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Neutron imaging characterization of water and heat transport in a evaporative cooled fuel cell

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Motivation

- Polymer electrolyte fuel cells (PEFC) generate electricity by converting hydrogen and oxygen into water.
- As a by-product of the chemical reaction, heat can damage the PEFC. Increased temperatures can indeed dry out the membrane and stop the reaction.
- A new concept is developed at PSI which would both cool down more efficiently, and reduce complexity and volume of the stack.[1]

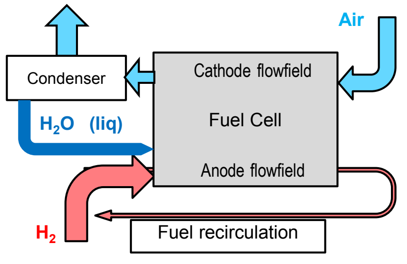

Fig 1: Principle of the evaporation cooling fuel cell stack

- Cooling is managed by bringing liquid water in the fuel cell itself through channels on the anode side, parallel to the hydrogen channels.
- Water is pumped by capillarity pressure towards the membrane by modified Gas Diffusion Layers (GDL).
- Water evaporates in the cell, providing the cooling effect.

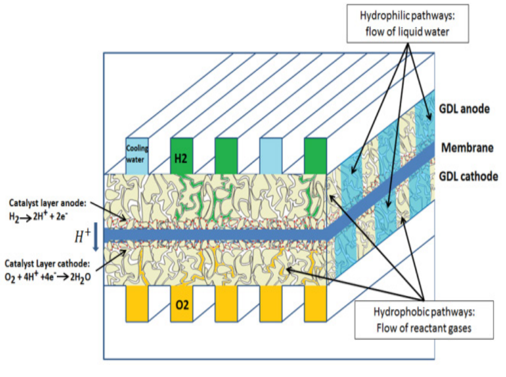

Fig 2: Water and gases transport in modified GLDs pattented by PSI

- GDLs need to transport liquid water and reactant gases separately to avoid flooding.
- A synthetic method developed at PSI turns a classic GDL into a succession of hydrophobic and hydrophilic layers, defining separate pathways for gases and liquid water.[1,2]

Thermal Test Cell design

- Test bench thermal boundary conditions must be representative of a fuel cell stack.
- In a fuel cell stack, between 2 cells, heat fluxes are opposite:
  $$\vec{\varphi}_{anode_i-cathode_{i+1}} = -\vec{\varphi}_{cathode_{i+1}-anode_i}$$
- Assuming equal temperature distributions:
  $$\vec{\varphi}_{anode-cathode} = -\vec{\varphi}_{cathode-anode} = -\lambda_{flowfields}\cdot\vec{\nabla}T_{anode-cathode}$$
- In a classical test bench, compression body's temperature kept constant. Therefore, the heat fluxes from cell towards body not representative of stack conditions
- Measurements of the flow field's temperature ($T_{flowfields\ anode}$ and $T_{flowfields\ cathode}$) and heat fluxes $\varphi_{flowfield-body}$
- Peltier thermoelectric coolers create heat flux in the opposite direction $\varphi_{Peltier}$
  $$\varphi_{total} = \varphi_{anode-body} - \varphi_{Peltier} = -\lambda.\frac{\Delta T_{flowfields\ anode-cathode}}{\delta_{flowfield}}$$

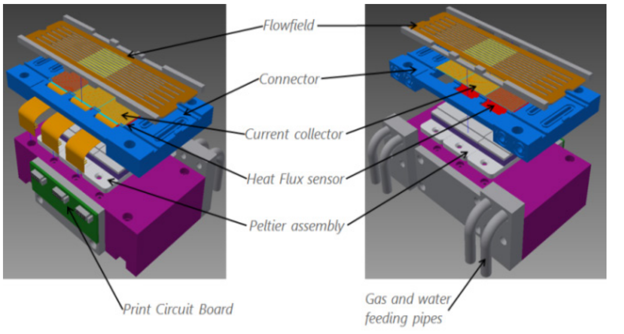

Fig 3: Design of the thermal test bench

Pattern wettability: Neutron Radiography of a GDL

- Water was injected via a rectangular channel in perpendicular direction to the hydrophilic lines (500 µm width, spaced 1 mm).
- Capillary pressure values were set by controlling the water pressure (height of an elevated tank) and neutron radiography was performed (*through-plane*).
- Lateral transport of water was captured at low capillary pressured (10 mbar).
- Line width broadening was captured at higher pressures.

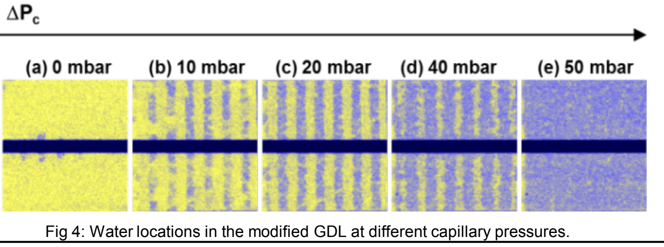

Fig 4: Water locations in the modified GDL at different capillary pressures.

Conclusions and outlook

- A thermal test bench has been designed and built in order to prove the principle of evaporative cooling…
- Modified GDLs with patterned wettability have been developed and characterized with capillary pressure-saturation combined with neutron radiography.
- Optimization of the material synthesis and injection strategy will be carried out.

Acknowledgement

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References

[1] P. Boillat, et al., *European Patent Application*, EP14184065.2 (2014)
[2] A. Forner-Cuenca, et al., *Advanced Materials*, under review (2015)