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Comparative experimental study of the performance of two different types of HTPEM MEAs

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Outline

- •Different membrane technologies
- •Experimental setup
  - Fuel cell control system
  - Impedance system
- •Experimental results
  - Polarization curve comparison
  - Electro-chemical impedance spectroscopy
  - Impedance measurements during break-in
- •Summary and outlook

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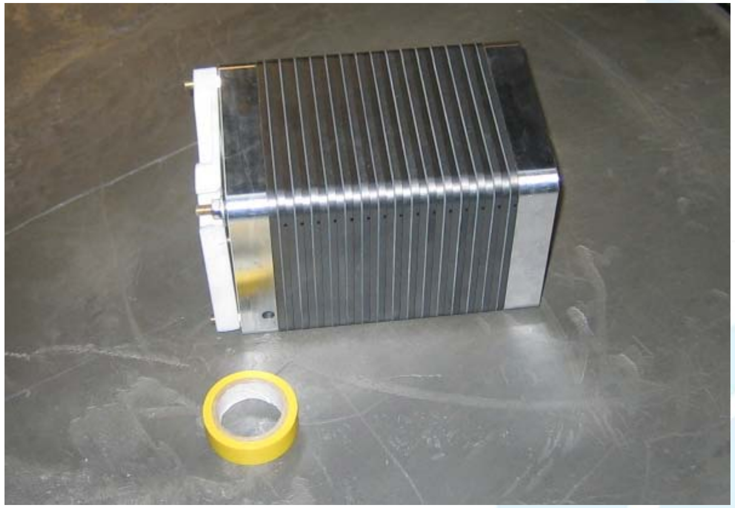
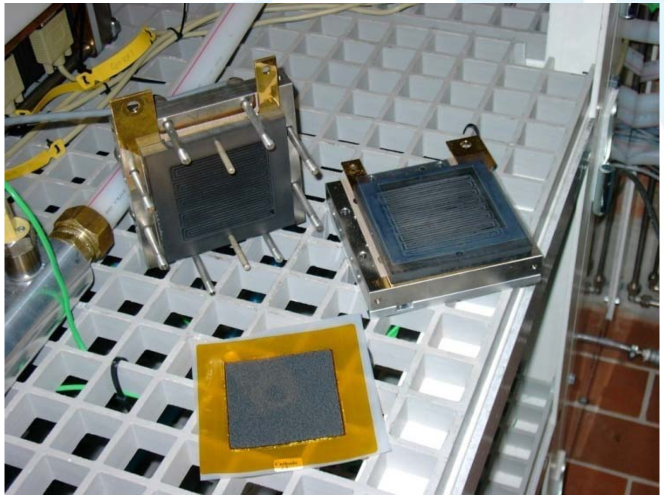
High temperature PEM fuel cells



High Temperature PBI based PEM Fuel Cell

Membrane polymer: PBI (polybenzimidazole)
Proton conductor : H_3PO_4 (Phosphoric acid)
Fuel cell temperature: 120-200 ^{o}C
Typical operating range: 160-180 ^{o}C



Advantages

- Less complex polymer
- CO tolerant up to 2-3%
- No humidity control = Simple stack and system design
- Cooling possible at all ambient conditions

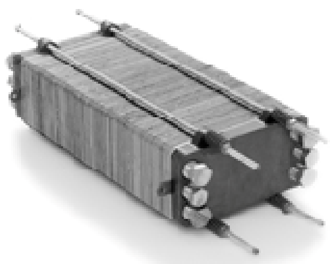
Disadvantages

- Lower cell voltage than LTPEM
- Long start-up time because of high temperature
- Liquid water should not be present

HTPEM fuel cell stacks by Serenergy:

Serenergy®
The Power of Simplicity

350W Off-grid battery charger (methanol)
1 kW Air cooled system
3 kW Air cooled system
5 kW liquid cooled stack



Selected MEAs:

Danish Power Systems®

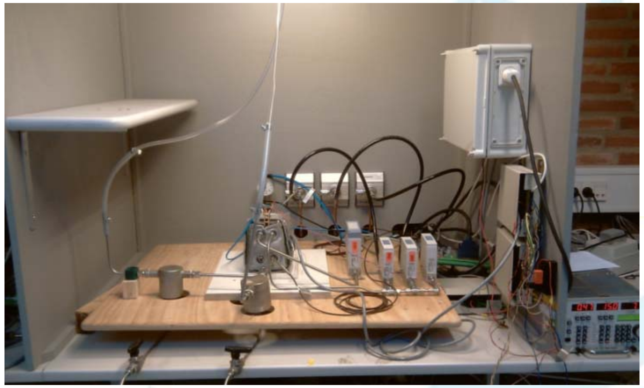
4 MEAs:
Dapozol G77 membranes
Varying catalyst loading
Varying GDL thickness
Varying polymer content in CL

