Polymer Electrolyte Fuel Cells

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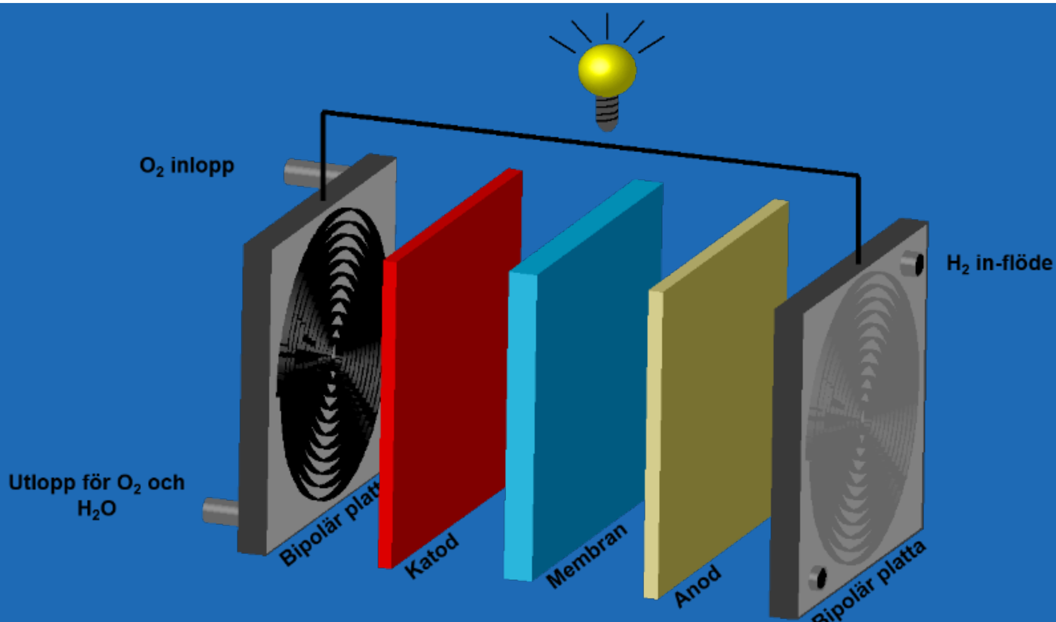
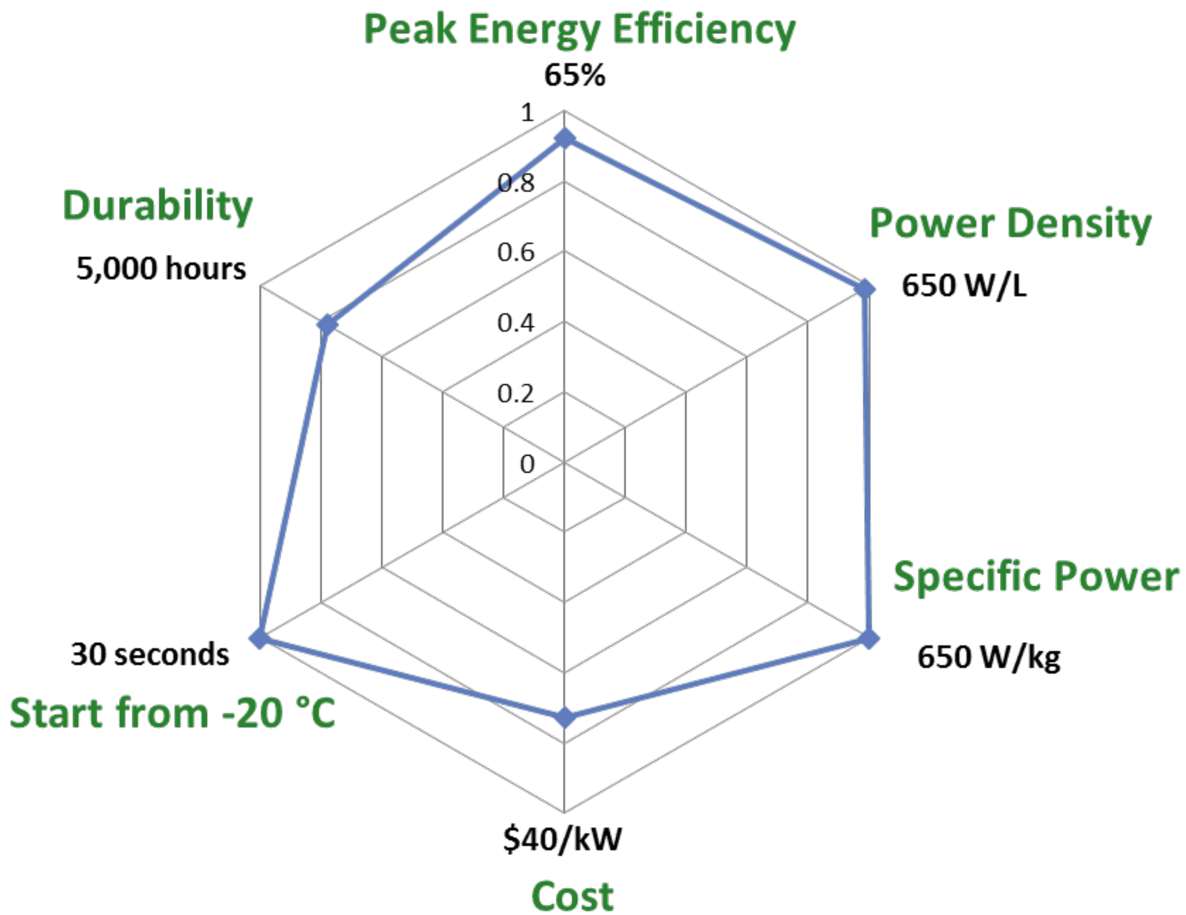
Applied Electrochemistry, KTH



