Overview of ID-FAST

Investigations on degradation mechanisms and Definition of protocols for PEM Fuel cells Accelerated Stress Testing

APPROACH & INSIGHTS

ID-FAST Final Workshop

16th December 2021 - Online in the Framework of the EFC21

Introduction

Start date 01/01/2018
~~3~~ 4-year project

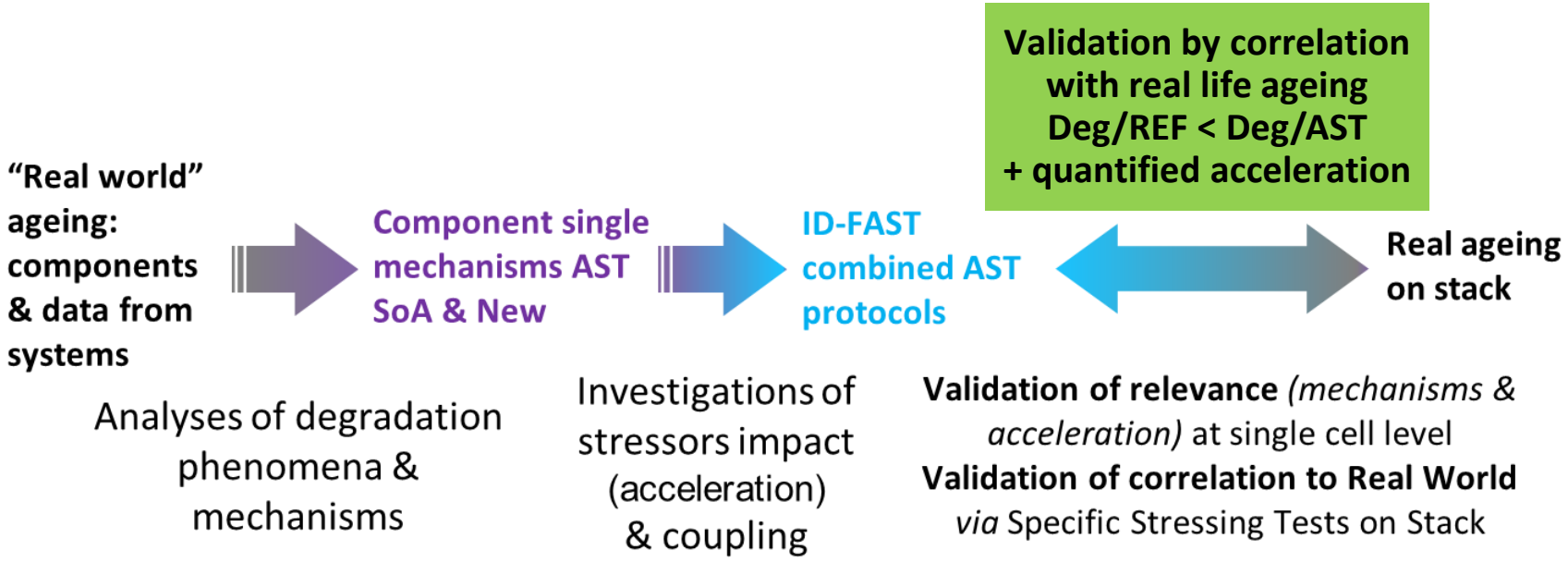
Overall aim was to **support and promote the deployment of fuel cell vehicles,** by accelerating the development of next generation designs, thanks to **Accelerated Stress Tests (AST)** for Proton Exchange Membrane Fuel Cells (PEMFC)

Summary

- ID-FAST worked on the development of PEMFC specific ASTs and link to real durability.
- Core focus is on degradation understanding and validation of new ASTs relating in-situ, ex-situ and modelling data, before, during and after ageing to get insights on mechanisms involved.
- Required starting point is to know the impact of real ageing: post-mortem analyses and also the definition of a representative real ageing protocol applicable as the reference.
- Experiments and simulations involving single or coupled mechanisms and various stressors allowed to propose accelerating protocols first applied on single cells.
- Validation with different MEAs, stressing tests on stacks, and correlation of ageing and degradation in AST and real life conditions are concluding the project.

