Second Act

Simulation, statistics and Experiments Coupled to develop Optimized aNd Durable µCHP systems using ACcelerated Tests (GA 621216)

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Programme Review Days 2017
Brussels, 23-24 November

PROJECT OVERVIEW

- Call year: 2013
- Call topic: SP1-JTI-FCH.2013.3.1 - Improving understanding of cell & stack degradation mechanisms using advanced testing techniques, and developments to achieve cost reduction and lifetime enhancements for Stationary Fuel Cell power and CHP systems
- Project dates: 01/05/2014 – 31/10/2017 *(+6M)*
- % stage of implementation 01/11/2017: 97%
- Total project budget: 4 643 707 €
- FCH JU max. contribution: 2 523 254 €
- Other financial contribution: funding NRC Norway (< € 130 000)
- Partners: CEA, EWII, Nedstack, ICI, Polimi, DLR, JRC, Sintef, TU-Graz

Origin & Concept

Origin

3 projects:

Degradation issues
& Stationary application

Stayers	H2 PEMFC
Keepemalive	H2 & Reformate PEMFC
Premium Act	Reformate PEMFC & DMFC

Second Act

1-Better understanding
[cells & stack]
[H2, Reformate & DMFC]

→

2-Demonstrating lifetime improvements
[stack core components modifications]
(enabling >20,000 h for H_2 syst. case)

Focus

- **Active layers**
- **Heterogeneity** in MEA operation
- **Failures** caused by defects in components or critical events

→ *lifetime improvements by modifications of the MEA*

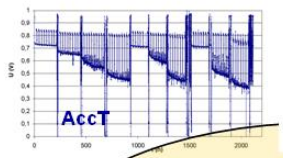
Concept

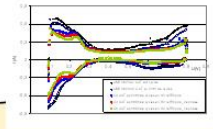
mechanisms

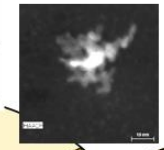
identification and local resolution

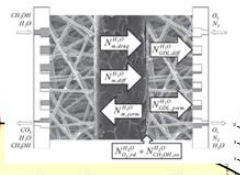
reversible / permanent

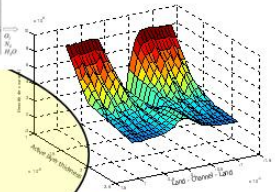
Heterogeneities











Experimental investigation of degradation processes

Understanding

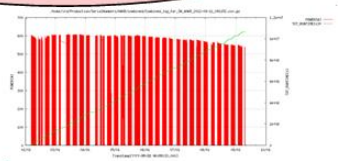
Statistical analysis and Simulation of stack performance degradation

Objects and data for degradation analyses

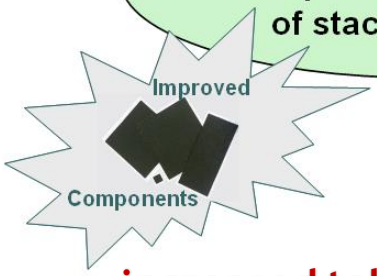
Proposal of developments for system lifetime enhancement

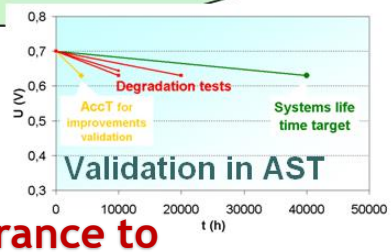
Fuel Cell Systems - Reference components and degradation data

Improvement of components & increase of stacks durability



Field tests





causes for failure

quantify performance degradation

increased tolerance to applications' relevant modes

PROJECT PROGRESS/ACTIONS - Degradation of performance (effect of gradient electrodes)

Second Act

Achievement to-date

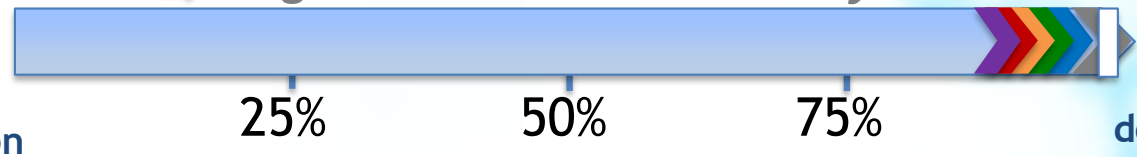
% stage of implement.

