May 2025

PhD Offer

Sodium/Carbon or metal composites as anode of solid state sodium-ion battery

General Informations

Workplace: Nancy and Clermont-Ferrand, France
Type of contract: PhD contract funded by ANR, in the framework of the PEPR project “Batteries”
Contract period: 36 months
Expected date of employment: 1 October 2025
Proportion of work: Full time
Remuneration: About 2200 € gross / month (minimum)
Desired level of education: Master’s degree in materials science or chemistry
Experience required: -

Subject description

Although sodium-ion batteries (SIBs) have been studied as early as the 1970s, their developments are much less advanced than Lithium-ion batteries (LIBs). The mechanism of sodium storage and solid electrolyte interphase (SEI) formation is currently partially understood. The PEPR project COFLUENSS (for *FLUorination for ENhanced Solid-state Sodium-ion battery)* focuses then on this objective with an all-solid Na battery with polymer electrolyte and fluorinated electrodes which act for the mitigation of the dendrite formation, the stability enhancement at the interfaces (MEI and SEI), the synthesis of new anode and cathode materials that may be included in self-standing electrode. Since gas/solid fluorinated electrodes will be used the electrolyte free of PFAS will be explored in the battery, the beneficial contribution of fluorine will be provided by the electrodes. To address dendrite formation, a key challenge in sodium metal anodes, the thesis work will replace pure sodium anodes with composites reinforced with carbon-based materials or metal fillers.

Carbon fillers will be prepared by pyrolysis of electrospinned polymer. Depending on the obtained results, carbon would be replaced with metallic fillers. These fillers will be pre-treated with gas-phase fluorination (F_2) to enhance their sodiophilic properties. The formation of a thin NaF layer on these materials' surfaces will improve sodium wettability and is expected to significantly mitigating dendrite growth.
A protocol will be developed in order to realize the sodium impregnation and the comparison between fluorinated and non-fluorinated fillers will be realized. Finally, fluorination of the composites surface will also be envisaged before testing materials for Na-ion battery application.

We are looking for a candidate with a Master 2 or an engineering degree with a specialization in the field of solid-state chemistry or material sciences,. Curiosity, a taste for experimentation and commitment are qualities expected for this project.

Themes / Context

This thesis is part of the COFLUENSS project “COextrusion and FLUorination for ENhanced Solid state Sodium ion battery”, involving 4 research units from 3 universities and the CNRS. The project is based on the observation that sodium ion batteries (SIBs), despite research dating back to the 1970s, remain less developed than lithium ion batteries (LIBs). Indeed, the mechanisms of sodium storage and solid electrolyte interphase (SEI) formation are not fully understood, requiring advanced in situ/operando characterizations and theoretical simulations. SEIs in SIBs are less stable than in LIBs, leading to secondary reactions and performance degradation. Controlling the material-electrolyte interface (MEI) and SEI is therefore crucial to improving cycle stability and electrochemical performance.

COFLUENSS therefore aims to develop an all-solid-state sodium-ion battery with a polymer electrolyte, exploiting fluorine to mitigate dendrite formation, stabilize interfaces and synthesize new electrode materials. The project focuses on:

Protecting the active material surfaces against electrolyte attack and suppressing the surface degradation. Ensuring the stability of active materials is crucial for improving the performance and lifespan of SIBs. This objective focuses on preventing degradation, which directly impacts battery efficiency and durability.
Contributing to the understanding of both the side reactions at the material-electrolyte interface and the formation of the solid electrolyte interface to achieve high reversibility of sodium plating/stripping and stable interface polymer electrolyte/electrode. A deep understanding of these interfaces is essential for enhancing battery performance and safety. This knowledge is critical for developing stable and efficient electrolytes and electrodes.
Defining the most efficient route for surface and bulk fluorination and performing its up scaling. Identifying the optimal fluorination processes is foundational for enhancing material properties and achieving the desired chemical stability in battery components. This objective is key to advancing both materials science and battery engineering.
Quantifying the performance gain for optimized anode/cathode combinations. Measuring performance improvements from optimized material combinations helps prioritize material choices and design strategies for better battery performance.
Developing environment-friendly and scalable processes for (co-)extruding new generation electrolytes and electrodes at the laboratory scale. Creating scalable and sustainable manufacturing processes is essential for transitioning from laboratory research to industrial production. This objective underpins the feasibility and environmental impact of the project.

Supervision Details

Supervision will take place alternatively at the ICCF's Clermont-Ferrand site and at Institut Jean Lamour (Nancy). It will be complementary in terms of skills in elaboration of 3D carbon or metals architectures, sodium impregnation and associated material characterizations and electrochemical tests. This PhD contract will provide a rare opportunity for a highly motivated candidate to study every stage in the preparation of a sodium-ion battery anode, from the formulation to their testing in a battery in operation.

