FURTHER-FC Newsletter #2
Further Understanding Related to Transport limitations at High current density towards future ElectRodes for Fuel Cells

News: Publication about reversible and irreversible degration and nanoscale thermal conductivity measurements of fuel cell electrodes

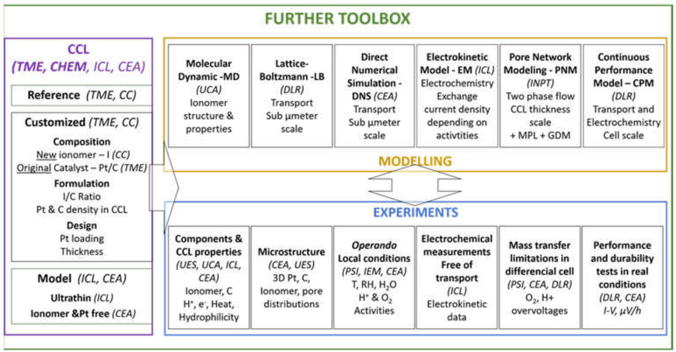
Ambition

The CCL is the most limiting component in terms of performance and durability, mainly due to the conditions in which the ORR occurs along with its sluggish kinetic. The fundamental reasons of, and the relative contribution of the phenomena (kinetic or transport) on performance limitations of CCL are still under discussion. We aim at better understanding the relationships between the composition/structure of CCL made of Pt based NP supported on Carbon, their effective transport properties/limitations and finally the overall fuel cell performance. This is a prerequisite to a rational design of effective CCL which will allow to make highly efficient and durable MEA with low platinum loading. Thus, our ambition is to bring new knowledge on the:

- Microstructure of the CCL
- Correlation between transport properties of CCL and its components (Platinum, Carbon, Ionomer)
- This will be reached due to a combination of new components to produce novel MEAs along with extensive experiments and modelling leading to improved MEAs

Besides that, the performance of fuel cells gets affected by reversible and irreversible performance losses. A detailed review on these processes was published in relation to FURTHER-FC.

FUTHER-FC TOOLBOX



https://further-fc.eu/

Recent Publications and Results

Publication: Review on mechanisms and recovery procedures for reversible performance losses in polymer electrolyte membrane fuel cells

Content:

The recovery of performance losses in polymer electrolyte membrane fuel cells due to reversible degradation phenomena is an important topic to enable high system efficiency, reliable performance benchmarking and specific material improvement for a given application. Detailed knowledge of both, the sources for reversible performance loss and corresponding recovery mechanisms, are required to achieve cost and durability targets for fuel cell commercialization. This review paper provides a detailed overview of the mechanisms responsible for reversible performance losses. Moreover, it presents general requirements for the recovery of these losses and summarizes specific recovery procedures available in the literature. Eventually, it provides recommendations how to recover the performance loss caused by a certain reversible degradation mechanism. The study is aiming to present general recommendations for suitable recovery strategies and procedures for reliable testing in laboratories and for improved efficiency of operating systems

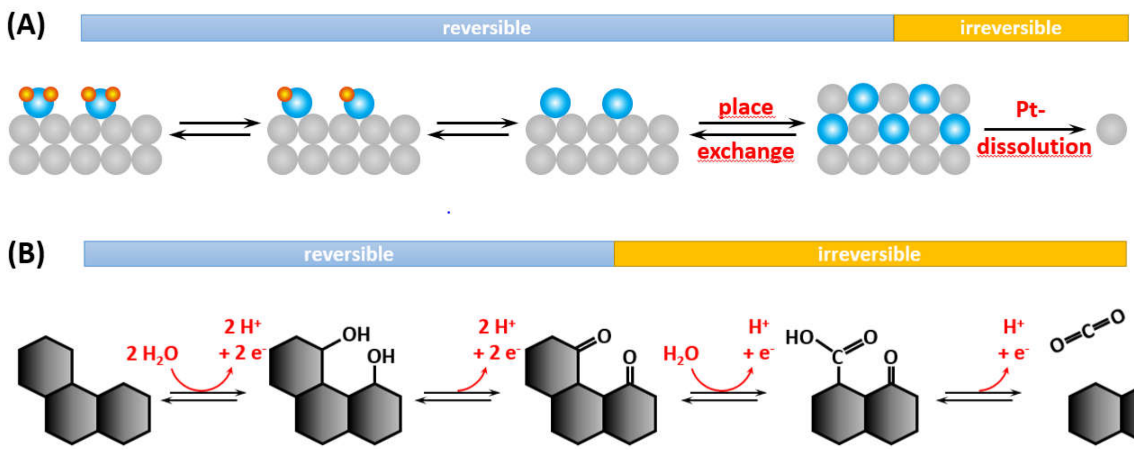
Highlights:

- Detailed overview of the mechanisms responsible for **reversible performance losses**.
- General requirements for the recovery of different reversible performance losses.
- Specific **recovery procedures** for different reversible performance losses.
- Recommended recovery procedures for **laboratories and system operation**.