Target reached

Degradation rates divided by 2 to 10

Demonstration of improvement

Gen1 Initial Degradation



Gen2 Lower degradation

Gen1= homogeneous electrodes ➔ Gen2 = gradient electrodes

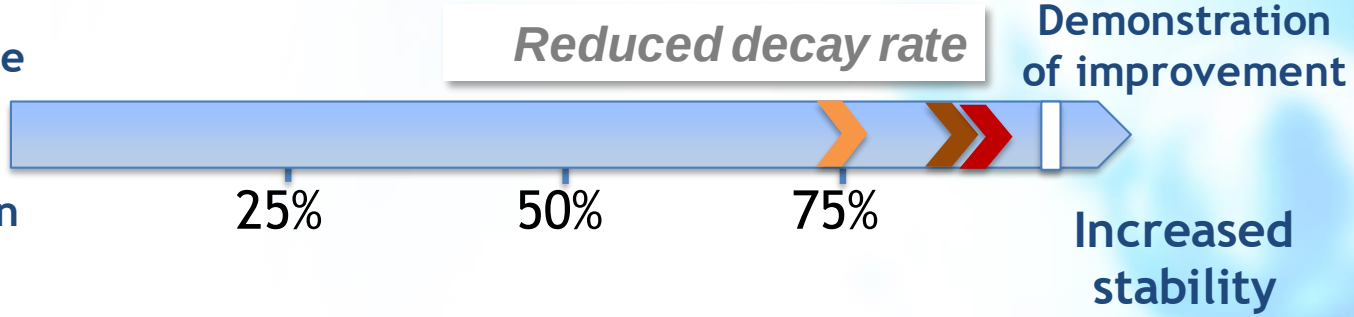
Aspect addressed	Parameter (KPI)	Unit	SoA 2017	Second Act	
				Gen1	Gen2
Performance degradation of MEAs in cell and stacks for different operation modes	DMFC (25 cm^2) Degradation rate @ fixed load	µV/h (500 h)	90	35	11
	DMFC (180 cm^2) Degradation rate @ fixed load	µV/h (500 h)	-	150	50
	H2/Air PEMFC (25 cm^2) Degradation rate vs. specific test	µV/h (1000 h)	-	30	16
	H2/Air PEMFC (220 cm^2) Voltage & ECSA loss (%) vs. ast SU/SD	% (70 cy)	-	-40% & -60%	-8% & -10%
	Reformate/Air PEMFC (220 cm^2) Degradation rate @ fixed load	µV/h (800 h)	-	350	35

PROJECT PROGRESS/ACTIONS - Durability of PEMFC stacks (improved components or strategy)

Second Act

Achievement to-date

% stage of implement.

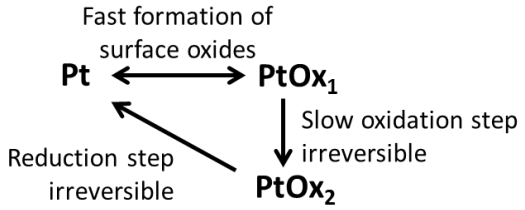


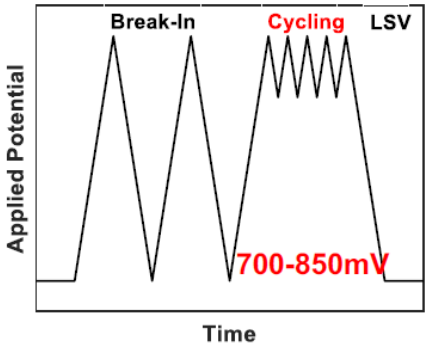
Aspect addressed	Parameter (KPI)	Unit	SoA 2017	Second Act	
				Ref. case	Improved
Durability and stability of H2/Air PEMFC stacks (reversible and non-reversible losses for different operation modes)	75 cells - Fixed load Degradation rate	µV/h (hrs)	2 (20000)	19 (10000)	**14 (15000)**
	75 cells - Start-Stop Voltage loss vs. 1250 cy	%	-	-11%	-4% (cathode catalyst)
	8 cells - fixed load Degradation rate (incl. reversible)	µV/h (over 100hrs step)	-	180	18 (Air starvation strategy)

