PEMICAN Project
(GA n°256798)

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www.pemican.eu

PEMICAN OVERVIEW

- PEM with Innovative low Cost core for Automotive applicatioN
- Overall purpose: Reduce Pt cost of PEMFC down to ideally 0.15 gPt/kW for automotive application
- Topic SP1-JTI-FCH.2009.1.3: Development and optimisation of PEMFC electrodes and GDLs
- Start/end dates: 01/04/2011 ➔ 31/03/2014 ➔ project is finished
- Budget:
  - € 3,96 million
  - FCH JU contribution € 1,86 million
  - no other funding

cea liten

OPEL Wir leben Autos.

SOLVAY asking more from chemistry®

TIMCAL GRAPHITE & CARBON

tecnalia

Imperial College London

Technological targets and achievements

Status before project	AIP target	Project Target	Current status/achievements/ comments
~ 1	Pt cost ~ 0,15 gPt/kW	0.15 (@0,675 V, H_2/air, 80°C, 50%RH, Stoe 1,2/2)	0.5 (0.3 seems feasible) W/cm² and µV/h are more important than gPt/kW 1W/cm² (AUTOSTACK)
	Ensure durability under dynamic operation (5000 h)	Loss = 5-10% of initial perf ~ -30 µV/h Stress test is used (DECODE)	Reached ~ -33 µV/h (1000 h) Strongly depends on test protocol
~ 500	Pt loading ~ 100 µgPt/cm²	100 µg/cm²	Reached
	Contribute to the development of European Industry solutions	Promote Aquivion^R ionomer (Solvay) and Carbon Blacks (Imerys Graphite & Carbon)	Reached, some potential interest demonstrated Some commercial launches are planned

Scientific targets and achievements

Status before project	AIP target	Project Target	Current status/achievementS
No clear information on proton resistance in the active layer	Study proton conduction in the active layer	Develop innovative test stand.	Reached, test stand is operational. First results on H^+ resistance have been obtained.
Link local properties of active layer/ performance is unclear	Improve modeling	Improve performance modeling	Partially reached (more reliable inputs)
		Develop innovative Pore Network Model of cathode catalyst layer.	Reached Link local properties to performance Gas diffusion is overestimated

Technological targets and achievements

- Development of new raw materials ➔ reached
  - Aquivion^{R} dispersion with different conductivity, EW, water handling… ➔ can be better (/Nafion) at low RH, positive influence on durability
  - Carbon blacks with different wettability, conductivity, porosity…➔ good candidate for MPL, can help tuning Pt size

