

Multiphysical simulation of a low temperature PEM fuel cell

Fabian Gumpert¹, Lara Kefer¹, Susanne Thiel²,
Maik Eichelbaum², and Jan Lohbreier¹

¹Technische Hochschule Nürnberg, Applied
Mathematics, Physics and Humanities, Germany

²Technische Hochschule
Nürnberg, Applied Chemistry, Germany



The banner features a teal background with a network of hexagonal nodes and lines. In the center, the word "H2ero" is written in white with a circular outline, and "Net Zero" is written in a larger, bold white font next to it. Below this, the text "Propelling global carbon neutrality by accelerating the European hydrogen industry" is displayed. A central graphic shows a white figure in a dynamic pose, wearing a cape with a green "G" and a blue "H2" logo. Two dark teal call-to-action buttons at the bottom left and right encourage users to visit the Hydrogen Europe and Hydrogen Europe Research websites.

H2ero Net Zero

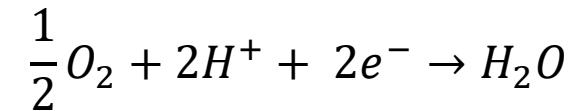
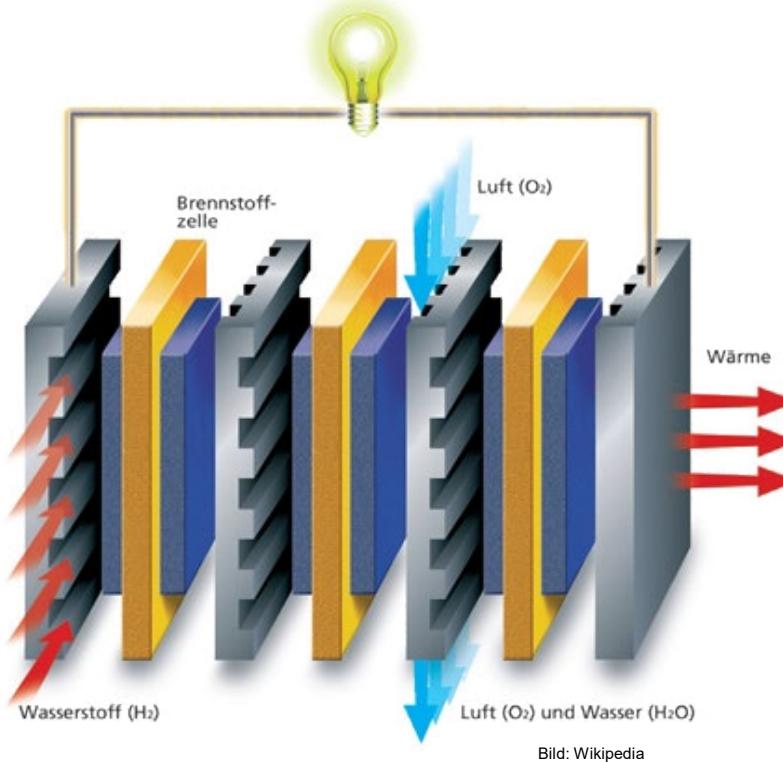
Propelling global carbon neutrality by accelerating the European hydrogen industry

