Ph. D. Thesis proposal

"Study of the III-V/Si nucleation for integrated photonics on silicon"

Context of the proposal:

The Ph. D. position described below will be funded half by the ANR project ANTIPODE (grant N° ANR-14-CE26-0014-01) and half by the Région Bretagne through the ARED program (allocations de recherche doctorale). The position will be open on September 2015, and will last for three years. The deadline for the application is the 22nd of june 2015. The candidate will be welcome in the FOTON laboratory (CNRS) of INSA (engineer school) in the city of Rennes (western part of France).

Scientific content:

Up to now, silicon is considered as the ruling material for the photovoltaic industry and the whole semiconductor chip industry including the dominating CMOS (Complementary Metal Oxide Semiconductor) processing technology. One of the hot topics developed in the recent years besides in the development of highly efficient lasers on Silicon.[1] FOTON laboratory proposes to develop heterogeneous epitaxy of efficient III-V nanostructure-based optical emitters on silicon, by using the GaP, which is nearly lattice-matched to the silicon.[2,3,4,5] This should ensure a single crystal coherent growth, which is very promising for the development of highly efficient devices. Nevertheless, the crystalline growth of III-V semiconductors nanostructures on silicon is still limited by numerous defects generated during the nucleation of the first few atomic monolayers. In the proposed approach, the quality of the GaP layer is strongly dependant of the silicon surface quality.[6,7] This was also noticed by other members of the ANTIPODE consortium, being specialists of GaSb/Si laser devices (IES Montpellier) and GaN/Si devices (CRHEA Valbonne).

The thesis proposed here aims to understand the impact of the silicon surface shape at the atomic scale on the crystalline growth of GaP and other III-V compounds. To this purpose, **silicon layers will be grown by Ultra High Vacuum Chemical Vapor Deposition, and surface state will be analysed at the atomic level using Atomic Force Microscopy, or Scanning Tunneling Microscopy (STM)** by the candidate in close collaboration with the Rennes institute of Physics (IPR). III-V semiconductors will then be grown on the top of it by Molecular Beam Epitaxy (MBE) and analysed as well by STM, Transmission Electron Microscopy (TEM) and Synchrotron X-ray diffraction available in the ANTIPODE consortium. Finally, characterizations of the III-V/Si epilayer at the atomic scale will be

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[1] D. Liang and J. E. Bowers, Nat. Photon. **4**, 511 (2010).
[2] K. Volz et al., J. Cryst. Growth **315**, 37 (2011).
[3] K. Yamane et al., J. Cryst. Growth **312**, 2179 (2010).
[4] T. J. Grasman et al., Appl. Phys. Lett. **94**, 232106 (2009).
[5] A. Létoublon et al. J. Cryst. Growth **323**, 409 (2011).
[6] Grassman et al. Appl. Phys. Lett. **102**, 142102 (2013); doi: 10.1063/1.4801498
[7] Quinci et al. J. Cryst. Growth **380**, 157 (2013).

confronted to atomistic simulations performed by the candidate, the main objective being the understanding of the defects generation during the III-V/Si crystal growth.

Collaborations:

This work will be performed in a highly collaborative research team. He/She will work in strong collaborations with other members of FOTON Lab and IPR, which are well-recognized in their research field, using results from Atomic Force Microscopy (AFM), UHVCVD-MBE growth experimental setups and UHV scanning tunnelling microscopy (STM). He/She will also benefits from collaboration at the national level through members of the consortium (IES, CRHEA for III-V epitaxy, LPN and CEMES for Microscopy) or at the international level.

About FOTON Laboratory (INSA-Rennes):

FOTON laboratory is part of the CNRS (biggest French research institute). FOTON is recognized at the European level through participations to European Networks of Excellence on nanostructures properties and devices SANDIE and EPIXNET. FOTON has also been recognized as part of a "Labex" (Laboratory of excellence) and of an IRT (Technological Research Institute) at the national level.

The laboratory has a large experience in the growth,[8] structural,[9] optical[10] and electrical characterisation of III-V semiconductor nanostructures, and for the development of semiconductor-based devices such as Light emitting diodes[7], edge lasers[11], or Vertical Cavity Surface Emitting Lasers (VCSELs).[12] In order to use its know-how on the conventional and low-cost silicon substrate, FOTON Lab has explored since 2010 the coherent integration of III-V semiconductors on Silicon.[13]

About the candidate:

The candidate should have advanced knowledge in semiconductors, basic knowledge of solid state physics, basic knowledge of optics, thermodynamics. The applicant should have good level in english, a liking for complex experimental setups as well as simulations, and should be able to interact easily with other members of the research teams. He/She should show good capacities in oral and written english expression and be able to present research results verbally in international conferences. The candidate should show a real motivation to work in a group, and participate actively to the regular meetings and reports.

Supervision & Contact :

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[8] C. Paranthoën et al., Appl. Phys. Lett. **78**, 1751 (2001).
[9] A. Létoublon et al., Phys. Rev. Lett. **92**, 186101 (2004).
[10] C. Cornet et al., Phys. Rev. B **74**, 035312 (2006).
[11] D. Zhou et al. Electron. Lett. **45**, 50 (2009).
[12] O. Castany et al. Appl. Phys. Lett. **98**, 161105 (2011).
[13] T. Nguyen Thanh et al., J. Appl. Phys. **112** 053521 (2012).