Sujet thèse / PhD subject 2025

Titre Thèse	Conception et fabrication de composants RF à polarité Azote sur substrat de silicium	
PhD Title	Design and fabrication of Nitrogen-polar III-Nitrides HEMTs on silicon for RF applications	
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Projet phare principal	Composants	
Demande de fléchage IEMN ? (Energie / Nanocaractérisation / Technologies Neuromorphiques)	Non : Flagship choisi :	
Demande de labellisation Université de Lille (GREAL, labellisée)	Oui : Label : **GREAL**	
Financement demandé	Contrat Doctoral Etablissement	ULille ☒ Centrale Lille ☐ JUNIA ☐
	Région ou Autre ☐ Préciser :	Co financement (Préciser l'origine, demande en cours, et si acquis ou pas) : ANR PRCE, demande en cours

Résumé / Abstract :

This thesis is targeting the development of Nitrogen-Polar III-Nitrides on silicon substrates using Molecular Beam Epitaxy. N-polar III-Nitrides will be achieved by polarity inversion using a thin epitaxial metallic layer of Niobium Nitride (NbN). Polarity inversion, more specifically from metal-polar to nitrogen-polar, using this approach has been recently demonstrated. The work will focus on the development and optimization of this innovative process (hybrid semiconductor/metal/semiconductor heterostructures), to study and understand the properties of N-polar III-N materials. The goal of the project is the achievement of high structural quality with low impurity concentrations N-polar planar III-N heterostructures grown on silicon substrates. The N-polar III-Nitrides optimized in the project will be used to develop full RF HEMTs in order to evaluate their potential for high frequency applications (>40 GHz).

The N-Polar project aims to develop innovative processes for the epitaxial growth of nitrogen-polar GaN heterostructures on silicon substrates for the first time, as well as associated technologies for high-performance RF HEMTs, with a particular focus on improving thermal management. The growth will be conducted using Ammonia-Molecular Beam Epitaxy (NH3-MBE), with the goal of achieving a pure nitrogen-polar GaN-based heterostructure by mastering NbN epitaxy and understanding interface formation to avoid the formation of metal-polar domains.
The project will also explore various approaches to fabricate nitrogen-polar HEMTs, including alloyed contacts and epitaxial regrowth of contacts, to enhance electrical performance by developing a backside assembly process for heat management.
III-Nitrides ((Al,Ga,In)-N) have enabled advancements in device fabrication, particularly in RF HEMTs. However, traditional metal-polar structures have limitations at high frequencies, while nitrogen-polar HEMTs offer improved efficiency and power, making them suitable for next-generation RF applications in wireless technologies and communications. The shift to a nitrogen-polar structure allows for better management of two-dimensional electron gas (2DEG) characteristics and optimization of back-barrier and contact resistances.

The project addresses challenges such as hillock formation, impurity incorporation, and the development of technology specific to nitrogen-polar devices. While high magnesium doping is used to stabilize nitrogen-polar GaN, it introduces defects that are not ideal for transistors, highlighting a gap in achieving device-quality nitrogen-polar epilayers on silicon. The N-Polar project proposes a new approach to overcome these challenges by utilizing the successful growth of III-N/NbN heterostructures to enhance the development of nitrogen-polar structures, which has never been achieved before.

The project aims to create original epitaxial growth processes and technological components to fabricate high-performance nitrogen-polar GaN-based transistors, potentially leading to advancements in microwave technology for wireless applications. By using silicon substrates as a foundation, the project promises significant industrial impact and differentiation from existing SiC-based solutions, which are predominantly sourced outside of Europe.

The PhD candidate will carry out TCAD simulation, fabrication and characterization of these novel devices.