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Centre for Nanoscience and Nanotechnology
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Title: **Nanoscale analyses of semiconductor nanowire properties for development of flexible energy harvesters**

Job title: PhD fellow (funded by ERC NanoHarvest grant)
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Applications are accepted until 15.01.2017; PhD expected starting date 15.02.2017

Motivation Energy harvesting appears as a promising way to fabricate portable power supplies or battery chargers for nomad electronic devices. Conversion of ambient energy would make them truly energy-autonomous without the need of power grids. Flexible devices such as photovoltaic converters and piezoelectric harvesters provide an amount of new functionalities and have the potential to open up a new branch of industry. In particular, mechanical flexibility enables realization of portable energy converters integrated on light and flexible supports such as plastic or even textile fabric improving their portability and significantly reducing the device cost.
Presently, flexible devices mainly use organic semiconductor materials. However, despite the recent progress, organic devices are still facing the instabilities caused by oxidation, recrystallization and temperature variations, which degrade the electrical conductivity of organic layers and interfaces in the active regions. The conversion efficiency is also lower in comparison to their inorganic counterparts. However, the inorganic semiconductor devices are mechanically rigid; the fabrication of flexible devices from conventional thin film structures is quite challenging and requires micro-structuring of the active layer. To avoid the micro-structuring step, it is advantageous to shrink the active element dimensions and to use bottom-up nanostructures, such as nanowires, instead of two-dimensional films. Nanowires show remarkable mechanical and optoelectronic properties stemming from their anisotropic geometry, high surface-to-volume ratio, and crystalline perfection. They are mechanically flexible and can stand high deformations without plastic relaxation. To summarize, polymer-embedded nanowires offer an elegant solution to create flexible optoelectronic devices, which combine the high efficiency and the long lifetime of inorganic semiconductor materials with the high flexibility of polymers.

This PhD project proposes to exploit the advantages of III-V semiconductor nanowires to develop novel flexible photovoltaic (PV) devices with high conversion efficiency. To enhance the performance of nanowire PV devices, bottlenecks related to the design, material growth and processing have to be removed. In particular, for nanowire solar cells standard macroscopic PV characterization averaged over millions of nano-objects does not provide all the information necessary to understand the device physics and to optimize the performance. It is essential to push the comprehensive analyses down to the nanometric scale and to probe individual nanowire p-n junctions in order to analyze the material quality, to determine the surface recombination rate, to assess the wire-to-wire homogeneity and to detect eventual failures. The objective of this PhD project is to achieve an in-depth understanding of fundamental physical phenomena governing the

carrier generation, extraction and collection in nanowires at different scales. To this end, the PhD candidate will make use of our recently developed multi-scale technique combining electrical (Electron Beam Induced Current) and optical (Laser Beam Induced Current and photoluminescence) characterization tools (illustrated in Fig. 1) to tackle the conversion mechanism from the single nanowire level up to the whole device level. These advanced characterization tools will provide access to the key parameters governing the PV conversion (minority carrier diffusion length, carrier density, surface recombination velocity, etc). The recruited PhD fellow will also carry out the fabrication of flexible nanowire devices using the dedicated clean-room facilities of CTU-IEF-Minerve. Combining the advanced modeling with the experimental investigation, the candidate will establish novel device architectures and fabricate high-efficiency flexible PV converters.

In addition, the PhD candidate will have an opportunity to collaborate with several of the best European research groups via the on-going European projects of the group.

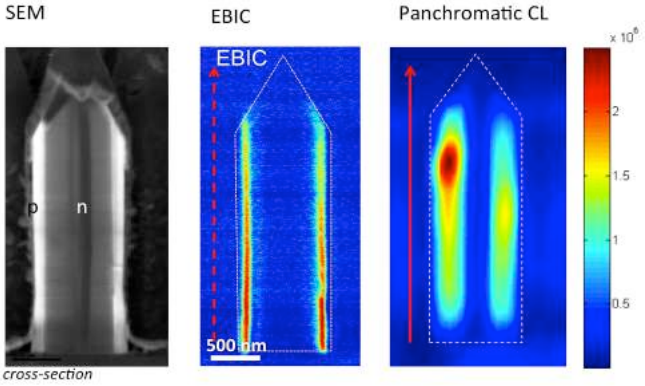

Fig. 1 : SEM image and the corresponding EBIC and cathodoluminescence maps of a core/shell p-n junction nitride nanowire.

Related papers of the team :

1. N. Guan, X. Dai, A. Messanvi, H. Zhang, J. Yan, E. Gautier, C. Bougerol, F. H. Julien, C. Durand, J. Eymery, and M. Tchernycheva, “Flexible White Light Emitting Diodes Based on Nitride Nanowires and Nanophosphors”, ACS Photonics 3, 597 (2016).

2. X. Dai, A. Messanvi, H. Zhang, C. Durand, J. Eymery, C. Bougerol, F. H Julien, M. Tchernycheva “Flexible Light-Emitting Diodes Based on Vertical Nitride Nanowires”, Nano Letters 15, 6958 (2015).

3. M. Tchernycheva, V. Neplokh, H. Zhang, P. Lavenus, L. Rigutti, F. Bayle, F. H. Julien, A. Babichev, G. Jacopin, L. Largeau, R. Ciechonski, G. Vescovi, and O. Kryliouk, ”Core-Shell InGaN/GaN Nanowire Light Emitting Diodes analyzed by Electron Beam Induced Current Microscopy and Cathodoluminescence Mapping”, Nanoscale 7, 11692 (2015).

4. P. Lavenus, A. Messanvi, L. Rigutti, A. De Luna Bugallo, H. Zhang, F. Bayle, F.H. Julien, J. Emery, C. Durand and M. Tchernycheva “Experimental and theoretical analysis of transport properties of core-shell wire light emitting diodes probed by electron beam induced current microscopy”, Nanotec 25, 255201 (2014).

5. L Yu, L Rigutti, M Tchernycheva, S Misra, M Foldyna, G Picardi, P.R. i Cabarrocas “Assessing individual radial junction solar cells over millions on VLS-grown silicon nanowires”, Nanotech. 24, 275401 (2013).

6. M. Tchernycheva, L. Rigutti, G. Jacopin, A. de Luna Bugallo, P. Lavenus, F. H. Julien, M. Timofeeva, A. D. Bouravleuv, G. E. Cirlin, V. Dhaka, H. Lipsanen, L. Largeau “Photovoltaic properties of GaAsP core–shell nanowires on Si (001) substrate” Nanotech. 23, 265402 (2012).

Person requirements

We are searching for a candidate with a good academic record in physics, material sciences or related areas, who is motivated to pursue research in nanotechnologies, and in particular in the science and technology of nanowires. A good command of English language, with oral and written skills is required.