//EU HYDROGEN RESEARCH DAYS
15-16 NOVEMBER

CAMELOT

Understanding Charge, Mass, and Heat Transfer in Fuel Cells for Transport Applications

Patrick Fortin

SINTEF AS

www.camelot-fuelcell.eu

patrick.fortin@sintef.no

Clean Hydrogen Partnership

European Hydrogen Week

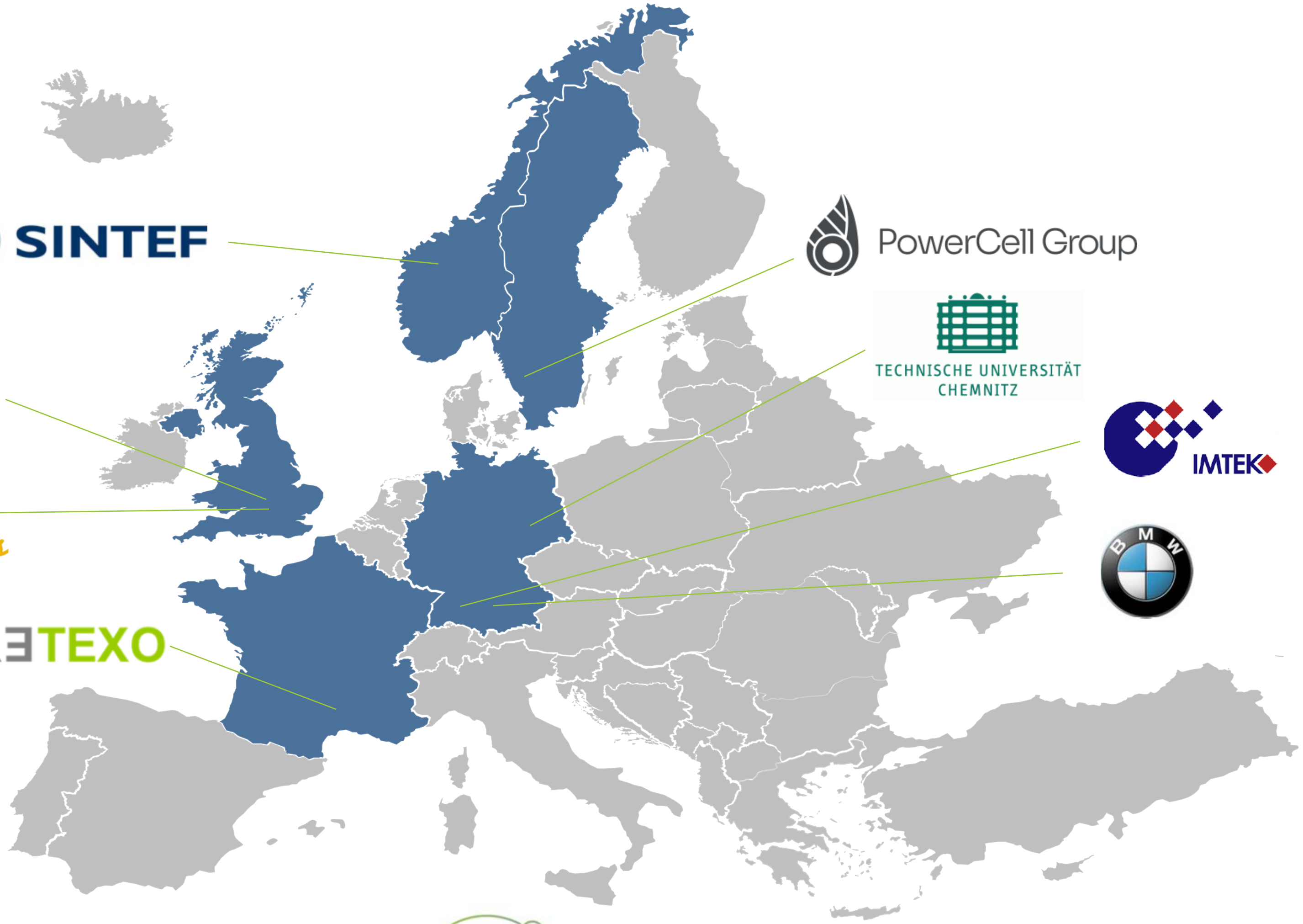
Co-funded by the European Union

Project Overview

- Call year: 2020
- Call topic: FCH-01-4-2019 - Towards a better understanding of charge, mass and heat transports in new generation PEMFC MEA for automotive applications
- Project dates: January 1, 2020 – December 31, 2023
- % stage of implementation 01/11/2023: 95 %
- Total project budget: 2 295 783.50 €
- Clean Hydrogen Partnership max. contribution: 2 295 783.50 €
- Other financial contribution: -
- Partners: SINTEF AS, Johnson Matthey Fuel Cells Ltd, Chemnitz University of Technology, BMW, University of Freiburg IMTEK, PRETEXO, Fast Simulations UG, Powercell Sweden AB

