New Energy World JU
fuel cells & hydrogen for sustainability

CISTEM
Construction of Improved HT-PEM MEAs and Stacks for Long Term Stable Modular CHP Units

Optimization of the PBI membrane doping procedure

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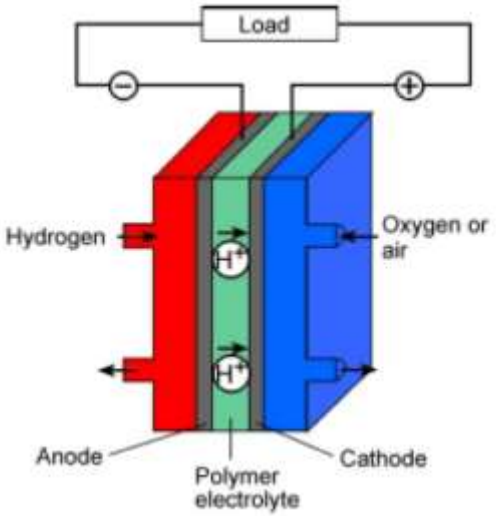
High Temperature PEMFC

anode

$$2H_2 \rightarrow 4H^+ + 4e^-$$ $E^0 = 0$ V

cathode

$$4H^+ + 4e^- + O_2 \rightarrow 2H_2O$$ $E^0 = 1{,}23$ V



Main components

Membrane ”solid electrolyte“ permeable for H^+
PBI based polymers

Electrodes gas diffusion electrode with porous structure
platinum metals based catalyst

High temperature advantages

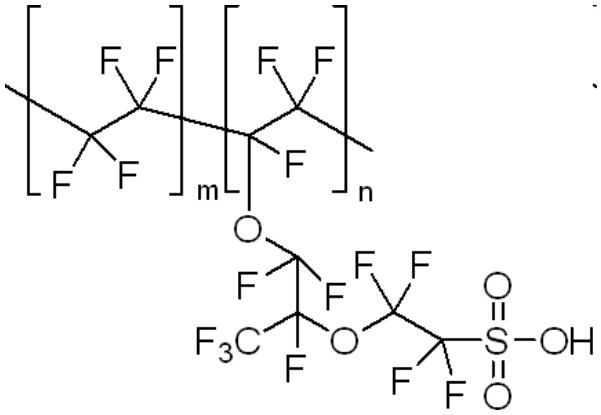
- simple water management
- limited CO poisoning
- electrode reactions kinetics enhancement

Polymer electrolyte membranes (PEM)

perfluorinated sulfonated-polymers (e.g. Nafion®)

- good chemical and mechanical stability
- H^+ conductive (when swollen by liquid water)

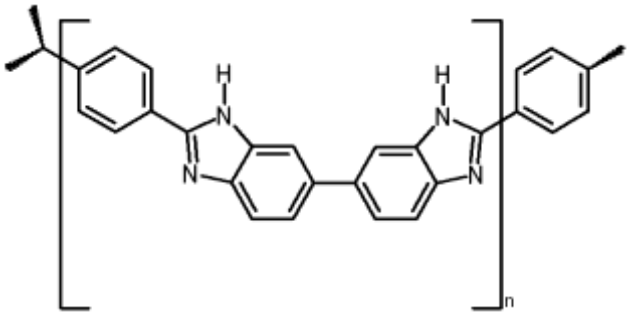
-> loosing H^+ conductivity above water boiling point!



polybenzimidazole (PBI) membranes

- impregnated by H_3PO_4

-> H^+ conductive up to 200 °C



Membrane doping procedure

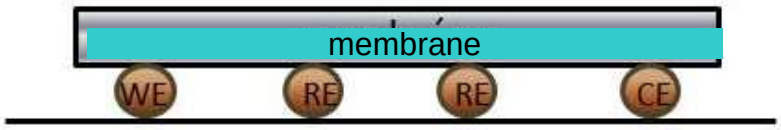
- membrane cutting
- immersion to H_3PO_4
- doping time 2-8 h room temp.