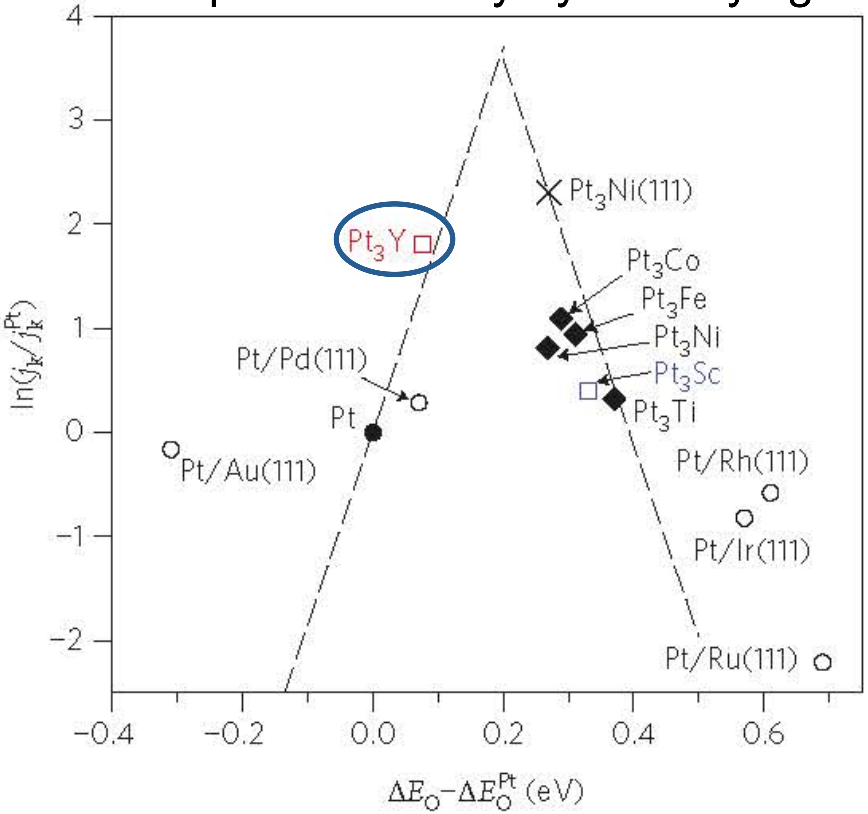
Achieved 2020 Targets PEMFC automotive



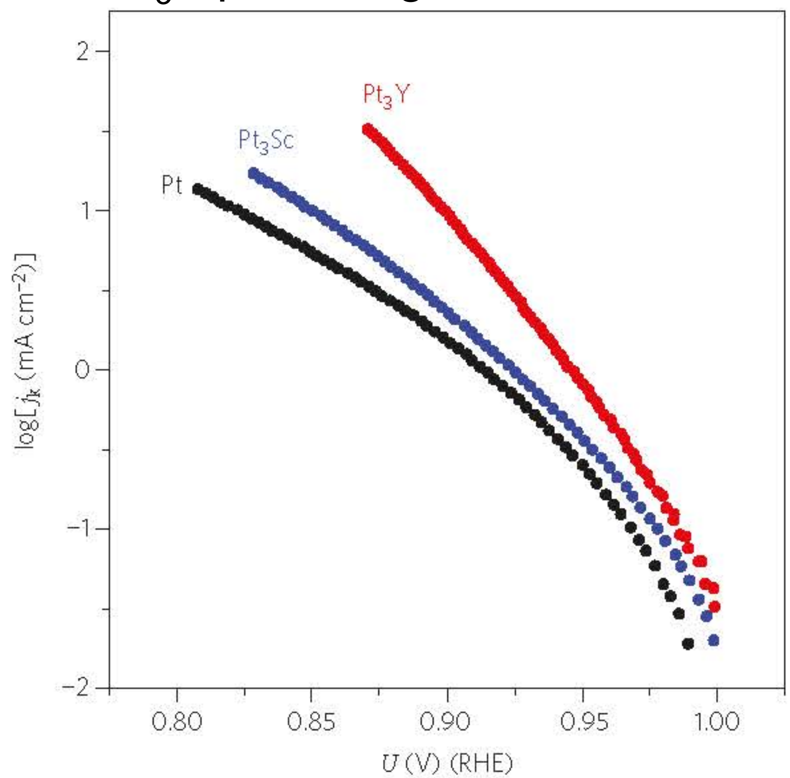
Department of Energy. USA, 2016

Alternative cathode catalysts for PEMFC

Improved activity by Pt alloying

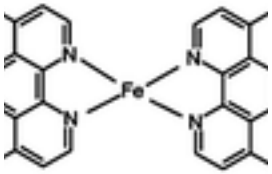


Pt_3Y promising

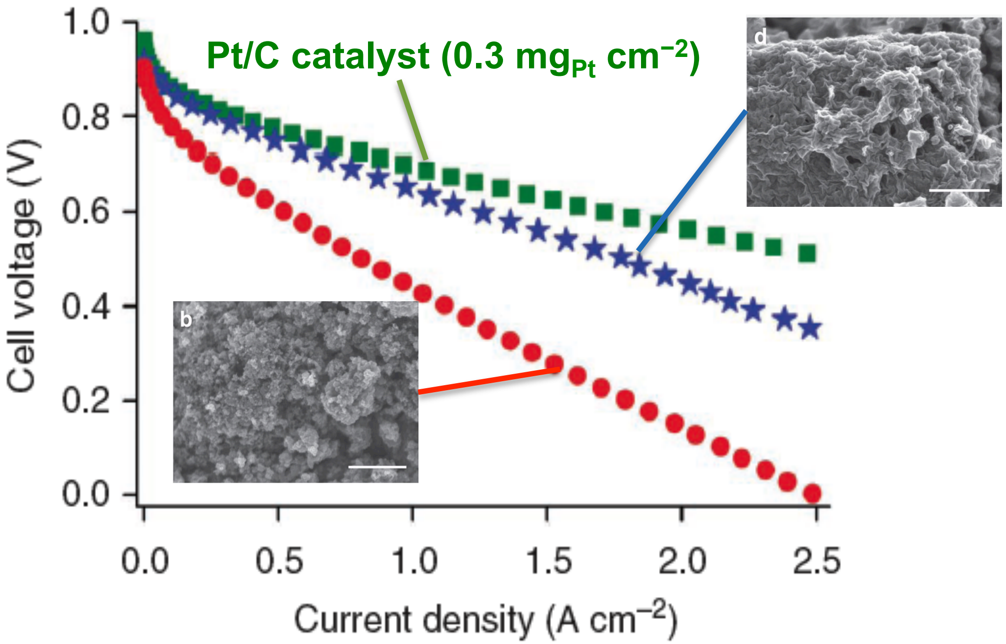


J. Greeley, I. E. L. Stephens, A. S. Bondarenko, T. P. Johansson, H. A. Hansen, T. F. Jaramillo, J. Rossmeisl, I. Chorkendorff