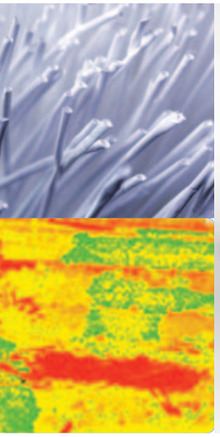
IMS 7f-Auto

High Throughput, Fully Automated SIMS Tool



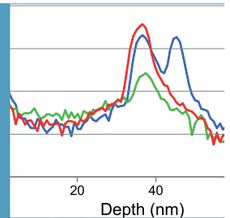


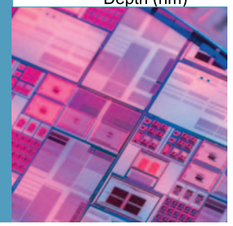
SEMICONDUCTORS

PV & LED DEVICES

MATERIAL SCIENCES

ENVIRONMENTAL STUDIES







CAMECA® SCIENCE & METROLOGY SOLUTIONS / AMETEK®

The IMS 7f-Auto is the latest version of our successful IMS 7f, the most versatile CAMECA Secondary Ion Mass Spectrometer. It has been optimized for challenging applications such as glass, metals, ceramics, Si-based, III-V & II-VI devices, bulk materials, thin films...

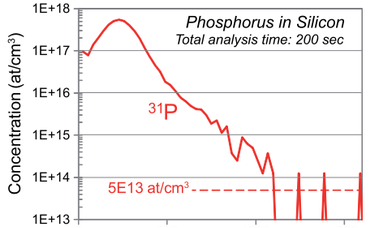
Semiconductors

Fulfilling industry requirements for efficient device development and process control

Best detection limits for dopants and impurities

Dopant analysis

With the CAMECA **IMS 7f-Auto**, **depth profiles up to several microns in-depth** can be analyzed within minutes with impressive sensitivity and high dynamic range. For the three main dopants of Si (B, P, As), a **detection limit in the ppb range** can be achieved.

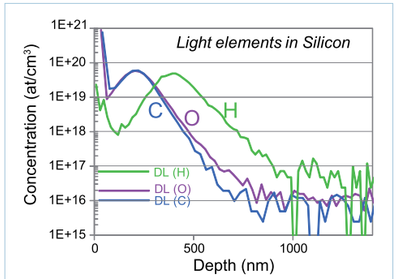


Ultimate detection limits and **high sample throughput** for deep implants.

In particular, phosphorus analysis in Si requires to use **high mass resolution** in order to resolve the $^{31}P/^{30}Si^{1}H$ mass interference.

Light elements measurements

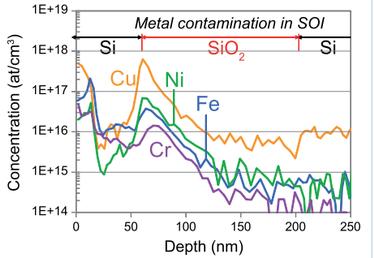
The best detection limits for light elements (H, C, N, O) require **optimized vacuum** in the analysis chamber and **high sputter rate** in order to minimize the residual gas contribution present in the analysis chamber. The CAMECA **IMS 7f-Auto** offers such conditions, and thus guarantees excellent detection limits, **which surpass the capabilities of competing techniques such as TOF-SIMS**.



Excellent detection limits for light elements (hydrogen, carbon, oxygen).

Metal contamination

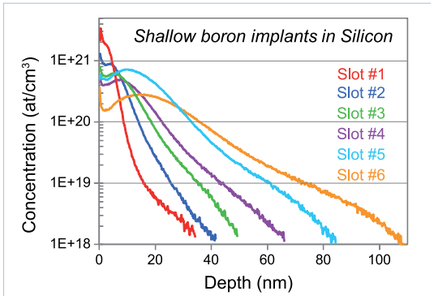
The **IMS 7f-Auto** also offers **high transmission at high mass resolution**, excellent abundance sensitivity, as well as **oxygen flooding technique** for increasing the ionization yield of metal species, thus providing the **best detection limits** for metal analysis in silicon based materials.



Metal (Cr, Fe, Ni, Cu) contamination is detected with **high sensitivity** at Si/SiO_2 and SiO_2 /Si substrate interfaces in silicon on insulator (SOI) sample.

High depth resolution for shallow depth profiling

Operation with low impact energy of primary ions provides **excellent depth resolution** performance while keeping **good sensitivity**. Therefore, the **IMS 7f-Auto** can be used for characterizing the in-depth elemental distribution of dopants and impurities on shallow implanted samples or thin layer structures.



