



Latest advances in Alkaline Membrane Fuel Cell (AMFC) technology

Dario R. Dekel

Co-founder and Vice-President R&D and Engineering

CellEra

Caesarea, Israel

3rd CARISMA International Conference – September 3rd, 2012



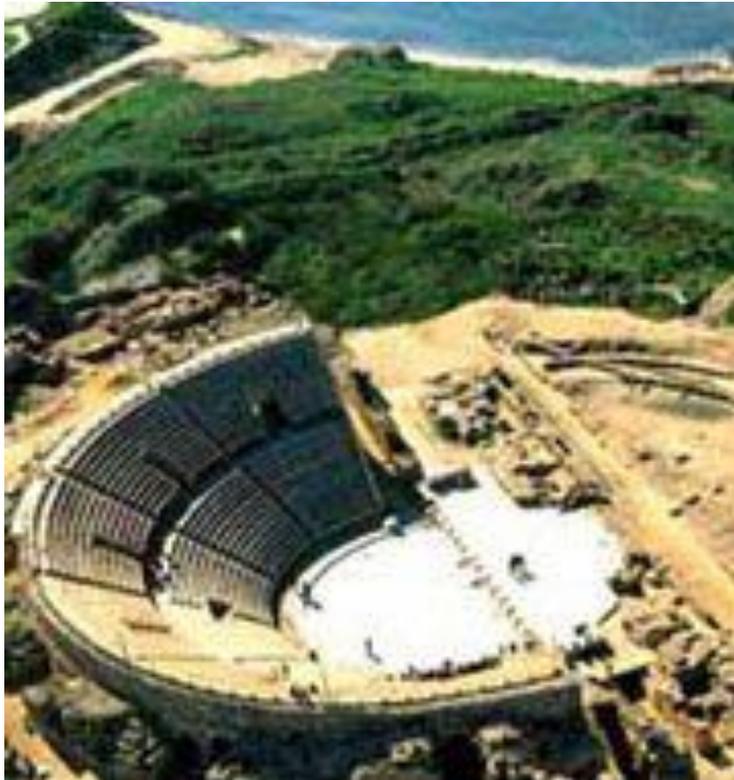
OUTLINE:

1. About CellEra
2. Latest developments in AEMs
3. Are there any available anion conductive ionomers ?
4. Stability challenges – backbones and functional groups
5. What about electrocatalysts ?

[Off-the-record]: some data on CellEra's cells and stacks

WHERE WE ARE

FOUNDED IN DECEMBER 2007
LOCATED IN CAESAREA, ISRAEL



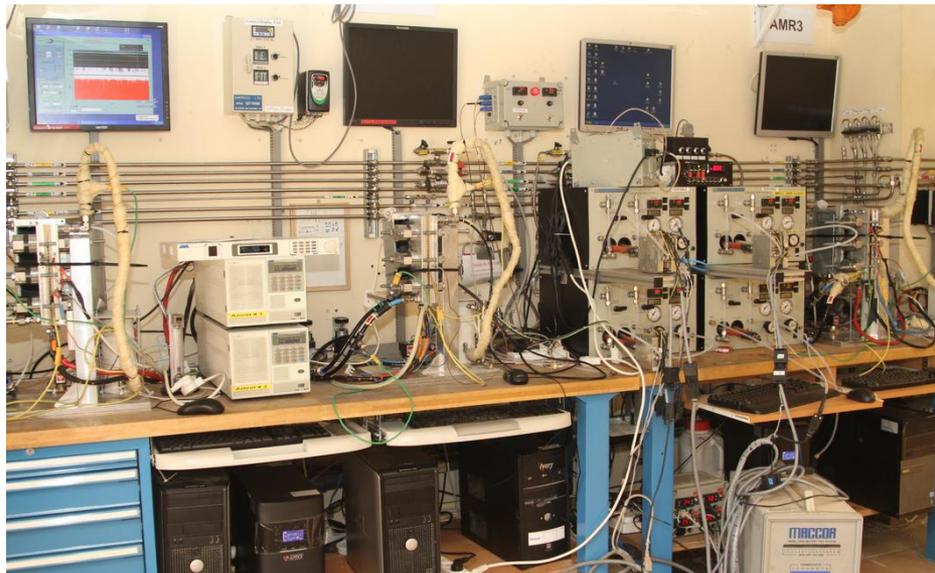
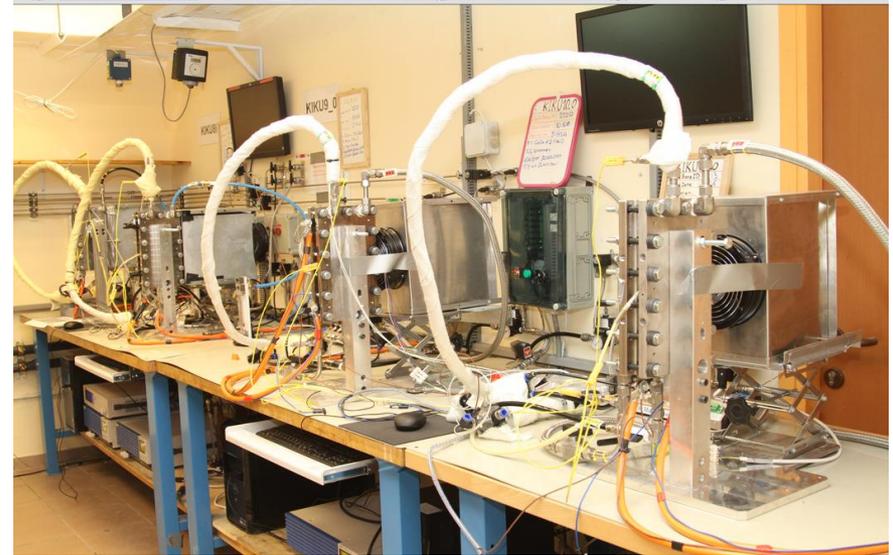
Roman amphitheatre (22BCE),
at Caesarea National Park



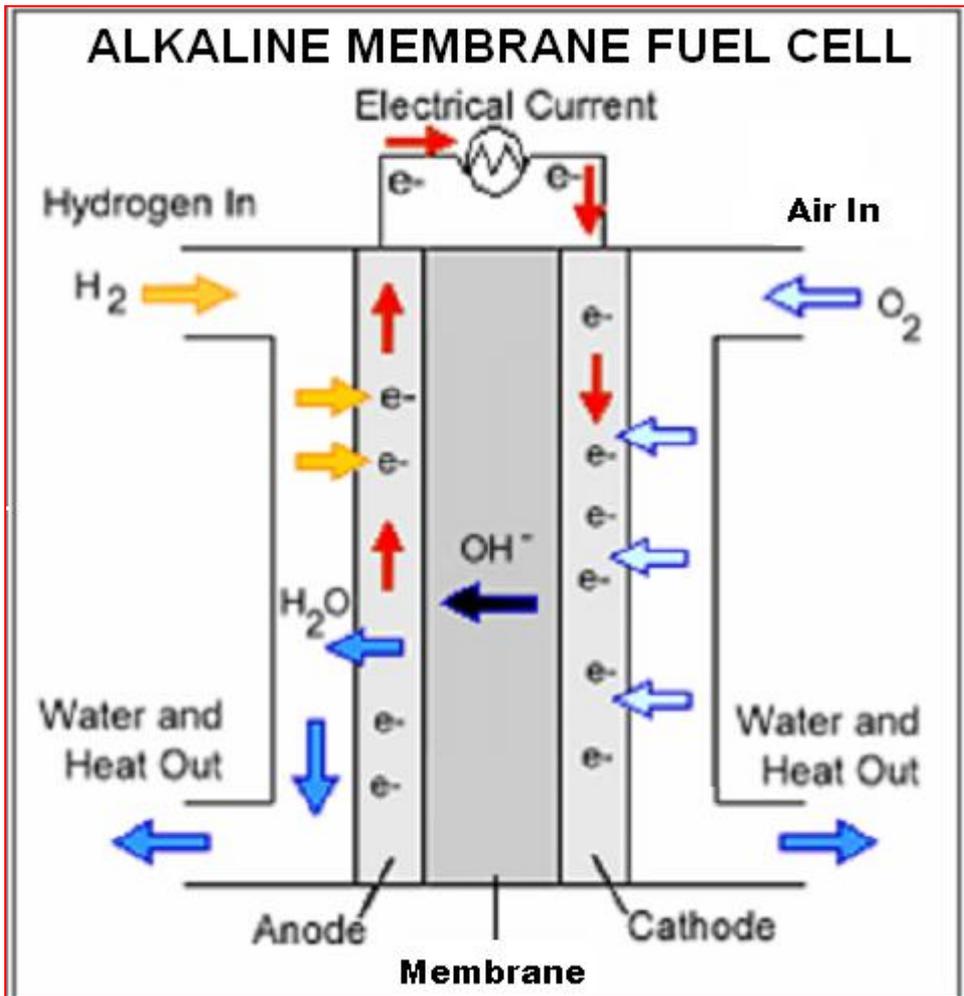
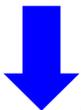
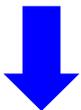
Views from Haifa at Caesarea's surroundings

WHO WE ARE

- 17 people
(incl. 5PhD, 4MSc, 4BSc)
- AEM-CCM production lab
- Polymer & chemical lab
- 20 FC stations in 2 testing labs
- Stack & system lab



OH- cond. inks



OUTLINE:

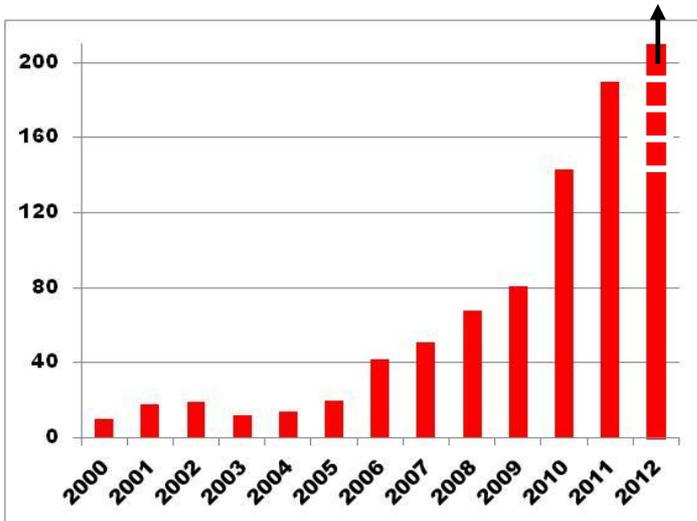
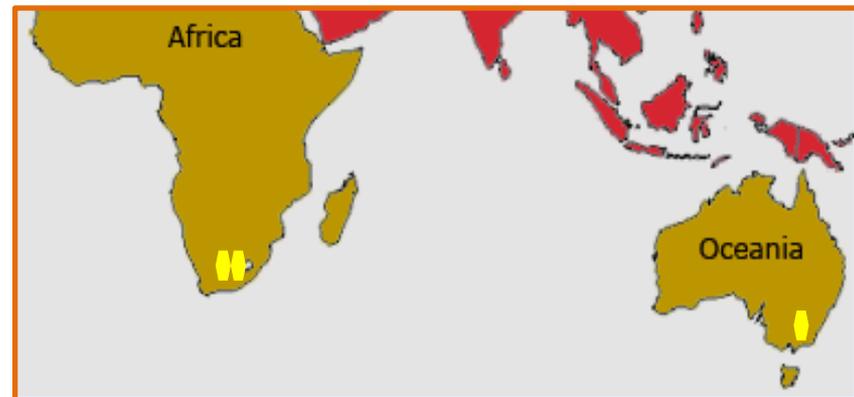
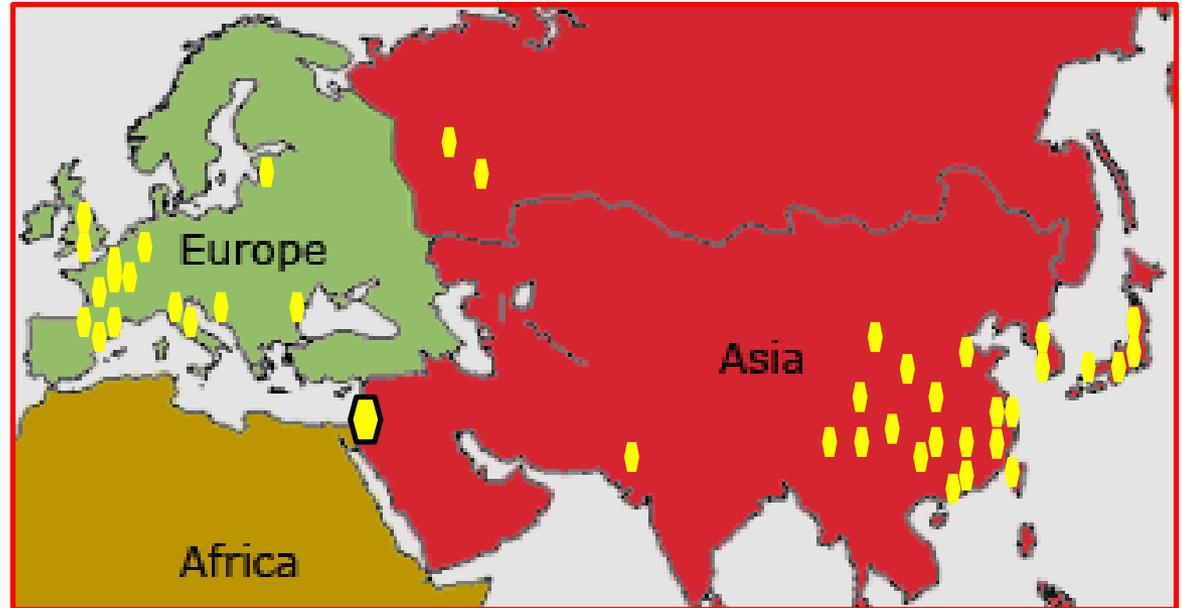
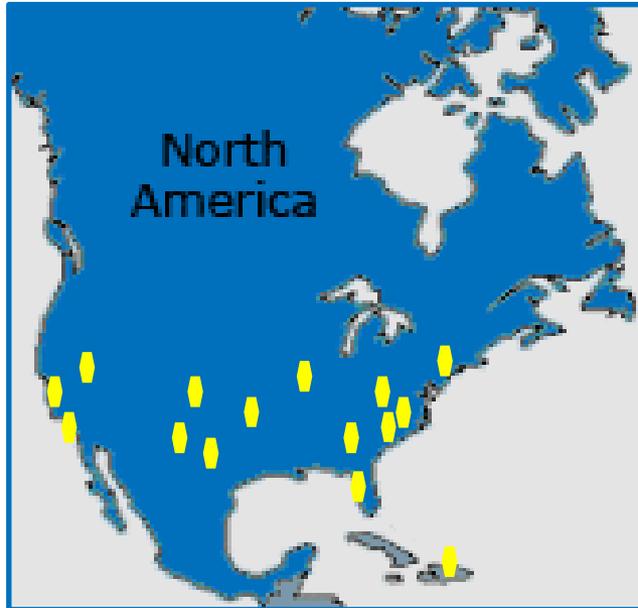
1. About CellEra

2. Latest developments in AEMs

3. Are there any available anion conductive ionomers ?
4. Stability challenges – backbones and functional groups
5. What about electrocatalysts ?

[Off-the-record]: some data on CellEra's cells and stacks

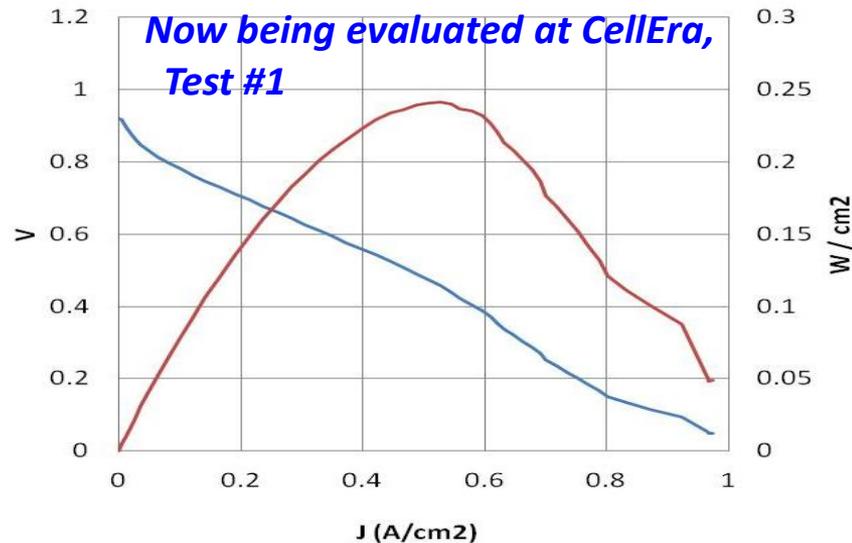
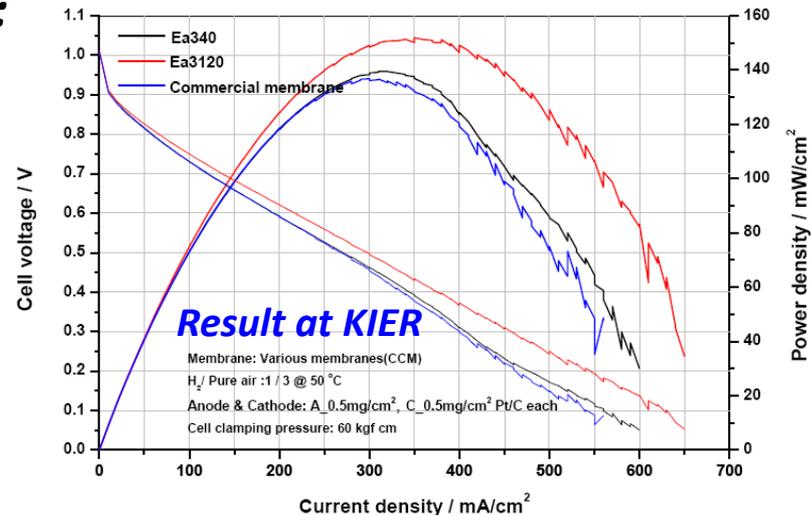
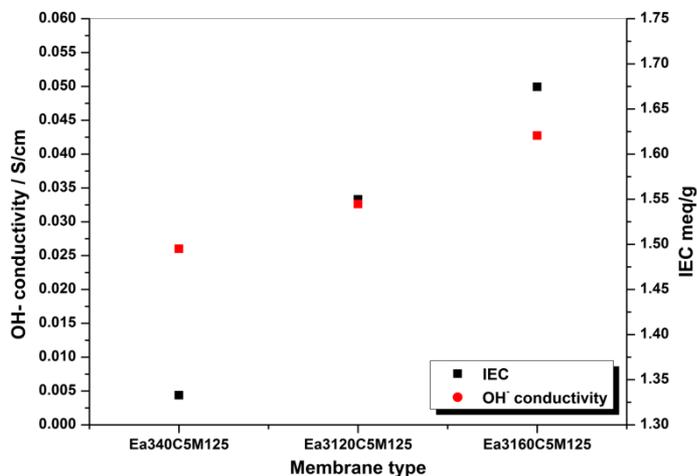
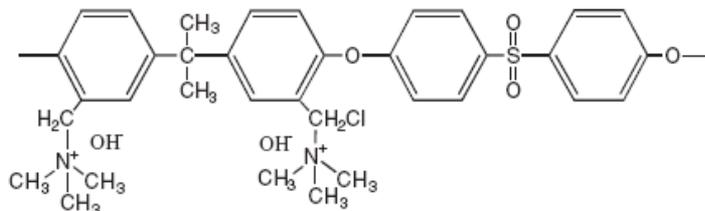
WORLDWIDE AMFC RELATED RESEARCH



*Publications with "alkaline membrane" and "fuel cell" from ISI Web of Science search engine.

