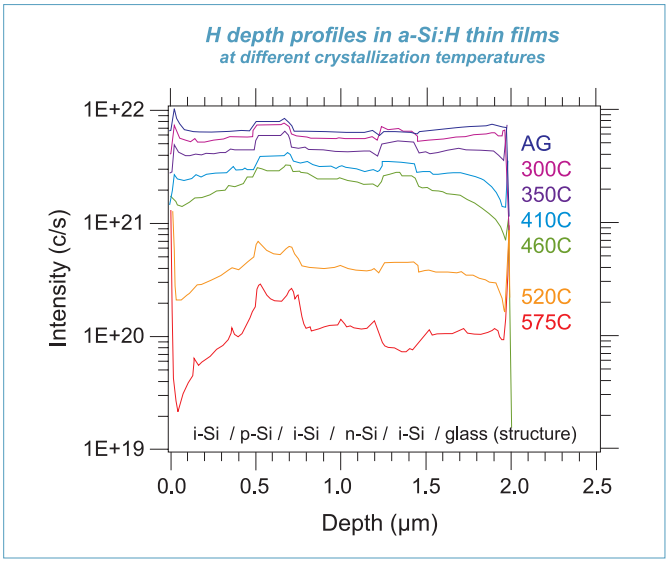
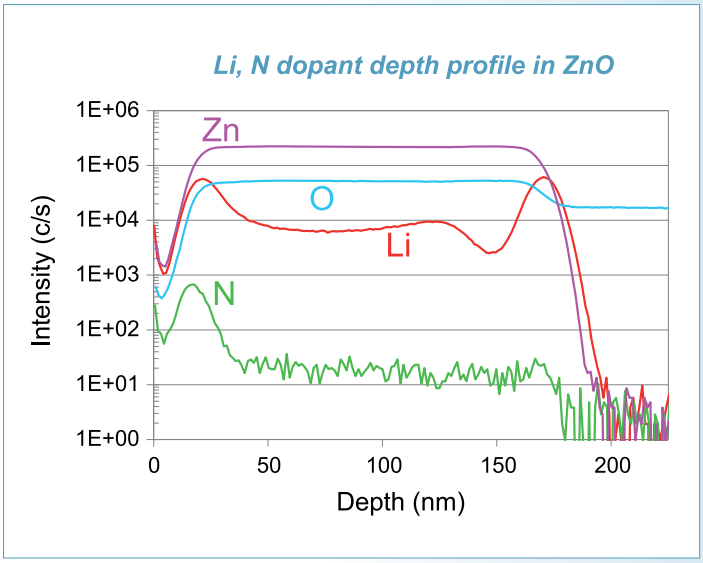
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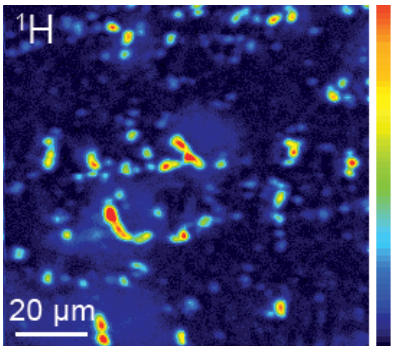
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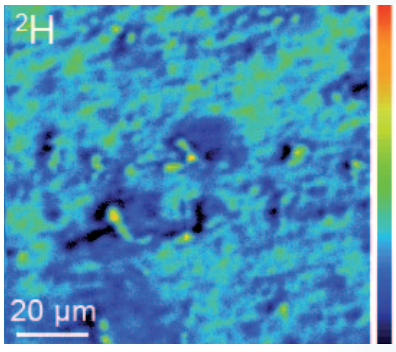
IMS 7f-Auto

Analysis of light elements with benchmark detection limits and high throughput









Semiconductor & PV

LED & Display

Metallurgy

Nuclear Science

CAMECA IMS 7f-Auto: The high throughput SIMS tool with benchmark performance on light element analysis

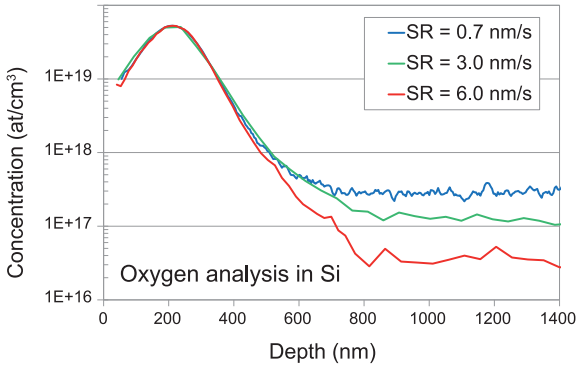
During the analysis of light elements, and more specifically of residual gas species like H, C, N, and O, detection limits are affected by the background level due to residual gases (H_2, H_2O, CO_2, N_2, O_2 and hydrocarbons) in the UHV specimen chamber of Secondary Ion Mass Spectrometry (SIMS) instruments. It is known that background levels depend on the sticking coefficient between the residual gas species and the matrix materials. For instance, the oxygen detection limit varies with the partial pressure of water vapor, and it degrades as the matrix Al-content increases, because of the increasing sticking coefficient between H_2O and the matrix.

