New components and concepts for polymer fuel cells in vehicle applications

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Fuel cell conference 2017

Nya komponenter och koncept för polymera bränsleceller till fordon

Project start: 2014-01-01

Project end: 2017-08-31

Partners:

KTH (Main applicant)

Lunds universitet, Chalmers, Sandvik Materials Technology, AB Volvo, Scania AB, Volvo Personvagnar AB, Powercell Sweden AB, Intertek Semko AB, Vätgas Sverige

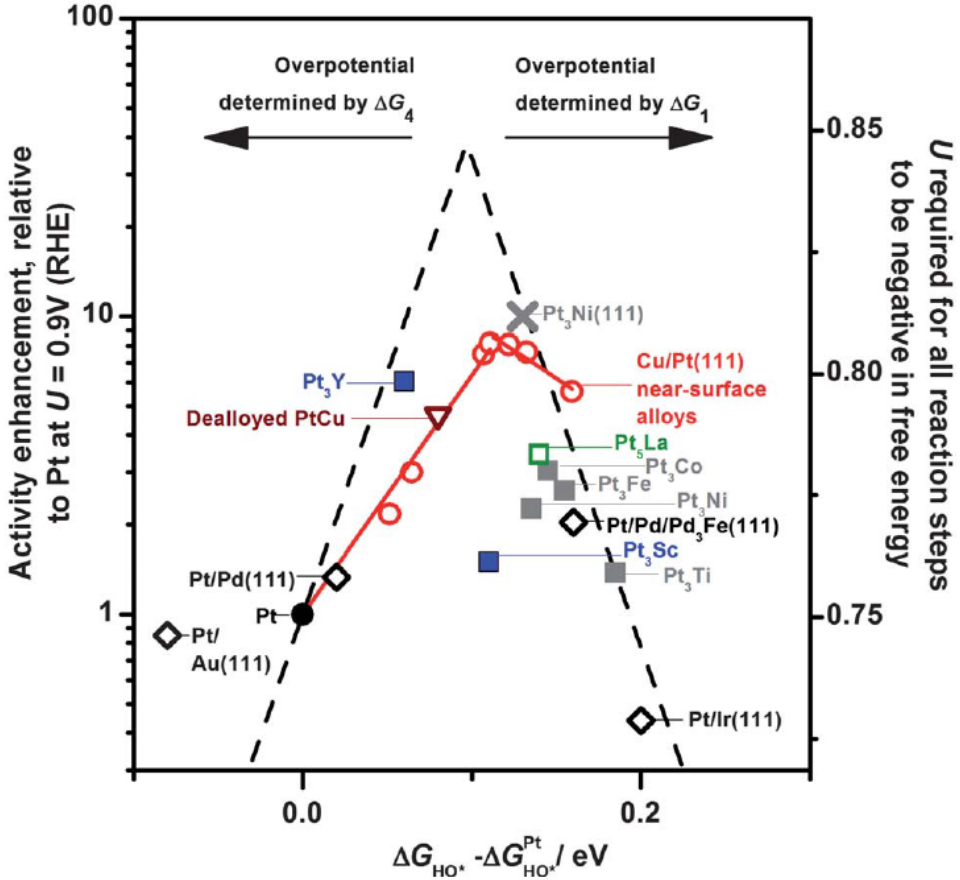
Fordonsstrategisk forskning och innovation (FFI), Energi & Miljö

Outline

- Introduction
- Electrochemical Performance of Thin-Film Pt_3Y Electrodes in PEMFC (collaboration with Chalmers)
- Anion-exchange membrane fuel cells (collaboration with LU)
- Evaluation of bipolar plates (collaboration with Sandvik)
- Conclusions

The optimal ORR catalyst

Should bind OH ~0.1 eV weaker than Pt



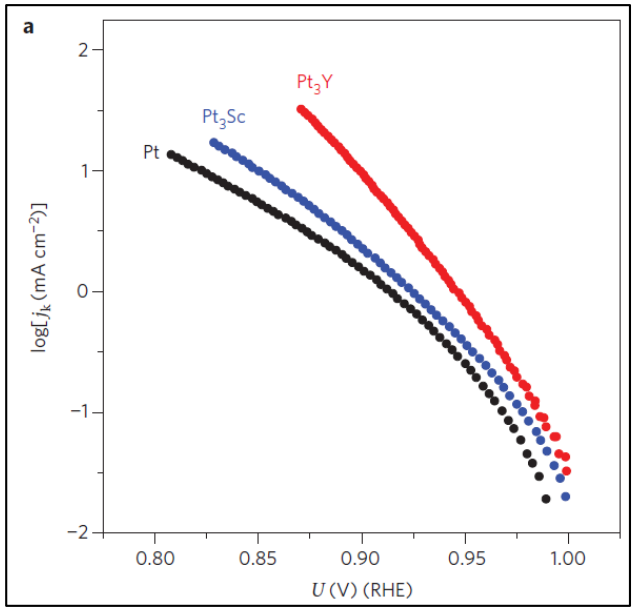
I. E. L. Stephens et al. *Energy Environ. Sci*. 5, 6744, 2012

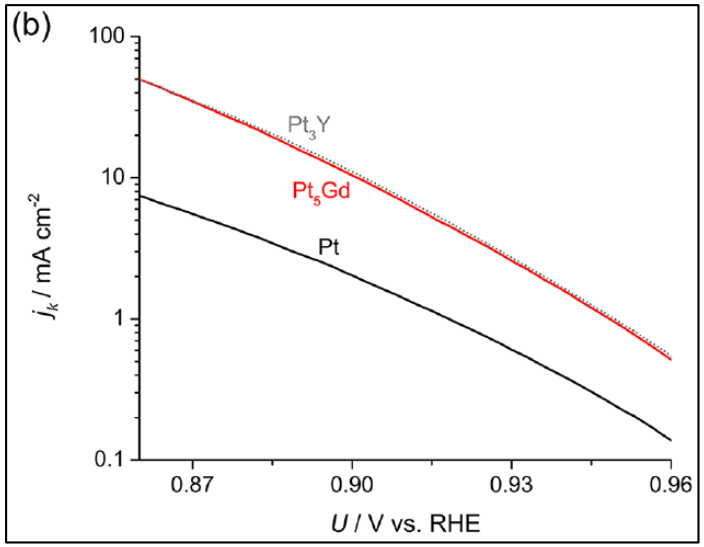
Solution - Alloys:

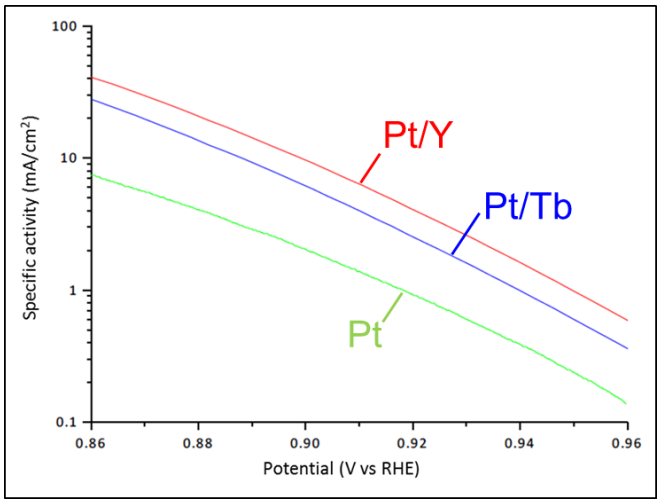
- with transition metals, e.g. Pt_3Ni, Pt_3Co, Pt_3Ti, Pt_3Fe, etc.
- with Rare Earth Elements Pt_3Y, Pt_3Sc, Pt_5Gd, Pt_5Tb, etc.

