PEMICAN

PEM with Innovative low cost Core for Automotive applicatioN

(256798)

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(French Atomic and Alternative Energy Commission)

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3.96/1,86 M€

Reduce Pt cost of PEMFC down to ideally 0.15 gPt/kW for automotive application

6 partners

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OPEL
Wir leben Autos.

SOLVAY SPECIALTY POLYMERS ITALY

TIMCAL GRAPHITE & CARBON

tecnalia

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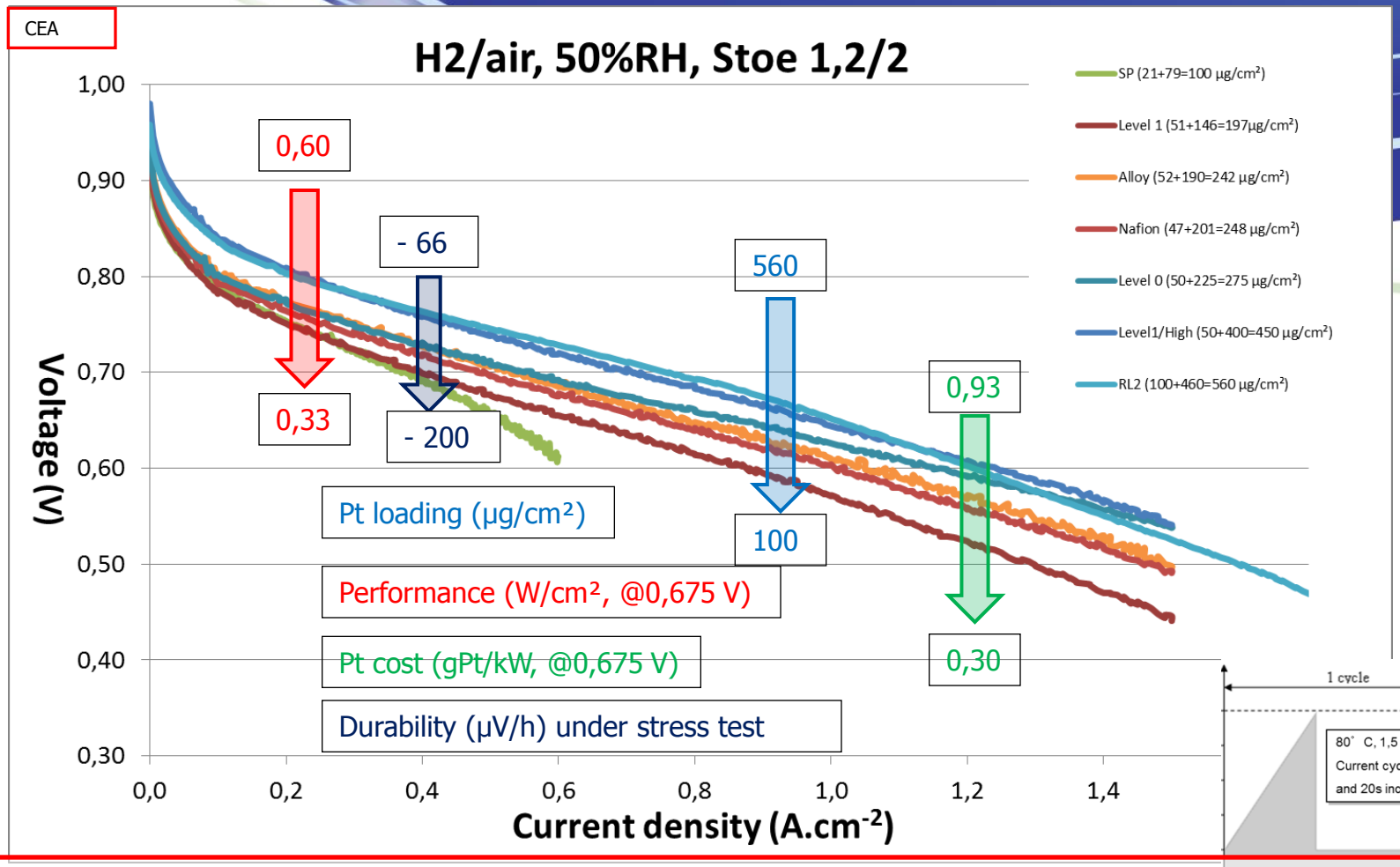
Technological approach