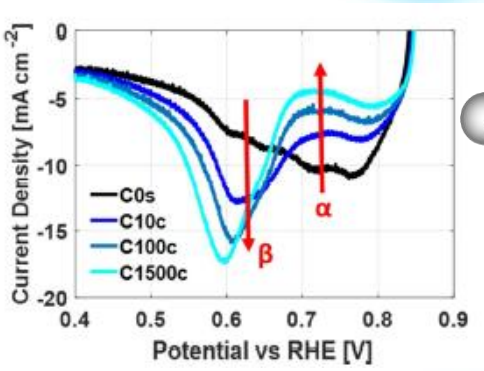
PROJECT PROGRESS/ACTIONS - Understanding and validation of degradation mechanisms

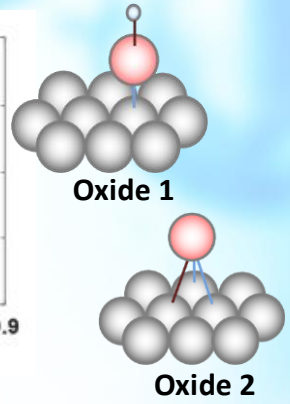
Coupling modelling and specific experiments

PtOx investigation for the interpretation of reversible losses



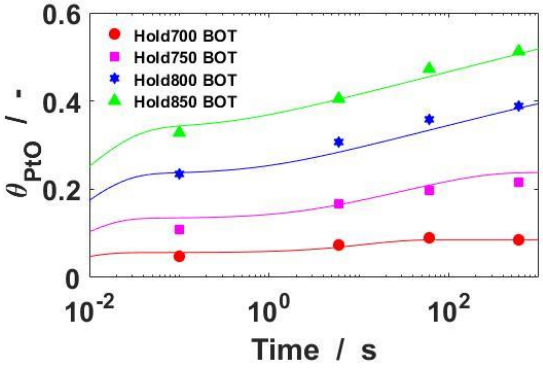




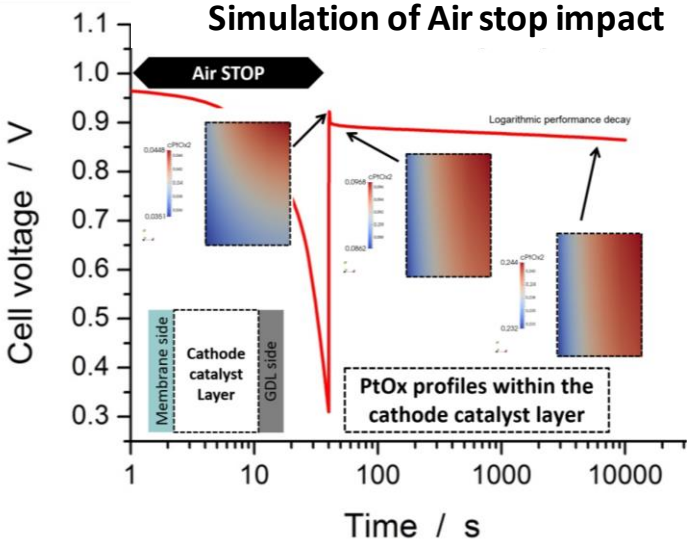


Pt oxide coverage evolution

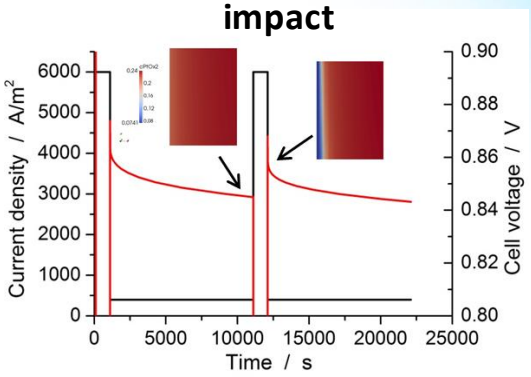
Experimental (symbols) and simulated (lines)