Objectives & concept

1. **Identification of real ageing degradation mechanisms and quantification of their impact,** *as the basis for the identification of stressors and the development of relevant ASTs*
2. **Development and application of performance degradation models integrating several degradation mechanisms, for the simulation of accelerated ageing**, *as a tool for the development and validation of combined ASTs and later-on prediction*
3. **Development and validation of ID-FAST methodology: AST protocols and transfer functions correlating accelerated degradation to real world degradation**.



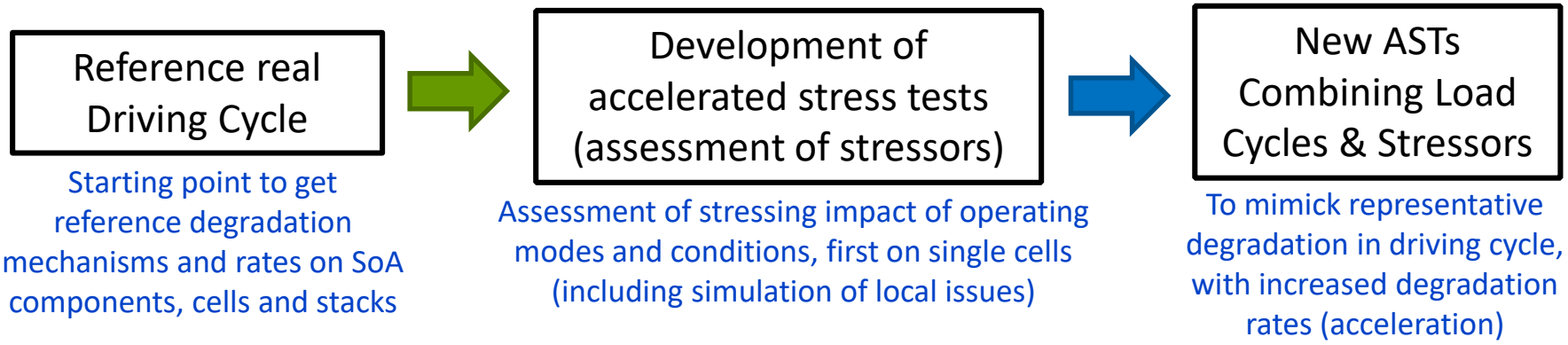
Technical Plan & WPs

Focusing on scientific and technological R&D activities

4 Main steps	Aim	WPs
Identification or confirmation and quantification of degradation phenomena (morphology, composition and properties of components) involved in real ageing	Determination of major causes of components degradation for real aging case in correlation with operating conditions	WP1 and WP2 mainly
Analysis of stressors and of their accelerating factor for each single mechanism AST	Identification of stressors and quantification of their impact on degradation	WP2, WP3 and WP4
Analysis and development of combined AST protocols (superposition of degradation modes and acceleration through coupling)	Definition of combined AST with regard to their relative impact	WP2, WP3, WP4 and WP5
Validation of combined ASTs and development of transfer functions to link AST ageing in single cell to real ageing in stack, with realistic lifetime estimation	Validation of correlation to real world ageing and definition of a methodology to predict stack lifetime	WP1, WP2, WP3, WP4 and WP5

Basic idea: Drive-cycle-based ASTs

- Selected basic approach



- Specific points regarding the approach
  - **In general: starting from the definition of a driving cycle deduced from application data**
  - **In operando ASTs are defined – «artificial states» avoided (e.g. long term OCV, N_2 atm. if not needed for safety reasons)**
  - **Validation on several state of art materials (components and stacks for automotive case)**

