Membranes for Energy Conversion and Energy Storage with Fuel Cells and Batteries

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FuMA-Tech Gesellschaft für funktionelle Membranen und Anlagentechnologie

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For You and Planet Blue. | BWT BEST WATER TECHNOLOGY

There are no alternatives to water, but there are various alternatives to energy.

Water Technologies for a Better Life !
Fuel Cell and Battery Technologies for a Better Quality of Life !

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BWT – We go for 98.5%

For You and Planet Blue.

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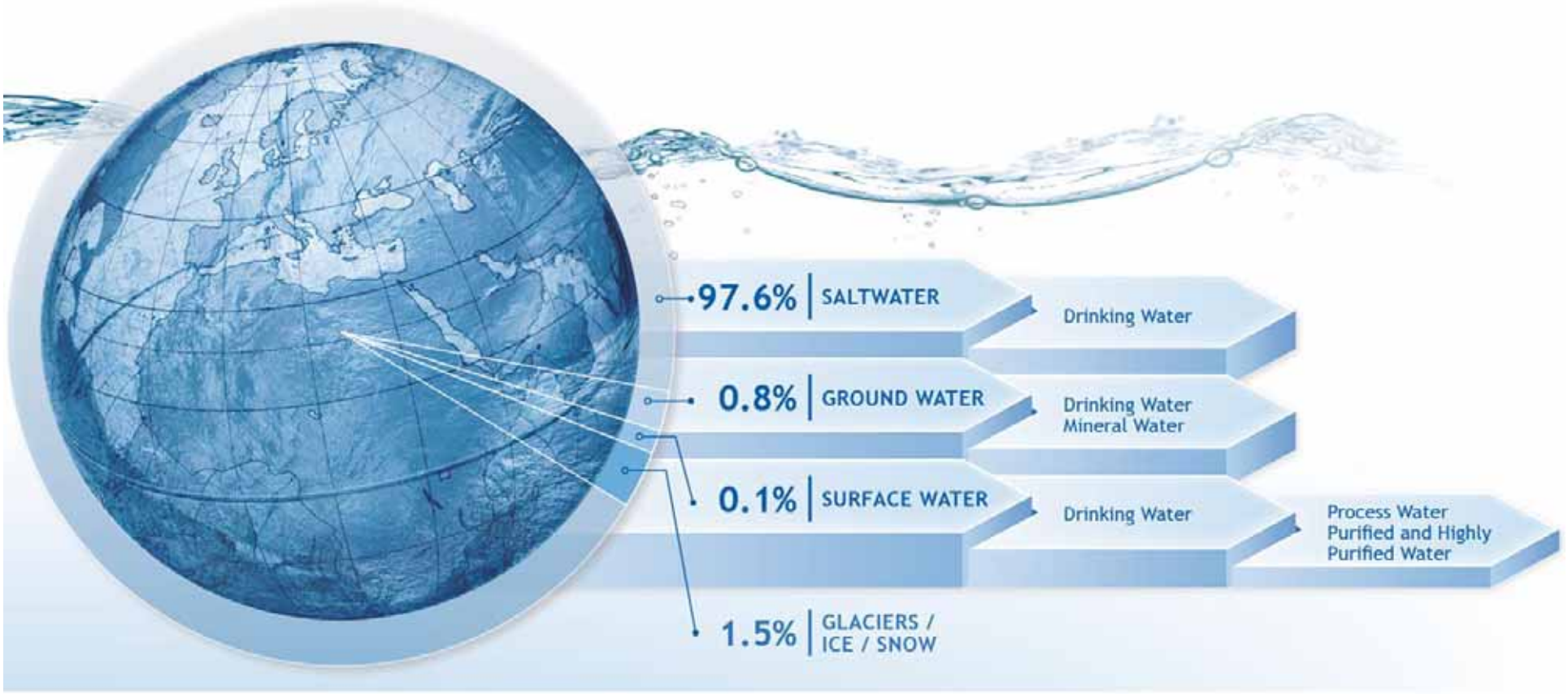
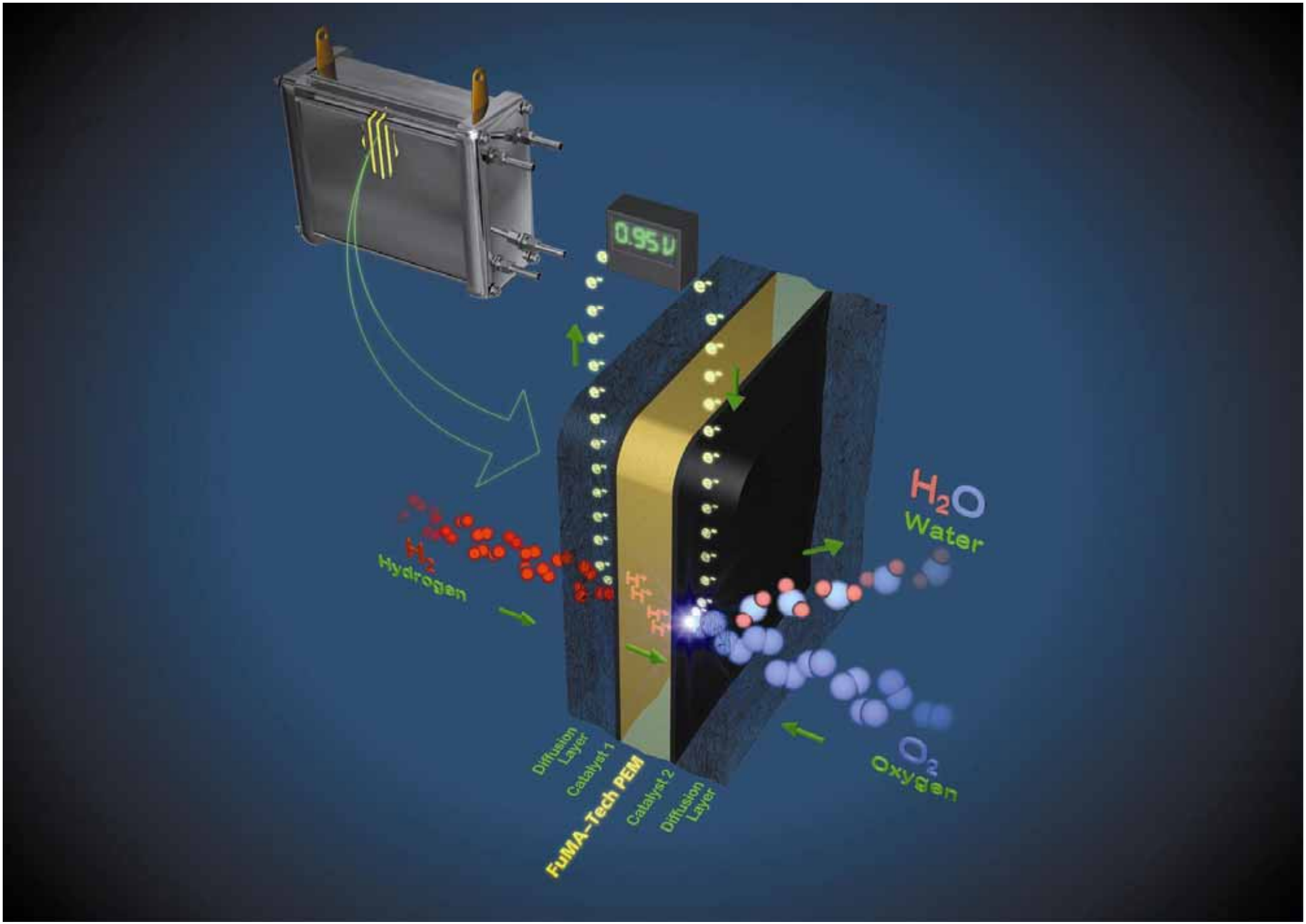