Common microanalysis techniques such as Glow Discharge Mass Spectrometry fail to measure the H, C, N, and O composition because of high background signal limitations. Time-of-Flight SIMS can analyze atmospheric gas elements, but with mediocre detection limits only, due to a too low acquisition speed and contamination issues resulting from its intrinsic pulsed ion beam design.

Based on the dynamic SIMS technique, the IMS 7f-Auto is designed to achieve excellent detection limits on light element measurements, thanks to:

- Continuous ion beam sputtering and magnetic sector mass spectrometer design providing extreme sensitivity;
- UHV analysis chamber with optimized vacuum conditions, minimizing the background level created by residual gases. The chamber is also equipped with a liquid nitrogen trap to lower the partial pressure of water vapor;
- Fully automated six-holder storage chamber with sample outgassing capabilities. Compared to the conventional two-holder airlock, the storage chamber provides a much higher throughput, as multiple samples can be pumped overnight in order to achieve optimized detection limits;
- High density Cs primary ion beam allowing high sputtering rates that significantly improve the detection limits.

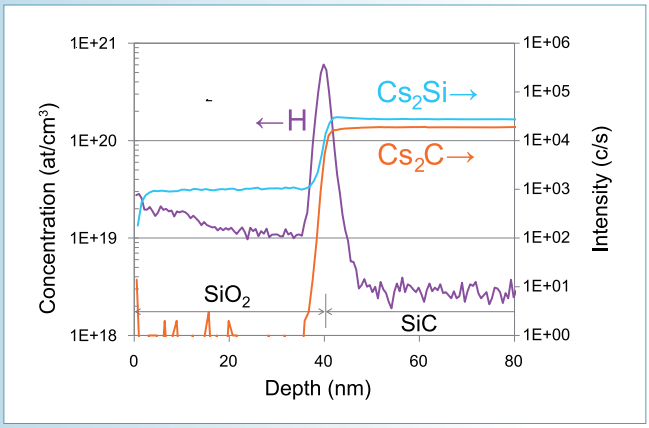
Moreover, the IMS 7f-Auto offers depth profiling capabilities with high depth resolution and high throughput, and can provide information about uniformity with sub-micron lateral resolution.



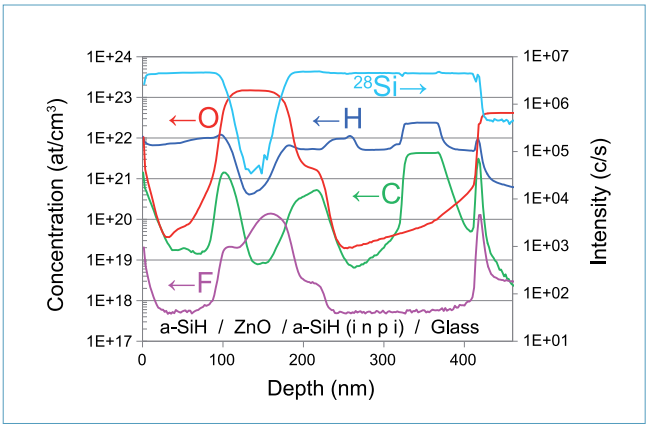
Oxygen depth profiling in a Si standard sample using high 15keV impact energy Cs^+ primary beam under different sputter rate (SR) conditions. High SR conditions minimize the background contribution from the residual gas in the analysis chamber and thus improve the detection limit. A depth profile can be recorded up to several microns within minutes, and excellent detection limit in the low E16 at/cm³ is achieved with such optimized conditions.

Semiconductor & PV

Dynamic SIMS is recognized as one of the most efficient techniques for characterizing novel microelectronics materials and thin-film PV structures such as CdTe, CIGS, ZnO, etc... Thanks to its high sensitivity and ability for depth profiling of thin films, the IMS 7f-Auto is the tool of choice to measure concentration levels of impurities and dopants, to monitor multilayer composition with good depth resolution, and to investigate component interdiffusion through interfaces which are critical for device performance.