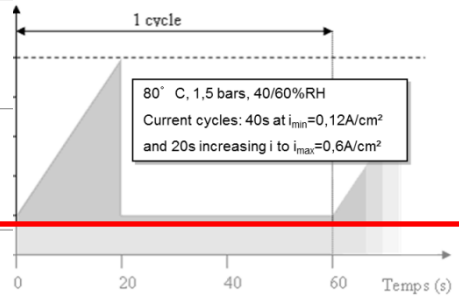
- **Manufacture low loaded active layers**
  - *Thin electrodes (classical and alternative methods)*
  - *Structured cathodes with gradients*
- **Check influence of raw materials on performance**
  - *Aquivion^{R} ionomer and membrane*
  - *Carbon black (additive to the ink or support for Pt)*

Scientific approach

- **Improve experimental characterization of active layers:** *H^{+} conductivity, gas diffusion, fundamental electrochemistry…*
- **Improve modeling** to better link local properties of CL to performance *; more reliable inputs and experimental validation ➔ basis for future design tools?*

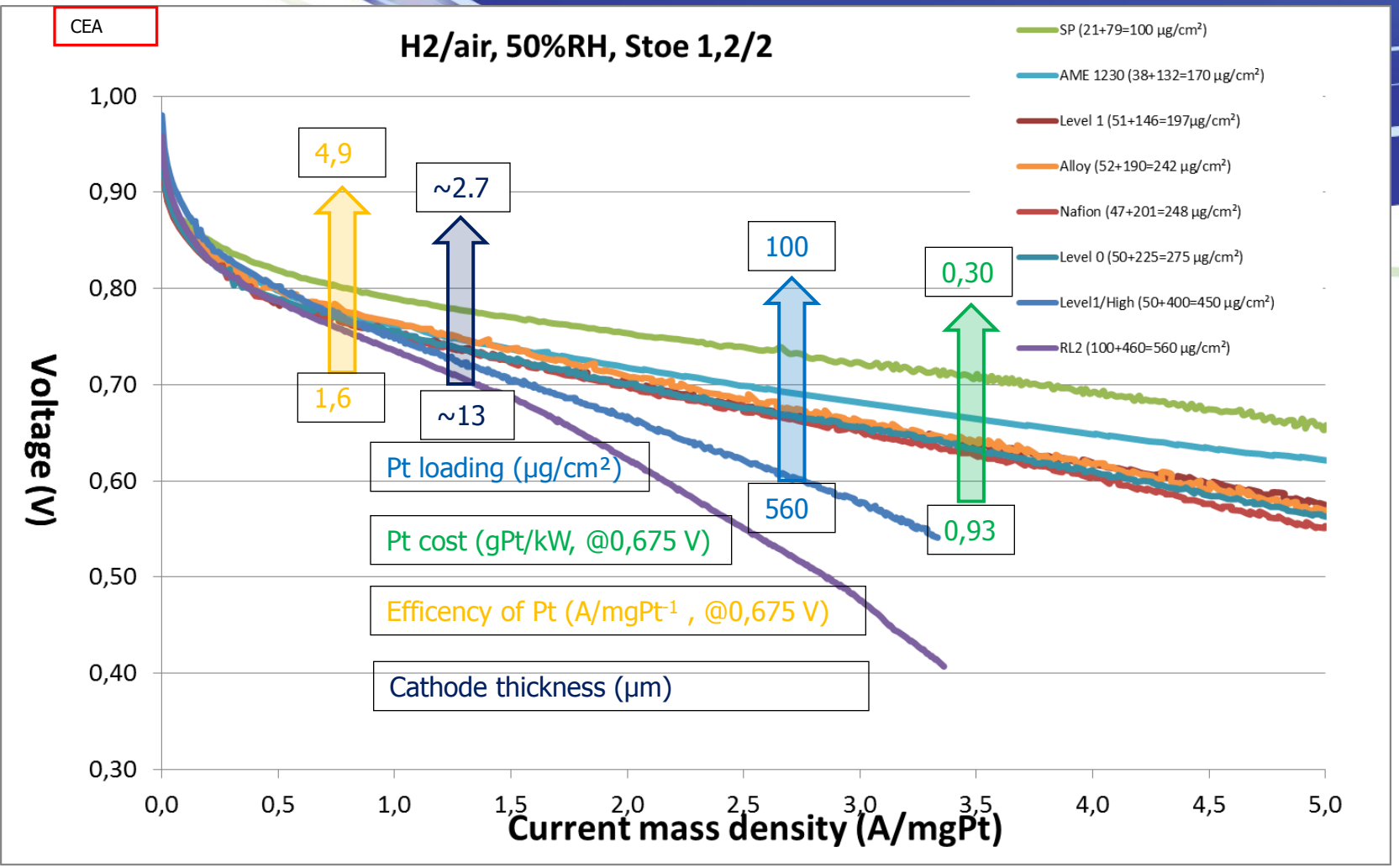
Some results on low loaded MEA





- ***Pt loading can be largely reduced***
- ***Performance decreases with Pt loading***
- ***Pt cost can be reduced from 1 to 0,30 gPt/kW (initial target=0,15)***
- ***Durability (stress test, 100-200h) decreases with Pt loading***

