KeePEMalive
(GA no.: 245113)

Programme Review Day 2011
Brussels, 22 November

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SINTEF Materials & Chemistry

Project Information

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KEEPEMALIVE

Partner	Country	Category	
ECN	**NL**	**Research**	**Coordinator until 28th February 2011**
SINTEF	**NO**	**Research**	**Coordinator as of 1st of March 2011**
CNRS	FR	Research	
EIfER	DE	Research	
SEAS	DK	Industry	
IRD	DK	Industry/SME	
FumaTech	DE	Industry	
Tech. Univ. Graz	AU	University	
JRC, Petten	NL	Research	

SP1-JTI-FCH.2008.3.3: Degradation and lifetime fundamentals

Start date: 1 January 2010
Duration: 36/42* months
Cost: €2.9 million
FCH JU funding: €1.3 million
* *Prolongation request pending*

Goals, Targets and Milestones

KEEPEMALIVE's goals include establishment of:

- *improved understanding of degradation and failure mechanisms for stationary PEM fuel cells,*
- *accelerated stress test (AST) protocols, sensitivity matrix and lifetime prediction models*

Targets for µ-CHP systems based on Low Temperature PEMFCs:

- *Lifetime of 40 000 h under real operation conditions*

Milestones

- *M1: First set of AST protocols defined using input from real life operation*
- *M2: Identification of key degradation issues*
- *M3: Definition of improved AST protocols focussing on key issues*
- *M4: Materials improved with respect to key issues available*
- *M5: Availability of assessed AST protocols & lifetime prediction model*

RELIABLE LIFETIME PREDICTION WITHIN 400 HOURS

Activities & Approach

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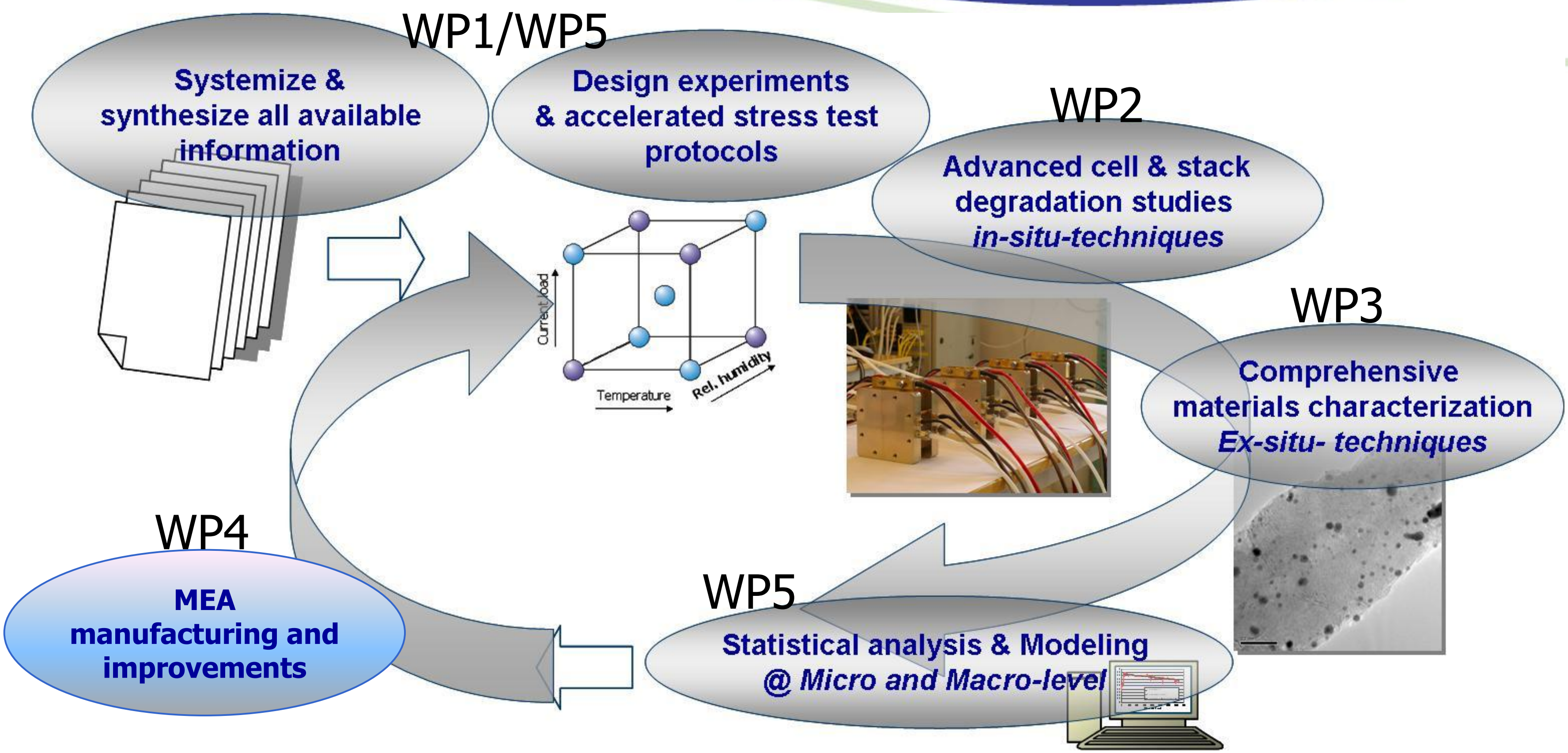
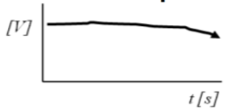
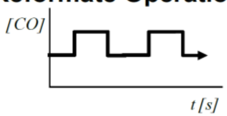
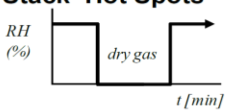
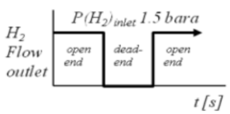
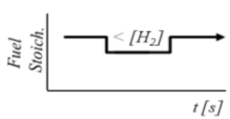
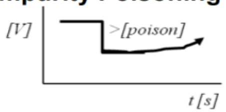
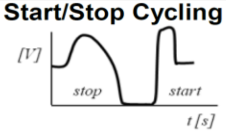
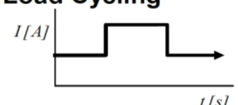
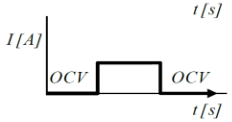