fumasep®

- Ion-exchange membranes
  - Micro-heterogeneus anion- and cation exchange membranes
  - IEx-membranes for electrodialysis and donnan dialysis
  - Bipolar membranes
  - Oxidation stable and chlorine tolerant anion-exchange membranes
  - Membranes for capacitive electrodeionisation
  - Membranes for RED energy production
  - Membranes for sea water desalination
- Perfluorinated membranes for electrolysis
- Membrane humidifiers
- Flat sheet membranes for ERV applications


0.95 V
H_2O
Water
H_2
Hydrogen
O_2
Oxygen
Diffusion Layer
Catalyst 1
FuMA-Tech PEM
Catalyst 2
Diffusion Layer

Membrane Humidifier

Water-to-Gas

and

Gas-to-Gas

humidifier:

1 kW
3 kW
5 kW
10 kW

100 kW

FUMAPEM Membranes

fumion®

- membrane polymers and ionomers for MEA fabrication

fumapem®

- membranes for fuel cells, batteries and electrolysers:
  - F-series – fully fluorinated membranes for LT-PEM
  - AM-series – acid doped membranes for HT-PEM
  - S, ST and P-series – hydrocarbon type membranes for DMFC
  - FAA – anion exchange membranes for alkaline fuel cells
  - FAAM – anion exchange membranes for alkaline electrolysers
  - FAP – anion membranes for vanadium redox batteries

fumea®

- catalyst-coated membranes for water electrolysis

New FUMATECH production site

For You and Planet Blue.

New membrane production site in Bietigheim-Bissingen from 2013

Membranes for Energy Conversion

Shortcomings with todays PEM

Today's market hurdles for PEM fuel cells

- Hydrogen infrastructure (renewable H_2, reformate, …)
- Durability, reliability and life-time
- Cost
  - Reduction of Pt-loading, non noble metal catalysts (AFC)
  - Lower cost materials (hydrocarbon membranes, …)
  - System simplification
    - Non humidified operation (dry proton conductors, …)
    - Increased operation temperature (improved PFSA, …)

