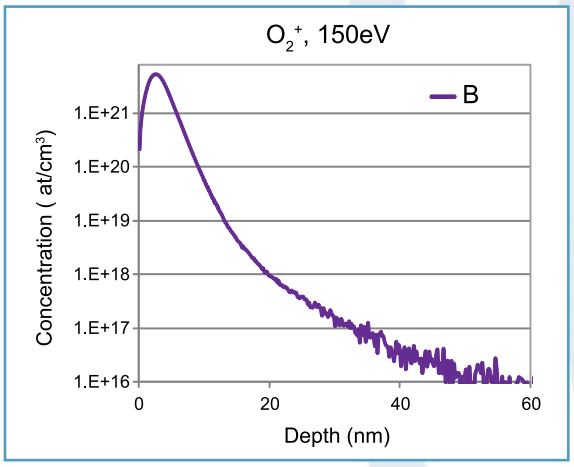
Arsenic

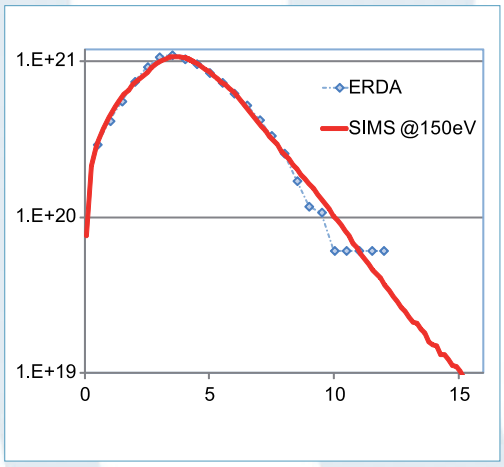




SIMS results for this As profile show good agreement with HR-RBS data.

Boron

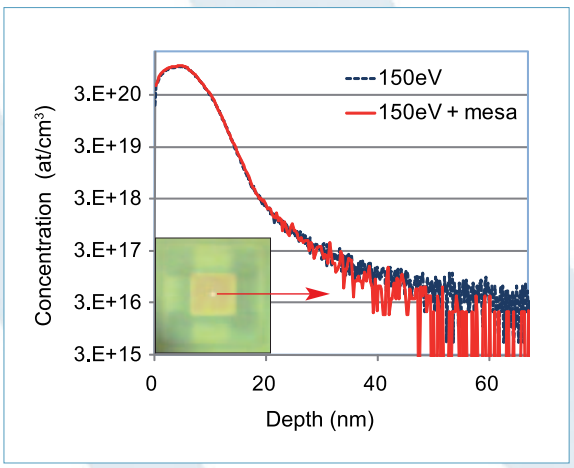




SIMS results for this as-implanted B profile using EXLIE conditions are comparable with ERDA profile.

Even more challenging is the analysis of structures with small lateral dimensions.

The capabilities of EXLIE conditions are further challenged when analyzing a structure with small lateral dimension such as test patterns. At very low energies, primary ion beam focusing on the surface is limited. **High dynamic range depth profiles could suffer from crater edge effects** during small-area analysis.
However, sample preparation using the so-called **MESA technique significantly improves the dynamic range in small pattern depth profiles**. The figure on the right shows such an improvement for a 100µm analysis area while sputtering with 150eV primary beam. A trench around the pattern is removed using a higher energy for better throughput. A new software option enables **fully automated MESA preparation** prior EXLIE profiling on the **IMS Wf** & **SC Ultra**.



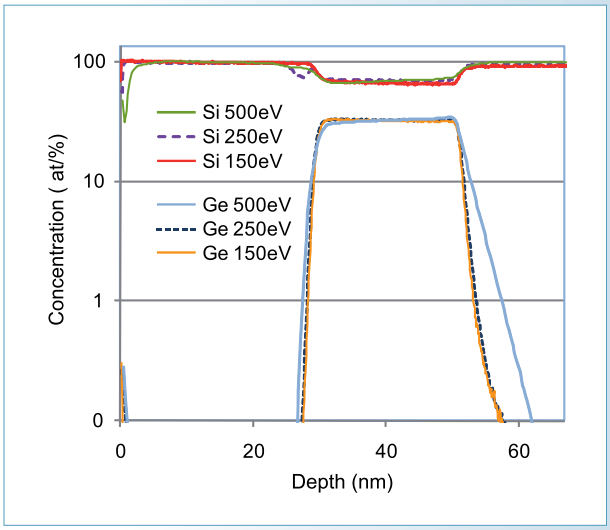
EXLIE SIMS enables the analysis of ultra thin films with ppm detection limits and sub-nanometer depth resolution.

SiGe layers

Depth profiling with ultimate sensitivity thanks to EXtreme Low Impact Energy SIMS.

Recent research confirms that the use of **EXLIE conditions minimizes SIMS artifacts at the near surface regime as well as interfaces** associated with sputter and ion yields variation.

This is demonstrated in the figure on the right presenting results for a SiGe layer at three different O_2^+ impact energies including 150eV. The profile overlay confirms the reduction of transient sputtering processes when the energy decreases. **Depth resolution is continuously improved while reducing the impact energy.** The decay length measured on SiGe/Si interface @50nm was 4.6-1.8-1.5nm/decade for energies 500-250-150eV, respectively.



The CAMECA IMS Wf/SC Ultra is the only EXLIE SIMS instrument delivering simultaneously sub-nanometer depth resolution, high dynamic range, and good sample throughput for advanced semiconductor applications.

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