and J. K. Nørskov , Nature Chemistry, 2009, 1, 552-556

Non-precious metal catalysts (Fe-N-C)

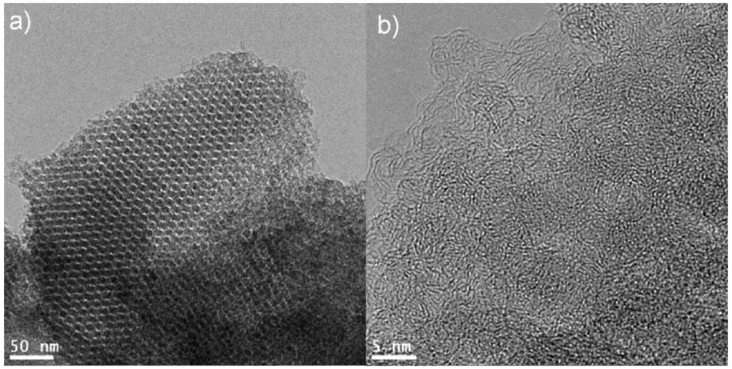


Increased porosity → Better I-V performance



E. Proietti et al. Nature Comm. 2, # 416 (2011)

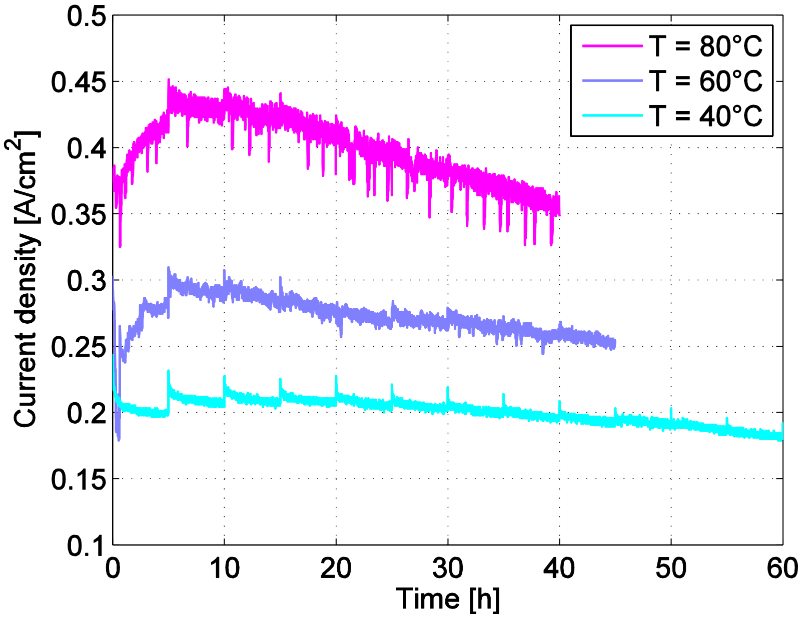
Highly ordered mesoporous NPM catalyst



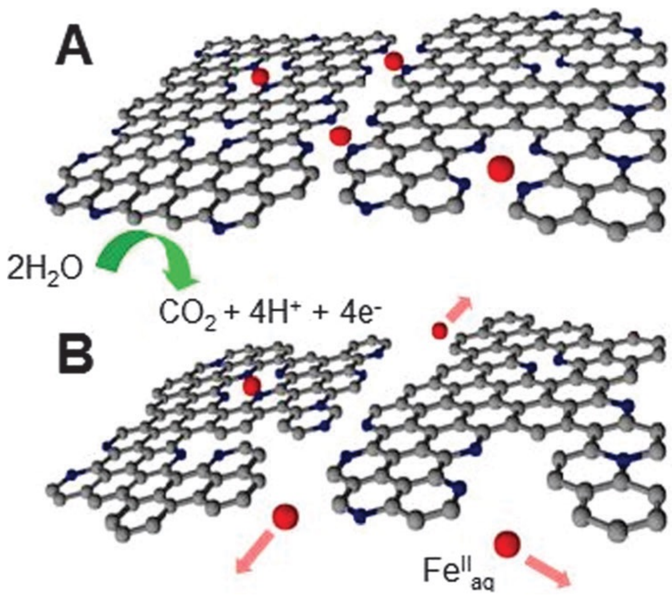
J. K Dombrovskis, A.E.C Palmqvist, PhD Thesis, Chalmers 2016