KEEPEMALIVE

Stressing Situation	*Accelerated Stress Test (AST)*
Continuous Operation 	Water Management (*i.e.* 'Flooding') , winter
Reformate Operation 	CO exposure
MEA drying / Stack 'Hot Spots' 	Humidity cycling
Dead-end H_2 mode 	Mechanical stressing, mimic hydrogen purge
Fuel Starvation 	Sub-stoichiometric Hydrogen Supply
Impurity Poisoning 	(Combined) Effect of Air pollutants, SO_2, and NH_3.
Start/Stop Cycling 	ON/OFF Cycle allowing air influx on anode (*i.e.* summer)
Load Cycling  	Load Cycling (*i.e.* fall, , spring) OCV cycling (summer)

WP 1: From real-life operation to experimental program

Main objective: To provide guidance for the experimental program and to define AST protocols. This will be achieved by:

- *Identification of relevant operational conditions for µ-CHP and related stationary applications*
- *Definition of the experimental program and establishment of AST protocols*

Main achievement:

Initial set of AST protocols identified based on conditions found to be detrimental during real-life operation of PEMFCs for µ-CHP applications

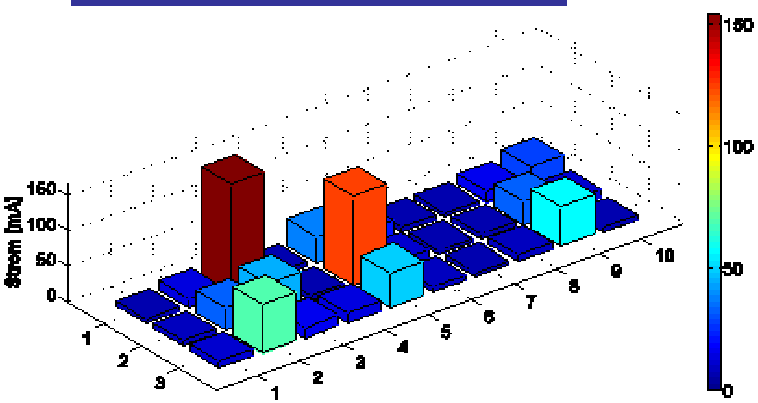
WP 2: Accelerated Stress Tests on stacks and single cells