Efficency of Pt



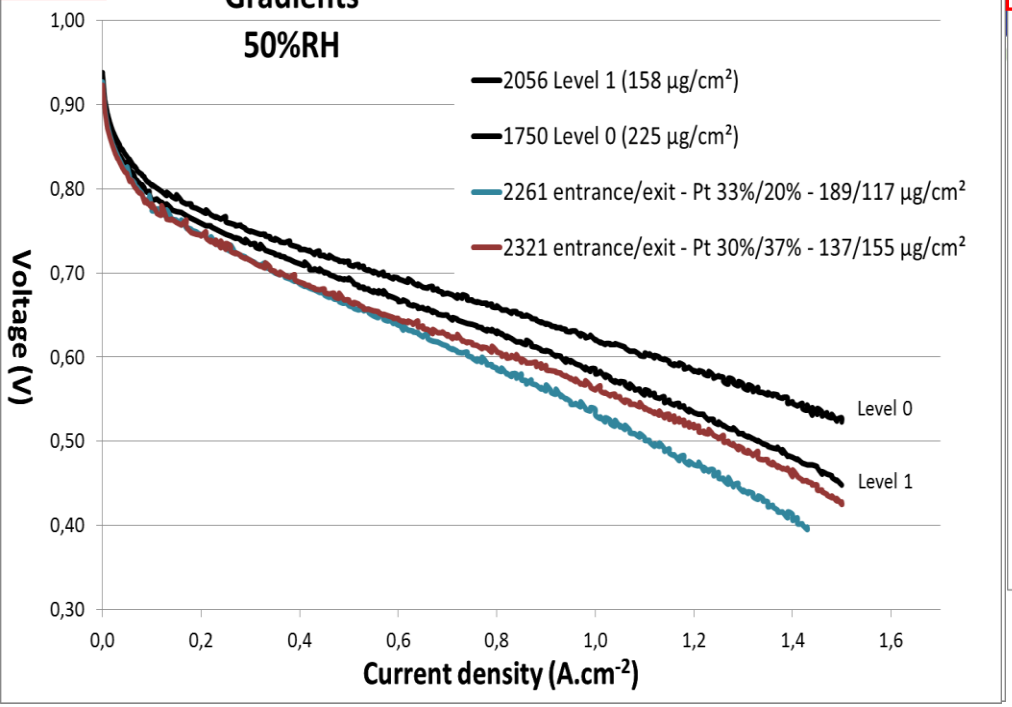
- ***Pt efficency increases when Pt loading decreases***
- ***Limitation by proton/gas transport***

Alternative low loaded electrodes

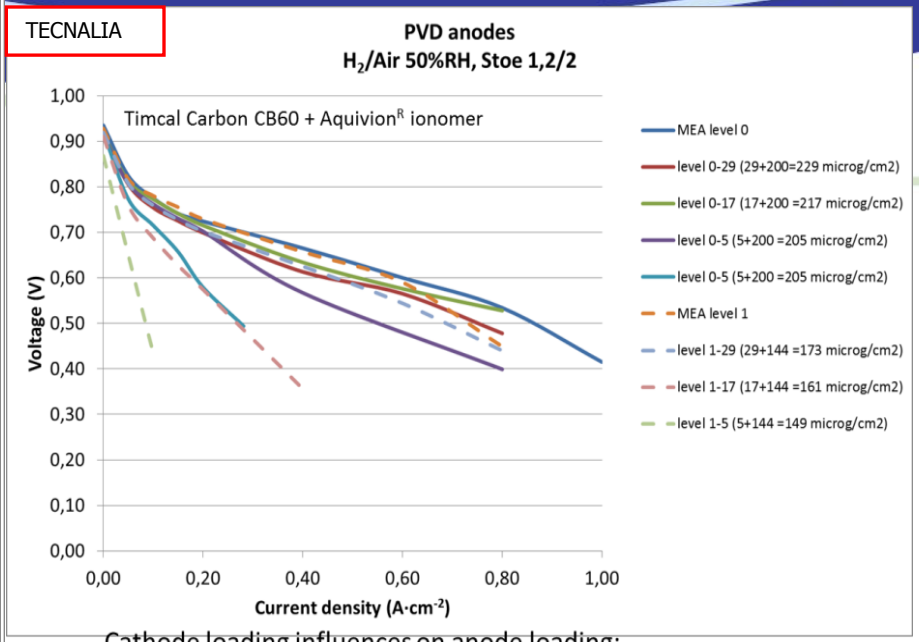
Cathode: gradients to remove Pt from regions with low i