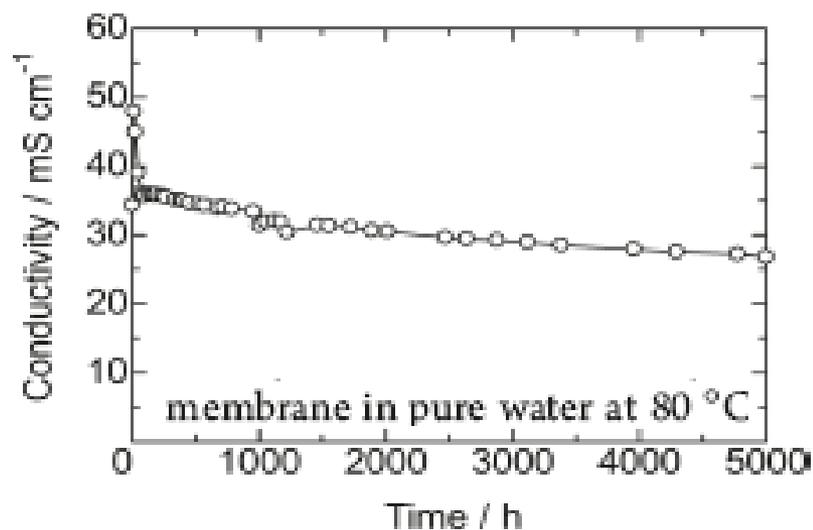
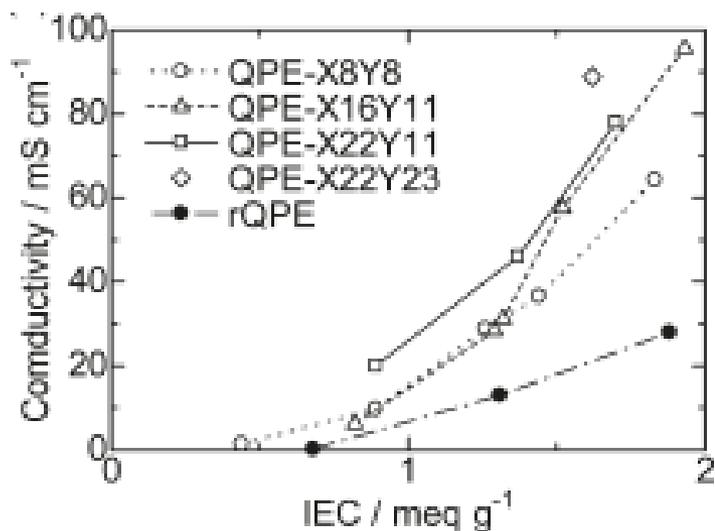
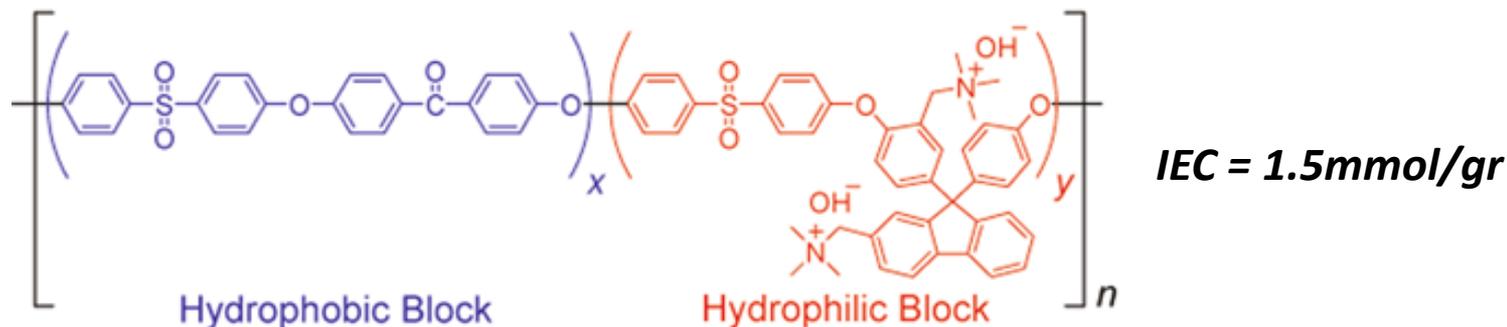
NEW STRUCTURED AEMs

New anion conducting pore-filling membranes:



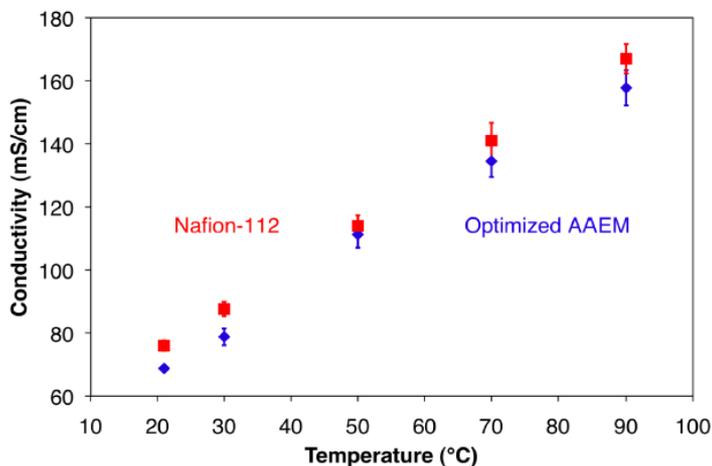
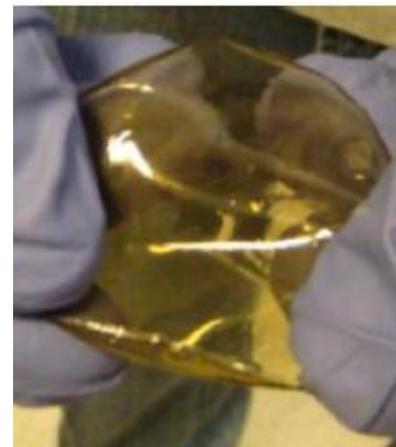
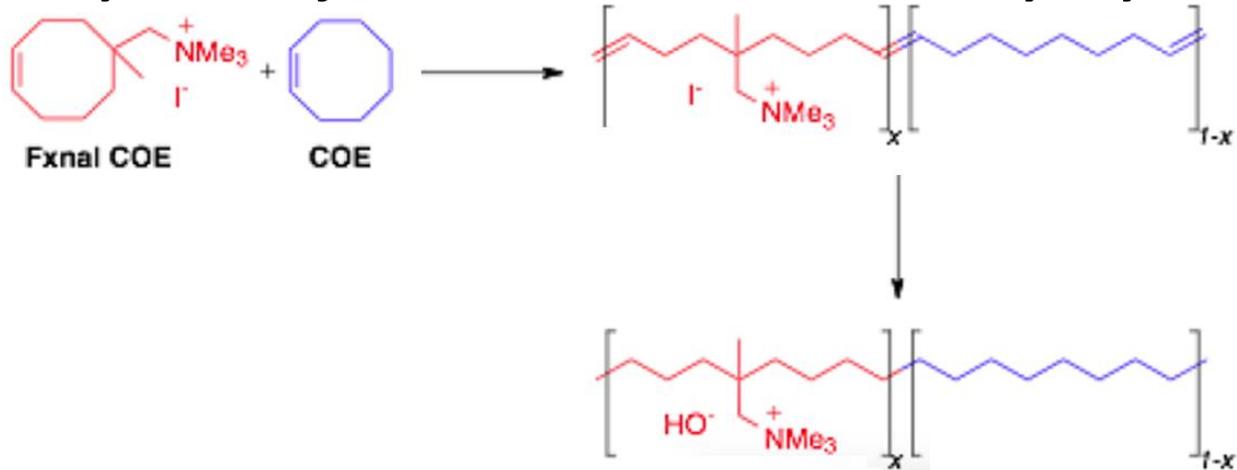
NEW AEMs -- COPOLYMERS

Anion conductive hydrophobic-hydrophilic multiblock poly(arylene ether)s:



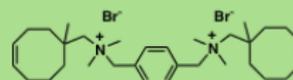
NEW AEMs -- HIGHER OH- CONDUCTIVITIES

Simplified synthesis of Ammonium Functionalized Polyethylene:



Highest conductivity @RT:

65 mS/cm



IEC = 2.3mmol/gr

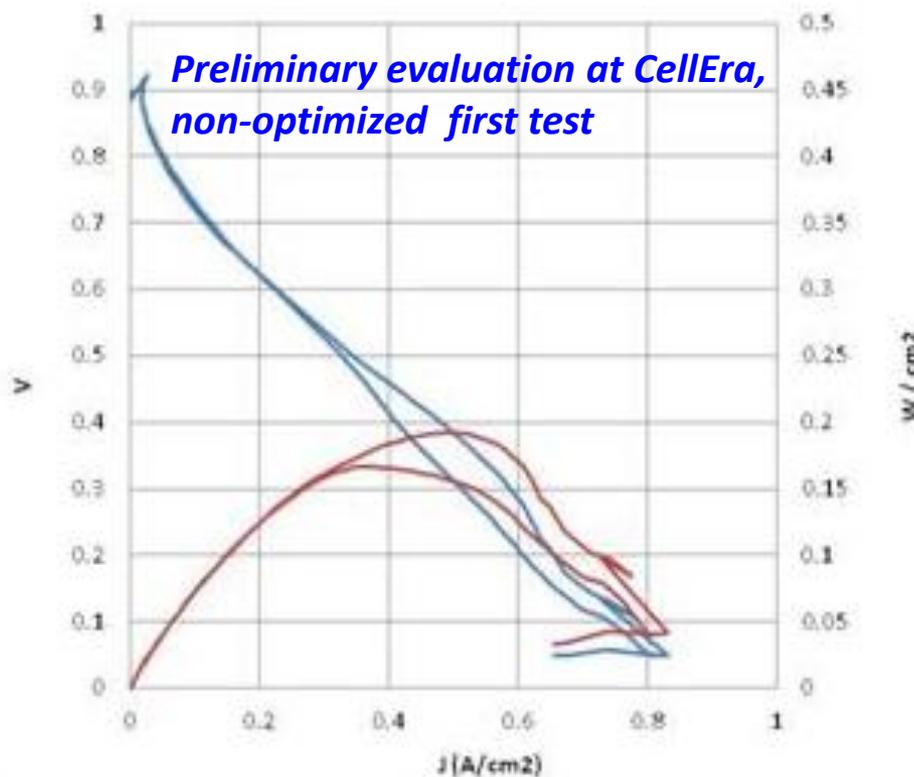
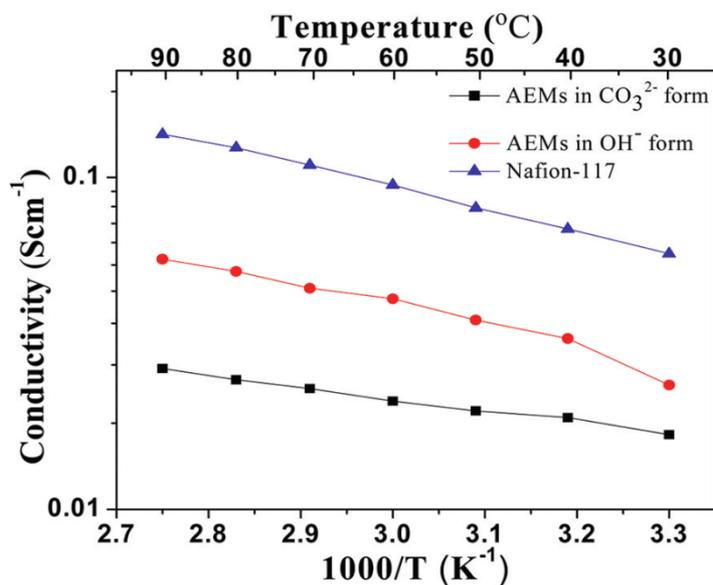
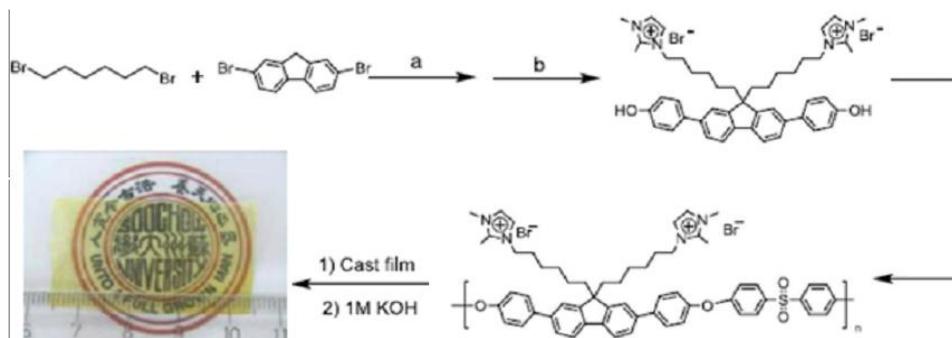
WU=110%