Items for discussion and extension

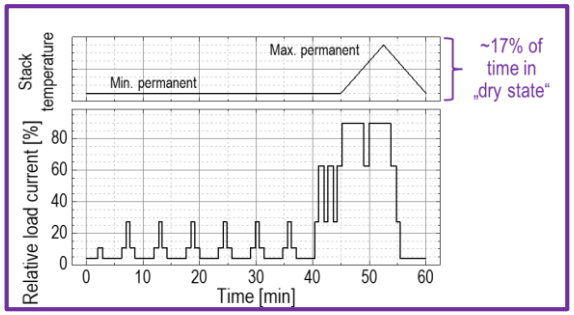
- Identified required points about extendability to other applications
  - **Status on the development of the driving cycles**
    - relevant usage profiles to be known
  - **Need to assess specific stressors**
    - exacerbating the power losses on the whole range
  - **Sufficient understanding of mechanisms for new applications**
    - From this project:
      - active layer components and induced membrane degradation most relevant for automotive case;
    - For long-term lifetime applications:
      - GDL and BPP could present a higher impact
      - Integration of GDL and BPP issues in ASTs: relevance and feasibility

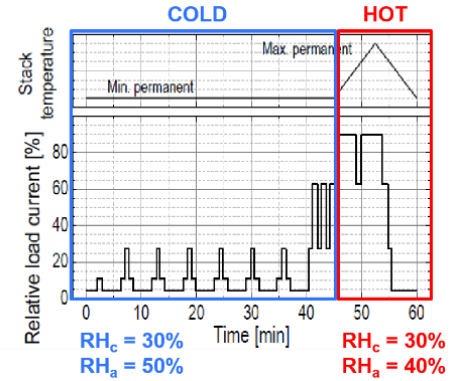
OVERVIEW OF ACTIONS, INVESTIGATIONS, RESULTS

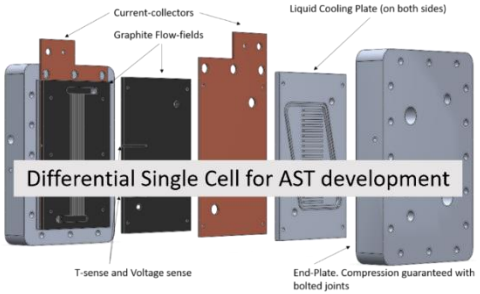
Ageing and degradation characterizations

- Specification and application of endurance test protocols reproducing real ageing in controlled conditions (WP1)

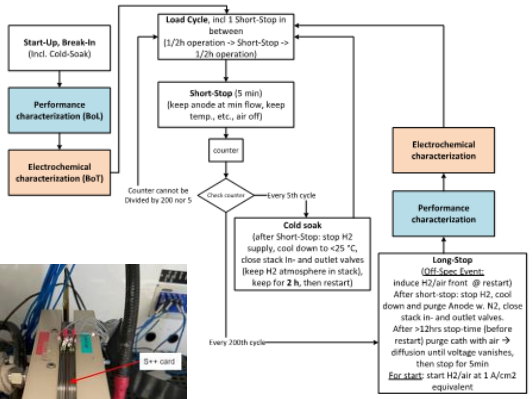
Single cells & stacks

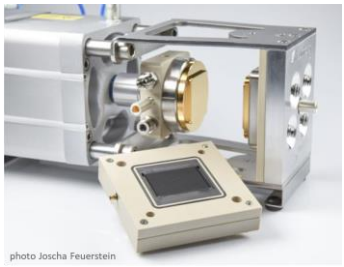


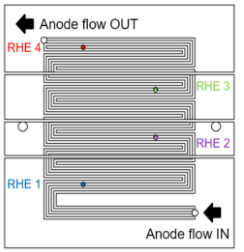




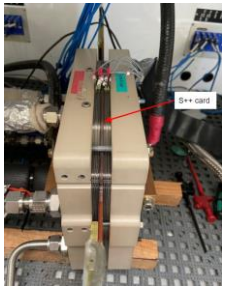
Andrea Bisello et al 2021 - J. Electrochem. Soc. 168 054501

