PROBion analysis

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Improving atmospheric elements detection limits in III-V semiconductor materials (GaN, AlGaN, GaAs, AlGaAs, AlInAs, InP)

Over the last years, Probion Analysis research and development efforts allowed to drastically reduce detection limits of atmospheric elements (hydrogen, carbon and oxygen) in different semiconductor materials. Monitoring very low concentrations of atmospheric elements is a key point for our clients looking for a yield improvement thanks to contamination reduction. A new experimental protocol was developed to obtain state-of-the-art detection limits for atmospheric elements.

-Interest:

Semiconductor based devices performance can be reduced due to the presence of atmospheric contaminants (H, C and O). Therefore secondary ion mass spectrometry (SIMS) has to be able to detect very low concentrations of these elements. In conventional SIMS analysis, atmospheric elements quantification is limited by in-situ contamination, in spite of the ultra vacuum used in optimal experimental conditions (<10^{-10} Torr). Increasing the sputtering rate is also used to improve the detection limit, but the latter remains relatively high.
Sample-holder degassing and raster changing technique or “double raster” technique [1,2] were improved and introduced in our standard protocol.
Theoretically, the “double raster” technique allows to get rid of the atmospheric element in-situ contamination contribution during the SIMS analysis. Thanks to this technique, the real element concentration is measured at each point of the SIMS profile, excluding the residual vacuum contribution of the SIMS analysis chamber.

-Experimental method:

The night before the analysis, the sample-holder is placed in the introduction sas of the IMS (vacuum level around 10^{-7} Torr), and degassing is carried out thanks to a heating lamp.
The next day, after introducing the sample-holder into the chamber (vacuum level <10^{-10} Torr), a first profile is measured using a “small” size raster, followed by a second profile using a “large” size raster.

A specific treatment is then carried out on the two profiles, in order to get rid of the residual vacuum contribution.

-Results:

The graphs below show some examples of atmospheric elements (H, C and O) SIMS profiles using our new experimental protocol including the sample-older degassing and the “double raster” technique. Different materials were analyzed including **GaN, AlGaN, GaAs, AlGaAs, AlInAs and InP**. In sub-figure c) an order of magnitude improvement is observed for oxygen in a GaN/AlGaN multilayer thanks to our new experimental process, in comparison with the conventional one.

-Low concentrations detection:

Measured concentrations of H, C and O in the different materials are given in the table below. **These figures can be considered as detection limits as long as lower concentration values are not obtained.**

Table – Atmospheric elements measured (in atoms/cm^3) in GaN, AlGaN, GaAs, AlGaAs, AlInAs and InP materials.

Matrix	GaN	AlGaN	GaAs	AlGaAs	AlInAs	InP
H	$3x10^{16}$	$3x10^{16}$	$3x10^{16}$	$3x10^{16}$	$5x10^{16}$	$3x10^{16}$
C	$3x10^{15}$	$3x10^{15}$	$3x10^{15}$	$3x10^{15}$	$2x10^{15}$	$3x10^{15}$
O	10^{16}	10^{16}	10^{16}	10^{16}	10^{16}	10^{16}

Probion Analysis
37 rue de Fontenay
92220 Bagneux FRANCE
Tel : (33) 1 46 12 05 00 -- Fax : (33) 1 46 54 10 33
email : maurice.quillec@probion.fr -- web: http://www.probion.fr