BASF
The Chemical Company

2 MEAs:
Celtec P2100
Celtec P1000*

Experimental setup

HTPEM heated single cell assembly, straight flow channels

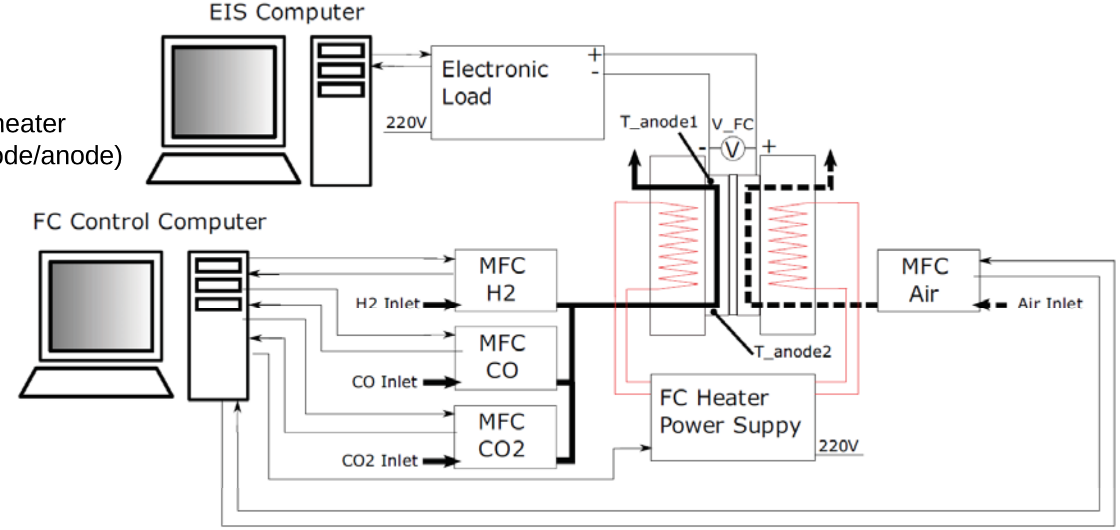


Two National Instruments based control systems:

- Automated fuel cell control system (Labview)
- Impedance measurement system able to superposition signals onto fuel cell current

Hardware:

- Fuel Cell Control System
  - NI PCI 6401 AO DAQ card
  - NI PCI 6229 AI DAQ card
  - NI PCI 4351 AI DAQ card
  - TDI Power RBL 488
  - Bürkert 8711 MFC H2
  - Bürkert 8711 MFC CO
  - Bürkert 8711 MFC CO2
  - Bürkert 8712 MFC Air
  - 230VAC controlled electrical heater
  - 2 Type T thermocouple (cathode/anode)
- EIS measurement system
  - NI PCI 6259 DAQ card
  - Load signal switching relays



Measurement matrix

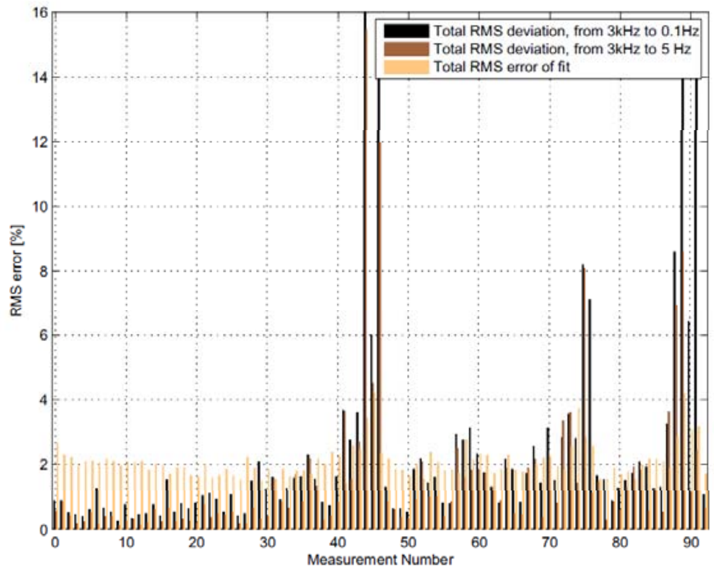
Impedance measurement sequence

Multiple measurements in the same operating point in order do increase the reproduceability of the measurement and ensure steady-state conditions.

DAPOSY Matrix CO CO Experiment parameters:

Index	T_fc [C]	I_fc [A]	y_CO [%]	y_CO2 [%]	lambda_H2	lambda_O2	delay [s]	IV curve (1 or 0)
0	120	5	0	0	1.2	4	30	1
1	120	10	0	0	1.2	4	30	0
2	120	15	0	0	1.2	4	30	0
3	130	5	0	0	1.2	4	30	1
4	130	10	0	0	1.2	4	30	0
5	130	15	0	0	1.2	4	30	0
6	140	5	0	0	1.2	4	30	1
7	140	10	0	0	1.2	4	30	0
8	140	15	0	0	1.2	4	30	0
9	150	5	0	0	1.2	4	30	1
10	150	10	0	0	1.2	4	30	0
11	150	15	0	0	1.2	4	30	0
12	160	5	0	0	1.2	4	30	1
13	160	10	0	0	1.2	4	30	0
14	160	15	0	0	1.2	4	30	0
15	170	5	0	0	1.2	4	30	1
16	170	10	0	0	1.2	4	30	0
17	170	15	0	0	1.2	4	30	0
18	180	5	0	0	1.2	4	30	1
19	180	10	0	0	1.2	4	30	0
20	180	15	0	0	1.2	4	30	0
21	180	10	0.15	0	1.2	4	60	1
22	180	10	0.15	25	1.2	4	60	1
23	180	15	0.15	0	1.2	4	30	0
24	180	15	0.15	25	1.2	4	30	0
25	170	10	0.15	0	1.2	4	60	1
26	170	10	0.15	25	1.2	4	60	1
27	170	15	0.15	0	1.2	4	30	0
28	170	15	0.15	25	1.2	4	30	0
29	160	10	0.15	0	1.2	4	60	1
30	160	10	0.15	25	1.2	4	60	1
31	160	15	0.15	0	1.2	4	30	0
32	160	15	0.15	25	1.2	4	30	0
33	150	10	0.15	0	1.2	4	90	1
34	150	10	0.15	25	1.2	4	45	1
35	150	15	0.15	0	1.2	4	45	0
36	150	15	0.15	25	1.2	4	45	0
37	140	10	0.15	0	1.2	4	90	1
38	140	10	0.15	25	1.2	4	45	1
39	140	15	0.15	0	1.2	4	45	0
40	140	15	0.15	25	1.2	4	45	0
41	130	10	0.15	0	1.2	4	120	1
42	130	10	0.15	25	1.2	4	60	1
43	130	15	0.15	0	1.2	4	60	0
44	130	15	0.15	25	1.2	4	60	0