 HYDROGEN EUROPE

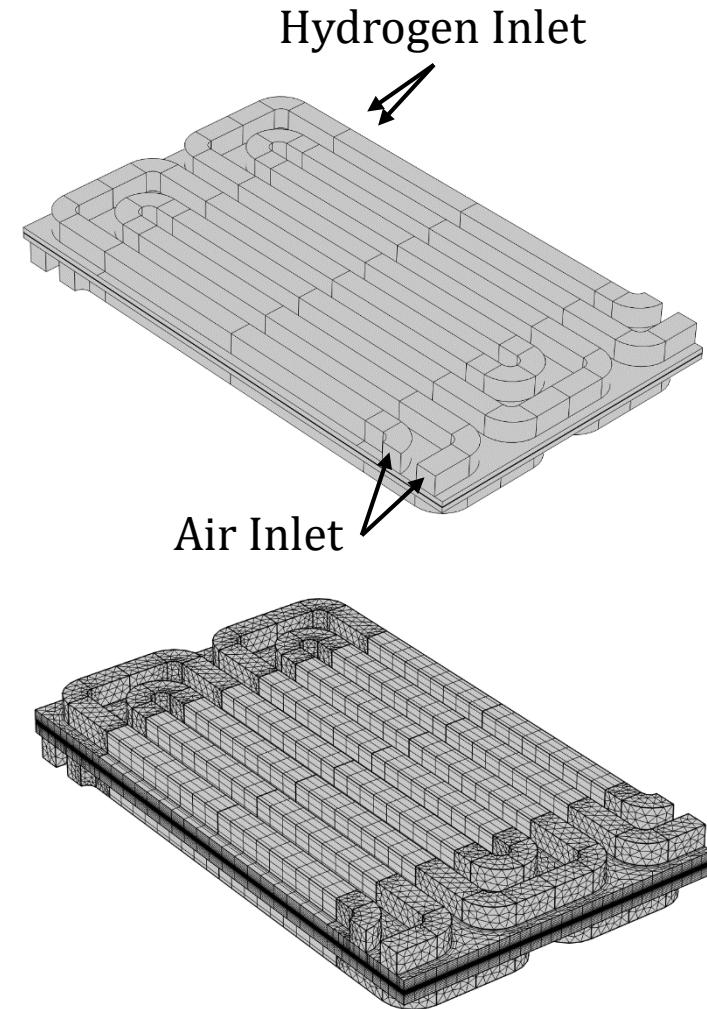
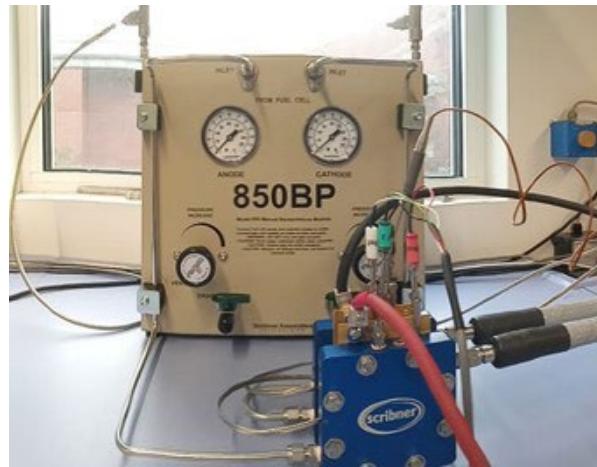
 HYDROGEN EUROPE RESEARCH

<https://hydrogogeneurope.eu/>

What do we simulate?



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:

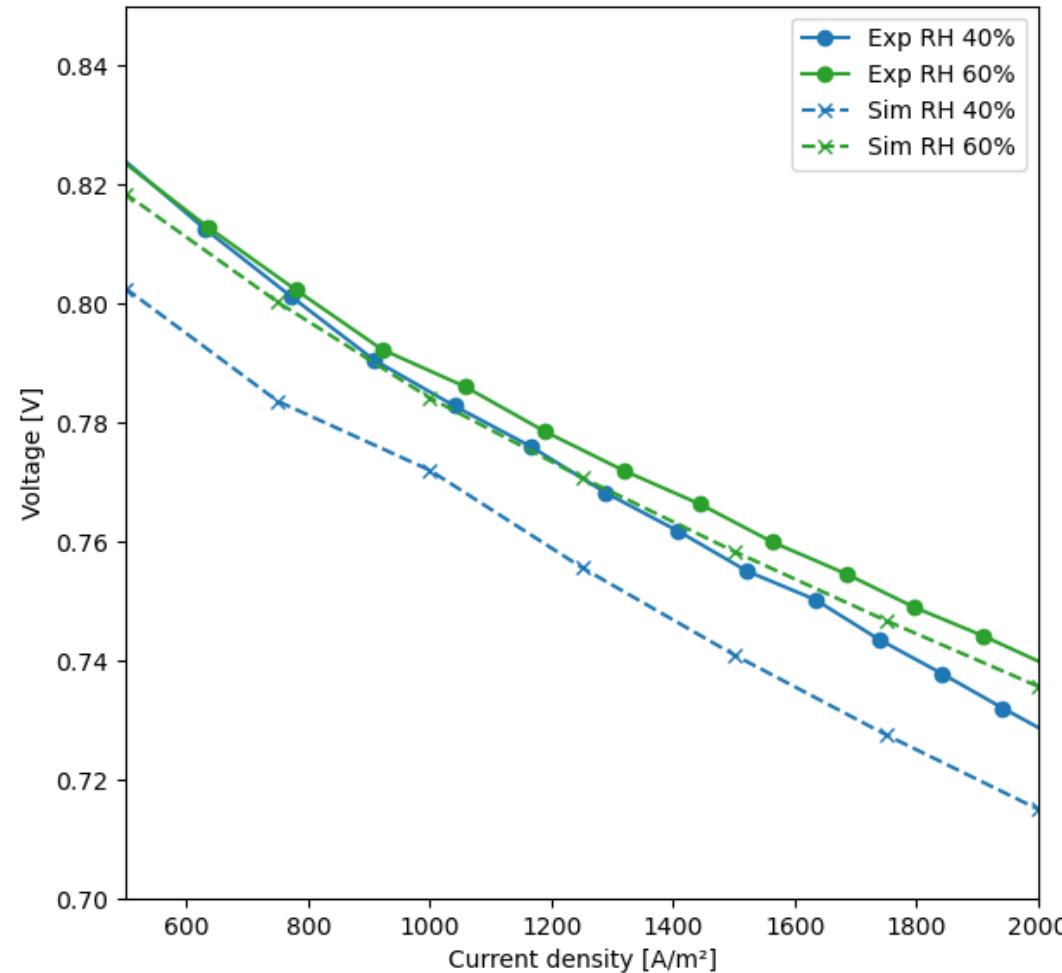
$$\vec{u} = -\frac{\kappa}{\mu} \nabla p \text{ (Darcys law)}$$

