Swiss Competence Center for Energy Research
Efficient Technologies and Systems for Mobility

In cooperation with the CTI
Energy funding programme
Swiss Competence Centers for Energy Research
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Swiss Confederation
Commission for Technology and Innovation CTI

Neutron imaging characterization of a Polymer Electrolyte Fuel Cell (PEFC) with evaporative cooling

Our project aims at developing a system of evaporation cooling for PEFC, using modified Gas Diffusion Layers (GDL). These GDLs, developed at PSI, alternate hydrophilic and hydrophobic regions, allowing for separate transport of the liquid water intended for evaporation and humidification on one hand, and the reacting gases on the other hand. In order to characterize the heat transfers in the cell, a thermal test bench was built. Neutron Imaging was used to characterize the water management. Our results show a good segregation of water and gases in the GDLs, a good humidification, reasonable performances as well as a potential cooling power of around 1W/cm².

M. Cochet, A. Forner-Cuenca, D. Scheuble, V. Manzi-Orezzoli, P. Boillat
Electrochemistry *Laboratory , Paul Scherrer Institut, CH-5232 Villigen,Switzerland*
Contact: magali.cochet@psi.ch

Introduction

- Cooling and humidification of PEFCs are required to avoid drying the membrane and stopping the reaction
- A new concept is developed at PSI[1,2] to both cool down and humidify simultaneously.

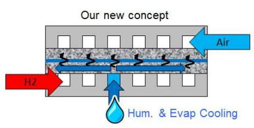

Fig. 1: Scheme of the evaporation cooling concept of PSI

- Liquid water is brought in the fuel cell itself through channels in the anode flowfields.
- It is pushed into the GDL and evaporates there
- Since GDLs are hydrophobic porous media, new GDLs are required

GDL with patterned wettability

- A synthetic method developed at PSI[1,2] turns a GDL into a succession of hydrophobic/hydrophilic layers
- Water is pumped by capillarity into the hydrophilic sections even at negative capillary pressures[4]
- With a FEP coating of 70%, the hydrophobic zones are free of liquid up to a capillary pressure of 20*mbars*

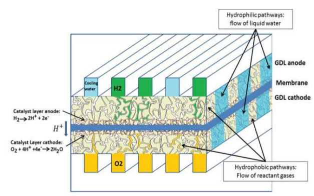

Fig. 2: Modified GDLs in a PEFC with evaporation cooling

- Separate pathways for gases and for liquid water are well defined

Thermal test cell

- A thermal test cell is built to charaterize heat transfers within the cell

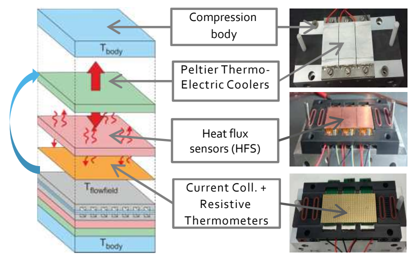

Fig. 3: Thermal test cell

- Measured heat fluxes are corrected for losses:

$$\phi_a = \phi_{HFS\ An2} - \phi_{losses\ anode}$$
$$\phi_c = \phi_{HFS\ Ca2} - \phi_{losses\ cathode}$$

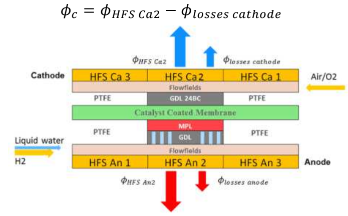

Fig 4: Processing of the heat fluxes

Neutron Imaging of water in the PEFC

- Neutron beams are transmitted by dense materials such as metals, but absorbed by water.
  - Perfect tool to visualize water in a PEFC

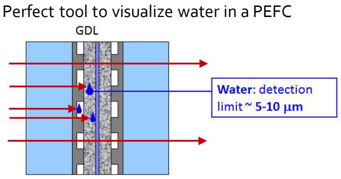

Fig 5: Principle of Neutron Imaging

- Neutron Imaging shows clearly the cooling water channels, the filling hydrophilic lines in the GDL..

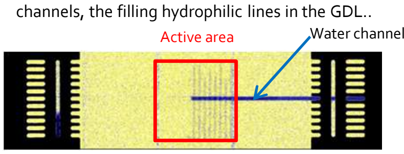

Fig 6: Neutron Imaging of the water in the PEFC

- Lines filled quickly, despite strong evaporation rates
- At 80°C, 1 liquid channel is enough to sustain high evaporation rates

Performances and cooling power

- Polarization curves at T=80°C with dry gases

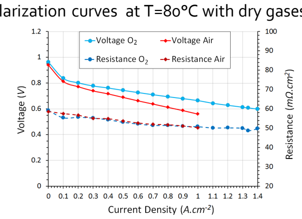

Fig 7: Voltage and resistance versus current density

- Reasonable performances for air and O_2
- Resistance close to the optimal value for the membrane: **Good humidification**

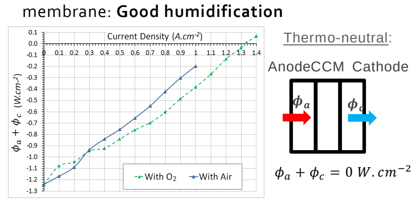

Fig. 8: Cooling power versus current density

- Evaporation cooling compensates heat losses up to: $\begin{cases} i = 1.32\ A.cm^{-2} \text{ for } O_2 \\ i \approx 1.2\ A.cm^{-2} \text{ for Air} \end{cases}$

Expected Impact

The expected impacts include:

- less complex and more compact PEFC stacks
- increased volumetric energy density
- a reduction of costs

All of these would help make the commercial use of PEFCs in automotive applications more attractive.

Additionally, the results provided by the test cell will help validate numerical models developed for fuel cells[3].

References

[1] P. Boillat, et al., *European Patent Application*, EP14184065.2 (2014)
[2] A. Forner-Cuenca et al., Engineered Water Highways in Fuel Cells: Radiation Grafting of Gas Diffusion Layers, Advanced Materials, 27, 41, 6317-6322, (2015).
[3] J. Dujc et al., Modelling the Effects of using Gas Diffusion Layers with Patterned Wettability for Advanced Water Management in PEFCs, Journal of Electrochemical Energy Conversion and Storage, Submitted 2016.
[4] A. Forner-Cuenca et al., J. Electrochem. Soc. 2016 163(9): F1038-F1048

Partners

Paul Scherrer Institute

ICP Institute of Computational Physics