PhD Thesis proposal - 2016

Laboratory: Laboratoire Charles Coulomb (L2C) – Univ. Montpellier
Address: Bat. 11, Place Eugène Bataillon, 34090 Montpellier
Head of the laboratory: P. Lefebvre

Advisor: Nicolas Izard and Laurent Alvarez
Email: nicolas.izard@umontpellier.fr, **Phone:** +33 4 67 14 35 28
Email: laurent.alvarez@umontpellier.fr, **Phone:** +33 4 67 14 35 41

Electro-optical properties of encapsulated carbon nanotube network

Context:

These last years, a new research field about carbon nanotube (SWNT) photonics emerged thanks to their strong photoluminescence (PL) in the near infra-red (NIR). Several progress have been made, such as SWNT integration with silicon waveguide, coupling with photonic cavities, or observation of single photon source. These pioneering results open the way for SWNT photonic applications, but focused on exciton engineering by optical pumping. On the other hand, few studies buckled up with electrical driving to achieve electro-luminescence (EL), which is mandatory for any real breakthrough of SWNT in the photonic realm. These early results were achieved on individual SWNT acting as a channel in a field effect transistor, which induce severe limitations. Thus, use of mesoscopic scale networks comprised of a few tens up to a few hundreds of semiconducting nanotube (s-SWNT) would be much more favorable for the emergence of applications, with better signal and homogeneity and without individual nanotube addressing issues.
This PhD project relies on the study of two kinds of nanotube samples: i) empty nanotubes sample strongly enriched in s-SWNT by specific sorting, allowing to emit in a broad NIR range according to the wide diameter distribution ii) hybrid nano-materials consisting in photo-active molecules confined into s-SWNT. These systems have been shown to display significantly enhanced PL with respect to empty tubes, allowing to either increase the emitted intensity or to reduce the amount of s-SWNT in the network, preventing PL quenching. In addition, confined molecules alter the PL properties of SWNT with specific diameter, allowing to narrow and control the NIR emission range.
The main objective of this PhD thesis project is to optimize nano-system network (empty tubes or hybrid materials) in order to achieve in a controlled way efficient electro-luminescence.

Scientific and technical work, prerequisites:

Electroluminescence mechanism at the single nanotube level is now well established, but mechanisms of light emission when nanotubes are assembled into networks are still under discussion. Thus, the first part of the work will concern the study of EL by a film of nanotubes. In addition, confinement effect when photo-active molecules are encapsulated inside nanotubes are still not clear. One important part of the work will be dedicated to the understanding of the physical properties of the hybrid nano-systems.

The different tasks involved in this PhD thesis will be:
- use advanced techniques developed at L2C to specifically extract s-SWNT.
- use L2C know-how in encapsulation to insert specific molecules inside s-SWNT.
- realize and characterize electroluminescent devices at the single nanotube scale, using several configuration to optimize the electroluminescent recombination. Advanced devices investigation will be performed to serve as a basis for physical modeling/
- study of the supramolecular organization of photo-active molecules inside nanotubes for PL/EL optimization.
- transfer the know-how gained at the single nanotube scale to a network made from s-SWNT. The principal scientific challenge will be to realize an efficient carrier injection into a dense nanotube

networks. The physical mechanisms involved will be studied and modeled.

Skills:

This project is adapted for a PhD student with a background in physics, applied physics or nanosciences. Prior knowledge of carbon nanotube science is not necessary, but basic knowledge of solid state physic is mandatory. The PhD thesis involve substantial experimental work in clean room and free space optical setup, the taste for experimental work is mandatory.

This PhD thesis is strongly multidisciplinary, requiring a strong involvement in material science for semiconducting carbon nanotube extraction, manipulation and orientation into 2D networks, and molecules encapsulation. A strong expertise in optics and spectroscopy is required as well, for sample investigations by Raman spectroscopy, and electro-optical measurements (micro-photoluminescence, photo-current and EL). Moreover, photonic structures will be fabricated in clean room environment, allowing to develop skills in nanofabrication during the thesis.
The PhD student will benefits from an existing collaborative network composed of several teams at L2C, the Laboratoire Aimé Cotton (Univ. Paris-Sud, Orsay) and the CEA Saclay, in particular for chemistry support.
This research subject is an opportunity for a motivated student to form himself to state of the art techniques, and acquire an interdisciplinary profile that is widely sought for in today's research.