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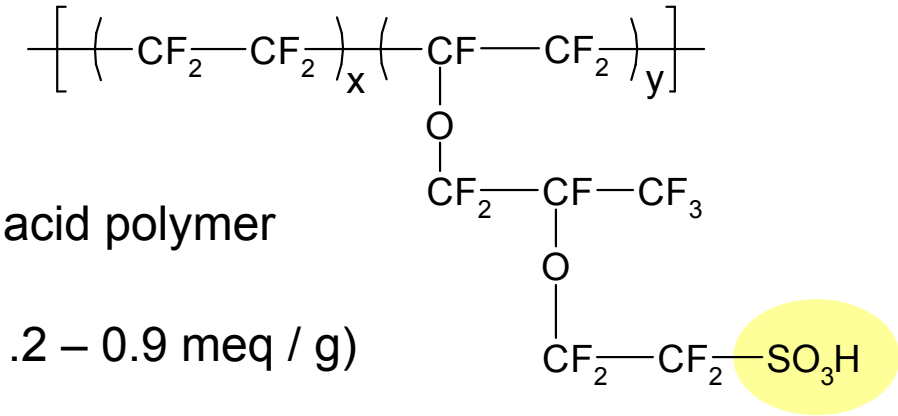
Low and medium temperature FC on hydrogen / air