Stability problems with NPM (Fe-N-C) catalysts

Degradation at 0.5 V hold



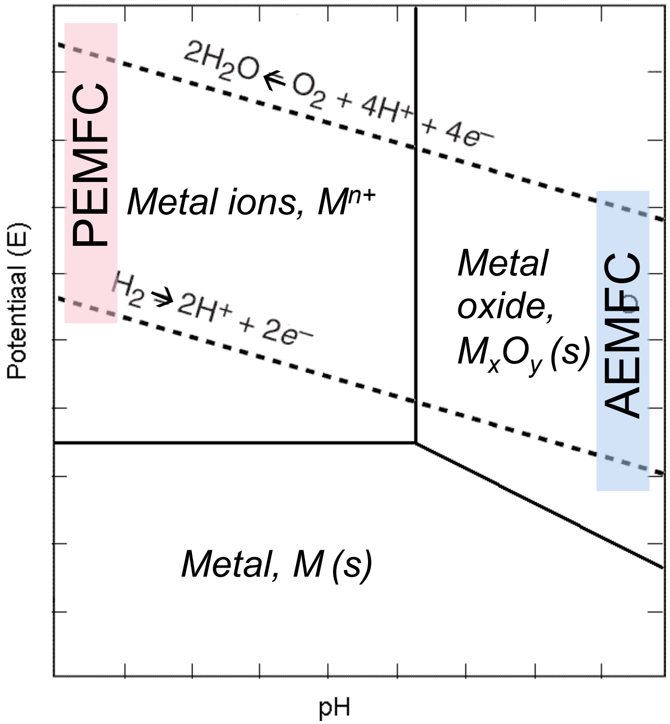
C corrosion, OH-radicals, others?



Collaboration with F. Jaouen (Université de Montpellier),

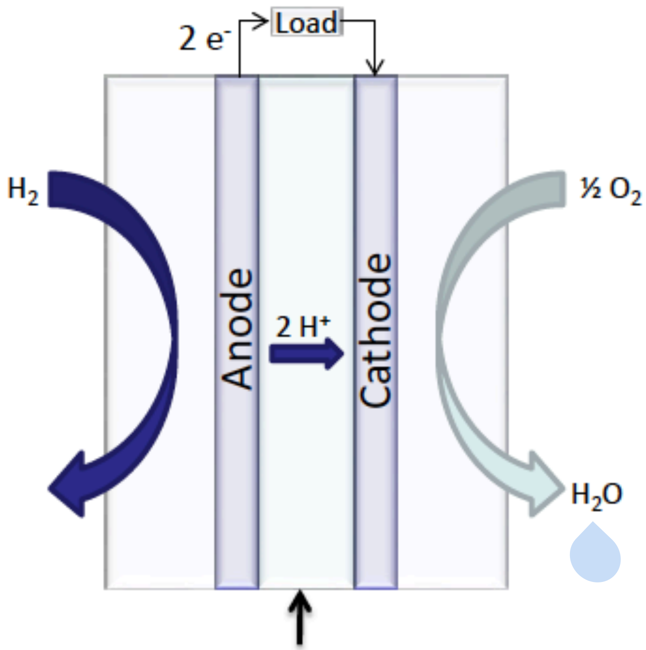
Goellner V Et al. , 2014, Phys.Chem.Chem.Phys, vol. 16, pp. 18454-18462

Anion Exchange Membrane Fuel Cell (AEMFC)

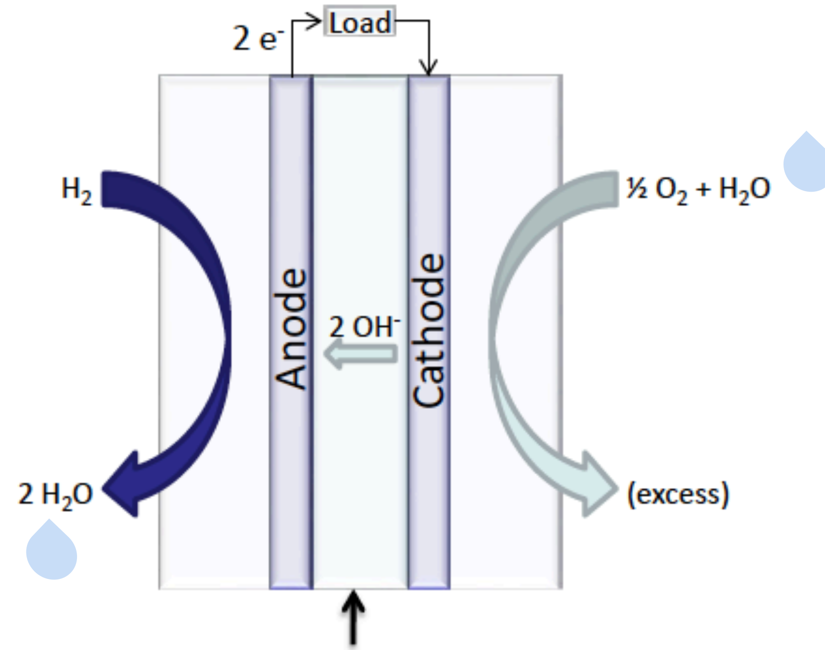


Type	Cation exchange membrane	Anion exchange membrane
Counter ion	H^+	OH^-
Advantages	High conductivity Good ionomer solution	Pt-free catalysts Oxygen reduction
Issues	High material costs Fuel crossover	Low conductivity Low temperature stability CO_2 sensitive

AEMFC versus PEMFC



Proton-Exchange Membrane (PEM)



Anion-Exchange Membrane (AEM)

- Requires precious metal electrocatalysts

- Potential to use non-precious metal catalyst

Field-tested 2kW AMFC System (Cellera)