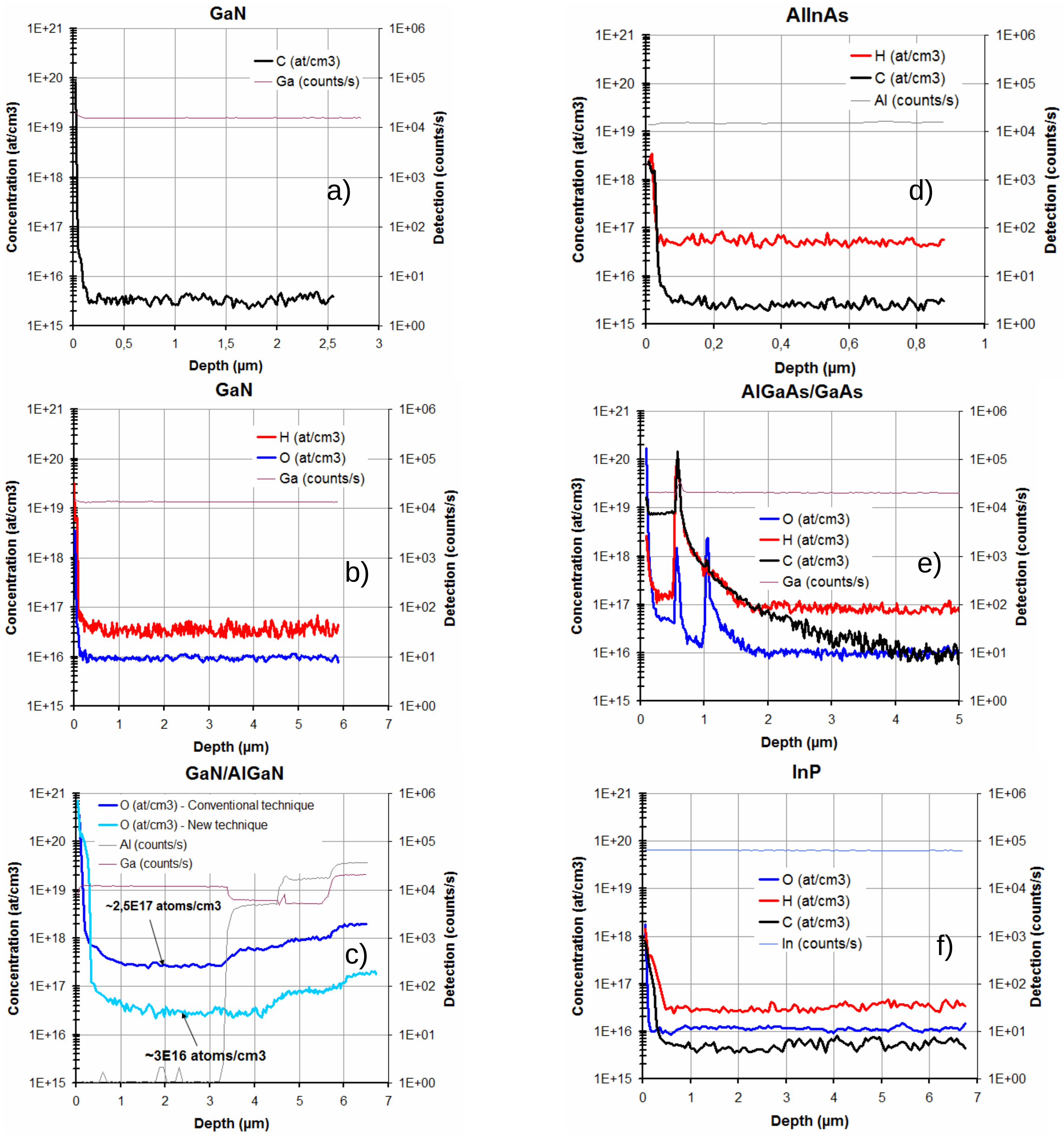

Figure – Examples of atmospheric elements H, C and O SIMS profiles in different III-V semiconductor materials: a), b) GaN, c) GaN/AlGaN multilayer, d) AlInAs, e) AlGaAs/GaAs multilayer and f) InP.

References: **[1]** A. Ishitani et al. "Improvement of oxygen detection limit in silicon by use of the secondary ion energy distribution and background subtraction" *Proceedings of the International Conference of Materials and Characterization for VLSI*, 1988, 124-129 **[2]** B.-S. Park et al. "Improvement in the SIMS measurement of bulk nitrogen in silicon" *Conference: High Purity Silicon VIII - Proceedings of the International Symposium* Volume 5 2004.