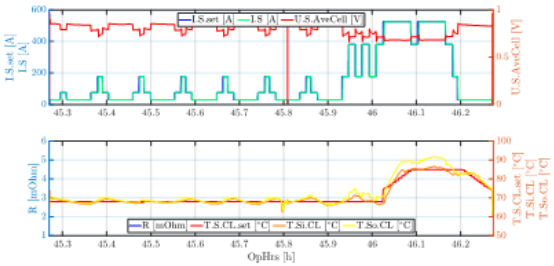


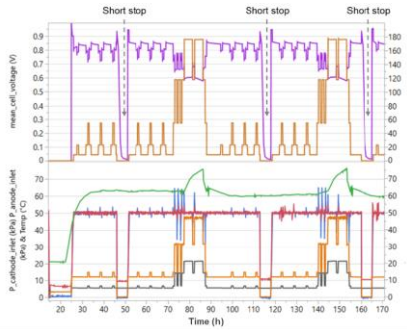




Rabissi C. et al 2018. Journal of Power Sources, 397, 361







✓ *Assessment of phenomena to support modelling and empirical AST developments*

Ageing and degradation characterizations

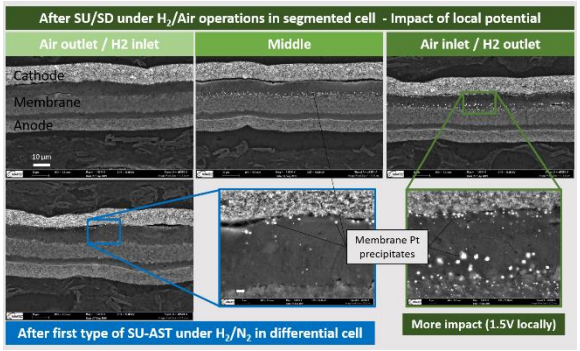
- Post-mortem specific analyses on each stack component (WP2)

CL, GDL, Membrane, BPP samples - Spatially & vertically resolved distributions
Elemental compositions / Morphology changes / Properties changes

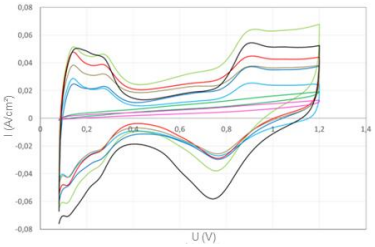
- Beginning of project → Selection of aged samples from stacks of previous projects

COBRA autostack core IMPACT IMPALA HyWAY

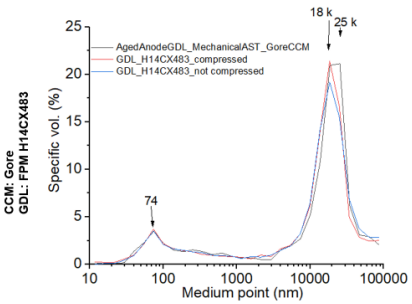
- Along the project → Analysis of mechanisms involved during ID-FAST ageing tests



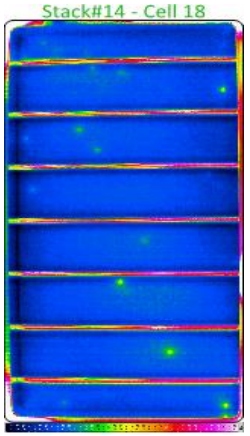
Electron microscopy on the CCM and Pt catalyst



Electrochemical measurements on aged MEA samples from stacks



Porosimetry analysis of GDLs



IR thermography on MEAs

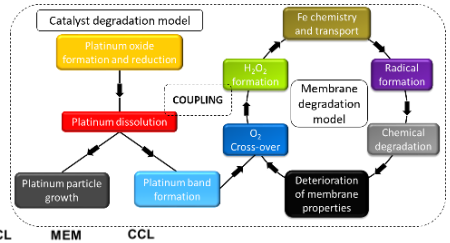
Mitzel, "Operando and ex-situ investigation of PEMFC degradation" ECS Transactions (2019)
D. Garcia-Sanchez „Local impact of load cycling on degradation in polymer electrolyte fuel cells", Applied Energy (2020)