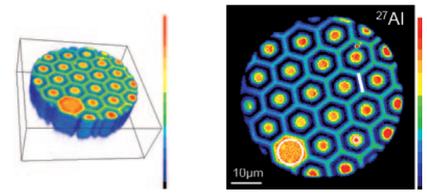
Excellent depth resolution for low energy depth profiling: O_2^+ 500 eV for ultra shallow implant technology.

3D mapping using ion imaging capabilities

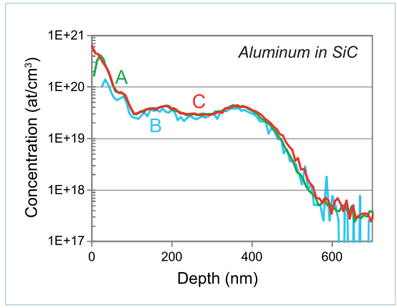
3D mapping obtained from series of ion images is a powerful tool for investigating dopant distribution uniformity, surface concentration, dose and junction depth.

In this example, the Al dopant distribution in a silicon carbide (SiC) power device has been investigated using the **powerful imaging capabilities** of the **IMS 7f-Auto**.

Using the **CAMECA WinImage software**, it is possible to obtain a **3D reconstruction** as well as **retrospective depth profiling** from the acquired ion images which were recorded sequentially while sputtering in-depth.



2D & 3D aluminum mapping in honeycomb SiC structure. Field of view: 60 µm in Ø.



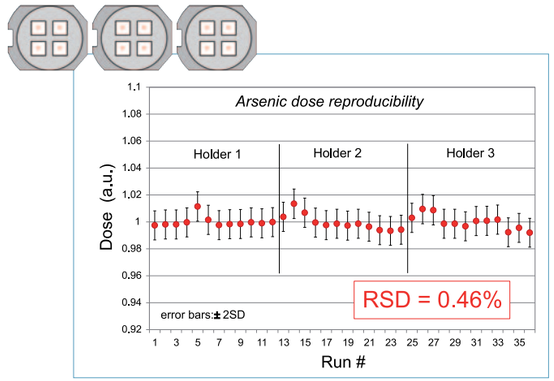
Quantitative Al depth profiles obtained from three different areas A, B & C (see figure above).

Ultimate reproducibility at high throughput

The **IMS 7f-Auto** can analyze **multiple samples holders in chained or remote mode**, possibly overnight, thanks to its **new** motorized storage chamber and sample transfer.

Using **new automated tuning**, ultimate reproducibility on different windows and different holders can be achieved (RSD < 0.5 %), together with excellent detection limits, high throughput and productivity (tool can be used 24h a day with minimum operator intervention).

The **IMS 7f-Auto** is the first SIMS instrument designed to perform measurements in **fully unattended** and automated mode on different holders, with **unequalled throughput and reproducibility**.



Arsenic dose reproducibility test on 3 sample holders, each holder containing 4 samples (3 runs for each sample).
Excellent reproducibility, both window to window and holder to holder.

Photovoltaic materials

Supporting R&D and production of novel materials for renewable energy

Upgraded metallurgical Si

Silicon based solar cell device manufacturing is based on photovoltaic Si feedstock of upgraded metallurgical-grade silicon (UMG-Si) with at least 6N purity. The quality control of the Si purification process is mandatory to ensure high yield manufacturing.

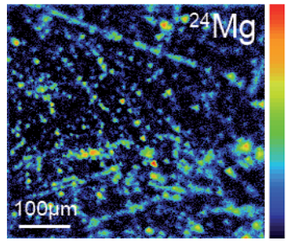
The **IMS 7f-Auto** can quantitatively measure trace element concentrations with high confidence, high throughput and with a detection limit spreading in ppb to ppm range depending on the species of interest (see table). **Excellent detection limits** are achieved for light elements, dopants, metals and other impurities.

Measurements are performed with a **high sputter rate** (typically half a micron per minute). Thus in 10 minutes, 5 µm depth can be explored, providing information on trace element uniformity distribution.

The **IMS 7f-Auto** also offers a **sub-micron spatial resolution** using scanning ion imaging capabilities. An example of elemental mapping in PV polysilicon is shown on the right.

Species	Detection limit at/cm³	Detection limit ppb
H	7E+16	1 400
B	1E+13	0.2
C	2E+16	400
O	2E+16	400
Na	3E+13	0.6
Al	1E+13	0.2
P	5E+13	1
K	2E+12	0.04
Ca	7E+11	0.01
Cr	5E+12	0.1
Mn	5E+12	0.1
Fe	2E+14	4
Co	2E+13	0.4
Ni	6E+14	12
Cu	2E+14	4
As	1E+13	0.2
Mo	1E+14	2
W	5E+13	1

SIMS detection limits in silicon for 15ng of analyzed material. Throughput: 4-6 analyses/hour.



