Advances in Doped SiGe Characterization

Compositional Measurement of Thin Multilayers in Patterned Wafer Pads

The SiGe characterization challenge

Silicon-Germanium, owing to its high electron and hole mobility, has multiple applications in high-speed microelectronic device technology. Dynamic SIMS is used to monitor the concentration of Ge and B in thin SiGe layers due to its high sensitivity and ability to profile in depth. However, the depth profile quantification can be challenging for $Si_{1-x}Ge_x$ multilayer structures because sputter rate and ion yield are known to vary with the Ge concentration. By creating optimal sputtering conditions which minimize these effects we demonstrate profiling thin SiGe:B multilayers.

Oxygen is the preferred primary ion to increase the useful yield of the doped Boron in SiGe. Sputtering conditions must be selected according to the required depth resolution. For relatively thick films (> 100 nm) with no strict interface resolution requirement (>2.5 nm for 100 nm depth), an impact energy of 1keV is traditionally employed. However, at these energies, thin layers are often sputtered through without sufficient data density to characterize the layer. Much lower energies are required to accurately characterize the doped thin film.

Instrumental improvements to meet the challenge

Recent developments in ion sources coupled with primary column improvements in our magnetic sector SIMS instruments enable a reduction in sputtering impact energy while retaining a tightly focused beam of high ion density. Resulting depth profiles using EXtreme Low Impact Energy (EXLIE) show a significant improvement in depth resolution. This note demonstrates clearly delineating very thin (<5 nm) SiGe multilayer structures with an extremely good (<1 nm/ decade) resolution.

Achieving Sub-nanometer Depth Resolution of Thin Multilayers with EXtreme Low Impact Energy SIMS

A SiGe structure with nanometer sized features has been effectively measured in a small pad located on the scribe line. The SIMS data acquisition is performed using an ultra low impact energy of 200 eV and analyzed using the checkerboard mode in which we create a series of SIMS maps of compositional distribution and then do layer by layer 3D reconstruction. A 3D data representation of the patterned structure with matrix (Ge, green and Si, gray) and dopant (B, red) distribution is shown in Figure 1 overlapping a depth profile that resolves the SiGe multilayers with a sub-nanometer/decade resolution.

Figure 2 shows a comparison of raw data depth profiles for B and Ge obtained in wafer die on scribe line pattern using 200eV and 1keV primary ion impact energy conditions. The significantly enhanced depth resolution at 200 eV compared to 1keV impact energy for the thin multilayers is shown. The thin B doped layers are virtually unresolved while using the relatively high impact energy condition of 1keV.

Our improvements to oxygen ion source and primary column design provide a concurrent benefit of giving access to sputter rates up to 3 nm/min for O2+ @ 150eV (compared to 6 nm/min at 1 keV). This high sputter rate at low energy enables retaining a high dynamic range of up to four decades.

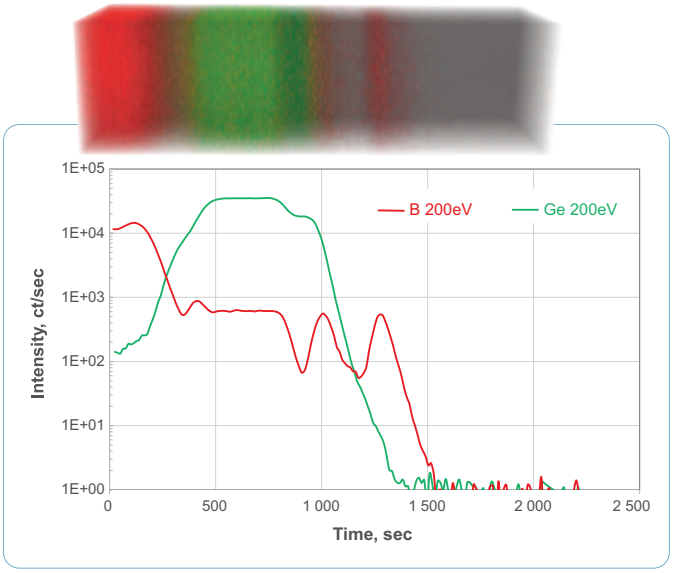


Figure 1:
Depth profile of B doped SiGe showing sub-nm compositional profile resolution. The profile has been optimized for B detection and maximum depth resolution.
(Concentration profiles are omitted for customer confidentiality.)