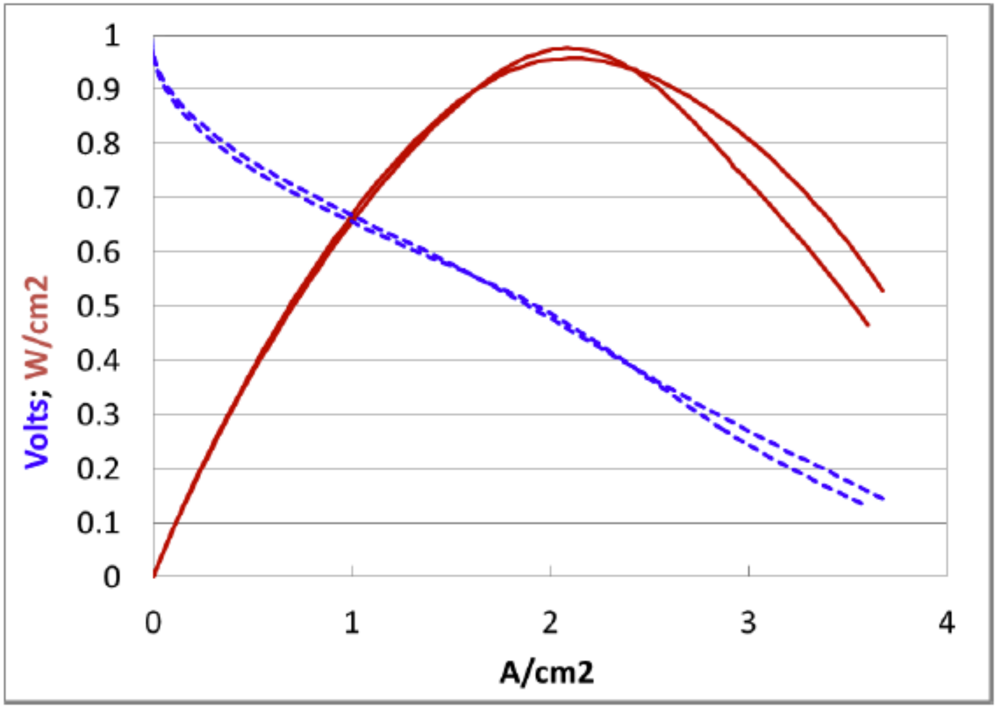
- 6-month 2kW H_2/Air stack-system test
- Live site backup capability
- Aluminum hardware; air-cooled
- Cathode water exchanger / dry anode
- Pressure - ambient air / 1.5bar(g) H_2

AMFC Status – Single (well-humidified) Cell

Polarization curve – 5cm2 H_2/Air
Pt-free Ca, Pt-catalyzed An;
CO_2-free air

T_{cell} = T_{air}(humf) = 75°C
P_{air}; P_{H2} = 1;3 bar(g)

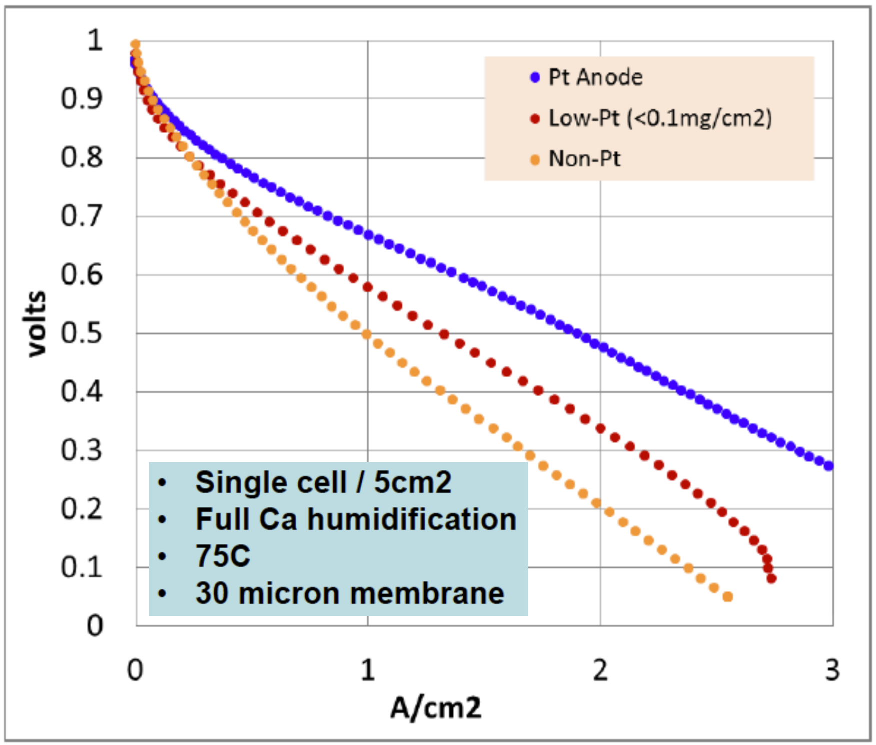
30µm thick, polyhydrocarbon membrane



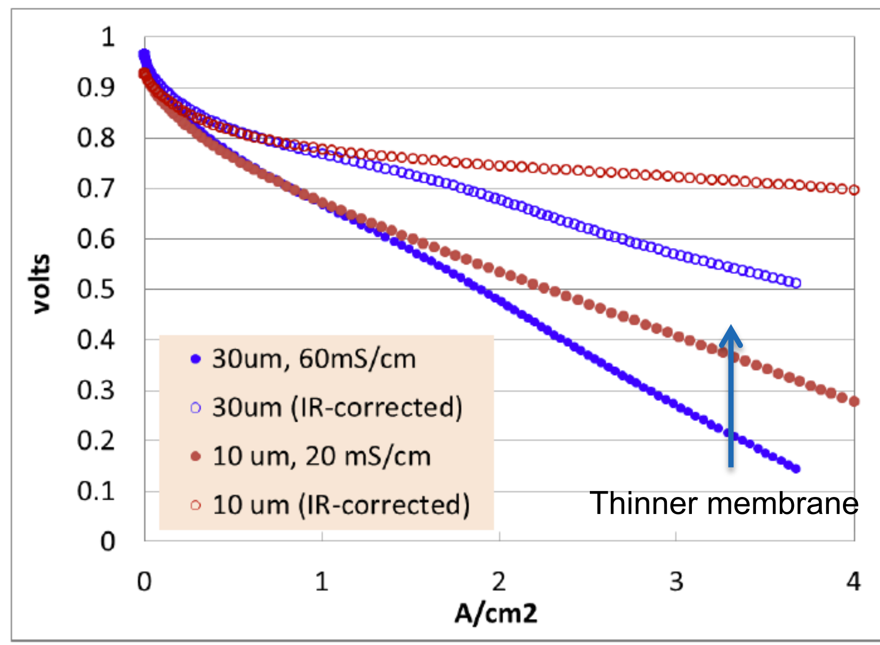
- Performance level of Proton Exchange Membrane (PEM) fuel cells is within reach, however:
  - Air humidification and overall water management are critical
  - CO_2 handling adds to system complexity in operation at lower T_{cell}

