IPID4all Doctorate Research Exchange with University of Alberta
Feedback report

Peter Wagner

NEXT ENERGY
(www.next-energy.de)
EWE-Forschungszentrum für Energietechnologie e. V.
at the University of Oldenburg
Carl-von-Ossietzky-Straße 15
D-26129 Oldenburg
Germany
Tel.: +49 441 99906-316
Fax: +49 441 99906-109
E-Mail: peter.wagner@next-energy.de

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DLR-Institut für Vernetzte Energiesysteme e. V.
E-Mail: p.wagner@dlr.de

Marc Secanell, PhD

Energy Systems Design Laboratory
(http://www.esdlab.mece.ualberta.ca/)
Department of Mechanical Engineering
University of Alberta
10-358 Donadeo Innovation Centre for Engineering,
9211-116 Street NW,
Edmonton, AB, Canada T6G 1H9
Phone: (780) 490 8808 (cell)
(780) 492-6961 (office)
E-mail: secanell@ualberta.ca

Duration stay: July 19-25, 2017

Re: Polymer electrolyte fuel cell characterization, testing and numerical analysis, modification of simulation tool OpenFCST for High Temperature PEM Fuel Cells

Introduction

I am the team leader of the Characterization Group at the DLR Institute of Networked Energy Systems (DLR VE, previously until 30.06.2017 as NEXT ENERGY). Our main foci are a) Investigation of degradation of High Temperature Polymer Electrolyte Fuel Cells (HT-PEM FC) to gain better insight into degradation paths and causes, for example on Membrane Electrode Assemblies (MEAs) and bipolar plates (BPP); b) development of long term stable materials for HT-PEM FCs like MEAs and BPP in cooperation with industry; c) further improvement of X-ray computer tomography as suitable instruments for Begin-of-Life and End-of-Life investigations on fuel cell components; d) Modelling lifetime of HT-PEM fuel cells with new approaches including the OpenFCST software package of Dr. Secanells group from the University of Alberta (UoA).

The aim of my visit to UoA was to establish a fruitful collaboration in the area of polymer electrolyte fuel cell numerical modelling and characterization with UoA and the nanoLAB characterization facility of the Mechanical Engineering Faculty. This collaboration includes the joint development of OpenFCST, an open-source fuel cell program developed at the University of Alberta, to extend its capabilities to include the analysis of high temperature polymer electrolyte membrane fuel cells (HT-PEM), a core area of research at our DLR institute. We also established collaboration on studying inkjet printing as a manufacturing method for high temperature electrodes, and the use of the characterization tools developed at the UoA to further understand transport in the materials used for high temperature fuel cells developed at DLR VE (NEXT ENERGY). Collaboration would include short visits, up to 3 months, of students and researchers for both contributing organizations.

As a first outcome of my visit, a student from my group – Julia Hülstede - is currently staying in Edmonton for an internship to manufacture and characterize Low Temperature and HT-PEM MEAs with new catalyst supports developed in Oldenburg. She is also evaluating some opportunities for her upcoming Master thesis, which could be a joint collaboration between UoA, University of Oldenburg and DLR VE.

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Research Undertaken

I spent three days at the Department of Mechanical Engineering at UoA. During this time, I toured the facilities and learned about the facilities and scientific groups including imaging, synthesis, characterization and testing tools at Dr. Secanells group as well as nanoFAB characterization facility. I also met several colleagues of Dr. Secanell as well as Dr. Eric Flaim being the director of the nanoLAB facility. I exchanged information with many researchers in their laboratories.

The first day of my visit, I also delivered a seminar to Dr. Secanells research team introducing the main experimental and numerical activities with regard to HT-PEM fuel cells in my group. This included a detailed introduction into HT-PEM MEA degradation under various operation conditions like load cycling, constant load operation etc. I also received a detailed insight into the current work of Dr. Secanells PhD and Master students and advised some of them on issues with regard the electrochemical characterization in fuel cell test benches and evaluation of data.

Based on our discussions, a future collaborative plan was developed to extend OpenFCST to high temperature fuel cells, assess the potential for inkjet printing for fabrication of high temperature fuel cell catalyst coated membranes, and to design a framework for graduate student visits within the IPID4all DAAD program or other funding schemes.

