Long-life PEM-FCH &CHP systems at temperatures ≥100°C (G.A. 245339)

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Application Area: SP1-JTI-FCH.3: Stationary Power Generation & CHP

Project type: Research and Technological Development

Topic: SP1-JTI-FCH.3.3 Degradation and lifetime fundamentals

Start date: 01-01-2010 End date: 31-12-2012
Duration: 36 months

Project total costs: € 2.927.174

Project funding: € 1.360.277

Partner number	Partner name	Country
1 (coordinator)	CNR-ITM (CNR)	Italy
2	The University of Roma “Tor Vergata” (URoma2)	Italy
3	Aix-Marseille Université (UProvence)	France
4	The University of Saarbruecken (USaar)	Germany
5	Edison	Italy
6	Fumatech	Germany
7	MATGAS 2000 A.I.E. (MatGas)	Spain
8	Cracow University of Technology (CUT)	Poland

Project Structure

URoma2

CNR
Fumatech
UProvence
Usaar

WP1 – Long-life membranes for PEMFCH

MatGas

WP3 – Life-time tests and prediction techniques, establishment of accelerated test technique

Usaar
Edison
CNR
Fumatech

Usaar

WP2 – New concept of MEA with improved durability

CNR

CUT

WP4 – Dissemination and exploitation of results

URoma2
Fumatech
UProvence
Usaar

Edison MatGas CNR

Project goals, targets, and milestones

The **main objective** of the present project is to give a clear demonstration that **long-life SPG&CHP systems based on PEMFCHs operating at temperatures ≥ 100°C can now be developed** on the basis of recent knowledge on the degradation mechanisms of membranes disclosed by some participants in this project.

Milestones

Milestone no.	Milestone name	Delivery date from Annex I
M1	Kick off meeting	achieved
M2	PFSA membrane stability ex-situ test	achieved
M3	SAP membrane stability ex-situ test	achieved
M4	Single PEMFCH design and building	achieved
M5	Modular multi-cell system design and building	achieved
M6	Degradation and lifetime test	achieved
M7	Innovative MEA operating above 100°C	achieved
M8	Cost of use and discard MEA	achieved
M9	Publications, patents, conferences	During the project activity

Specifications foreseen in LoLiPEM project

PEM parameters	PFSA	SAPs
	End of project	End of project
operating temperature of membrane (maximum)	120°C	140°C
operating temperature in fuel cell (maximum)	120°C	140°C
membrane conductivity @ 90%RH	> 0.1 S/cm	> 0.07 S/cm
liquid water uptake @ 100°C	40%	< 50%
mechanical integrity @ RH cycling and condensing conditions	Yes	Yes
MEA performance @ 0.65 V	0.7 A/cm²	0.7 A/cm²

To improve the durability and stability of the MEA at a temperature higher than 100°C, the following new strategies have been applied :

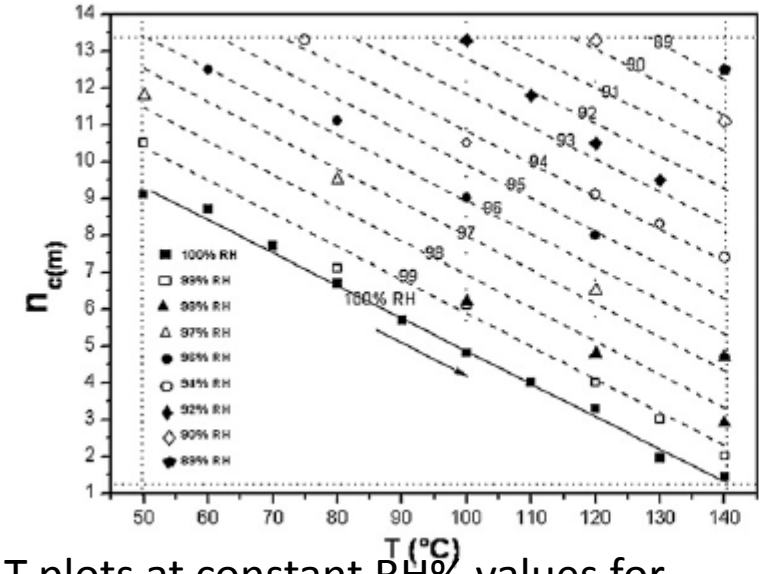
For membranes:

- Thermal annealing & Chemical cross-linking

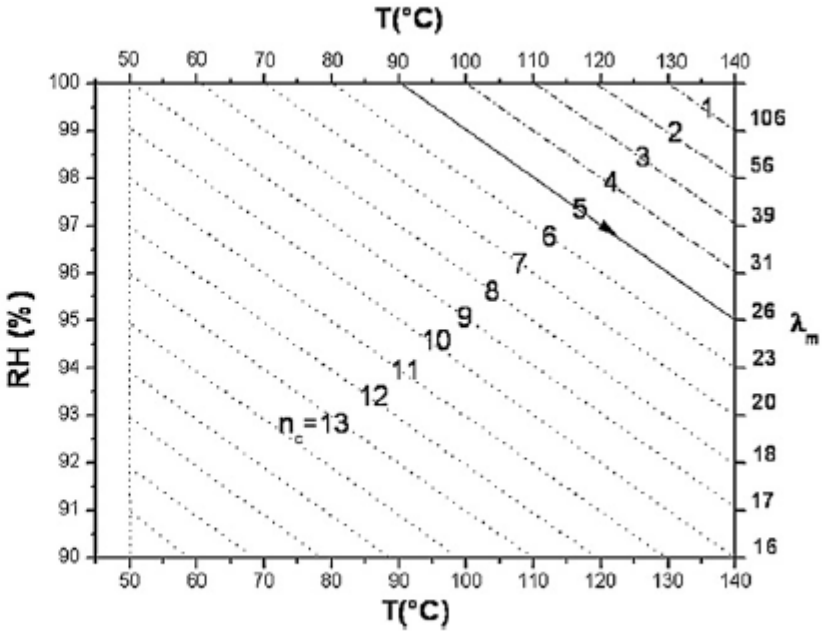
- For the catalyst
  - novel electrodeposition techniques from precursor layers, which enables to deposit electrocatalysts directly onto gas diffusion layers (GDL) and thus transforms them directly into gas diffusion

- For MEAs
  - Novel procedure for MEA preparation including pre-treatment of the membrane, slow heating and cooling during the hot pressing

PFSA MEMBRANE

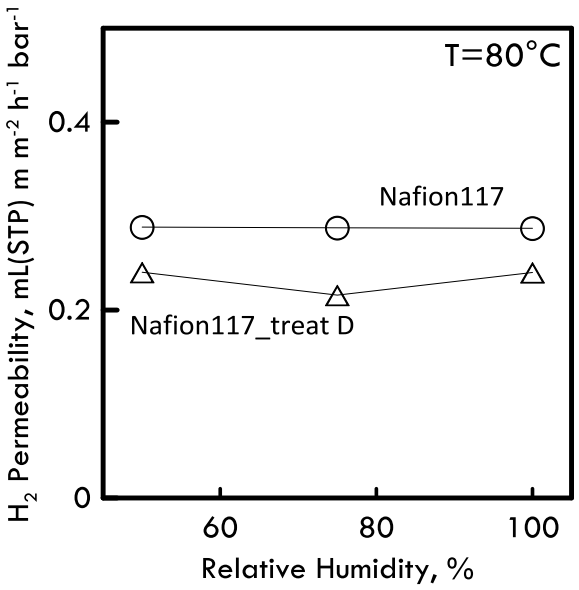


n_c - T plots at constant RH% values for Nafion 117 membrane (annealed at 120°C for 15 h)

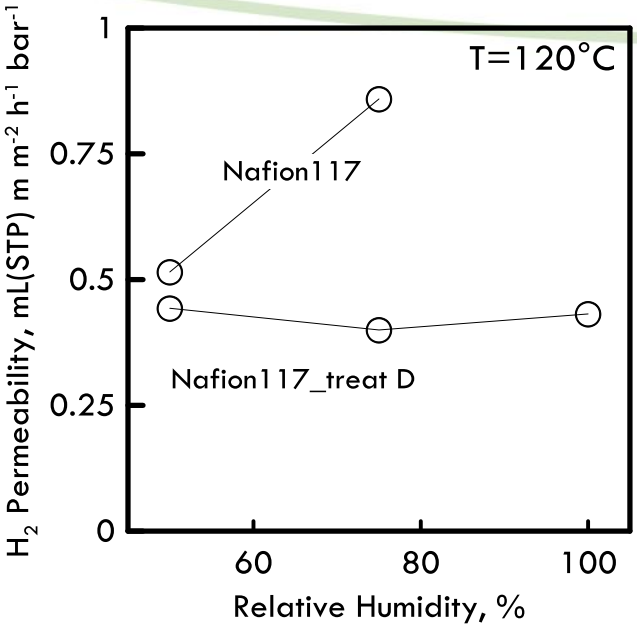


Conversion of the left plots in T-RH% plots for constant n_c values. The zone with n_c values <6 represents an instability zone for temperatures >80°C when RH% = 100.