Room for performance improvements

Anode catalyst and structure



Membrane thickness, OH^- conductivity, and water-management



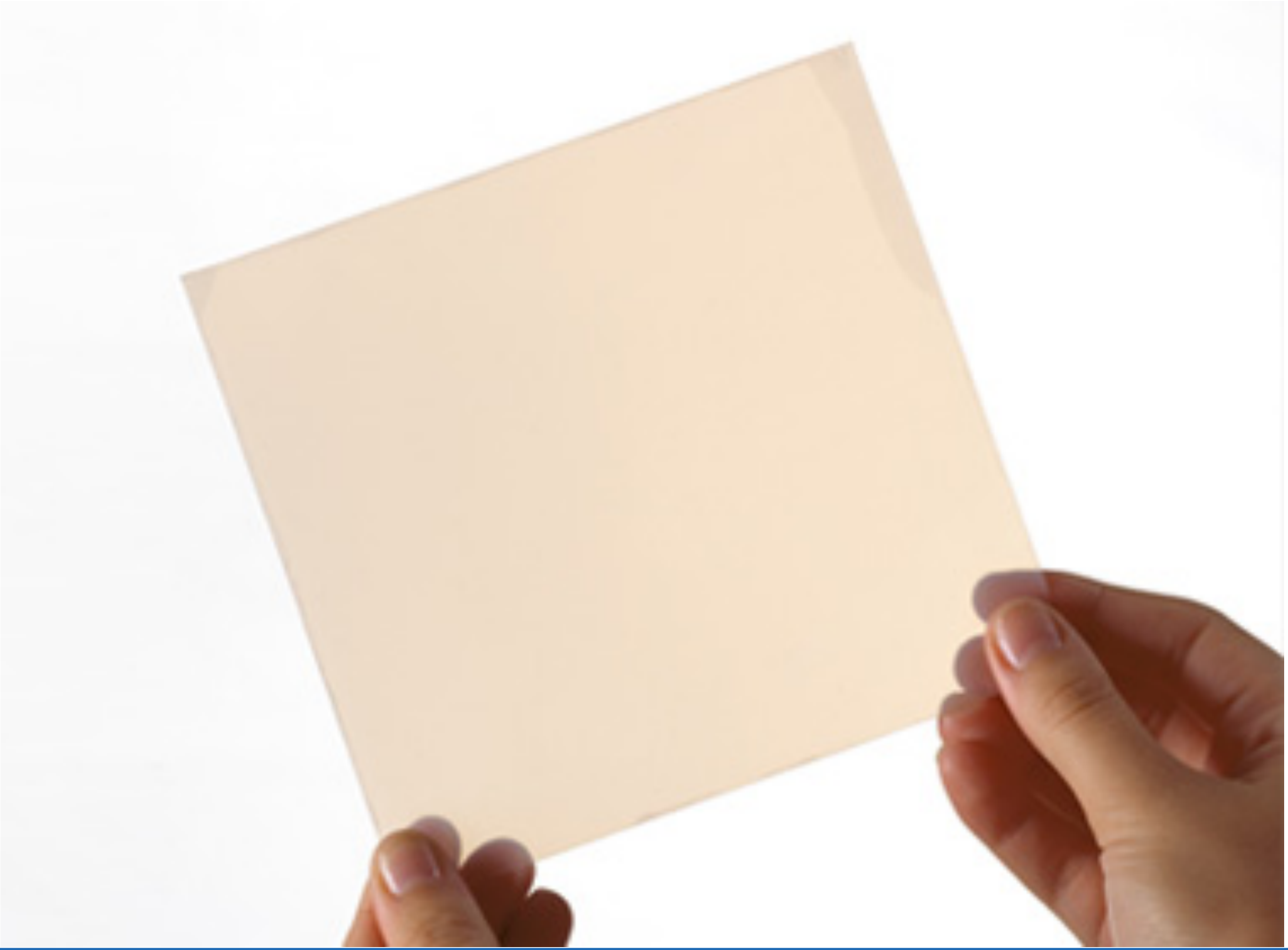
Selected Issues & Research Needs

- **Higher anode activity**
- **Membrane - operation at T > 80C / water mobility**

- Anode activity: significant progress has been made
  - Near-Pt activity with Pd-based catalyst [2];
  - Pt-containing bimetallics show activity greater than Pt [3];
  - Advances in fundamental understanding of alkaline HOR [4,5]
- Anode challenge today: also substantially **water management**
- Membrane:
  - Tokuyama A201 – technology of *ca*. 2008 – is still the leading commercial "standard" membrane
  - i.e. *"membrane/ionomer issues" – including the need for higher operation temperature and higher water mobility – have not been adequately resolved!*

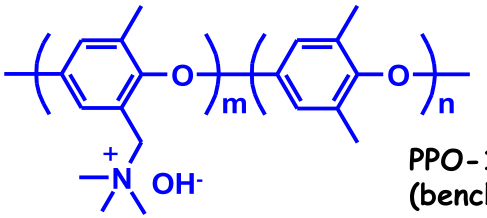
KEY BOTTLENECK !