Anode: PVD to reduce loading

CEA



TECNALIA



Cathode loading influences on anode loading:

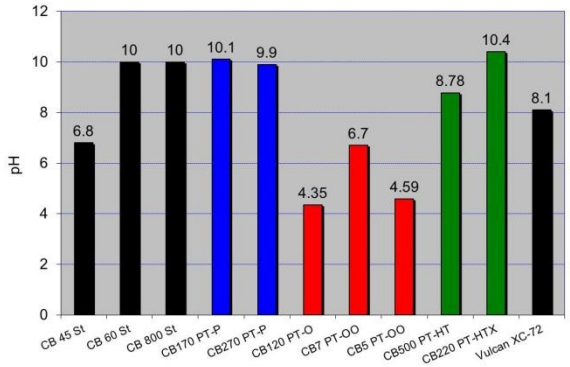
Level 0 → optimum 17 µgPt/cm² (17+200=217 µgPt/cm²)

Level 1 → optimum 29 µgPt/cm² (29+144=173 µgPt/cm²)

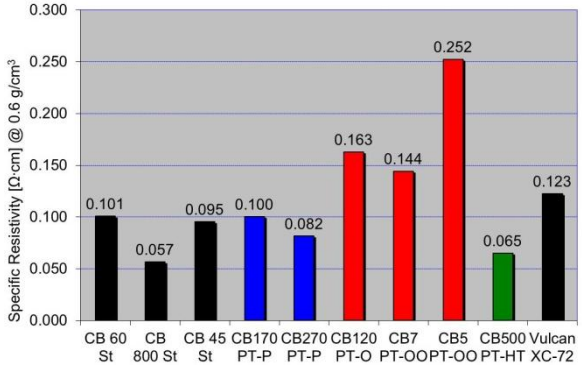
- ***Structured electrodes have been produced*** *(rib/channel, inlet/outlet, thickness)*
- ***Pt near membrane and outlet is more useful but positive influence of structuration is not so obvious***
- ***Gain in Pt loading on the anode is not so obvious***

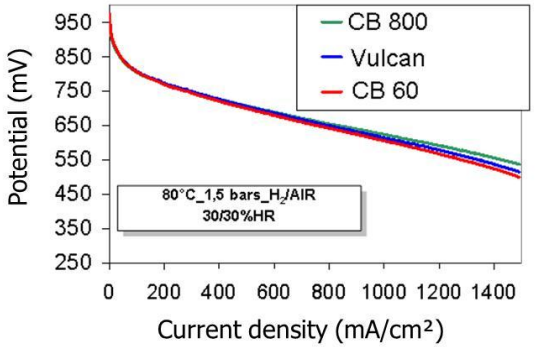
Check influence of Carbon Blacks

Additive to the ink (cathode)
Pt support (anode)



TIMCAL





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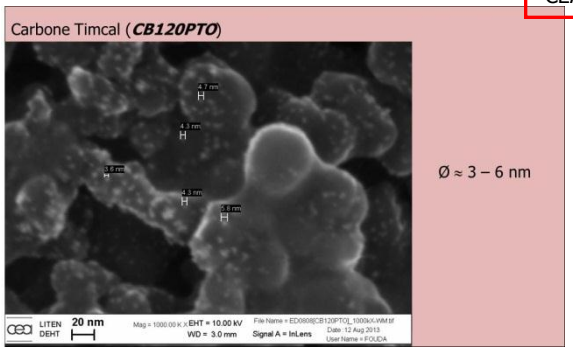
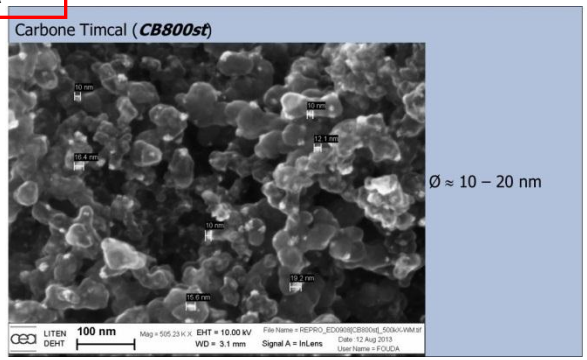
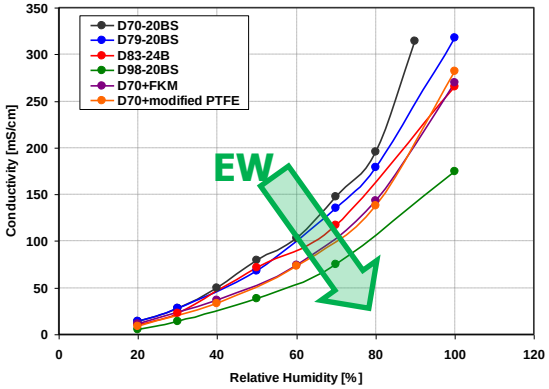


