



H2020 Marie Curie Actions- Innovative Training Network

INDEED

Innovative Nanowire DEviceE Design

Job title: Doctoral Research Fellowship (PhD)

Title: Flexible nanowire light emitting diodes

Location: University Paris Sud, Université Paris Saclay
Centre for Nanoscience and Nanotechnology
15, rue Georges Clémenceau
91405 Orsay Cedex, France

PhD Starting date: 1/10/2017

Duration: 3 years (subject to the host institution probation period where applicable)

Closing date: Applications should be submitted before **15/07/2017**

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Gross Living Allowance: 41425.2 € per year plus mobility allowance. Salary is subject to national taxes and employer's costs.

PhD Research project

Flexible optoelectronic devices provide an amount of new functionalities and have the potential to open up a new branch of industry. In particular, flexible light emitting diodes (LEDs), are today a topic of intense research driven by applications such as bendable displays, conformable light sources, bio-medical devices, etc. Today the flexible technology is dominated by organic semiconductors, which however exhibit low efficiency and a limited lifetime especially for the blue spectral range. For example, organic LEDs have a much lower luminance and a shorter lifetime in comparison to the LEDs based on inorganic nitride semiconductors. 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.

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. The objective of this PhD project is to develop a reliable technology for red, green and blue nanowire flexible micro-LEDs and to demonstrate a prototype of a display. Nanowire arrays embedded in a flexible film and lifted-off from their native substrate will be used as the active material. Figure 1 shows an example of flexible blue, green and phosphor-converted white LEDs previously demonstrated in the group [1, 2].



Figure 1: flexible nanowire blue, green and white LEDs under operation.

The lift-off and transfer procedure enables the assembly of free-standing layers of nanowire materials with different bandgaps without any constraint related to lattice-matching or growth conditions compatibility [1]. This concept therefore allows for a large design freedom and modularity since it enables combination of materials with very different physical and chemical properties, which cannot be achieved by monolithic growth. For RGB LEDs nanowires of different semiconductor materials (GaAsP and InGaN) will be employed.

The PhD candidate will focus on the technological development of the displays using clean-room facilities of the C2N and on the device testing using optical spectroscopy and microscopy set-ups (photoluminescence, electroluminescence, EQE, electron beam induced current microscopy, etc).

Recent papers of the group :

[1] Xing Dai, Agnes Messanvi, Hezhi Zhang, Christophe Durand, Joël Eymery, Catherine Bougerol, François H Julien, Maria Tchernycheva « *Flexible Light-Emitting Diodes Based on Vertical Nitride Nanowires* » Nano Letters 15 (10), 6958-6964 (2015).

[2] Nan Guan, Xing Dai, Agnès Messanvi, Hezhi Zhang, Jianchang Yan, Eric Gautier, Catherine Bougerol, François H. Julien, Christophe Durand, Joël Emery and Maria Tchernycheva, “*Flexible White Light Emitting Diodes Based on Nitride Nanowires and Nanophosphors*”, ACS Photonics 3, 597–603 (2016).



Context

This research fellowship programme (PhD) will be carried out within the context of the INDEED network, a Marie Skłodowska-Curie Actions– *Innovative Training Network* (ITN) – project funded by the European Commission, under their H2020 program. Through the project activities, the Fellows/PhD students will have the opportunity to come in contact and collaborate with some of the best European research groups. English is the official language of the INDEED project. Additional details are available in “*Further particulars*”.

Responsibilities

- (1) Perform high quality research in the bespoke research project under the guidance of the supervisory team.
- (2) Meet the members of the supervisory team on a regular basis.
- (3) Participate in the activities of the Network as specified in the Grant Agreement and/or required by the node coordinator, including secondments in other network nodes and taking part in the network meetings and in the training activities.
- (4) Write up the results of the research activity and present research papers and publications at meetings and conferences, as advised by the supervisors.
- (5) Widen the personal knowledge in the research area and undertake complementary training.
- (6) Keep records of the activities, such as research, training, secondments, visits, leave of absence, etc.

Person Specification

The successful candidates *must satisfy the eligibility criteria* (see below) and have:

- (1) An excellent academic record in physics, engineering, material sciences or related areas.
- (2) A keen interest in pursuing research in nanotechnology, and in particular the science and technology of nanowires
- (3) The ability to work independently and as a member of a research team.
- (4) Excellent interpersonal and communication skills.
- (5) A good command of English language, with excellent oral and written skills.