OUTLINE:

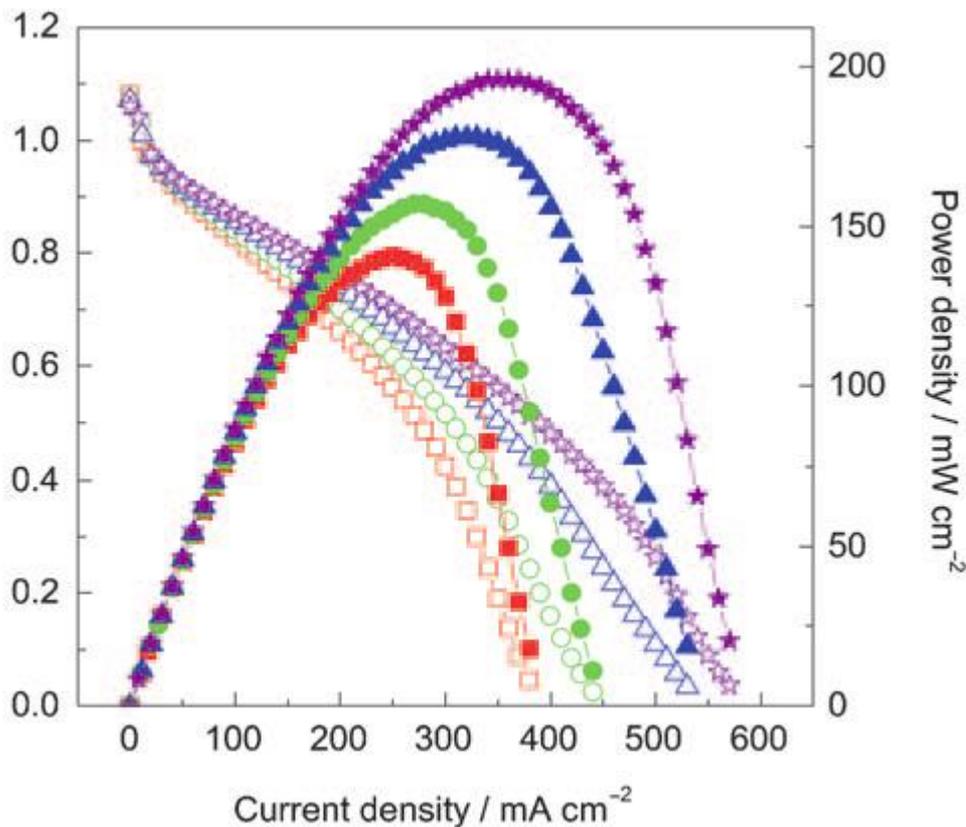
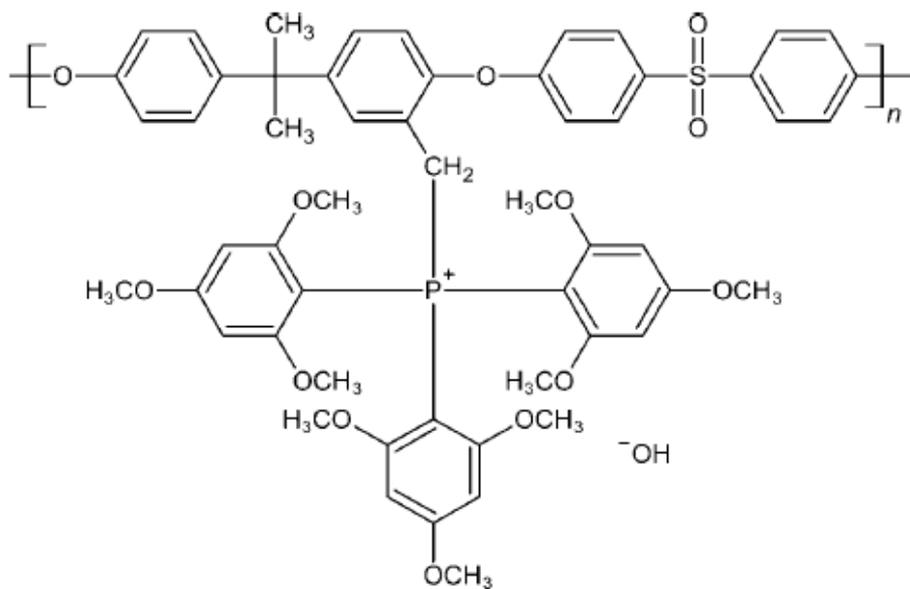
1. About CellEra
2. Latest developments in AEMs
- 3. Are there any available anion conductive ionomers ?**
4. Stability challenges – backbones and functional groups
5. What about electrocatalysts ?

[Off-the-record]: some data on CellEra's cells and stacks

Imidazolium Polyfluorene Ionomer:

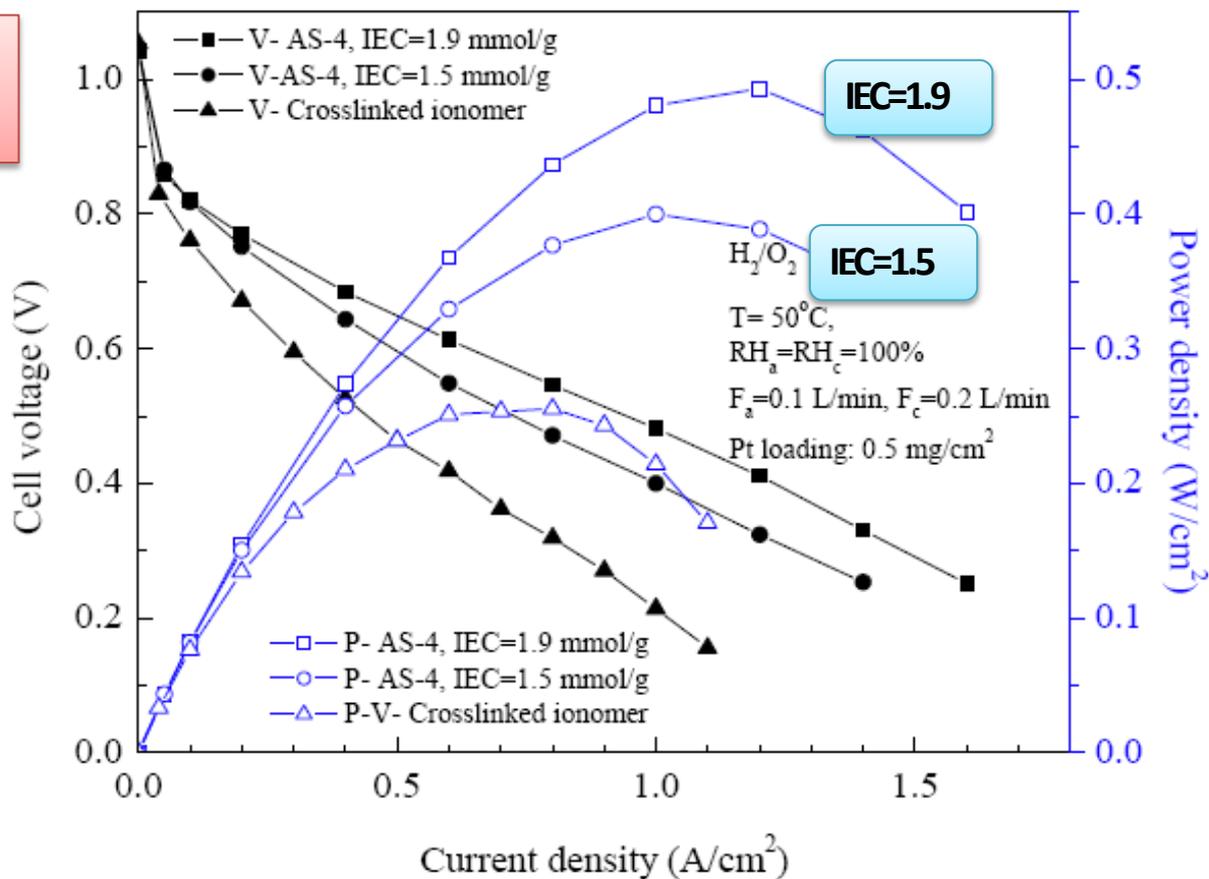


Polysulfone quaternary phosphonium hydroxide as ionomer:



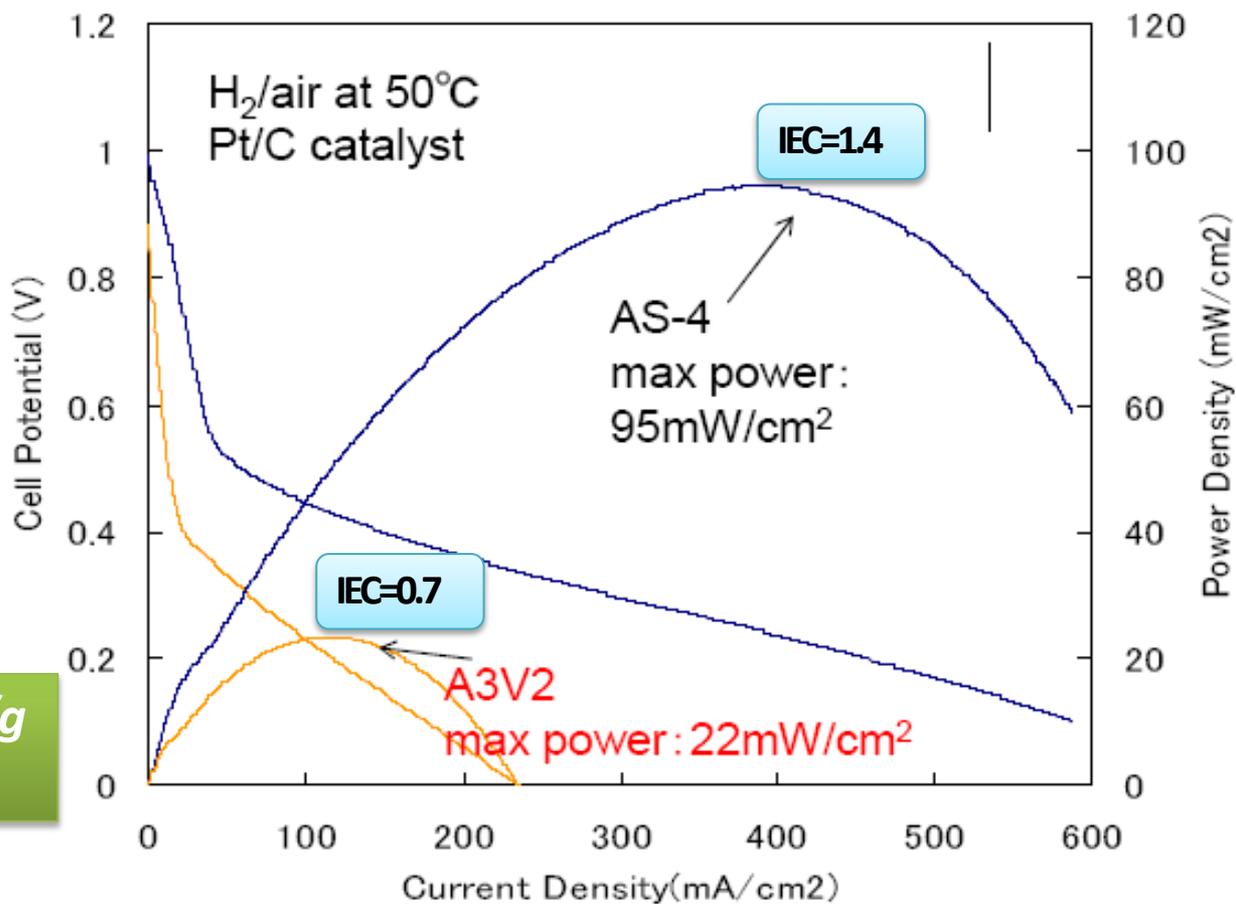
IONOMER -- THE CHALLENGE

Today's available ionomers are limited by their IEC



IONOMER -- THE CHALLENGE

Another example:



Ionomers with IEC > 3.0 mmol/g need to be developed !





