Holistic Design of Nanohybrid Electrocatalytic Materials for Efficient Energy Conversion

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Context

Heterogeneous electrocatalysis is at the heart of key electrochemical systems for the energetic transition. These include conversion devices of decarbonized electricity to fuels or high value products and from fuels to electricity. Thus, the electrocatalyst materials play a determining role in device performance, cost and lifetime. However, although numerous nanocatalysts are found extremely promising in liquid electrolytes of the laboratory environment, there are still critical barriers preventing their fruitful integration into practical low temperature electrochemical devices requiring solid electrolytes, such as proton- or anion- exchange membrane fuel cells and electrolysers. Despite each electrochemical device having its own specificities (chemical nature of the catalysts and reactants or pH of the solid electrolyte) a fundamental and common bottleneck concerns the transposition of promising catalysts to performing membrane-electrode assemblies, *i.e.* the formation of an efficient and stable three-phase boundary interface between the catalyst surface, the reactant and product phase(s) and the solid electrolyte allowing high mass, ionic and electronic transport rates. In general, the state-of-the-art in electrode design still follows a scheme introduced in the 90s consisting of supporting metal nanoparticle catalysts on a high surface area electron-conducting support before addition of an ion-conducting ionomer binder. Despite each individual component of this interface being subject to intensive research efforts regarding their optimization, the promising catalyst materials remain systematically underperforming in practical systems.

Objectives

The proposed PhD project aims at developing a new concept of nanohybrid functional structures able to address most of the issues that have been identified for the state-of-the-art electrodes design regarding initial performance and long-term stability. The originality of the project relies on the holistic approach followed, consisting of exploiting the peculiar continuous structure of an emerging and promising class of structurally-disordered [1] nanocatalyst, that are metal aerogels [2], as a lever to redesign an alternative three-phase boundary interface with numerous key advantages. To achieve this goal, the PhD candidate will be invited to build upon various approaches currently available in the Electrochemistry for Energy (ELFE) group of the Institut Charles Gerhart Montpellier (ICGM) regarding the elaboration of both inorganic and organic functional nanomaterials. The developed materials structural, chemical and electrocatalytic properties will be investigated through a wide range of techniques including *operando* synchrotron-based methods in both liquid half cells and practical fuel cell and electrolyser devices.

Minimum qualifications:

- Experience in the synthesis and characterization of polymeric materials and/or metal nanoparticles/aerogels.
- Experience with electrochemical systems (fuel cell or electrolyser).
- Communication skills in English for dissemination of the results in international conferences and peer-reviewed journals.

Preferred qualifications:

- Experience in MatLab (or Python) coding for large dataset analysis is highly desired.

Contact:

MSc grades, cover letter explaining the motivation, CV and contact details of 2 references should be sent to Dr. Raphaël Chattot (raphael.chattot@umontpellier.fr).

1. Chattot, R. et al. Surface Distortion as a Unifying Concept and Descriptor in Oxygen Reduction Reaction Electrocatalysis. Nat. Mater. (2018).
2. Cai, B. & Eychmüller, A. Promoting Electrocatalysis upon Aerogels. Adv. Mater. 1804881 (2018)