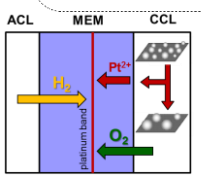
➔ ***Assessment of phenomena to support modelling and empirical AST developments***

Modelling of MEA components

Modelling of mechanisms and designs & Simulation (WP3)

Modelling of CCM materials

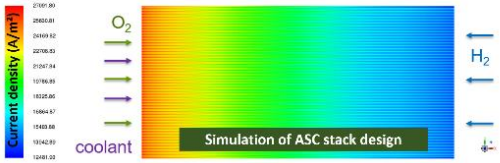




T. Jahnke, "Physical Modeling of Catalyst Degradation in Low Temperature Fuel Cells: Platinum Oxidation, Dissolution, Particle Growth and Platinum Band Formation", J. Electrochem. Soc. (2020)

B. Randrianarizafy, "Modelling carbon corrosion during a PEMFC startup: simulation of mitigation strategies", Energies 13 (2020)

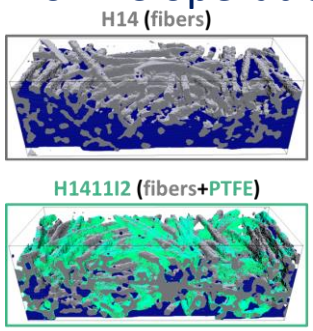
Cell designs simulations

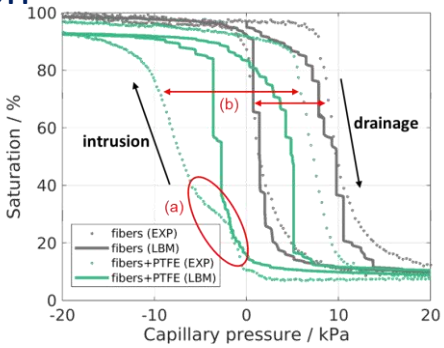


P. Sarkezi-Selsky "Lattice-Boltzmann simulation of two-phase flows in the GDL and MPL of Polymer Electrolyte Fuel Cells", EFCF 2019

A. Bisello, "The effects of Platinum oxide species on performance degradation in Polymer Electrolyte Fuel Cells", EFC19

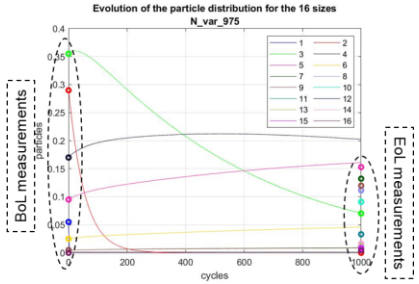
Simulation of GDL microstructure, properties and degradation impact on FC operation

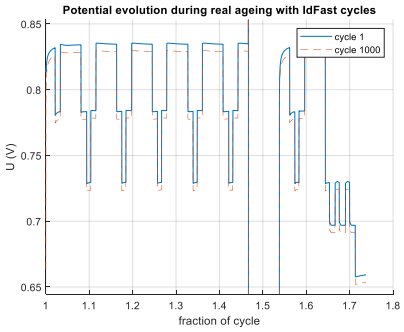




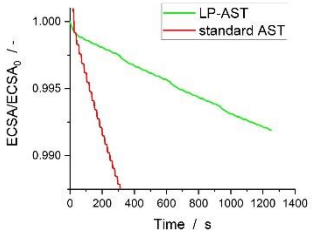
P.Sarkesi Selsky Parametric studies on capillary hysteresis" (DLR) (to be published) "Lattice Boltzmann simulation of liquid water transport in gas diffusion layers of proton exchange membrane fuel cells:

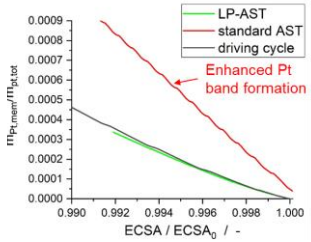
Simulation of drive cycles on the long-term with Pt particles degradation





