AAP China Scholarship Council - CSC 2024

PROJET DE RECHERCHE DOCTORALE (PRD)

Titre du PRD : Operando investigation of optoelectronic devices using photoemission

DIRECTION de THESE

Porteuse ou porteur du projet (***doit être titulaire de l'HDR***) :

NOM : Lhuillier

Prénom : Emmanuel

Titre : CR ou Autre :

Section CNU : 28

Email : el@insp.upmc.fr

Unité de recherche : Code (ex. UMR xxx) et Intitulé : INSP - UMR7588

Ecole doctorale de rattachement : ED397 - Physique et Chimie des Matériaux

Nombre de doctorants actuellement encadrés : 2+2à moitié

CO-DIRECTION de THESE (HDR) ou CO-ENCADREMENT (Non HDR) :

NOM : Pierucci

Prénom : Debora

Titre : CR ou Autre :

Section CNU : 28

Email : pierucc@insp.upmc.fr

Unité de recherche : Code (ex. UMR xxx) et Intitulé : INSP - UMR7588

Ecole doctorale de rattachement Sorbonne Université : ED397 - Physique et Chimie des Matériaux ou autre :

Nombre de doctorants actuellement encadrés : 0

CO-TUTELLE INTERNATIONALE envisagée : ☐ OUI ☒ NON

DESCRIPTIF du PRD :

*Ce texte sera affiché en ligne à destination des candidates et candidats chinois : il ne doit pas excéder **2 pages** doit être rédigé en **ANGLAIS***

Nanocrystals are semiconductor nanoparticles with size-tunable optical spectra. Their bright luminescence makes them appealing for applications such as displays, where they have reached commercial status as green and red light sources. To transition such optically active materials into devices in a rational manner, the electronic structure of the material needs to be unveiled. The traditional method employs optical spectroscopy (static or time-resolved methods). However, these methods suffer from limitations, particularly in their sensitivity to energy differences rather than the absolute energy states. To overcome these limitations, alternative methods like electrochemistry or X-ray photoemission are necessary. Traditionally, these methods are used to unveil the band alignment, a creucial aspect in designing photodiode stacks. However, such methods also face clear limitations as they do not consider the realistic environment of the active material once it's in a device, neglecting the impact of an electric field. Therefore, current device designs now require more advanced methods that involve operando investigation of the active materials.

The INSP group has a dual culture between device fabrication and operando measurements using photoemission. This year, the group received new funding from Europe (ERC) and the Paris area to develop experimental facilities. They will be equipped with state-of-the-art photoemission facilities capable of performing operando measurements. This platform will have extremely broad capabilities by combining various X-ray sources with a broadband optical spectrometer, allowing coverage across five orders of magnitude in energy from 10 meV to 5 keV. This versatile platform will enable coverage of a wide range of processes, from deep core levels to electronic confined transitions and finally phonons. The use of various X-ray sources will also allow probing at different depths, ranging from very surface-sensitive conditions to in-depth analysis within the device.

The platform will also encompass microscopy capabilities; both the photoemission and optical microscope will have the ability to image with a resolution down to 5 µm. This imaging capability is crucial for conducting experiments on devices and correlate strcture to properties. Furthermore, the platform will integrate operando facilities, enabling measurements under bias, various temperatures, and under illumination. This unique platform will provide material characterization across energy scales spanning over five decades, offering microscopy facilities and operando capabilities.

With this unique platform, our goal is to unveil the electronic structure of devices during operation. The targeted range of devices includes light-emitting diodes, phototransistors, and light detectors. The devices will be fully fabricated by the involved student, supported by our chemistry engineer.Once the nanoparticles heve grown, the student will be responsible to transform them into electrically active materials, deposit them onto pre-fabricated electrodes inside the cleanroom, and performing standard device characterization. The originality of the project lies in conducting a correlational study between the performance of the device and the operando study of the electronic structure.

Moreover, in addition to the in-house measurements conducted on the new instrument, we will also perform synchrotron experiments (mostly at synchrotron Soleil). This will allow us to benefit from the high irradiance and advanced capabilities associated with photoemission beamlines, including time-resolved and nanophotoemission techniques. The team has a strong involvement with such instruments, securing 3-4 beamtimes a year. This will provide complementary measurements and offer a large-scale facilities environment for the applicants.

Context: The PhD applicant will join the Optoelectronics of Confined Nanomaterials group, headed by Emmanuel Lhuillier, a CNRS researcher. The group benefits from various facilities,including material synthesis (wet lab, glove box, structural characterization tools), device fabrication facilities (clean room) and characterization tools (spectrometers, equipment for electrical characterization). The group has a long experience in optoelectronic devices and colloidal nanomaterials.

Skills from applicants: Applicants are expected to have a solid background in physical chemistry and in semiconductor science. Curiosity is a must, as the project is highly interdisciplinary. The group is very international; thus, fluency in English is a requirement.

Relevant references from the group

Mapping the Energy Landscape from a Nanocrystal-Based Field Effect Transistor under Operation using Nanobeam Photoemission Spectroscopy, M Cavallo, et al, Nano Letters 23, 1363 (2023)

In situ mapping of the vectorial electric field within a nanocrystal-based focal plane array using photoemission microscopy, A Khalili, et al, ACS Applied Electronic Materials 5, 4377 (2023)

Coupling Ferroelectric to colloidal Nanocrystals as a Generic Strategy to Engineer the Carrier Density Landscape, M Cavallo, et al, Advanced Functional Materials, 2300846 (2023)

AVIS de l'Ecole Doctorale :

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Fichier à envoyer par mail simultanément
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