INSTITUT PASCAL (UMR6602 UCA/CNRS) - Group PHOTON/ IIIVAH (Epitaxie en Phase Vapeur aux Hydrures) - Allocation half UCA/half McMaster Hamilton University

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Titre du sujet de thèse

Devices based on micro- and nanostructures grown by Vapor Phase Epitaxy (VPE) processes

Since 2010, Institut Pascal (IP) is a unique laboratory in the world that can synthesize ultra-long III-V nanowires (NWs) of pure crystalline quality by hydride vapor phase epitaxy (HVPE). HVPE is now argued to be a very promising method to resolve current technological challenges at micro- and nano-scales, especially for III-arsenide (III-As) synthesis [1]. In particular, in SAG (selective area growth), where the growth occurs on specific sites on a patterned substrate, the selectivity is completely ensured in HVPE thanks to the use of III-chloride precursors ($GaCl_g$, $InCl_g$). These features are crucial for the fabrication of devices based on organized nanowire arrays. The target applications constitute high-performance technological building blocks for optoelectronic and spintronic sensors and components related to energy conversion and transport.

This PhD will follow a current collaboration with McMaster since 2018. At present several nanostructures have been synthesized by the HVPE process. The project will be split into two periods at McMaster and IP. The PhD will follow his/her first period at McMaster to perform the optical, electrical and structural characterization at the Canadian Center for Electron Microscopy (CCEM), equipped with record high resolution electron microscopy. Regarding the growth process, the PhD will be trained on MOVPE and HVPE-MOVPE hybrid processes to develop novel structures.

In the second period at IP, the student will perform the growth experiments of III-As nanostructures with an emphasis on the material composition to cover red and infrared emission wavelengths. Thermodynamic and kinetic modelling studies will be conducted. P-type and n-type doping experiments will constitute an important task on binary materials (GaAs and InAs) and on ternary alloys ($Ga_{1-x}In_xAs$).

The main target of the PhD applications are military and naval sensing devices and nuclear / electrical power converters [2] thanks to McMaster expertise in these fields. This task will allow the PhD to acquire high skills in device development in addition to epitaxy.

This PhD is part of NanoSpring action of CIR-CAP 2025 which regularly support scientific exchages between UCA and McMaster.

It is also involved with the project PAI NanoSpring which aims to fabricate III-V arrays based on phosphides, with variable nanowire geometry and variable emission wavelength depending on the composition of the ternary $Ga_{1-x}In_xAs$ material. The target applications are the field of display or anti-counterfeit marking thanks to a tunable emission ranging from visible to IR.

[1] CrystEngComm, Advanced paper, https://doi.org/10.1039/D0CE01385D
"Long catalyst-free InAs nanowires grown on silicon substrate by HVPE"
G. Grégoire, E. Gil, M. Zeghouane, C. Bougerol, H. Hijazi, D. Castellucci, V. Dubrovskii, A. Trassoudaine, N. Isik Goktas, Ray R. LaPierre, Y. André
[2] Journal of Applied Physics 127 (24), 244303, https://doi.org/10.1063/1.5138119
"Design and optimization of nanowire betavoltaic generators"
DL Wagner, DR Novog, RR LaPierre