PFSA MEMBRANE

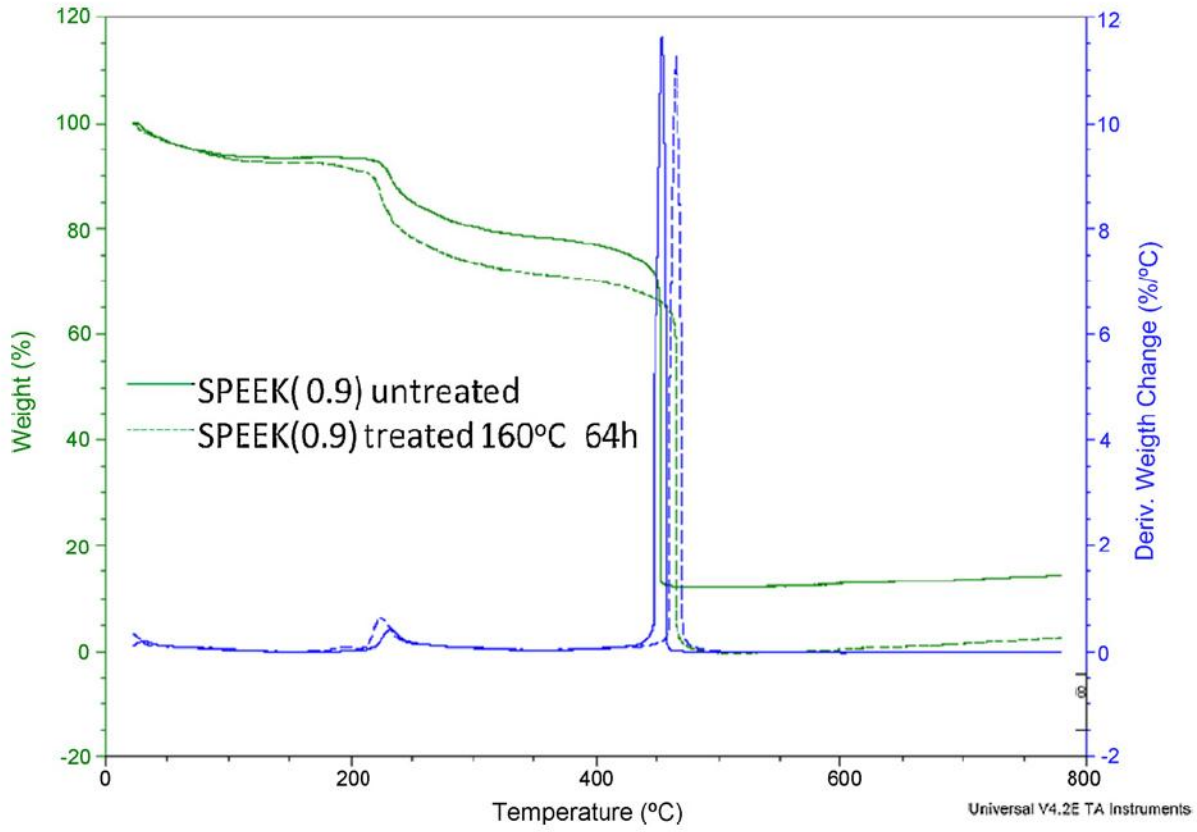


Globally, the Nafion 117 thermally annealed showed a lower permeability than Nafion at all the operating conditions investigated.