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

- Chemical reactions:

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

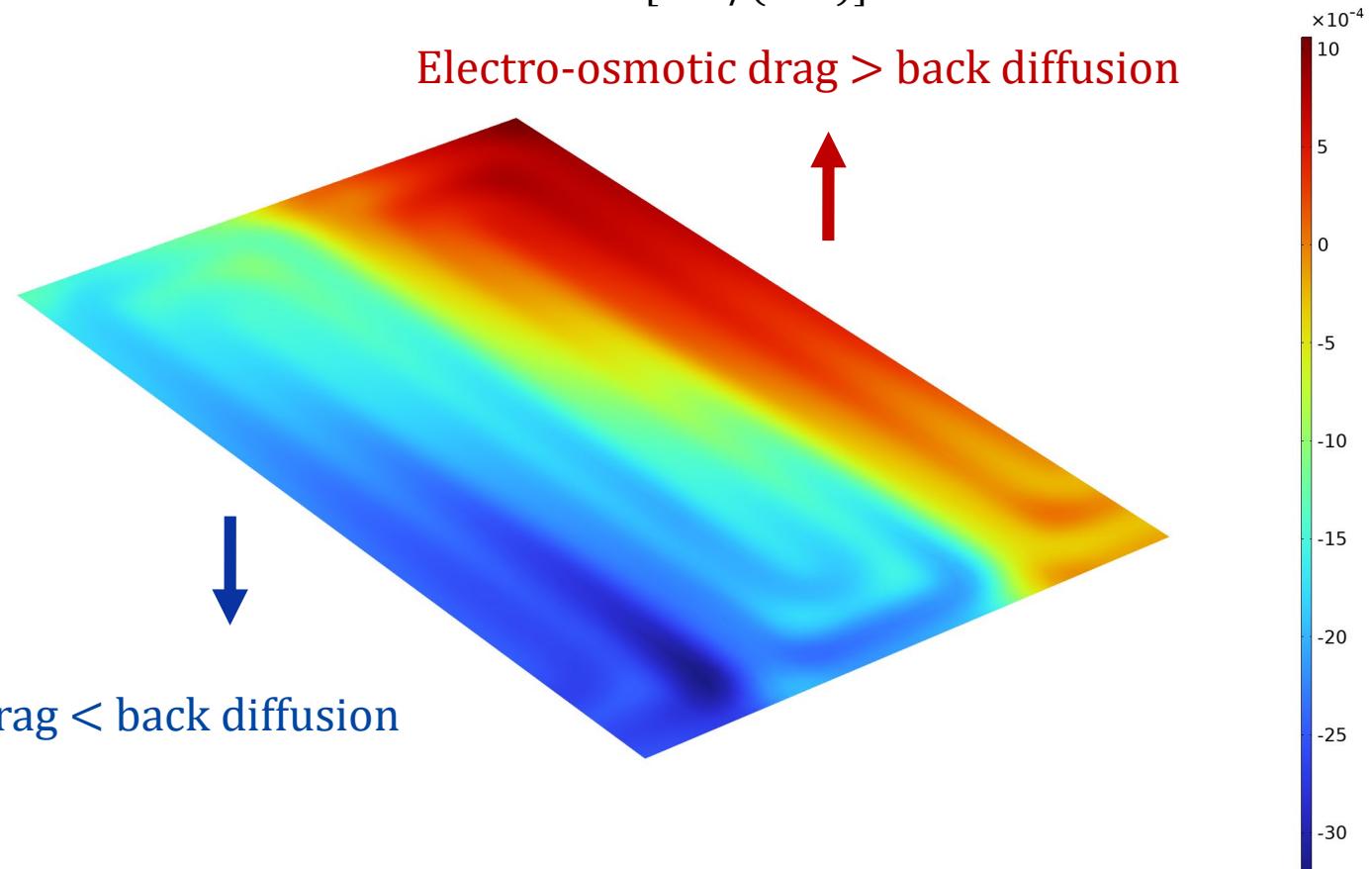
U-I-Characteristic: Simulation and Experiment