Main objective: To obtain quantitative data on the impact of stressing conditions by application of AST protocols to single cells and stacks

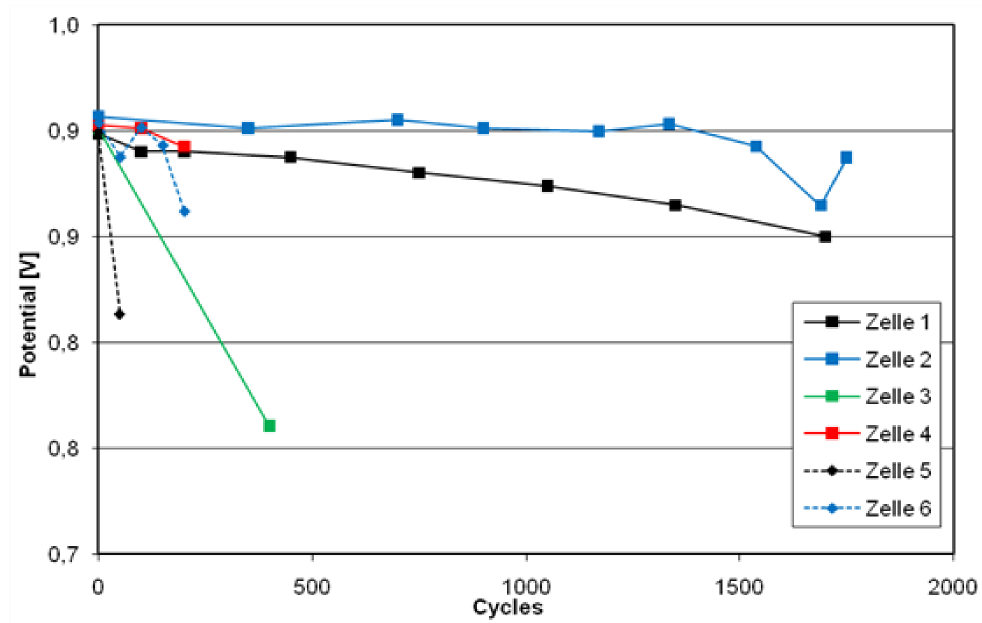
Main achievement: Initial test program to be completed in November 2011

Example of results, fuel starvation protocol tested in segmented cell

85°C, 40%RH, 0,4A/cm²



FS5: current density distribution during EOL hydrogen diffusion measurement



Comparison of decreasing cell voltages at 5 mA current density of all test cells

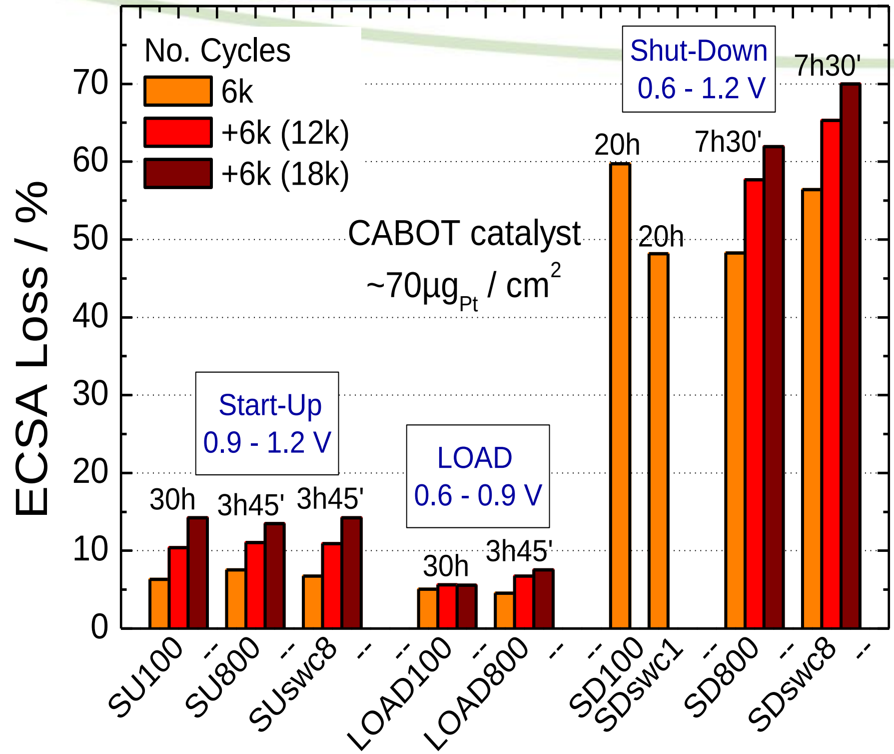
WP 3: *Ex-situ* characterization of materials