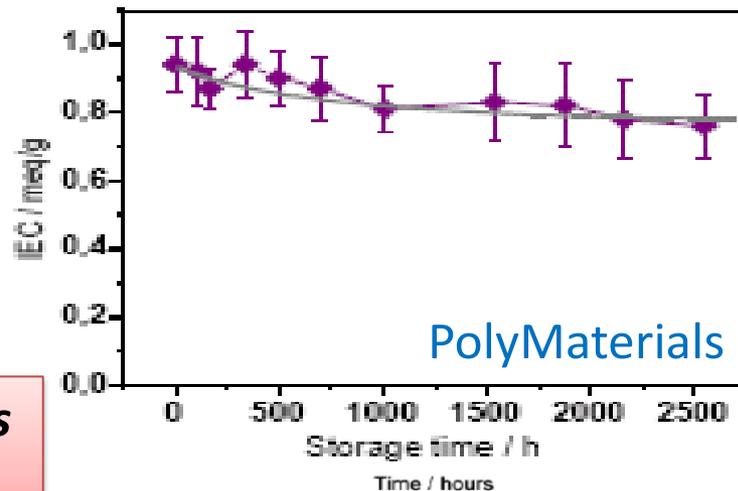
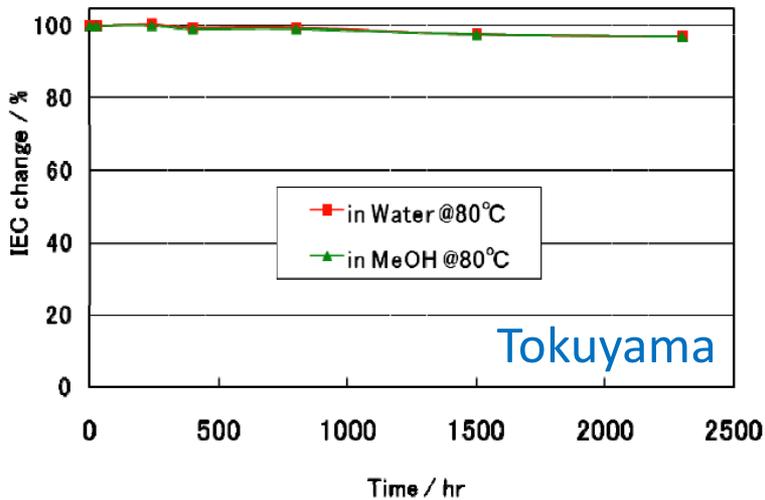
OUTLINE:

1. About CellEra
2. Latest developments in AEMs
3. Are there any available anion conductive ionomers ?
- 4. Stability challenges – backbones and functional groups**
5. What about electrocatalysts ?

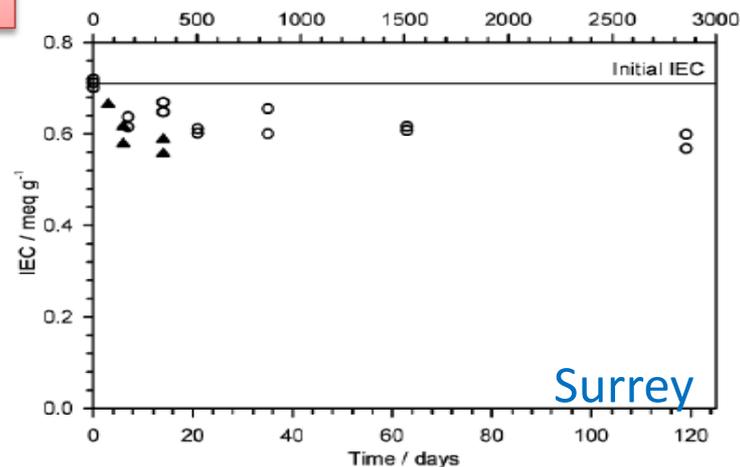
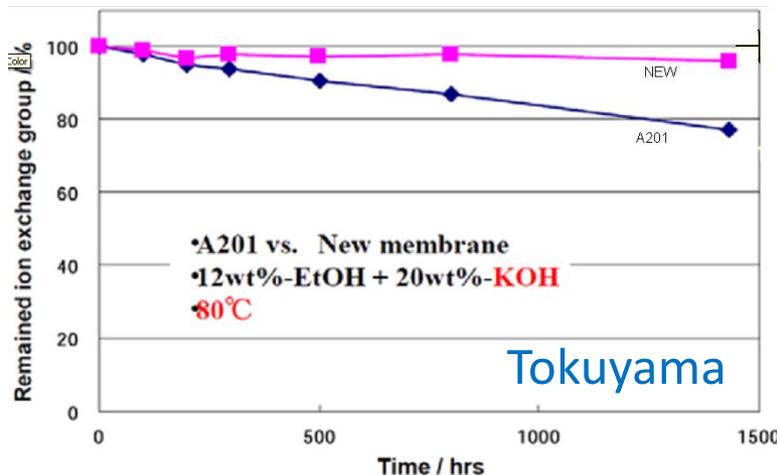
[Off-the-record]: some data on CellEra's cells and stacks

ARE OH- CONDUCTIVE POLYMERS STABLE?

Reported durability tests of OH- conductive polymers:



Are those tests relevant ?

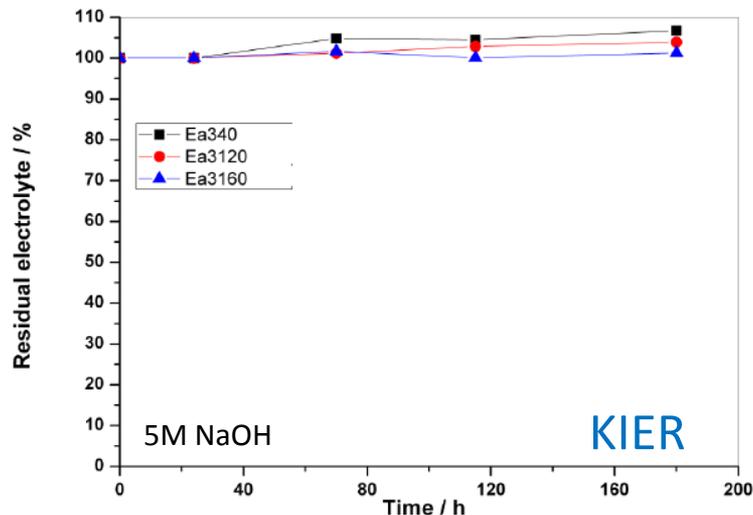
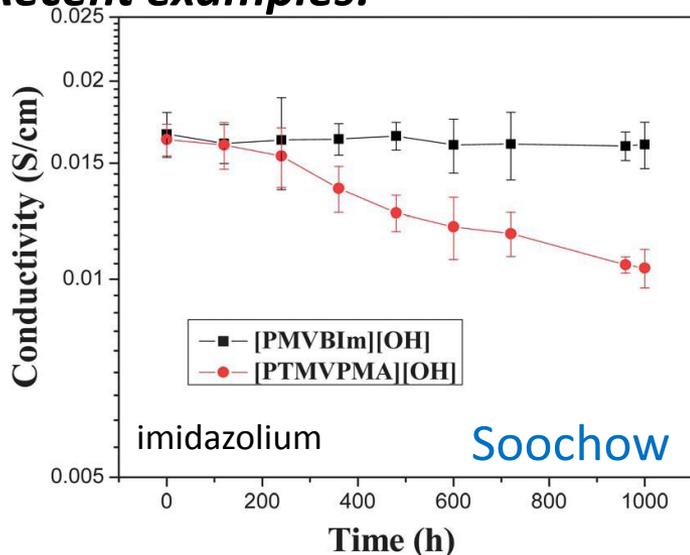


Yanagi and Fukuta, ECS Trans., 16 (2), 257 (2008)

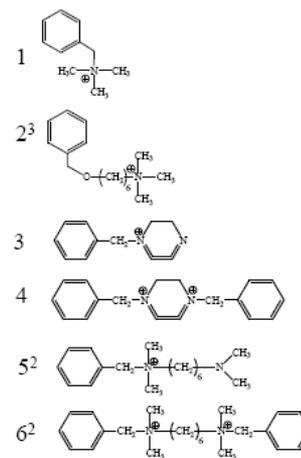
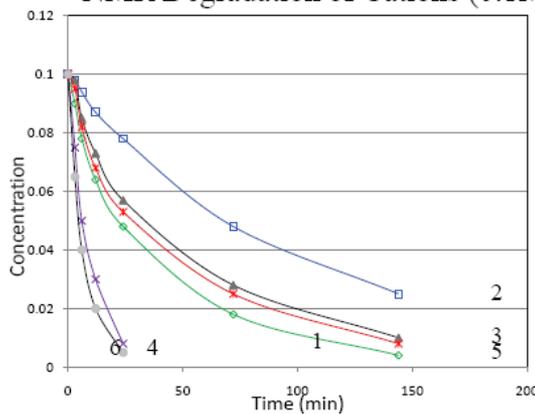
Varcoe et al.: J. Phys. Chem. B.110 (2006) 21041. Gärtner et al.: 1st Carisma (2008) France

ARE OH- CONDUCTIVE POLYMERS STABLE?

Recent examples:



NMR Degradation of Cations (0.1M) in 2M NaOH at 160°C



Half-life (min)	Literature ¹ (min)
23	29.1
73	
36	42
8	2.3
29	
7	

All durability tests were done in liquid water – not so relevant !!

¹Bauer, B.; Strathmann, H.; Effenberger, F. *Desalination* 1990, 79, 125.

