Soutenance de Thèse

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L'institut Photovoltaïque d'Ile de France (IPVF)
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Amphithéâtre

Etude de composants optiques et optoélectroniques à base de nanotubes de carbone

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(travaux de thèse dirigés par Monsieur Laurent VIVIEN)

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Title: Study of optical and optoelectronic devices based on carbon nanotubes

Keywords: Carbon nanotube, silicon photonics, optoelectronics

Abstract: Silicon photonics is widely recognized as an enabling technology for next generation optical interconnects. Nevertheless, silicon photonics has to address some important challenges. Si cannot provide efficient light emission or detection in telecommunication wavelength range (1.3µm-1.5µm). Thus sources and detectors are implemented with Ge and III-V compounds. This multi-material approach complicates device fabrication, offsetting the low-cost of Si photonics. Nanomaterials are a promising alternative route for the implementation of faster, cheaper, and smaller transceivers for datacom applications.

This thesis is dedicated to the development of active silicon photonics devices based on single wall carbon nanotubes (SWCNTs). The main goal is to implement the basic building blocks that will pave the route towards a new Si photonics technology where all active devices are implemented with the same technological process based on a low-cost carbon-based material, i.e. SWCNT.

Indeed, carbon nanotubes are an interesting solution for nanoelectronics, where they provide high-performance transistors. Semiconducting SWCNT exhibit a direct bandgap that can be tuned all along the near infrared wavelength range just by choosing the right tube diameter. s-SWCNTs provide room-temperature photo- and electro- luminescence and have been demonstrated to yield intrinsic gain, making them an appealing material for the implementation of sources. SWCNTs also present various absorption bands, allowing the realization of photodetectors.

The first objective of this thesis was the optimization of the purity of s-SWCNT solutions. A polymer-sorting technique has been developed and optimized, yielding high-purity s-SWCNT solutions. Based on this technique, several solutions have been obtained yielding emission between 1µm and 1.6µm wavelengths.

The second objective was the demonstration of efficient interaction of s-SWCNT with silicon photonics structures. Different geometries have been theoretically and experimentally studied, aiming at maximizing the interaction of s-SWCNT with optical modes, exploiting the electric field component transversal to light propagation. An alternative approach to maximize the interaction of s-SWCNT and the longitudinal electric field component of waveguide modes was proposed. Both, a power emission threshold and a linewidth narrowing were observed in several micro disk resonators. These results are a very promising first step to go towards the demonstration of an integrated laser based on CNTs.

The third objective was to study optoelectronic SWCNT devices. More specifically, on-chip light emitting diode (LED) and photodetector have been developed, allowing the demonstration of the first optoelectronic link based on s-SWCNT. s-SWCNT-based LED and photodetector were integrated onto a silicon nitride waveguide connecting them and forming an optical link. First photodetectors exhibited a responsivity of 0.1 mA/W, while the complete link yielded photocurrents of 1 nA/V.

The last objective of the thesis was to explore the nonlinear properties of s-SWCNT integrated on silicon nitride waveguides. Here, it has been experimentally shown, for the first time, that by choosing the proper s-SWCNT chirality, the sign of the nonlinear Kerr coefficient of hybrid waveguide can be positive or negative. This unique tuning capability opens a new degree of freedom to control nonlinear effects on chip, enabling to compensate or enhancing nonlinear effects for different applications.