//EU HYDROGEN
RESEARCH DAYS
15-16 NOVEMBER

Project Partners



SINTEF

Johnson Matthey
Inspiring science, enhancing life

FAST Simulations

PRETEXO

PowerCell Group

TECHNISCHE UNIVERSITÄT CHEMNITZ

IMTEK

BMW

Clean Hydrogen Partnership

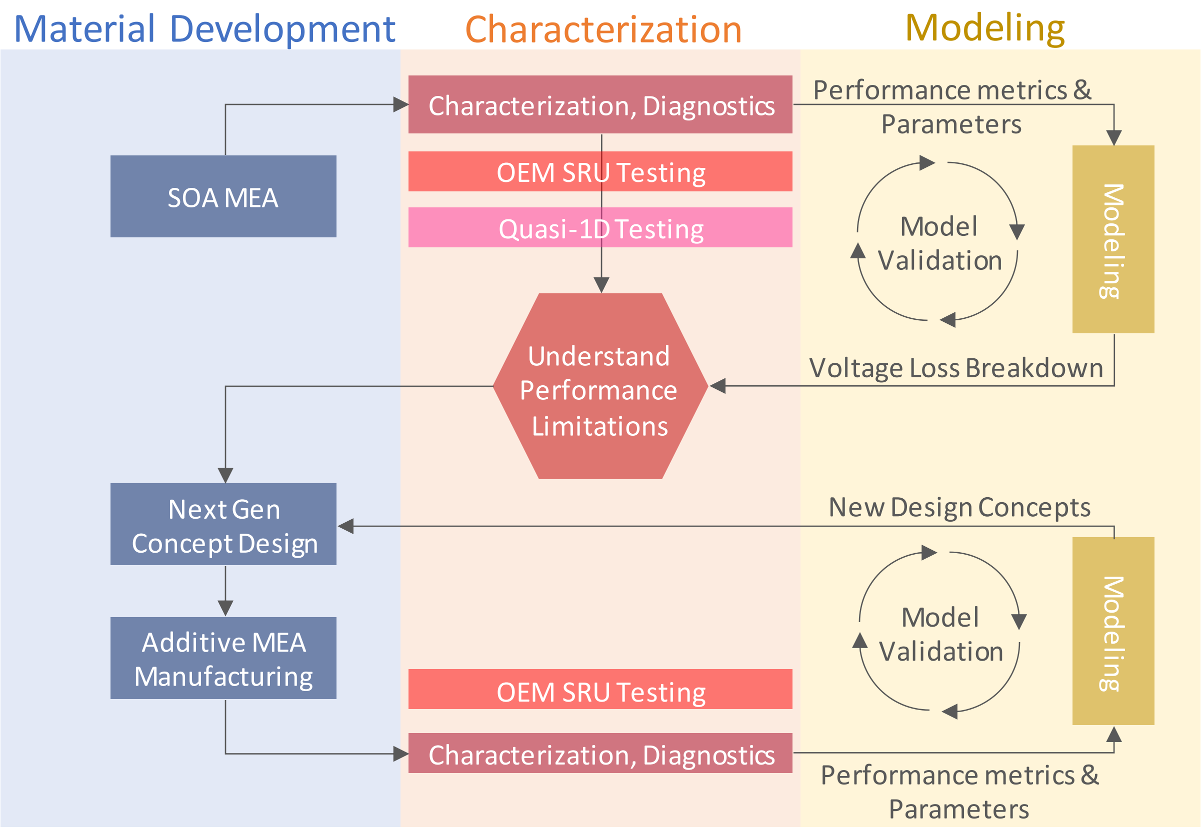
European Hydrogen Week

Co-funded by the European Union

Project Summary

Objectives

- Improve the power density of fuel cells by understanding the performance limitations of MEAs
- Diagnose the fundamental transport properties that limit performance in SoA and prototype MEAs
