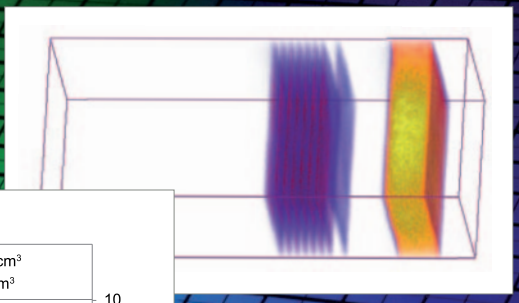
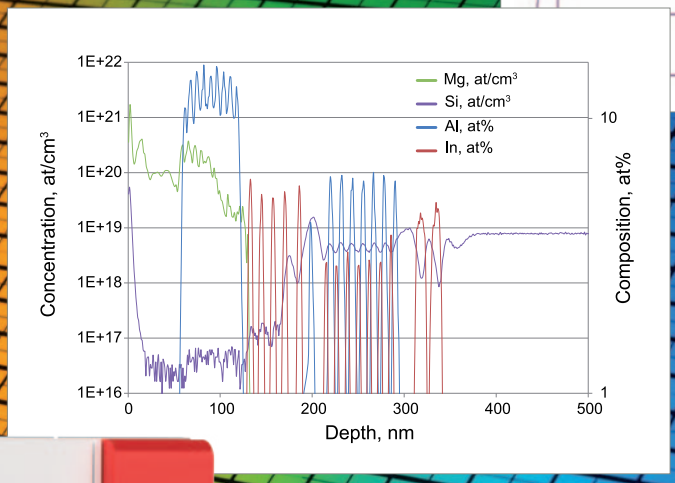
CAMECA®
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IMS Wf & SC Ultra

High Performance Ultra Low Energy SIMS for Advanced Semiconductors

*IMS Wf & SC Ultra: The CAMECA **EXLIE* SIMS** Advantage.*

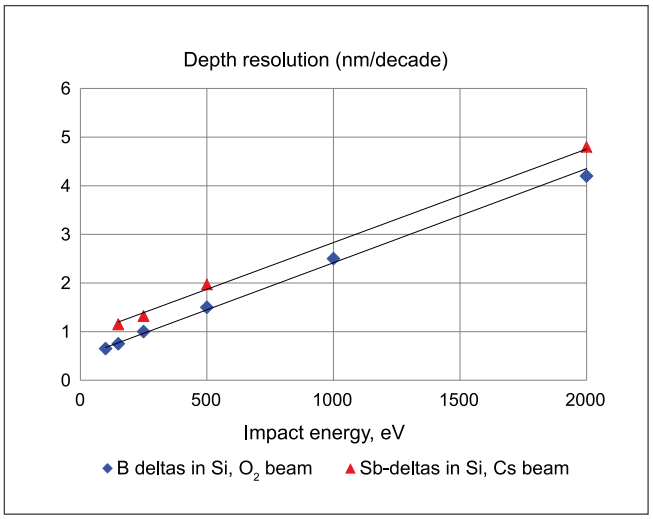
The **IMS Wf** and the **SC Ultra** are the only Secondary Ion Mass Spectrometers to offer a large range of impact energies (150eV to 13keV) with no compromise on mass resolution and primary beam density, thus ensuring unequalled analytical performance at high throughput for all types of semiconductor materials.

The continuous scaling down of semiconductor devices pushes the limits of junction depths below the 10nm range, with a dopant 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.

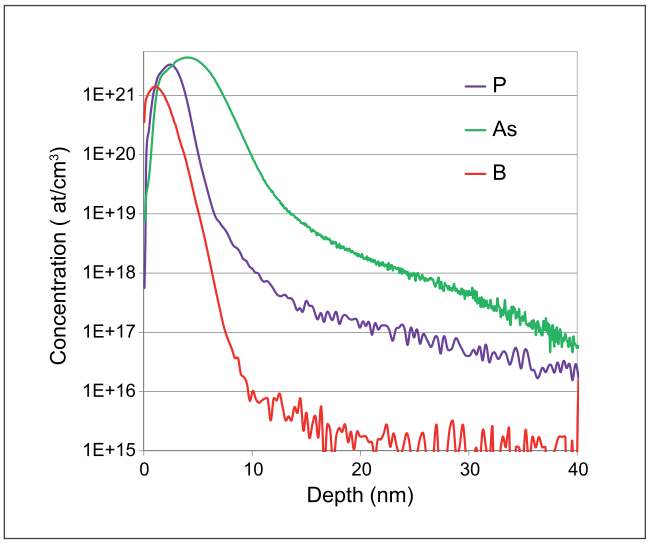
The CAMECA **IMS Wf** and **SC Ultra** magnetic sector SIMS are equipped with state-of-the-art Cs^+ and O_2^+ ion sources offering optimized primary beam density at very low impact energies and thereby providing access to sputter rates of several nm/min for both Cs and O_2 at 150eV, making them tools of choice for high throughput profiling at sub-nanometer depth resolution.

The accuracy of the EXLIE SIMS depth profiles has been evaluated by comparing SIMS profiles obtained under different sputtering conditions (Cs^+ and O_2^+) with quantitative NRA, RBS, HR-RBS and ERDA data. See «Advanced secondary ion mass spectroscopy quantification in the first few nanometers of B, P, and As ultra shallow implants», A. Merkulov et al., J. Vac. Sci. Technol. B 28, C1C48 (2010).

***EX**treme **L**ow **I**mpact **E**nergy



Depth resolution strongly depends on impact energy of sputtering beam. Depth resolution is evaluated using monolayer (delta) doped periodic structures with few nanometres spacing (5-10nm) between doped layers (B for O_2 primary beam/ Sb for Cs primary beam).