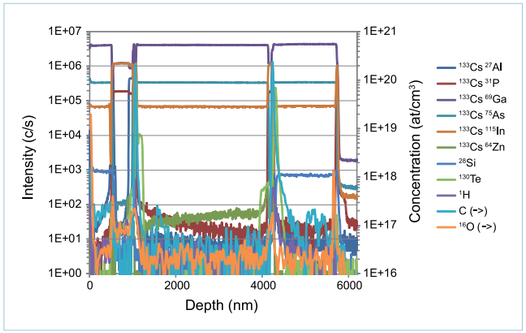
Mg mapping on a poly-Si sample. Field of view: 500 x 500 µm².

Multilayered PV devices

The production of efficient multilayered PV devices requires the formation of sharp interface transitions between layers of varying composition. Inaccurate placement of dopants or a graded transition in layer composition can often degrade device performance. **Characterization of the in-depth distribution** in a solar cell multilayer structure with the **IMS 7f-Auto** is shown on the right.

The **IMS 7f-Auto** proves extremely useful in addressing the various issues of multilayered PV material characterization, among which:

- Layer interface quality
- Doping concentration and distribution
- Impurity control



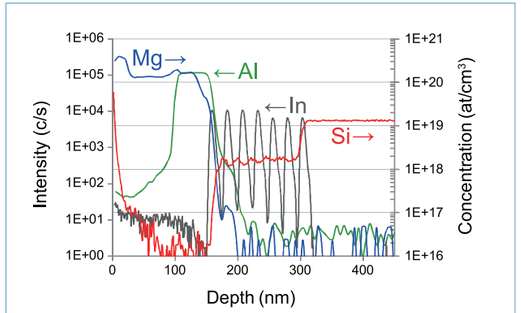
Depth profiling in GaAs- and InP-based **triple junction solar cell** on Ge substrate

LED devices

The state of the art tool for the detection and in-depth distribution of dopants and impurities

LED technology is based on multilayer structures (GaAs, GaN, GaP...), doped with species like Mg, Si, Zn (charge carriers) and with electrical properties affected by contamination from species such as H, C, O.

Like for Si technology development for ICs, dynamic SIMS is a key technique for R&D of LED devices. The **IMS 7f-Auto** delivers depth profiles with **excellent detection sensitivity** for dopants and impurities, while keeping **high analysis throughput**. It also offers **high depth resolution**, which is essential for ultra shallow implant technology.



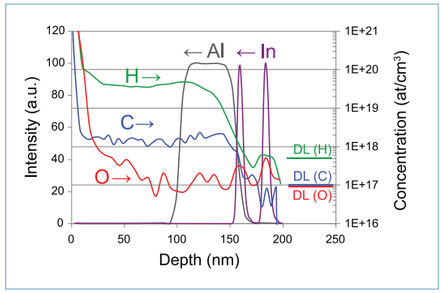
P- and N-type dopant profiles in Al/GaN/InGaN LED: Mg and Si dopants, Al and In matrix species.
A detection limit better than 1E16 at/cm³ is achieved for both Mg and Si.

Doping and structure composition monitoring

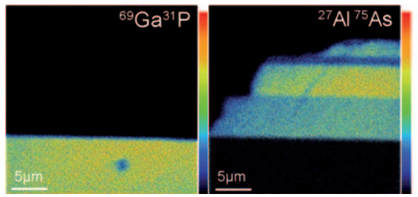
Depth profiling data are routinely obtained for both matrix and dopant species. Experimental conditions are selected in order to provide the **best detection limits** for both p- and n-type dopants and to ensure **optimized throughput and ease of use**.

Impurity control

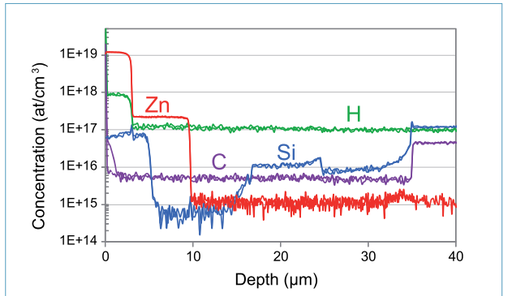
Thanks to the optimized vacuum in its analysis chamber and high brightness primary beam bombardment, the **IMS 7f-Auto** outcompetes all other analytical instruments on the market for the **analysis of light elements**. Detection limits for H, C, O are unequalled.



Impurities in AlGaN/InGaN LED. **Light elements analysis (H, C, O) with best detection limits.** Results show hydrogen and carbon levels above the detection limit within the first GaN and AlGaN layers.



