PhD thesis 2026-2029 at CEA/Leti & LTM Grenoble

Advanced chemical characterization of complex III-V heterostructures for optoelectronic and radiofrequency applications using FIB-ToF-SIMS and HAXPES

Keywords: III-V semiconductors, photodetectors, lasers, HBT (heterojunction bipolar transistor), FIB-ToF-SIMS, SIMS, HAXPES

Context of the PhD:

Heterostructures based on III-V semiconductors are nowadays used in many devices for radiofrequency applications, power electronics and optoelectronics. Materials such as arsenides (InGaAs, GaAsSb) and phosphides (InP) are known for their unique optical (direct bandgap) and electronic (high carrier mobilities) properties. Complex heterostructures are thus being developped for infrared detectors and for heterojunction bipolar transistors (HBT) designed for futur 6G wireless communication systems. They rely on complex stacks of ultra-thin layers (a few nm thick) engineered to achieve appropriate band alignment and enable optimal electron transport.

The quality of these devices requires a good control of their structural and chemical properties. The epitaxial growth processes must ensure high crystalline quality, a precise chemical composition with sharp interfaces and controlled doping levels in order to guarantee good devices electrical performances. The main challenge is to reduce element segregation or redistribution phenomena, in order to achieve abrupt interfaces. Another crucial point is to achieve a good control of dopants incorporation to reach high and reproducible doping levels.

For this purpose, advanced characterization techniques are required in particular to investigate the chemistry of such heterostructures. The thesis work will focus on the development of characterization methodologies for a complete 3D chemical analysis. This research will rely on the complementary expertise of LTM-CNRS in MOCVD growth processes and the expertise of CEA-Leti in materials characterization.

Work to be done:

At CNRS-LTM, the growth conditions will be optimized to achieve abrupt interfaces while reaching the desired composition, either uniform or with gradual contents. Carbon insertion as a new dopant known to be thermally more stable, is another challenge. The growth parameters will be optimized to reach high and reproducible carbon concentration levels.

The chemical characterization of such III-V heterostructures will be done using techniques available at CEA-Leti. Time-of-flight secondary ion mass spectrometry (ToF-SIMS) will provide in-depth chemical profiles with high sensitivity and high depth resolution, by optimizing experimental conditions (beam parameters, sample rotation, cryo-ToF-SIMS). Direct investigations on cross-sections will also be done using a new SIMS instrument arriving mid-2027 equiped with a focus ion beam (FIB). This new tool will also offer an improved spatial resolution allowing a complete 3D chemical analysis. This will be of crucial interest to optimize the selective epitaxy required for the devices fabrication as well as to investigate potential dopants diffusion or segregation across the structures.

Complementary informations will be obtained with hard X-ray photoelectron spectroscopy (HAXPES) allowing the non destructive chemical analysis of buried interfaces as well as the quantification of major elements across the structures. Scanning transmission electron microscopy (STEM) combined with electron dispersive spectroscopy (EDS) will also provide valuable structural and compositional information. Atomic Force Microscopy (AFM) will also be implemented using an advanced mode called scanning spreading resistance microscopy (SSRM) to investigate the dopants distribution across the structures.

Profile and required skills:

The candidate must hold an engineering degree or a research-oriented Master’s degree, with background in materials science, solid-state physics or semiconductor physics. The requested PhD work requires a taste for experimental work. The candidate is also expected to have good communication skills in both French and English and the ability to report on his or her work. The candidate must demonstrate autonomy, rigor and dynamism.

By the end of the thesis, the candidate will have acquired solid experience in semiconductors characterization and growth.

PhD funding secured:

LabEx Microelectronics project: 36 months (2026-2029) ; starting date : Autumn 2026

Contacts:

Please attach to your application your CV including the grades and ranking for Master 1 and Master 2, as well as one or two references from your internship or academic supervisors.

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