AN 372
SIMS Quantification for Compound Semiconductors

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Discussion

The measurement of dopant and impurity concentrations as a function of depth in compound semiconductors is often accomplished using Secondary Ion Mass Spectrometry (SIMS) because of its very low detection limits and excellent depth resolution. Because the secondary ion yields of impurities under the SIMS measurement are dependent upon the matrix composition, the quantification of this measurement requires the use of appropriate reference materials for each layer in the structure.

An example of a reference material used by the Evans Analytical Group for compound semiconductors is an epitaxial layered structure of GaAs/InGaAs:Te/AlGaAs:Si/GaAs:C/GaAs:Si grown on a GaAs substrate. A SIMS profile of the dopants and impurities Te, Si, C, and H, plus the signals for In and Al as a function of depth are shown in Figure 1. The actual data displayed in the figure are six repeat analyses of this calibration, or reference, standard to show precision. The higher signals, above 1018 atoms/cm3 in concentration, are used for calibration. The lower signals can be used as a measure of background concentration in those matrices.

One of the more challenging quantification issues in SIMS occurs at the interface of materials with major changes in matrix compositions. However, using appropriate reference materials and SIMS data processing software it is possible to obtain accurate concentration profiles of impurities through these interfaces. This is demonstrated in Figure 2 by performing a SIMS depth measurement of a silicon ion implant through the interface of an InGaP layer on GaAs. The depth distribution of ion implants are well understood, and Figure 2 shows the expected Si concentration as a function of depth through the interface. A similar demonstration is shown using a carbon ion implant through the same interface, as seen in Figure 3. The concentration profile before and after this interface matches the expected ion implant distribution (i.e., the matrix effect on the SIMS ion yield in the two matrices has been accounted for).

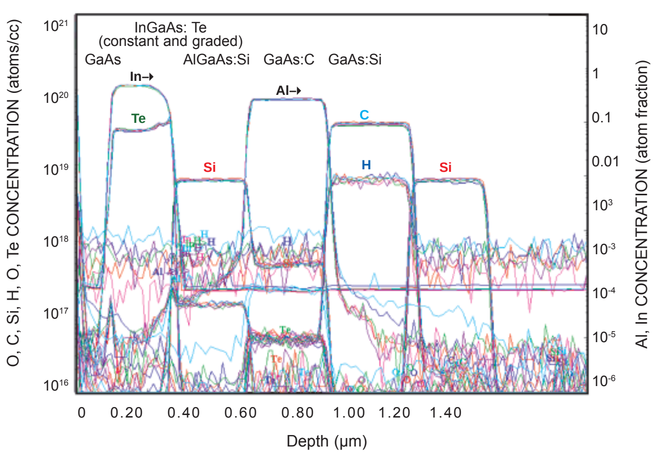

Figure 1. Six analyses of calibration standard

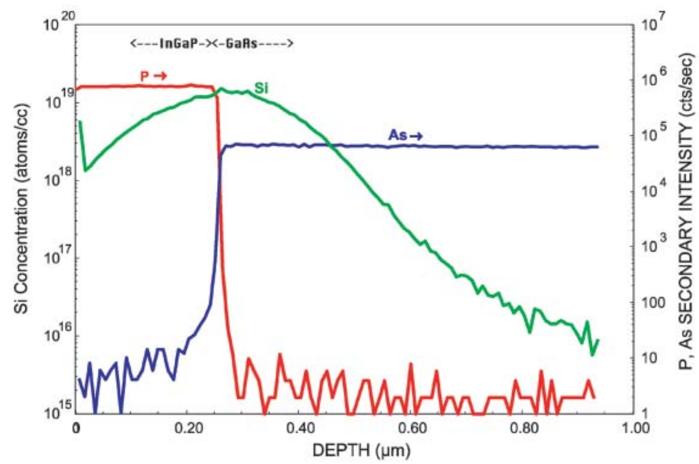

Figure 2. Si Implanted Across InGaP/GaAs

To illustrate the value of the quantification of the SIMS measurement used by the Evans Analytical Group, Figure 4 shows the concentration depth profile of Si in a very thin (10's of nm) layered structure of InGaAs, GaAs, InGaP on GaAs. The combination of quantification and excellent depth resolution provides critical information for the development and manufacture of compound semiconductor devices.

The calibration materials and the many samples that have been analyzed also provide a means of determining detection limits for the common dopants in compound semiconductor materials. Table 1 lists detection limits determined for several materials under depth profiling conditions.

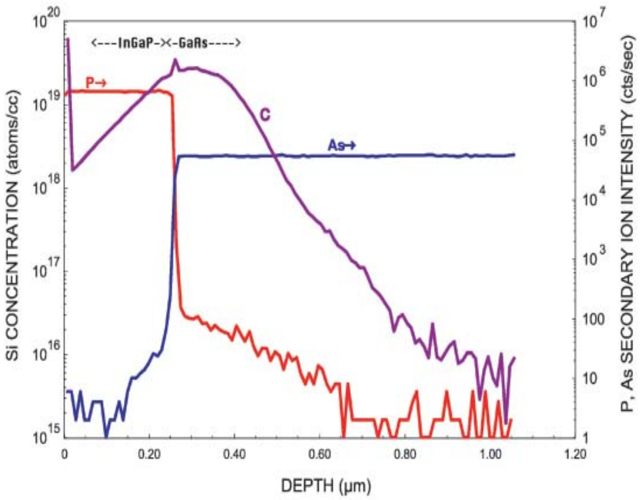

Figure 3. C Implanted Across InGaP/GaAs

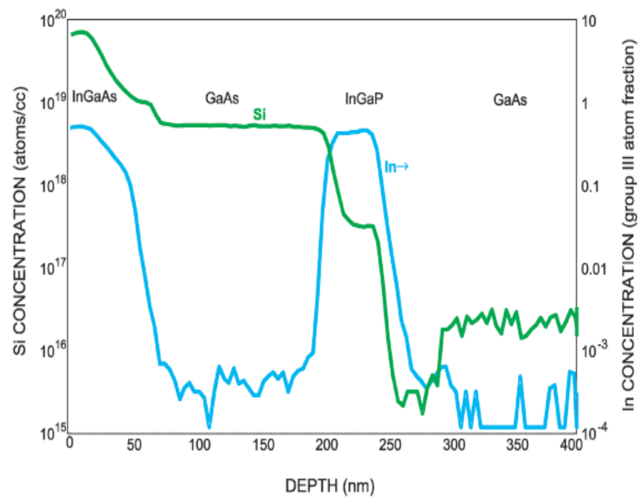

Figure 4. InGaAs, GaAs, InGaP HBT

Table 1. SIMS Detection Limits in atoms/cm³

	GaAs	AlGaAs	InGaAs	InGaP	InP
H	1E17	1E17	1E17	1E17	1E17
C	3E15	3E15	3E15	3E15	3E15
O	3E15	1E16	3E15	3E15	3E15
Si	6E13	1E15	6E13	6E13	6E13
Te	1E13	1E13	1E13	1E13	1E13
Se	1E13	1E13	1E13	1E13	1E13
S	6E13	6E13	6E13	1E15	1E15
Br	1E14	1E14	1E14	1E14	1E14

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