Scanning ion imaging at cross section of AlGaAs/GaP multilayer structure. Initial $^{27}Al^{75}As$ image presents an interference with $^{71}Ga^{31}P$ species. Using the CAMECA WinImage software, it is possible to substract the $^{71}Ga^{31}P$ contribution (deduced from the $^{69}Ga^{31}P$ mapping) in order to obtain the true $^{27}Al^{75}As$ image.



Overlay of two depth profiles of H, C, O, Si and Zn in GaP-based LED sample. Results show that a **high throughput** can be achieved, with a total depth of ~40 µm reached in less than 1h20min. The overlay of the two runs demonstrates an **excellent repeatability**.

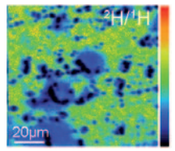
Material sciences

Extreme sensitivity and high lateral resolution for investigating a wide variety of materials

Mapping on metallurgical samples

For metallurgical applications, 2D mapping or 3D volume reconstruction of trace or major species is of major interest.

Thanks to its unique **2D & 3D ion imaging** capabilities, the **IMS 7f-Auto** is the tool of choice for metallurgical applications. Powerful image processing functions are also available using the **CAMECA WinImage software**.



D/H isotope ratio image in D implanted Ti samples (at depth ~3 µm).
Field of view: 100 x 100 µm².
Lateral resolution ~1 µm.

Insulator analysis

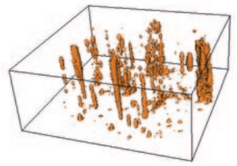
The **IMS 7f-Auto** can be equipped with the Normal-Incidence Electron Gun (NEG) for **easy and effective sample charge compensation**. In negative ion polarity mode, this uniquely designed system performs a self adjustment of the sample surface potential, allowing perfect analyses for all types of insulating materials (multilayer structures, glass, diamond…).

Small area analysis

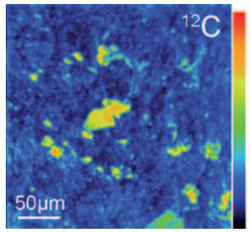
The **IMS 7f-Auto** provides **sub-micron lateral resolution**, which is of great interest for material analysis.

In this example, analysis of a Sn/Cu wire structure was performed using the **Scanning Ion Image** ("Microprobe") mode, which is **ideal for small area analysis**.

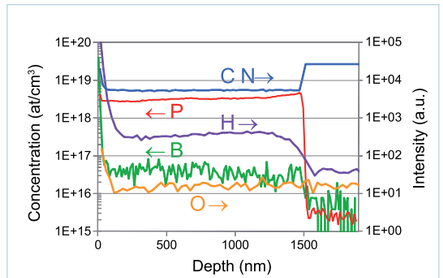
Using the **CAMECA Checkerboard software**, it is possible to obtain a **retrospective depth profile** from the acquired ion images that were recorded sequentially while sputtering in-depth. Note the **high dynamic range** in imaging mode, unique to CAMECA magnetic sector SIMS.



3D reconstruction of Ti volume distribution in metallic alloy. 100 Ti direct ion image planes. Field of view: 150 µm in diameter. Lateral resolution: ~1 µm.

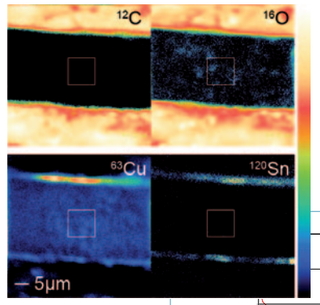


C segregation in a steel sample.
Field of view: 250 x 250 µm².

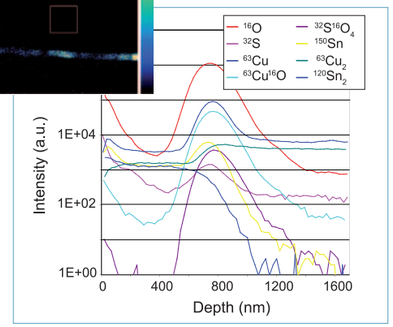


B, P, H, C, O depth profiling in synthetic diamond.
Excellent signal stability demonstrates **efficient charge compensation**.

Data from: T. Kociniewski et al, Phys. stat. sol. (a) 203, 3136–3141 (2006)



C, O, Cu, Sn scanning ion images on Sn/Cu wire structure.
Field of view: 50 x 50 µm².

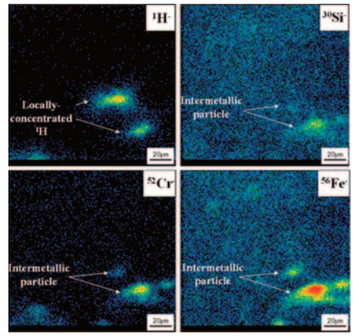


Retrospective depth profiles obtained from the central area shown above.

