

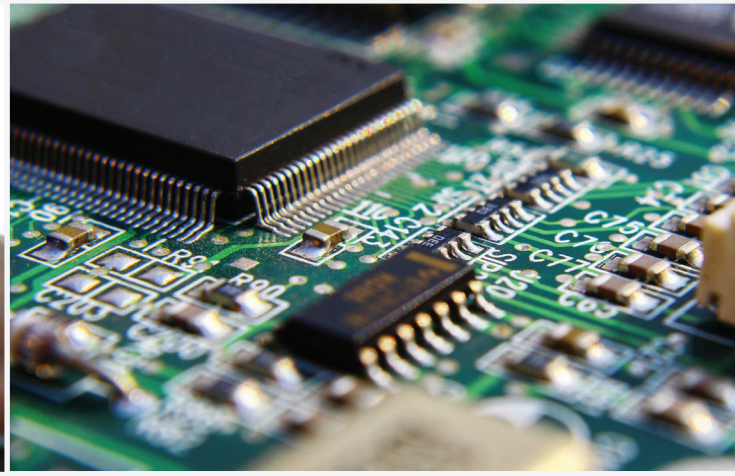

SIMS ANALYTICAL SERVICES FOR COMPOUND SEMICONDUCTOR HIGH SPEED ELECTRONICS

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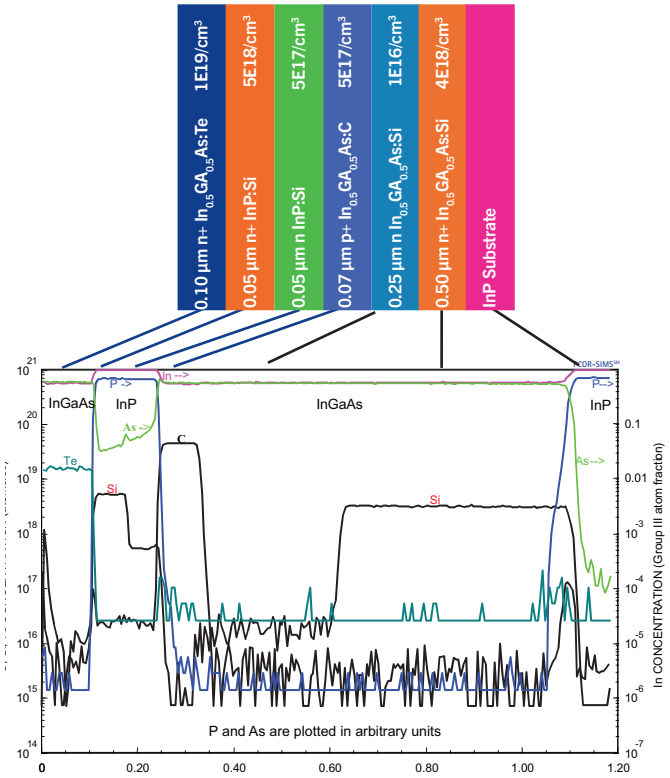
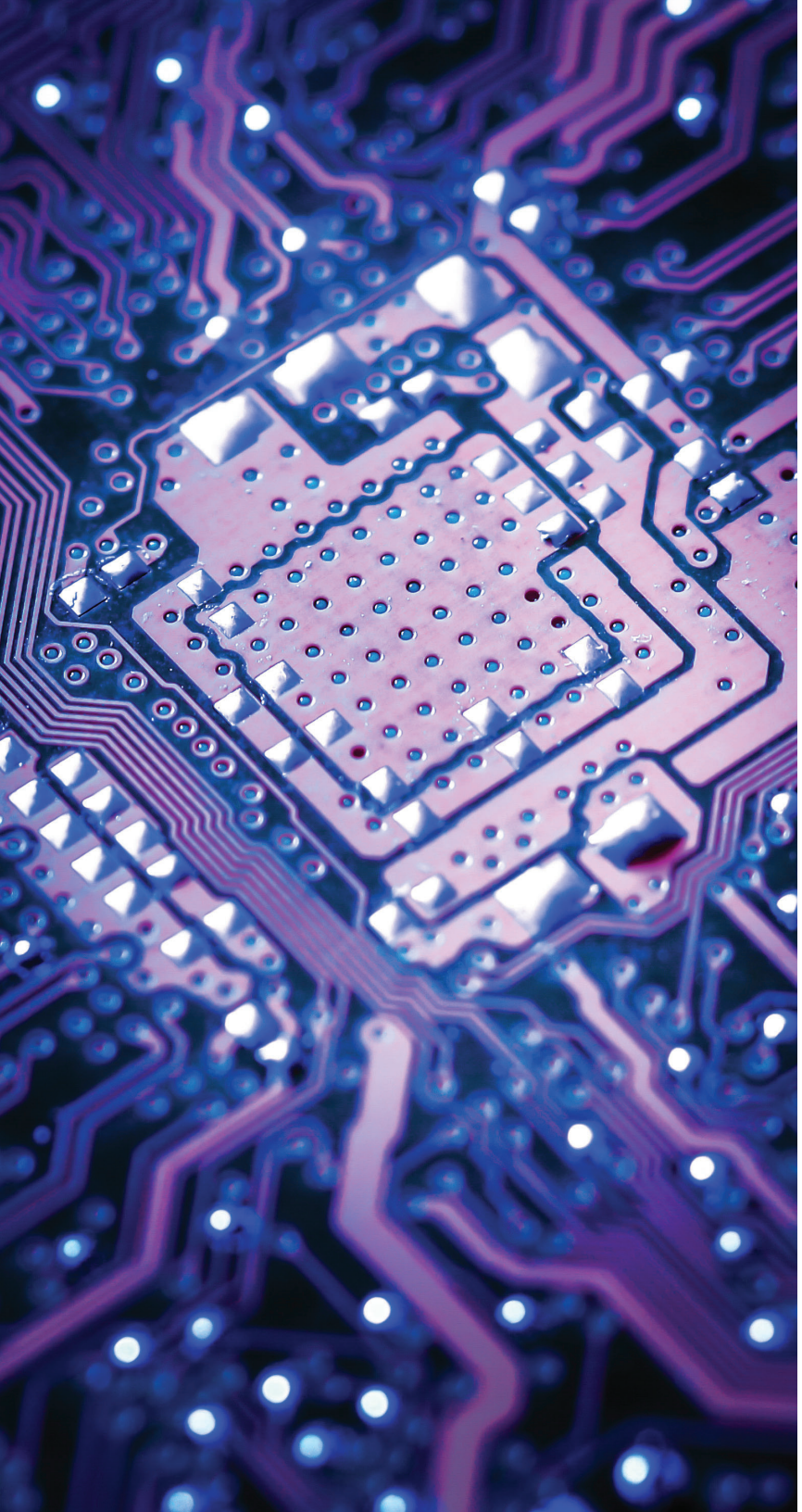
SIMS Analysis for Optimizing Epi-Layer Growth

Compound semiconductors are responsible for the explosive growth of high-speed electronics, especially in communication applications and advanced mobile appliances. These high-value and highly versatile materials require complex processing to achieve the device performance and reliability required for high-volume applications.

One of the most critical processing steps is the formation of complex epi layer structures. In order to monitor and optimize III-V epitaxial wafer growth, one needs to be able to confirm the overall structure, impurity content, and composition of the layers being grown. At Eurofins EAG Laboratories (EAG) we provide customers with this confirmation using specially formulated Secondary Ion Mass Spectrometry (SIMS), called PCOR-SIMS^{SM}. PCOR-SIMS^{SM} provides customers with the dopant concentrations of the layers as well as stoichiometry and thickness with greater accuracy than regular SIMS. An example of this is illustrated below where the structure given to the wafer grower is compared with the resulting PCOR-SIMS^{SM} profile of the wafer grown by that recipe. This shows if the target compositions and thicknesses were actually achieved.



