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Multiphysical simulation of a low temperature PEM fuel cell

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https://hydrogeneurope.eu/

What do we simulate?

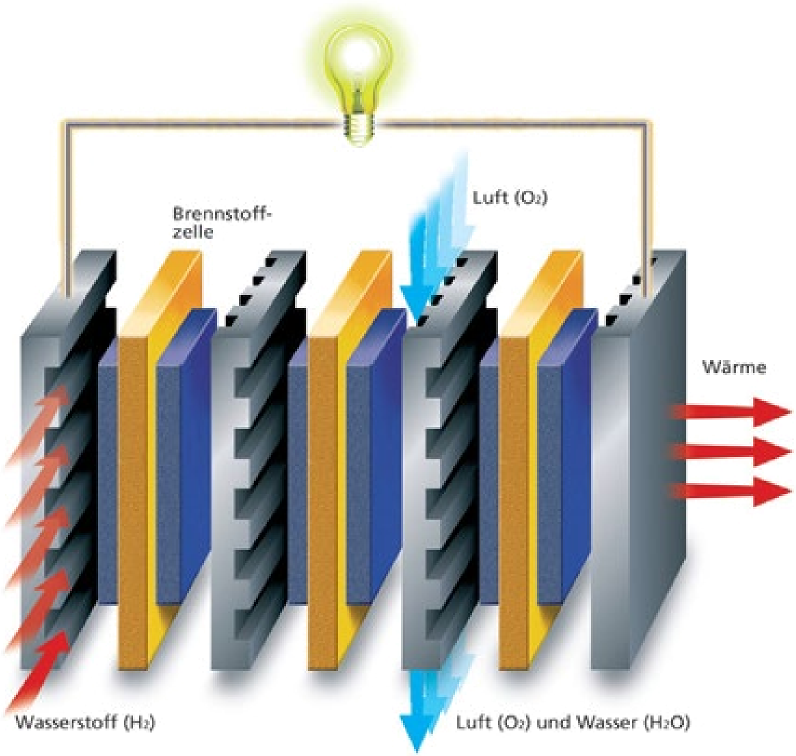

Bild: Wikipedia

$$H_2 \rightarrow 2H^+ + 2e^-$$

$$\frac{1}{2}O_2 + 2H^+ + 2e^- \rightarrow H_2O$$

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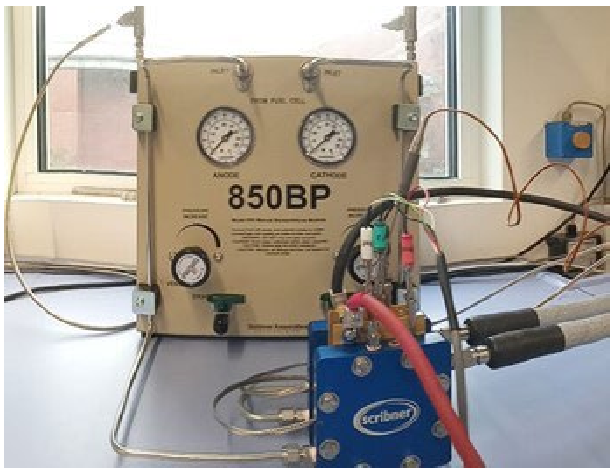
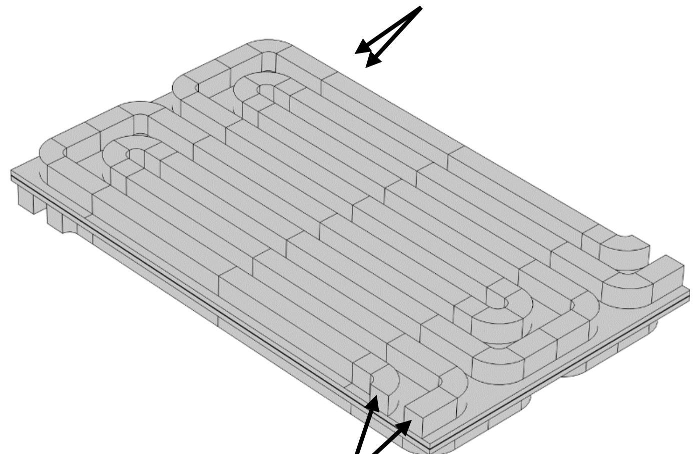
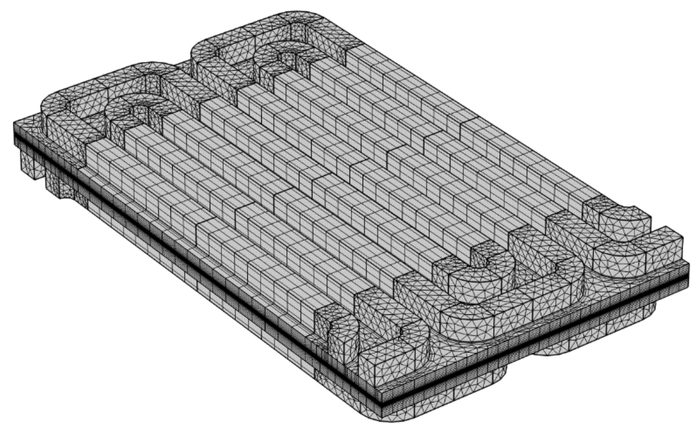
Experiment and modell