Simulation of Air stop impact



Simulation of load cycling impact



PROJECT PROGRESS/ACTIONS - Understanding and validation of degradation mechanisms

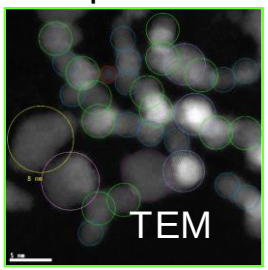
Second Act

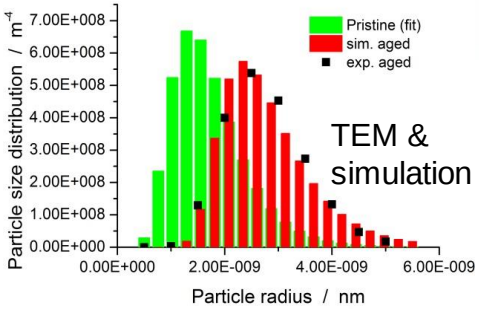
Coupling modelling and specific experiments

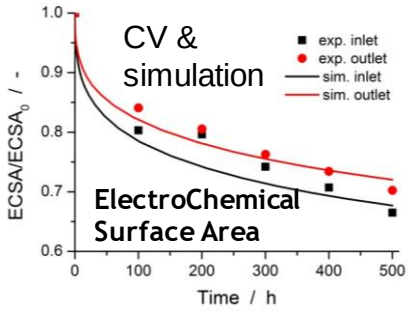
Catalyst Layers degradation after DMFC ageing

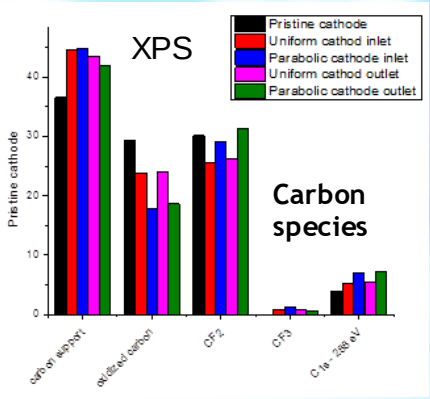
Measurements and simulation of materials modification and ECSA losses