** Note that female candidates are particularly encouraged to apply.*

Desirable

Any or combination of the following will be a clear advantage.



- A demonstrable ability or potential to produce research published in peer-reviewed journals.
- A good strategic fit with existing research expertise in the host institution and the *INDEED* network
- Knowledge of, or willingness to learn, the language of the host institution (French).

Eligibility Criteria

The candidates must meet all the criteria listed below

- (1) Be in the first four years (full-time equivalent research experience) of his/her research career and not have a doctoral degree at the time of recruitment by the host organisation. Full-Time Equivalent Research Experience is measured from the date when the researcher obtained the degree entitling him/her to embark on a doctorate (either in the country in which the degree was obtained or in the country in which the researcher is recruited, even if a doctorate was never started or envisaged. However, full time spent on non-research related activities may be discounted, where each case is evaluated on its own merit.
- (2) **At the time of recruitment by the host organisation, must not have resided or carried out their main activity (work, studies, etc.) in the country of their host organisation for more than 12 months in the 3 years immediately prior to the reference date. Short stays such as holidays and/or compulsory national service are not taken into account.**
- (3) Prior to starting their position, the successful fellows must have completed the courses that would have allowed them to enrol in a doctorate program either in the country where they are studying or in the country offering the position.
- (4) Gross living allowance is subject to employment laws and employer costs deduction.
- (5) Mobility Allowance: In addition to the salary, the successful fellows will receive a *mobility allowance* of 7200 Euros per annum. Fellows married at the time of recruitment are also eligible to receive a *family allowance* of 6000 Euros per annum. All of the payments are subject to relevant host country employment laws and deductions of all compulsory contributions for both employer and employee.

Further particulars



The INDEED project

Nanowires (NWs) exhibit unique properties that make them potential building blocks for a variety of next generation NanoElectronics devices. Recent advances have shown that NWs with predefined properties can be grown, offering a new paradigm enabling functional device prototypes including: biosensors, solar cells, transistors, quantum light sources and lasers. The critical mass of scientific knowledge gained now needs to be translated into of NW technologies for industry. FP7-MSCA NanoEmbrace (ITN) and FUNPROB (IRSES) , made substantial contributions to NW research, producing excellent scientific and technological results (> 100 journal papers published) and delivering outstanding training in nanoscience and transferable skills to ESRs.

Despite demonstrable scientific and technological advantages of NWs, NW-based technology concepts have not yet been translated into market-ready products, because industry and academia have not worked hand-in-hand to commercialize the research findings. Thus, it is essential that NW research is now directed towards customer-oriented scientific R&D; whilst applying innovative industrial design techniques to ensure rapid translation of the basic technologies into commercial devices.

This ambitious challenge requires close collaboration between academia and the nascent NW industry, combining the efforts of scientists and engineers to address market needs. Building upon our previous achievements, a team of leading scientific experts from top institutions in Europe, strengthened by experts in innovative design and industrial partners with an excellent track record of converting cutting edge scientific ideas into market products has formed the INDEED network to address this challenge. To enhance employability, INDEED will train young ESRs to become experts with a unique skill set that includes interdisciplinary scientific techniques, industrial experience through R&D secondments and innovative design skills.

The INDEED consortium

Coordinator: University of Durham, Durham UK.

Academic Beneficiaries (10 including coordinator)

Ecole Polytechnique Federale de Lausanne (Switzerland) ; Consiglio Nazionale delle Ricerche (CNR, Italy: *Institute of Microcroelectronics and Microsystems, Rome and Istituto Officina dei Materiali, Trieste*); University of Copenhagen (Denmark); Centre National de la Recherche Scientifique (CNRS, France: *Centre for Nanosciences and Nanotechnology, Paris and Institut supérieur de l'électronique et du numérique, Lille*);



Lappeenranta Institute of Technology (Finland); University of Newcastle (UK); Lunds University (Sweden); The University of Liverpool (UK); Université Paris-Sud (France).

Industrial Beneficiaries (2)

Innolume GmbH (Dortmund, Germany); Imina Technologies (Lausanne, Switzerland).

Associate Partners (13)

ITMO University (Russia), PragmatIC Printing (UK), Peratech (UK), Horiba (France), Digital Surf (France), Thundernil (Italy), APE research(Italy), Quantum DX (UK), Microsoft Station Q (Denmark), Semimetrics Ltd (UK), Université Paris-Saclay (France), Höganäs (Sweden), General Electric (Germany), Riber (France).