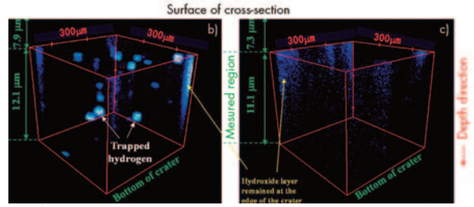
Hydrogen in aluminum alloy

The hydrogen atom **easily invades into metals** and interacts with various lattice defects, such as dislocations, grain boundary, and secondary particles, causing degradation of the mechanical properties, well-known as hydrogen embrittlement. In this study, the researchers have thoroughly excluded the possibilities of false detections (due to H background) and for the first time succeeded in detecting and visualizing real hydrogen trapped at the intermetallic particles.

The design of the **IMS 7f-Auto** is **optimized for the analysis of light elements**, thanks to the low vacuum levels in the analysis chamber and the high-density Cs primary beam bombardment. This study demonstrates the SIMS is a powerful technique to visualize the local distribution of hydrogen in metallic materials.



2D and 3D imaging of hydrogen trapped at intermetallic particles in a practical aluminum alloy (6061-T6) that has been exposed to high-pressure hydrogen gas (100 MPa, 200 °C for 300 hours).
a) 2D ion maps of ^1H together with ^{28}Si , ^{52}Cr , ^{56}Fe
b) 3D image of ^1H
c) 3D image of ^1H after thermal desorption measurements



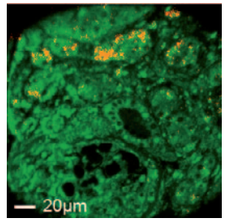
Data from : J. Yamabe et al, Int. Journal of Hydrogen Energy, 42, 24560 - 24 568 (2017)

Environmental studies

Using powerful imaging capabilities

Trace element mapping

The example on the right shows results of a study concerning the biological effects due to chronic exposure to low levels of uranium contaminant.
This work shows that **IMS 7f-Auto** **ion imaging** is a powerful analytical method to **detect trace elements** and produce elemental **cartography at the sub-micrometer scale**.



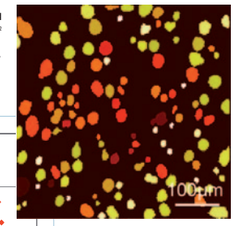
U microdistribution in the renal cortex of rats following chronic exposure to low U level in the drinking water.
Superposed ^{40}Ca (green) and ^{238}U (red) scanning ion images, obtained on different structures of the rat kidney after 9-month contamination.
Field of view 200 x 200 µm².
Lateral resolution <1 µm.

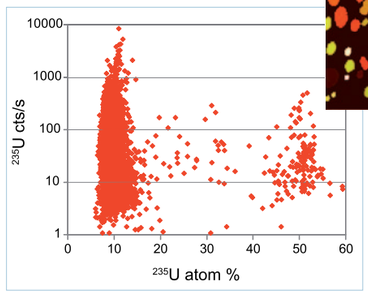
Data from: Ch. Tessier et al, Microsc. Microanal. 18, 123–133 (2012)

Particle analysis

The **IMS 7f-Auto** is also used for precise isotopic analysis of uranium particles in nuclear safeguards applications.
It can be equipped with the **CAMECA automated particle measurement software** (**APM**, optional) for fast sample screening in order to **determine the location and enrichment** of uranium particles. The selected particles are then re-analyzed individually in order to obtain their **precise isotopic composition**.

APM screening on a sample area of 500 x 500 µm² showing a total of 127 particles.





Isotope composition obtained from the APM particle screening on a quality control sample containing 10% and 50% enriched U particles.
A total of 16,214 particles could be identified within 5 hours.

CAMECA leads the way in SIMS technology thanks to a unique magnetic sector instrument design. The new IMS 7f-Auto is designed to deliver ultimate precision elemental and isotopic analysis with increased ease of use and productivity.

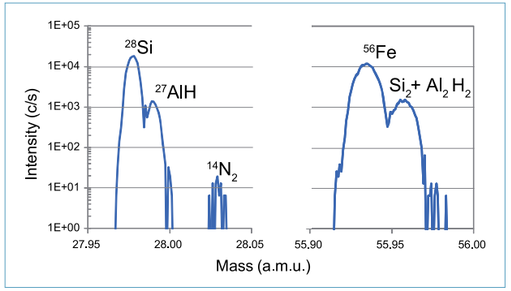
A superior instrument design

... from the leader in SIMS instrumentation

The **IMS 7f-Auto** combines the field proven instrumental advantages of the IMS 7f:

- Unparalleled **depth profiling capabilities**
- Extreme **sensitivity**
- High **mass resolution**
- High dynamic range
- **Best detection limits** on light and trace elements
- Both direct and scanning **ion imaging** modes

...with additional developments towards improved automation and operation efficiency.