²J.R. Varcoe, R.C.T. Slade, G.L. Wright and Y. Chen, *J. Phys. Chem. B*, 110, 21041 (2006).

³Tomoi, M.; Yamaguchi, K.; Ando, R.; Kantake, Y.; Aosaki, Y.; Kubota, H. *J. Appl. Polym. Sci.* 1997, 64, 1161.

Qiu et al.; *J. Mater. Chem.*, 22 (2012), 1040

Choi et al.; FC Seminar (2011)

Pivovar et al.; AMR for DOE Hydrogen Program (2011)

OUTLINE:

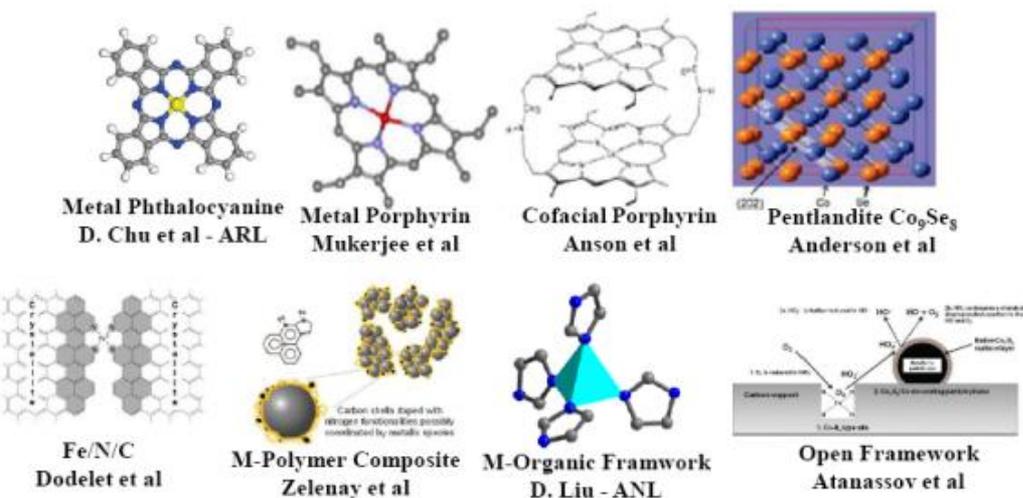
1. About CellEra
2. Latest developments in AEMs
3. Are there any available anion conductive ionomers ?
4. Stability challenges – backbones and functional groups
5. **What about electrocatalysts ?**

[Off-the-record]: some data on CellEra's cells and stacks

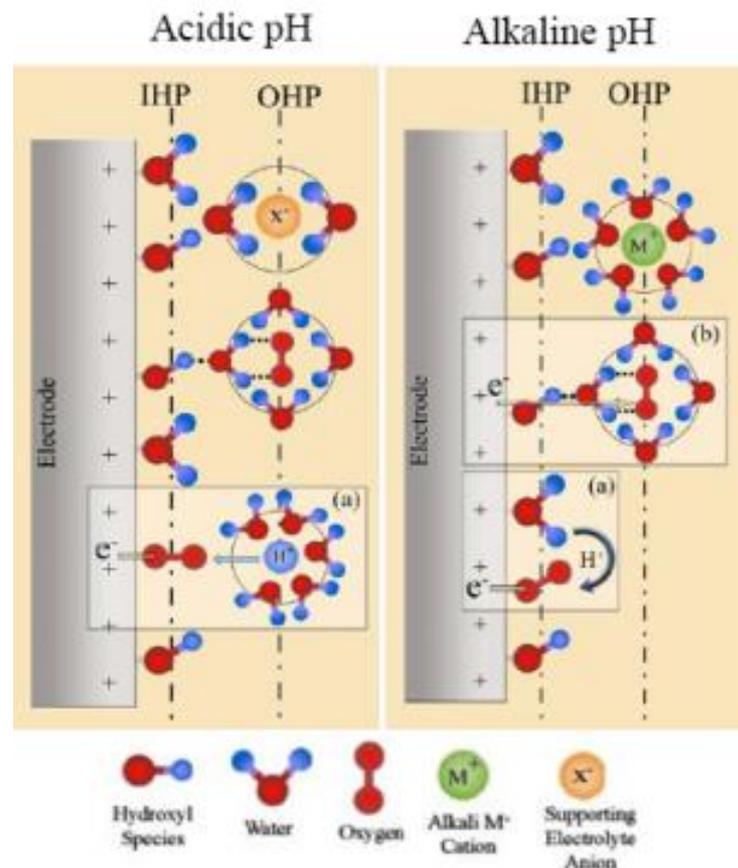
CATALYSTS FOR AMFCs: A NEARLY UNEXPLORED FIELD

Scarce work done on the catalyst front for AMFC technology:

Non-PGM studies focus on PEM development

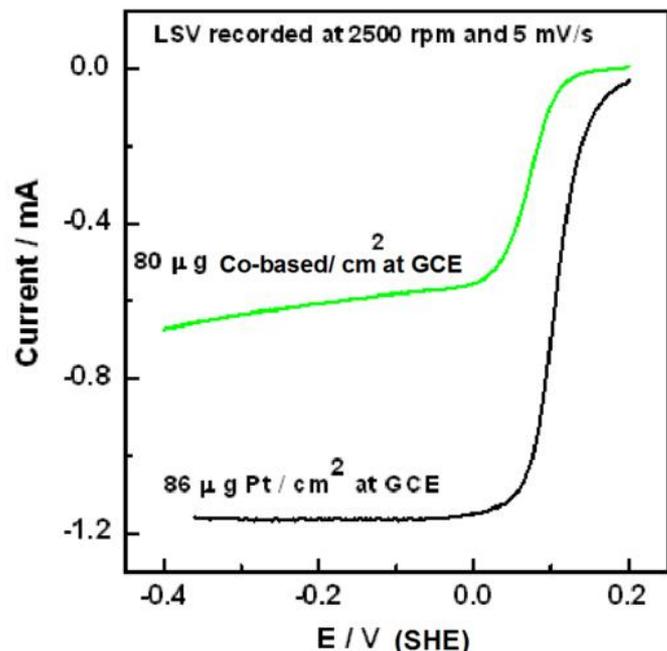


*Non-Pt studies targeted
ONLY for ORR catalysts !!*



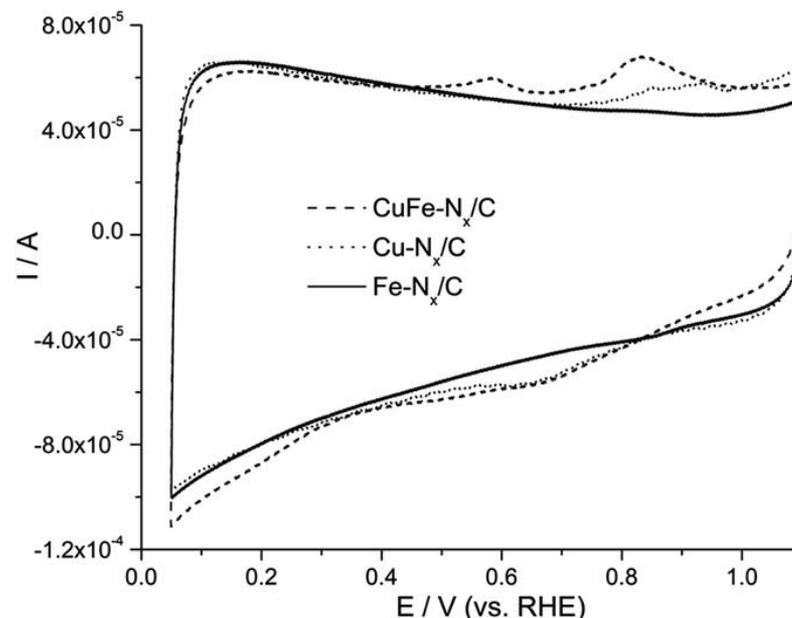
ORR CATALYSTS FOR AMFCs

Cathode catalysts – Just a few studies have only now started:



LSV response recorded at 5 mV s⁻¹ scan rate for Co-based/C and Pt/C in O₂-saturated 1M KOH solution

Cell potential comparison between Pt/C and Co-based/C with air, were only 67mV.



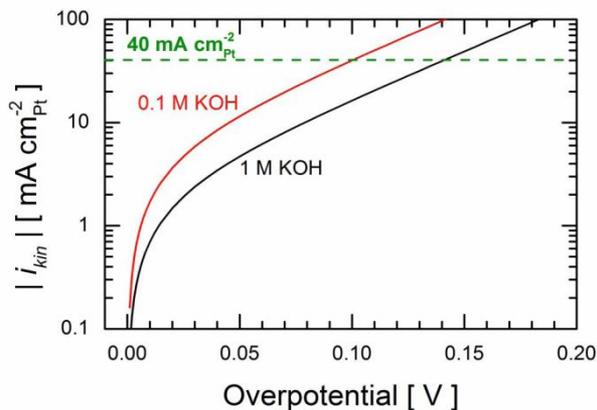
Cyclic voltammograms of CuFeN_x/C, CuN_x/C, and FeN_x/C catalysts in Ar saturated 0.1 M KOH

The kinetic current density of the CuFeN_x/C material was higher than a commercial Pt/C catalyst

ANY ALTERNATIVE TO Pt FOR HOR CATALYSTS?

Anode catalysts – Fundamental studies by the TUM's group:

Estimated Tafel plots for the HOR on Pt(pc) at 80°C:

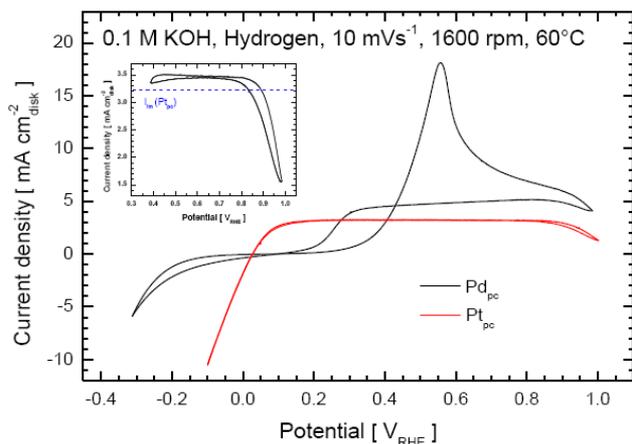


Ultra-low Pt-loadings would involve a prohibitive overpotential loss of ~140 mV

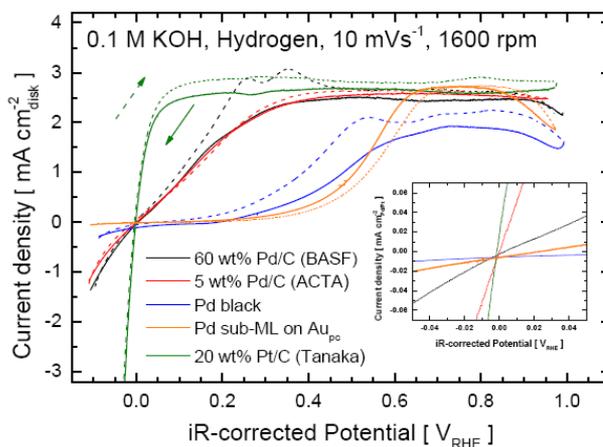


Crucial need for developing catalysts for HOR !!