Deviation between consecutive impedance measurements



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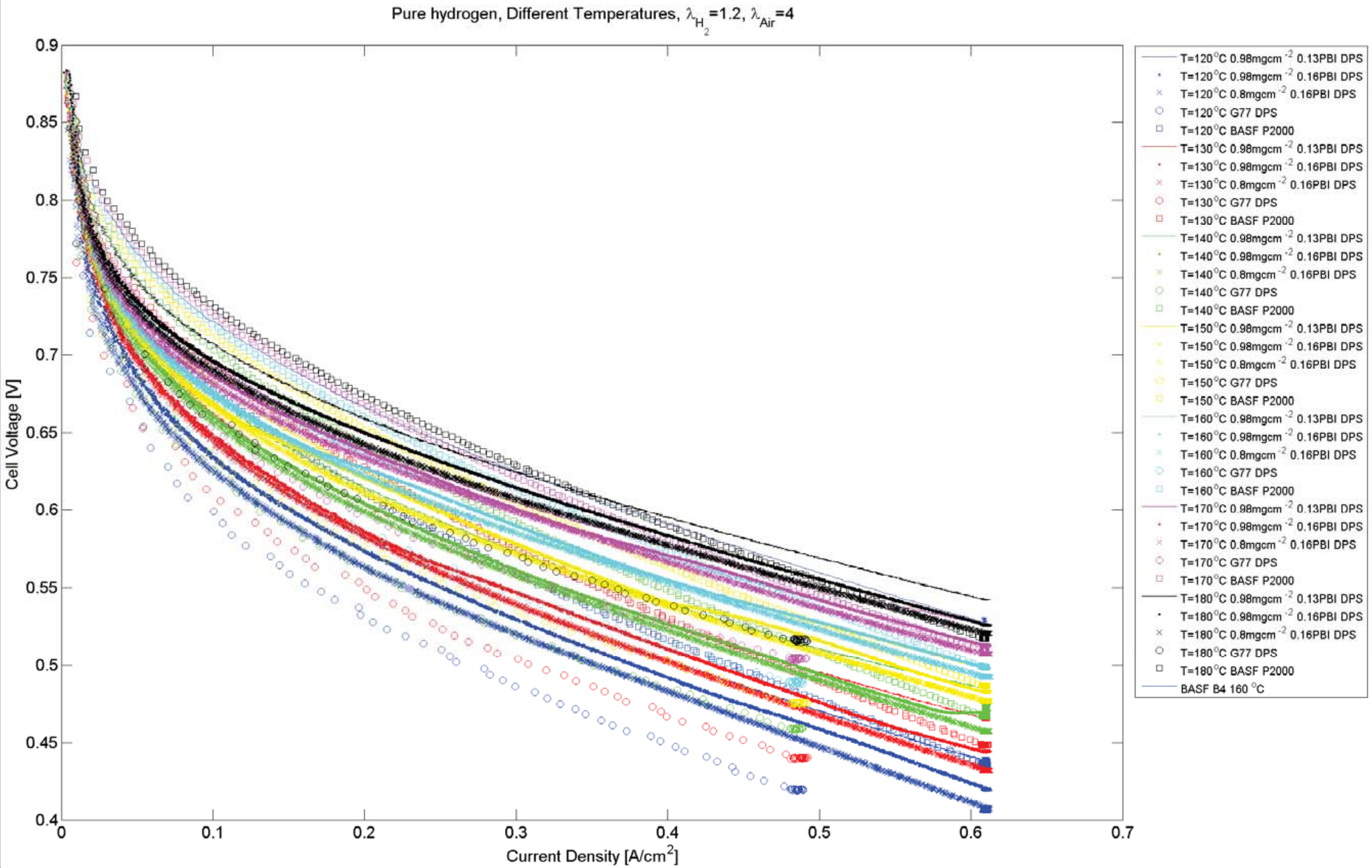
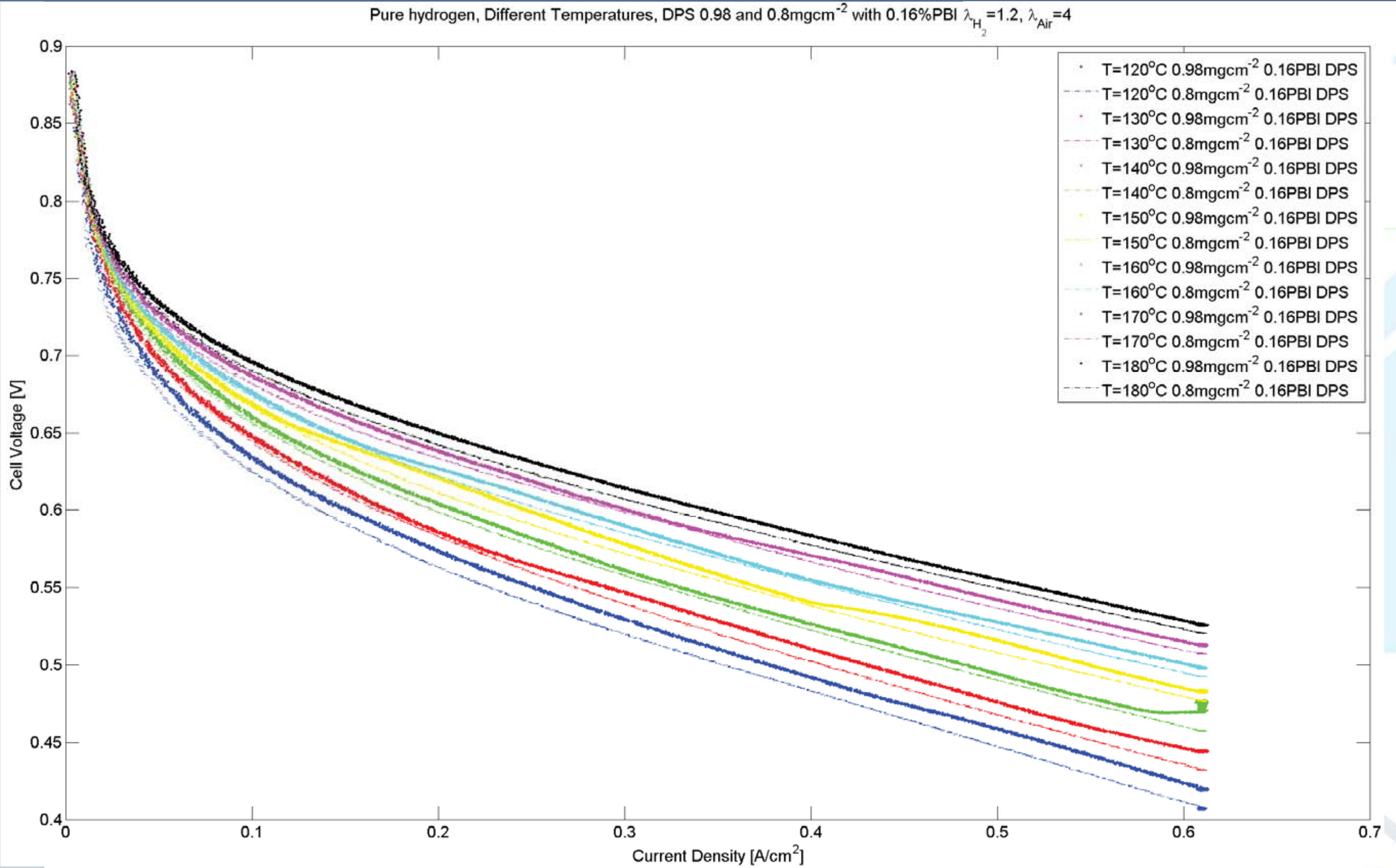
Polarisation – 120C to 180C , Pure H2