Pt-Rare Earth Metal alloys as ORR catalysts

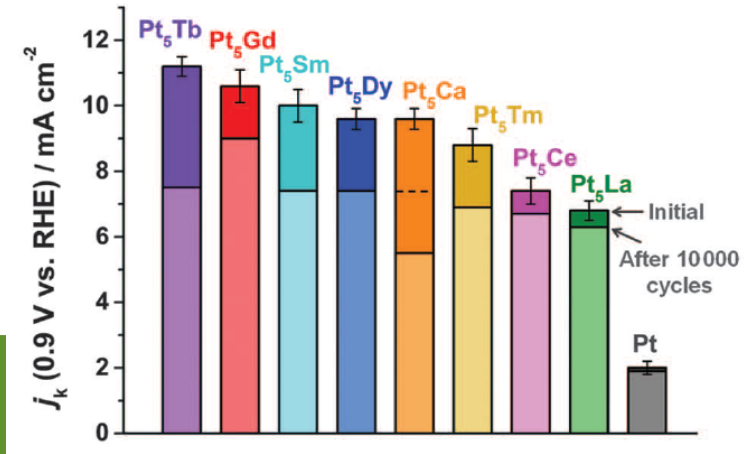
Rotating disk electrode evaluation of Pt-RE bulk samples:

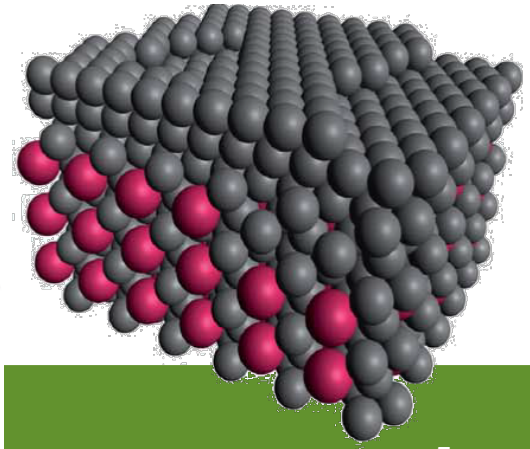






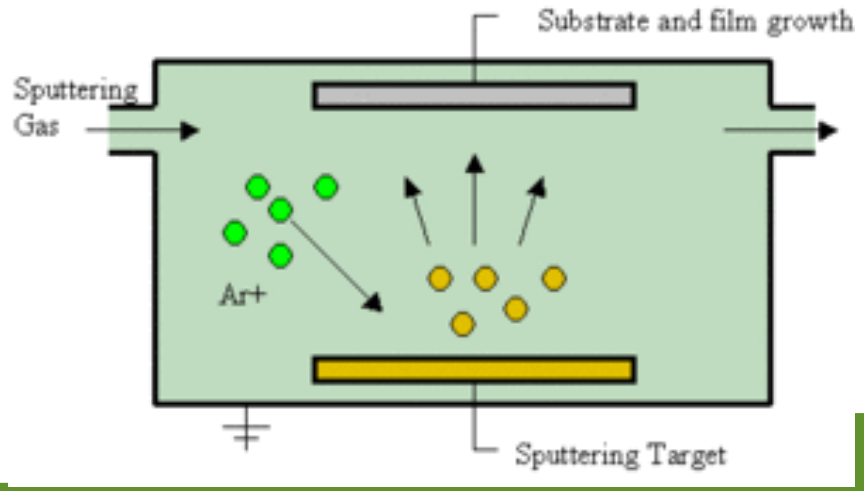
J. Greeley et al. *Nature Chemistry*, 1, 552, 2009
M. Escudero-Escribano et al. *JACS* 134 (40), 16476, 2012
I. E. L. Stephens et al. *Energy Environ. Sci.* 5, 6744, 2012
P. Malacrida et al. *J. Mater. Chem. A*, 2, 4234–4243, 2014
M. Escudero-Escribano et al. Science, 352 (6281), 2016





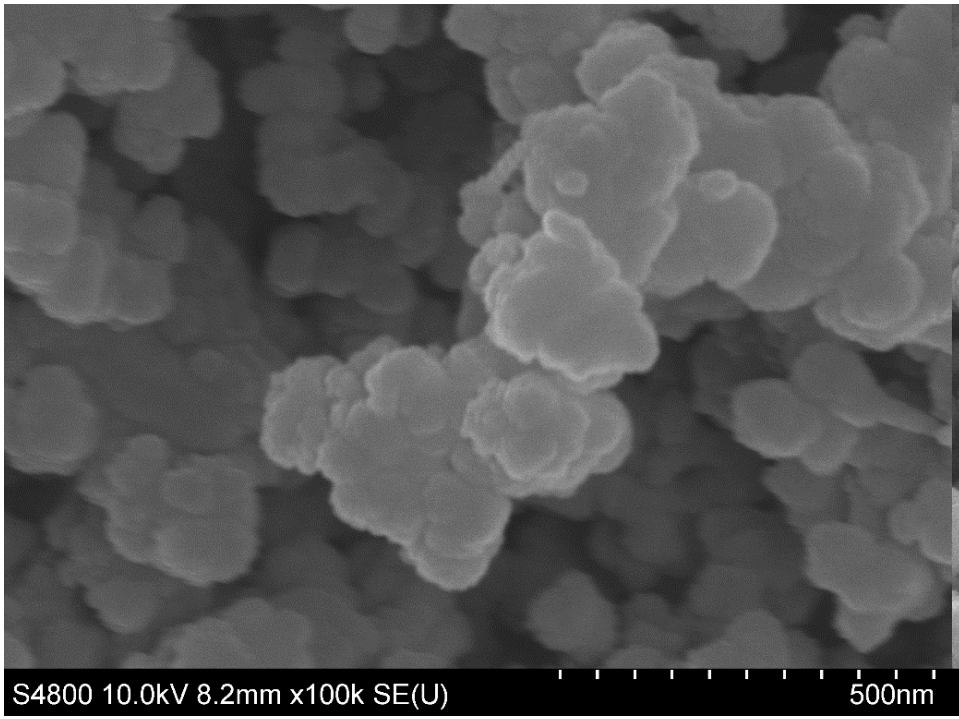
Sputter deposition

- Single target co-sputtering with Pt-target and clips of Y-foil.
- Composition controlled by the fraction of Y-clips on the Pt-target
- DC magnetron sputtering at 1.5 Å/s.
- Base pressure < 1.5×10^{-6} mbar and sputtering in 5 mTorr under 50 cm^3/min Ar-flow.
- 60 nm thick catalyst sputtered onto GDL (Carbel CL)