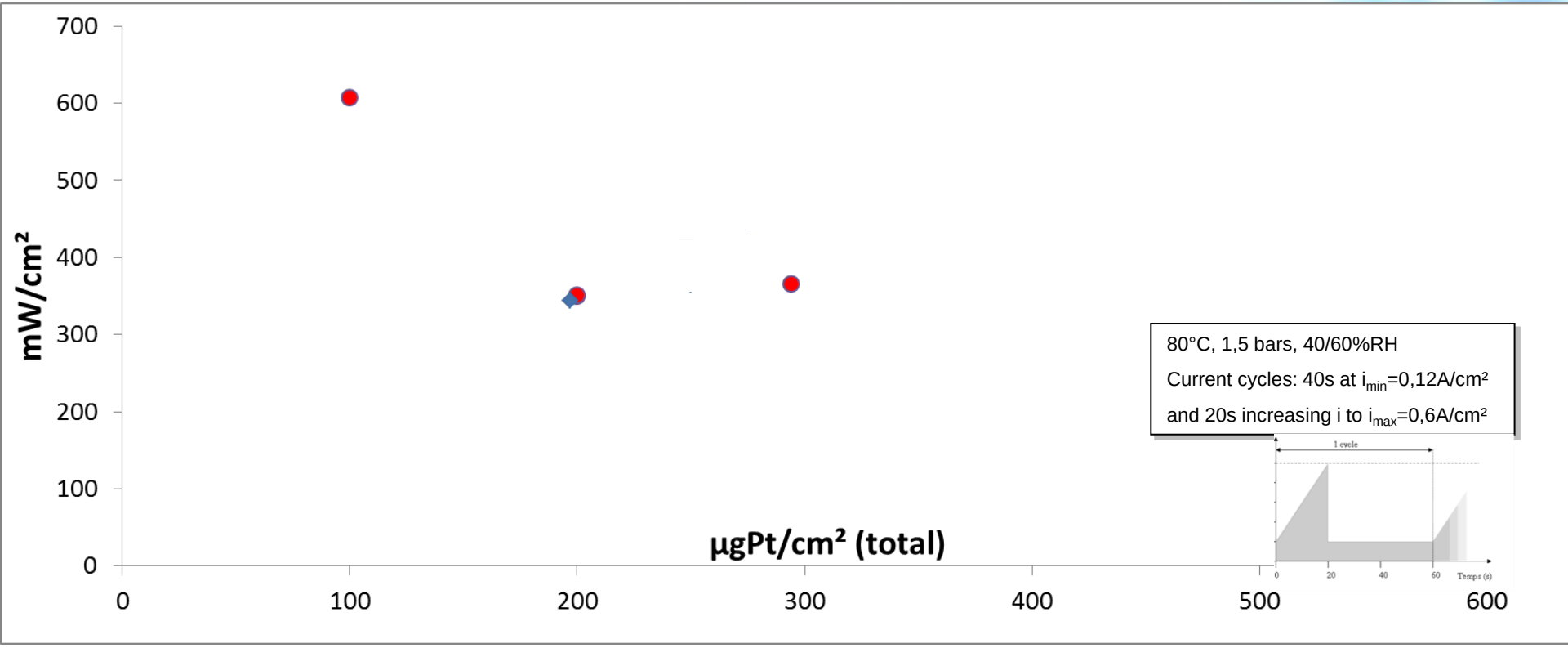
- Development of low loaded electrodes ➔ partially reached, remaining issue is W/cm^2
  - Down to 37 µg/cm^2 (classical processes)
  - All Milestones have been reached except the final one (MEA Level 3, 0.15 gPt/kW) ➔ W/cm^2 is to be increased
  - Durability has been improved: specific Aquivion^{R} ionomer and preparation method

- Validation of alternative manufacturing processes ➔ reached, additional work is of interest
  - Electrodes with Pt gradients ➔ no clear influence on performance, durability?
  - Physical Vapour Deposition ➔ very low loadings (2 µg/cm^2)
  - Direct Electro-Deposition ➔ possibility to tune Pt size

Technological targets and achievements

Main results

Performance (0.675V, H_2/air, 50%RH, Stoe 1.2/2, 80°C, 1.5 bara, 25 cm² cell) and durability (stress test protocol below)