Membrane development



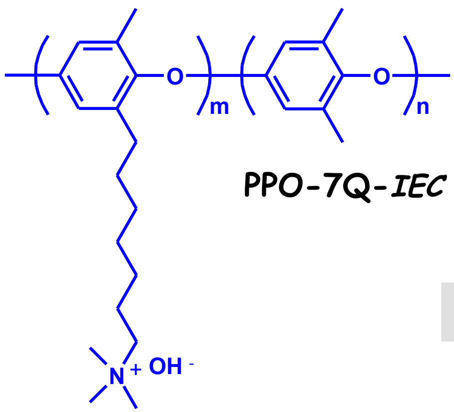
Alkaline membranes:
Aromatic instead of fluorinated (Nafion)

Aromatic AEM



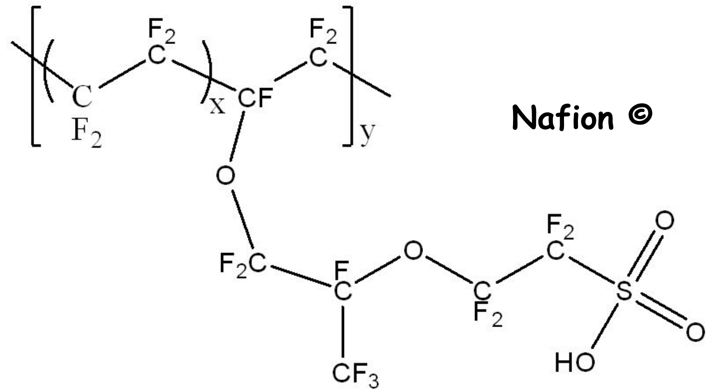
PPO-1Q-IEC
(benchmark)

Modified Aromatic AEM



PPO-7Q-IEC

Typical material in PEMFC



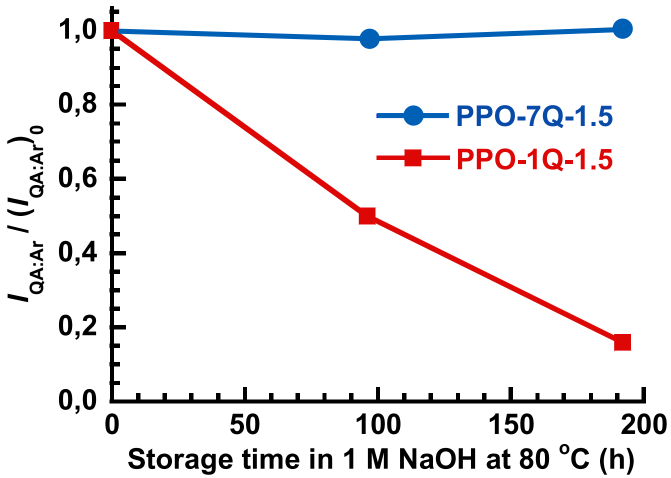
Nafion ©

Improved performance:

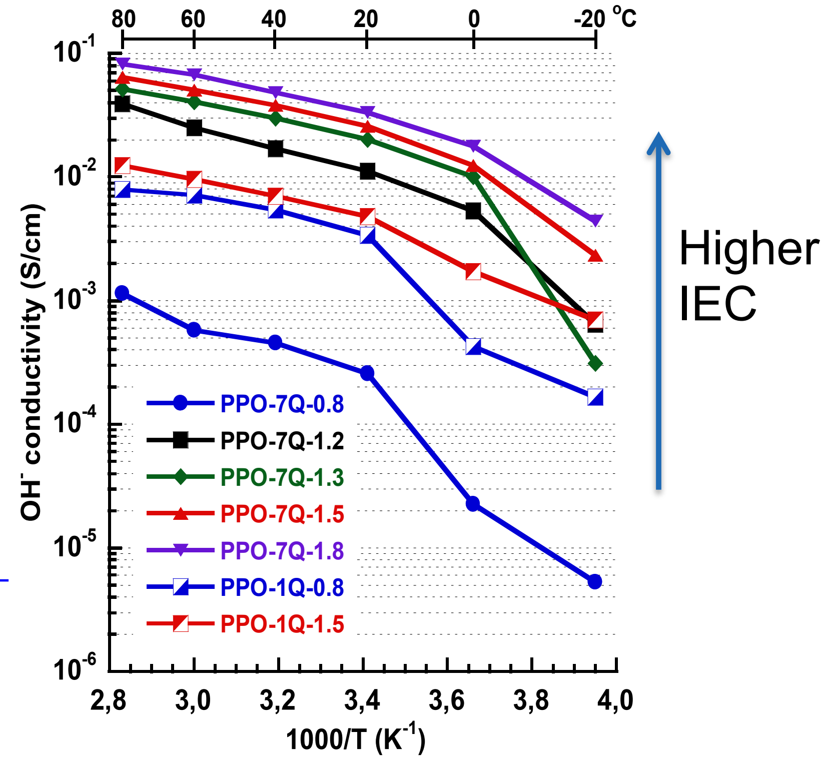
- Higher flexibilty
- Better conductivity
- Better phase separation and thereby more ion-conductive regions