Polarisation – Varying Pt loading



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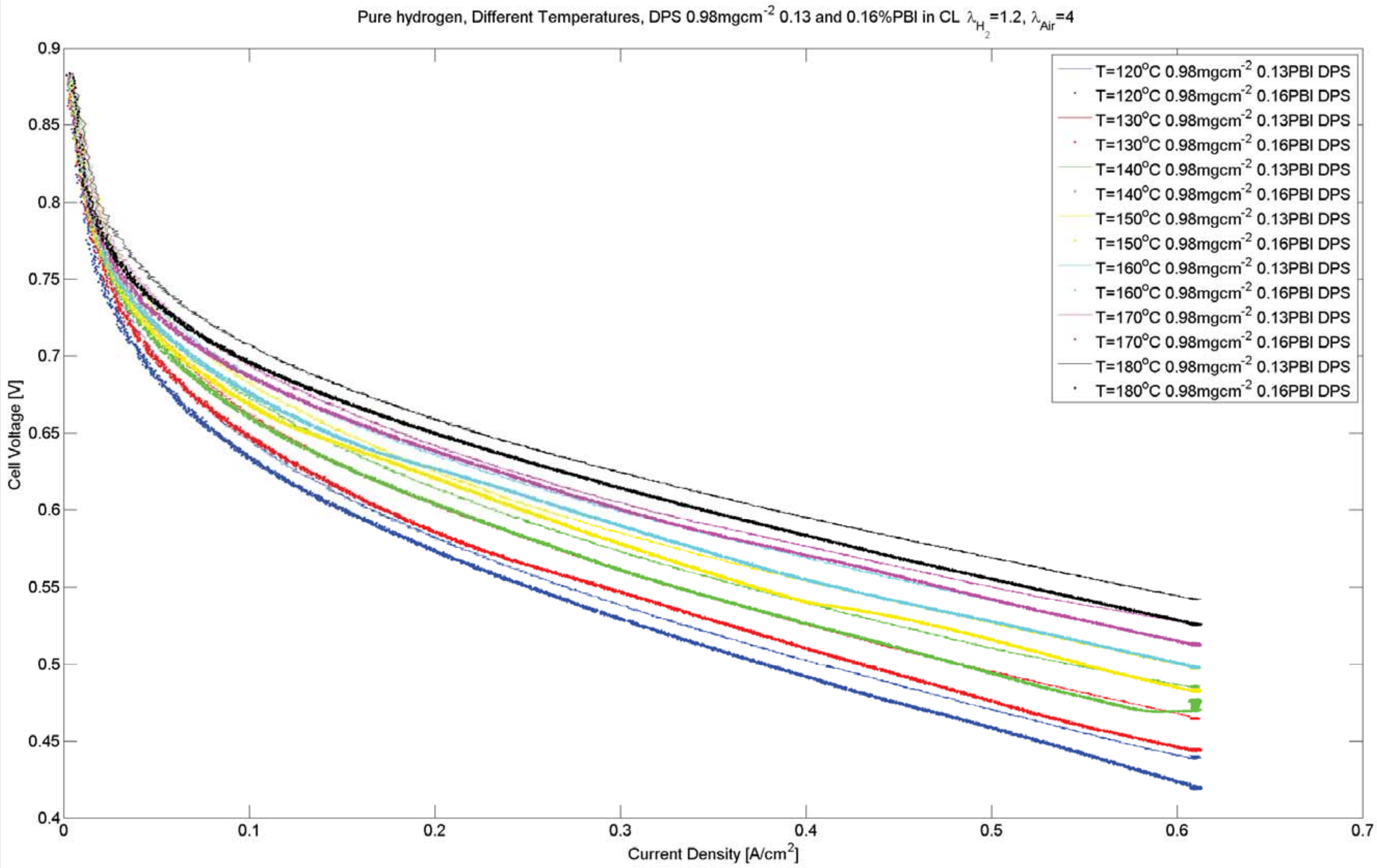
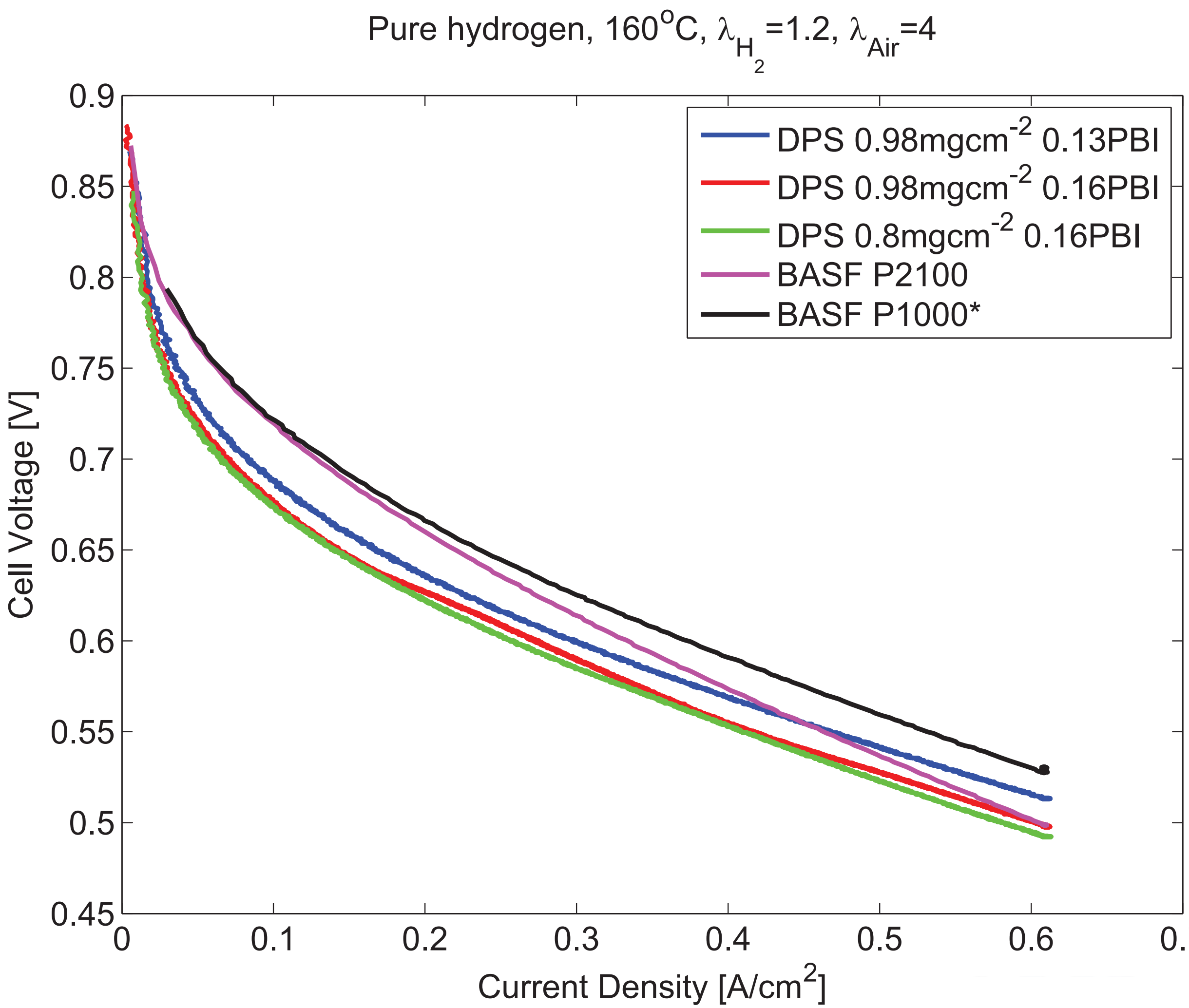
Polarisation - Varying PBI content in CL



