M2 Internhip Position (April 2021-September 2021)

Title: Microstructural characterization and modeling of electrodes using image analysis and stochastic geometry for solid oxide cell application

Host institution: Ecole Nationale Supérieure des Mines de Saint-Étienne (MINES Saint-Etienne), FRANCE
SPIN / LGF, UMR CNRS 5307
Salary (net): ~1200 euros/month
Candidate profile: M2 student in image analysis
Contact: Johan DEBAYLE (MINES Saint-Etienne) / debayle@emse.fr
Partner: Jérôme LAURENCIN (CEA Grenoble)
Duration: 5-6 months

Description

- **General context**

The ECOREVE project (ANR-18-CE05-0036) deals with the steam electrolysis at high temperature using Solid Oxide Cells (SOCs). The aim is to optimize the microstructure and architecture of the electrodes to improve the SOCs performance and durability, which is a major technological challenge.

To guide electrode fabrication and optimization, electrochemical properties can be modeled through the generation of numerical microstructures, validated on real three-dimensional electrode reconstructions. Indeed, electrodes have a fine and complex microstructure that plays a key role in cell performance and durability. Simulations at the microscopic scale can be conducted, as a guide for the analysis of the role of the microstructure as well as the relationship between the elementary reaction mechanisms at the electrodes and the degradation phenomena of the cells.

- **Objectives**

In this general context, the objective of this internship is to model and characterize the microstructure of SOCs electrodes. Previous works have been already done on spatially homogeneous microstructures. Nevertheless, degradation phenomena of the cells can generate some heterogeneity within the microstructure with the appearance of phase gradients. Some image processing, analysis and modeling tasks will then needed:

  - Image filtering and segmentation in order to identify the different phases. Classical techniques of thresholding and watersheding will be used.
  - Morphometrical characterization of the different phases. Different features will be computed such as volume fraction, size distribution, tortuosity and spatial dispersion.
  - Geometrical modeling of the microstructures. Some tools from stochastic geometry (specifically truncated random fields) will be investigated.
  - Fitting to the real data in order to get a representative model of the microstructures. Optimizations tools will be carried out to fit the model to the real data.

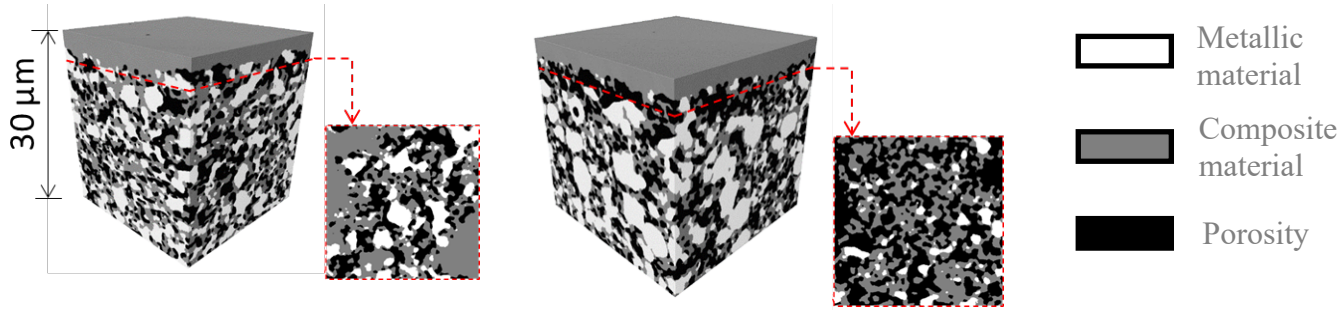

Figure 1: Electrode degradation after operation in electrolysis mode at high temperature (images acquired at ESRF).

References

[1] H. Moussaoui, J. Debayle, Y. Gavet, P. Cloetens, and J. Laurencin. Particle-based model for functional and diffusion layers of solid oxide cells electrodes. Powder Technology, 367:67-81, 2020.

[2] H. Moussaoui, J. Laurencin, M. Hubert, R. Sharma, P. Cloetens, G. Delette, Y. Gavet, and J. Debayle. Stochastic Geometrical and Microstructural Modeling for Solid Oxide Cell Electrodes. ECS Transactions, 91(1):2031-2043, 2019.

[3] H. Moussaoui, R. Sharma, J. Debayle, Y. Gavet, G. Delette, and J. Laurencin. Microstructural correlations for specific surface area and triple phase boundary length for composite electrodes of solid oxide cells. Journal of Power Sources, 412:736-748, 2019.

[4] H. Moussaoui, J. Laurencin, Y. Gavet, G. Delette, M. Hubert, P. Cloetens, T. Le Bihan, and J. Debayle. Stochastic geometrical modeling of solid oxide cells electrodes validated on 3D reconstructions. Computational Materials Science, 143:262-276, 2018.

[5] R.C. Gonzalez and R.E. Woods. Digital Image Processing. Prentice Hall, 2008.

[6] S.N. Chiu, D. Stoyan, W.S. Kendall, J. Mecke. Stochastic Geometry and its Applications. John Wiley & Sons Ltd, 2013.

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