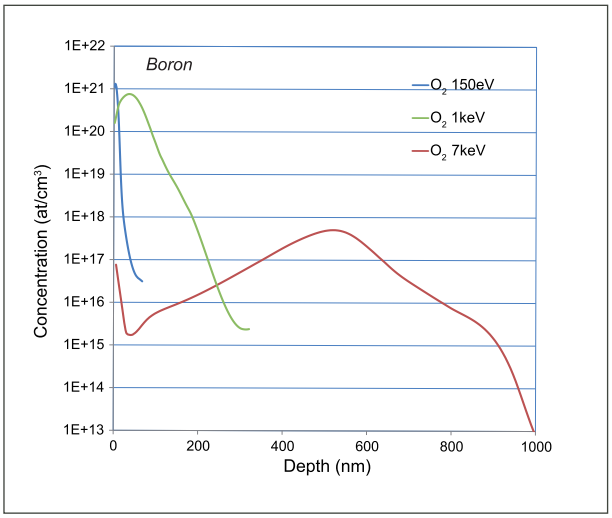


EXLIE SIMS depth profiles of BF_2, P, As implants. The use of very low impact energies does not affect the dynamic range of the elements of interest, and therefore allows profile quantification in a wide concentration scale range.

EXLIE SIMS

Implant Monitoring:
From Deep to Ultra Shallow

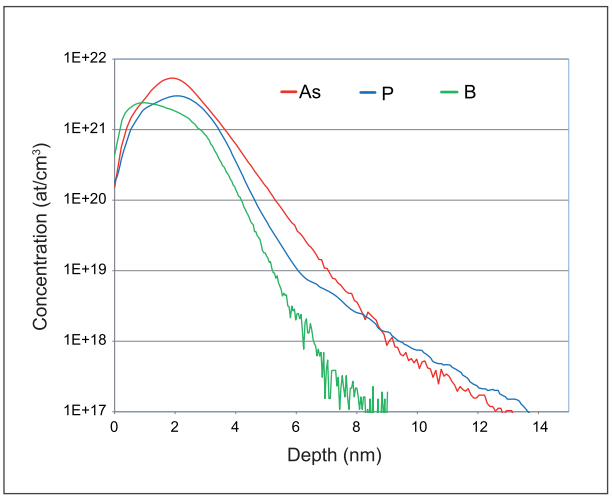
A wide range of primary ion impact energies allow selection of adequate analytical conditions in order to obtain a true in-depth concentration distribution. High dynamic range in every profile is a key element to high precision measurement.



Deep to shallow B implant depth profiling using optimized impact energy conditions: for B 200keV->7keV, for B 10keV -> 1keV, for B 500eV -> 150eV.

EXLIE conditions allow accurate profile quantification.

The data on the right show that the main advantage of the EXLIE recipes is to combine sub-nm depth resolution with an accurate near surface quantification, giving the true implanted dopant species distribution.

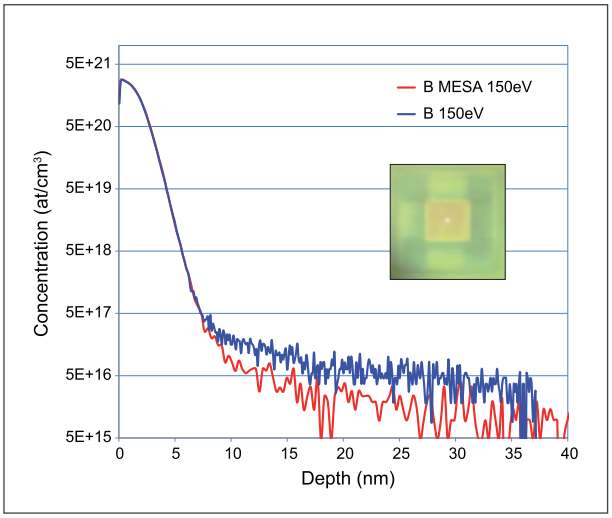


Low energy implantation profiles revealing real distribution within the first 10nm. As: 250eV - P: 200eV - B: 100eV.

MESA software option for small pattern analyses

The capabilities of EXLIE conditions are further challenged when analyzing a structure with small lateral dimension such as test patterns. High dynamic range depth profiles may suffer from crater edge effects during small-area analysis. However, sample preparation using the MESA technique significantly improves the dynamic range in small pattern depth profiles. MESA is a special sample preparation scan mode used to create a trench around the future area of analysis to eliminate the crater edge affect.

The figure on the right shows such an improvement for a 100 x 100 μm^2 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 to EXLIE profiling on the **IMS Wf** and **SC Ultra**.

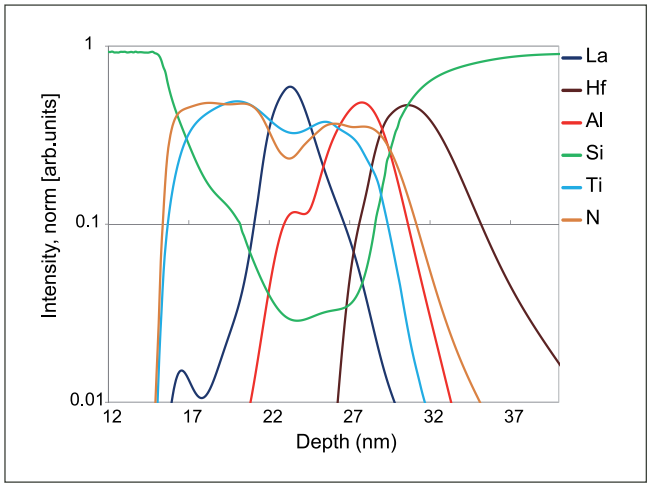


Thin Film Metrology

HKMG

High-K Metal Gates (HKMG) grown by Atomic Layer Deposition (ALD) are very thin multi-layers structures (few nm). Thickness is further reduced as the gate size stretches, leading to mono-atomic layers in the stack.

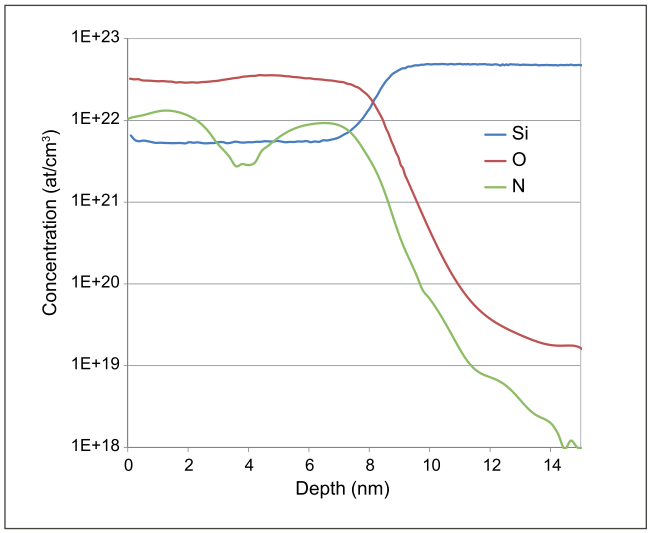
Delivering high throughput profiling at sub-nanometer depth resolution, the **IMS Wf** and **SC Ultra** address all issues in the fabrication and quality control of such complex devices.