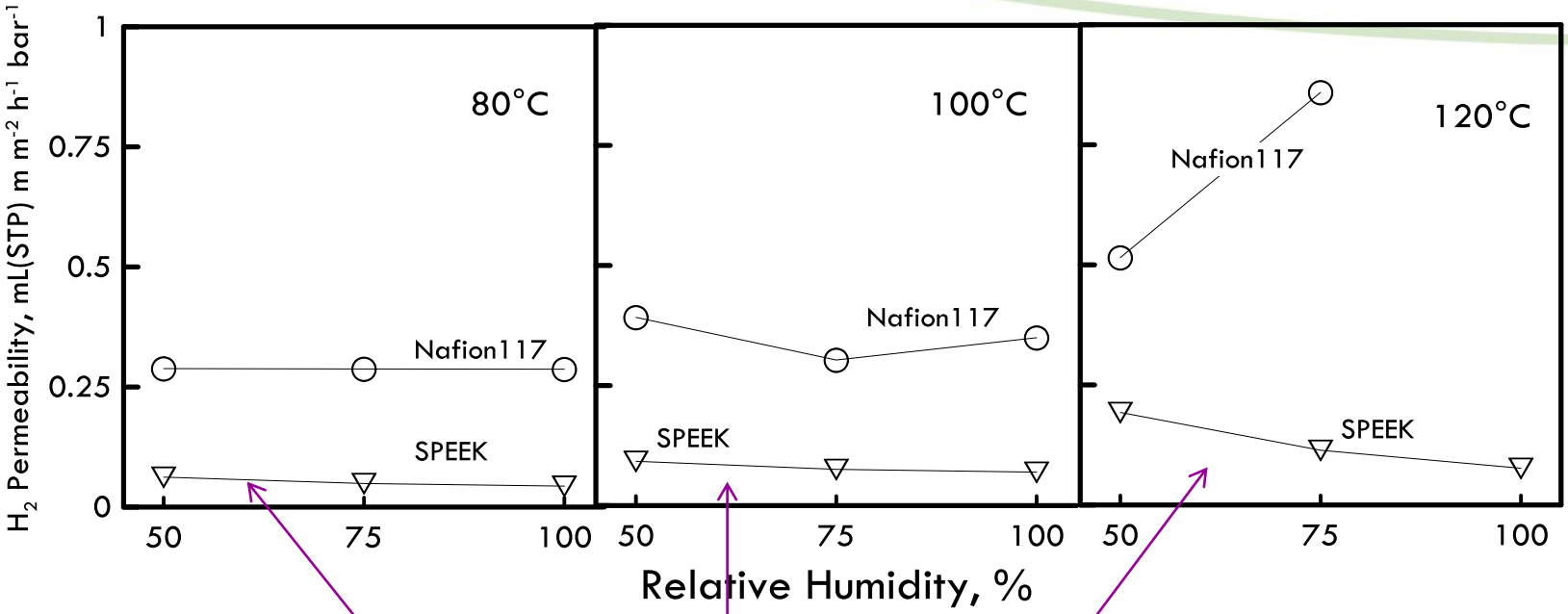
At 120°C, the Nafion thermally annealed continued to exhibit a stable trend contrarily to what happened for the Nafion that showed an unstable behavior yet at RH equal to 75% and was broken at RH of 100% .

SAP MEMBRANE



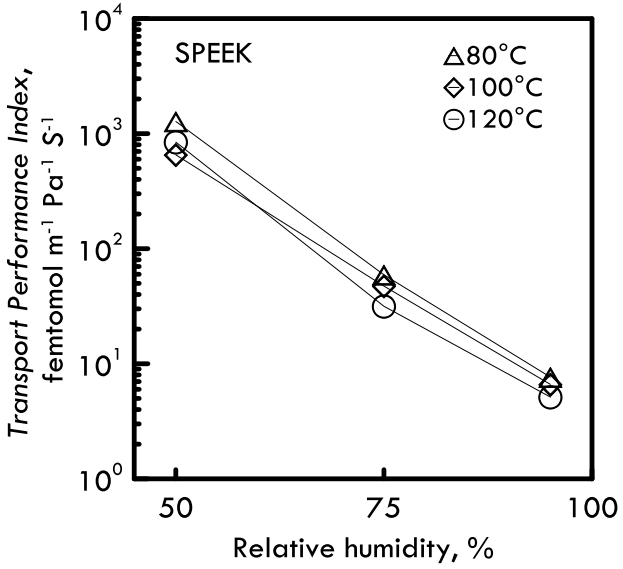
Comparison of thermogravimetric curves for untreated (solid line) and annealed (dashed line) SPEEK with initial DS = 0.9. The reduction of second mass loss due to sulfonic acid groups for annealed SPEEK can be related to the degree of cross-linking between macromolecular chains.

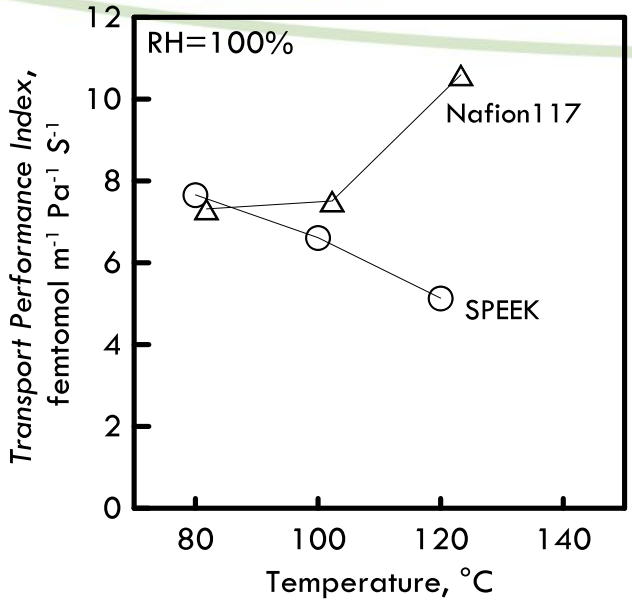
SAP MEMBRANE



SPEEK shows a lower permeability than Nafion 117 at all the operating conditions investigated.