Hydrogen oxidation on Pd(pc):



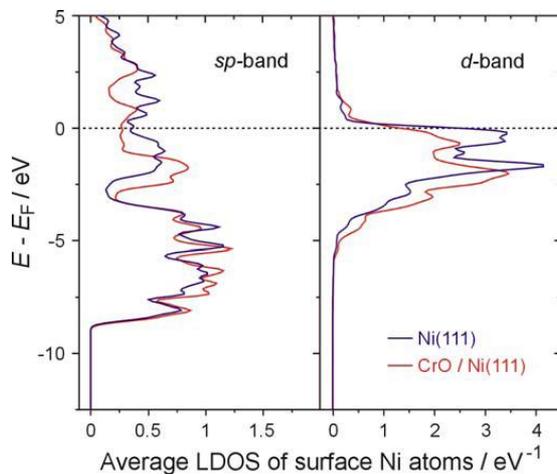
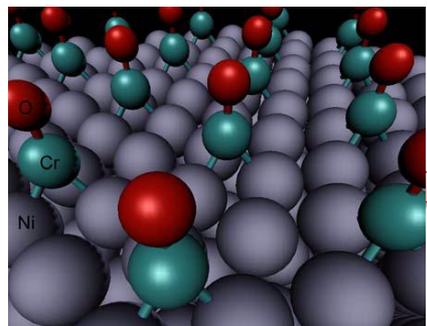
HOR activity of different Pd-based catalysts:



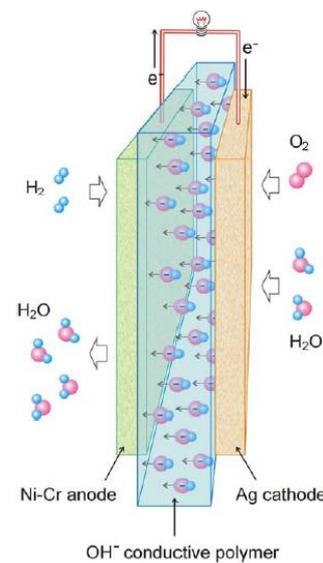
Activities of Pd-based catalyst are 5-to-10-times lower than that of the commercial Pt/C material

HOR CATALYSTS FOR AMFCs

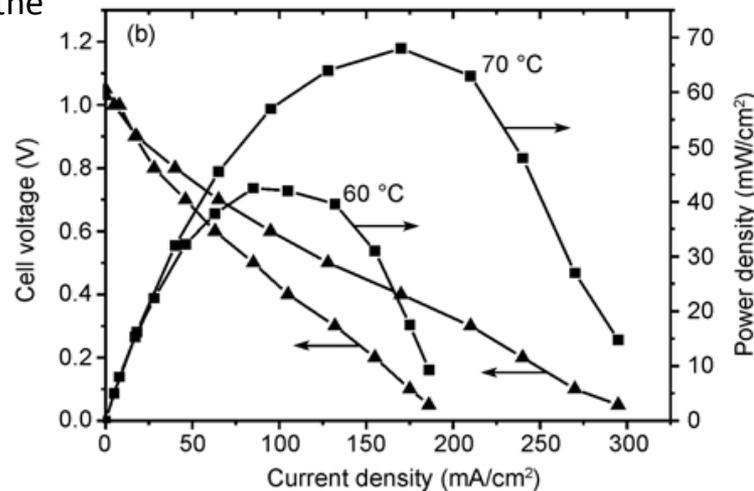
Anode catalysts – scarce studies (!): A metal decorated Ni catalyst



DFT calculations to evaluate the effect of Cr oxide modification on the electronic structure of Ni surface.



Best power density result published for a complete non-Pt cell: 70mW/cm²



OUTLINE:

1. About CellEra
2. Latest developments in AEMs
3. Are there any available anion conductive ionomers ?
4. Stability challenges – backbones and functional groups
5. What about electrocatalysts ?

[Off-the-record]:

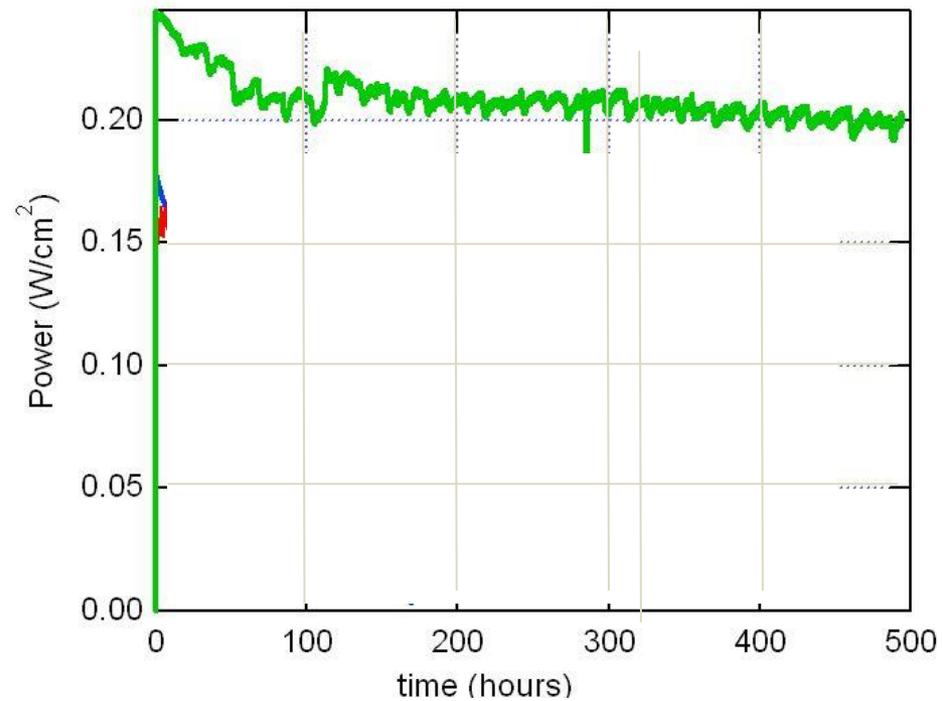
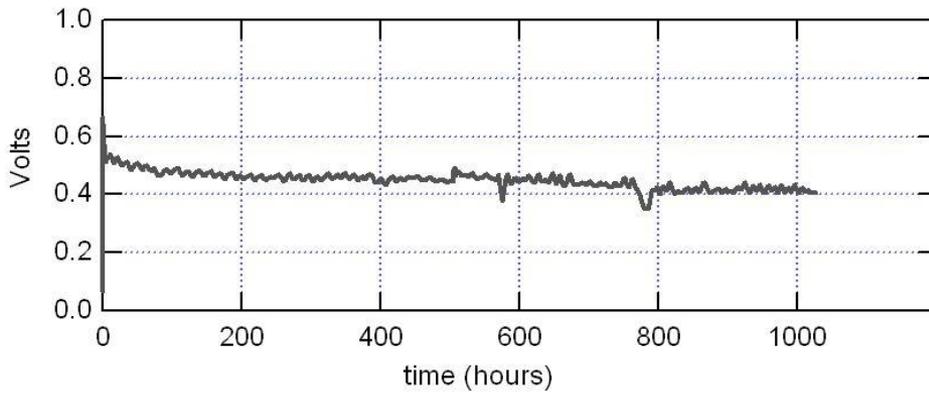
some data on CellEra's cells and stacks

we do have time for it, right?



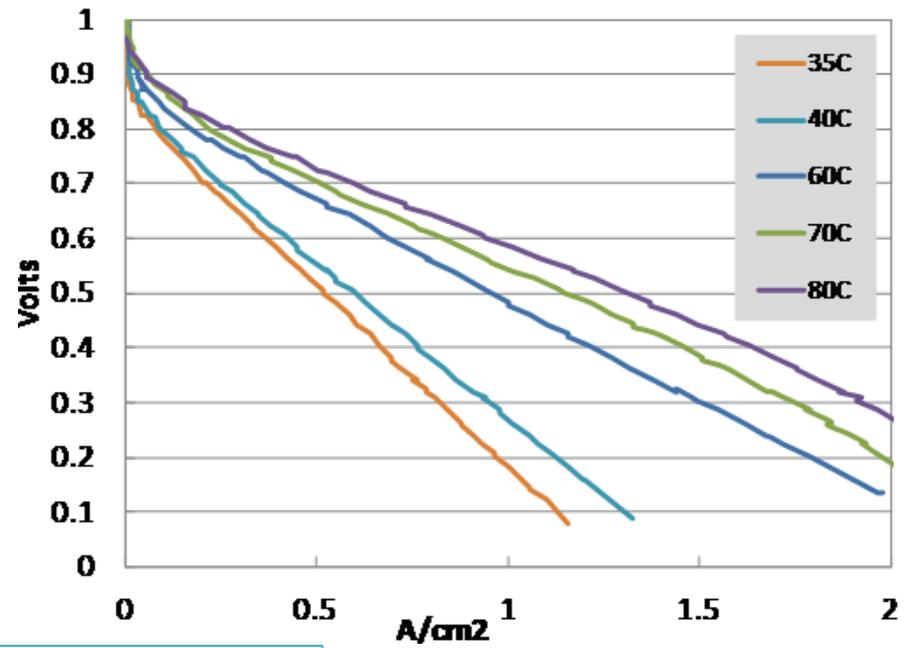
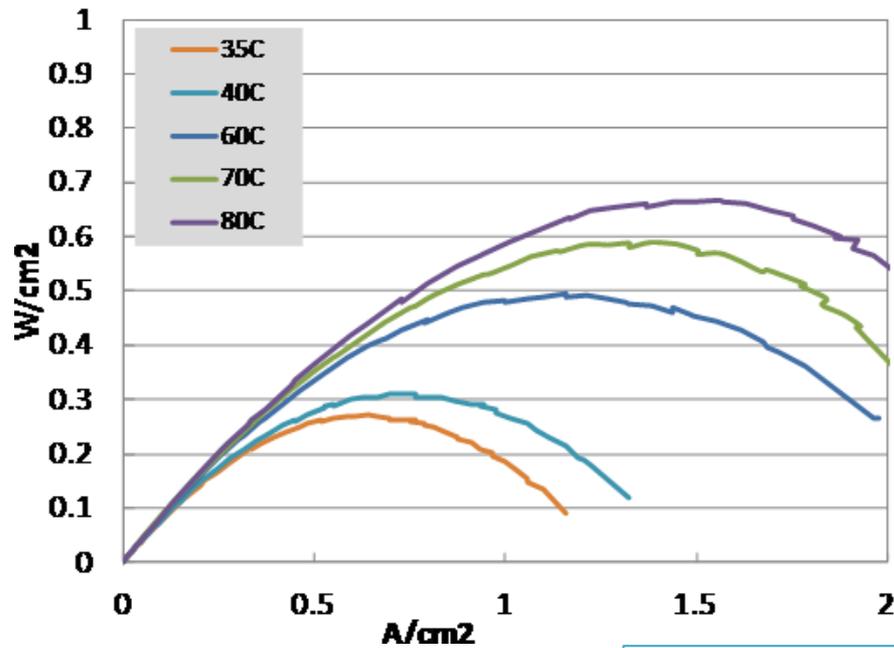
CELLERA's ACHIEVEMENTS

Longevity tests : hundreds of hours...