High depth resolution profile of HKMG obtained with 250eV Cs beam.

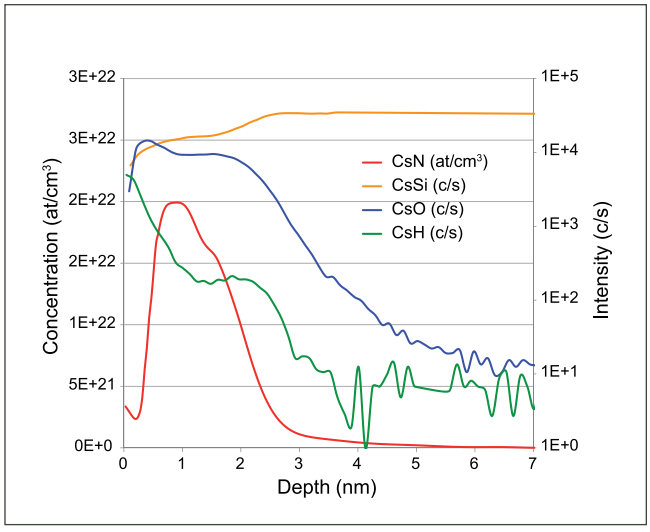
SiON

The use of silicon oxynitrides as gate dielectrics is well established in modern semiconductor device fabrication. The nitride content subtly raises the dielectric constant compared to silicon dioxide and creates a diffusion barrier for dopants. The optimization of these layers as well as their production and quality control require sophisticated metrology methods. Only EXLIE SIMS can give access to the three major parameters: N dose, layer thickness and O, Si, and N in-depth concentration distribution.



Quantitative profile of SiON structure obtained with 250eV Cs beam.

Analyzing structures with a layer thickness of a few nanometres and concentration levels ranging from a few atomic % down to several orders of magnitude is a challenge that the **IMS Wf** and **SC Ultra** can meet thanks to their unique combination of extremely low impact energy primary beam, high efficiency secondary ion extraction optics, and ultra high vacuum (10^{-10}mbar range) in the analytical chamber. Thanks to these instrumental advantages, the **IMS Wf** and **SC Ultra** perform depth profiling of SiON structures with the highest dynamic range and depth resolution.

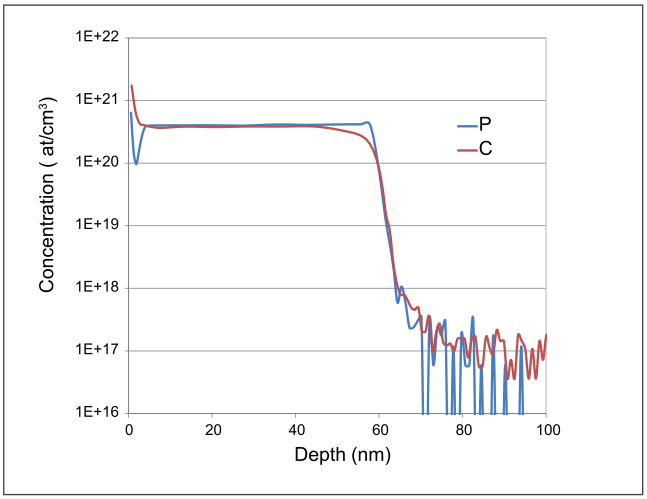


Nitrogen depth profile of shallow 2nm SiON structure obtained with 250eV Cs beam.

Ultimate Depth Resolution with Highest Sensitivity

Si:C:P

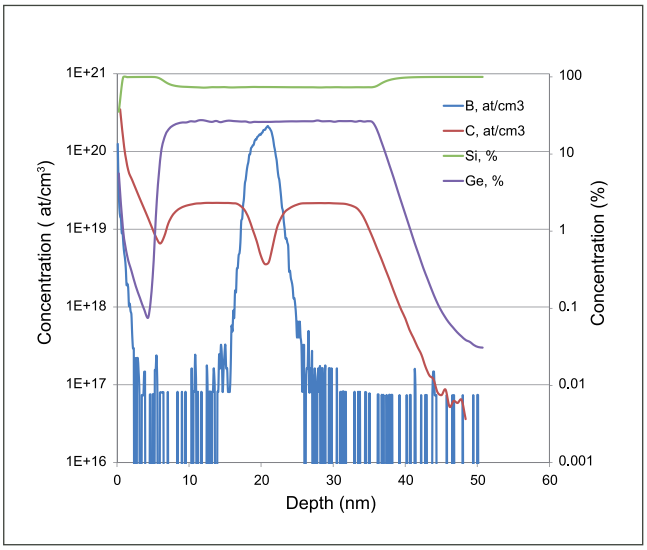
Precise control of the phosphorus and carbon distribution at the interface is essential to monitor the diffusion into shallow Si:C:P/SiGe structures. Thanks to the low impact energy of their primary beam and their high mass resolution capabilities, the **IMS Wf** and **SC Ultra** reach the best detection limits and the highest throughput on the market for this application.



Low energy depth profile of Si:C:P structure obtained with 250eV Cs beam.