Mass spectra obtained in Al alloy. High mass resolution is required in order to resolve numerous mass interferences among which ^{28}Si from ^{27}AlH and $^{14}N_2$, as well as ^{56}Fe from $^{28}Si_2$ and $^{27}Al_2H_2$ ions.

New in-line primary column

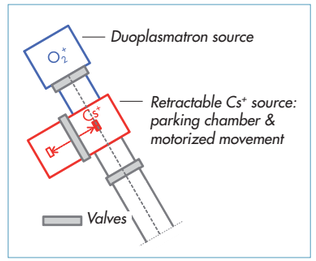
The **IMS 7f-Auto** is equipped with a redesigned, in-line primary column allowing **easier operation** and **faster primary beam tuning**.

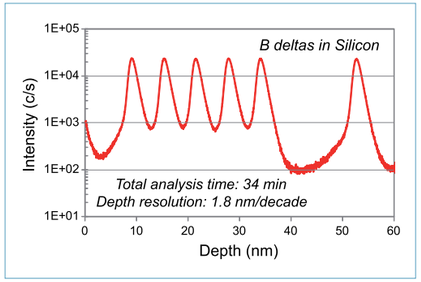
A source chamber allows simultaneous mounting of both **duoplasmatron and cesium microbeam high brightness ion sources**, for the analysis of electropositive and electronegative species, respectively. A schematic of the primary column is shown on the right. **Switching source operation** as well as the start-up and shut-down of the sources are **fully computer controlled**.

An **accel-decel extraction system** makes possible to run analyses with O_2^+ primary ions at an **impact energy as low as 500eV**, providing excellent depth resolution.

Primary beam monitoring is also available, one Ip value being stored per data point. This ensures reliable primary beam drift correction, and thus guarantees **optimized precision and measurement repeatability**.

The **duoplasmatron source** is mounted at the top, in-line with the primary ion column.
The **cesium microbeam source** is retractable: it moves between the parking chamber (when not used for analysis) and the working position, in-line with the primary column.





Excellent depth resolution using low impact energy conditions: O_2^+ bombardment at 500 eV and oxygen flooding technique.

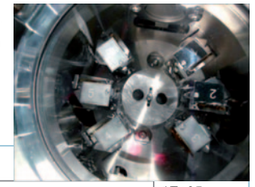
Automated storage chamber

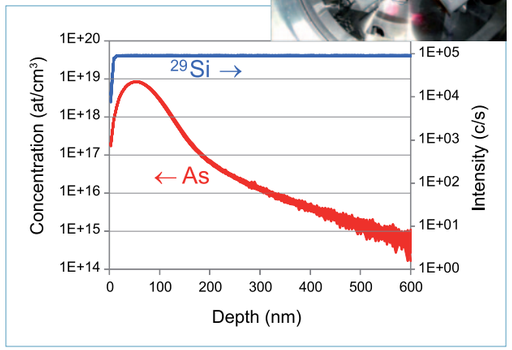
In order to meet the growing demand in terms of throughput performance, a **new motorized storage chamber** has been developed allowing to keep up to 6 one-inch diameter sample holders under vacuum. This is important for applications requiring good vacuum quality.

The **holder exchange** between the storage chamber and analysis chamber is **fully motorized and computer controlled**, allowing a set of analyses to be performed in automated, unattended or remote mode on multiple sample holders.

Combined with **automatic routines** for precise centering of the secondary beam, **excellent short and long-term reproducibility** can be achieved **on different windows** and/or **multiple sample holders**.

Automated storage chamber for up to 6 sample holders with motorized holder exchange.



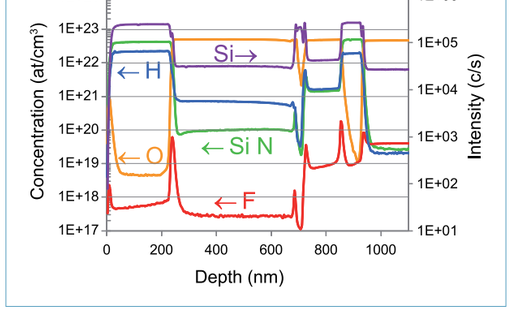


Overlay of 36 As implant profiles in Si.
3 sample holders, each containing 4 samples, 3 runs for each sample.
Excellent reproducibility for implant dose measurement: RSD = 0.46 % on As medium energy implant in Si.
Total duration: 5h30min.