Polarisation – DPS and BASF

•New P1000 showing impressive performanc comparred to

•DPS MEA shows good performance at high current densities.



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Selected impedance comparison

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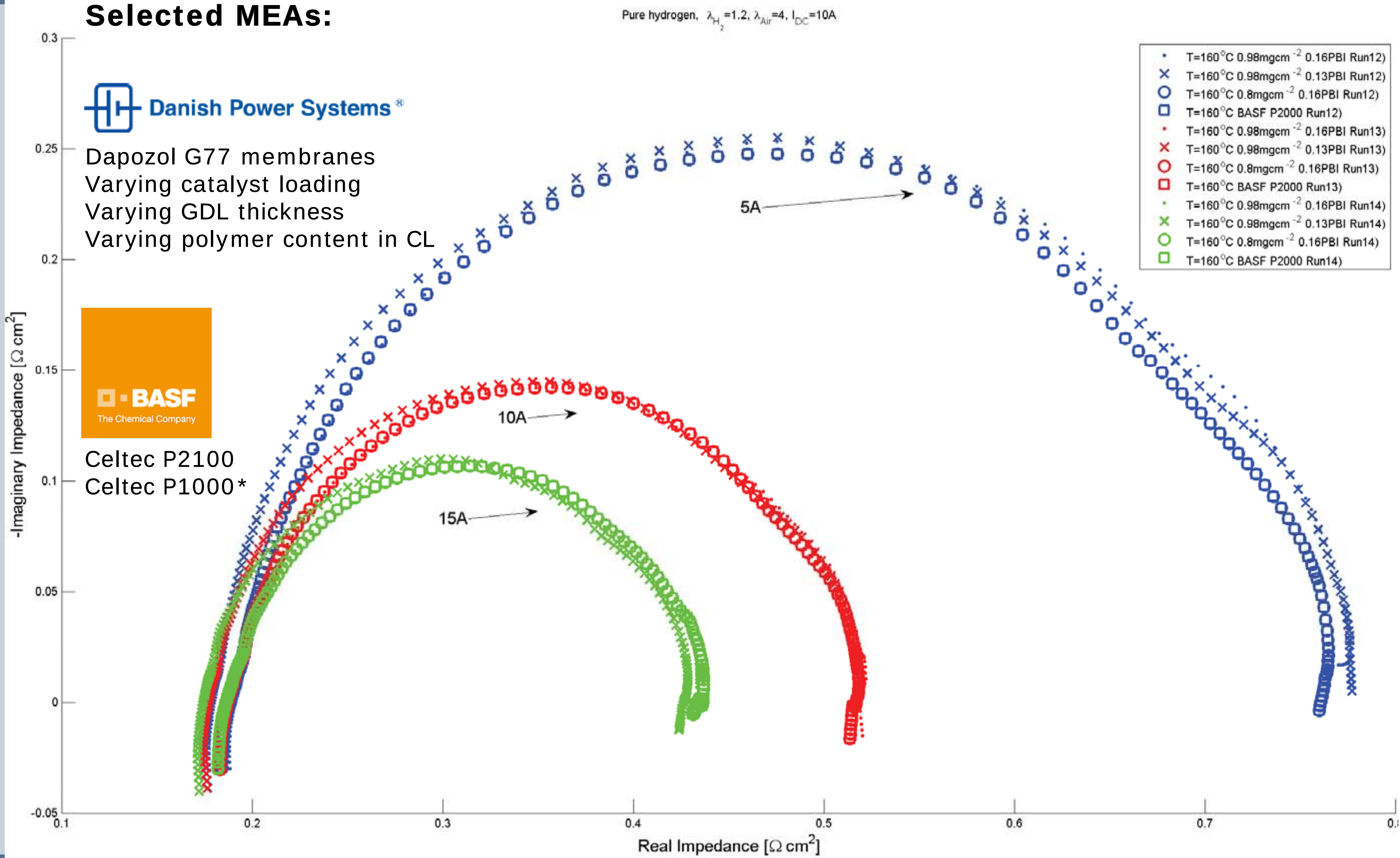