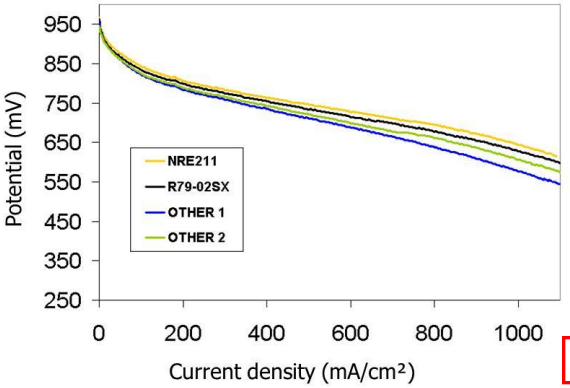


- *Different CB: wettability, porosity, conductivity, stability…*
- *Good performance when used to produce MPL*
- *No clear positive influence when added to the ink*
- *But influence on catalyst size when used as a catalyst support*

Check influence of Aquivion^{R} grade

Membrane Dispersion





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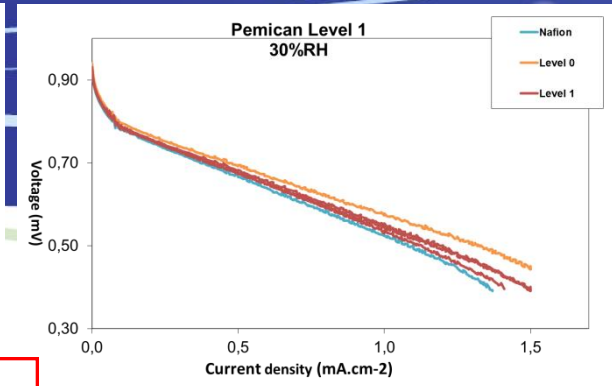
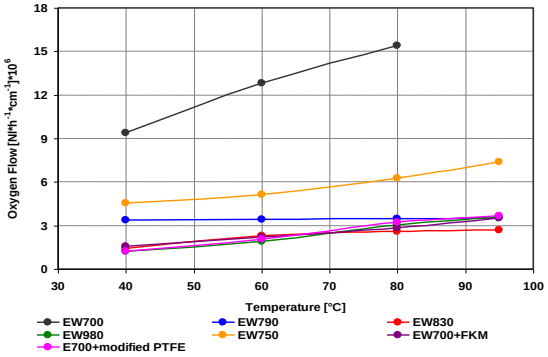
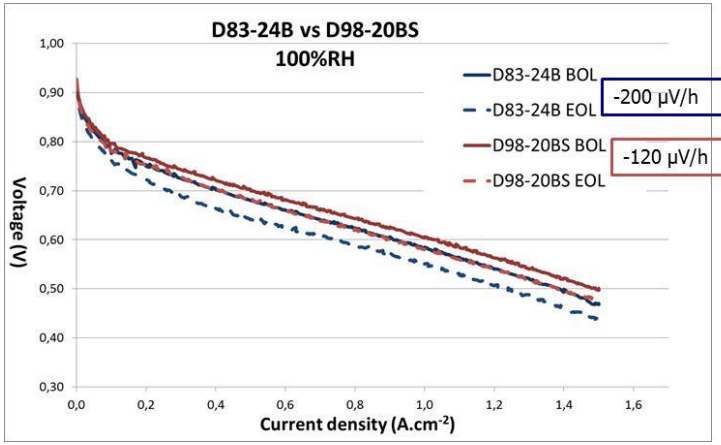


