Développement de matériaux à base de graphène fonctionnalisé pour le stockage électrochimique

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Stage pouvant se poursuivre en thèse : Oui

Résumé :

Ce projet de stage de M2 s'inscrit dans la thématique de recherche du laboratoire sur le développement de matériaux architecturés à base de graphène, conçus pour le stockage électrochimique de l'énergie. Les propriétés particulières du graphène, telles que sa grande surface développée et sa conductivité élevée, font du graphène un matériau d'intérêt pour des applications dans des systèmes de type supercondensateur (SC). Toutefois, le graphène ayant tendance à se ré-agréger, la surface vraiment active pour l'adsorption des ions reste limitée, et les performances électrochimiques obtenues sont loin de celles attendues. Afin de palier à ce phénomène, l'impact de la macroporosité des dérivés de graphène est un point clé adressé dans de nombreuses études bibliographiques décrivant notamment les effets de la structuration 3D du graphène. Malgré la morphologie en feuillets du graphène peu d'études sont menées sur l'impact de sa potentielle structuration lamellaire.

Les travaux récents menés au laboratoire consistent à développer des assemblages de feuillets de graphène pontés entre eux par des molécules organiques bi-fonctionnelles dans le but de préserver la surface active pour l'adsorption des ions au sein d'électrodes pour SC. Le but du stage est de développer ce type d'architecture en utilisant différentes natures de pilier afin de favoriser le transport ionique au sein du matériau. L'étudiant réalisera donc la synthèse d'oxyde de graphène, sa fonctionnalisation et réalisera les caractérisations électrochimiques.

Sujet détaillé :

Electrochemical double-layer capacitors (EDLC), also known as supercapacitors (SCs), are devices that store energy through charge separation from electrolytic ion sorption on charged electrode surfaces. Porous carbons such as activated carbons (ACs) are traditionally used as electrode materials due to their high surface areas and low costs. In parallel to ACs, various graphene derivatives have been proposed as potential materials for SCs owing to their high electrical conductivities, large surface areas and mechanical flexibilities. Reduced graphene oxide (RGO), readily prepared from graphene oxide (GO), is extensively studied as a model graphene-like material. RGO displays good power capability but suffers from low capacitances as the reduced graphene sheets partially restack through ?- ? interactions.

It has been shown that graphene sheets could be assembled to form structured graphene frameworks to limit this restacking but also translate the properties of individual sheets to functional materials and allow practical applications. The key features of these frameworks in terms of electrochemical storage applications are their graphitization level, their structural or textural disorder, and their porosity.

Exploring the layered structures of graphene derivatives for ion sorption is another approach followed to avoid graphene layers restacking. The graphitic stack with 3.3 Å inter-layer separation is too small for ion sorption but could be tuned with an intercalant to exhibit an expanded layer structure. Recently, in our group, we synthesized a class of pillared graphene materials with varied inter-layer separation using alkyl diamines as pillars (Fig. 1), speculating that such expanded layered structures could offer additional ion sorption sites and improve storage performances in supercapacitors (SCs). These pillared graphene materials have then been assembled into graphene hydrogel to optimize the ions transport inside electrode bulk porosity. The impressive storage performances achieved demonstrated the success of this strategy.

The specific objectives of this internship are to synthesize and characterize such pillared graphene materials. New pillar molecules chosen to facilitate and promote the ions transport inside the graphene galleries will be tested. Graphene assemblies with varying bulk porosity will be prepared. Physico-chemical characterization will be performed on all samples to allow a comprehensive comparison of the various materials properties. The most interesting graphene?based assemblies will be selected and tested electrochemically in supercapacitor cells.

This internship will hence involve i) to perform basic synthetical steps, ii) to conduct selected characterization on the carbon architectures (TGA, IR, SEM) ii) to take part to specific analysis (XPS, XRD) and iii) to do electrochemical characterization of the materials. The student will have an active part in the laboratory life and will be asked to report on his work.

Compétences requises :

To carry out this project we are looking for students with a background in chemistry and who are now in a Nanoscience related Master Research.
Surface chemistry/characterization knowledge and an interest for the energy storage field would be appreciated.