- removing of H_3PO_4 droplets

Membranes:
PBI and APcl (crosslinked PBI)
by Fumatech (Germany)

Membrane conductivity

- measuring temp. 160°C
- EIS 20Hz–20kHz

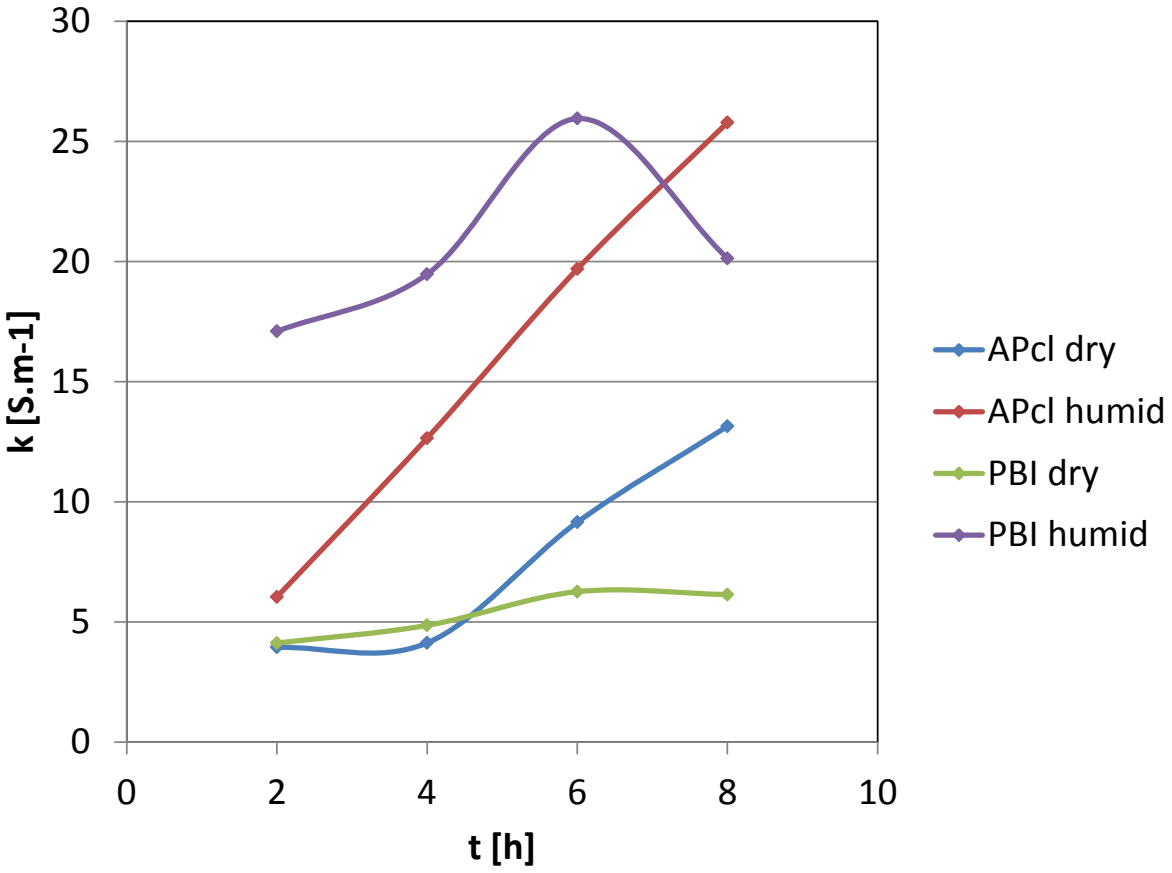


four electrode arrangement

1. dry conditions
   - 10 ml/min N_2
2. humidified conditions
   - 10 ml/min N_2
   - 0,6 ml/min H_2O (l) ~800ml/min (g)

