Dynamic SIMS Applications in Multilayer Films

Improved Dopant Quantification in Insulating Thin Films

Dynamic Secondary Ion Mass Spectrometry (D-SIMS) detects doping ions in the matrix with excellent precision and reproducibility. However, when the sample matrix is not well conductive, charged particles may accumulate on the surface during SIMS analysis, preventing reliable depth profiling. The Normal-incidence Electron Gun (NEG) of the CAMECA D-SIMS tools provides an electron beam flux that neutralizes charged samples and is therefore commonly used for charge compensation on insulating samples. Compared to other techniques (coating of a thick metal layer, implantation of a conductive rod on the sample or application of a metal grid on the surface), the use of the CAMECA NEG, unique in design, enables SIMS analysis on insulating samples and does not degrade SIMS depth resolution and sensitivity.

Detecting the elements of interest in complex samples such as SiN/SiO_2 multilayered structures proves particularly challenging. Scientists at WinTech Nano-Technology Services have worked on a NEG-based methodology that can be applied to other insulating multilayered samples. Presented here are analytical results for three samples with SiN/SiO_2 interlaced structures using IMS 7f-Auto (Table 1).

The SIMS depth profiles presented in Figure 1 show that using Cs primary beam with negative secondary ion detection, the SiN/SiO_2 interlaced structure of all three samples could be successfully analyzed. Si and O signals are quite consistent with the structure and the B signal fits with the expectations.

The NEG provides different charge compensation mechanisms depending on the secondary polarity (negative or positive modes). With the Cs primary beam, when negative secondary ions are detected, a cloud of low-energy electrons is formed just above the sample surface. When positive charge is created at the sample surface, the sample will take out to the cloud the exact number of electrons required for the compensation. Even if insulating material changes from SiO_2 to SiN, efficient charge "self-compensation" is achieved (Figure 2). When using O_2^+ primary bombardment, when positive secondary ions are detected, the charge compensation method is quite different because the sample voltage is positive. In this positive mode, the NEG delivers a beam with high energy electrons on the sample surface. In this case, for achieving charge compensation, the NEG parameters have to be adjusted depending on the sample matrix (SiN or SiO_2). Therefore, the positive mode may not provide correct charge compensation during acquisition on multilayered samples.

The study demonstrates that the Cs primary beam bombardment, negative secondary ion detection, combined with the NEG can be applied for SIMS depth profiling of insulating samples, including multilayered sample structures such as SiN/SiO_2. In negative mode, NEG provides charge "self-compensation", which is a very efficient method for high precision measurements in insulating samples.

Layer (top to glass substrate)	A	B	C
SiN	/	1000 Å	500 Å
SiO	1000 Å	/	1000 Å
Poly Si	500 Å	500 Å	500 Å
SiO	3000 Å	3000 Å	3000 Å
SiN	1000 Å	1000 Å	1000 Å
Energy	B36K	B25K	B39K
Dose	1.00E+15		

Table 1:
The interlaced structures of three SiO_2 and SiN samples doped with 1E15 atoms/cm² of boron.

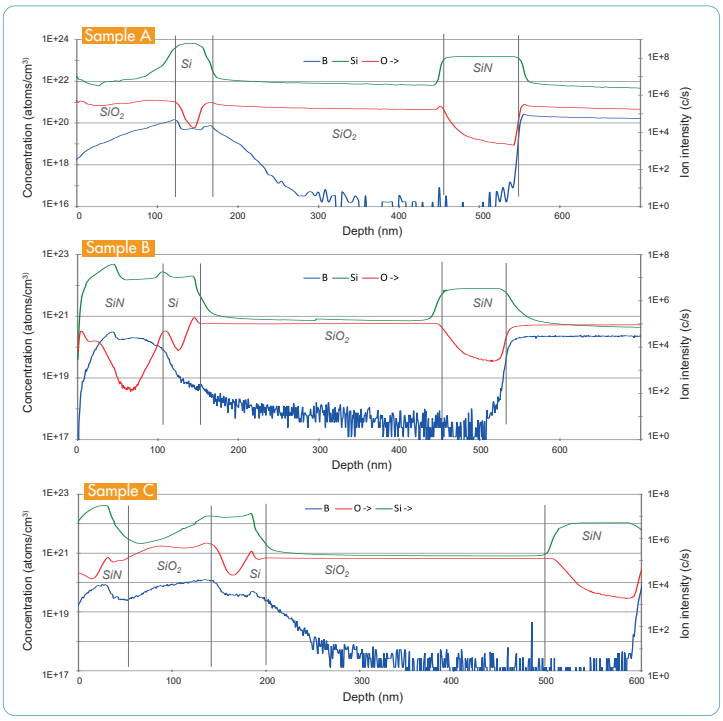


Figure 1:
Depth profiles for all samples using IMS 7f-Auto Cs^+ primary beam; IE 9keV; analytical chamber at 5E-9 mbar; NEG on; 200 µm × 200 µm raster size.