Targets | Nafion | Aquivion | Gradients

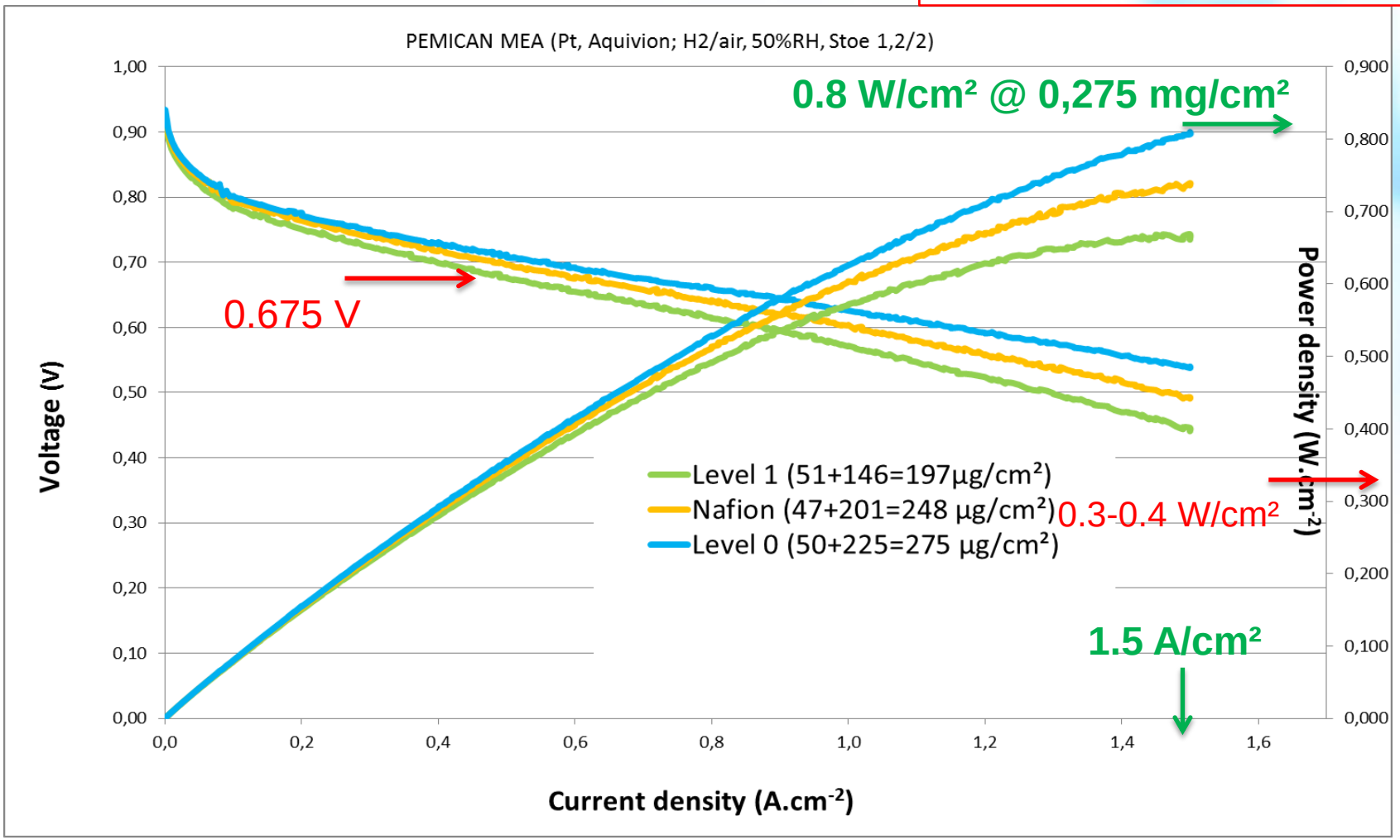
Technological targets and achievements

- Improvements
  - Pt loading can be reduced: 0.6 ➔ 0.1 mg/cm²
  - Pt cost can be reduced: 0.9 ➔ 0.5 (done) ➔ 0.3 gPt/kW (realistic)
  - Durability can be improved: - 300 ➔ - 33 µV/h (**stress protocol**)

- Main issues
  - Durability decreases as Pt loading decreases ➔ can be improved with specific ionomer and preparation method
  - Performance decreases as Pt loading decreases ➔ main focus for the future

Technological targets and achievements

Autostack: 1 W/cm²@1,5 A/cm², 0.5 mgPt/cm² ?



Scientific targets and achievements

- Characterization of electrodes ➔ reached, additional work is of interest
  - Classical laws overestimate gas diffusion ➔ major output for the models
  - Proton resistance of AL decreases as RH increases
  - Fundamental electrochemistry ➔ improved Butler-Volmer relationship

- Modelling ➔ reached, additional work is of interest
  - Improved performance models (more reliable inputs) ➔ analysis of loading, structuration, limitations…
  - Innovative Pore network Model (mass/charge coupling) ➔ influence of local properties on performance, inputs to performance models (gas diffusion)…

- Analysis of performance limitation ➔ added and reached, additional work is of interest (new materials)