DOF: ~340.000

Relevant equations (solved in a coupled way)

- Electrical current flow density:

$$\vec{i} = -\sigma_{eff} * \nabla\Phi$$

- Computational Fluid Dynamics:

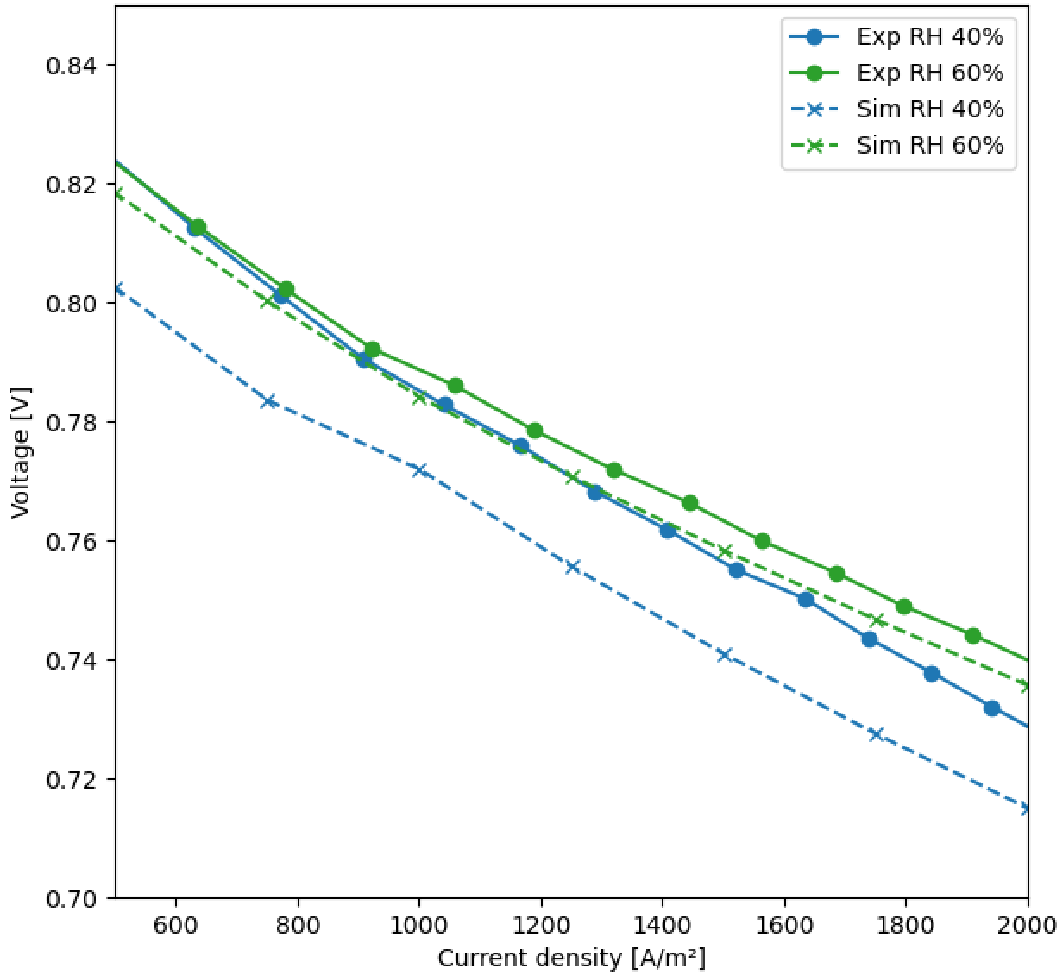
$$\vec{u} = -\frac{\kappa}{\mu}\nabla p \text{ (Darcys law)}$$

$$\frac{\partial}{\partial t}(\rho\epsilon_p) + \nabla \cdot (\rho\vec{u}) = Q_m \text{ (Continuity eq.)}$$