conductivity cell

Membranes conductivity



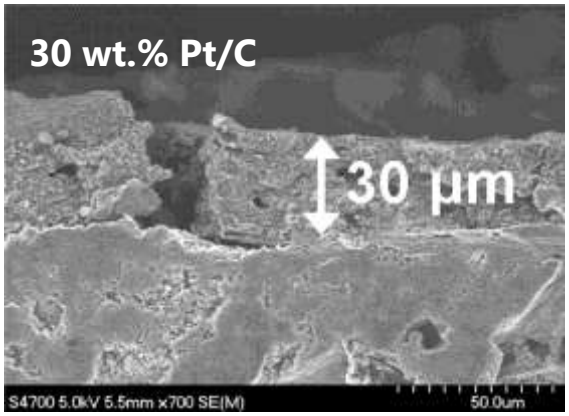
t = 160°C

HT-PEM FC – set up

laboratory HT-PEMFC 6.25 cm^2

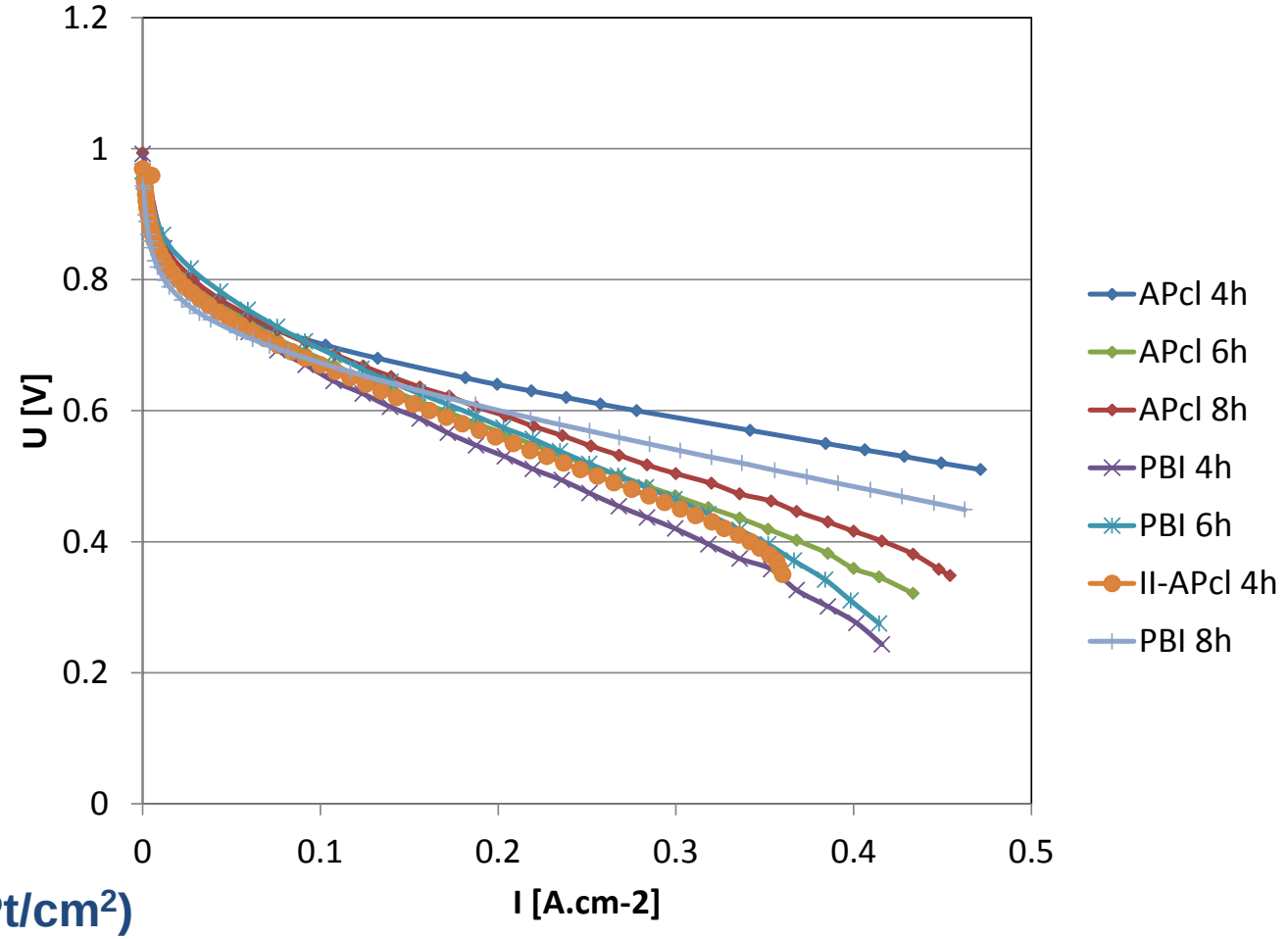
- PBI based membranes
- 160 °C
- Cathode: O_2 / 20 ml min^{-1}
- Anode: H_2 / 30 ml min^{-1}

