PAUL SCHERRER INSTITUTE (PSI)
Laboratory of Electrochemistry (LEC) - Laboratory for Neutron Scattering and Imaging (LNS)

Project Description for an Internship or Semester – / Bachelor– / Master Thesis

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Neutron Dark-Field Imaging for the Visualization of Water in Porous Layers of Fuel Cells

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17/09/2018

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1 Motivation

Polymer electrolyte fuel cells (PEFCs) are electrochemical devices which convert the chemical energy of hydrogen to electricity and are used in stationary and mobile applications as for example cars. Optimization of water management of fuel cells is an important lever to improve their performance and increase their live time. Water that is produced by the electrochemical reaction occurring in the fuel cell leaves the cell either in gaseous or liquid form through porous gas diffusion layers (GDLs) which are placed between the electrodes and the gas flow channels. When most of the pores of the GDL are filled with liquid water, the access of gases to the electrodes is blocked and the fuel cell performance drops. In order to understand the relation between cell parameters (e.g. operation conditions, flow field design, GDL materials), liquid water distribution and performance, methods that allow for visualization and quantification of water in the GDL are of great interest. Conventional neutron transmission imaging is a powerful tool for visualizing the water distribution behind typically used flow field materials such as aluminum or steel during in situ experiments. In order to quantify water in the different layers over the cross section, imaging of the cell can be performed with the cell membrane parallel to the beam [1]. To avoid saturation of the signal due to large water thicknesses, the width of the cell is limited to 20-30 mm in this configuration. Neutron dark-field imaging offers new possibilities to visualize water in the GDL, as this technique is selectively sensitive to microstructures. The dark-field image (DFI) is obtained simultaneously to the conventional transmission image when a neutron grating interferometer [2] is placed in the beam. The produced interference pattern without any sample is a sinusoidal intensity variation with an amplitude that is defined by the characteristics of the interferometer and beam. A sample that contains microstructures in the size range from one to several tens of micrometers and with scattering length densities different from their surroundings causes neutron scattering to ultra-small angles, which results in a reduced amplitude of the sinusoidal interference pattern. The DFI value is a measure for this interference amplitude loss and is measured for every pixel of the image. Because large homogenous structures do not cause coherent neutron scattering at ultra-small angles they do not significantly influence the DFI value. Therefore, dark-field imaging can be applied to selectively visualize and analyze the water distribution in the GDL without disturbance of the signal from water present in flow channels (Figure 1). In addition, this imaging method can also be used to visualize changes in microstructure of the GDL which appear when the GDL is damaged.

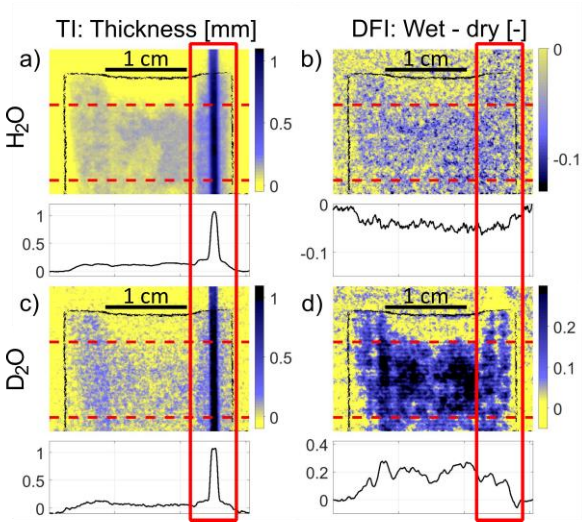

Figure 1: Color coded images showing the water distribution in a GDL (Freudenberg H2315): yellow = dry, blue = water present. [a,c]: Water thickness images (WTIs) calculated from trans-mission images (TIs): a) H_2O, c) D_2O. [b,d]: Difference of DFIs between dry and water filled GDL: b) H_2O, d) D_2O. The dashed red lines in the images indicate the area for which the profile is plotted below the images.

2 Project description

The project will be tailored to the interests of the trainee or student and her/his time limitations. The preferred start time from our side is beginning of November and the minimum time for the internship or thesis is two months, the maximum six months. The main task is supporting the preparation and conduction of two neutron imaging beam times on the subject of PEFCs. In the first beam time, conventional neutron transmission imaging will be used to study the water distribution of a cell operated with specially modified GDLs and interdigitated flow fields. In the second beam time neutron dark-field imaging will be performed simultaneous with fuel cell operation for the visualization of water distributed in the GDL. Beside hands-on work during fuel cell experiments and beam times, the trainee/student will have the chance to acquire or improve programming skills (image processing, fuel cell experiment analysis), knowledge in electrochemistry and/or grating interferometry.

3 Tasks & Schedule

The trainee or student is supervised by Muriel Siegwart and Dr. Pierre Boillat at PSI in order to manage the task listed in the schedule. Depending on her/his interests and time limitations, she/he can stay from 2 up to 6 months.

- The preparation of beam times includes:
  - Assemble fuel cells
  - Operate a fuel cells installed at a test bench
  - Analyze results from fuel cell operation (with Matlab, Python or Excel)
- Support of beam time includes:
  - Install test bench inside beam line
  - Operate fuel cell simultaneously to neutron imaging
  - Setup the neutron grating interferometer (second beam time)
  - Image processing (with Python, Matlab or/and IDL)
- In case the trainee or student wants to stay longer than three months:
  - Optimize image processing of data obtained with neutron grating interferometer to improve contrast-to-noise ratio
  - Establish a theoretical fundament for the analysis of dark-field signal from a multi-phase sample

The dates of the two beam times are:
1) Friday, 16.11 – Monday, 19.11.2018
2) Friday, 14.12 – Tuesday, 18.12.2018

Knowledge in Physics, Engineering, Programming or Electrochemistry is helpful but not required.

Task	1	2	3	4	5	6
Literature study						
Performing fuel cell experiments for beam time preparation						
Beam time support						
Analyze electrochemical results / image processing						
Image processing / Write short report						

4 References

[1] P. Boillat, D. Kramer, B.C. Seyfang, G. Frei, E. Lehmann, G.G. Scherer, A. Wokaun, Y. Ichikawa, Y. Tasaki, K. Shinohara, Electrochem. commun. **10(4)**, 546-550 (2008).

[2] A.P. Kaestner, S. Hartmann, G. Kuhne, G. Frei, C. Grunzweig, L Josic, F. Schmid, E. H. Lehmann, Nucl. Instrum. Meth. A **659 (1)**, 387-393 (2011).

[3] C. Grünzweig, F. Pfeiffer, O. Bunk, T. Donath, G. Kuhne, G. Frei, M. Dierolf, C. David, Rev. Sci. Instrum. **79(5)**,(2008).

5 Application

Please send your application including your resume and your grades to muriel.siegwart@psi.ch. In case you have questions, do not hesitate to contact me via email or phone (+41 56 310 57 72).