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BASF Nyquist plot - pre/post break-in

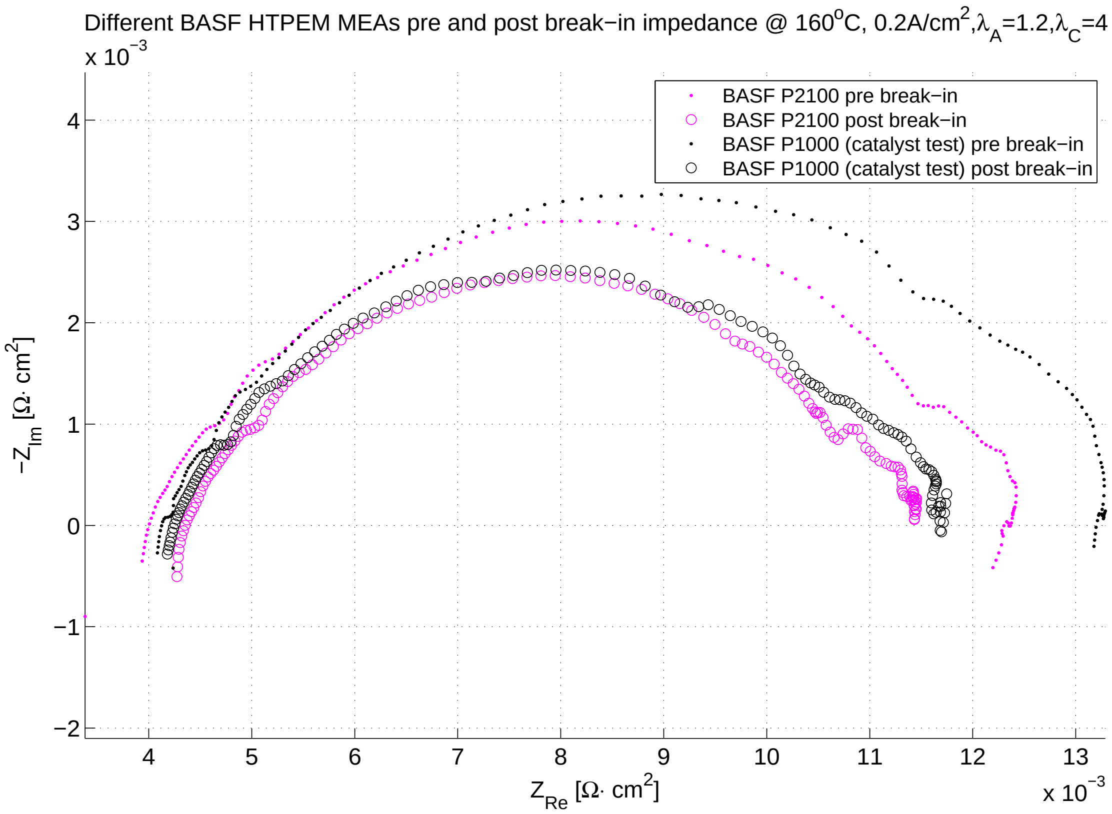
Impedance behaviour:

Both P1000 and P2100 cells show quite dramatic changes in most of the impedance spectrum, both in high, intermediate and low frequencies.

Membrane resistance increases during break-in due to acid removal

The main changes contributing to these changes are expected to be, acid reallocation i.e. the combined movement of acid into and away from the gas difusion and catalyst layer.

Water content and production is also expected to play an important role and needs further investigation.