➔ what is the best we could expect? (0,675V, H_2/air, 80°C, 1.5 b, RH50%, pure Pt)

  - Coupling between models and characterization

  - Ideal electrode (no transport loss)

70 µg/cm² (7 anode + 63 cathode)	1 W/cm² (Autostack)	0.07 gPt/kW

  - Real electrode (transport losses)

100 µg/cm²	0,32 W/cm²	0.3 gPt/kW
600 µg/cm² Pt *6	0,600 W/cm² Power *2…	1.0 gPt/kW

➔ Increase gas diffusion

➔ *And/or increase catalyst performance*

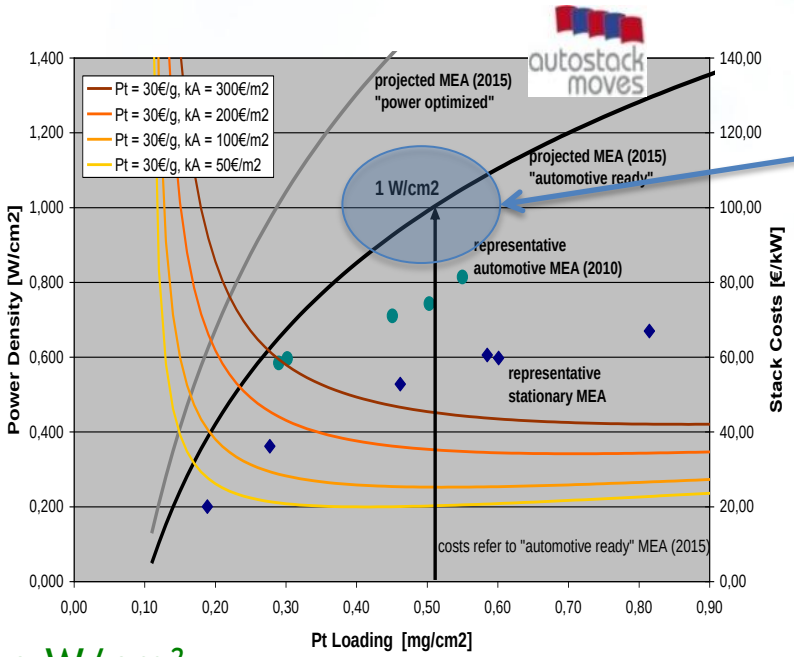
RISKS AND MITIGATION: technological

- Final target (MEA Level 3, 0.15 gPt/kW) has not been reached:
  - gPt/kW can be reduced (Pemican)

  but 1 W/cm² seems mandatory with a higher gPt/cm² if necessary (Autostack^{MOVE})

➔ 0.5 gPt/kW is the first target to reach

Then 0.15…



0.5 gPt/kW!

  - Potential actions to increase W/cm²

➔ Improve gas diffusion at 0.5 mg/cm²

➔ Otherwise/in parallel improve catalyst to increase perf with lower Pt loadings

➔ *Introduce new materials…*

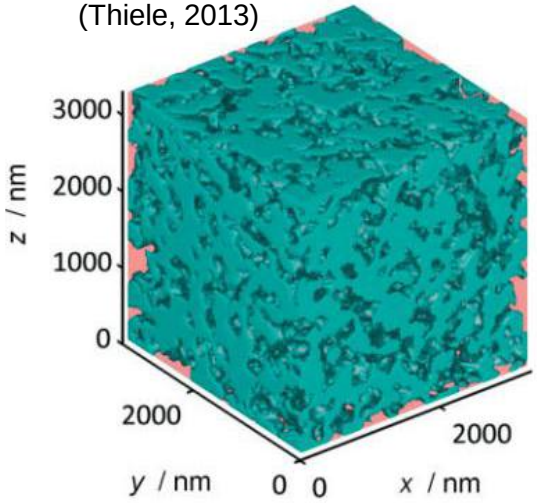
  - µV/h could be a lower issue than W/cm² (Pemican)