Main objective: To characterize MEA and stack components at beginning-of-life, end-of-test and end-of life

- *to develop ex-situ accelerated ageing tests for individual MEA component (bipolar plate, C-supports, supported catalysts, membranes)*
- *to relate operation conditions to ex-situ characterization observations*

Main achievements:

- Post mortem studies revealed most vulnerable areas of MEAs
- Improved AST protocols for catalyst stability



Example: Catalyst stability (CABOT) as function of potential cycling. Identi-fication of optimized AST procedure

Technical Accomplishments & Progress

WP 4. Preparation and improvement of MEAs and components

Objectives:

- To provide state of the art membranes, electrodes, MEAs and stacks.
- To develop and provide improved individual materials, MEAs and stacks with higher durability.

Main achievements:

- Improved membranes provided based on testing of 4 candidates
- Selection of improved catalyst materials from Tanaka (Japan)

WP 5. Design and evaluation of experiments

Objectives:

- Identify critical operating conditions for PEM fuel cell stacks
- Propose new Accelerated Stress Tests (AST) for PEM fuel cells
- Develop lifetime prediction models

Main achievements

- Provided experimental design incorporated into initial AST protocols.

Correlation with AA-S MAIP

Part 2, slide 1 of 4

- **MAIP Section 3.4.3 Stationary Power Generation & Combined Heat & Power:**

" The overall objective of this application area (AA-S) is to improve the technology for fuel cell stack and balance of plant components to the level required by the stationary power generation and CHP markets by bridging the gap between laboratory prototypes and pre-commercial systems."

"The goal of this application area is to achieve the principal technical and economic specifications necessary for stationary fuel cell systems to compete with existing and future energy conversion technologies. For example: electrical efficiencies should be >45% for power only units and >80% for CHP units, combined with lower emissions and use of multiple fuels. In addition, substantial effort is needed to address lifetime requirements of 40,000 hours for cell and stack, as well as competitive costs, depending on the type of application."

" Long-term and breakthrough orientated research will concentrate on degradation and lifetime fundamentals related to materials and typical operation environments for all power ranges.

Correlation with AA-S AIP08

Part 2, slide 2 of 4

- **AIP08 Section 2.2 Specific topics for the 2008 Call for proposals:**

*"The emphasis of the application area Stationary Power Generation will be on **long-term basic research to better understand degradation/failure mechanisms and the lifetime requirements of all technologically mature fuel cell stack types** (SOFC, MCFC, **PEMFC**) for different fuels and levels of power.*

***For lifetime predictions, research is necessary to establish methodologies as well as tools for modelling**, operational controls **and diagnostics**. **Research should result in novel diagnostic** and control **tools and improvements of components** and systems **in terms** of functionality, performance and **lifetime**.*

Project Achievements vs. MAIP/AIP

Part 2, slide 3 of 4

- **KeePEMalive has:**

- *gathered highly skilled European actors in a fruitful Pan-European cooperation*
- *established an overview of real-life operation conditions for µ-CHP applications*
- *manufactured and improved Membrane and Electrode Assemblies (MEAs)*
- *linked up to leading Japanese catalyst manufacturer Tanaka*
- *developed an initial set of Accelerated Stress Test (AST) protocols, to be revised*
- *identified the key stressors causing degradation through*
    - *field tests with PEM fuel cells for µ-CHP applications*
    - *comprehensive in-situ single cell testing, incorporating long-term test*
    - *ex-situ characterization of cells and corresponding material changes*
- *tested commercial materials as bench-mark for MEAs developed in consortium*
- *provided feedback to project partner on MEAs performance and durability*
- *and thereby* ***achieved better understanding of degradation/failure mechanisms and valuable input for developing a lifetime prediction model***

Gaps & Priorities in RTD&D in MAIP/AIP

- **KeePEMalive has identified the following gaps/bottlenecks:**
  - *Need for improved understanding of mutual influence of operational conditions on degradation*
  - *Combined effects of chemical and mechanical degradation*
  - *Acceleration of degradation rates*
  - *Relevance of ex-situ degradation test with respect operation in real life*