fumapem® F

fumion® F - perfluorinated ionomer

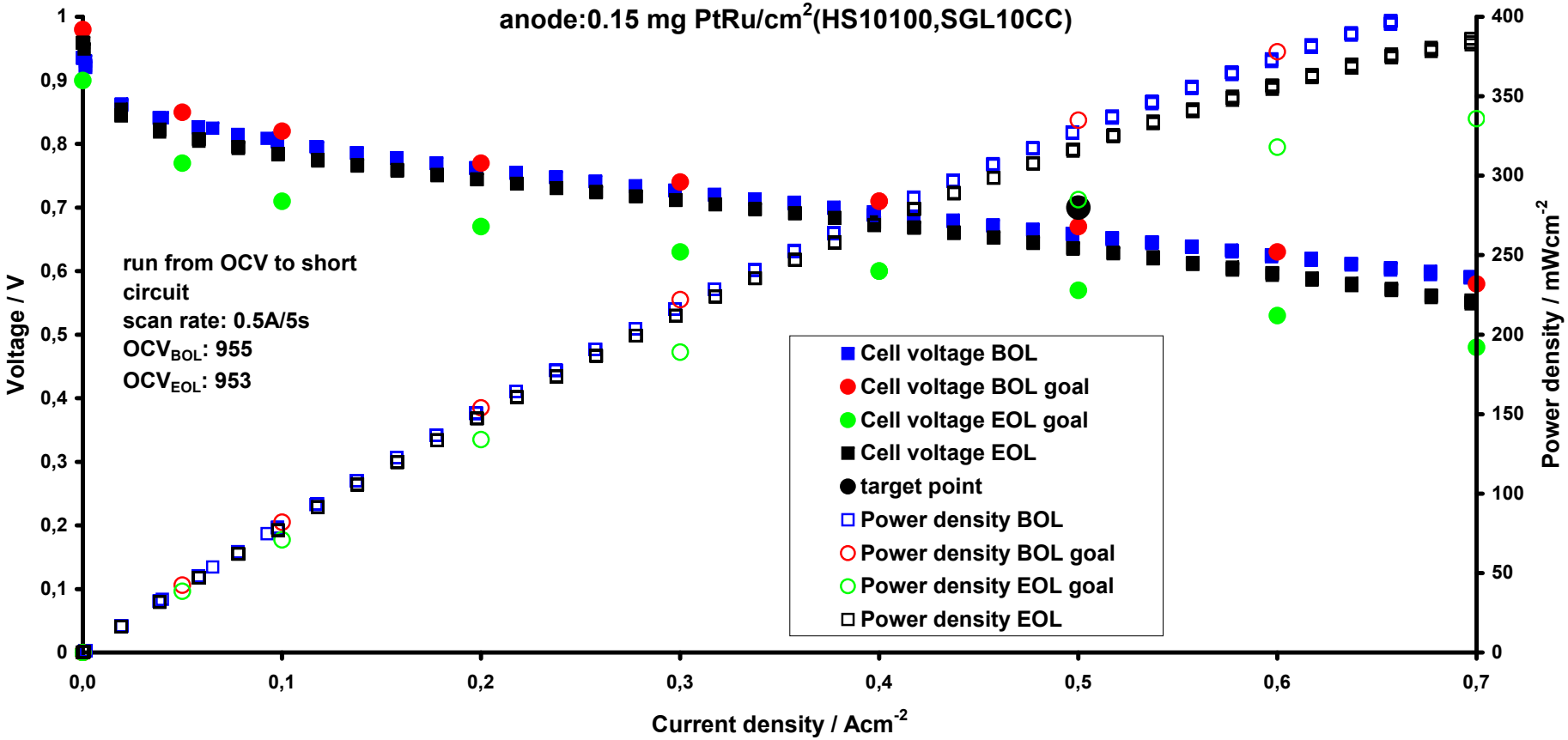


fumion® F

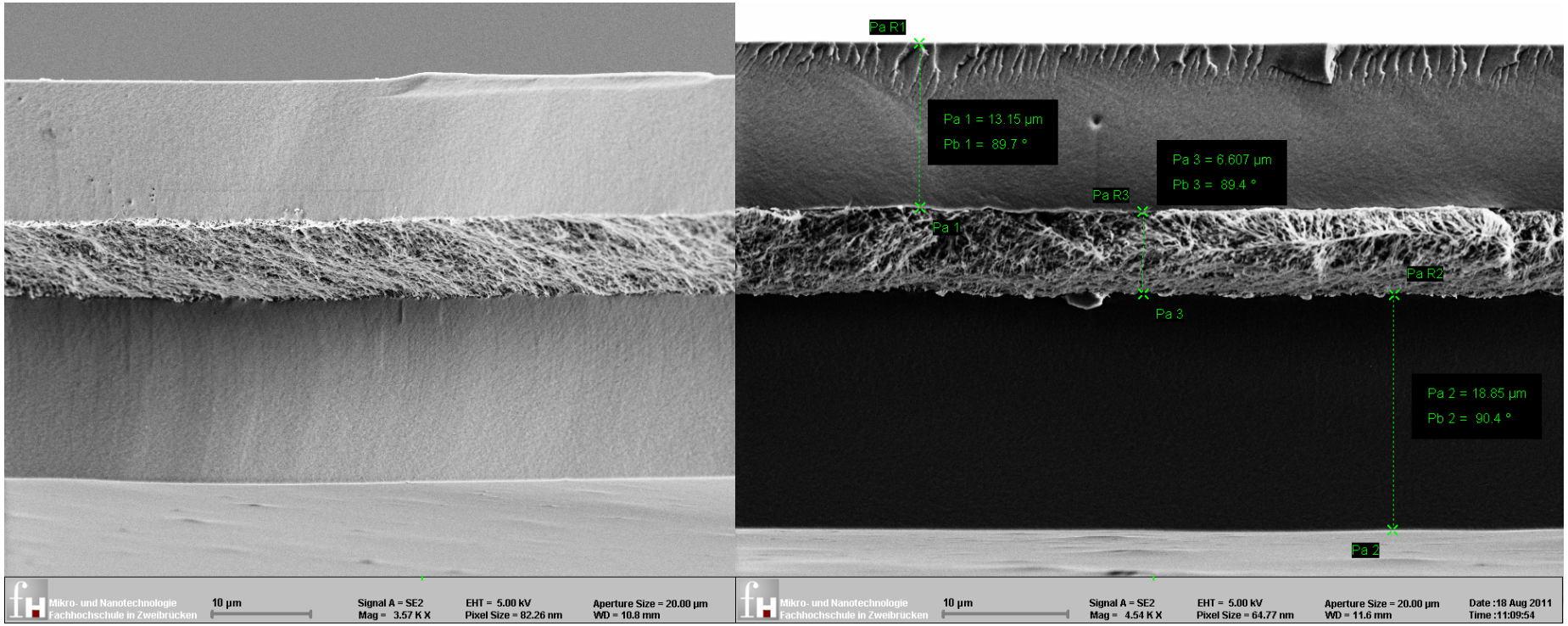
- long side-chain perfluorosulfonic acid polymer
- EW = 820 – 1100 g / eq (IEC = 1.2 – 0.9 meq / g)
- glass transition temperature T_g ~ 110 °C (EW = 900)
- end-group protected by polymerisation
- high molecular weight, low PD
- membrane thickness 30, 40 and 50 µm
- reinforcement (optional)

Durability of fumapem® f-950 in LT-PEMFC

Durabilty test: 600cycles:1h 0.5A/cm^2,2h 0A/cm^2
PEMFC at 65°C, 7-layer MEA 25cm^2
F950, 20wt%Fumion
1bara, λ_{H2}:1.5(85% r.h.), λ_{air}:2.5(85% r.h.)
c_p:1N/mm^2, cathode:0.4 mg Pt/cm^2(HS13100,SGL10DC)
anode:0.15 mg PtRu/cm^2(HS10100,SGL10CC)