Link to FURTHER-FC:

- Reliable characterization of transport properties is a key requirement for the achievements in FURTHER-FC
- Reversible degradation phenomena in the developed MEAs must be recovered before testing
- Degradation analysis in FURTHER-FC requires separation of reversible and irreversible degradation

Reversible and irreversible degradation processes for catalyst oxidation (A) and catalyst support oxidation (B)



Reference:
Jens Mitzel, Qian Zhang, Pawel Gazdzicki, K. Andreas Friedrich; Review on mechanisms and recovery procedures for reversible performance losses in polymer electrolyte membrane fuel cells; Journal of Power Sources 488 (2021) 229375

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Contaminants causing reversible performance losses in PEMFCs

Impurity Source	Classification	Contaminant	Mechanism	Impact
Air	Nitrogen contaminants	NO_x: NO, NO_2	Catalyst poisoning	Kinetic
		NH_3	Membrane poisoning	Ohmic, kinetic
	Sulfur contaminants	SO_x: SO_2, SO_3 H_2S COS	Catalyst poisoning	Kinetic
Hydrogen	Carbon contaminants	CO_x: CO, CO_2	Catalyst poisoning	Kinetic
	Sulfur contaminants	H_2S	Catalyst poisoning	Kinetic
Bipolar plate	Metal ions	Fe^{2+}, Fe^{3+}, Ni^{2+}, Cu^{2+}, Cr^{3+}	Membrane poisoning	Ohmic
Membrane	Degradation products	SO_4^{2-}	Catalyst poisoning	Kinetic
	Metal ions	Na^+, Ca^{2+}	Membrane poisoning	Ohmic

German Aerospace Center - Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR) Role in FURTHER-FC

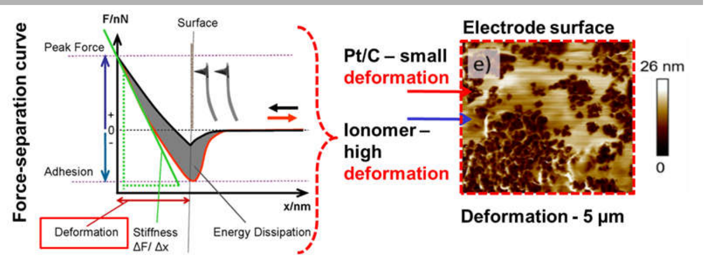
The goal of DLR is the understanding performance limitations of PEMFC MEA at ultra-low Pt loading (<0.1 mg/cm2) and ultra-thin MEA components by means of modeling and experimental techniques in order to propose mitigation approaches for performance limitations.

Nanomechanical Properties and Scanning Thermal Microscopy (SThM) Measurements of fuel cell electrodes

Atomic Force Microscopy (AFM)

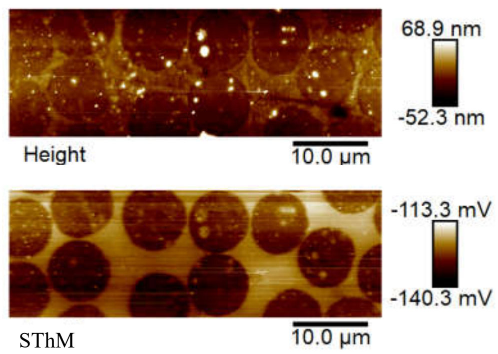
Using AFM one can discern the different components in the PEMFC and PEMWE electrodes. They consist of catalyst, support materials and (ionomer) binder, the distribution of these components affects MEA performance and degradation rates. Tapping PeakForce-Mode (Bruker Corp.): Evaluation and mapping of adhesion force, phase shift, stiffness (DMT modulus), maximal force, dissipation energy, deformation and current.

Scanning Thermal Microscopy uses special AFM probes that work as a nano-thermometer.

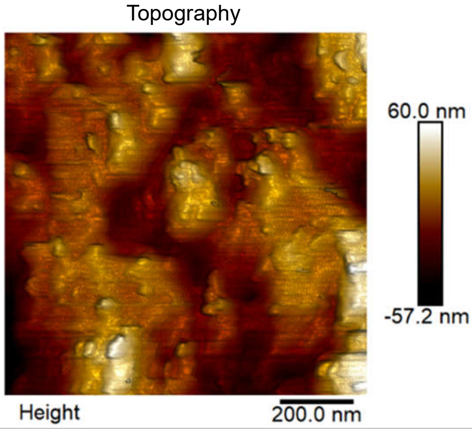


Scanning Thermal Microscopy allows mapping of thermal conductivity at a resolution < 100 nm. More negative values shows dissipated heat and thus a higher thermal conductivity

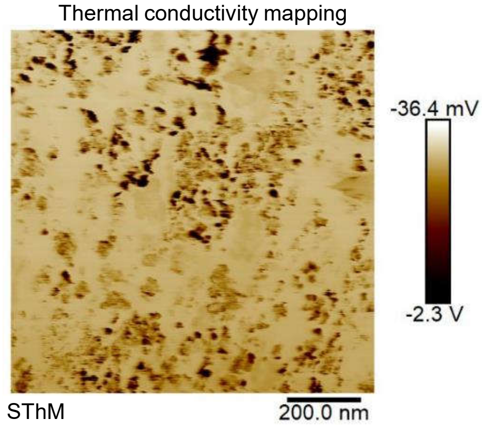
Reference sample: Carbon fibres in Epoxy resin



Topography



Thermal conductivity mapping



University of Applied Sciences Esslingen (UES) Role in FURTHER-FC

The University of Applied Sciences in Esslingen uses AFM based techniques to further understand the properties and distribution of ionomer and catalyst particles in the catalyst layer. In the last decade UAES was doing research aimed at fuel cell and electrolyser materials. UES expect to deliver an even more detailed analysis of fuel cell membranes and catalyst layers including electronic and ionic current, O_2 diffusion and reactivity at the catalyst at nm scale as well as thermal conductivity measurements. The contribution of the UES will be unique techniques to provide inside in the ionomer properties in real electrodes and model electrodes.

Acknowledgement

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