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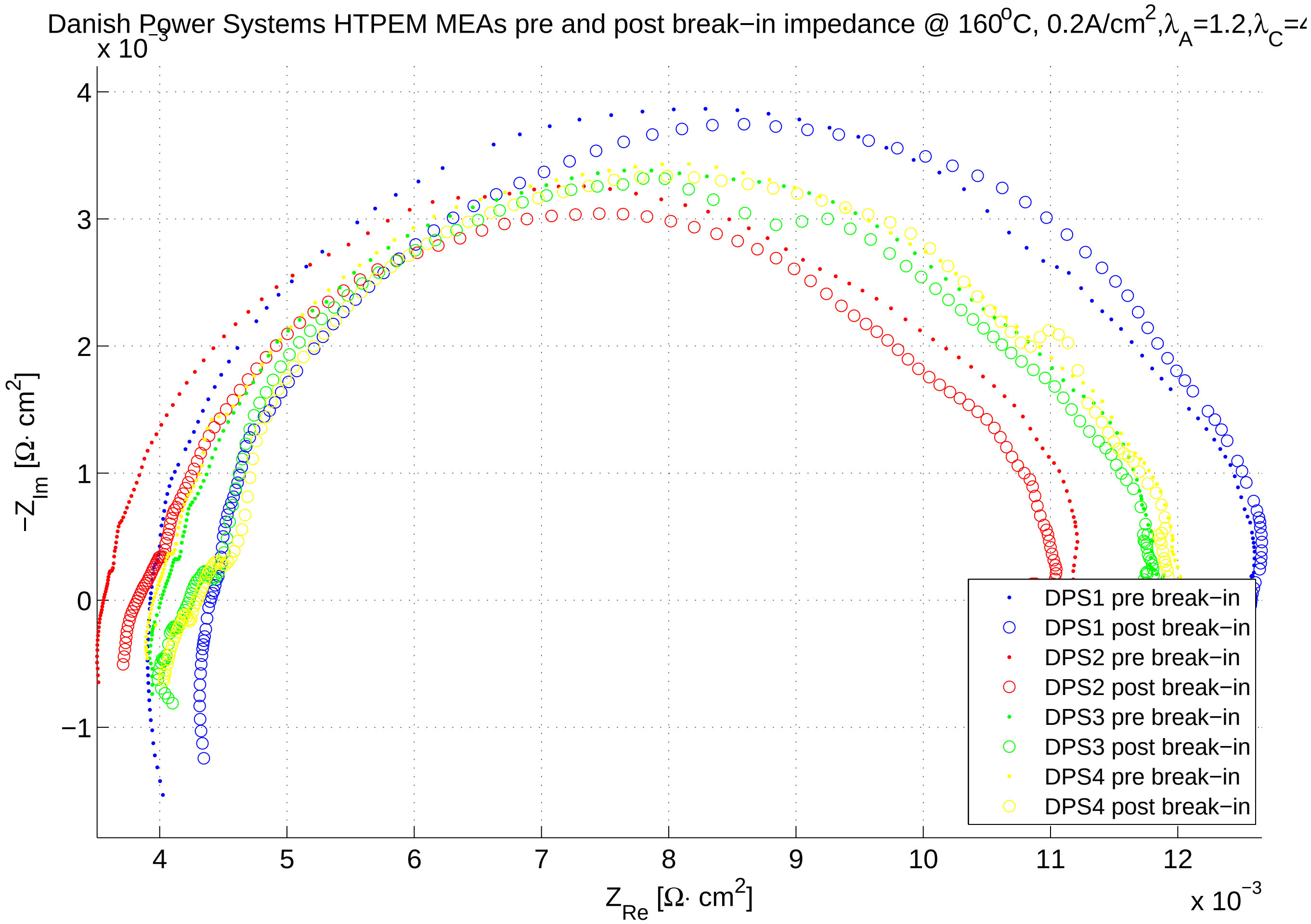
DPS Nyquist plot - pre/post break-in

Impedance behaviour:

Not as dramatic difference between pre and post break-in impedance comparred to BASF membranes due to different membrane types and production methods. Less changes are occuring at intermediate and low frequencies.

Generally a slightly higher increase in membrane resistance is experienced.

Only slight differences of the chosen variations in catalyst loading and polymer content in the catalyst layer, with the most promesing performance in the MEAs with the least PBI content in the CL



Summary and Outlook

Conclusions

•Two different types of HTPEM MEAs are examined. With the experimental methods and setups developed the general operation and the differences can be studied. Particularly differences are identified during break-in using EIS. DPS MEAs seem to have quite fast break-in time, and show high current capabilities, while the BASF MEAs also show excellent low temperature operating capabilities.

•Measuring selected impedances during break-in can be used as a guideline to determine proper break-in time.

•Setup also have possibility of varying the gas concentrations and stoichiometries and switch between dry and wet anode gasses.

•High frequency impedance decrease is primarily related to membrane resistance, and the presence of phosphoric in the catalyst. The changes are expected to be due to phosphoric acid re-allocation / water contribution.

Future work

•Development of even better measurement automation for improved statistical data.

•Development of detailed transient models that are able to reproduce the impedance spectrum, and evaluate impedance changes at a small scale (catalyst, GDL, membrane).

•Further tests should be conducted with reformate gas, looking at the effects of water, CO, CO2 and residual fuel in the gas, and how it affects the impedance.

•Half cell measurements could greatly enhance the understand and seperation of anode and cathode contributions to cell performance.

Acknowledgements

Ackowledgements

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Thank you!

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