CELLERA's ACHIEVEMENTS

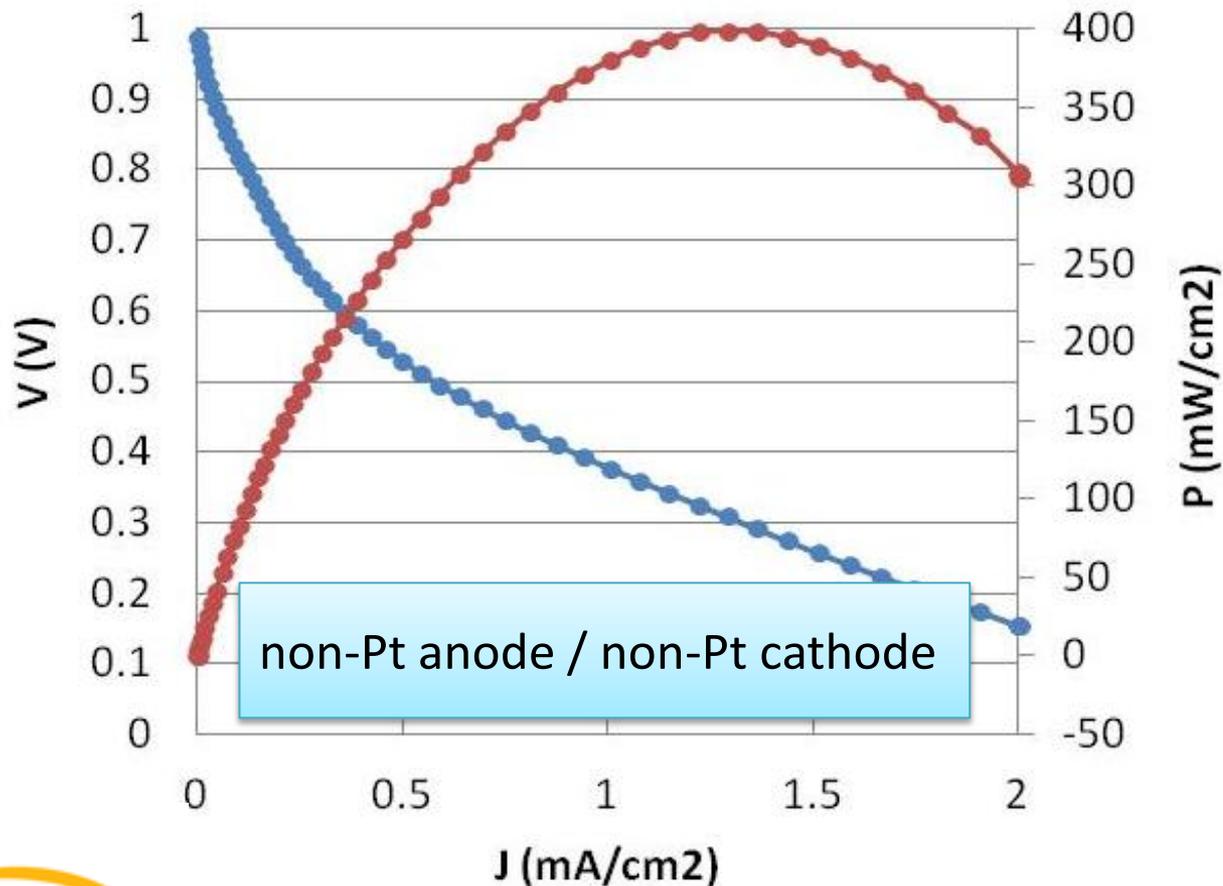
State of the art – Max. power density for H₂/air: ~700mW/cm² !!



Pt anode / non-Pt cathode

CELLERA's ACHIEVEMENTS

State of the art – Non-Pt based cell (H₂/air): max. 400mW/cm² !!

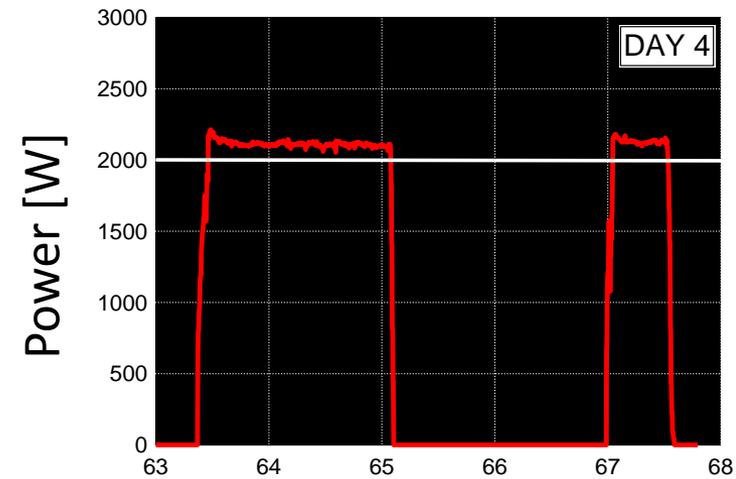
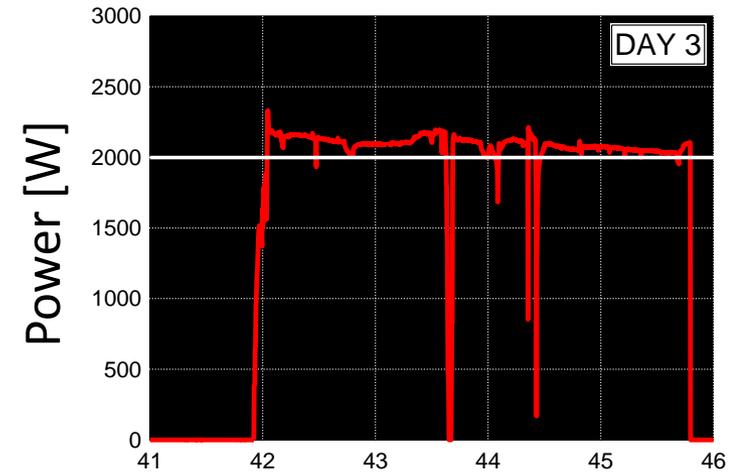


CELLERA's ACHIEVEMENTS

State of the art – 2 kW CellEra's AMFC stack !!



First field test, outdoors, 45C ambient
(July 2011@Texas)

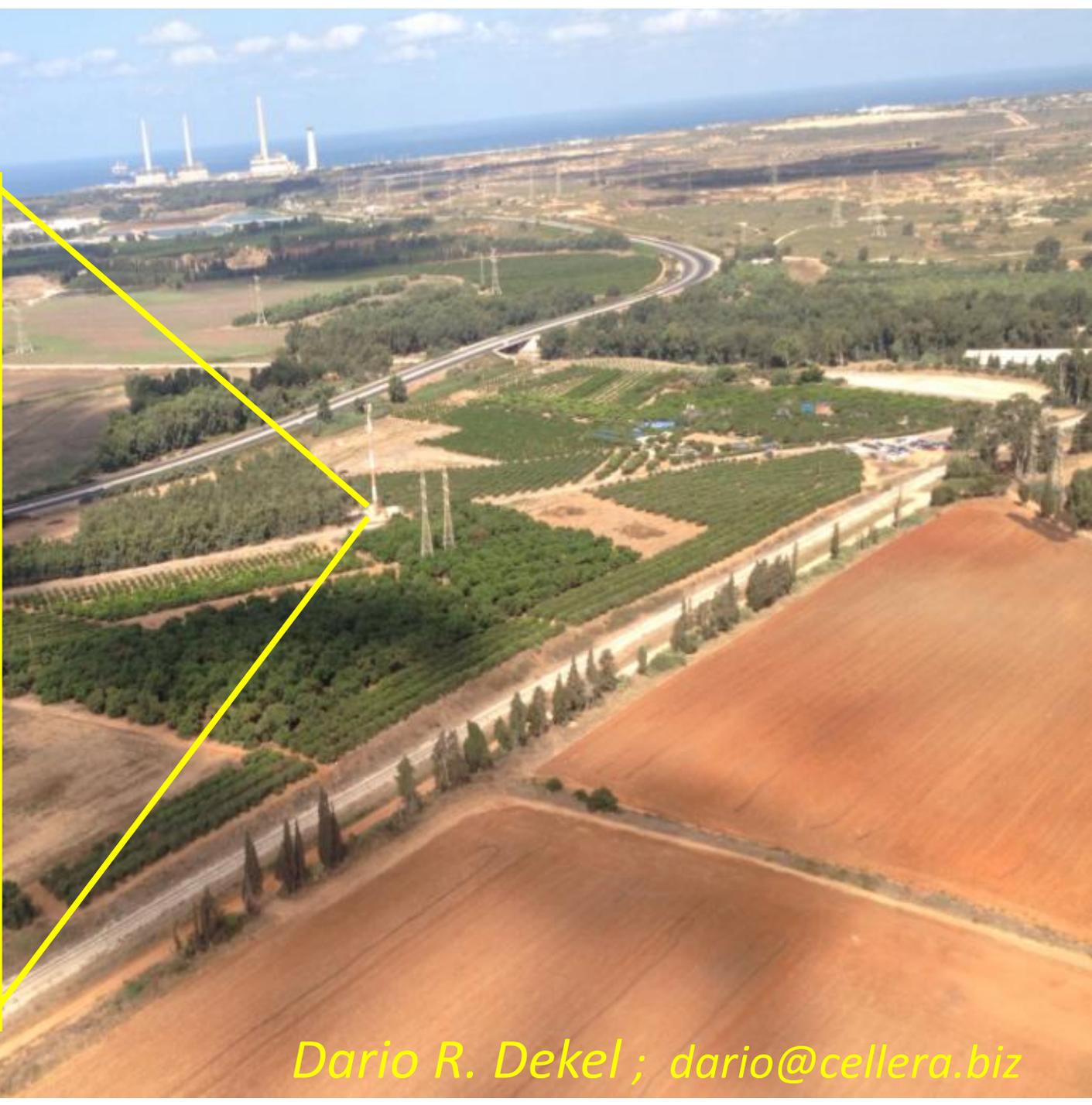


Time [h]



Dario R. Dekel; dario@cellera.biz

November 2012@Israel



Dario R. Dekel ; dario@cellera.biz