Reinforced Membranes F-940rf

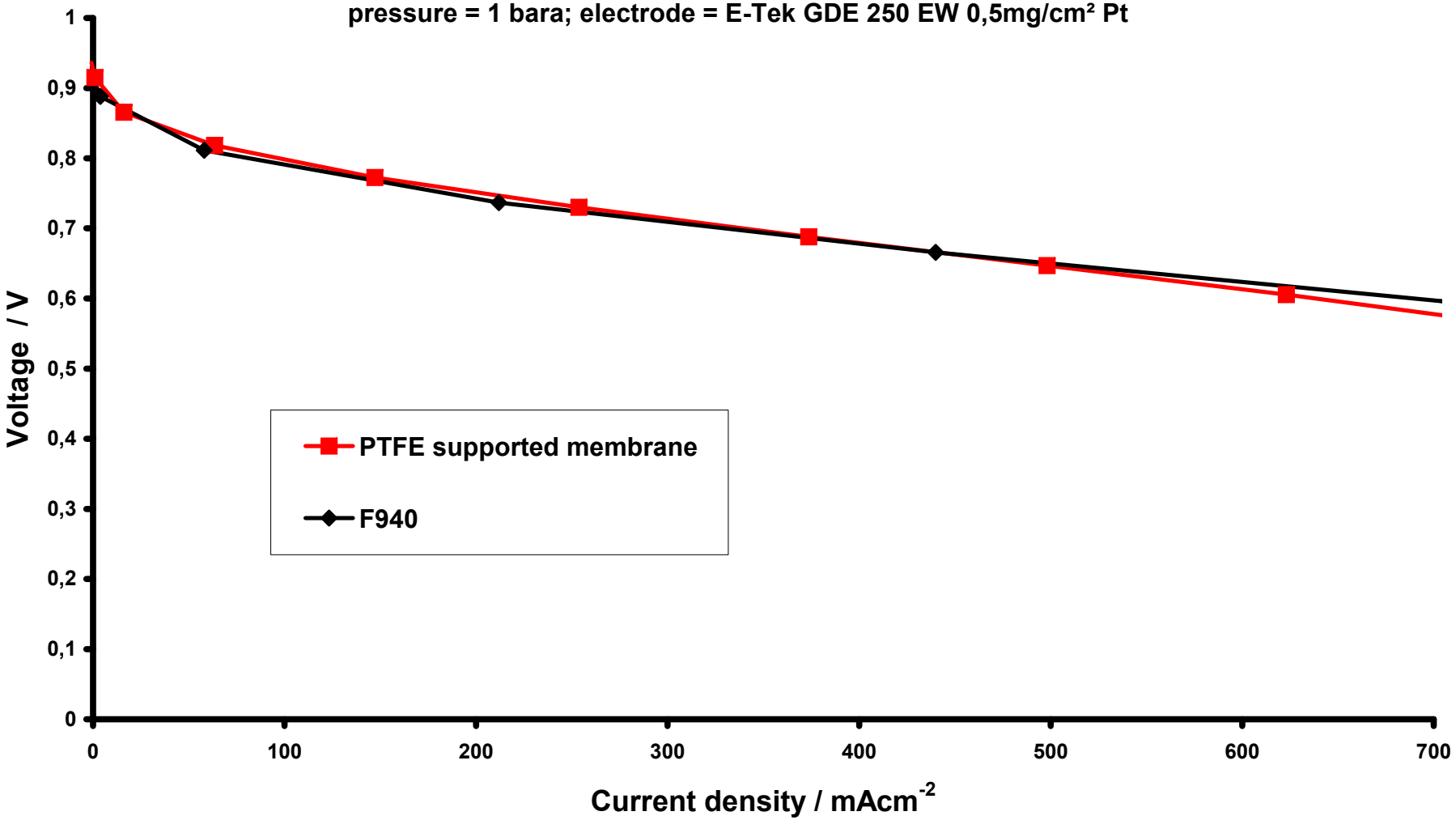


fumapem® F-rf

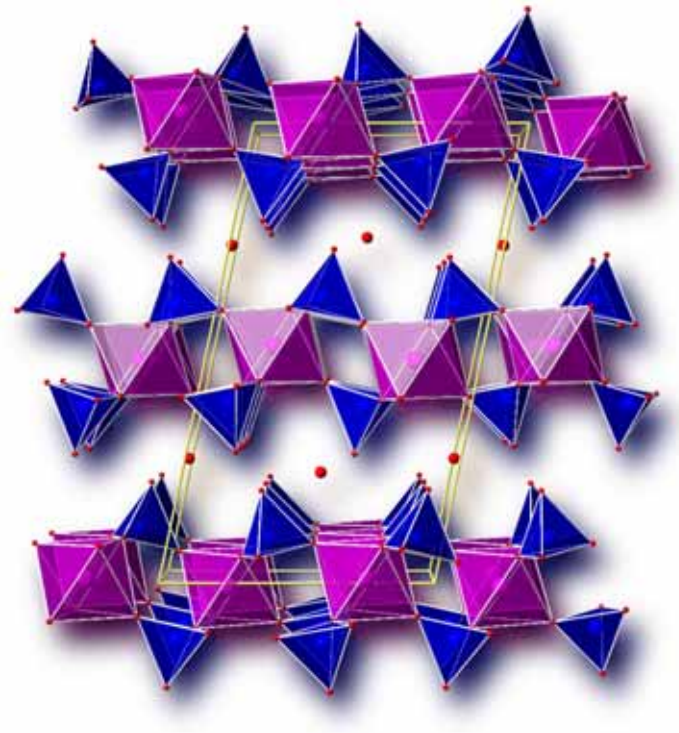
Reinforced Membranes F-940rf

Membrane = PTFE supported PFSA (thickness = 30 - 40 µm)