- Extend a leading open-source model to enable the accurate simulation of SoA MEAs using automotive SRU hardware
- Produce MEAs with features that have the potential to enable disruptive performance increases and to validate the open-source model for beyond-SoA MEAs
- Propose new beyond-SoA MEA designs in automotive SRU geometries that address SoA performance limitations and provide simulation tools that guide rational development of new MEA concepts

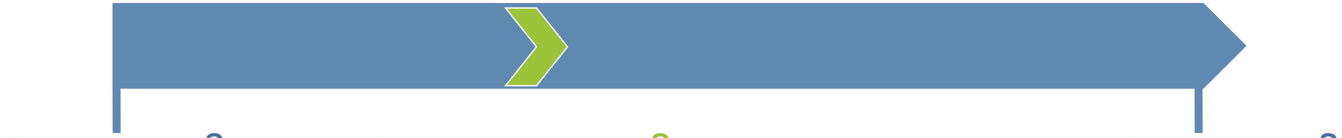


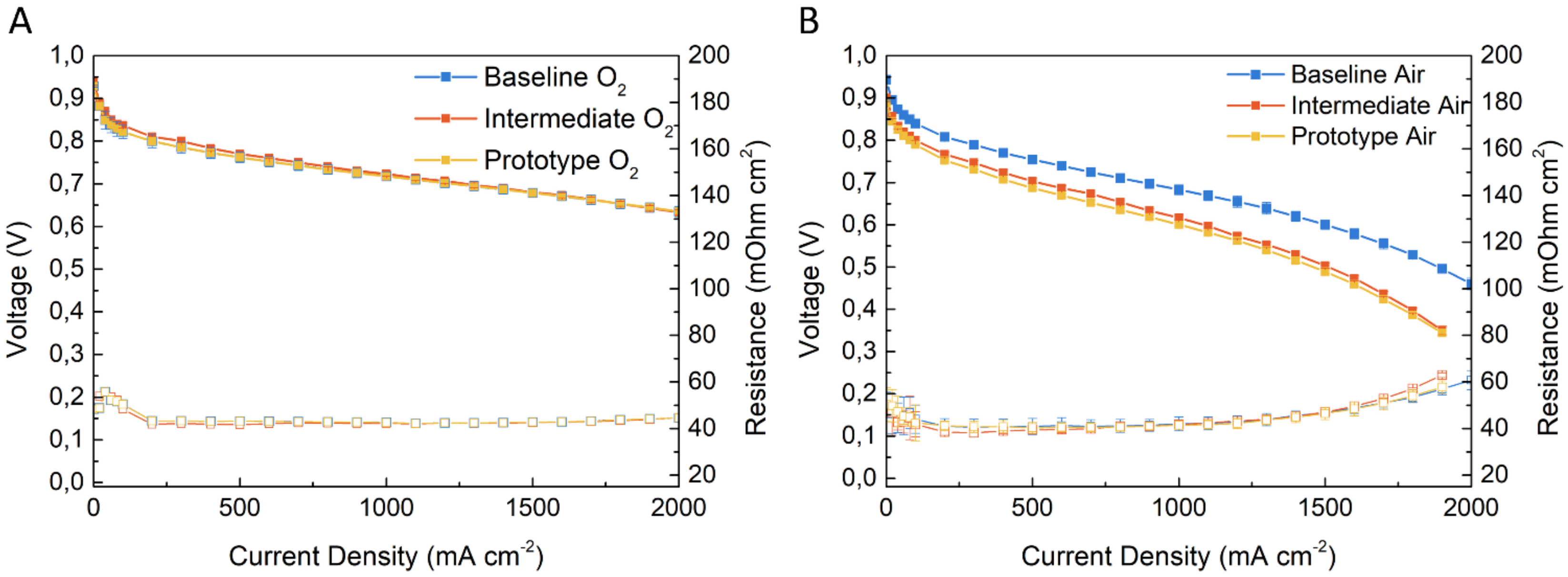
MEA: Membrane Electrode Assembly
SoA: State-of-the-Art