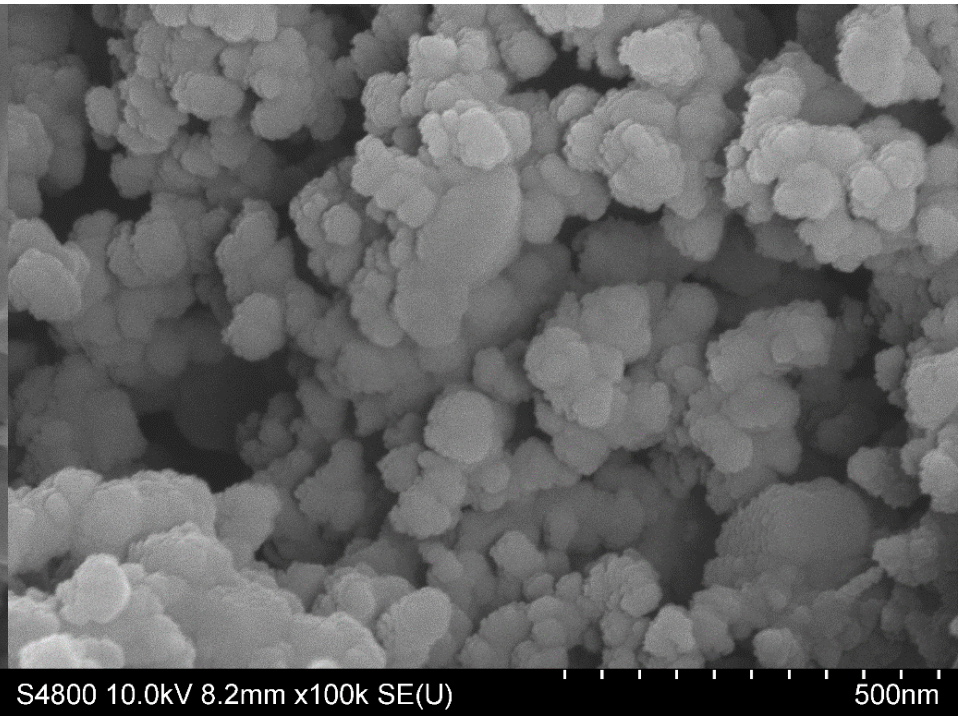


SEM analysis after acid pretreatment

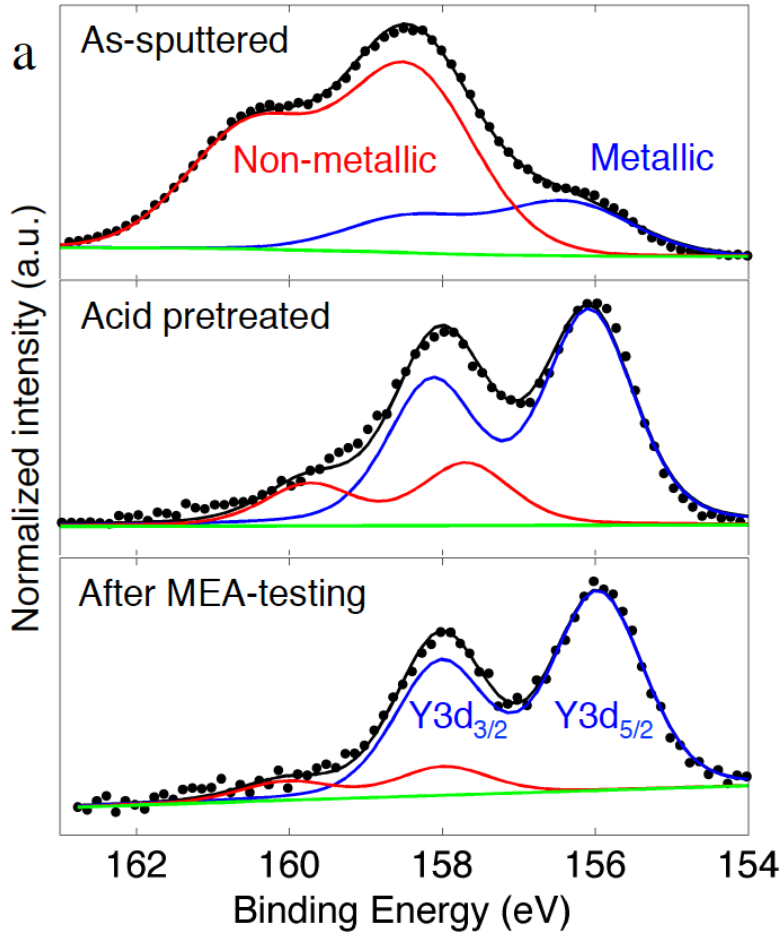
Pt_3Y as produced

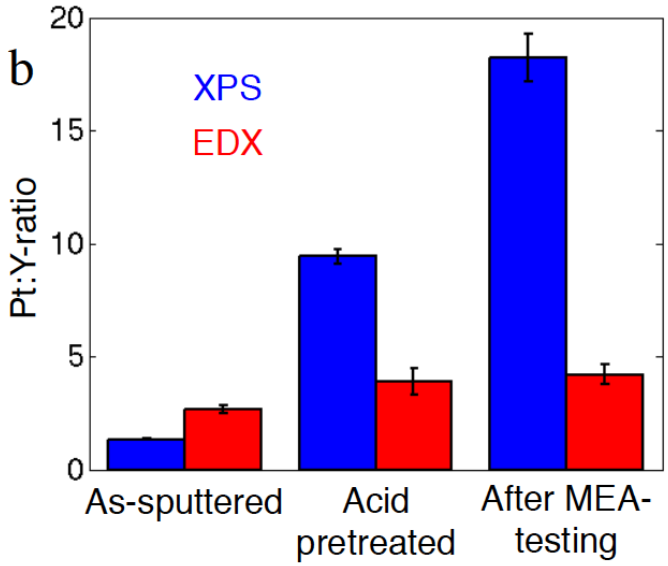


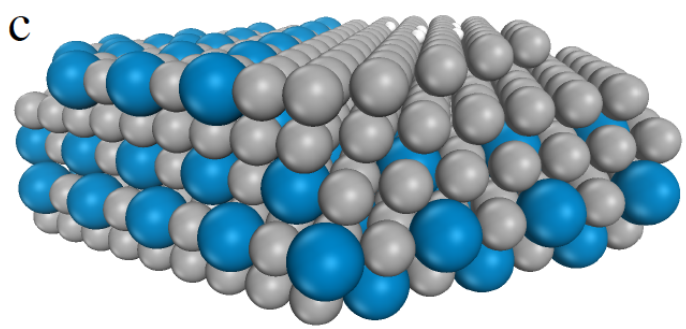
Pt_3Y acid pretreated