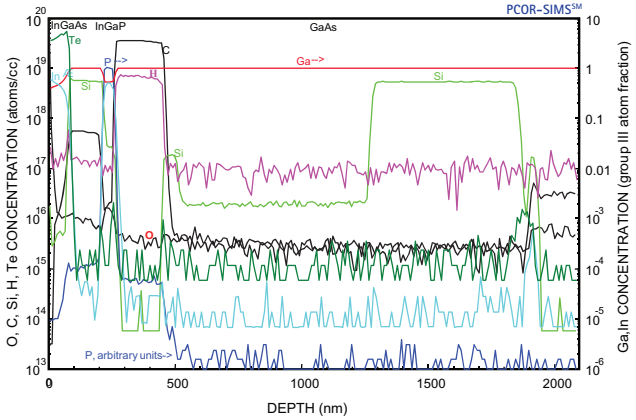


In order for a SIMS depth profile to be useful in optimizing III-V epitaxial wafer growth, EAG scientists must make sure that the calibration of the SIMS profiles is correct. The scientists analyze ion-implanted standards for calibration of dopants and impurities in both arsenide and phosphide materials to ensure that sensitivity factors are correct. They also use well-characterized layers of AlGaAs, InGaAs, and InGaP for Group III atom fraction determination in grown layers - correcting for differences in sputtering rates between dissimilar layers to ensure that the plotted layer thicknesses are correct. Our proprietary PCOR-SIMS^{SM} method covers all these different calibrations at every data point to provide the most accurate concentration and layer thickness data. Lastly, there must be detection limits that are low enough to make sure that dopant and impurity levels that are significant to processing can be detected.

	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

Detection Limits in Typically Grown III-V Epi Layers (at/cm^3)

The chart to the right is an analysis of an HBT structure with a Te-doped InGaAs contact, graded cap layers, and an InGaP emitter. The GaAs collector and sub-collector include three different Si concentrations. Hydrogen and sulfur contamination are found in the carbon-doped base layer. Oxygen impurity levels in the grown layers are in the mid-E15/cm^3 range. Note also that there is sufficient depth resolution to measure impurity levels very near the surface in the top contact layer, and dopant concentrations in thin buried layers (e.g. the Si doping in the InGaP emitter layer) can be measured.