OEM: Original Equipment Manufacturer
SRU: Single Repeat Unit

Project Targets - Power Density

1.8 W/cm² @ 0.08 mg_{Pt}/cm^2

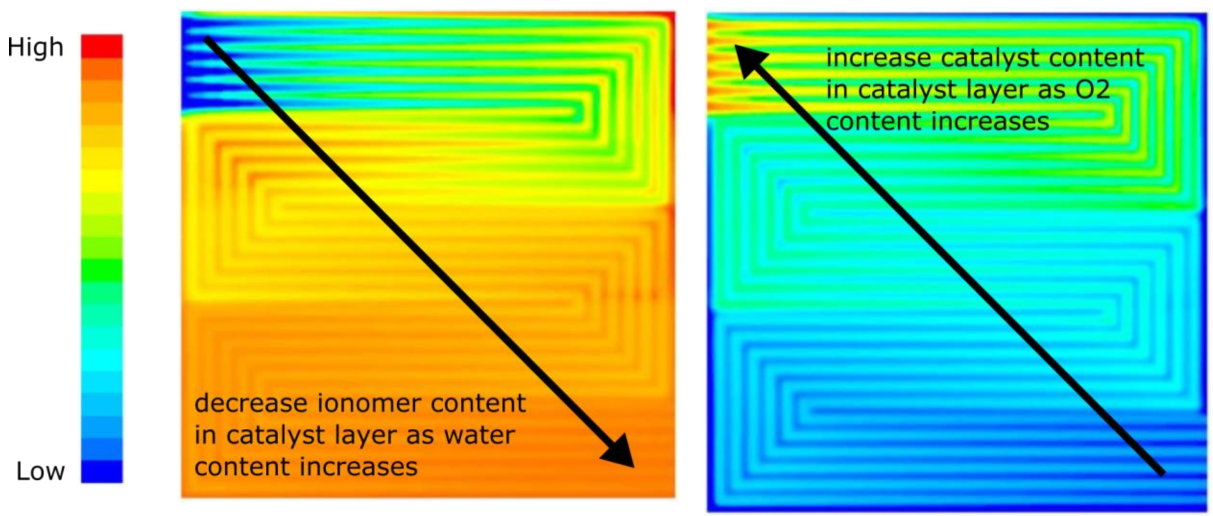




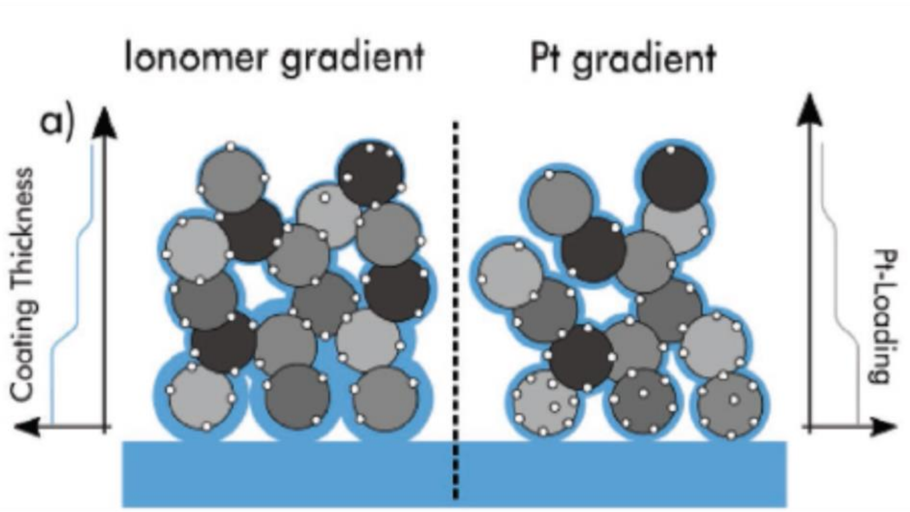
- We have achieved power densities of 0.75 W/cm² using 0.1 mg_{Pt}/cm^2 at the cathode
- Polarization curves collected using conditions outlined in the EU Harmonised Test Protocols for PEMFCs
  - 80 °C;
  - anode: ~50% RH, 1.5 bar_g, λ= 2.0
  - cathode: ~30% RH, 1.3 bar_g, λ= 2.5

