Institut des Matériaux Jean Rouxel
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PhD topic 2022

Recycling wastewater absorbents as energy storage electrodes

Keywords
Electrodes, Recycled materials, Water purification, Energy storage device

Supervisors
Supervisor : Thierry Brousse - 06 83 40 36 12– Thierry.Brousse@cnrs-imn.fr
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Secondment : Prof. Patrik Johansson, Chalmers University of Technology - SWEDEN

Fiancement / *Financial support*
European project DESTINY/ Région Pays de la Loire

Location
Main location at Institut des Matériaux Jean Rouxel, Nantes.

Lab
IMN or Institut des Matériaux Jean Rouxel (www.cnrs-imn.fr) in Nantes is a CNRS/University of Nantes joint laboratory (UMR CNRS 6502) on solid state chemistry and physics of materials. IMN is composed of 5 teams with 110 permanent researchers and 110 PhD students and post-doc researchers. The ST2E team at IMN is one of the world leaders in the synthesis of new pseudocapacitive materials/high power battery electrodes for energy storage devices. The main skills of the IMN group is the use of genuine synthesis methods to obtain electrode materials for different kind of devices. Further, the team focuses on evaluation using different electrochemical techniques and to unveil the mechanisms underlying charge storage performance. The team is composed of Dr. O. Crosnier and Prof T. Brousse, both experts in materials chemistry and electrochemistry applied to energy storage devices.

Topic
The removal of heavy metal cations from wastewater is a major environmental and recycling problem. Today this requires the use of adsorbents able to uptake as many cations as possible, in order to reach a high purifying efficiency. Carbon based materials, such as graphene-based foams or ionic exchange resins, have been proposed, and indeed some of them reach unprecedented efficiency – up to 300 wt. % Pb (II) removal by a graphene oxide foam composite. The trapped cations subsequently have to be released in another solution of used water and in the end precipitate as solid waste and most often stored as toxic garbage in specific places.
In this project, we propose to take advantage of cation loaded carbon foams and recycle/make use of them to prepare high capacity electrodes for energy storage devices operated in various electrolytes, from aqueous media to ionic liquids. By shrewdly combining the cations trapped in the adsorbent, full devices can be assembled with high energy/high power using recycled adsorbents. Alternatively, the composition of ionic exchange resins can be tailored to reach a desired stoichiometry of multi-cationic compounds and then pyrolyzed under different atmospheres to obtain oxides dispersed in a carbon matrix, that can be used as electrodes for various devices, from metal-ion batteries to supercapacitors.
In this project, two main directions will be followed. The first one will be the synthesis of carbon-based composite foams with high efficiency for the recycling of heavy metal cations from wastewater solutions. The adsorbent will be exposed to different water-based solutions containing individual species such as Pb2+, Cu2+, Ni2+, Zn2+, etc. The electronic conductivity

will be tuned in order to prepare an electrode containing an electroactive cation. The electrochemical behavior will be investigated in different electrolytes with respect to both capacity and cycling ability. Further, the charge storage mechanism will be investigated with respect to cation dissolution into the electrolytes employed, which would decrease the cycling efficiency of the electrode. The latter will be more specifically investigated during a 6 months secondment at Chalmers University of Technology, Göteborg, SWEDEN, under the supervision of Prof. Patrik Johansson. Operando confocal Raman spectroscopy focused above the surface of the electrode will be one approach to elucidate the phenomena responsible. Pending on results and interests the PhD student will also be exposed to modeling of the solubility by e.g. DFT+COSMO-RS approaches.
A second original approach will consist in trapping multicationic solutions in an ion exchange resin that will be pyrolyzed in order to obtain the related oxides with a controlled morphology that will be further investigated as electrode materials for batteries, electrochemical capacitors and hybrid devices. The influence of annealing processes (temperature, atmosphere, etc.) on the electrochemical properties of the obtained compounds will be further investigated with respect to sustainable development.

Profile

The candidate (M/F) should have a background in chemistry and/or materials science and related characterization techniques. Knowledge and practice of electrochemical analysis (cyclic voltammetry, galvanostatic studies, electrochemical impedance, etc...) would be an asset for this topic.

How to apply :

Please read the text below carefully and follow instructions

The Call for applications for DESTINY Cohort#2 (24 NEWS PhD topics!) started on November 15th. It will end on Monday January 17, 2022, at 5PM French time.
The applicant reads the Guide for applicants (**https://www.destiny-phd.eu/how-to-apply**) explaining the Eligibility Rule (MSCA rules) & the list of documents to be provided.
The candidate fills in 2 files to submit her/his application (please note that a resume and a classic cover letter are not enough to be eligible !!). The 2 files to be filled are called Application Form n°1 and Application Form n°2, and each one contains precise information (information about the candidate, requested files, master/bachelor transcripts, original essay, English test, etc.). The templates and instructions must be downloaded from the DESTINY website: https://www.destiny-phd.eu/how-to-apply

Before January 17, 2022, 5pm French time, the candidate submits her / his application file (application form N°1 and N°2) on the DESTINY Call published on the CNRS employment portal site at the following address: https://emploi.cnrs.fr/Offres/Doctorant/FR3104-CHRMAS0-004/Default.aspx?lang=EN. A guide detailing the steps to follow is available on the DESTINY website: https://www.destiny-phd.eu/how-to-apply

E-mail addresses of supervisors are given in order to ask for more details on the PhD topic. Direct applications for the PhD position to the supervisors will not be considered. Selection process will be made by a scientific panel of researchers from DESTINY program.