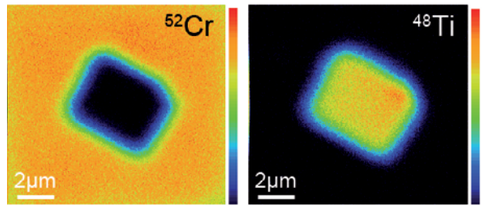
State-of-the-art mass spectrometer & detection system

The **IMS 7f-Auto** inherits the field-proven secondary column design of the IMS 7f.

- **Normal-Incidence Electron Gun (NEG)** ensuring easy and reproducible analysis on all types of insulating materials. For negative secondary ion analysis, it provides low energy electron (few eV) and an auto-compensation mode of charging-up effects.
- 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**.
- Outstanding imaging capabilities:
  - **Direct Ion Imaging** ("Microscope") mode: visualization of stigmatic images useful for day-to-day instrument tuning and for easy location of analytical areas.
  - **Scanning Ion Imaging** ("Microprobe") mode: a focused primary beam is scanned over the sample surface, providing high (sub-micron) lateral resolution. This flexible imaging mode is well adapted to small area analysis.
  - **3D imaging reconstruction** is possible for scanning ion imaging by acquiring successive 2D images as a function of depth.



SiN and SiO_2 based multilayer **insulating sample** analyzed using the NEG.
Efficient charge compensation provides excellent signal stability.



Scanning ion imaging analyses on small area (12 x 12 µm²) showing Titanium-rich precipitates in Cr-Fe-Ni alloy.

Fully automated tool operation...

Easy and automated instrument operation

New auto-tuning routines have been specifically developed for the **IMS 7f-Auto** including, among others: aperture centering, detector adjustment and parameter centring. These advanced routines not only increase the ease-of-use, but also **enhance the reproducibility of the instrument by minimizing operator-related biases**.

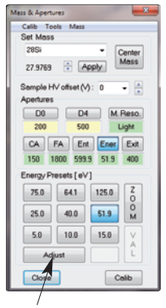
The **IMS 7f-Auto** also includes all software capabilities for easy instrument setup already available in the previous IMS 7f model: complete load-save of instrumental settings and analysis recipes; automated, unattended chain analyses.

On instruments equipped with the **Automated Storage Chamber**, multiple holders can be analyzed in chained 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.



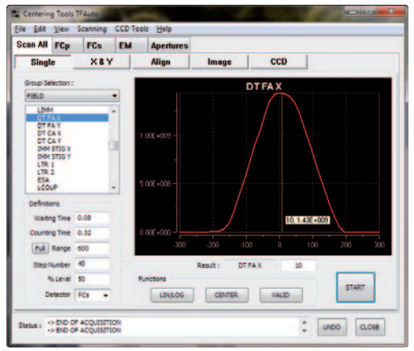
Overall secondary column tuning



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

Energy slit position adjustement

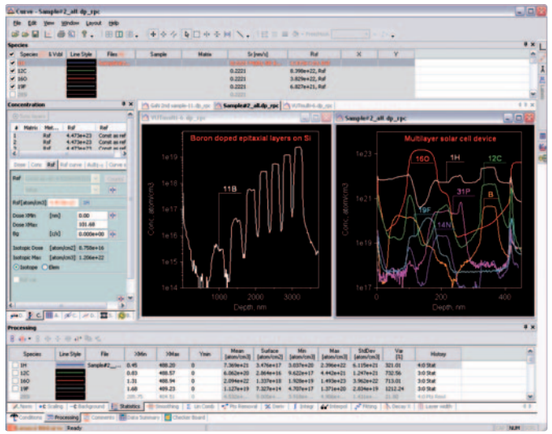
Automated scanning routine



WinCurve data processing software

WinCurve offers **powerful data processing capabilities** (for depth profiling, mass spectra...), tools for **real-time visualization of SIMS data**, together with **batch processing for improved productivity**.

- Modern, user-friendly environment
- Flexible visualization with a wide range of options
- Advanced depth and concentration scale calibration capabilities for bulk and multilayer samples
- Easy report creation functionalities.
- Database for calibration parameters.



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

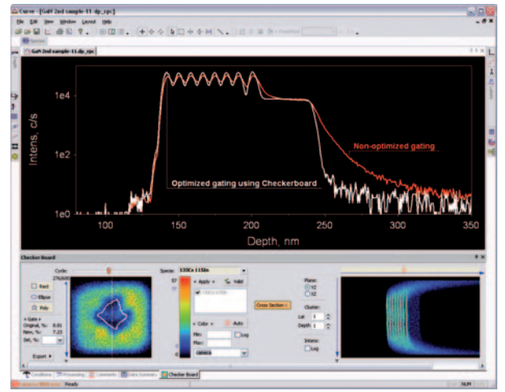
... and user-friendly software

Checkerboard for optimized depth profiling

Checkerboard is an acquisition and processing function which is implemented in the "Analysis" and "WinCurve" software packages of the **IMS 7f-Auto**. 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/of dust particle (if any) present at the crater bottom. It is extremely useful for selecting the area of interest when performing small area analysis.