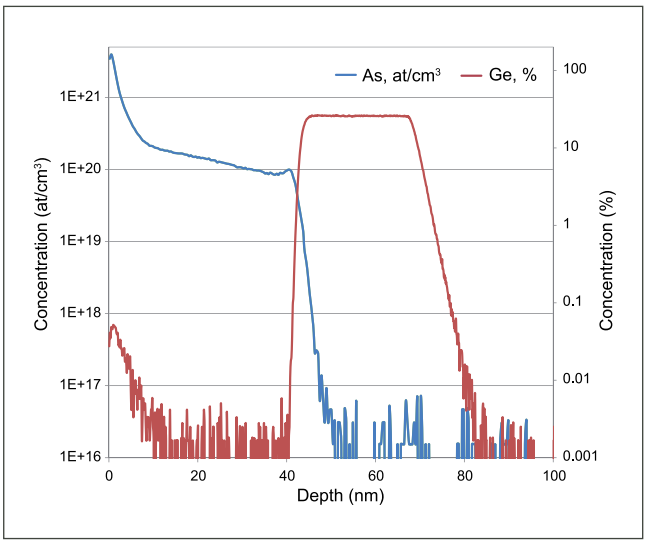
SiGe

SiGe based semiconductors are widely used today in fast switching devices. Increasing the frequency of such devices requires precise control of p- and n-type dopants in low dimensional transistor structures such as HEMT (high electron mobility transistor) or HBT (heterojunction bipolar transistor). The **IMS Wf** and **SC Ultra** deliver reliable data for R&D and manufacturing control of such challenging multilayer structures.



High resolution composition/concentration depth profile of SiGe:C:δB structure obtained with 500eV O_2 beam.

Precise characterization of the arsenic distribution at the SiGe interface is essential in order to control As diffusion into the shallow SiGe structure. Combining both low impact energy sputtering conditions and high mass resolution, the **IMS Wf** and **SC Ultra** achieve the best detection limits and throughput for this application.

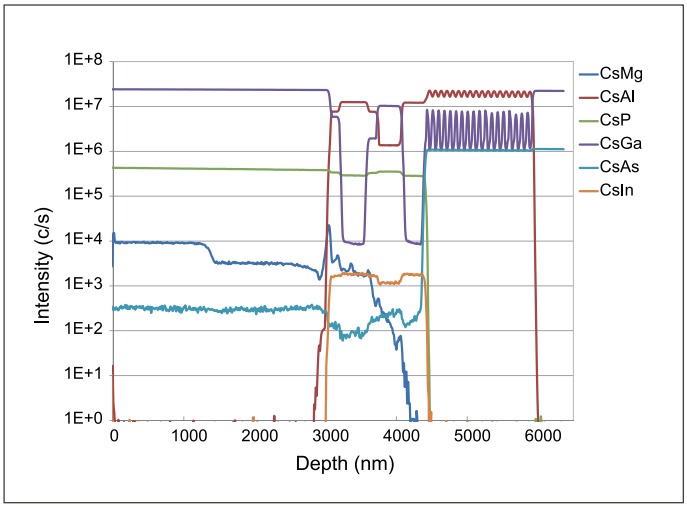


High mass resolution (MRP = 10,000) As concentration depth profile of highly doped poli-Si / SiGe layer structure obtained with 500eV Cs beam.

Optoelectronics & LED Device Development

The production of efficient optoelectronic devices (PV, III-V compounds based LEDs...) requires the growth of sharp interfaces between very small layers of different composition.

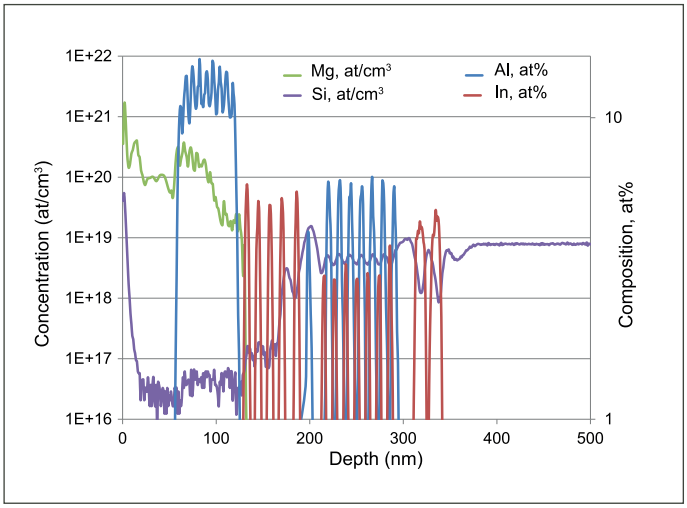
Delivering high depth resolution profiles with excellent detection sensitivity, the **IMS Wf** is the tool of choice for controlling layer interface quality, dopant and impurity in these complex structures. Its fully automated wafer handling capabilities also ensure unequaled data turnaround which is essential in high volume manufacturing environments.



Depth profiling in AlGaInAsP:Mg/GaAs optoelectronic structure showing a high dynamic range and excellent depth resolution up to 6µm depth.

Doping and structure composition monitoring

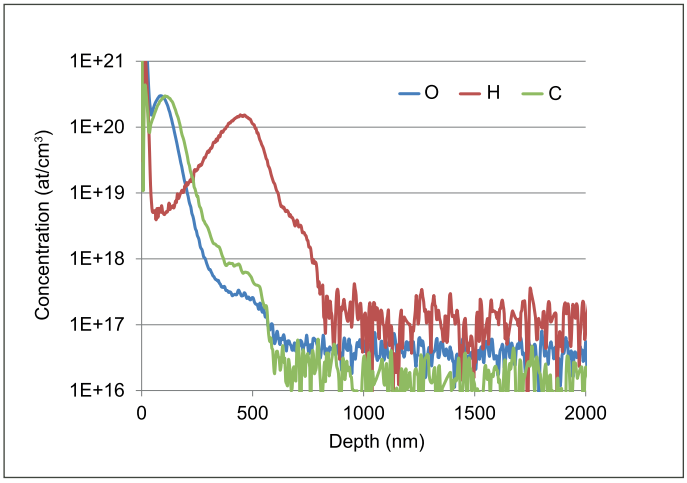
Depth profiling data are routinely obtained for both matrix and dopant species. Experimental conditions are selected in order to provide the best detection limits for both p- and n-type dopants and to ensure optimized throughput and ease of use.



LED structure. Mg, Si, Al, In depth profiles obtained with 1keV Cs show the excellent depth resolution and detection limits for Mg and Si dopants.

Impurity control

Thanks to the ultra clean vacuum in the analysis chamber and high brightness primary beam bombardment, the **IMS Wf** and **SC Ultra** outcompete all other analytical instruments on the market for the analysis of light elements. Detection limits for O, H, C are unequalled.