Project Targets – Graded Catalyst Layers

- Concentration, temperature, and pressure gradients exist during PEMFC operation
- Can we take advantage of additive manufacturing techniques to overcome concentration gradients?

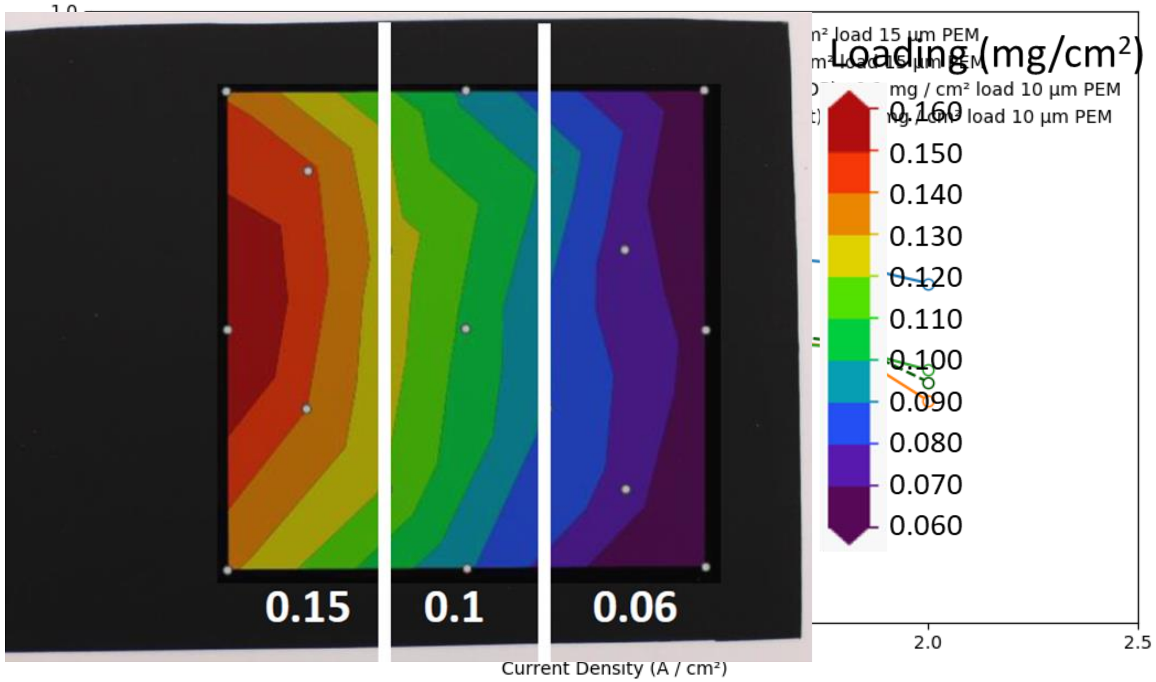


The respective effect of under-rib convection and pressure drop of flow fields on the performance of PEM fuel cells
Chao Wang, Qinglei Zhang, Shuiyun Shen, Xiaohui Yan, Fengjuan Zhu, Xiaojing Cheng & Junliang
Scientific Reports, 7:43447. DOI: 10.1038/srep43447