$$Transport\ Performance\ Index\ (TPI) = \frac{2 \cdot H_2\ Permeability}{Proton\ conductivity}, \qquad mol\ s^{-1}\ Pa^{-1}\ S^{-1}$$





The comparison of TPIs between SPEEK and native Nafion 117 highlighted the advantage offered by the SPEEK membrane.

- The TPI of SPEEK got the higher value at 80°C, afterwards it started to decrease as the temperature increased.
- the Nafion117 membrane, starting at 80°C from the same value of SPEEK, exhibited an increasing trend in the whole temperature range.
- *TPI* of the SPEEK, was always lower than the Nafion117 one, for temperature higher than 80°C

MEMBRANE

	Permeability (barrer) @ 100% RH		
	H_2	O_2	N_2
Nafion 117	118	64.3	29
Nafion 117 thermally annealed	87.6	38.9	22.5
SPEEK – Thermally annealed	15.9	3.5	4.3
SPEEK-WC(0.86) no CL	20.2	7.44	3.85
SPEEK-WC(0.86) CL with DAMP for 1.5 h	16	5.6	Under detection limit

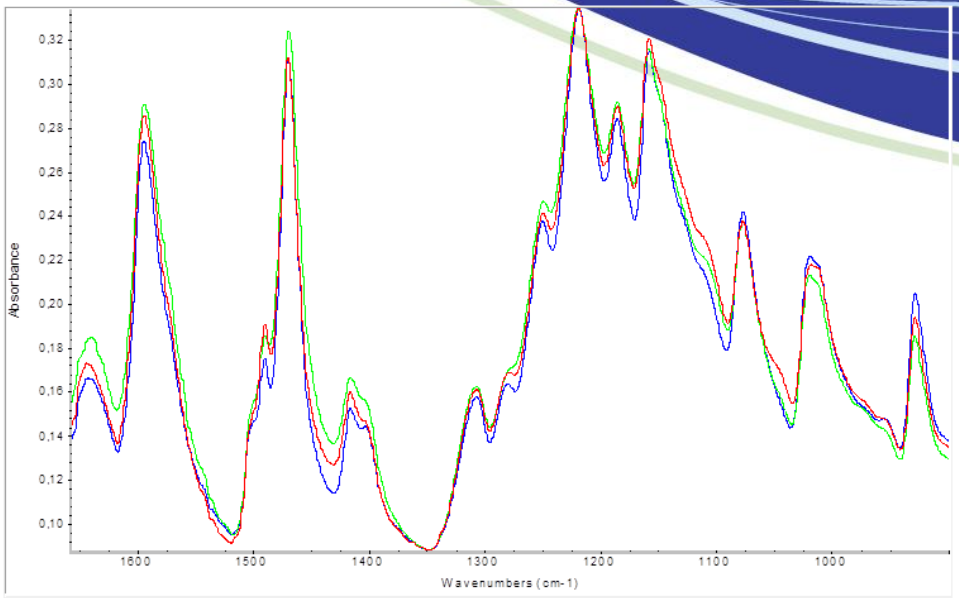
MOPEM

The MoPEM-CHP system has been designed as an innovative stack for the easy replacement of PEMFCHs and the facilitated use and discard of MEA.

The system is designed to allow adiabatic operations maximizing the recovery of heat produced.

The elements of the MOPEM have been properly designed for the innovative configurations of the system.

Post Mortem analysis ... some results



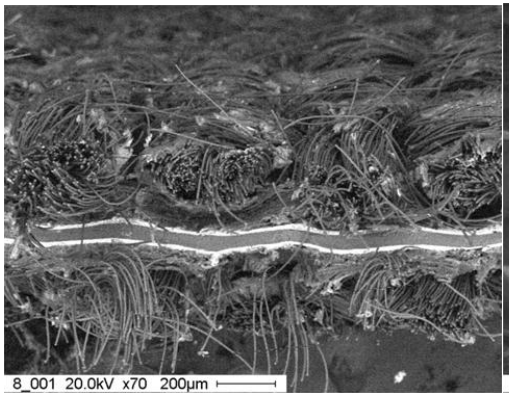
The FT-IR/ATR spectra of **SPEEK BM50/MEA active area** (green line), **SPEEK BM50/MEA no-active area** (red line) and **SPEEK LP29** (blue line, bare membrane) do not show any significantly difference