Light elements depth profiles obtained with 15keV Cs in GaN demonstrating excellent detection limits for O, H and C impurities.

Full Wafer Analysis with Optimized Repeatability

High precision and full wafer SIMS instruments are widely used in the fab in order to qualify implanters and thin film growth tools: SIMS is applied to reveal the dose/concentration non-uniformity in blanket wafers or over test-pads.

The CAMECA **IMS Wf** offers full 300mm wafer mapping capabilities along with unprecedented analytical precision. Wafer handling is performed by means of a robot and a shuttle designed to accommodate all wafer sizes.

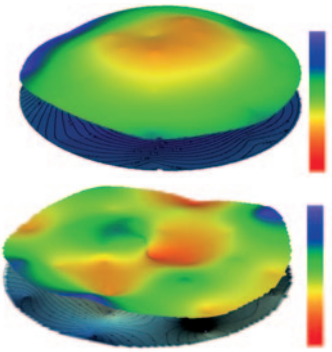
The **IMS Wf** achieves excellent short and long term stability on different windows and/or multiple sample holders, making it a reference tool for semiconductor industrial applications. Instrument factors (loading effect, position on the sample holder or wafer) are minimized and verified by extensive repeatability tests and sub-percent precision is guaranteed for a wide range of implantation or thin film growth processes.

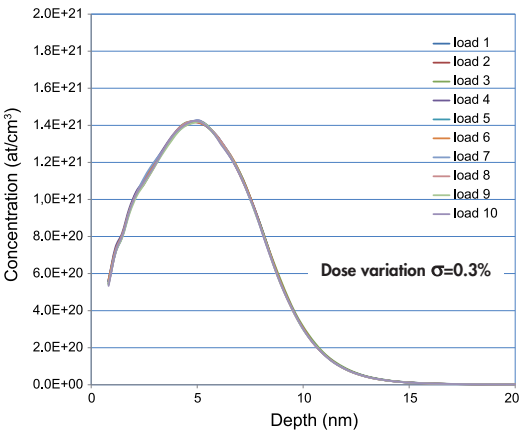
25 points mapping over 300mm wafers:

Top: B dose for a 2keV BF2 implant

Bottom:

N dose in a 2nm oxynitride SiON layer





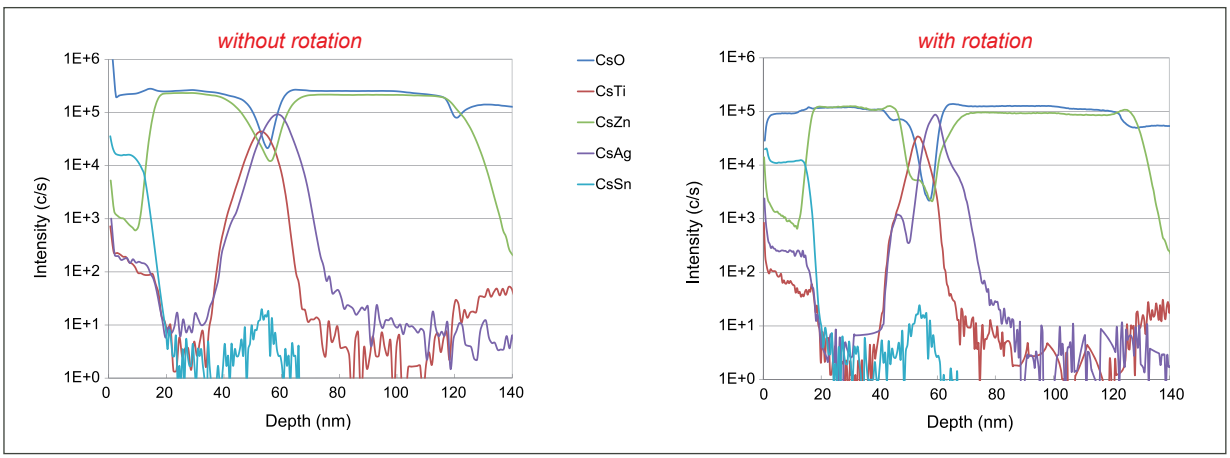
Repeatability test results of As dose measured in a 4keV As implanted wafer (10 loads/unloads).

Metal Thin Film Analysis

Surface roughness during sputtering dramatically limits the depth resolution for in-depth analysis of polycrystalline materials, even using low impact energy.

The **IMS Wf** and **SC Ultra** can be equipped with a fully eucentric rotation stage that significantly reduces this effect.

Depth profiles of on glass structure using Cs 500eV, without eucentric rotation stage (left), with rotation (right).



IMS Wf & SC Ultra:
A unique SIMS design, tailored to the needs of the semiconductor industry.

CAMECA is the world leader in SIMS technology thanks to a unique SIMS instrument design based on the magnetic sector principle. The **IMS Wf** and **SC Ultra** systems have been specifically developed to meet the increasing needs for dynamic SIMS measurements in advanced semiconductors and are the only tools on the market offering sub-nanometer depth resolution with no compromise on sensitivity, mass resolution, and analysis throughput.

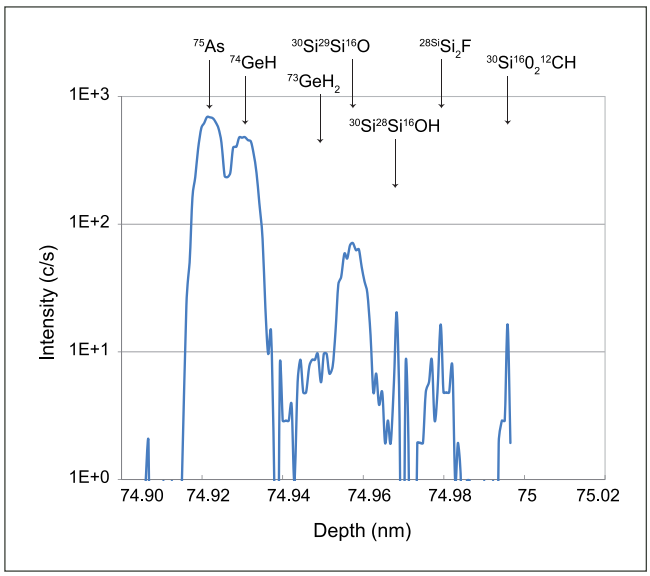
A flexible primary column configuration

The **IMS Wf** and **SC Ultra** can be simultaneously equipped with two primary columns:

- Floating Primary Column: mounted at 60° with respect to the sample surface normal, it is equipped with a cesium ion source.
  Impact energies: 150eV to 13keV
- Standard Primary Column: mounted at 36° with respect to the sample surface normal, it is equipped with an RF-plasma ion source running in the acceleration-deceleration mode.
  Impact energy range: 100eV to 10keV, depending on the source.