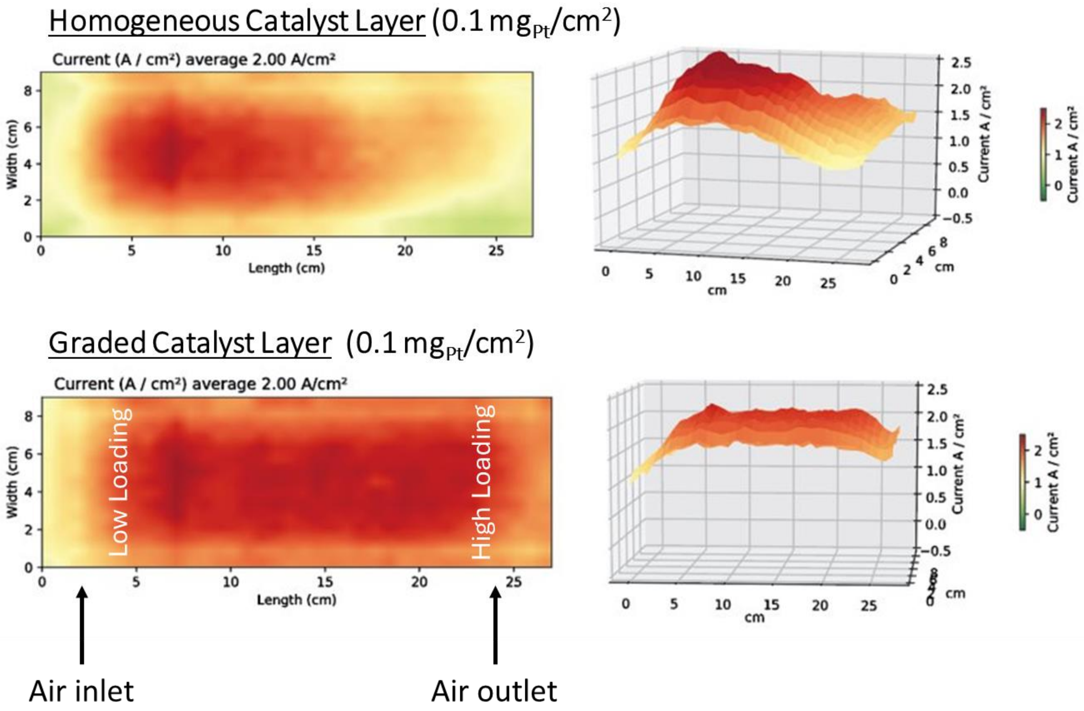
Tailoring the Membrane-Electrode Interface in PEM Fuel Cells: A Review and Perspective on Novel Engineering Approaches
Matthias Breitwieser, Matthias Klingele, Severin Vierrath, Roland Zengerle, and Simon Thiele*
Adv. Energy Mater. 2018, 8, 1701257

Project Targets – Graded Catalyst Layers



- Higher catalyst loadings towards the cathode outlet improves homogeneity of current density distribution and mass transport limitations
- Lower performance in kinetic and Ohmic region

