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Subject Proposal for exchange students

Preparation, advanced electrochemical and microstructural characterisations of SOFCs electrode material.

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Abstract:
In the current energy context, the research are turned towards the combination of several energy sources (nuclear energy, fossile fuel, biomass, water energy, wind energy, sun energy, …), Solid Oxide Fuel Cells (SOFCs) appear to be promising (Figure 1). The current devices operate at high temperature, typically 800-1000°C. One issue is to decrease the operating temperatures, but it is strongly connected to an increase of the cell resistance, not only on the electrolyte, but also on the electrodes. In that frame, new materials have to be developed. They must have good electronic and/or oxide ion conduction properties, be stable in oxidant environment, have a good porosity to allow the gas diffusion. It is essential to evidence new electrode materials, with mixed ionic-electronic properties, optimal in the considered temperature range.
The mechanism involved in an SOFC cathode material are complex (Figure 2). Several steps are involved: molecular oxygen diffusion, oxygen adsorption/dissociation, charge transfer, ionic species diffusion. The cells electrochemical properties are not only connected to the materials intrinsic properties (diffusion coefficient, surface exchange kinetics), but also to the electrode microstructure.

Figure 1.

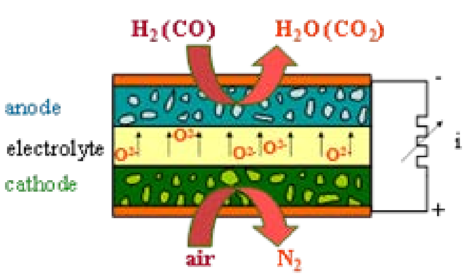

Figure 2.

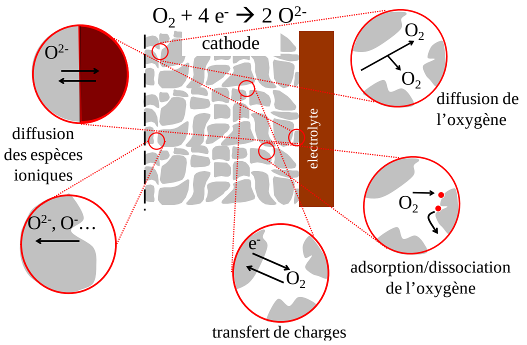

Figure 1. Schematic of a Solid Oxide Fuel Cell. Figure 2. Mechanisms involved in an electrode material.

In this context, the objective of the project is to optimize the preparation of SOFCs cells (materials synthesis by solid state reaction, innovative techniques for porous electrodes preparation), to go further in the understanding of the mechanisms involved in the oxygen reduction reaction in electrodes with innovative microstructures (Figure 3) obtained by:

- screen-printing [1-4]
- sol-gel macrostructuration techniques [5,6] (collaboration Dr. J. P. Dacquin, axe catalyse hétérogène, UCCS)
- Electrostatic Spray Deposition (collaboration Pr. E. Ejurado, LEPMI, Grenoble)

The impact of the microstructure on the electrochemical properties (technique of electrochemical impedance spectroscopy) and on the cell performances (U-i plot, power) will be studied, with a focus on the understanding of the physical phenomena involved, which requires a fine characterisation of the architectures microstructure.

Advanced microstructural characterisations will be considered, especially 2D SEM (Scanning Electron Microscopy) images treatment (collaboration Dr. E. Masson, TVES, Lille). This part of the project will consider an image treatment software (eCognition), based on an automatic data segmentation/classification procedure [7]. A Scanning Electron Microscope (SEM) with an Focussed Ion Beam (FIB) (IEMN, Lille) will be used. It consists in collecting SEM images on successive cross-sections with the objective to reconstruct in 3D (Figure 4) the analysed electrode and to extract information on the porosity, the tortuosity, the percolation paths, …

Figure 3.

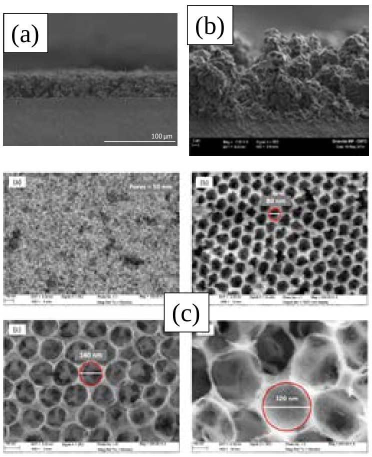

Figure 4.

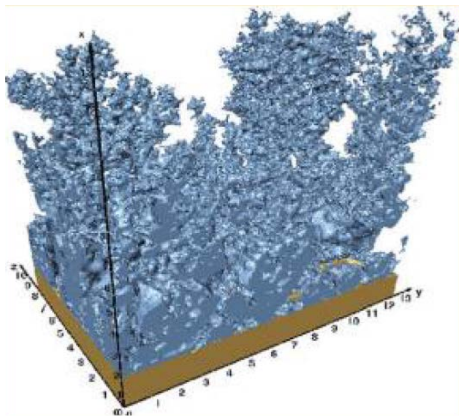

Figure 3. SEM images of porous materials prepared (a) by screen-printing, (b) by ESD, (c) from polymer balls of 50 nm, 110 nm, 150 nm, 350 nm [5]. Figure 4. 3D reconstruction of FIB-SEM images of an electrode material [8].

Bibliography:
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<u>Keywords</u>: electrode, fuel cell, screen-printing, ESD, controlled porosity, electrochemical characterisations, electrochemical impedance spectroscopy, microstructural characterisations, SEM, FIB-SEM, image treatment, 3D reconstruction