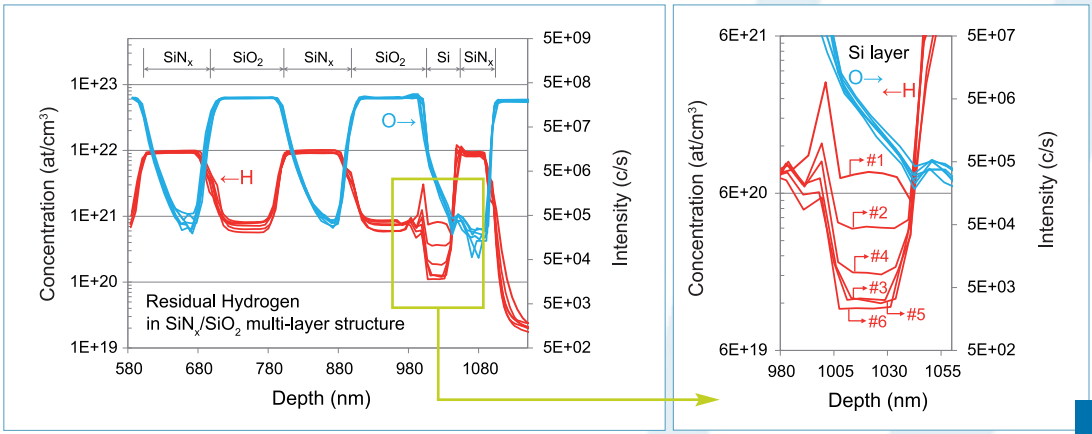


H, C, Si depth profiling in a SiO_2/SiC sample using low impact energy Cs^+ primary beam (2keV) and analyzing MCs_2^+ positive secondary ions. The MCs^+ technique is commonly selected for analyzing multilayer samples due to reduced matrix effects and easier quantification. The H content could be measured in both SiO_2 and SiC layers. The data reveal high dose hydrogen contamination at the SiO_2/SiC interface.



H, C, O, F analyses in thin-film solar cell device, performed using low impact energy Cs^+ primary beam (3keV) for optimizing the depth resolution when sputtering through the thin layer structure. The electron gun was used for charge compensation since ZnO layer and glass are insulators. H, C, O, F elemental composition could be obtained for the different layers.

LED & Display



Hydrogen depth profiling in multi-layered sample structure: $SiN_x/SiO_2/SiN_x/SiO_2/Si/SiN_x$ on glass substrate.

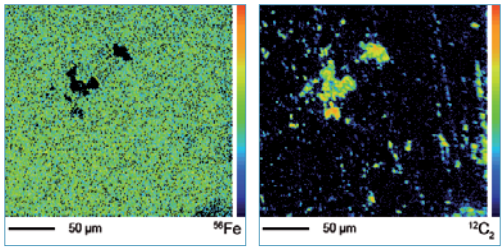
Six samples prepared under different process conditions (annealing, de-hydrogenation, hydrogenation) were analyzed in order to investigate how the process affects the Hydrogen content in the Si layer.

	H (atom/cm³)	Mean Rate
#1	8.04E+20	7.2
#2	3.62E+20	3.3
#3	1.28E+20	1.2
#4	1.86E+20	1.7
#5	1.25E+20	1.1
#6	1.11E+20	1.0

For R&D of LED devices and electroluminescent thin-film structures, information on low-level impurities (H, C, O, N...) introduced during processing and/or ageing is of major importance for a better understanding of device lifetime and failure modes.

Thanks to their extreme sensitivity and superior depth profiling capabilities, dynamic SIMS tools are ideally suited for thin-film materials characterization. Using the IMS 7f-Auto, the in-depth distribution of impurities on different layers can be investigated with good depth resolution together with excellent detection limits.

Metallurgy



Scanning ion imaging (microprobe mode) analyses performed on B inclusions in a metal sample, using Cs^+ primary bombardment and negative secondary conditions. The maps show the presence of a high Carbon contamination in the metal inclusion.

Dynamic SIMS is widely used for the microcharacterization of metallurgical samples, thanks to its unique advantages: low detection limits for all species (H-U), possibility to use isotopic tracers, and capability to visualize their distribution in 3 dimensions.

The IMS 7f-Auto provides high (sub-micron) lateral resolution and outstanding ion imaging capabilities that are applied to studies on a wide variety of materials: diffusion phenomena in polycrystalline samples, surface imaging analysis in alloys, study of inclusions and segregation effects...