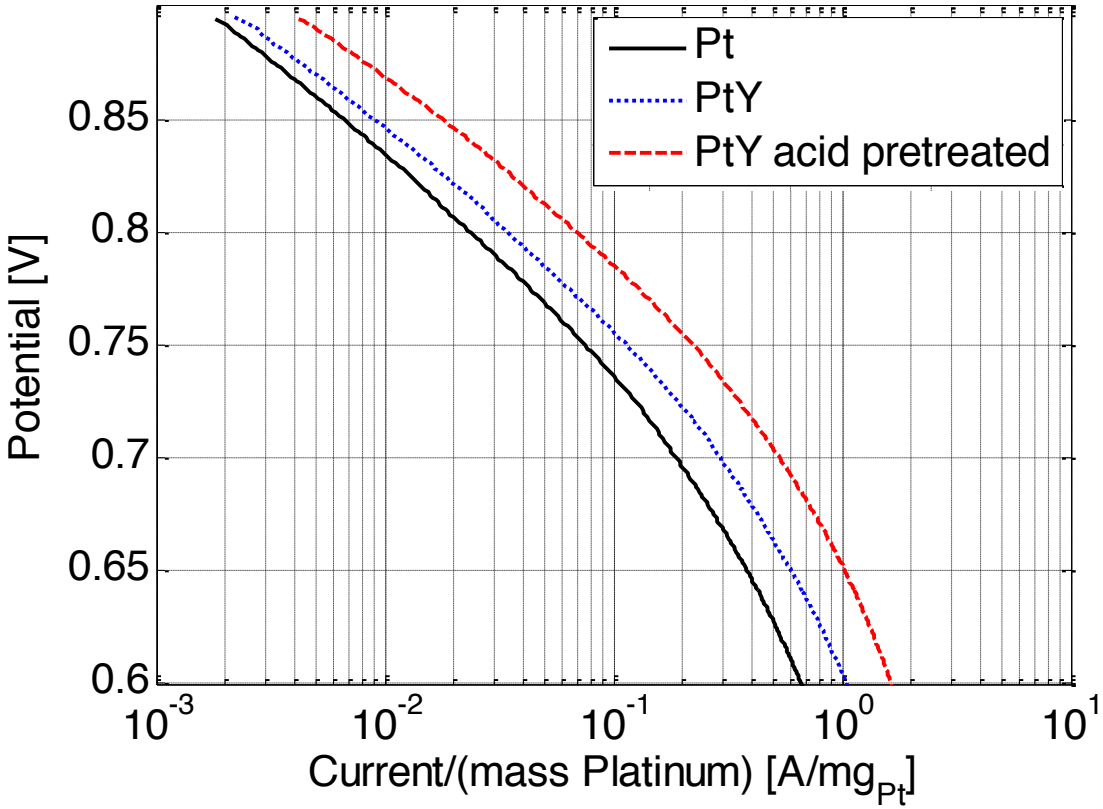
Pt_3Y acid pretreatment (XPS-data)







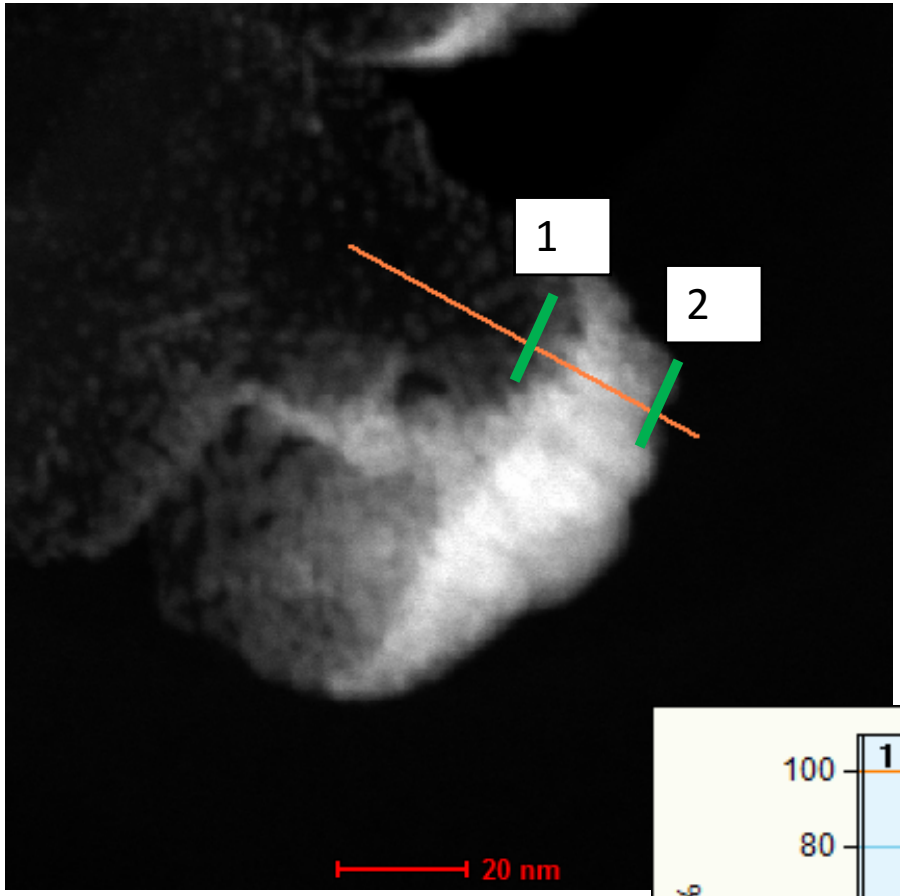
Pt_3Y performance (mass basis)



- Higher activity for both Pt_3Y samples
- Mass determined from the deposited amount