The following three main target areas were identified:

- Study of crack formation during testing in LT-PEM inkjet printed and doctor bladed MEAs
    - Goal: To study the structure of the GDL materials from ESDLab at beginning of life with μ-CT to obtain parameters like porosity, tortuosity and others as experimental input values to Open FCST.
    - Methodology: Investigation of ESDLab prepared 25 cm^2 MEAs by inkjet and doctor blade, as well as conditioning and testing protocol. DLR VE will use one of the MEAs for imaging the structure at beginning of life, and another one for testing and then imaging at end of life. (One extra MEA as backup)
    - Expected outcome: Determine if the fabrication method used prevents the development of cracks during testing. Better understanding of inkjet printed electrode degradation.
- HT-PEM CCMs:
    - Goal: Assess the feasibility of fabricating HT-PEM CCMs by inkjet printing
    - Methodology: Use the PBI membrane (not doped) that DLR VE has provided to UoA. Print a 25 cm^2 CL with 40%wt Pt/C catalyst to a loading of about 0.2 mg/cm^2 with 20%wt Nafion in both anode and cathode. DLR VE will assess performance.
    - Expected outcome: Assess the feasibility of using CCMs for HT-PEM.
- Modelling of HT-PEM:
    - Goal: Develop a HT-PEM model in OpenFCST
    - Methodology: Gas transport, reactions, etc. models are already developed. The main goal will be to develop a model for proton transport in PBI membranes and for phosphoric acid migration inside the MEA. DLR VE is providing experimental data.
    - Expected outcome: Extend OpenFCST to HT-PEM. Use OpenFCST to provide insight on the optimal operating conditions and composition of HT-PEM electrodes.

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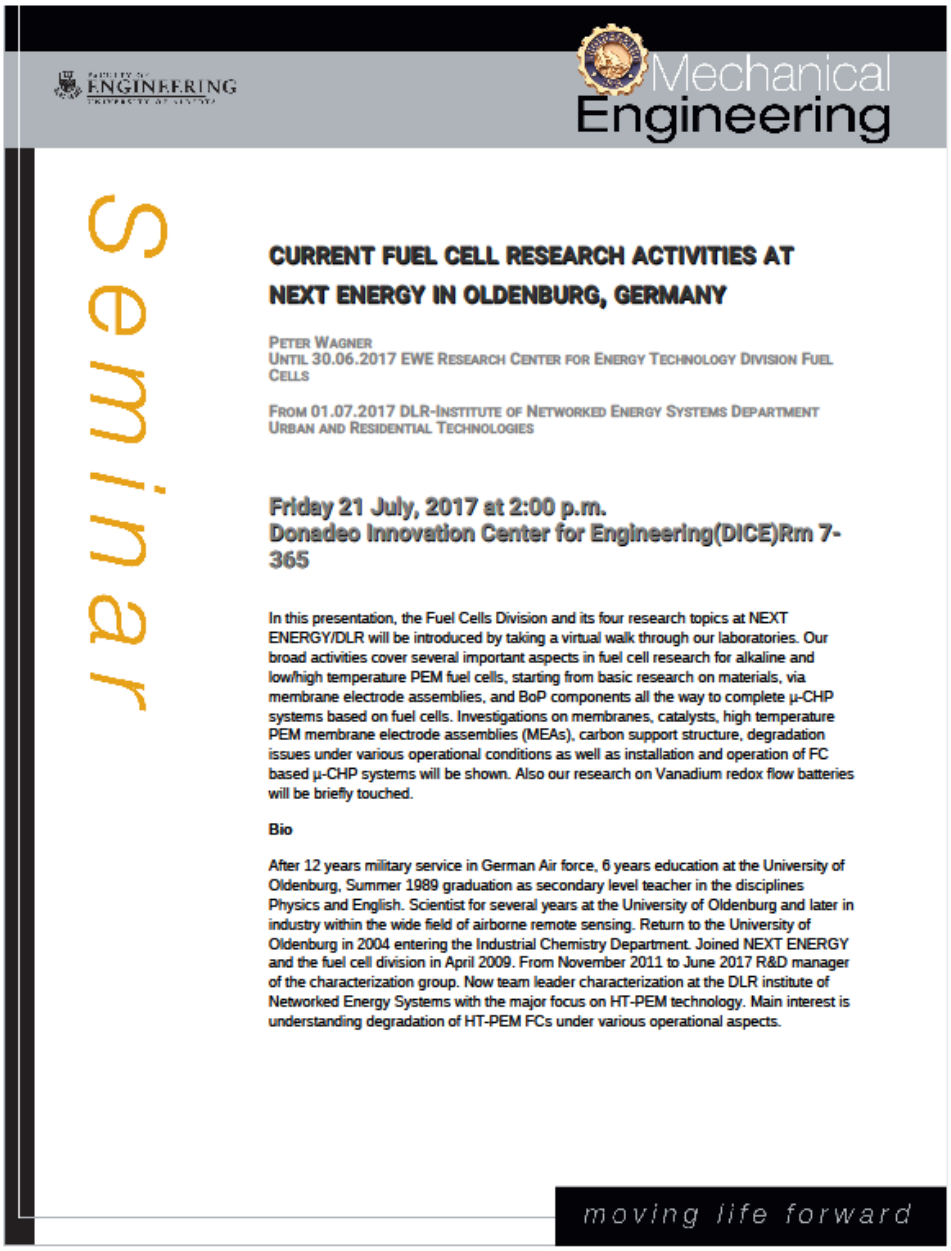
On the second day of my visit I delivered a presentation to the Department of Mechanical Engineering, introducing the fuel cell research activities at DLR VE in Oldenburg.