SEM images:

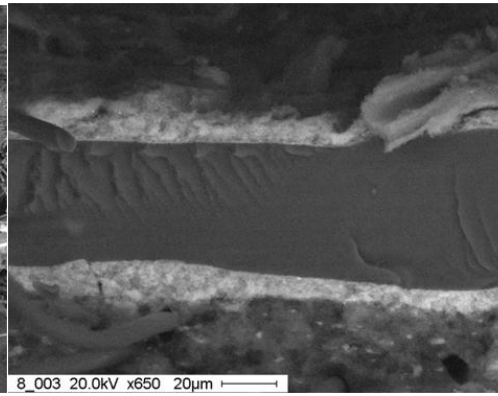
membrane SPEEK BM50

anode and cathode: ELAT E-TEK+SPEEK

SEM/BSE images do not show Pt particle penetration inside the membrane

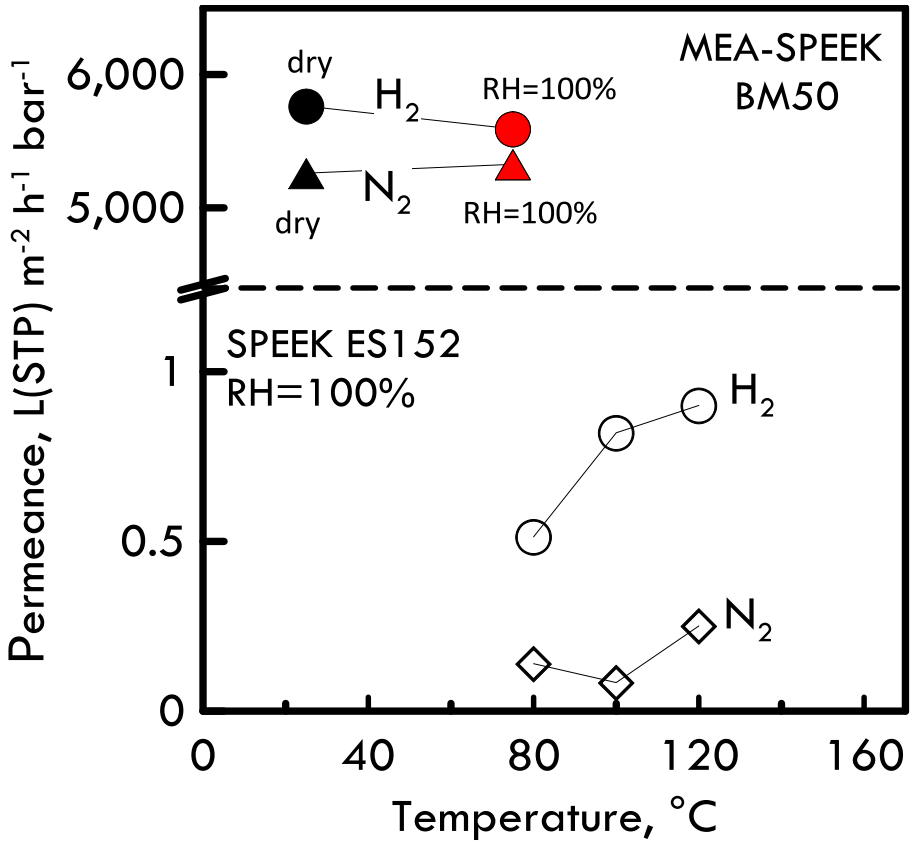


Magnification x70
SEM – BSE detector



Magnification x650
SEM – BSE detector

Post Mortem ... some results



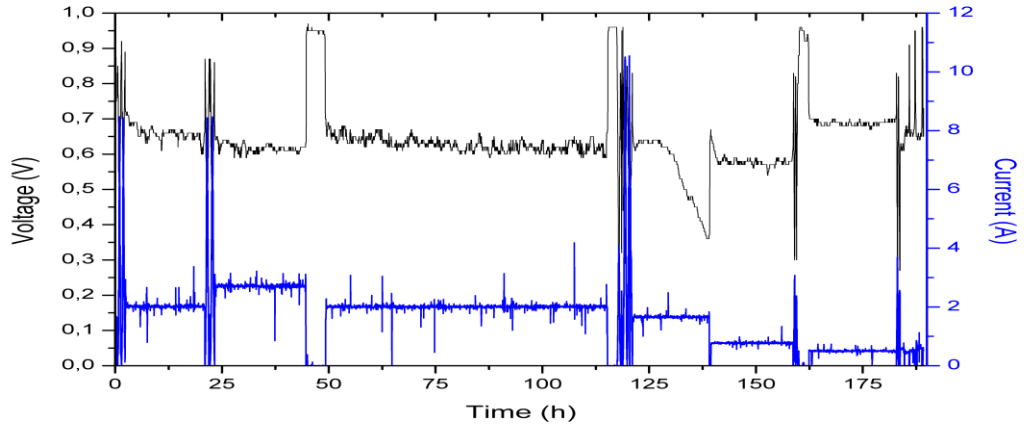
The permeances exhibited by the MEA is more than **3 order** higher than the ones measured on a membrane similar to the one present in the MEA.

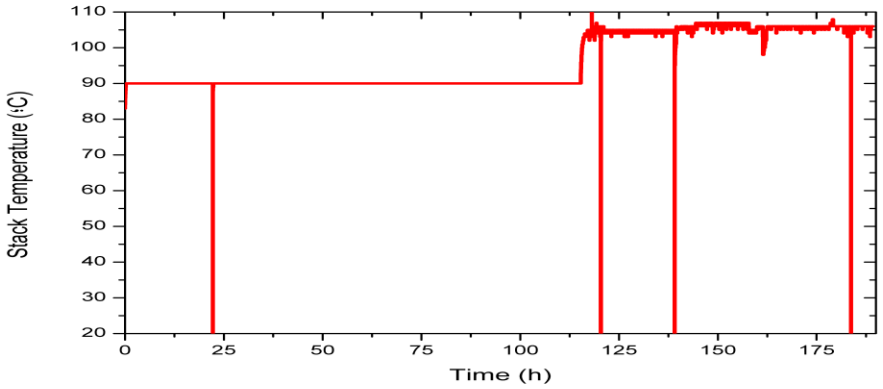