Avoiding to re-run the measurements, **Checkerboard** greatly improves the **quality of the depth profiling data** and the **throughput** of the instrument.

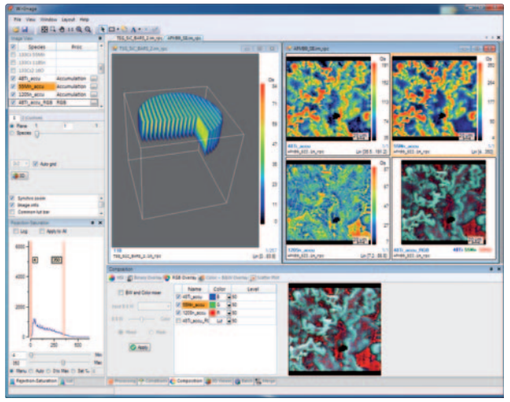


Checkerboard data post-processing on a LED structure showing indium-based MQWs layers: surface roughness is revealed by the non-uniformity of the Indium crater image.
Using Checkerboard, **depth resolution is dramatically improved** by optimizing the size and position of the gate.
Bottom left: 2D crater view and gate.
Bottom right: crater cross section.

WinImage for powerful image processing

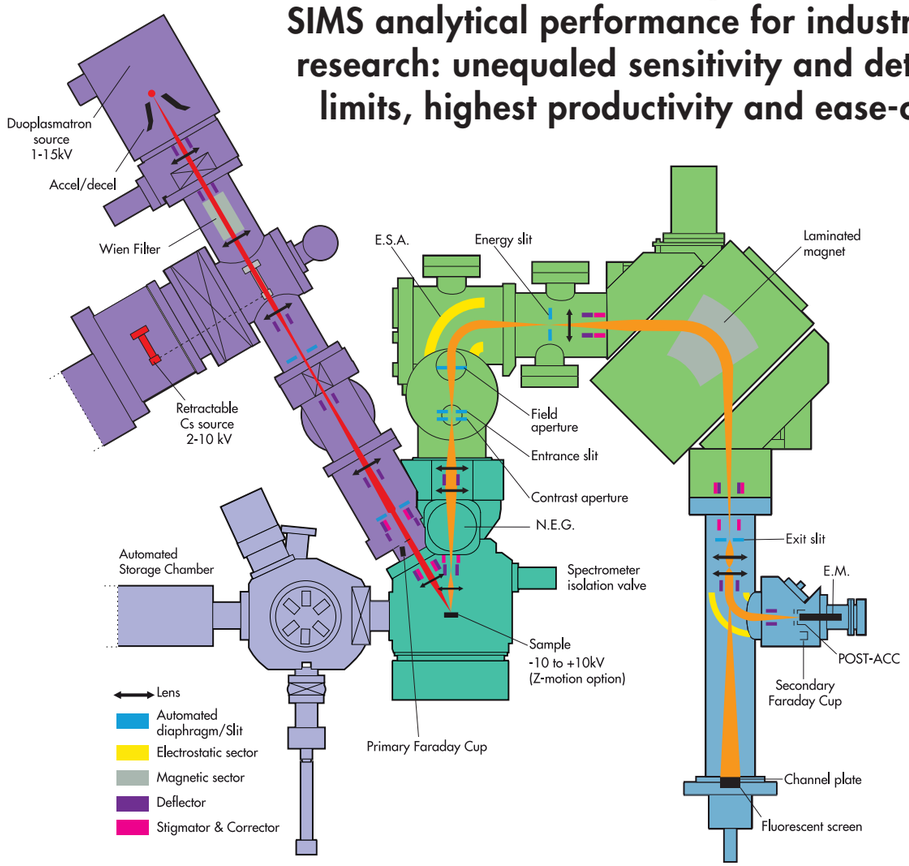
A **new version** of the CAMECA image processing software **WinImage** is now available on the **IMS 7f-Auto**. **WinImage** offers powerful **image visualization, processing & printing functions** in a user-friendly, flexible interface.

- **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 dozens of powerful SIMS image processing functions (includes a set of Aphelion™ imaging libraries).

CAMECA IMS 7f-Auto: Setting new standards in SIMS analytical performance for industry and research: unequaled sensitivity and detection limits, highest productivity and ease-of-use.



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