FURTHER-FC

FURTHER UNDERSTANDING RELATED TO TRANSPORT LIMITATIONS AT HIGH CURRENT DENSITY TOWARDS FUTURE ELECTRODES FOR FUEL CELLS

Project ID	875025
PRR 2025	Pillar 3 - H_2 End Uses - Transport
Call Topic	FCH-01-4-2019
Project Total Costs	2 735 031.25
Clean H_2 JU Max. Contribution	2 199 567.35
Project Period	01-01-2020 - 31-08-2024
Coordinator Beneficiary	COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, FR
Beneficiaries	UNIVERSITE DE MONTPELLIER, UNIVERSITE DE MONTPELLIER, CHEMOURS FRANCE SAS, THE CHEMOURS COMPANY FC, LLC, HOCHSCHULE ESSLINGEN, TOYOTA MOTOR EUROPE NV, ECOLE NATIONALE SUPERIEURE DE CHIMIE DE MONTPELLIER, University of Calgary, INSTITUT NATIONAL POLYTECHNIQUE DE TOULOUSE, DEUTSCHES ZENTRUM FUR LUFT - UND RAUMFAHRT EV, IMPERIAL COLLEGE OF SCIENCE TECHNOLOGY AND MEDICINE, PAUL SCHERRER INSTITUT, CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS

https://further-fc.eu/

PROJECT AND GENERAL OBJECTIVES

FURTHER-FC proposes an innovative route towards a better understanding of performance limitations inside proton exchange membrane fuel cells (PEMFC), focusing on the performance cost and durability of the cathode catalyst layer (CCL) for innovative high performing low-Pt loaded PEMFCs for automotive application. The approach is based on the development of innovative and/or improved modelling and experimental tools to analyse the performance from the ionomer film layer scale to the full CCL scale.

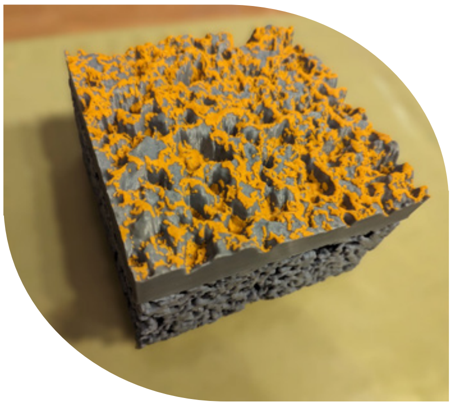
NON-QUANTITATIVE OBJECTIVES

- Combine original and advanced methods with fundamental characterisations and advanced models on CCL to investigate transport and electrochemical issues.
- Describe the CCL structure, transport properties and mechanisms, at its different scales.
- Characterise local conditions in the CCL during operation.
- Establish the link between the structure and properties of the CCL, local operating conditions, and performance.
- Validate CCL with improved catalyst efficiency and durability.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

Components and Testing:

- Development and testing of various membrane electrode assemblies (MEAs) with different Pt loadings, ionomer types (D2020 vs. HOPI), and carbon supports, and ultra-low catalyst loadings (10–50 µg/cm²) have been developed and tested.
- Performance analyses of MEAs using techniques like limiting current analysis, electrochemical impedance spectroscopy, and I-V curves.
- Selection and testing of a final high-performance MEA.



Ex-Situ Characterisation:

- Analysis of cathodic catalyst layers and gas diffusion layers through advanced imaging (X-ray, FIB-SEM, TEM, AFM, SAXS, SANS), focusing on Pt nanoparticle distribution, ionomer coverage, and microstructural properties.
- Measurement of key properties such as electronic, protonic, thermal conductivities, wettability, and oxygen transport resistance in thin ionomer films (~6.5 nm).

Performance Limitations and Water Management:

- Investigation of local water content and distribution during operation.
- Analysis of performance limits related to oxygen reduction reaction and hydrogen oxidation reaction kinetics.

Modelling, Simulation, and Development of multi-scale models:

- Sub-micron scale: Lattice-Boltzmann simulations of local ORR rates and transport processes.
- GDL/MPL scale: Heat conductivity and gas diffusion simulations based on 3D imaging.
- CCL scale: Modelling of oxygen diffusion, proton conductivity, and ionomer distribution.

Clean Hydrogen Partnership
Co-funded by the European Union

- Cell scale: Integration of these properties into performance models for improved accuracy.

Dissemination and Impact:

- Organisation of workshops, publication of 16 peer-reviewed articles, participation in 21 conferences, and sharing of results via newsletters and social media.
- Preparation of a 3D printed model consolidating data from project partners.

Advances Beyond State-of-the-Art:

- Enhanced electron tomography techniques for detailed 3D imaging of Pt distribution.
- Improved quantification of ionomer distribution using combined microscopy methods.
- Measurement of transport properties of ultra-thin ionomer films under various conditions.
- Used operando Small Angle Neutron Scattering (SANS) to characterise water content in MEAs.
- Development of advanced modelling tools linking microstructure to cell performance, validated by experiments.

Key Findings on CCL Structure and Transport:

- Achievement of a better agreement between simulations and experiments for proton conductivity using real microstructural images and ionomer reconstruction.
- Confirmation of significant proton transport through liquid water in primary pores.
- Computation of water retention curves consistent with experimental data based on microstructural imaging.

Performance Limitations and Future Work:

- Deeper understanding of the impact of ionomer type, carbon support, and catalyst loading under various conditions.
- Proposed explanations for performance limits, some that are validated and others that require further study.
- Suggested experiments to further improve catalyst layer performance and durability with reduced catalyst amounts.
- Manufactured CCLs showing enhanced performance and durability, notably with HOPI ionomer for automotive applications and heavy-duty conditions.

FUTURE STEPS AND PLANS

- TOYOTA MOTOR EUROPE, a leading actor in fuel cell vehicles, provided FURTHER-FC access to a wide network of characterisation and modelling technologies.
- Knowledge developed by FURTHER-FC in terms of material developments, analysis of performance limitations and developments of innovative modelling tools has been provided to European industrial partners.
- A methodology developed within FURTHER-FC will be applied for batteries through the recruitment of a PhD student who was involved in FURTHER-FC.

Clean Hydrogen Partnership
Co-funded by the European Union