SOLVAY



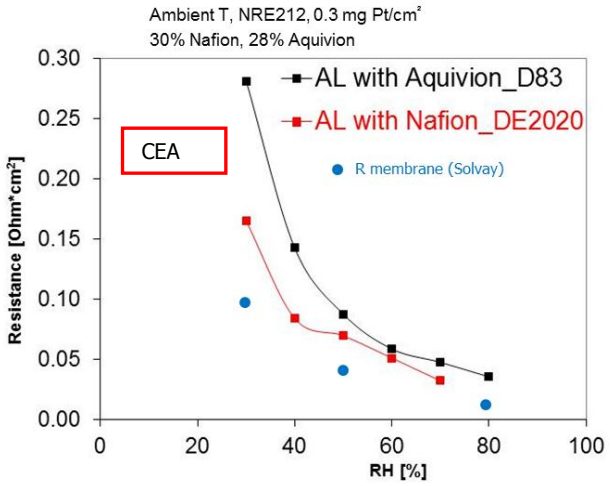


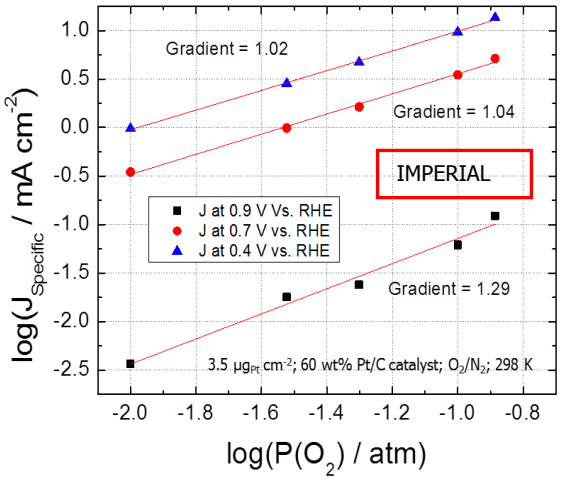
- *Different Aquivion^{R}: EW, stability, conductivity…*
- *Good performance with reinforced Aquivion^{R} membrane*
- *The positive influence is limited except under low RH*
- *Positive influence on durability*

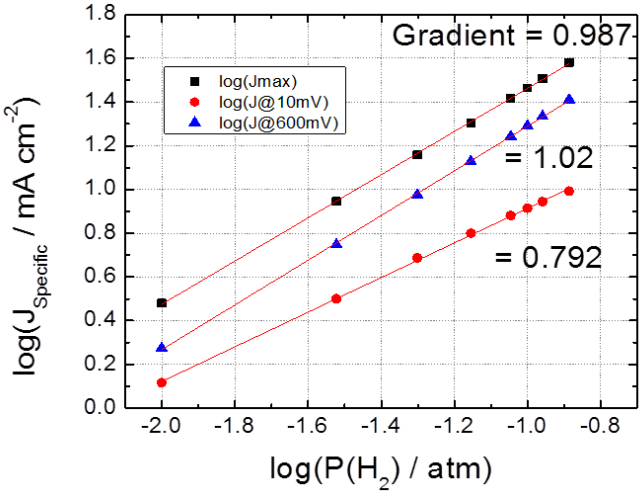
Better understanding
Better inputs to models
Innovative test-stands

Experimental characterization of active layers

$$j_{orr} = j_0 (a_{O2})^{\beta} (a_{H2O})^{\gamma} \left(\exp\left(\frac{\alpha\, nF}{RT} \eta \right) - \exp\left(-\frac{(1-\alpha) n F}{RT} \eta \right) \right)$$







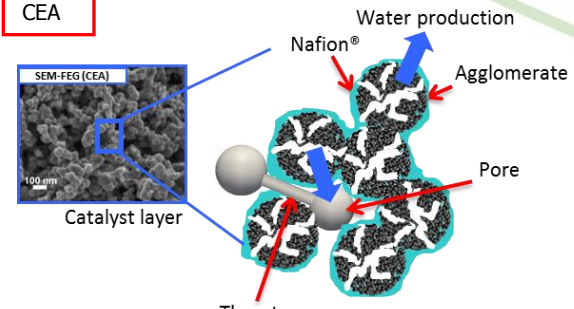
"Ideal representative" fuel cell 1 W/cm² (iR Free, 298K, O_2, 100%RH)
Cathode (0.71V@1.43 A cm^{-2}): 35 μg_{Pt} cm^{-2}
Anode (0.01V@1.43 A cm^{-2}): 8 μg_{Pt} cm^{-2}
Cell: 0.7 V, 1.43 A cm^{-2} using **43 μg_{Pt} cm^{-2}**
➔ **To be investigated for Air**