- Chemical reactions:

$$E_{eq} = E_{eq,ref}(T) - \frac{RT}{nF} \cdot ln \prod_i \left(\frac{p_i}{p_{ref}}\right)^{v_i} \text{ (Nernst eq.)}$$

U-I-Characteristic: Simulation and Experiment



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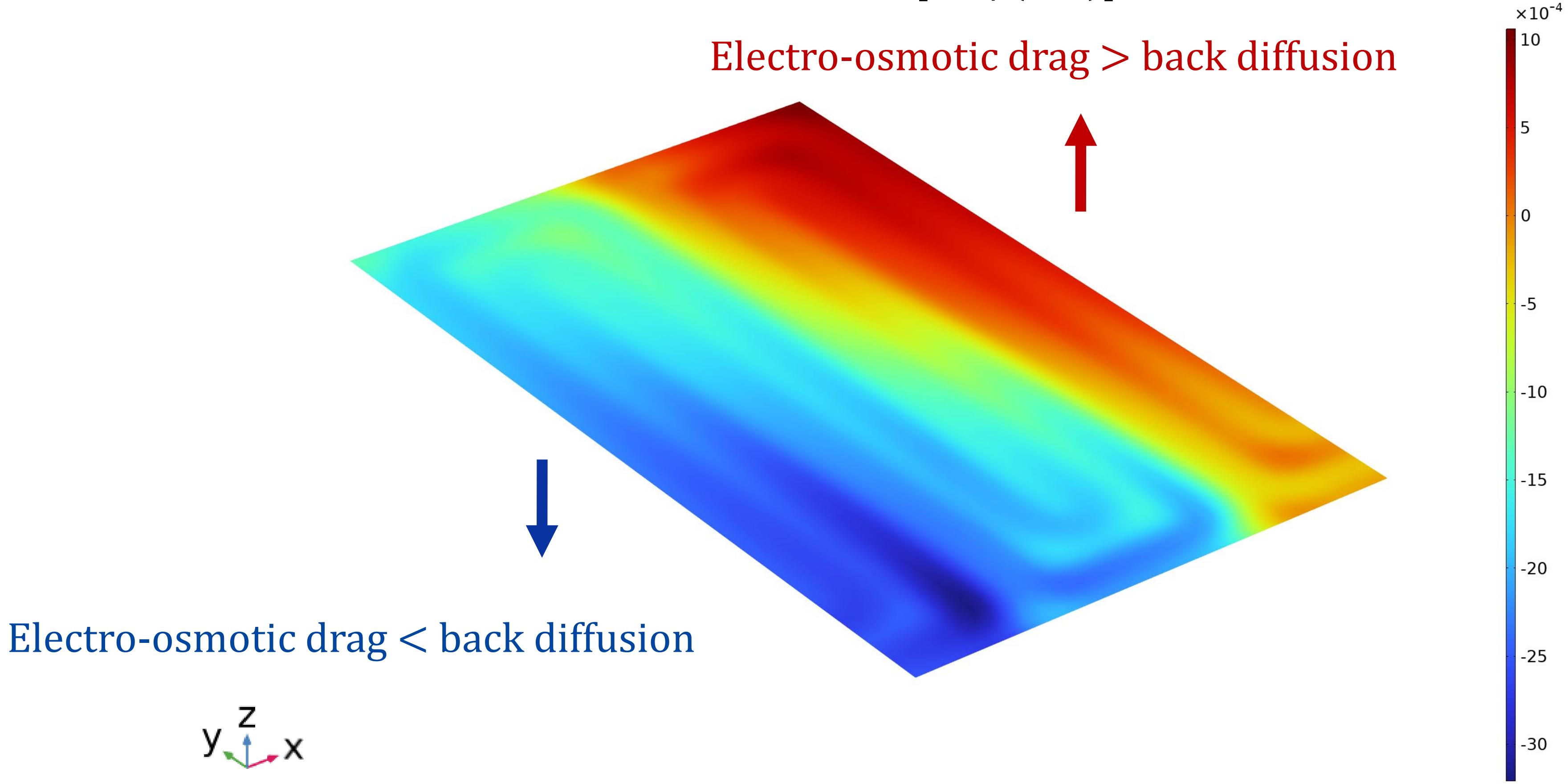
H_2O flow

Molar Mass Flow Rate [mol/(m²s)]



Terminology from K.-H. Choi, D.-H. Peck, C.S. Kim, D.-R. Shin, T.-H. Lee, J. Power Sources, 86 (2000), pp. 197-201