Improvment with longer side chain

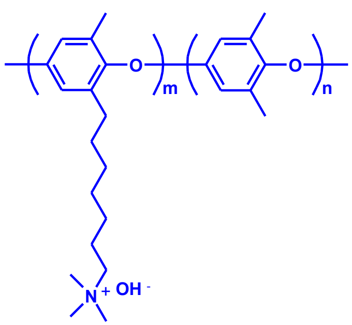
Better stability



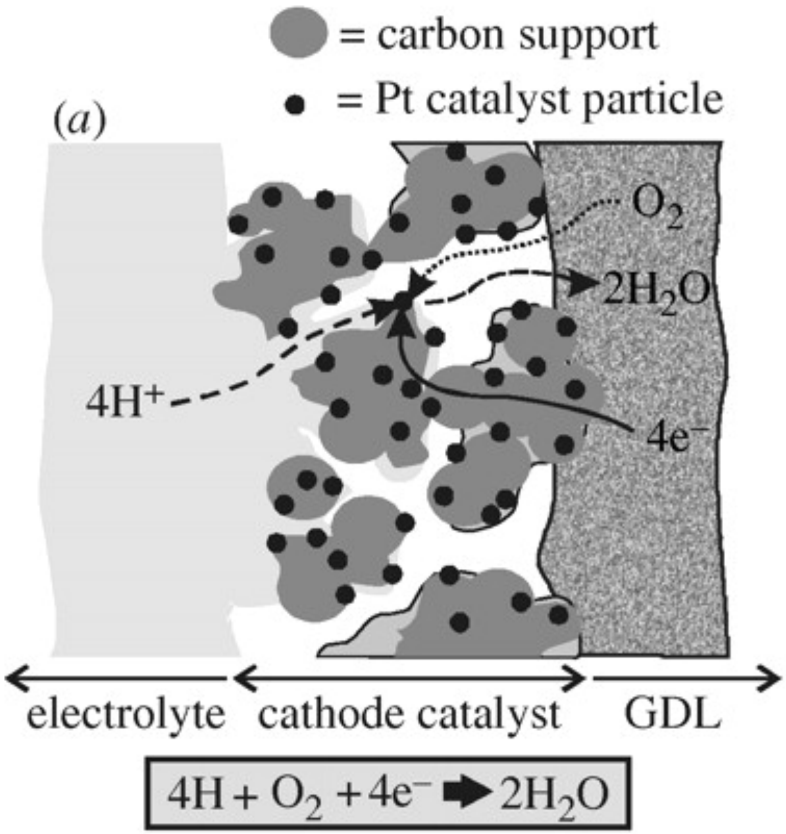
Better conductivity



- Short chain: PPO-1Q-IEC
- Long chain: PPO-7Q-IEC

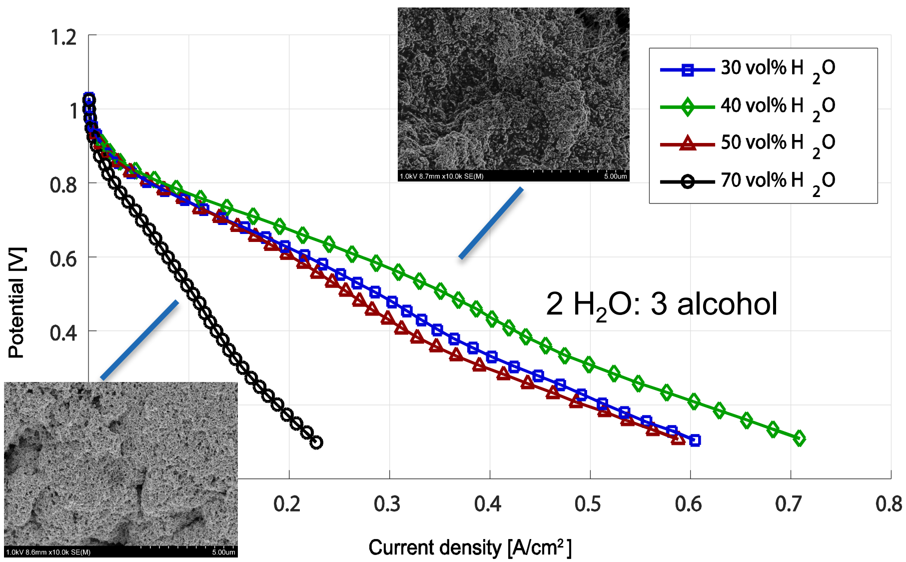


Electrode development

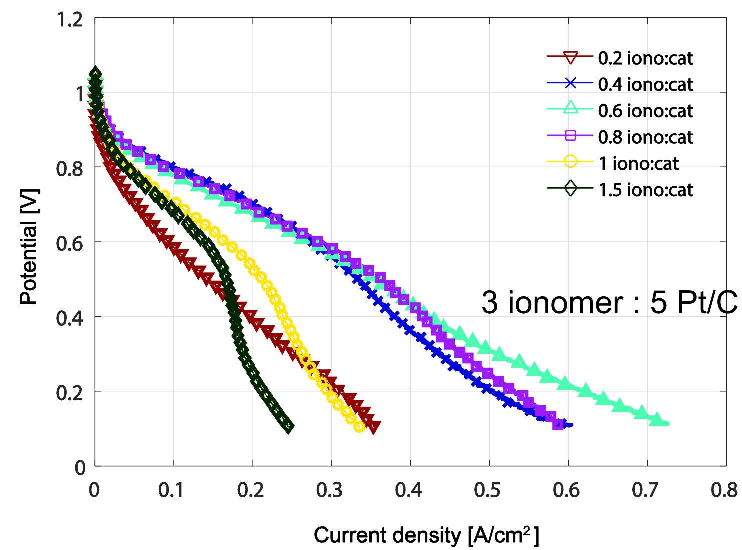


Influence of electrode structure on performance

Solvent composition in catalyst ink

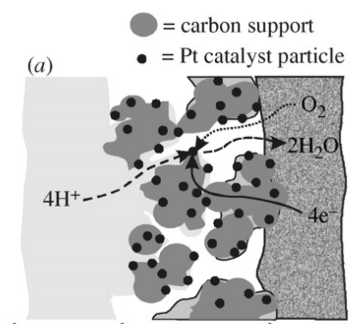


Ionomer : Pt/C catalyst content



For good performance:

Optimum amount and homogeneous distribution of ionomer and pores in the electrode



Conclusions

- Typical PEMFC – a mature technology
    - Costs reduction possible by alloying or NPM catalysts
- AEMFC interesting alternative but needs more research:
    - Stable anion exchange membranes and ionomers
    - Electrode morphology and structure
    - Non-platinum catalyst

FFI Fordonsstrategisk Forskning och Innovation

”**New components and concepts for PEFC in vehicle applications**” *KTH, Lund University, Chalmers, Sandvik, Cell Impact, PowerCell, Intertek, Vätgas Sverige, AB Volvo, Volvo Cars, Scania*