Fast & easy sample handling

- **IMS Wf:** its airlock system, sample stage, and analysis chamber are compatible with wafers up to 300 mm. Up to 100 samples can be loaded in one batch thanks to the multiple sample shuttles, transfer between the airlock and the analysis chamber is fully automated.
- **SC Ultra:** the airlock system and sample stage can accommodate a sample holder that has a useful area of 75 mm x 75 mm with different window configurations to accommodate a large number of samples (up to 25) . Sample holder transfer is manual.



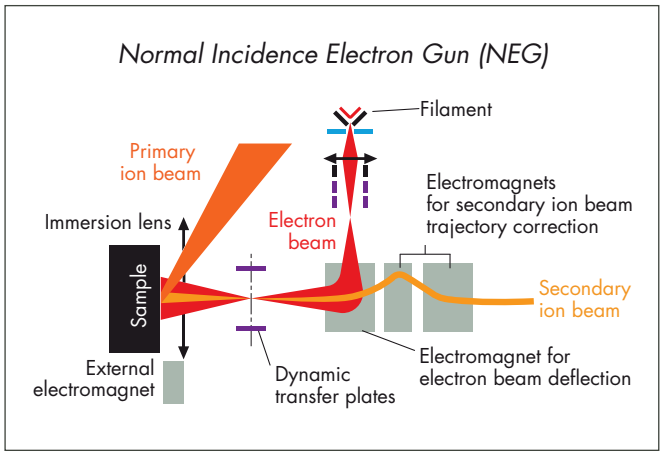
Mass spectrum of ^{75}As- peak obtained in SiGe layer. High mass resolution is required in order to resolve numerous mass interferences among which ^{75}As from ^{74}GeH and $^{30}Si^{29}Si^{16}O$.

Standard Features

	IMS Wf	SC Ultra
60° floating column	•	•
RF-Plasma ion source for 36° column	•	•
Motorized diaphragms and slits	•	•
XYZ axes, 75mm stage		•
XYZ axes, 300mm stage	•	
Transfer robot	•	
Oxygen flooding	•	•
S2/S8 certified	•	•

State-of-the-art mass spectrometer & detection system

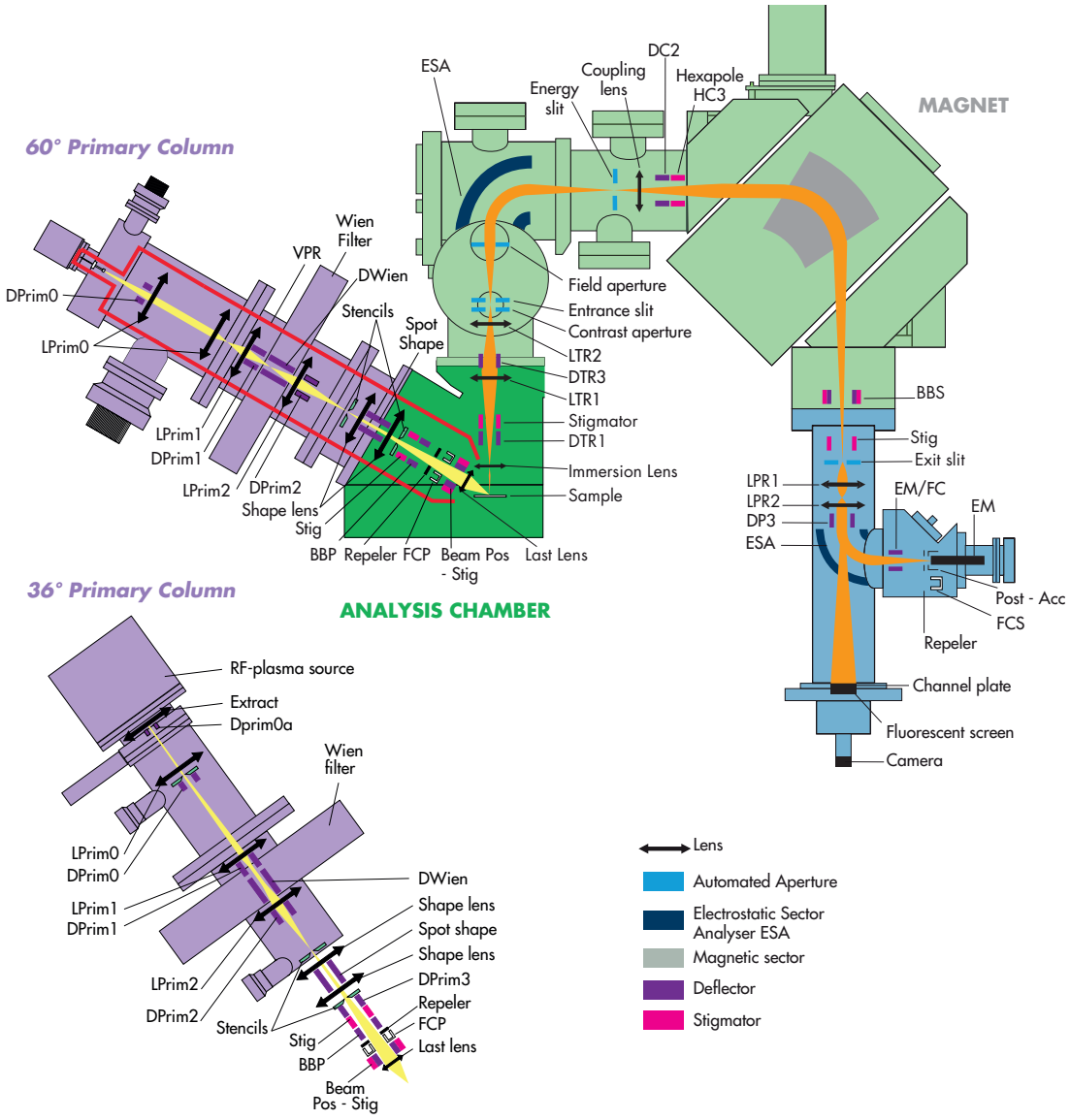
- Normal-Incidence Electron Gun (NEG) ensuring easy and reproducible analysis on all types of insulating materials. It provides low energy electrons (few eV) and an auto-compensation mode of charging-up effects for negative secondary ion analysis.
- Magnetic sector double focusing mass spectrometer with fast peak switching capabilities.
- Detection system combining one Faraday Cup and one Electron Multiplier, providing a counting system with a dynamic range of 10 decades.
- Fast pumping airlock with programmable outgasing lamp, optimizing throughput for applications requiring ultimate vacuum quality.