RISKS AND MITIGATION: scientific

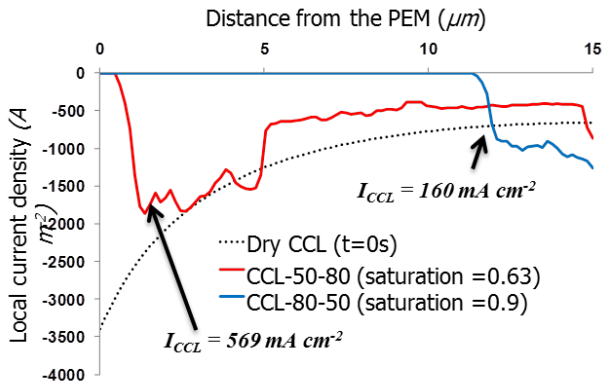
- Link local properties of active layer to performance: some more work is necessary…
  - Numerous improvements (Pemican): characterization, modeling…
  - Some basic understanding is still necessary:
    - Influence of raw materials
    - Influence of structure of the electrode

➔ Select 2-3 MEA and perform deep characterization/modeling on them

Nano X-Ray tomography
(Thiele, 2013)



Performance of the cathode
(Pore Network Model)



DISSEMINATION ACTIVITIES

- Presentation to conferences:
  - Workshop on material issues 2012 (Grenoble): presentation of project and main results CEA
  - CARISMA 2013 (Copenhagen): Low Pt anodes by PVD (Tecnalia)
  - EFCF 2013 (Luzern): presentation of project and main results (CEA), properties of Carbon Blacks (IMERYS GRAPHITE & CARBON)
  - FDFC 2013 (Karlsruhe): presentation of project and main results (CEA)
  - ISE 2014 (Lausanne): ORR/HOR measurements (Imperial)
  - SIMVEC 2014 (Baden-Baden): Performance model (Opel)

- Publications:
  - Pore Network Modelling of the cathode: IJHE 2012 (CEA), JPS 2014 (CEA)
  - Thin electrodes: Electrochem comm. 2014 (Imperial)

- Patents: ink formulation (CEA, 2014)

- Industrial Boarding with European partners (end-users, stacks, MEA or components developers…) in 11/2012

- Seminar at Imperial College (11/04/2013, CEA)

EXPLOITATION PLAN/EXPECTED IMPACT

- Exploitation of results
  - Aquivion^{R} based electrodes and membrane have shown potential interest
  - Innovative manufacturing processes
  - Innovative characterization techniques and models for future developments

- Results that go beyond international state-of-the art
  - Characterization of proton resistance of active layer
  - Improved Butler-Volmer relationship based on fundamental electrochemical experiments
  - Pore Network Model of the cathode coupling 2-phase flow with charge/heat transport
  - Analysis of performance limitation coupling characterization and modelling

EXPLOITATION PLAN/EXPECTED IMPACT

- Towards cost reductions and improved performance/durability
  - Durability can be improved by tuning properties of Aquivion^{R} ionomer
  - W/cm^2 and µV/h are of more importance than gPt/kW

- Use for industry
  - Manufacturing and characterization of new raw materials (Aquivion^{R}, carbons)
  - ➔ Some market launches are planned in 2016 and others in 2018

- Use for FCH-JU
  - Some recommendations (gas diffusion, link local properties to performance…) could be used for future calls
  - Some developments (models, characterization, materials…) could be useful for future developments
  - Degradation rate is strongly dependant on the test protocol

PEMICAN

Thank you for your attention

(Joël Pauchet, CEA/LITEN)

BACK-UP SLIDES

Technological targets and achievements

- Improvements
  - Pt loading can be reduced: 560 ➔ 100 µg/cm²
  - Pt cost can be reduced: 0.93 ➔ 0.57 (done) ➔ 0.3 gPt/kW (realistic)
  - Durability can be improved: - 300 ➔ - 33 µV/h (**stress protocol**)