



## PhD position

<https://bit.ly/3ecYaYF>

**Sujet :** Study of emerging technologies by advanced operando Electron Microscopy

**Workplace:** NANTES

**Scientific Responsible name:** Philippe Moreau

**Type of Contract:** PhD Student contract/ Thesis offer

**Section CN:** 28, 33

**Contract Period:** 36 months

**Start date of the PhD thesis:** 1<sup>st</sup> September 2021

**Proportion of work:** Full time

**Remuneration:** 2135.0 Euros gross monthly

### Description of the thesis topic:

Title: Study of emerging technologies by advanced operando Electron Microscopy

The recent development of our modern societies is largely based on the research and development of high-tech devices, which are at the origin of revolutions such as information technologies and electric mobility. However, the properties on which all these devices are based most often involve mechanisms that operate on a very small scale, much smaller than a micrometer (battery interfaces, micro-electronic junctions, sensor surfaces, etc.). In addition, most of these devices are not static, but operate through the application of electrical current or voltage. Until very recently, the nanoscale and operating characterization ("operando") of these devices was not possible, severely limiting their development. This situation is changing rapidly thanks to recent advances in transmission electron microscopy which now allow characterizations of devices subjected to different stimuli, in particular electrical, with a sub-nanometric resolution. However, the Jean Rouxel Materials Institute (IMN) has just acquired such exceptional equipment. In this context, the objective of this doctoral thesis will be to set up and develop such experiments at IMN. Three main areas of application will be targeted.

- The first will involve solid state batteries and more specifically the reaction and diffusion of sodium ions in typical electrode materials. Spectroscopic techniques such as electron energy loss spectroscopy will be used for this purpose.

- The study of memories for microelectronics will be the second type of application, in particular Mott's memories, linked to the discovery, at IMN, of a switching property between two resistance states via electrical pulses. In this case, a rapid and local structural characterization will be developed mainly through electron diffraction techniques (4D-STEM).

- Finally, deformation sensors with very high sensitivity and robust behavior under demanding temperature conditions will be analyzed. The modification of the piezoresistive properties of newly developed materials as a function of temperature will be understood through advanced imaging techniques. You will therefore need to use high-level analytical electron microscopy instruments including the Nant'Themis (S) TEM (Themis Z G3 from Thermo Fisher Scientific) equipped with an electron energy-loss spectrometer associated with very sensitive detectors (direct electron detection, iDPC...). You will need to develop experiments with dedicated sample-holders and perform them using appropriate analytical



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techniques. Finally, an important work of data processing will be necessary to extract the visualization of the changes caused by the electrical stimuli. You will have a strong interaction with the engineers of the platform as well as with the post-doctoral fellow who will be recruited on this project mainly for the preparation by FIB (with the ZEISS Crossbeam 550L recently acquired by the IMN) of the lamella that you then analyze with the Nant'Themis. You will therefore need to have good teamwork skills.

#### **Work Context:**

This PhD thesis is funded under a contract with I-SITE "NExT" (Nantes Excellence Trajectory) and is part of a larger project also including the recruitment of a post-doctoral researcher. It aims to popularize the operando or in situ experiments in the IMN laboratory and thus forge new partnerships, particularly with industrial partners. The targeted fields of application are broad and that is why 3 of the 5 IMN teams will be involved. The project is fully in line with the recent arrival in the IMN characterization platform of a probe-corrected (S) TEM microscope, monochromated and equipped with cameras and options allowing rapid measurements, at a sub-nanometric scale, of the evolution of compounds subjected to different stimuli. The host laboratory is the Institut des Matériaux Jean Rouxel (IMN), in Nantes, which is a joint research unit between the CNRS and the University of Nantes (UMR6502). The IMN is made up of more than 200 people, including more than 75 permanent researchers and professors and around 70 doctoral and post-doctoral researchers. The doctoral student will benefit from the interaction with many colleagues working in many fields of materials sciences through experiments using a multitude of advanced characterization techniques and simulations. The doctoral student will interact strongly with the postdoctoral researcher recruited more particularly for the preparation of TEM lamella thanks to the FIB of the characterization platform. The doctoral student will be enrolled in the 3M doctoral school (Matériaux Matières Molécules) and will be attached to the Storage and Electrochemical Transformation of Energy team. However, the Physics of Materials and Nanostructures (PMN) and Plasmas and Thin Films (PCM) teams will also be heavily involved. The doctoral student will be supervised by the scientific managers of the project.

#### **Constraints and risks:**

No specific constraints or risks

#### **Applicant's profile and requirements:**

You have (or are about to receive) a Master 2 or equivalent with a background in materials science, physical sciences, transmission electron microscopy, or related experience. You are enthusiastic and strongly interested in performing precise experimental work using advanced equipments and data processing methods. You want to invest in an interdisciplinary project with potential benefits for the industry. You are a quality-conscious, conscientious, creative and cooperative person, with a pronounced taste for scientific rigor. You are able to communicate with different audiences and have a high level of English. Some laboratory experience is necessary because of the expected experimental methodological developments. Experience in digital data processing would be a plus. Experience in the fields of transmission electron microscopy, spectroscopy (EELS, EDX), electrochemistry would also be appreciated.

#### **Geographic location:**

IMN



**Contact:**

For any further information, please contact Philippe Moreau, Etienne Janod and Eric Gautron (contact details below). All applications must be sent through the “CNRS job portal” (<https://bit.ly/3ecYaYF>) and must include a CV and a cover letter.

**Pr MOREAU Philippe**

Institution: University of Nantes – IMN

Postal address: 2, rue de la Houssinière - BP 32229, 44322 Nantes Cedex 3

E-mail address: [Philippe.Moreau@cnrs-imn.fr](mailto:Philippe.Moreau@cnrs-imn.fr)

**Dr JANOD Etienne**

CNRS Researcher

Institution: CNRS – IMN

Postal address: 2, rue de la Houssinière - BP 32229, 44322 Nantes Cedex 3

E-mail address: [Etienne.Janod@cnrs-imn.fr](mailto:Etienne.Janod@cnrs-imn.fr)

**Dr GAUTRON Eric**

CNRS Engineer

Institution: CNRS – IMN

Postal address: 2, rue de la Houssinière - BP 32229, 44322 Nantes Cedex 3

E-mail address: [Eric.Gautron@cnrs-imn.fr](mailto:Eric.Gautron@cnrs-imn.fr)