LP AST simulation





Realistic aging of LP AST vs AST under H_2/N_2

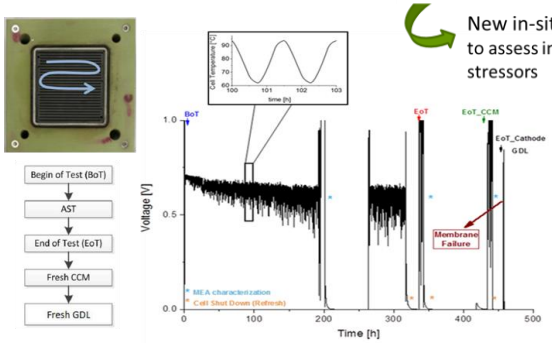
✓ ***Assessment of conditions impact, support to AST development and AST simulation***

Development of new ASTs

❑ GDL AST

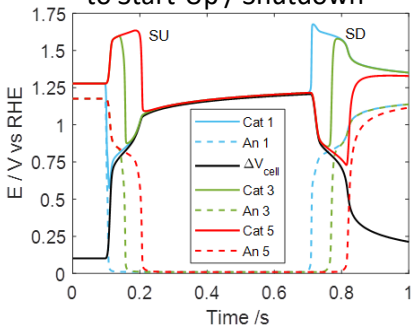
SoA data about impact & ex-situ tests

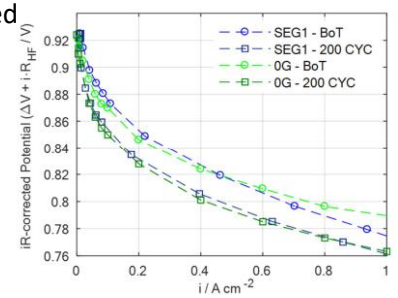
New in-situ tests & method to assess impact of identified stressors



❑ Start-up AST

Corrosion of carbon support related to Start-Up / Shutdown





Similar impact confirmed by comparison to real start-up

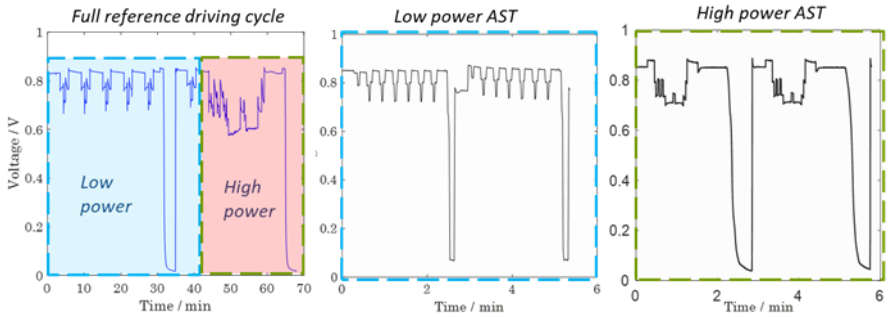
A. Bisello "In-operando investigation of the degradation mechanisms during startup/shutdown in PEMFC for automotive application", FDFC 2019

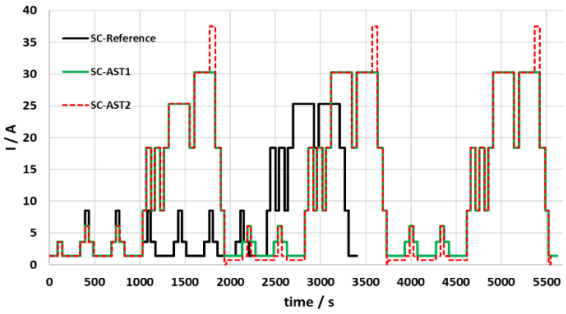
E. Colombo, "Local degradation study of PEMFC during start-up and shutdown cycling", EFC19

P. Gazdzicki "Carbon corrosion in PEMFC: linking startup / shutdown and accelerated stress tests", EFCF 2019

❑ New AST load cycles based on drive cycles

Cf. the technical presentations





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THANK YOU FOR YOUR ATTENTION