Gas: 5% H_2 (Ar) / O_2

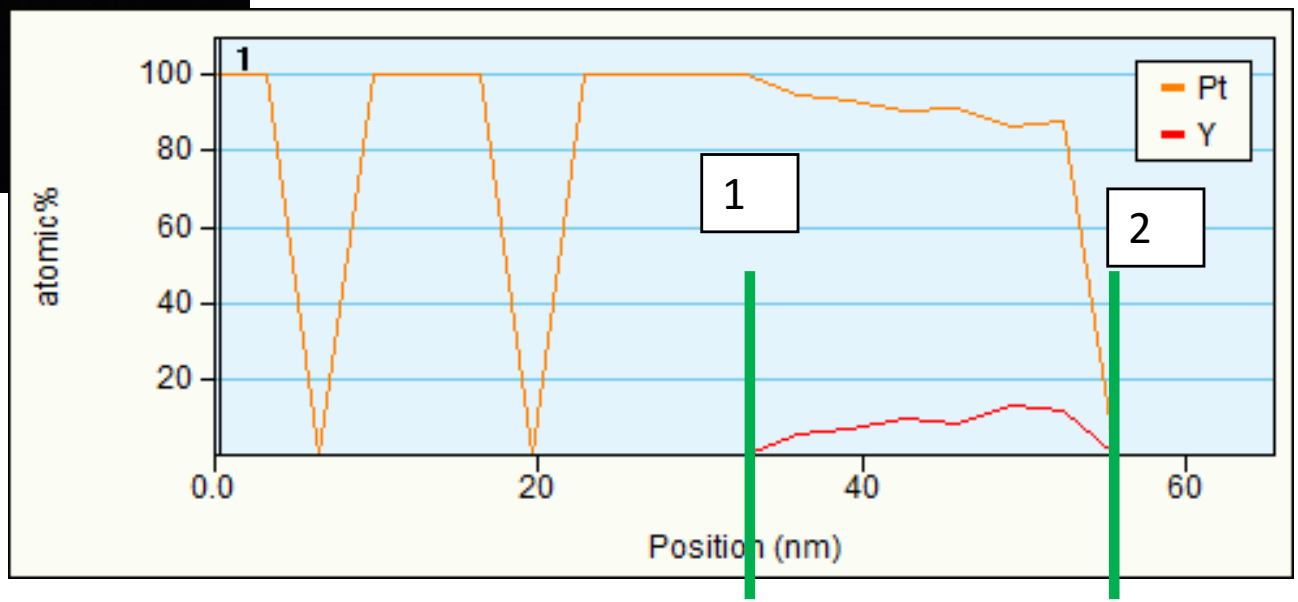
0.9 V-0.3 V, 20 mV/s, 80 °C



Atomic ratio

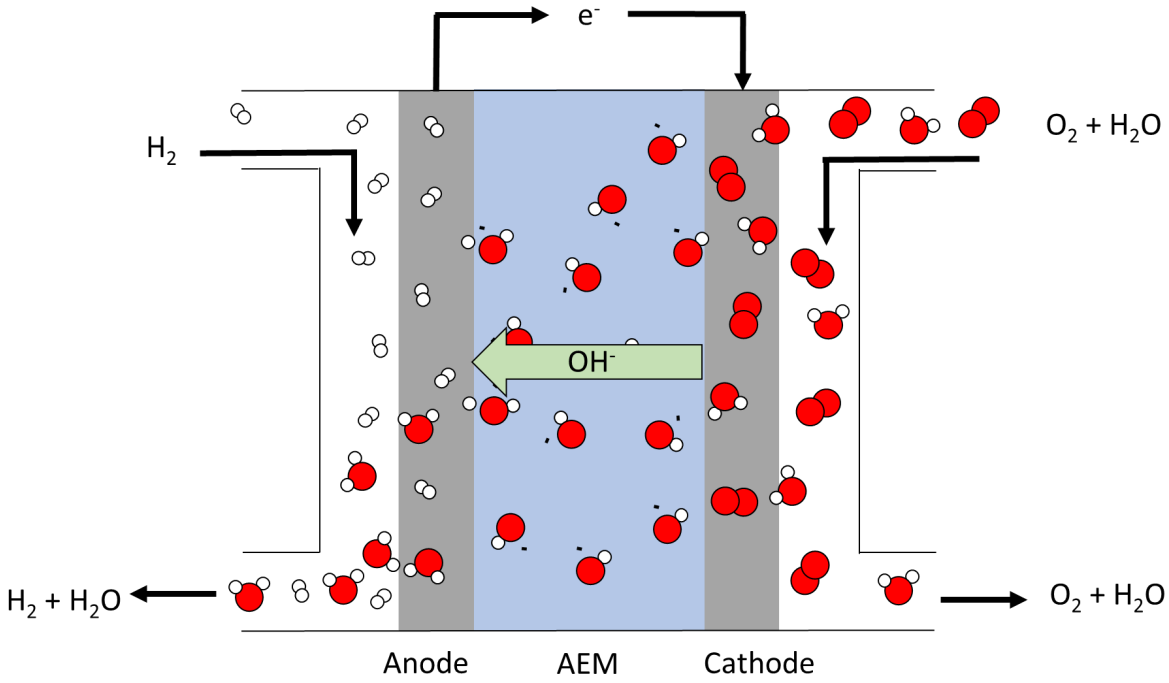
Y has ca. 15 atomic% in thickest parts (around 50 nm) and content decreases gradually when moving towards point 1. Beyond that point, where sputtered material is very thin, the detected material is only Pt and no Y.

Notice that the area studied in TEM has a film thickness of 20 nm (or lower), but was chosen to give a possibility to study a cross-section of the transition from “thick” to “thin” parts of the film.



SEM-EDX measured a content of 20 atomic% of Y. In those measurements mainly the thickest parts of the film contribute to the signal.