Scientific, Material, and Financial Conditions of the Research Project

The research will be carried out in fully equipped laboratories, with a doctoral contract secured.

Research Dissemination, Publication, and Intellectual Property Rights

The results will be disseminated through publications in international journals and presentations at specialized conferences. If deemed relevant by the research team, patent applications may also be considered.

Planned Collaborations

As the proposed work is part of a consortium of 4 laboratories, interactions are to be expected with the different partners, each in its own field of expertise. The labs are : Institut de Chimie de Clermont-Ferrand (ICCF, UMR-CNRS 6296), Laboratoire d'Electrochimie et de Physico-chimie des Matériaux et des Interfaces (LEPMI, UMR-CNRS 5631), Institut Jean Lamour (IJL, UMR-CNRS 7198) and Laboratoire Procédés et Ingénierie en Mécanique et Matériaux (PIMM, UMR CNRS 8006). Whenever necessary, leading experts will be consulted to address experimental, theoretical, or modeling-related challenges. Depending on the circumstances, additional research stays at partner laboratories in France or abroad may be considered.

Work context

The candidate will join two research teams specializing in materials science and electrochemistry: The « Carbon-based Material » team of IJL (https://ijl.univ-lorraine.fr/) which is internationally recognized regarding its work on the intercalation chemistry of metals into graphite and the *"Fluorinated Materials"* group at the Clermont-Ferrand Institute of Chemistry (ICCF, UMR CNRS 6296). Supervision will take place half at Nancy (IJL), and half at Clermont-Ferrand site where ICCF is located. It will be complementary in terms of skills in electrospinning, carbon science, fluorine and alkali metals chemistries; optimization, characterization and modification of materials by various fluorination methods, electrochemical properties and associated testing.

Skills

The candidate should have a very strong background in solid-state chemistry or materials science, but knowledge of batteries and electrochemical systems in general will be particularly appreciated. Ability to work under controlled atmosphere (glove-box) is expected. The candidate will have to demonstrate a great ease with the modern analytical techniques he/she will be trained in, to become quickly autonomous, and in particular, to deepen the physicochemical aspects involved (electrospinning, pyrolysis, grinding, electrical conductivity, surface treatment, in-depth physicochemical characterizations, electrode shaping and electrochemical testing). He/she will need to be dynamic, curious and persevering to carry out the multiple syntheses, characterizations, tests and interpretations of results, and demonstrate the ability to work in a team and in two distinct scientific environments.

Constraints and risks

The position you are applying for is located in a sector relating to the protection of scientific and technical potential. It therefore requires, in accordance with the regulations, that your arrival be authorized by the competent authority of the Ministry of Higher Education, Research and Innovation.

About Institut Jean Lamour and Institut de Chimie de Clermont-Ferrand

The Institut Jean Lamour (IJL; https://ijl.univ-lorraine.fr/)) is a joint research unit (UMR 7198) of CNRS and Université de Lorraine. The IJL is focused on materials and processes in science and engineering, and covers activities in condensed matter physics, materials, metallurgy, plasmas, surfaces, nanomaterials and electronics. The IJL staff consists of 183 researchers/lecturers, 91 engineers/technicians/ administrative staff, 150 doctoral students and 25 post-doctoral fellows.
The ***« Carbon-based Material »*** **team** of **IJL** is internationally recognized regarding its work on the intercalation chemistry of metals into graphite. The team is expert regarding its knowledge in the handling of alkali metals and other air-sensitive materials since decades and the elaboration and characterization (chemical, structural, textural) of (non)modified carbon materials.

The Institut de Chimie de Clermont-Ferrand (ICCF) is a Joint Research Unit (UMR 6296) under the auspices of the CNRS, the Université Clermont Auvergne and the Centre Hospitalier Universitaire de Clermont-Ferrand. The ICCF develops fundamental and applied research with strong industrial partnerships in various fields of chemistry, enabling it to respond to societal challenges linked to its three research areas: Chemistry and the Environment, Chemistry and Materials, and Chemistry for Life, with a particular focus on the design of innovative materials. The ICCF makes its technical skills, instrumental equipment and know-how available to meet the current needs of society and industry.

Application

Only high-quality applications will be considered: Master 2 average ≥ 14/20, 1st quartile. Applicants who do not meet these requirements are asked not to submit an application.

Applications should consist of a cover letter including a motivation statement, a curriculum vitae, and the contact details of at least one reference, together with diploma copies and/or marks obtained during the Master degree, and send it to:

- **sebastien.cahen@univ-lorraine.fr**
- **nicolas.batisse@uca.fr**

Then, interviews will be organised and visits of the labs will be possible on request.