This behaviour confirms the presence of macrodefects in the membrane inside the MEA.

Long term testing

MEA	Origin	Activation	Max T_Stack	Duration
ELE0162/NR212/ELE0070 **Nafion thermal annealed**	**USAAR/ URoma2**	**24h at room T**	**105ºC**	**189.23h**

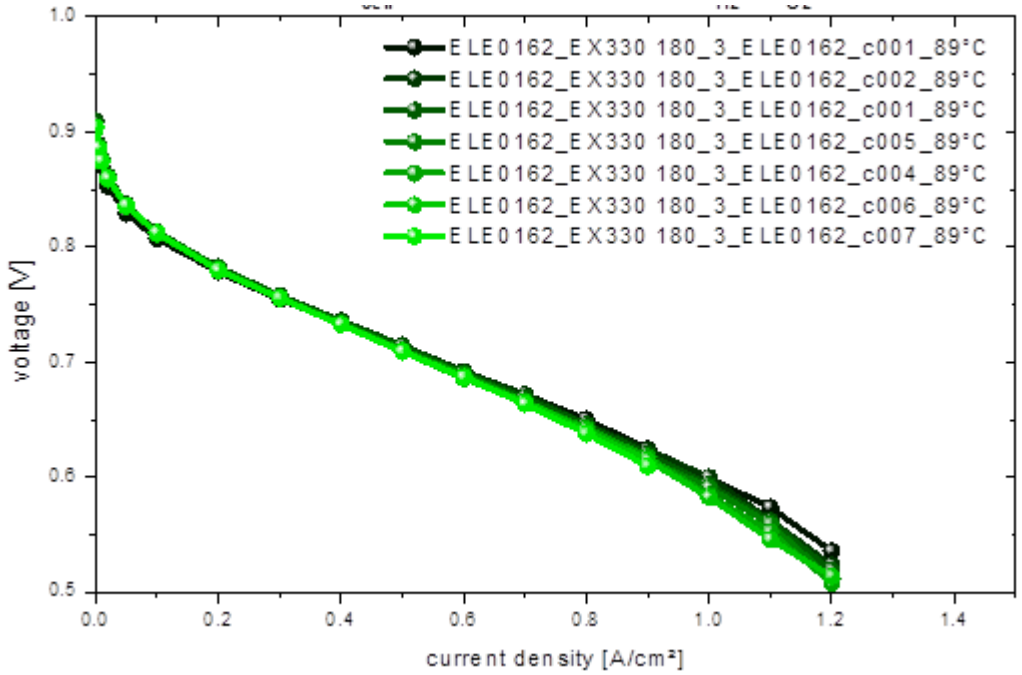
Successful tests carried out at 105°C





Electrical Measurement

- Polarization Results



- 0.8 A cm^{-2} @ 650 mV
- 0.4-0.5 mΩ

Alignment with MAIP

MAIP Section 3.4.3 Stationary Power Generation & Combined Heat & Power

The overall objective 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.