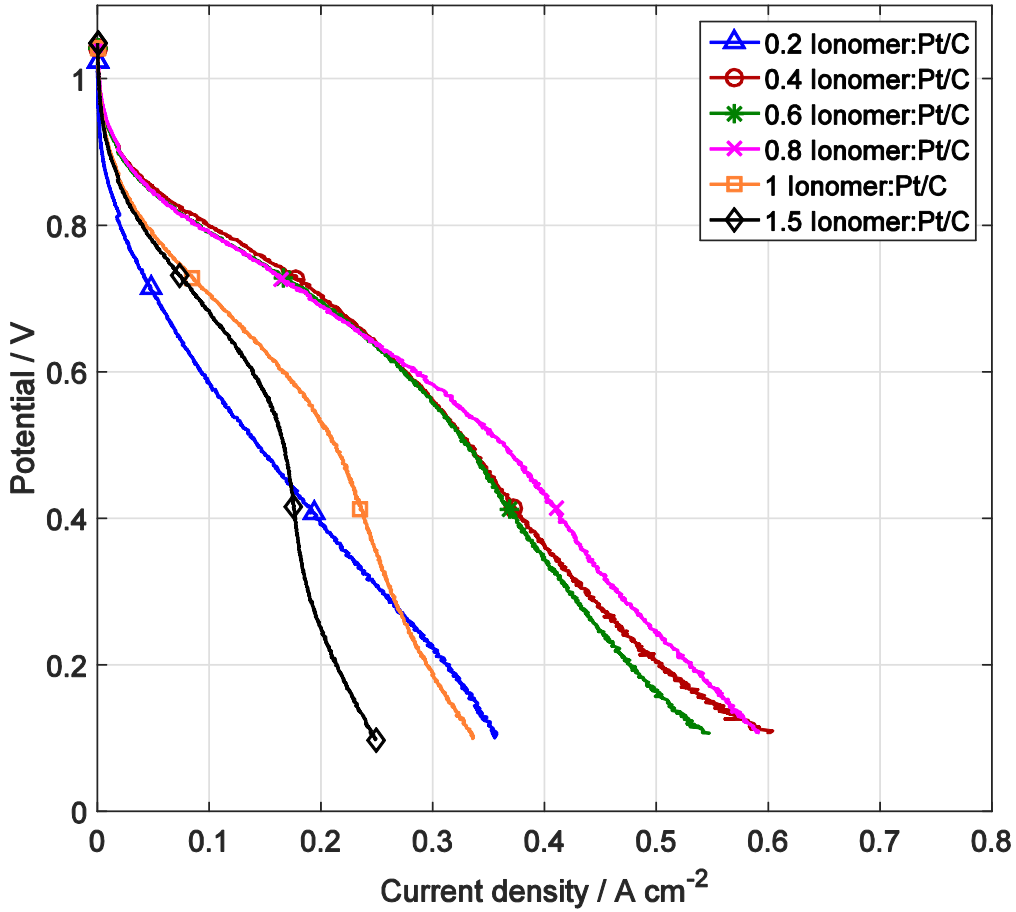
AEMFC – Working principle



Anode: $H_2 + 2OH^- \rightarrow 2H_2O + 2e^-$

Cathode: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

Ionomer to Pt/C weight ratio – Cell performance



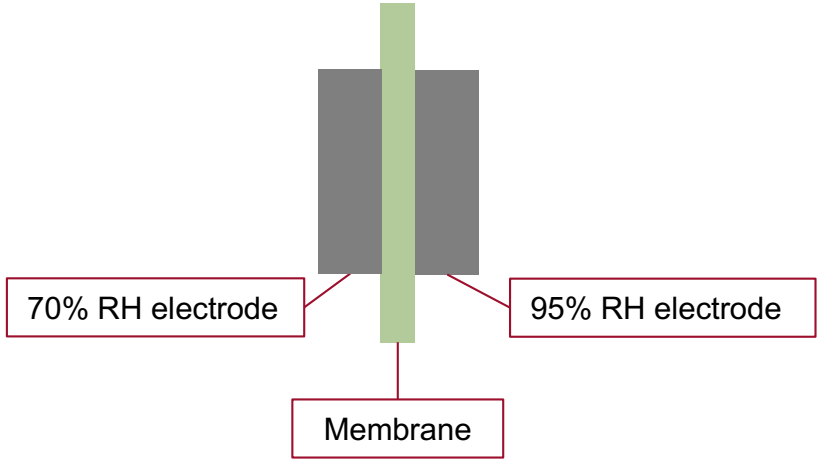
100% O_2 / 100% H_2, IR-corrected, scan rate 1 mV/s, Interval OCP - 0.1 V

- Best performance for 0.4-0.8 Ionomer:Pt/C ratio

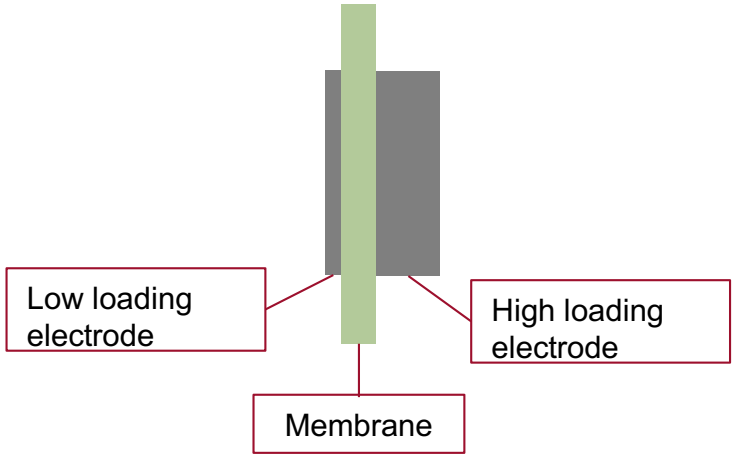
Experimental study

- Commercial membrane (Tokuyama)
- In-house electrodes (Pipetted)
- Reference loading 0.4 mg Pt/cm^2
- Commercial fuel cell housing (Fuel cell technologies)