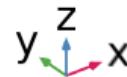
H₂O flow

Molar Mass Flow Rate [mol/(m²s)]

Electro-osmotic drag > back diffusion

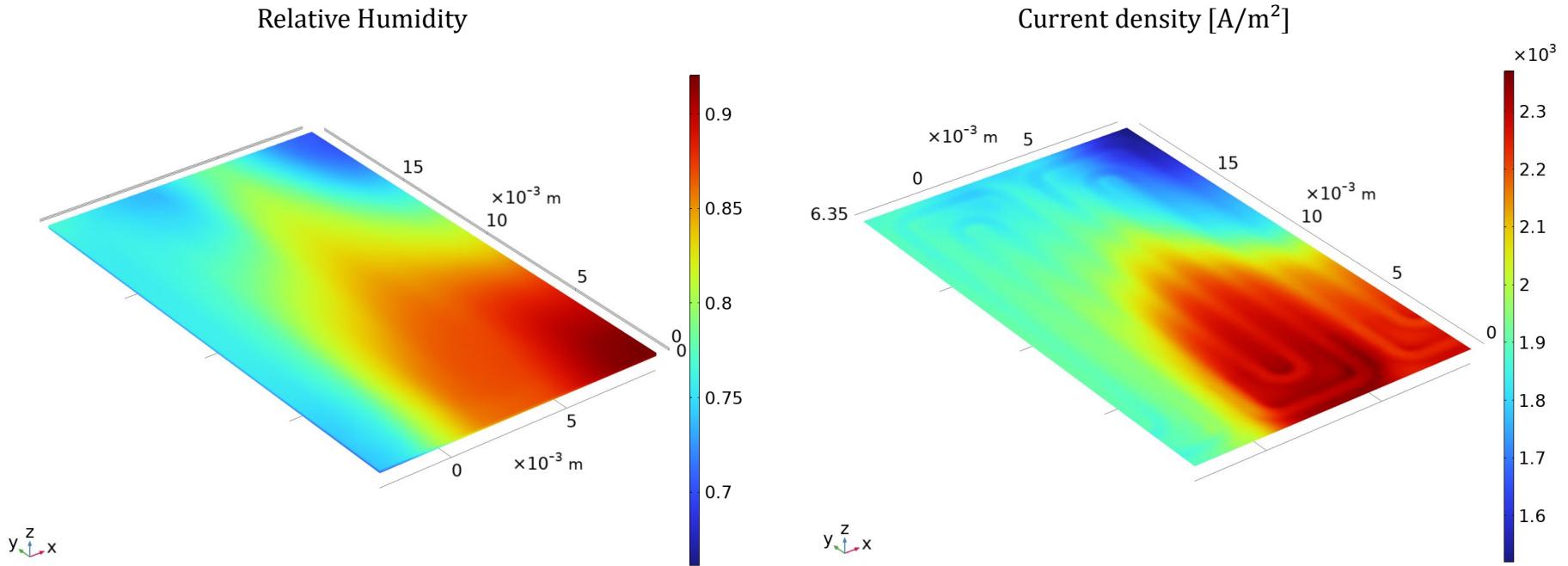


Electro-osmotic drag < back diffusion



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

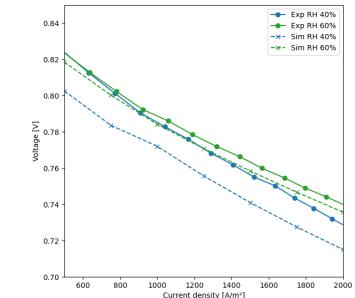
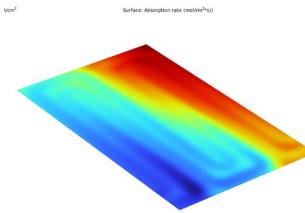
Membrane humidity and current density distribution



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

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!

Prof. Jan Lohbreier
jan.lohbreier@th-nuernberg.de

Fabian Gumpert
fabian.gumpert@th-nuernberg.de