- Optimized printing for gradient layers
- Total part loading 0.104 mg/cm2



- Current distribution measurements on an automotive PEMFC stack

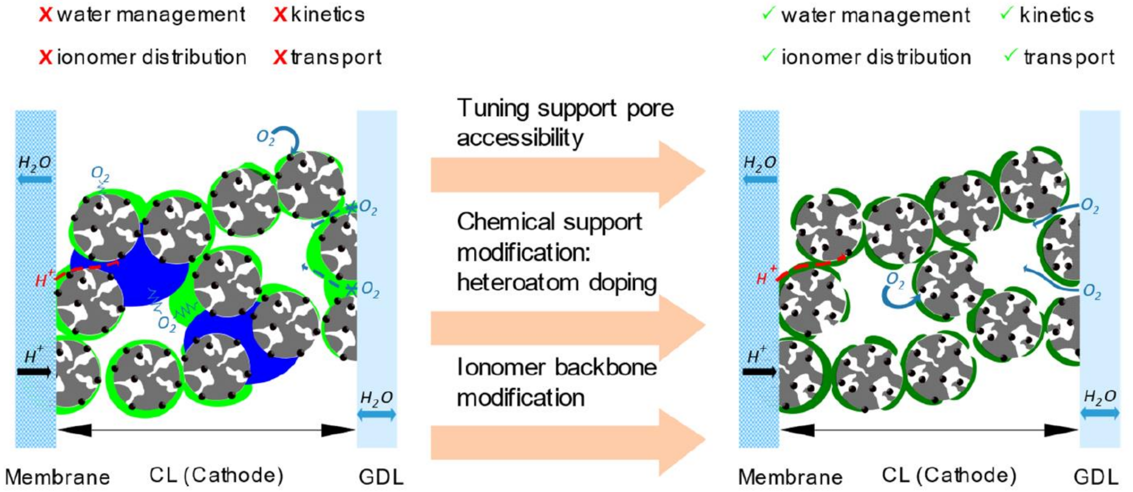
Clean Hydrogen Partnership

European Hydrogen Week

Co-funded by the European Union

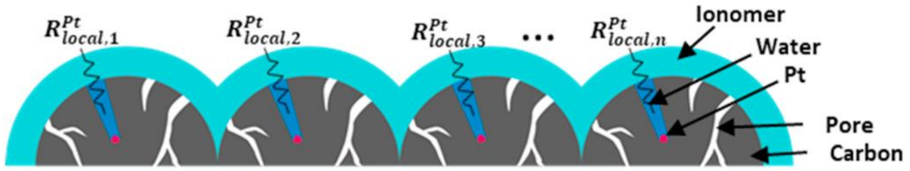
Risks, Challenges, and Lessons Learned

- As catalyst loadings approach 0.08 mg_{Pt}/cm^2 significant kinetic and mass transport limitations must be overcome



Sun, Y., Polani, S., Luo, F. *et al.* Advancements in cathode catalyst and cathode layer design for proton exchange membrane fuel cells. *Nat Commun* **12**, 5984 (2021).

$$\frac{1}{R^{Pt}_{local,Total}} = \sum_{i=1}^{n} \frac{1}{R^{Pt}_{local,i}}$$



D. Banham *et al*. *Journal of Power Sources* **490**, 229515 *(2021)*.

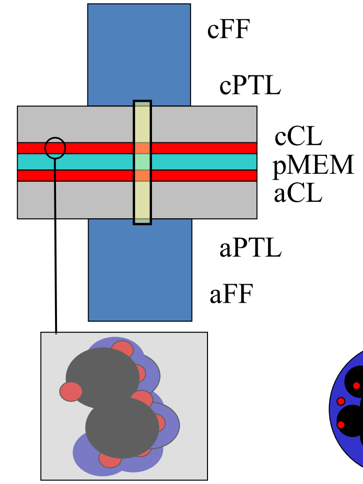
- Kinetics can be overcome through the development of new oxygen reduction reaction catalysts with high mass activities, e.g., shape-controlled Pt-alloys or PGM-free metal-nitrogen-carbon materials
- Mass transport limitations must be overcome through catalyst layer structure/morphology engineering, e.g., optimized carbon support porosity and surface area, optimized oxygen permeability of the ionomer, and maximizing triple-phase boundary

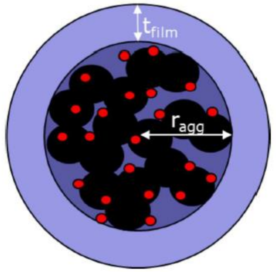
Exploitation Plan/Expected Impact

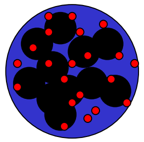
//EU HYDROGEN RESEARCH DAYS 15-16 NOVEMBER

Exploitation

Open-source 3D model developed that can be used to predict performance of PEMFC MEAs







Discrete Catalyst Model:

- No sub structure
- Effective properties only
- Gas transport in bulk pores
- Utilization through layer

Agglomerate Catalyst Model:

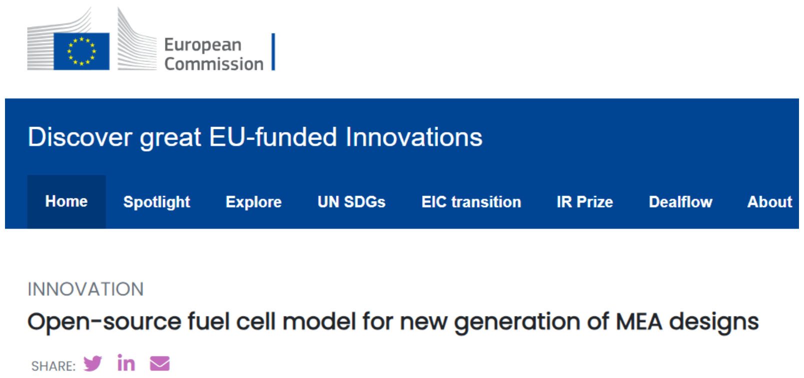
- Sub structure
  - water-filled
  - ionomer filled
- Effectiveness factor in the volume of the structure

INNOVATION RADAR

FAST Simulations

Impact

- Quantifying and predicting the local operating conditions inside a MEA
- MEA and MEA-component based design recommendations for increased performance



Clean Hydrogen Partnership

European Hydrogen Week

Co-funded by the European Union

//EU HYDROGEN RESEARCH DAYS
15-16 NOVEMBER

Dissemination Activities

We're hosting a workshop!

Join us in Chemnitz for a hands-on demonstration of our PEMFC model

camelot

UNDERSTANDING CHARGE, MASS AND HEAT TRANSFER IN FUEL CELLS FOR TRANSPORT APPLICATIONS

WORKSHOP 2023

Fuel Cell Modeling: Understanding Charge, Mass, and Heat Transfer in Proton Exchange Membrane Fuel Cells

www.camelot-fuelcell.eu

6-7 December 2023
Chemnitz University of Technology
Germany

The CAMELOT project is focused on understanding the limitations in performance of proton exchange membrane fuel cells to guide the development of next generation PEMFCs.

As part of this work, a free and open source Fuel Cell Performance Model has been developed and extended to describe the transport and kinetic processes in ultra-thin, low-loaded membrane electrode assemblies.

The workshop will provide attendees an understanding of the general theory behind the model and highlight the improvements made within the project, as well as a hands-on implementation of the model through tutorial sessions supported by the FAST Simulations team.

Clean Hydrogen Partnership

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under grant agreement No 875155. This Joint Undertaking receives support from the European Union's Horizon 2020 Research and Innovation program, Hydrogen Europe and Hydrogen Europe Research.

Co-funded by the European Union

Programme

Free registration @ www.camelot-fuelcell.eu

Wednesday December 6th, 2023

18:00	21:00	Networking Event

Thursday December 7th, 2023

8:30	9:00	Welcome and Introduction *P. Fortin, SINTEF & S. Saez, TU Chemnitz*
09:00	9:30	General Introduction to CAMELOT *P. Fortin, SINTEF*
09:30	10:30	General Introduction to FAST-FC *D. Harvey, FAST Simulations UG*
10:30	*10:45*	*Mid-Morning Break*
10:45	12:00	Thin Ionomer Model *J. Hrdlicka, FAST Simulations UG*
12:00	*13:00*	*Lunch*
13:00	14:00	Application of FAST-FC *D. Harvey, FAST Simulations UG*
14:00	15:30	FAST-FC Tutorials *D. Harvey and J. Hrdlicka, FAST Simulations UG*
15:30	*15:45*	*Mid-Afternoon Break*
15:45	17:30	Open Application and Q & A Session *D. Harvey and J. Hrdlicka, FAST Simulations UG*

Clean Hydrogen Partnership

European Hydrogen Week

Co-funded by the European Union

Acknowledgement

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under grant agreement No 875155. This Joint Undertaking receives support from the European Union's Horizon 2020 Research and Innovation program, Hydrogen Europe and Hydrogen Europe Research.

//EU HYDROGEN RESEARCH DAYS 15-16 NOVEMBER

Thank you for your attention!

patrick.fortin@sintef.no

Clean Hydrogen Partnership

European Hydrogen Week

Co-funded by the European Union