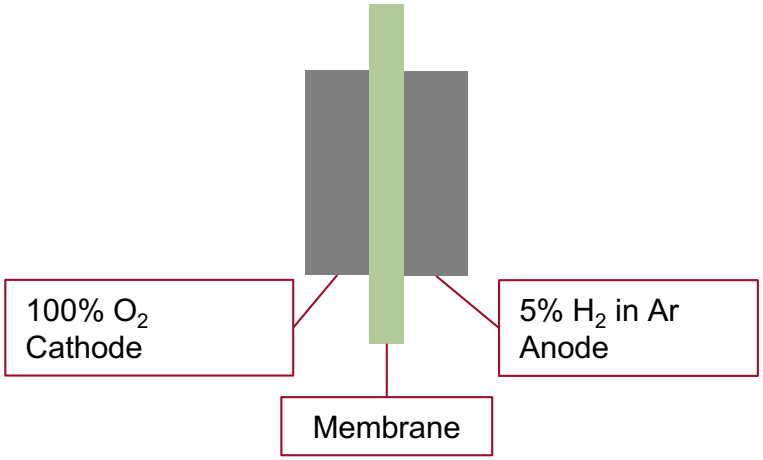
Changes in gas humidity



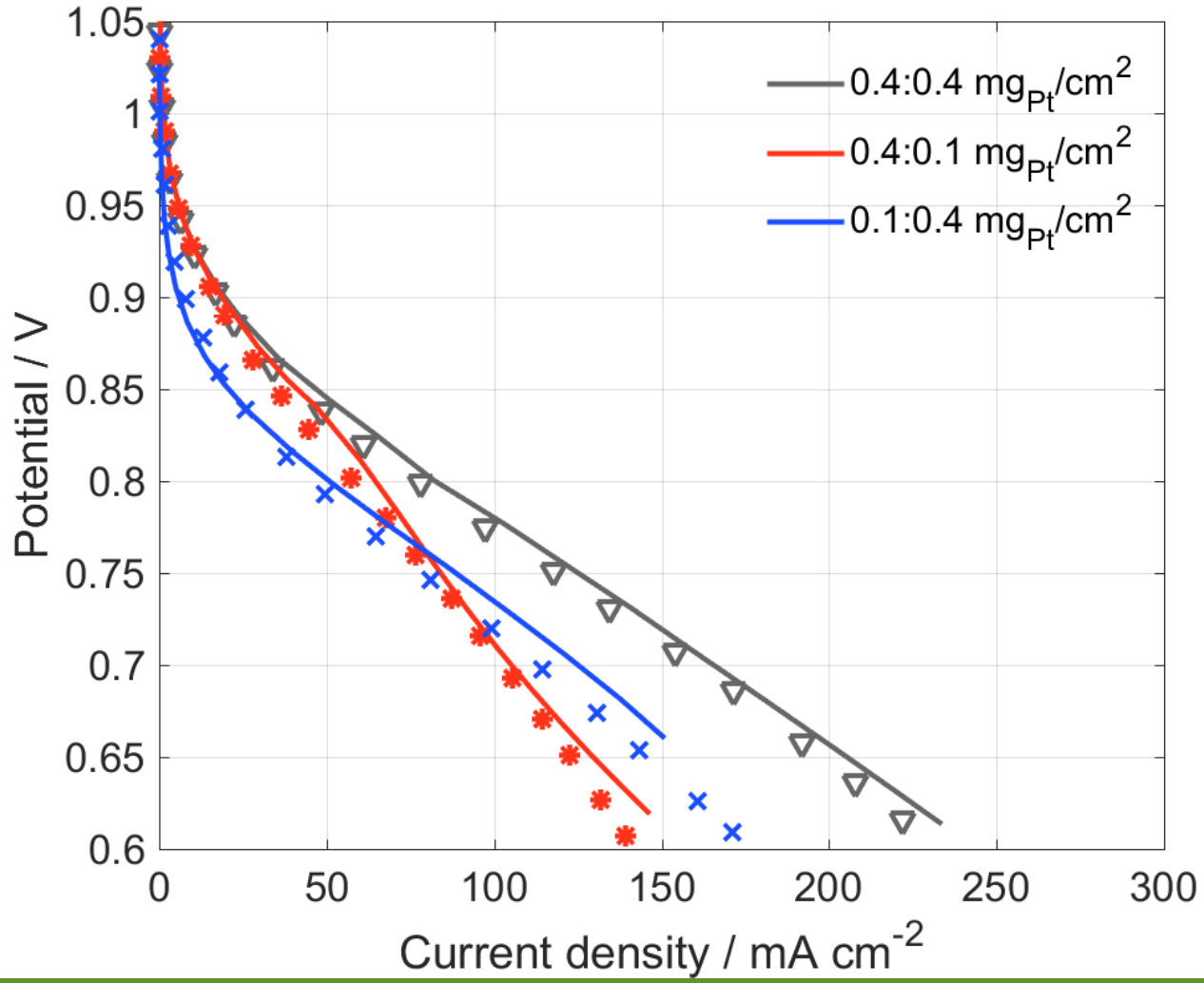
Asymmetrical cell tests



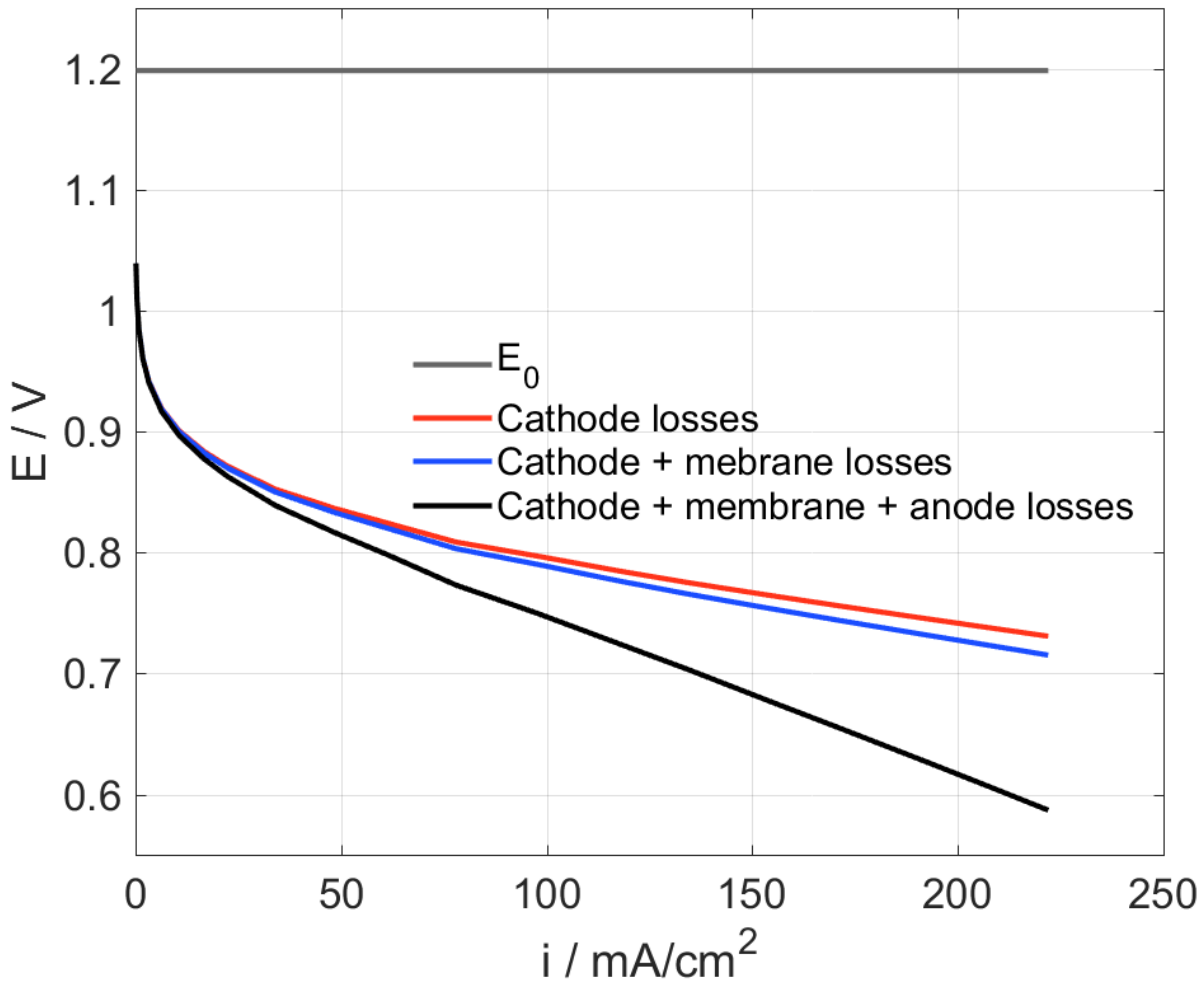
Lower partial gas pressure



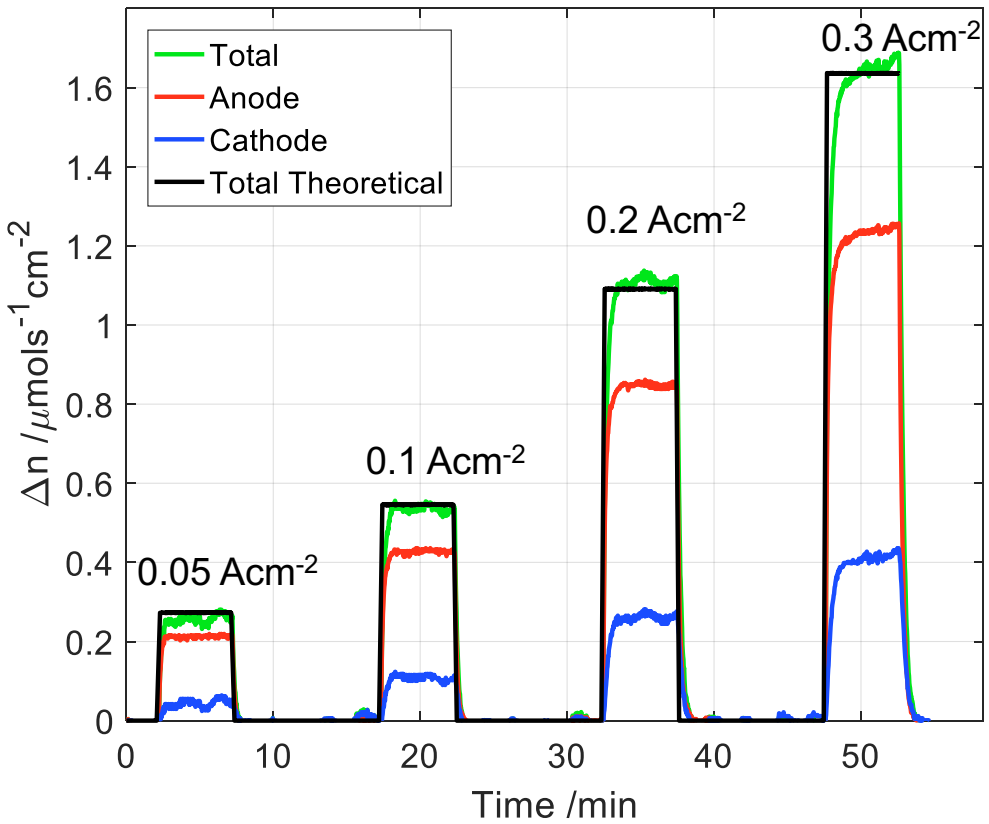
Model fitted to experimental data in the low current density region