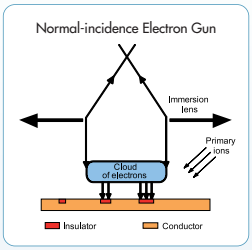
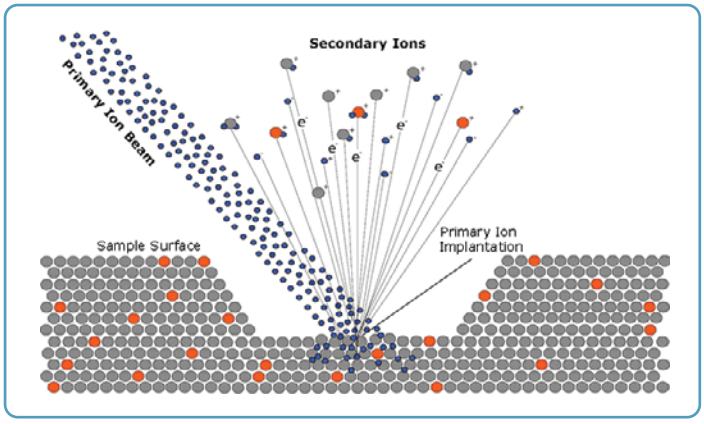


Figure 2:
The NEG produces an electron beam perpendicular to the sample surface. In negative ion extraction mode, the electrons emitted by the NEG produce a cloud of electrons with very low energy (few eV) near the sample surface, which results in charge "self-compensation", routinely used for high precision measurements in insulating samples.

Adapted from: H. Xu et al. Quantification of Doping Boron Ions in Si Embedded in Heavily Charging SiN/SiO2 Multiple-Layer Films by Dynamic SIMS.
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The Technique Behind

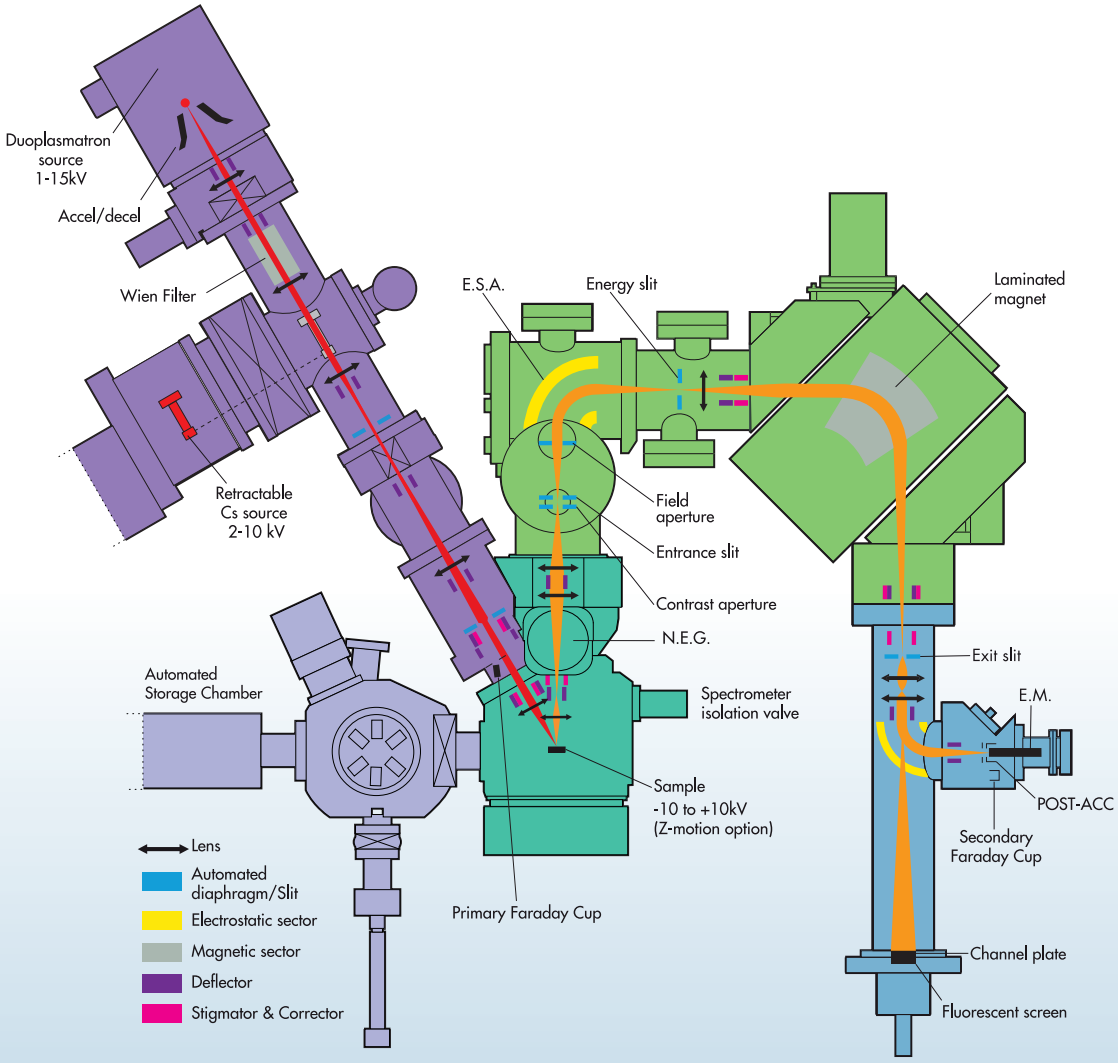


Dynamic SIMS

When a solid sample is sputtered by primary ions of few keV energy, a fraction of the particles emitted from the target is ionized. Secondary Ion Mass Spectrometry consists of analyzing these secondary ions with a mass spectrometer.

The SIMS technique is "destructive" by its nature (sputtering of material). It can be applied to any type of flat, solid material that can be kept under vacuum.

In dynamic SIMS, bulk composition and in-depth distribution of trace elements are investigated with a depth resolution ranging from sub-nm to tens of nm. SIMS is recognized as the most sensitive elemental and isotopic surface analysis technique.



CAMECA IMS 7f-Auto

The IMS 7f-Auto is a versatile SIMS tool offering reference detection sensitivity with high throughput and full automation. Its motorized storage chamber and sample transfer allows the analysis of multiple samples in chained or remote mode.

For more information please visit www.cameca.com/products/sims/ims7f-auto

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