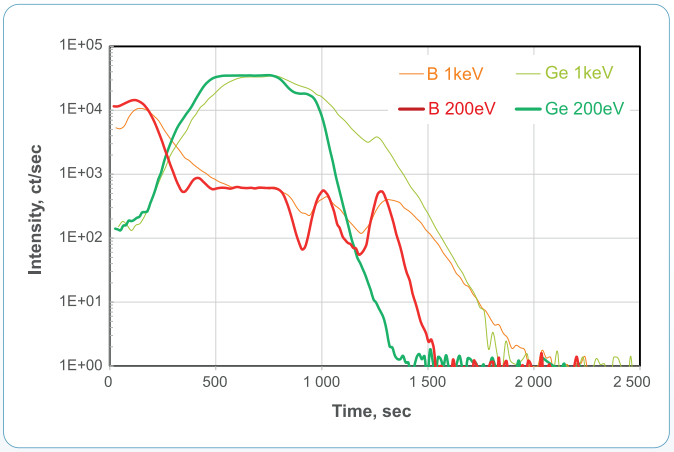
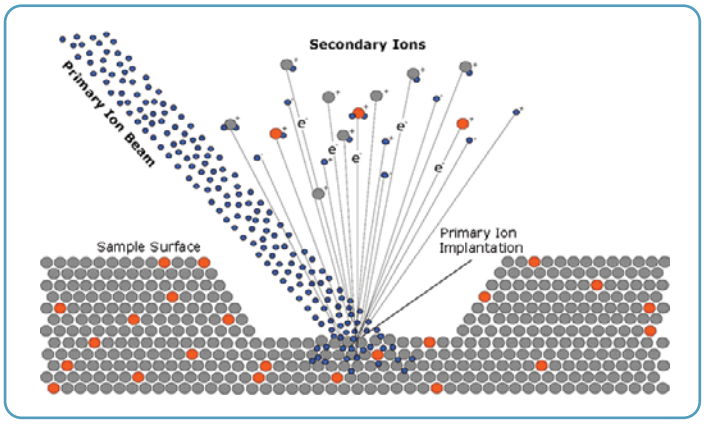


Figure 2:
Comparison of the resolution of the thin multilayers EXLIE (200 eV) and higher impact energy of 1 keV showing the impact energy reduction benefits for the pad analysis.
(Note that the time axes shown is adjusted to overlay in depth for the two profiles.)

The Technology 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.



Inspired from the Greek Akontio (javelin), AKONIS expresses the speed and precision of our analyses.

AKONIS

The new CAMECA AKONIS SIMS tool fills a critical gap in semiconductor fabrication processes by providing high throughput, high precision detection for implant profiles, composition analysis and interfacial data directly in the semiconductor manufacturing line. AKONIS provides a very high level of automation to ensure repeatability across tools for fab level process control and tool-to-tool matching.

Complementing the IMS Wf/SC Ultra as well as the SIMS 4550 (quadrupole SIMS) used to support the semiconductor industry via characterization labs, AKONIS - with full automation of instrument set-up and acquisition routines - enables rapid, within-fab analysis without compromise in analytical sensitivity.

AKONIS benefits from recent development in EXtremely Low Impact Energy (EXLIE) ionic column technology (< 150 eV), coupled with a full wafer handling system including a high resolution stage enabling measurements on pads down to 20 µm.

AKONIS is a leap forward in high precision characterization of implants, interfaces and compositional analysis along with high repeatability metrology for the most demanding semiconductor process development and control applications.

For more information please visit www.cameca.com/products/sims/akonis

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