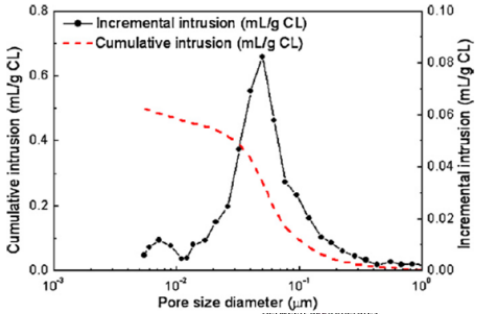
- *Proton resistance might be larger than the one of membrane (preliminary result)*
- *Butler-Volmer relationship should be corrected (preliminary result)*
- *A " realistic Ideal" fuel cell to reach 1W/cm² is to be more investigated*
- *Contaminants are suspected to have a large influence (preliminary result)*

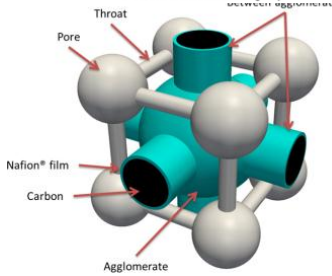
Pore Network Modeling

Take into account more realistic local properties
Link local properties to performance
Give inputs to performance model

CEA

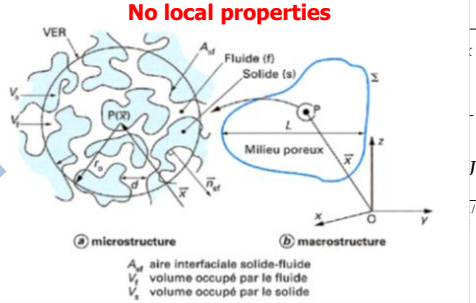




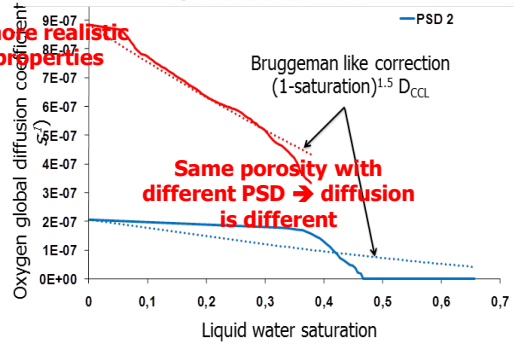


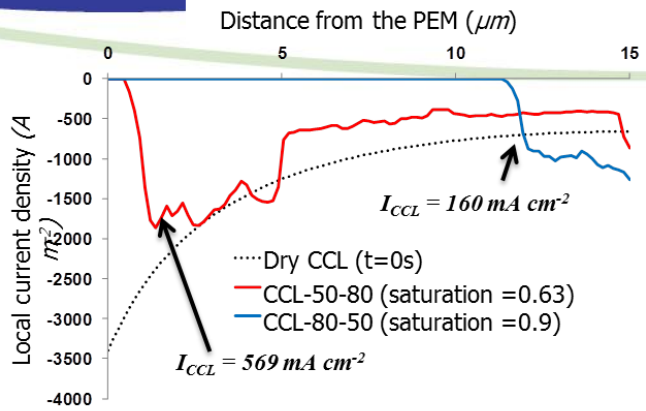
$D_{CCL}(m^2 s^{-1})$ $\varepsilon^{3/2} D_b$ $J_{O2} = -cD_b \frac{\partial x_{o2}}{\partial z}$

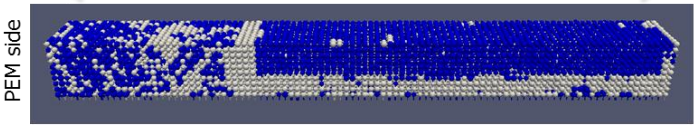
Classical average model: No local properties



PNM : more realistic local properties







CCL-**50-80**

Analysis of flooding

- *PNM has been set-up: charge/two-phase mass/heat/ electrochemistry*
- *Gas diffusion is overestimated by classical models, local properties are crucial*
- *Influence of local properties on performance can be analyzed*
- *Experimental validation*