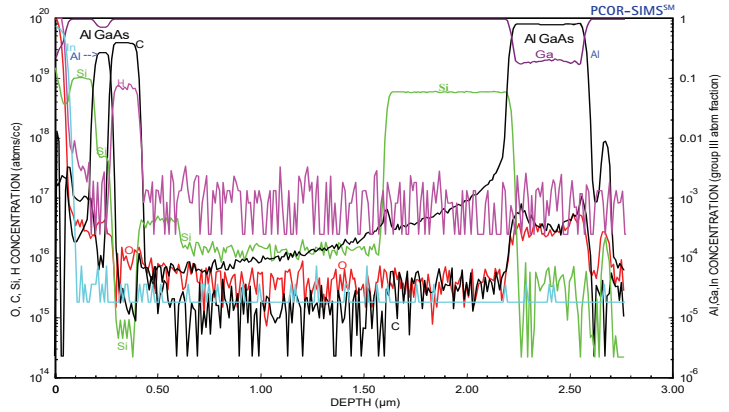


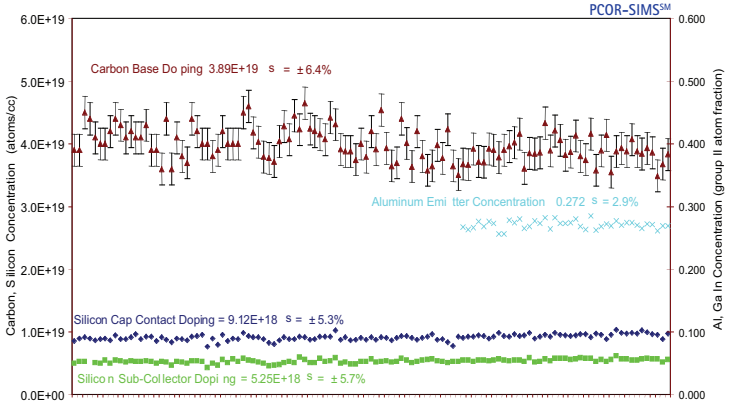
With the above detection limits and proper calibration, we can perform a complete dopant, impurity, stoichiometry, and layer thickness analysis.