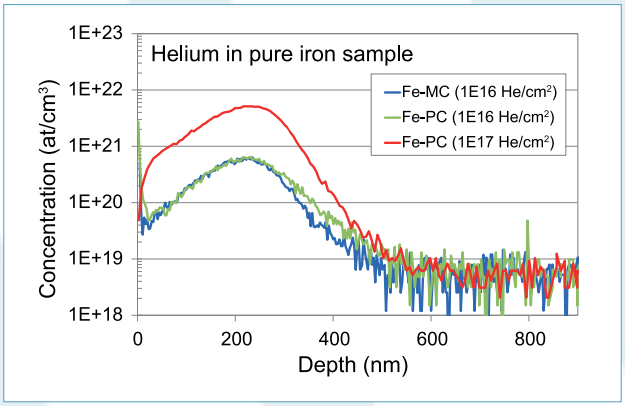
For ion imaging, two operating modes are available: Direct Ion Imaging ("Microscope mode") to acquire images up to a thousand times faster than with any scanning ion microprobe, ideal for 3D mapping; and Scanning Ion Image ("Microprobe mode") ensuring sub-micron lateral resolution imaging with O_2^+ and Cs^+ beam, well adapted to small area analysis.

Nuclear Science

In nuclear reactors, Helium migration and trapping may lead to swelling, hardening, drastic creep rupture, blistering... To ensure longevity of structural nuclear materials, it is thus of paramount importance to better understand helium diffusion mechanisms and to describe its distribution below the surface.

Compared to other techniques commonly used for the analysis of nuclear materials such as NRA (Nuclear Reaction Analysis), Proton back scattering or elastic recoil detection, SIMS provides better sensitivity, wide dynamic range and high depth resolution adding to the fact that the impurity profile can be directly obtained without any mathematical treatment.

In a recent study, Helium distribution in implanted monocrystalline and polycrystalline Fe samples was measured, and concentrations at or above 5E18 at/cm³ (~60 ppm) could be detected, confirming the superior depth profiling capabilities and excellent detection limits provided by the IMS 7f/7f-Auto instruments.



The use of Cs^+ primary ions in conjunction with the detection of $CsHe^+$ molecular ions proves an efficient method to overcome the very high first ionization potential of helium. Concentrations at or above 60 ppm could be measured.

Data from H. Lefaix-Jeuland et al, Nuclear Instruments and Methods in Physics Research B (2013).

CAMECA IMS 7f-Auto: Analyzing light elements with ppm level detection limits & ultimate reproducibility.

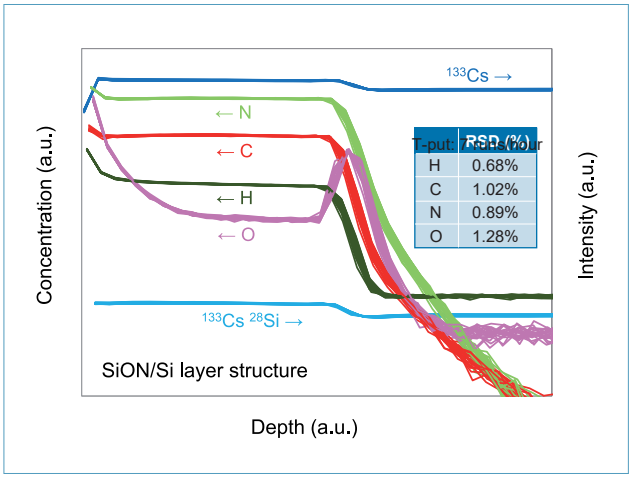
Excellent detection limits for atmospheric species

Thanks to its unique magnetic sector instrument design, the IMS 7f-Auto offers outstanding analytical performances: it combines extreme sensitivity, high mass resolution, high dynamic range and best detection limits on light and trace elements.

Typical IMS 7f-Auto detection limits for atmospheric species in Si, GaAs and GaN matrice layers in AlGaN/InGaN LED. Values obtained for depth profiling measurements with Cs primary bombardment at high impact energy, high sputter rate conditions.

Species	Detection limit					
	Si		GaAs		GaN	
	at/cm³	ppm	at/cm³	ppm	at/cm³	ppm
H	5E+16	1	2E+16	0.4	3E+17	6
C	2E+16	0.4	1E+16	0.2	1E+17	2
N	7E+14	0.014	-	-	-	-
O	2E+16	0.4	1E+16	0.2	1E+17	2

Benchmark reproducibility at high throughput for light element analysis



The IMS 7f-Auto can be equipped with an automated storage chamber, allowing to keep up to 6 sample holders under vacuum (with 4 samples each typically). This is particularly important for applications requiring good vacuum quality, such as light element analyses. After overnight outgassing (if required), it is possible to analyze multiple samples in fully unattended and automated mode, dramatically improving the intrument throughput. Ultimate reproducibility on different windows and different holders can be achieved, together with excellent detection limits and high productivity.

H, C, N, O concentration reproducibility test on thin film SiON samples, performed using Cs^+ primary ions at 2.5keV impact energy / MCs^+ mode. A total of 22 runs were performed in fully unattended mode on 8 samples (3 sample holders).

Results demonstrate excellent reproducibility on different windows and different holders (RSD ~1 %), together with high throughput (7 runs/hour).

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