Flexible primary ion source selection

According to the application field, each primary column will be equipped with a specific ion source combination:

- Cs source for the 60° primary column;
- O_2 RF Plasma source for the 36° primary column.



Fully Automated Tool Operation...

Easy and automated instrument operation

The **IMS Wf** and **SC Ultra** offer software capabilities for easy instrument setup: complete load-save of instrumental settings and analysis recipes; automated, unattended chain analyses.

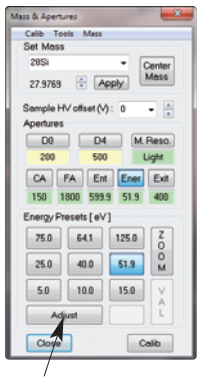
The **IMS Wf** model is equipped with a robotic storage chamber. The exchange between storage and analysis chamber is fully automated. Multiple holders can be analyzed in chained, unattended mode, dramatically improving the instrument productivity.

Remote monitoring from a distant PC is also available: checking data acquired during an automated chain analysis, launching a new sequence of analyses... This ensures high analysis throughput and allows multiple distant users to work on the tool.

New auto-tuning routines *based on scanning sequences are available:*



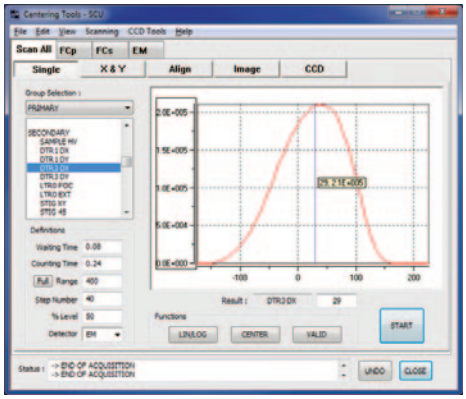
Overall secondary column tuning



Energy slit position adjustement



Sample transfer control

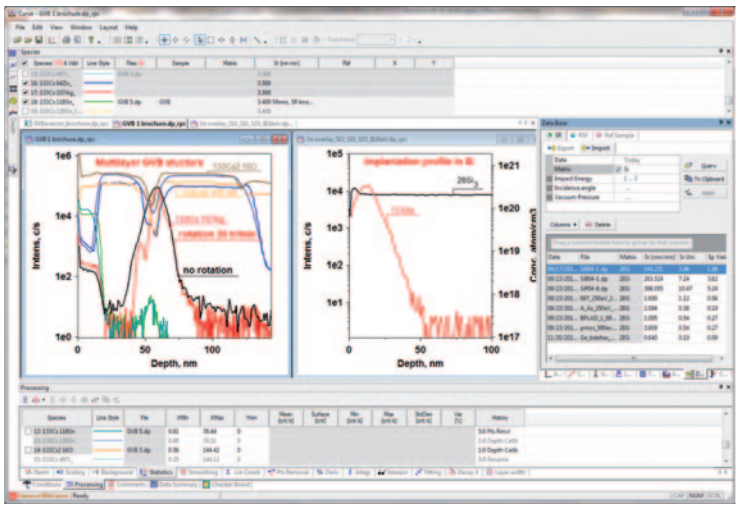


Automated scanning routine

SmartPro WinCurve software suite

A database-centered workflow assists the operator through the entire SIMS analysis process:

- Easy selection from tool calibration, data acquisition and analytical recipe database.
- SmartPro chain batch processing automatically applies the selected data acquisition conditions for fast, automated analysis.
- SmartPro database enables easy mining of the data acquired using SmartPro chain.
- WinCurve allows a wide range of visualization options for your data.
- Software algorithms are designed to address semiconductor specific analytical tasks such as ion implantation, layer growth, bulk to ultra thin layer samples including multilayers.
- Reports can be created within a few clicks.



WinCurve offers powerful data processing and visualization capabilities in a user-friendly, customizable interface.

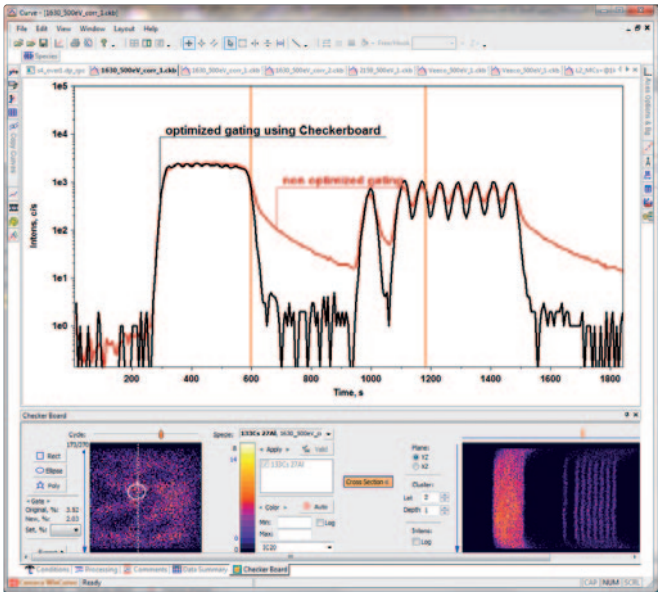
… and User-Friendly Software

Checkerboard for optimized depth profiling

Checkerboard is an acquisition and processing function in the "Analysis" and "WinCurve" software packages of the **IMS Wf** and **SC Ultra**. It combines the advantages of both depth profiling and scanning ion imaging modes.

