PhD candidate for: Scanning transmission electron microscopy characterisation of high energy density solid-state batteries for on board quantum technologies

Workplace: NANTES;
Contract Period: 36 months;
Salary: 2135 euros gross monthly

Proportion of work: Full time
Starting date: October, 1st , 2024

Objectives:

One of the main asset of quantum technologies could be their decrease need of electric power compared to present ones. Although a very controversial perspective, future technologies could happen to operate with smaller sources of energies and their miniaturisation might come up as a useful feature. Microbatteries could also be of much use for the coming era of Internet of Things (IoT). The "Q-batt" collaboration between IMN-CNRS in Nantes and University of Chicago proposes to target high-energy density innovative systems and characterize them at the nanometre level so that they can be optimized for the coming challenges of energy moderation.

Some microbattery configurations using a well-known solid state-electrolyte (amorphous oxynitride) show already quite reasonable performance but they can be hampered in various conditions (for example at moderately elevated temperature). In addition, the capacity mainly governed by the positive electrode chemistry (spinel phase) is smaller than that provided by more recently discovered compositions (like Ni-rich oxides), which could help increasing the energy density of such systems. Finally, new halide-based electrolytes could provide some extra-capacity or high-voltage stability of use to further increase the performance of microbatteries.

All these prospective improvements rely on the perfect knowledge and mastering of structures, chemistries and interfaces created in the whole microbattery, so that they can be corrected accordingly for higher performance. Such information can only gained with the adequate spatial resolution by the use of electron microscopy techniques and the objective of this PhD study is to develop, exploit and process such techniques to that end. Owing to the reactivity of all the components and their sensitivity to air moisture, the precise measurements are quite challenging (probably to be performed at cryogenic temperature) but the plate-form at IMN-CNRS has all the necessary high-level instruments and the expertize to make important advances in that field.

Job description / Activities:

The successful PhD candidate will concentrate on the characterization of thin films down to the nanometre level thanks to advanced electron microscopy and spectroscopy techniques. Three different devices will be studied in detail and compared, especially on the quality/nature of the interfaces existing/created within the microbattery. These analyses will be performed both on the pristine batteries and on batteries after cyling (a few cycles and prolonged cycling). Owing to complexity of such analyses and the previous expertize of the Meng's group at University of Chicago, a first well-known microbattery will be used to define and optimize the protocols at IMN's electron microscopy facility. Especially the usefulness of a cryogenic temperature will be explored to gain representative data. Then, the chemistry of the positive electrode will be changed to a more challenging and possibly capacity relevant nickel-manganese-cobalt oxide. Finally, the electrolyte part will also be replaced by a halide based one, which has very recently been shown by the collaboration IMN-Chicago University to have peculiar and innovative electrochemical behaviour.

To achieve all these high-level studies and gain a better understanding of these innovative devices at the relevant nanometre level, the PhD candidate will have access to unique imaging and analytical electron microscopy capabilities in the IMN (https://plassmat.cnrs-imn.fr/en/). Imaging and spectroscopy analysis will be performed using scanning transmission electron microscopy (STEM) and electron energy loss spectroscopy (EELS) thanks to the Nant'Themis (S)TEM (Thermo Fisher Scientific Themis Z G3). This probe corrected microscope is equipped with specialized holders for *operando* measurements, with low dose mode and highly sensitive detectors (iDPC, direct detection of electrons). Most importantly, sample holders required for handling air and beam sensitive samples will be available.

Especially, a unique (so far in France) sample holder allowing for low temperature (cryogenic) and vacuum transfer associated with double tilt capabilities will be extensively used.

Furthermore, samples as a form of thin films can best be analysed when prepared with a Focused Ion Beam to prepared thin lamella appropriate for (S)TEM. The PhD candidate will thus have also to use the Crossbeam 550L of IMN also equipped with transfer devices and cryo possibilities adapted for TEM lamella preparation.

Profile and requirements:

You hold a MSc in the physics, materials science, engineering or related disciplines.
You have some experience in characterization by electron microscopy techniques and image processing and analysis in relation with those.
You have good understanding of spectroscopic techniques (such as EELS, EDS) and have a good basic knowledge of electron mater interactions.
Your knowledge of materials chemistry is sufficient to take into account the specificities brought by compounds found in lithium batteries and the reaction they might lead to.
You have a special taste for delicate, precise and challenging experiments and are thus very dedicated and perseverant.
You can interact fluently in English with other researchers so that collaboration with the University of Chicago partner is fluid and efficient.
You are quality-oriented, conscientious, creative, and cooperative, with a taste for scientific rigor.
You are able to communicate to different audiences.

Work Context / Scientific framework of the position:

This PhD thesis is funded by CNRS as part of Joint Research Program with University of Chicago (within the framework of CNRS' "MITI" programs (Mission pour les Initiatives Transverses et Interdisciplinaires). The international collaboration is thus a major aspect of the PhD and the successful candidate will be a key asset to strengthen this collaboration. Periodic stays at University of Chicago will occur along the PhD time, in particular in connection with the synthesis of the microbatteries.

The location of the PhD will be essentially at IMN and registered at the French Doctoral School in Nantes. But many stays are planned at University of Chicago. The host laboratory is the Institute of Materials of Nantes Jean Rouxel (IMN, UMR 6502, http://www.cnrs-imn.fr). The IMN is a joined research centre between CNRS and the Nantes University, composed by over 200 staff members including over 120 permanent staff members (professors, CNRS researchers, engineers) and around 80 PhD students and postdoctoral researchers. The successful PhD candidate will benefit from interaction with numerous colleagues working on a number of fields of material sciences through experiments using a myriad of advanced characterization techniques and through simulations. Through this project, the PhD candidate will be part of a renowned group working on the development and characterisation of Li-ion batteries (Silicon, high Ni oxides, organic based…). The PhD student will be supervised both by a professor in this group (Philippe Moreau) and by a CNRS research director (Joël Gaubicher) with long experience in lithium battery materials and devices. Prof. Ying Shirley Meng will also take part in the regular follow-up owing to her long expertise in solid-state batteries and their thin films manufacturing. The PhD student will have direct and easy access to the electron microscopy facility at IMN allowing the development of cutting-edge experiments in the domain. .

Contraints and risks: No constraints or specific risks

Geographic location: IMN: map here

Contact: For any additional information on the project and/or recruitment process, please contact Prof. Philippe Moreau (philippe.moreau@cnrs-imn.fr) Dr. Joël Gaubicher (joel.Gaubicher@cnrs-imn.fr). All applications **(mandatorily in English)** must be sent through the "portail emploi CNRS" and must include a CV and a cover letter outlining your motivation.