- **Comments on priorities in terms of technical challenge**
  - *Within the framework of the KEEPEMALIVE project, priority is put on improved accelerated stress test protocols for fuel cells and materials*
  - *Combined effects and mutual influence of stressing conditions will be addressed, but the area is too wide to be covered completely within the project*

Training and Education

- "International Summer School on Advanced Studies of Polymer Electrolyte Fuel Cells", TU Graz, 30th August 2010: Integrated with KeePEMalive project activities. KeePEMalive project presented by Gaby Jansen

Safety, Regulations, Codes and Standards

- KeePEMalive activities are directed towards establishment of new stress test protocols

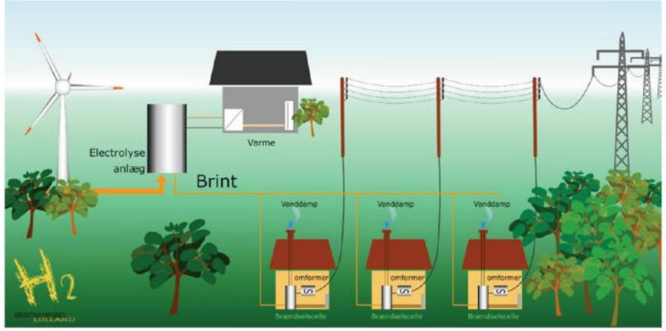
Dissemination and public awareness

- Public website www.keepemalive.eu, launched by ECN in February 2010.
- G.J.M.Janssen, "*Knowledge to Enhance the Endurance of PEM Fuel Cells by Accelerated Lifetime Verification Experiments*", Progress MEA 2010, La Grande Motte, France, 2010
- Poster presentation of KEEPEMALIVE at the FCH JU SGA in Brussels 9 -10 Nov. 2010
- A.M. Svensson: "*The KeePEMalive Project*", Presentation at Public Workshop on PEM Fuel Cells/DeCode final workshop, Gothenburg, Sweden, March 24th 2011.
- I. Mayrhuber, A. Stadlhofer, R. Strasser, V. Hacker, "*Degradation of PEMFCs operated under Fuel Starvation Conditions*", 62nd Annual ISC Meeting, Sept. 2011, Niigata, Japan.
- A. Ødegård, "*Experiences from AST in PEMFC*", 2nd INTERNATIONAL WORKSHOP ON DEGRADATION ISSUES OF FUEL CELLS, 21-23 Sept. 2011, Thessaloniki, Greece.

Technology Transfer / Collaborations

<u>The KeePEMalive project is linked to and interacts with a Danish µCHP demonstration project</u>

seas nve
Bass Baltic Sea Solutions
Danfoss
lollandkommune



IRD
Fuel Cell Technology

"Vestenskov
– the world's first hydrogen community"

3 Phases:

i) Electrolyzer for hydrogen production from wind (2006-2007)

ii) 5 selected homes equipped with µCHP (2007-2010)

iii) 35-40 selected homes equipped with µCHP (2010-2012)

Collaborations and links, KeePEMalive project:

- An active collaboration with the Japanese catalyst manufacturer Tanaka is formalized via FUMATECH, partner of the KeePEMalive project
- KeePEMalive has established contact to the networking group for US-DoE projects on Degradation of PEMFCs (Dr Silvia Wessel at Ballard). Participation in Workshops is planned for the future.
- Informal collaboration and exchange of information between FHCJU funded projects "STAYERS" and "DECODE" through partners SINTEF & JRC
- Link to previous work on testing protocols performed within framework of FCTESTQA

KeePEMalive's Future Perspectives

- Iterative approach ensures robust development and allows for tuning of ASTs
- Inter-laboratory variance higher than expected, need to increase reproducibility and carry out replicate measurements to ensure reliable data
- Contingencies needs to be considered to identify optional paths or off ramps
- Extra administrative workload related to replacing ECN as coordinator
- Delays in some deliverable. Corrective actions: Re-distribution / Amendment
- Increasing cooperation at EU, Member States or Regional will be pursued
- Alliance with industry realized through Tanaka, other similar alliances to be assessed towards industry, government, research centers, SMEs.
- Possible contribution to the future FCH JU Programme
  - *More reliable AST-protocols for stationary PEMFCs*
  - *Lifetime Prediction Model, code made available for use in new projects*