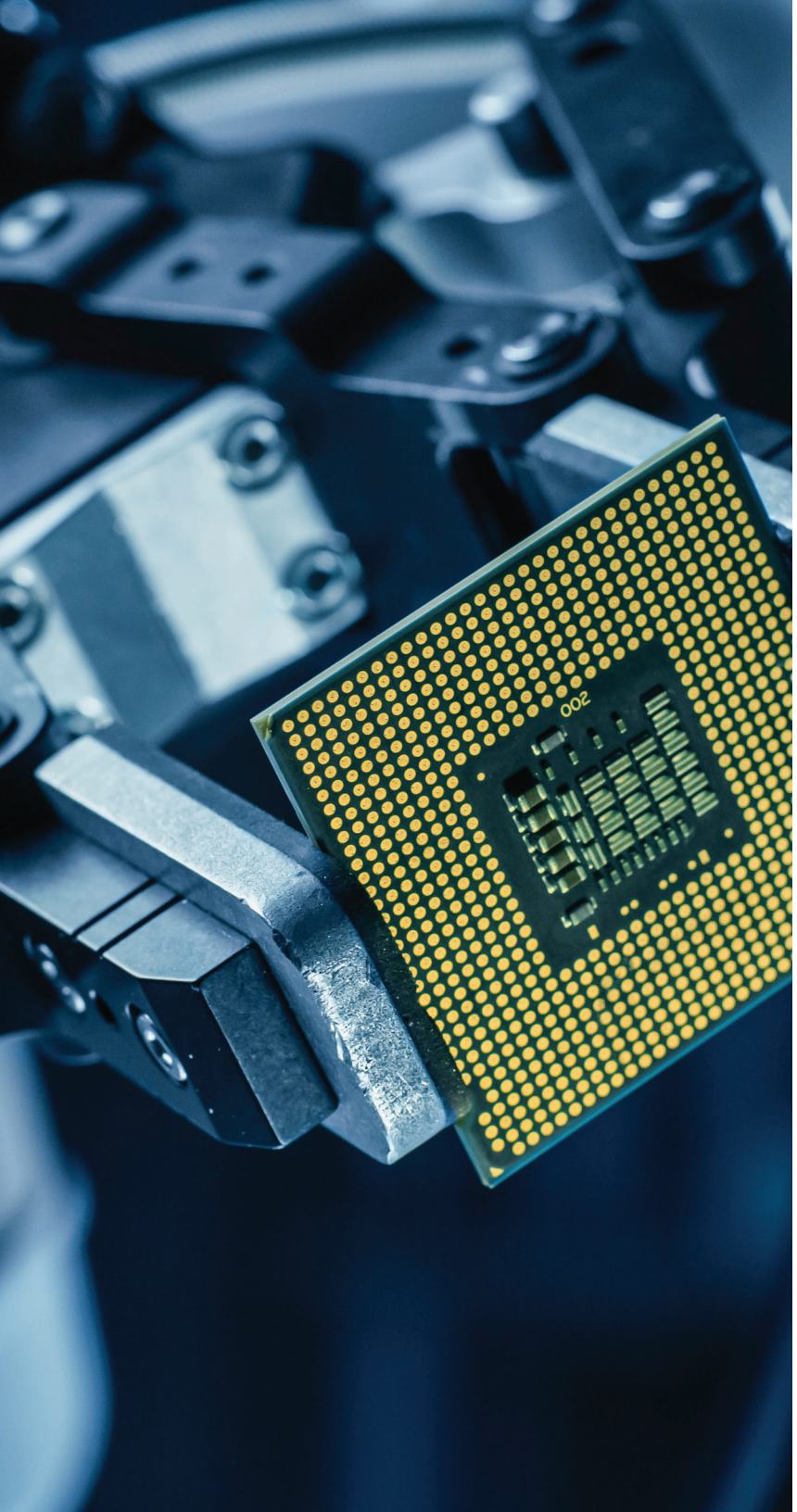
SIMS Reproducibility

Shown below is a SIMS depth profile of an AlGaAs-emitter HBT that EAG analyzed for over five years to demonstrate reproducibility of measurements. This control sample allows comparison of data over an extended period of time. The Si doping levels in the cap contact, collector and sub-collector layers, as well as the C doping level in the base layer were tracked. Additionally, the Al atom fraction in the emitter, the total epitaxial layer thickness, and the base/collector junction depth were also tracked.

A control chart for this sample is shown below. Data shown is from December 1995 through 2001. Relative standard deviations for the measured quantitites over a five-year period are on the order of 6% or less.

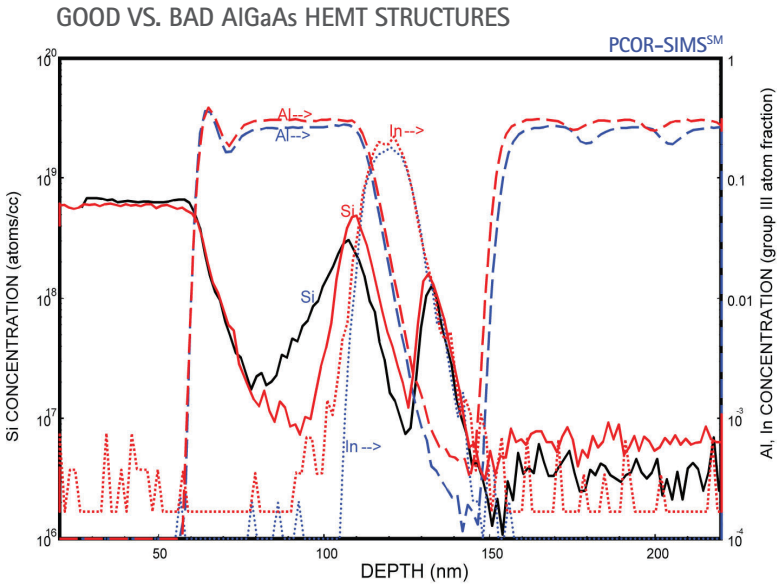






Process Development and Failure Analysis

PCOR-SIMS^{SM} can also be useful in process development and monitoring for pHEMT structures used in wireless communication devices. The very thin layers and sharp doping spikes in these structures require high depth resolution analysis. An example of the utility of using PCOR-SIMS^{SM} on these structures is shown below. Good and bad AlGaAs/InGaAs pHEMT structures are compared to determine if diffusion of either of the two Si doping spikes might be the cause of the difference in performance between the two structures. The uppermost Si doping spike in the bad sample has diffused up into the top AlGaAs layer while this has not occurred in the good sample. The deeper Si spike has not diffused in either sample. The higher out-diffusion of the Si dopant in the "BAD" sample has probably caused reduction of resistance in the Schottky layer leading to lower breakdown voltage than the "GOOD" sample.



RED = GOOD / BLUE = BAD

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When it comes to understanding the physical structure, performance, chemical properties and composition of materials, no other scientific services company offers the breadth of experience, diversity of analytical techniques or technical ingenuity of Eurofins EAG Laboratories. We don't just perform testing, we drive commercial success—through thoughtfully designed investigations, technically superior analyses, and expert interpretation of data.

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