Pt particles size

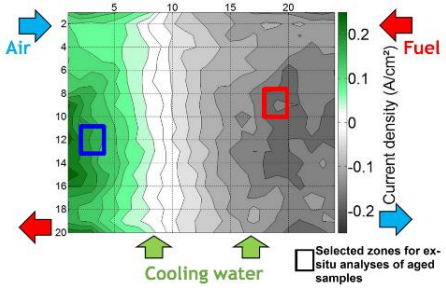


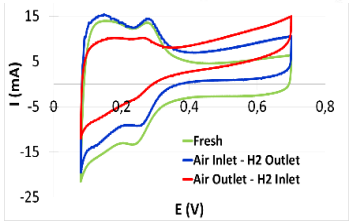




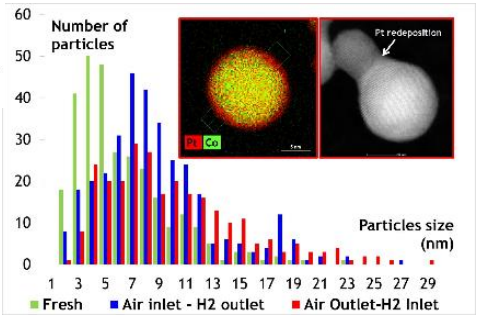


Impact of CO poisonning on degradation during ageing under reformate

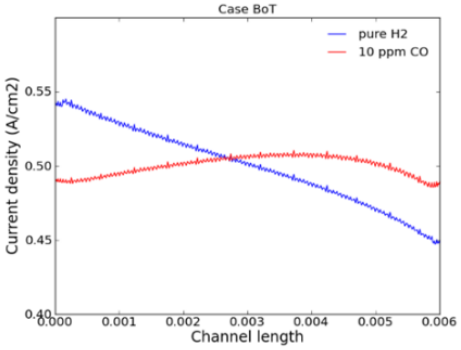


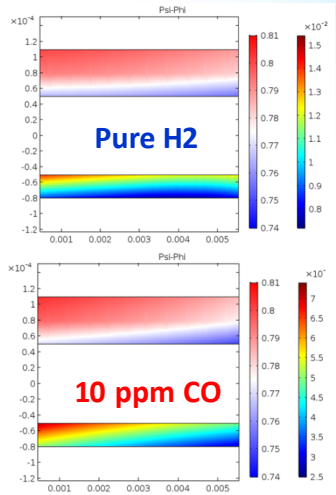


Analyses of local degradation by in-situ and ex-situ methods



Modelling of CO poisonning impact on current density distribution

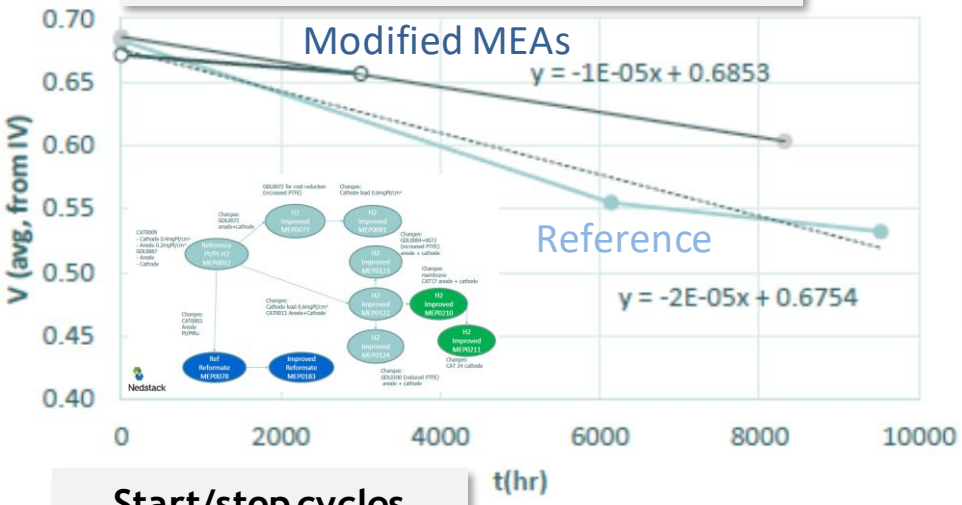




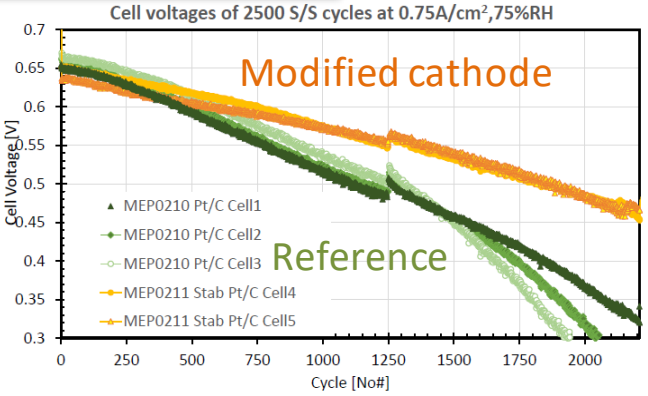
PROJECT PROGRESS/ACTIONS - Durability improvements demonstrated at stack level

