doi:10.1017/S1431927616002567
Microsc. Microanal. 22 (Suppl 3), 2016

Complementing Secondary Ion Mass Spectrometry with other Ion-, Electron- and Photon-based Analytical Microscopies

F. Horréard[1], P. Peres[1], A. Merkulov[1], D.J. Larson[2]

[1] CAMECA, 29 Quai des Grésillons, 92622 Gennevilliers, France.
[2] CAMECA Instruments Inc., 5500 Nobel Drive, Madison, WI 53711 USA

Dynamic secondary ion mass spectrometry (D-SIMS) is one of the most sensitive elemental and isotopic analysis techniques, allowing surface analysis, imaging and depth profiling. Two other key measures of the capability of this technique are depth resolution and lateral resolution. These parameters are not independent. The Cameca NanoSIMS permits a lateral resolution of 50nm but at the cost of a modest depth resolution of 10-20nm due to the atomic mixing induced by the 16keV primary ion impact energy. Inversely the Cameca IMS SC Ultra depth resolution reaches 0.7nm at 100-150eV impact energy but with a modest lateral resolution of ~5µm. Independently of spatial resolution, quantification of the local composition can be challenging in SIMS when concentrations reach “high” levels (above ~at. %) or at layer interfaces.

Thus, in order to solve analytical problems, it is often desirable to correlate SIMS with different analytical techniques or use synergies between them when available. We demonstrate the benefits of such approach through a series of practical cases taken from material science, nanotechnology, earth science and life science.

In microelectronics, new non-planar FINFET transistor technology with 3D structures and nanoscale dimensions poses serious challenges to doping methods and analytical methods like SIMS. Analytical HR TEM-EDS measurements can be performed on single transistor but lack sensitivity and the potential for quantification of very low dopants. Low energy SIMS dopant depth profiling and LEXES (low energy EPMA) dopant dose measurements can be performed on a large number of transistors and calibrate depth and concentration, see Figure 1 [1].

In a low boron steel study, segregation of boron toward grain boundaries can be qualitatively measured with the NanoSIMS. It is possible to analyze many GBs in field of view of several microns and subsequently choose several selected regions from which to extract lamella and shape needle specimens using a FIB-SEM for atom probe tomography (APT) analysis for quantitation of segregation at the nanometer scale, see Figure 2 [2].

In the study of stress-corrosion cracking in steel for pressurized water reactors, the strategy is to chain optical review, SEM review and NanoSIMS analyses on many crack tips. Being able to travel over millimeter distances on a sample permits measurement of a significant number of crack tips. A few lamella can then be extracted from selected regions for more extensive TEM and APT analyses. The NanoSIMS gives access to the distribution of light elements (H, D, B, etc.) and embrittling elements (S, P, etc.) over distances of several microns. TEM and APT offer near atomic resolution and structural information [3].

In a final example, dielectric nanoparticles (DNPs) embedded in rare-earth doped silica glass, fiber optic material were studied by correlating EPMA, TEM, NanoSIMS and atom probe tomography.

Each technique reveals complementary information at a different scale, up to the fully assessed composition of DNPs ranging from 1 to 15nm [4].

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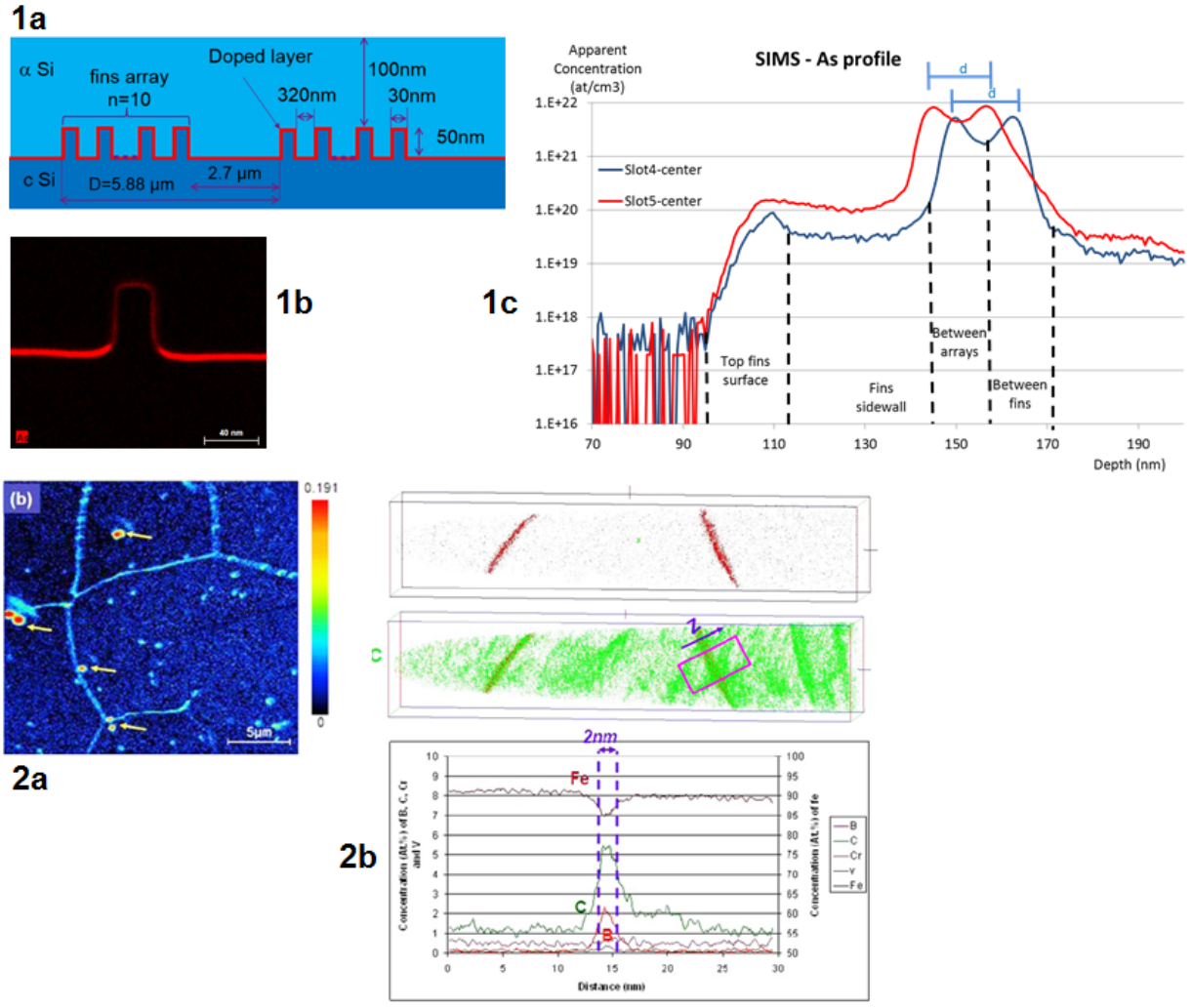

Figure 1. a) Schematic of FINFET test structure capped with amorphous silicon, b) TEM-EDS arsenic dopant image of one FIN-FET section, c) Low energy SIMS depth profile over an average number of FINs, providing implanted dose.
Figure 2. a) NanoSIMS boron image on 50ppm-boron steel. FoV: 40 × 40µm^2. Note precipitate along grain boundaries, b) Atom probe tomography analysis of a selected GB in the same specimen allowing its quantification.

https://doi.org/10.1017/S1431927616002567 Published online by Cambridge University Press