Project achievements in relation to the AIP/MAIP

AIP Specific Objectives/Expected Output per Topic/Call addressed by the project	Project Objectives & Targets	Timing (% of project duration passed)	Project Achievements - Current Status	Project Achievements - Expectation at the end of the project	Remarks (bottlenecks, risks, problems etc)
Reduce Pt cost from 1 down to ideally 0.15 (gPt/kW)	0.15	80	0.58 (0.3 is possible)	0.58	Lower realistic Pt loading to reach 1W/cm² is under investigation Key issue = gas diffusion? Ink optimization might be crucial
Ensure durability under dynamic operation (5000 h)	Loss = 5-10% of initial perf over 2500 h ➔ ~ -30 µV/h H_2/air @ 1A/cm²	20	~ -200 µV/h for "low" loaded Level 1 MEA (stress protocol, short duration)	~ -100 µV/h (same protocol, improved MEA, longer duration)	Durability is a key issue for low loaded MEA
Contribute to the development of European Industry solutions	Promote ionomer (Solvay) and CB (Timcal)	80		Advantages on Aquivion^R (Solvay) and Carbon Black (Timcal)	Potential alternative solutions to existing ones?
Reduce total Pt loading from 0.5 to ideally 0.1 mg/cm²	0.1	100	0.15 (0.1 is possible)	0.15	Key issue is high power density with low loaded MEA
Study proton conduction in the active layer	Develop innovative test stands	80	First results on H^+ conduction	Updated results and comparison with « classical » materials	Deduce local conductivity and link this with local property of active layer
Improve modeling	Develop innovative Pore Network Model and improve Performance one	80	First results on fundamental electrochemistry PNM allowed proposing improvements of classical PM PM allowed analysing local current generation		Partial experimental validation of models have been done but shall be completed in future projects

- Relationship to Earlier and Other Current Projects
  - IMPACT (degradation of low loaded MEA)
  - IMPALA (improved GDL to reach 1W/cm²)

- Dissemination Activities:
  - Some conferences, talk, publications…
  - Industrial boarding (meeting in 11/2012)
  - Presentation of final results and discussion (~ 03-04/2014, web-ex?)➔ you are welcome!

- Recommendations towards the Programme
  - More work on low loaded MEA to reach 1W/cm²

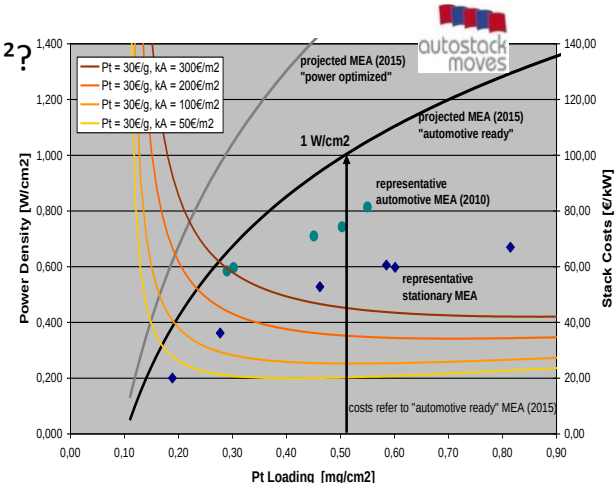
Main conclusions/perspectives

- Manufacturing of low loaded electrodes
  - Low loaded MEA have been produced (~100-150 µgPt/cm²)
  - Pt cost can be reduced from 1 to 0,30 gPt/kW (initial target = 0.15gPt/Kw)
  - Efficency of Pt is larger for thin electrodes ➔ limitation by gas/proton transport

Nevertheless, is it of interest to reduce even more Pt loading since

- Performance decreases with Pt loading: what is the Pt cost of gas/proton resistance?
- Durability decreases with Pt loading: main degradation on the cathode (tbc), degradation on longer duration is to be tested
- Low loaded MEA are suspected to be more sensitive to contaminants

- What would be a "representative ideal" Pt loading to reach 1W/cm²?
- Gas/proton transport is to be improved
- Trade-off Pt loading/power density/durability!



Main conclusions/perspectives

- Materials
  - Numerous Aquivion^{R} and Carbon Blacks have been produced and characterized
  - Aquivion could be interesting (low RH, durability)
  - Specific CB could be interesting (MPL, Pt size)
  - Specifications remain difficult ➔ better understanding is a key issue
  - Improvement on performance is up-to-date limited ➔ optimize ink for these new materials

- Characterization
  - Specific test-stands have been set-up
  - Preliminary results on H^{+} resistance and fundamental electrochemistry ➔ better inputs for the models
  - "Ideal representative" fuel cell is to be deeper analyzed ➔ cost of resistance (mg/Pt)?

- Modeling
  - Performance models have been improved and used to analyze local performance
  - Pore Network Model has been developed to account for local properties
  - Gas diffusion is generally overestimated ➔ better inputs for models
  - Multiscale coupling is to be analyzed
  - Experimental validation would be the next step before using models as design tools

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Thank you for your attention

(Joël Pauchet, CEA/LITEN)