ENGINEERING

Mechanical Engineering

Seminar

CURRENT FUEL CELL RESEARCH ACTIVITIES AT NEXT ENERGY IN OLDENBURG, GERMANY

PETER WAGNER
UNTIL 30.06.2017 EWE RESEARCH CENTER FOR ENERGY TECHNOLOGY DIVISION FUEL CELLS

FROM 01.07.2017 DLR-INSTITUTE OF NETWORKED ENERGY SYSTEMS DEPARTMENT URBAN AND RESIDENTIAL TECHNOLOGIES

Friday 21 July, 2017 at 2:00 p.m.
Donadeo Innovation Center for Engineering(DICE)Rm 7-365

In this presentation, the Fuel Cells Division and its four research topics at NEXT ENERGY/DLR will be introduced by taking a virtual walk through our laboratories. Our broad activities cover several important aspects in fuel cell research for alkaline and low/high temperature PEM fuel cells, starting from basic research on materials, via membrane electrode assemblies, and BoP components all the way to complete µ-CHP systems based on fuel cells. Investigations on membranes, catalysts, high temperature PEM membrane electrode assemblies (MEAs), carbon support structure, degradation issues under various operational conditions as well as installation and operation of FC based µ-CHP systems will be shown. Also our research on Vanadium redox flow batteries will be briefly touched.

Bio

After 12 years military service in German Air force, 6 years education at the University of Oldenburg, Summer 1989 graduation as secondary level teacher in the disciplines Physics and English. Scientist for several years at the University of Oldenburg and later in industry within the wide field of airborne remote sensing. Return to the University of Oldenburg in 2004 entering the Industrial Chemistry Department. Joined NEXT ENERGY and the fuel cell division in April 2009. From November 2011 to June 2017 R&D manager of the characterization group. Now team leader characterization at the DLR institute of Networked Energy Systems with the major focus on HT-PEM technology. Main interest is understanding degradation of HT-PEM FCs under various operational aspects.

moving life forward

On the third day of my visit I had personal talks again with students and Dr. Secanell discussing possible options for research visits at our institute in the future. We also organized the stay of my student Julia Hülstede at UoA as an intern at UoA and discussed option of possible subjects of her upcoming Master thesis.

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Personal Experience
The visit to the University of Alberta was absolutely helpful, very informative and especially for discussing our further collaboration in the improvement of OpenFCST definitely necessary. The opportunity to discuss many issues with the developers of the software directly was another reason to travel to Canada.
I was able to intensify the mutual understanding and good collaboration between both groups so that many plans for future joint projects have be made. Most impressive for me was the lab tour through the faculty and the nanoFAB facility which has all state-of-the-art characterization instruments under one roof.
During and after the seminars, I had the opportunity to discuss several issues with students directly and gained a good insight into their current research work. This allowed us to agree on further student exchanges. These interactions I think were important to attract graduate students from UoA to work in Germany as part of their academic education. Proof of the benefit of these interactions is that Khrystyna Yezerska is likely to apply for a research exchange next year.

Conclusions
I am convinced that the IPID4all program is one of the best programs to increase international collaboration. Having had the opportunity to spend three days at UoA, touring the facilities and talking to researchers as well as students gave me a very unique perspective that I do not think I could have achieved through teleconferencing. My visit set the starting point for future collaboration between both research institutions.

Outlook
As discussed in section “Research Undertaken” three areas of collaboration have been identified. My group is keen on working in these three areas with Dr. Secanell. Thus far, my student Julia Hülstede is already currently staying in Canada on an internship, manufacturing and characterizing MEAs with catalysts synthesised here in Oldenburg.
We also already established collaboration on µ-CT measurements with fuel cell materials provided by Dr. Secanell as preparation for a future joint publication.
Regarding goal 3, a PhD student in my group - Khrystyna Yezerska, has already started to work with OpenFCST and is likely to visit the University of Alberta in 2018 to obtain assistance in developing the necessary extensions to OpenFCST to simulate HT-PEM fuel cells.

Acknowledgement
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DAAD

Federal Ministry
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and Research