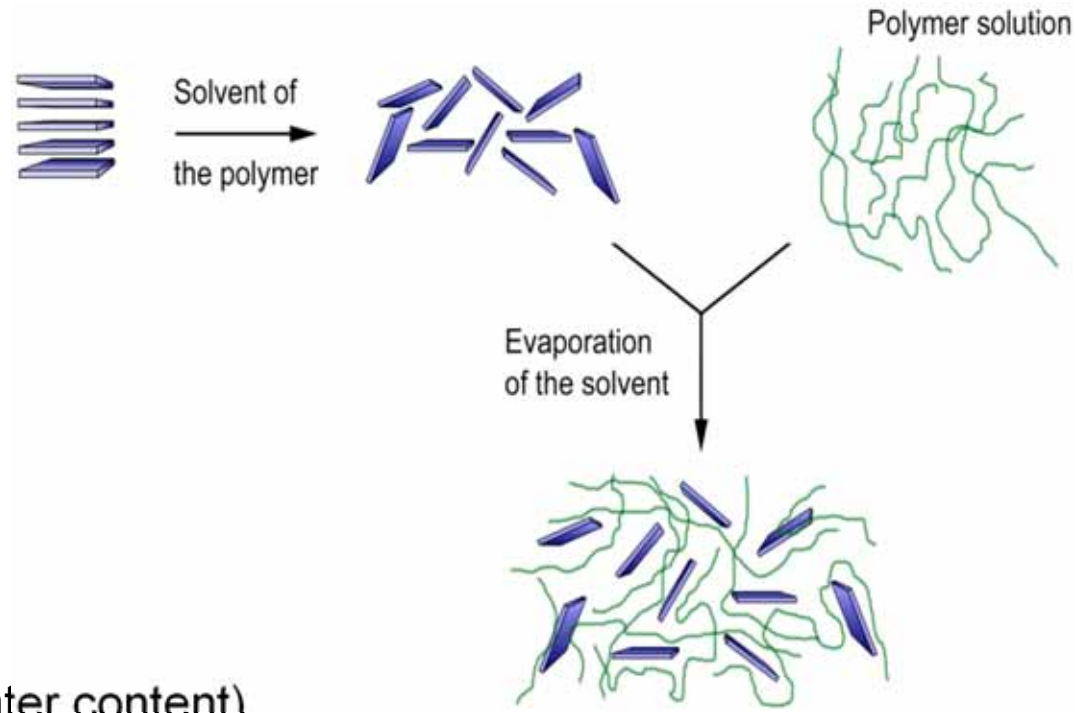
Test cell: QuickConnect 25 cm², Air: λ = 2.5; 100% r.h.; H_2: λ = 1.5, 100% r.h., pressure = 1 bara; electrode = E-Tek GDE 250 EW 0,5mg/cm² Pt



Zirconium phosphate $Zr(HPO_4)_2 \cdot H_2O$

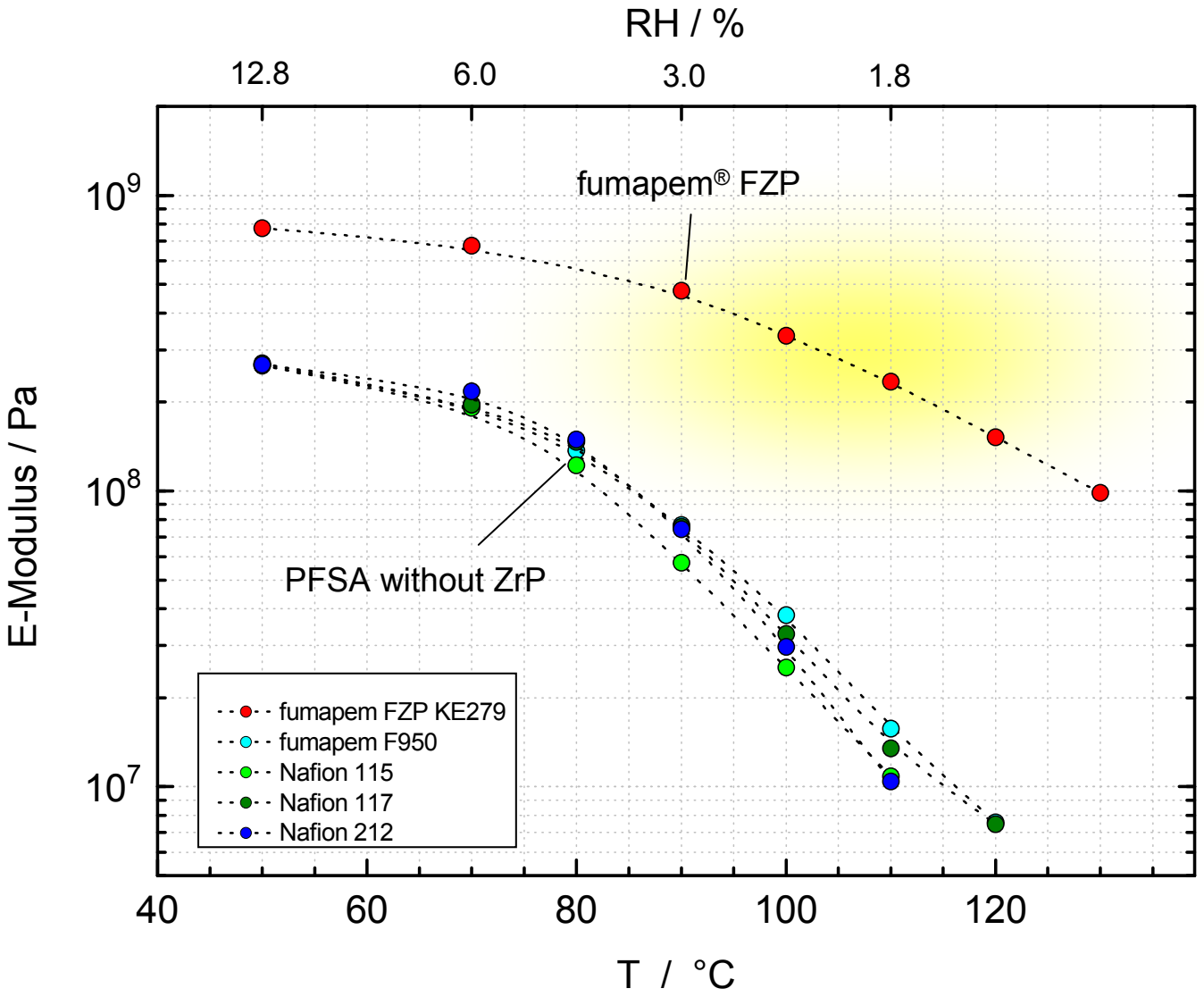


sol-gel method



- insoluble in water
- acidic sites (conductivity and water content)
- layered structure