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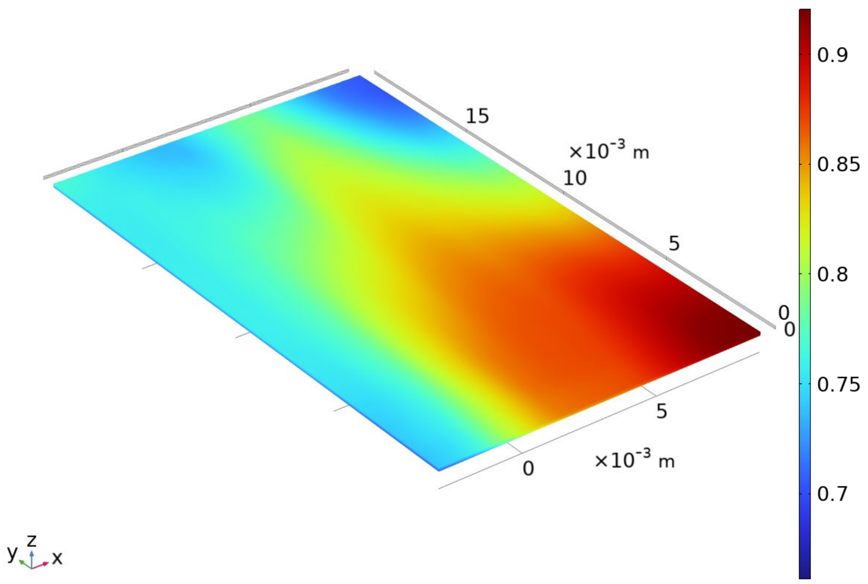
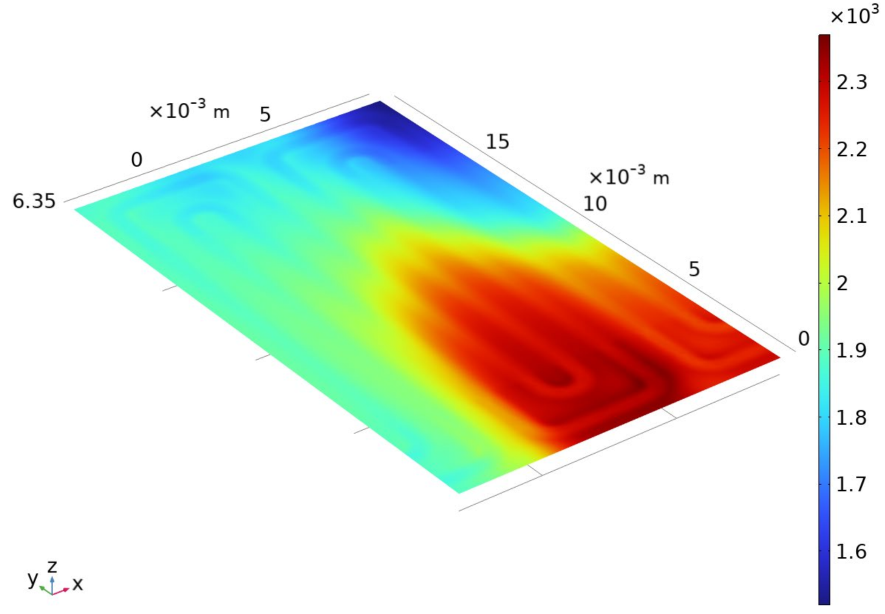
Membrane humidity and current density distribution

Relative Humidity



Current density [A/m²]



As expected: higher humidity results in a better conductivity and thus a higher current density.

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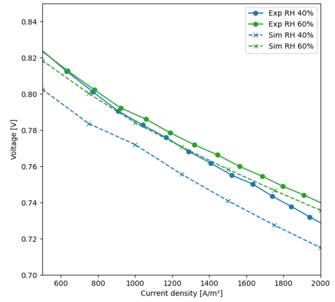
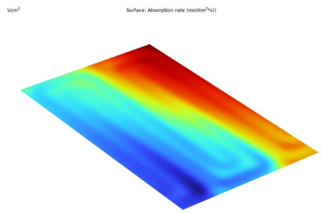
Conclusion & Outlook



- Successful comparison between experimental and simulative u-i-characteristic curves



- Investigation of water flow and humidity within the membrane and its impact on current density

?

- Improved CFD (Navier Stokes- and Brinkmann-equations)
- „Additional physics“:
  Temperature field
  Multiphase simulation (water condensation)

Thank you for your attention!

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