Improved stability in PEMFC stacks

Fixed load operation in field test

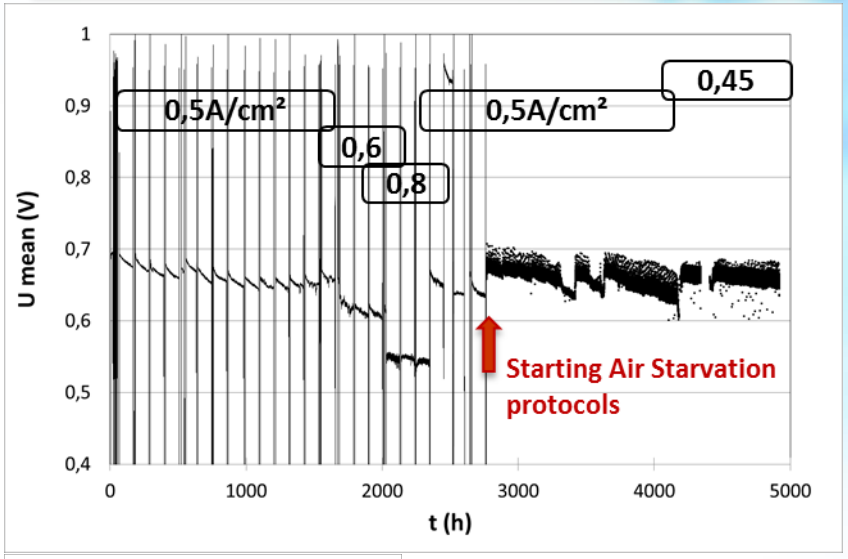


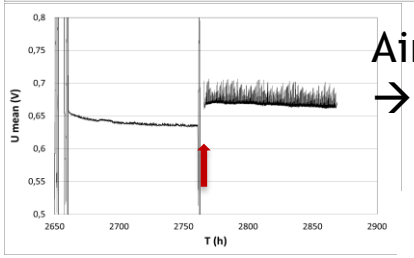
Start/stop cycles



Modified cathode catalyst → more stable performance in PEMFC stacks

Reversible losses at fixed load



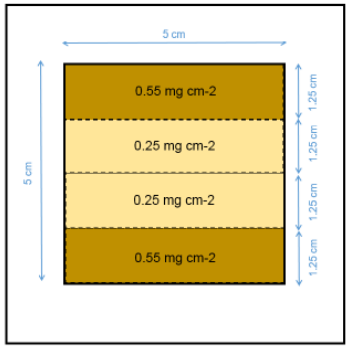


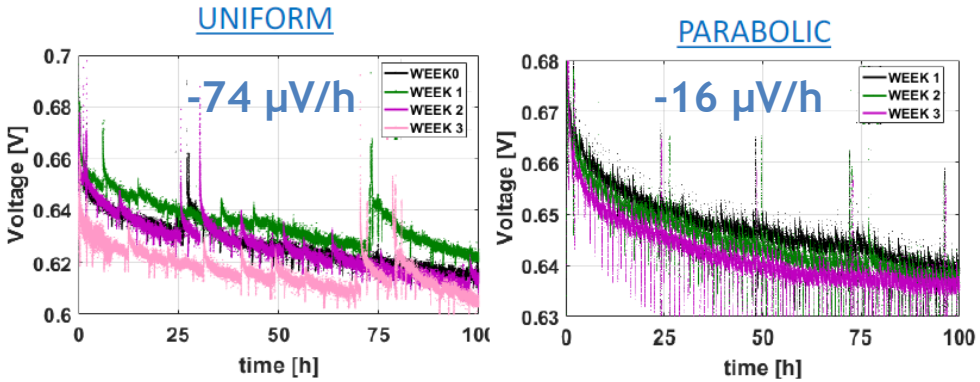
Air starvation → reduced reversible losses in PEMFC stacks

(total duration 4900hrs, total irreversible losses ~15µV/h @0,5A/cm²)

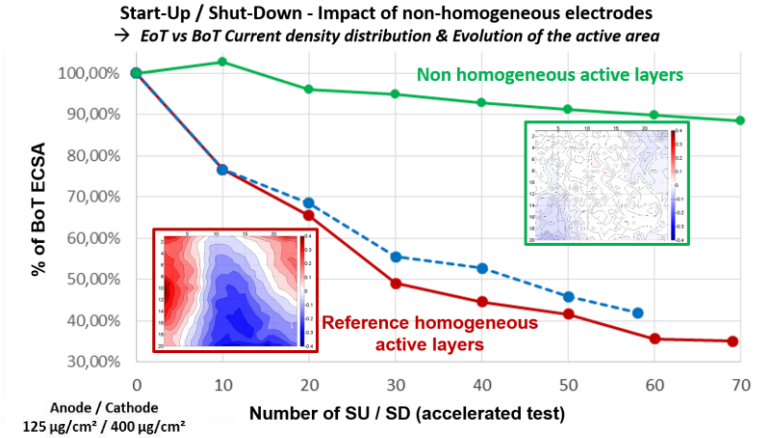
PROJECT PROGRESS/ACTIONS - Durability improvements with modified components