Performance of fumapem® FZP in MT-PEMFC



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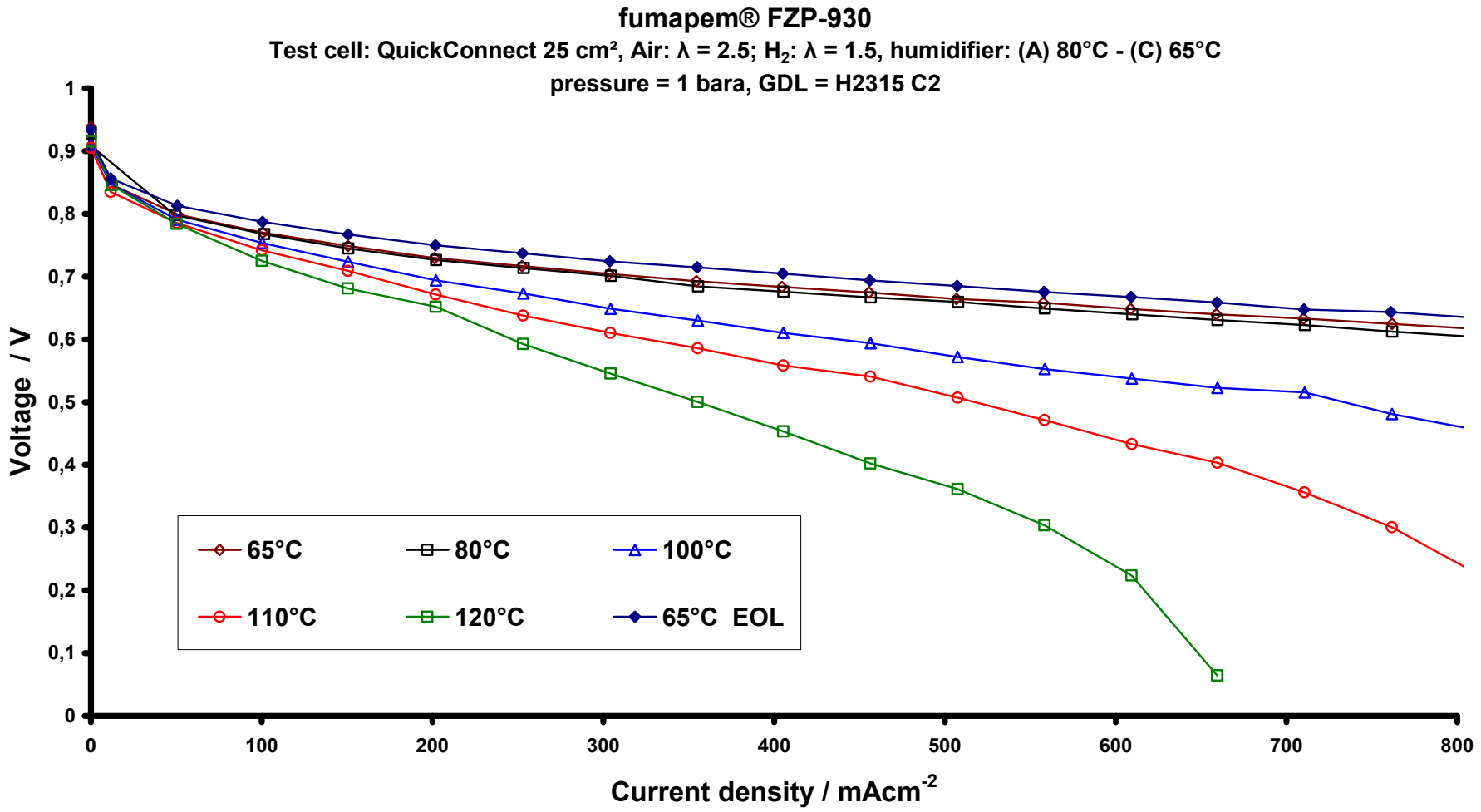
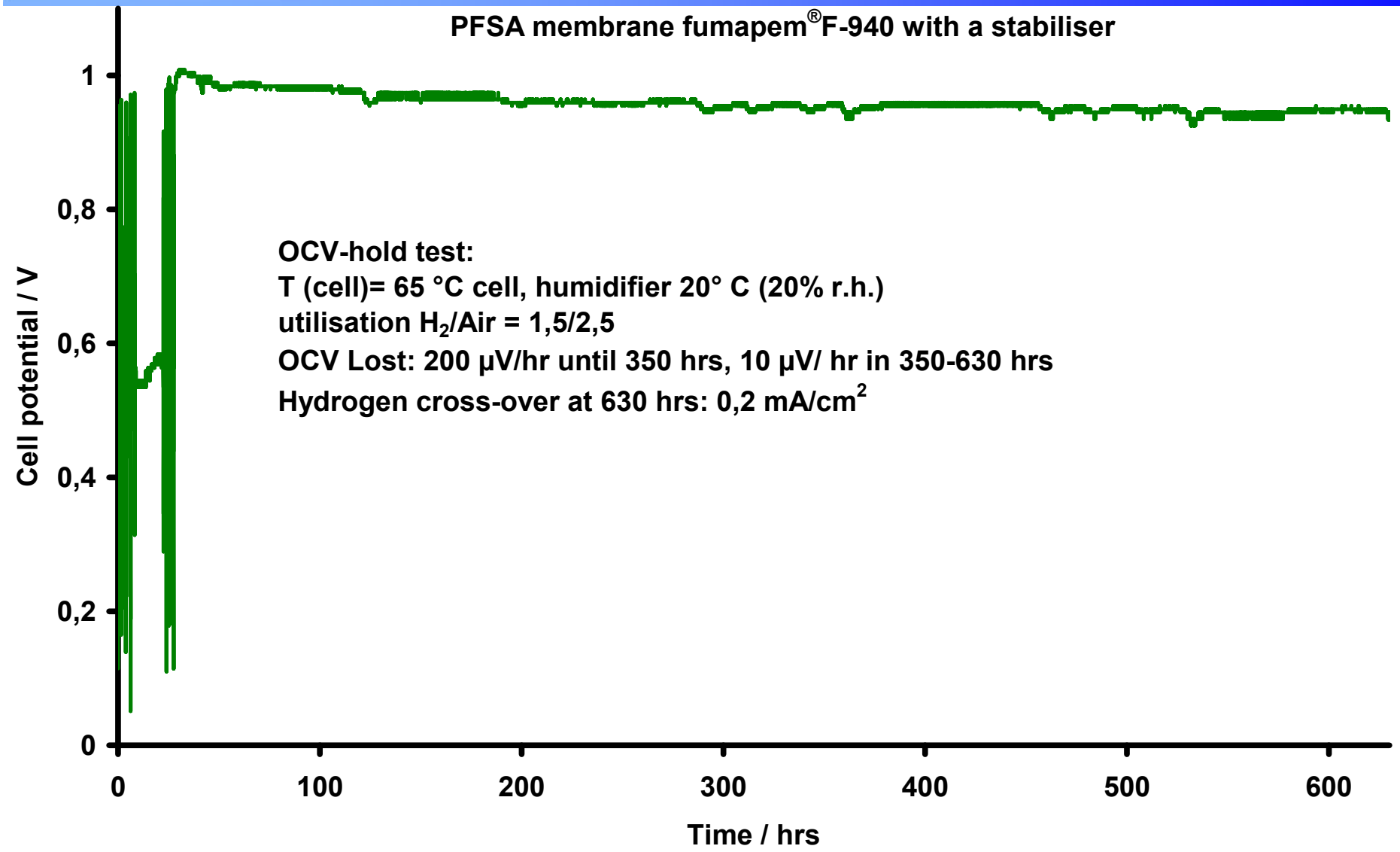


