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Chemistry of buried interfaces in III-V heterostructures using lab-scale HAXPES and ToF-SIMS

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High-energy X-ray photoelectron spectroscopy (HAXPES)¹ allows for higher depth sensitivity (~30 nm) compared to traditional XPS. This technique has recently become available in laboratory settings through instruments equipped with Cr K α (h ν = 5415 eV)² or Ga K α (h ν = 9251 eV)³ sources. It is particularly valuable for non-destructive chemical analysis of buried interfaces. In microelectronics, lab-scale HAXPES can provide better insight into device performances, which are closely linked to critical interfaces.

This will be illustrated through the investigation of heterojunction bipolar transistors on III-V semiconductors for radio-frequency applications. One strength of HAXPES is to be less sensitive to surface damages caused by ion sputtering. Therefore, when combined with Ar⁺ bombardment, it can provide access to deep interfaces, such as the top InGaAs/InP interface of the InGaAs(80 nm)/InP(80 nm)/InAlAs(50 nm)/InP heterostructure. The chemistry of this interface can be investigated through a careful analysis of the main core levels before and after crossing the interface. Complementary ToF-SIMS profiles bring valuable information regarding the abruptness of all interfaces with no interdiffusion of the major elements and M-SIMS helps to precisely locate the Zn doping within the stack⁴.

However, quantifying the chemical composition of such structures using lab-scale HAXPES remains challenging because of the need of reliable Relative Sensitivity Factors (RSFs). Such RSFs can be estimated through the analysis of reference samples or the calculation of photoionization cross-sections at high energy. This will be addressed through the quantification of the InGaAs and InP composition based on a 2-layers model⁵. Theoretical HAXPES core levels intensity ratios are compared to the experimental ones to estimate the InGaAs layer thickness left after sputtering and its composition. Limitations regarding the quantification of the buried InP layer, probably related to the analysis of more distant core levels, will be discussed.

Keywords: HAXPES, ToF-SIMS, M-SIMS, III-V heterostructures, InGaAs, InP.

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