'Physique et Chimie des Matériaux' – ED 397 – année 2020

PhD project for funding (max 1p), to send to

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Research unit (full name + acronym) : Chimie de la Matière Condensée de Paris (LCMCP)
Team if applicable : Reactive Materials for Electrochemical deviceS (RMES)
Address : 4 place Jussieu, T44-54/422

Supervisor name (HDR) : Christel Laberty-Robert Position : Lecturer SU
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Number of phD under supervision : 1 Participation to supervisor training? no Year
Co-supervisor name : D. Bregiroux & N. Krins HDR ? no
Research unit : LCMCP International co-supervision ? No
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Keyword 1 : Proton batteries Keyword 2 : Sol.-state chemistry
Keyword 3 : Synthesis Keyword 4 : Electrical charact.
Select co-funding programme if applicable : select

Project title : Exploring all solid state proton batteries

Project Description (~4000 characters, font 11 min):

We need green batteries: safe, made of available and fair trade resources, cheap and easy to process. Current Lithium-ion technology does not fulfill all these requirements yet, using Li-based materials and toxic flammable solvent.

In this context, we would like to think beyond all solid state Li-ion battery and propose an all solid state proton-ion battery. The main challenges facing solid state devices are (1) sufficient ionic conductivity of the solid electrolyte, and (2) efficient electrode/electrolyte interfaces, allowing for an easy charge transfer and little undesirable side reactions.

Here, we intend to use the know-how of the team to design a battery of nanomaterials, starting from a proton conductive hybrid organic-inorganic electrospun mattress, which we intend to intimately interface on both sides with the Ti- and Mn-nanoparticles-based active electrode materials on carbon cloth.

Until now, the development of proton-based batteries was associated with aqueous electrolyte, which was impeded by the limited electrochemical stability window of water. Recent work on water-in-salt electrolyte (small amount of free water) for Li-ion battery, has shown to successfully widen this range up to 3V. We believe that the here studied proton-conductive membranes could recreate similar behavior and delay the hydrogen evolution reaction. Proton is also the lightest and the smallest ion, high conductivities can be expected. Also using protons, we avoid any kind of dreadful dendrites. Finally, high capacity solid state electrode materials, able to electrochemically insert protons, have recently been described in the literature, including earth abundant titanate materials.

The PhD work will be organized into three work packages:

i) The synthesis, the characterization and the electrical characterization of the hybrid membrane.

ii) The synthesis, the characterization and the electrochemical characterization of the electrode materials. In particular, we will study the relationship between proton intercalation and structural modification. For this different tools will be used including X-Rays diffraction, Raman spectroscopy, SANS. A special attention will also be dedicated to the electrolyte/electrode interface to understand mechanism of proton transfer.

iii) The evaluation of the all solid state battery performance.

Expected results: i) the development of new concept of battery, ii) understanding electrode/electrolyte interface for limiting secondary reaction, iii) the development of flexible battery that can be easily implemented.

The PhD candidate will develop skill in the synthesis of material and their structural, microstructural characterization through various techniques (X-rays diffraction, Raman Spectroscopy, FIB-SEM, NMR spectroscopies) and in electrochemistry (electrical measurement, battery testing and electrochemical characterization of electrode). She or he will also develop autonomy as well as skills in management and team working.