Contributions to total potential drop



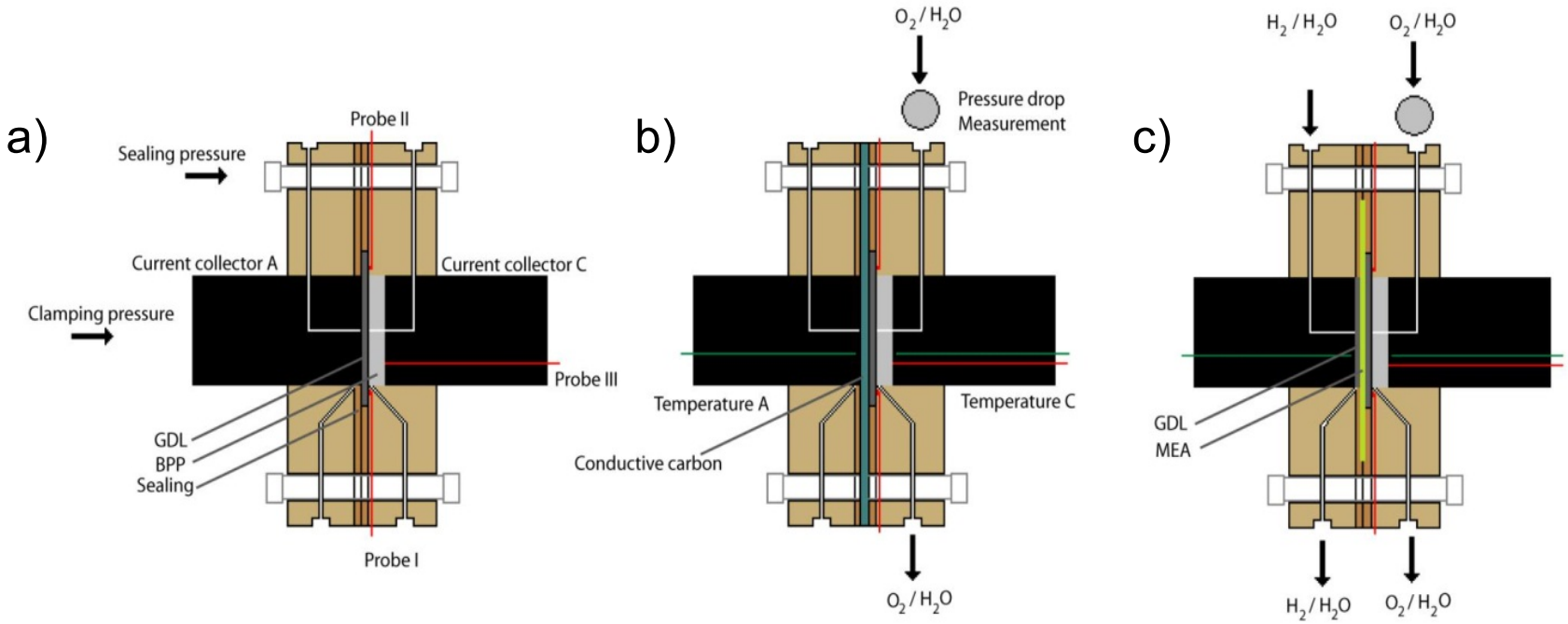
Water management – where is the water produced ending up?



Current density A/cm²	Ratio Anode/Cathode
0.05	4.7
0.1	3.9
0.2	3.3
0.3	3.2

100% O_2 / 100% H_2, 50 °C, 70 %RH, 0.4 mg Pt at both anode and cathode

Evaluation of bipolar plates



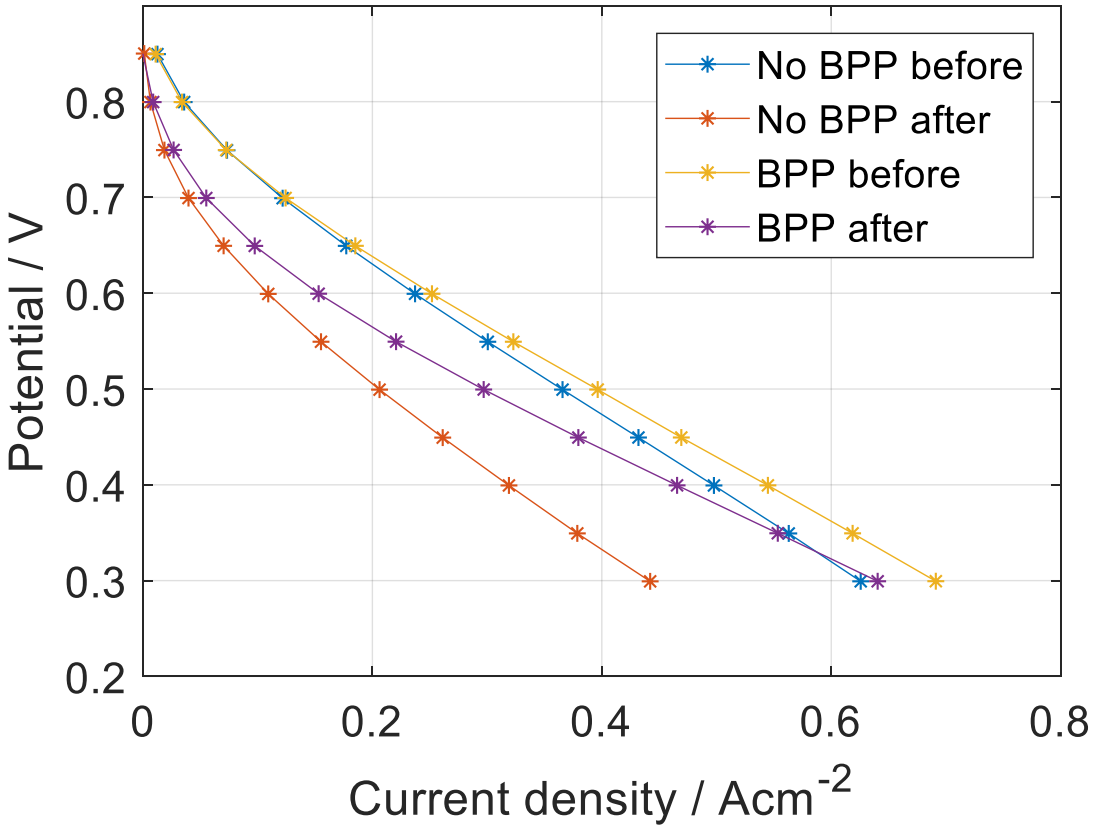
Ex-situ

Ex-situ simulated environment

In-situ

Bi-polar plate samples (area: 7 cm^2)

Degradation of MEA after accelerated stop-start sequence



Conclusions

- Pt_3Y has higher activity than pure Pt electrodes
  ~3 higher at 0.8 V (Mass basis)
  ~1.7 higher at 0.8 V (ECSA basis)
- Cell performance is limited by the performance of both electrodes. However, the cathode is more limiting at lower current densities.
- Measurements of water in outlet gases indicate substantial transport of the water produced at the anode side to the cathode side.
- Degradation is primarily on the MEA. No increase in degradation rate due to the coated bipolar plates.

Acknowledgements

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- Swedish Energy Agency
- StandUp for ENERGY
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