MOPEM

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

New membranes and electrodes

The aim will be to deliver new or improved materials as well as reliable control and diagnostics tools both at component and system levels.

Strategy for Post mortem analysis

Research and technological development will be directed towards developing components and sub-systems as well as novel architectures for cell and stacks leading to step change improvements over existing technology in terms of performance, endurance, robustness, durability and cost for all technologies.

New membranes and electrodes

MOPEM

Alignment with AIP

SP1-JTI-FCH.3: Stationary Power Generation & CHP

Development of control and diagnostics tools for operational performance including degradation and lifetime prediction (PEMFC, MCFC, SOFC technologies).

- Durability tests
- Accelerated tests
- Strategy for Post mortem analysis

Development activities on component and system in order to meet application-relevant functional and performance criteria (PEMFC, MCFC, SOFC technologies).

- New membranes and electrodes
- MOPEM

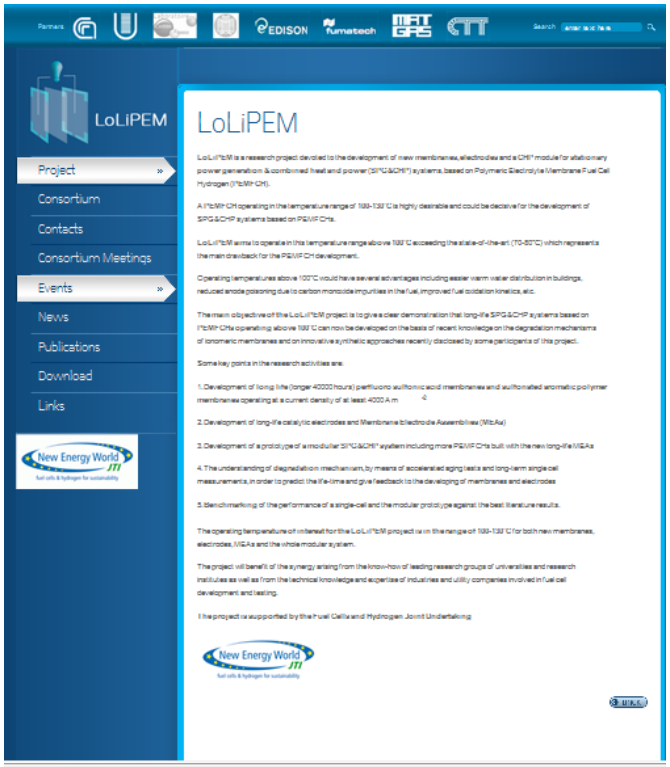
Research on factors impacting the degradation and lifetime of stacks (SOFC, PEMFC, MCFC technologies); exploration of synergies with back up and UPS units.

- Strategy for Post mortem analysis

Some of the major results

PEM parameters	PFSA	SAPs
operating temperature of membrane (maximum)	140°C	140°C
operating temperature in fuel cell (maximum)	105 °C	115°C
membrane conductivity @ , 90%RH	0.03 S/cm	0.091 S/cm SPEEK (180°C – 10 h)
liquid water uptake @ 100°C	32%	48% SPEEK (thermally treated at 180°C–20h) 25% (SPEEK-WC) 18% (SPEEK, Fumion E-490)
mech. integrity @ RH cycling and condensing conditions	Yes	Yes
MEA performance @ 0.65 V	0.8 S/cm still after 180 h	0.8 S/cm

Dissemination & public Awareness



The web site www.lolipem.eu is operative and the project brochure has been printed and is available as pdf file

Dissemination of project results through conference presentations, publication in high impact international journals

Training/education of various fellowship and post-doctoral researchers in materials science, processing of ionomers, characterisation of polymer and inorganic electrolytes

Technology Transfer / Collaborations

- Information letter on the LoLiPEM project was sent to 197 European stakeholders in the field of hydrogen fuel cells technologies such as European and national Technology Platforms, NEW-IG members & supporters, N.ERGHY, companies, institutions.

- The exploitation activities foresaw a comprehensive definition of market-oriented aspects of the developed technologies of Fuel Cells and are summarised in “the strategy of exploitation”. The strategy put attention on potential markets, business models and management of IPR issues emerging during implementation of the project.

Thank you for your attention