The Checkerboard mode allows the operator to modify the shape, size and position of the gate after the initial measurement has been performed, thus optimizing the rejection of crater edge effects and/or dust particles (if any) present at the crater bottom. It is extremely useful for selecting the area of interest when performing small area analysis.

Eliminating the need re-run the measurements, Checkerboard greatly improves the quality of the depth profiling data and the throughput of the instrument.



Checkerboard data post-processing on a LED structure showing indium-based MQWs layers: surface roughness is revealed by the non-uniformity of the Indium crater image.

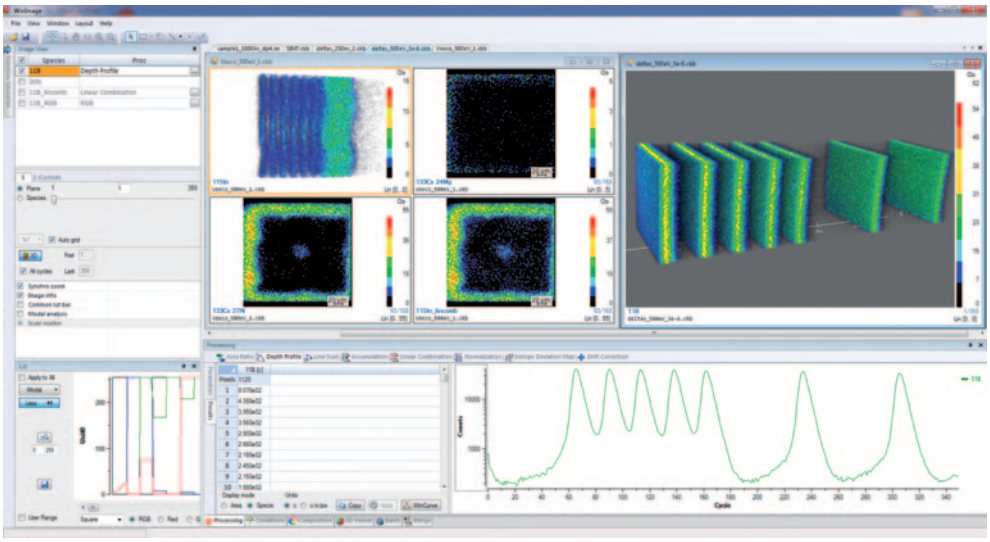
Using Checkerboard, depth resolution is dramatically improved by optimizing the size and position of the gate.

Bottom left: 2D crater view and gate.
Bottom right: crater cross section.

WinImage

WinImage offers powerful image visualization, processing & printing functions in a user-friendly, flexible interface.

- Image display: 1 to 64 images simultaneously, Rejection-Saturation, Lin-Log,…
- Image output: export with new options and high flexibility
- Data reconstruction from ROIs: Depth profile, Line scan, Area ratio
- Data processing: Accumulation of cycles, Linear combination, Normalization, Color + B&W overlay, RGB (Red-Green-Blue) overlay, Scatter Plot
- Batch mode: a given processing sequence can be applied automatically on multiple data files.
- 3D imaging reconstruction



WinImage software offers tens of powerful SIMS image processing functions (includes a set of Aphelion™ imaging libraries).

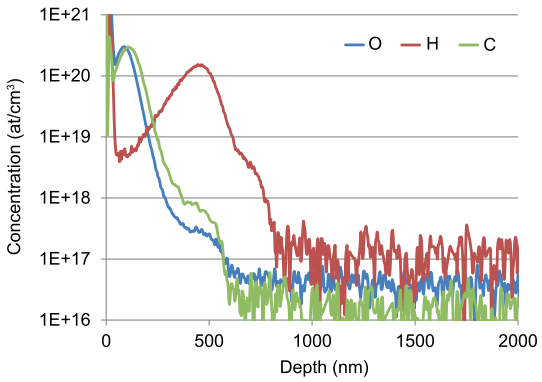
IMS Wf & SC Ultra

SIMS Excellence for the most challenging semiconductor analytical tasks.

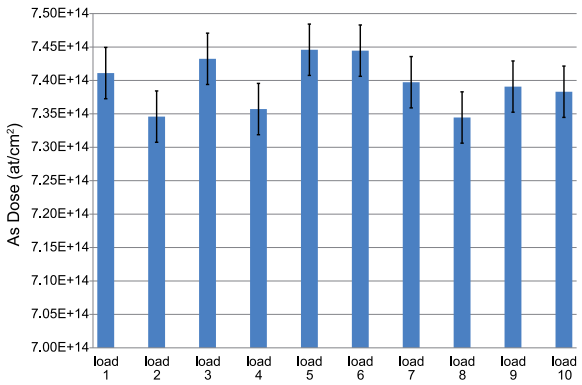


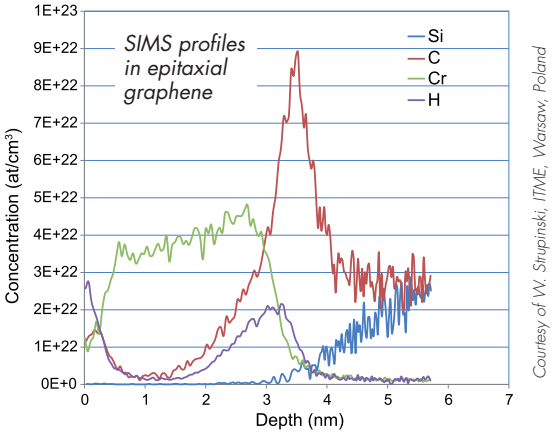
Combining EXtreme Low Impact Energy (EXLIE) SIMS capabilities, high mass resolving power and sensitivity with a high level of automation and productivity, the CAMECA **IMS Wf** and **SC Ultra** address the most challenging analytical and process control issues in the semiconductor industry: Extra shallow & high energy implants • Ultra-thin nitride oxides • HKMG • Metallic layers • SiGe doped layers • Si:C:P structures • PV and LED devices • Graphene • S2/S8 certified...

Impurity control in LED structure



High reproducibility for process control





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