Ecole Doctorale des Sciences Chimiques ED250

Intitulé du Sujet de Thèse : Eco-sustainable electrodes for fuel cells and all-solid-state batteries

Laboratoire : Madirel (UMR 7246)

Equipe : Axe 2 « Membranes, revêtements, dispersions »

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Contexte de l'étude

Introduction: Eco-sustainable materials, like biochar, can be produced from renewable sources and can be applied both as porous cathode in fuel cells (FC), as negative electrode of alkali batteries instead of the currently employed hard carbons, but also as conducting additive for low electronic-conducting positive electrode materials in batteries.
Hydrogen FC represent a major technology for clean energy conversion with applications in transportation and stationary power generation. However, their widespread adoption is hindered by the high cost and limited availability of critical raw materials (CRM), such as Pt, used as electrocatalysts. In this context, the development of more sustainable and cost-effective catalysts for FC reactions is imperative. This thesis aims to investigate biochar-based catalytic electrodes for the oxygen reduction reaction (ORR) and hydrogen oxidation reaction (HOR).
Developing all-solid-state batteries (ASSB) is the holy grail of battery research, especially for safety, which is paramount for the customer. This thesis project will tackle the endeavour by advanced battery electrodes compatible with solid polymer electrolytes, containing less CRM and more eco-friendly components, especially highly conducting N-doped biochar.
Impact: This thesis is part of the "Ion-MEET" AMidex international project. The collaboration of the Madirel team with Tor Vergata Univ. Rome, a leading research institution in the field, will also reinforce the international "Laboratory Ionomer Materials for Energy (LIME)".

Descriptif du projet

1) Development of innovative materials based on the exploitation of biomass for the preparation of biochar electrodes for FC and ASSB.

Highly conducting N-doped biochar will be prepared by hydrothermal carbonization (HTC, "hydrochar") from protein-rich waste biomass, eventually added with different nitrogen-containing biopolymers (e.g. chitosan from shrimp-shell) or biomolecules (e.g. melamine). HTC will be favored as an environmentally friendly pathway with low energy consumption. Hydrochar based electrodes and supports will be studied exploring different heteroatom doping and tailoring the pore structure by appropriate thermal treatments with careful consideration of the energy balance.
FC: we will study biochar-derived electrocatalysts combined with basic ionomers for the ORR and HOR in alkaline conditions. Coordination compounds of non-noble metals or nanocrystalline non-toxic metals will be added for better performance. The combination will also be tested for the easier HOR with acidic ionomers. Nanostructured catalytic electrodes with optimized ink formulation using biochar will be prepared by drop-coating and by electrospinning.
ASSB: N-doped hydrochar with various heteroatom dopants and structure will be studied as negative electrode material with solid electrolyte separator, but also as conducting additive in positive electrode formulations.

2) Life-cycle and degradation analysis by accelerated tests and post-mortem analysis.

The extent and nature of degradation processes will be evaluated by complementary techniques, including XRD, SEM, AFM, ion exchange capacity and conductivity measurements, FTIR, NMR and XPS spectroscopies.

Références Bibliographiques

[1] A. R. Nallayagari et al. ACS Applied Materials & Interfaces 2022, 14, 46537