GDE – self production in laboratory



GDE ~0.5mg Pt/ cm^2
XRD – Pt size 3.5 nm

PBI and APcl comparison



H_2 / O_2

160 °C

GDE (~0.5 mg Pt/cm^2)

100-200h conditioning period

optimized MEA

- Active area 6,25 cm^2
- membrane PBI (Fumatech, GmbH) 6h
- Electrodes - cathode: 1,35 mg/cm^2 Pt
  - anode: 0,59 mg/cm^2 Pt

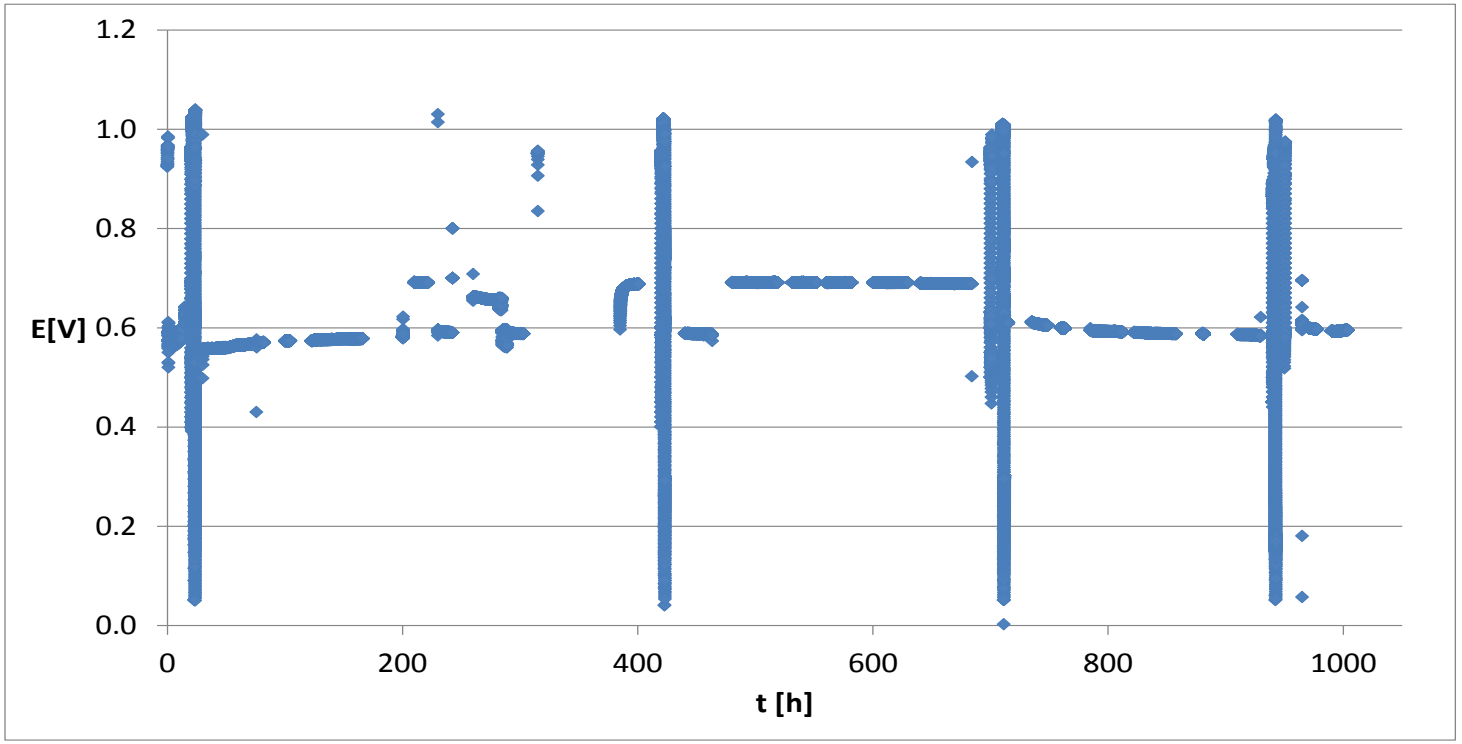
Durability test

Long term testing at constant load

- Operating temperature 160°C
- λ = 1.2/2.0 for H_2/air
- periodical electrochemical characterization: IV, EIS
- 1000 hours at 0.2 A/cm² constant load conditions