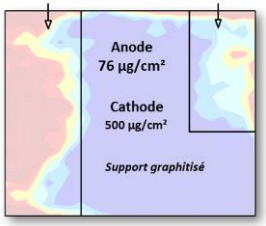
Reduced degradation with non-homogeneous electrodes

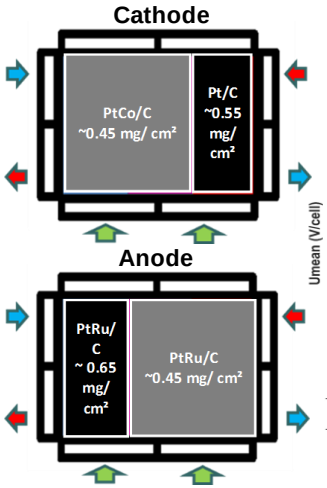


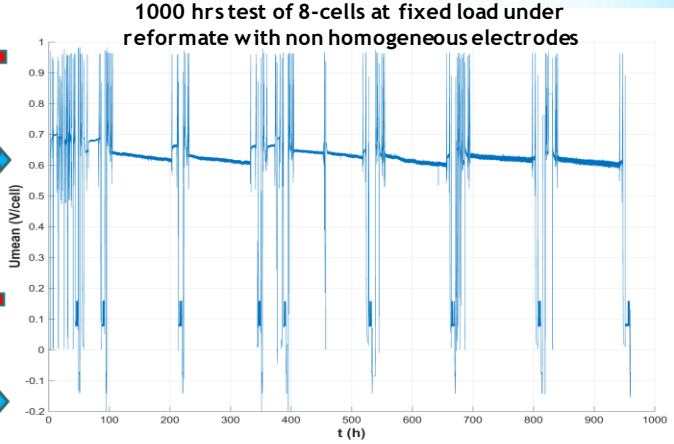


→ Applied on 180cm² cell









Modified cathode catalyst layer composition→ more stable performance demonstrated for both DMFC and PEMFC conditions

SYNERGIES WITH OTHER PROJECTS AND PROGRAMMES

- **Interactions with projects funded under EU programmes**

PremiumAct	Knowledge on methodology and protocols for degradation testing for H2PEM, Reformate PEM and DMFC
Keepemalive	Knowledge on methodology and protocols for degradation testing of PEMFC for stationary applications
Stayers	Knowledge on methodology and protocols for degradation testing of PEMFC for stationary applications
Pumamind	Methodology and knowledge for fuel cell development Interactions about the degradation models and mechanisms
Matisse	Joint development of segmented cell analyses by common partners (Nedstack and CEA) Contribution to Second Act first internal workshop (May 2016) - Nedstack S++® Results
Impact	Knowledge on discrimination of reversible/irreversible degradation Contribution to Second Act international workshop (held the 30th of January 2017 in conjunction to the 7th FDFC conference which took place in Stuttgart) P. Gazdzicki (DLR) – Degradation behavior of PEMFC
Stack Test	Recommendations on tests and data processing Contribution to Second Act international workshop (held the 30th of January 2017 in conjunction to the 7th FDFC conference which took place in Stuttgart) Jenz Mitzel (DLR) - Stack test – Development of tests and procedure to evaluate performance and durability
Hycora	Exchange about methods and analyses of fuel contaminants impact

- **Interactions with international initiatives**

collaboration with the EU harmonization activities related to fuel cell testing (development of hardware and protocols)

DISSEMINATION ACTIVITIES

Public deliverables

- ***D2.4 - Report on investigation of local degradation effects and on ex-situ analysis of mechanisms in pristine and aged samples***
- **D3.2 - Report on stack modelling with defaults propagation**
- **D3.4 - Report on local reversible mechanisms with interaction on irreversible degradation and durability validation at single cell level**
- ***D3.5 - Report on performance and durability modelling at stack level***
- ***D4.2 - Report on implemented improvements and analysis of their effect on durability***

Conferences/ Workshops

2 organised by the project

10 in which the project

Social media

www.second-act.eu

Publications: 4 (~30 communications in conferences)

- ***Effect of pinhole location on degradation in polymer electrolyte fuel cells*** - Merit Bodner; Christoph Hochenauer; Viktor Hacker (TU Graz). Journal of Power Sources (2015) 295, S. 336 – 348
- ***A combined in-situ and post-mortem investigation on local permanent degradation in DMFC*** - Fausto Bresciani (Polimi); Claudio Rabissi (Polimi); Matteo Zago (Polimi); Pawel Gazdzicki (DLR); Mathias Schulze (DLR); Laure Guetaz (CEA); Sylvie Escribano (CEA); Jacob L Bonde (IRD); Renzo Marchesi (Polimi); Andrea Casalegno (Polimi). J. Power Sources (2015)

Patents: 1

- Locally engineering PEM cells components with optimized operation for improved durability, 19/6/2017, PCT/IT2017/000120, Andrea Casalegno (Polimi), Claudio Rabissi (Polimi), Laila Grahl-Madsen (EWII)

Thank You!

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Concept

3 major aspects considered in order to improve the understanding on degradation and to propose effective stack improvements:

- The **active layers** are the components most critically affected by degradation
- **Heterogeneity in MEA operation** has a crucial role in determining the overall performance degradation
- A considerable fraction of **failures** has stochastic nature/characteristics, **caused by defects in components or critical events**, often associated to balance of plant (BoP) malfunctioning.

*The **lifetime improvements** expected at system level will be addressed here through modifications of the core components of the system, the **MEA**.*

Technical objectives /Expected results

- Analysing **long term lifetime tests data from existing systems** to identify main **causes for failure** related to system operation and **quantify performance degradation** of the stacks, over the long term (> 10,000 hrs)

- Conducting **lifetime tests to investigate degradation** at cell and stack levels and to better understand **mechanisms** involved.

- Developing, applying and **validating accelerated stress tests (AST) and specific tests representative of failures in harsh conditions**

- Developing and applying ***in-situ*** **and** ***ex-situ*** **investigation techniques for better identification and local resolution of the degradation mechanisms. Heterogeneities** considered over the cells surface and across the stacks.

- Developing **new statistical approach and models for better understanding and description** of systems **stochastic / deterministic** degradation, **reversible / permanent** degradation and **heterogeneities** of degradation in cells and stacks.

Technical objectives /Expected results

Second Act

Second Period

- **Demonstrating stack lifetime improvements** increased **tolerance to applications' relevant cycling or operating modes** (e.g. start/stop or idle), mainly through stack components modifications (in materials, components design, manufacturing processes…) for **Pure H2, Reformate PEMFC and DMFC**. For the improvements of Membrane Electrodes Assemblies that will be particularly considered as core components, two routes will be followed, one on **raw materials and manufacturing processes** to face mainly defects and one on **structured (non-homogeneous) electrodes and GDL** to face mainly degradation heterogeneities.
  - Improvements will address particular causes of performance degradation or sources of stack failure thanks to better understanding gained with experimental and modelling investigations
  - Improvements will be verified at cell and stack level in existing designs, following validated AST or specific harsh tests in conditions representative of the systems considered.

OPTIONAL SLIDES

You can use any of the following slides and insert them inside the presentation, otherwise delete them

RISKS AND MITIGATION

Second Act

Risk 1

Mitigation 1

Risk 2

Mitigation 2

Risk 3

Mitigation 3

EXPLOITATION PLAN/EXPECTED IMPACT

Exploitation

Explain

Impact

Explain

HORIZONTAL ACTIVITIES

Free slide illustrating activities on training, RCS (Regulations, Codes and Standards), public awareness, etc.