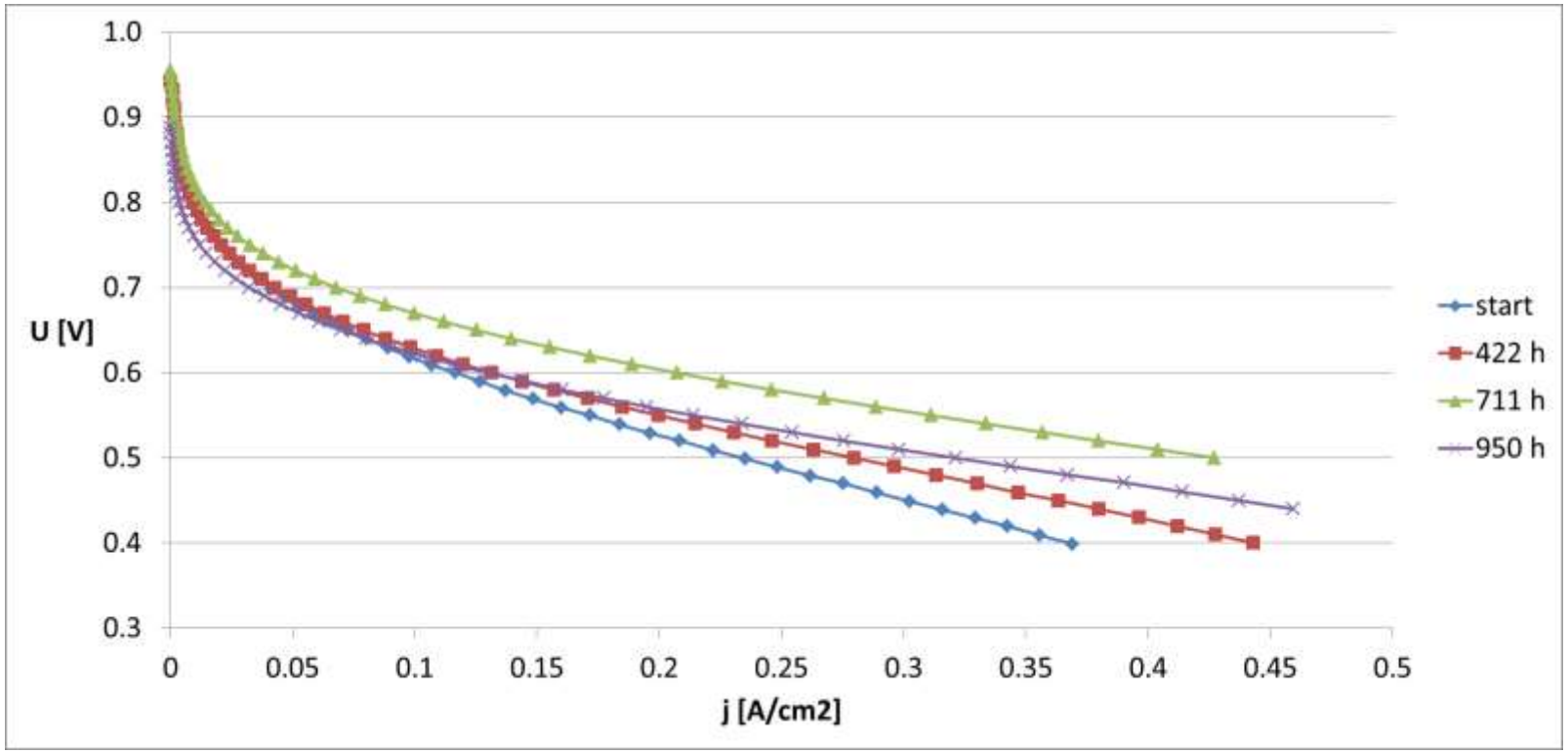
1000h test

- Temperature 160°C
- H_2 / air = 1.2/2.0
- 0.2 A/cm²



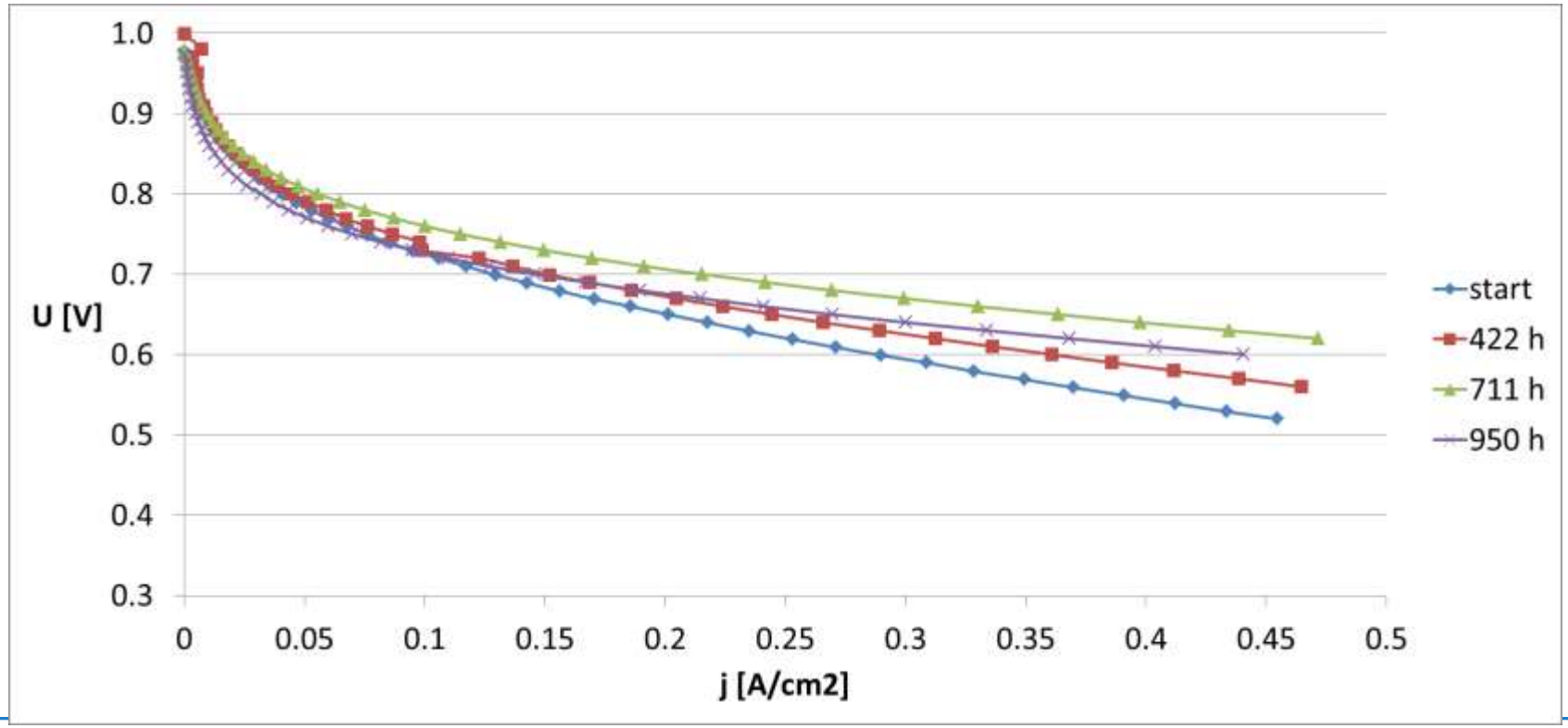
1000h test I-V curves

- Temperature 160°C
- H_2 / air = 1.2/2.0



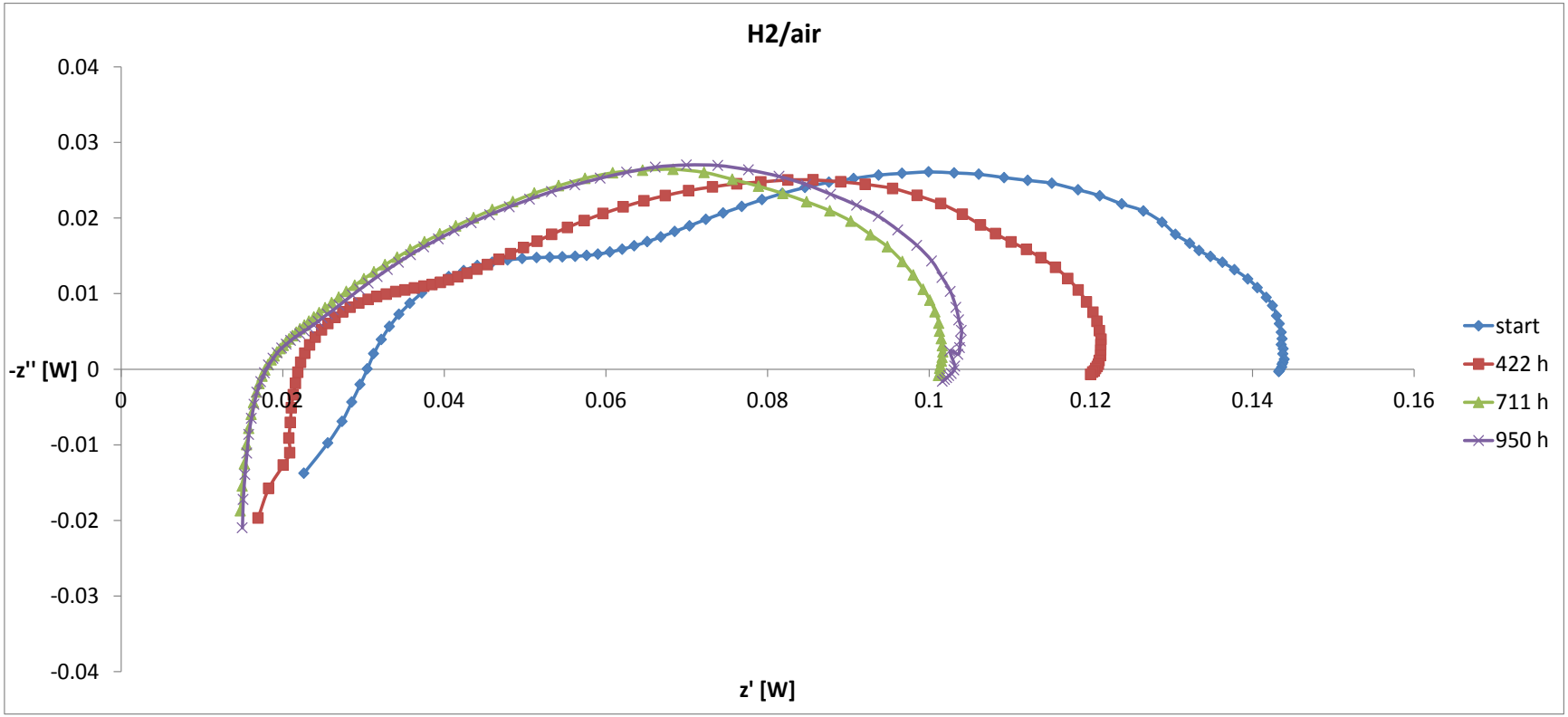
1000h test I-V curves

- Temperature 160°C
- H_2 / O_2 = 1.2/2.0



1000h test EIS

- Temperature 160°C
- H_2 / air = 1.2/2.0 at 0.2 A/cm^2



Conclusions

- crosslinking PBI causes slower membrane doping
- the conductivities of PBI membranes are more dependent on environment humidity than doping time
- HT-PEM MEA operated at 160 °C is able to operate without visible performance decrease over 1000h
- membrane conductivity improving during cell operation
- using oxygen rich gas – enhancement of performance

Thank you !

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