Stabilized Membranes F-940xs



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High temperature reformate / air

fumapem® AM

ABPBI

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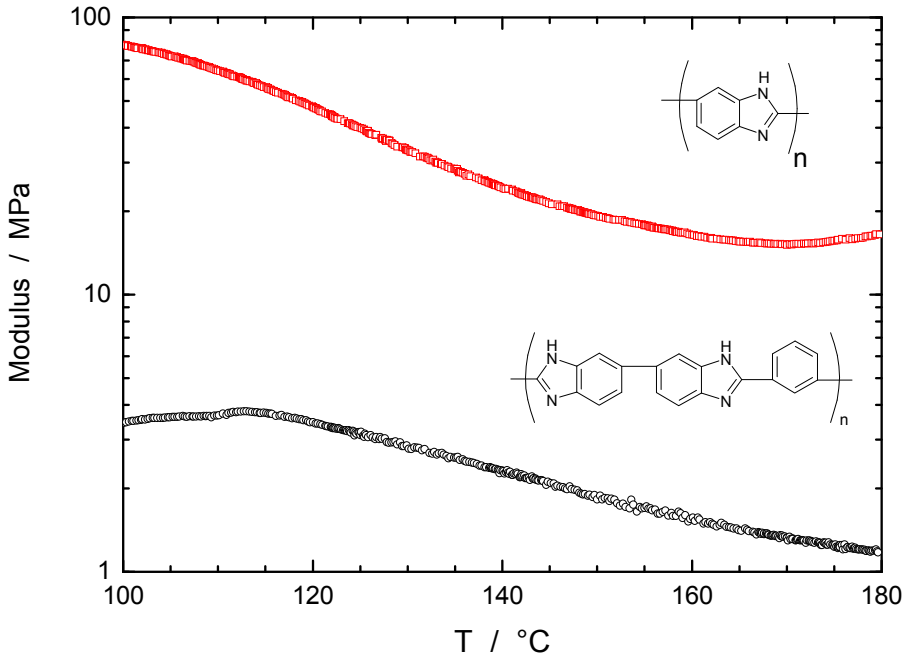
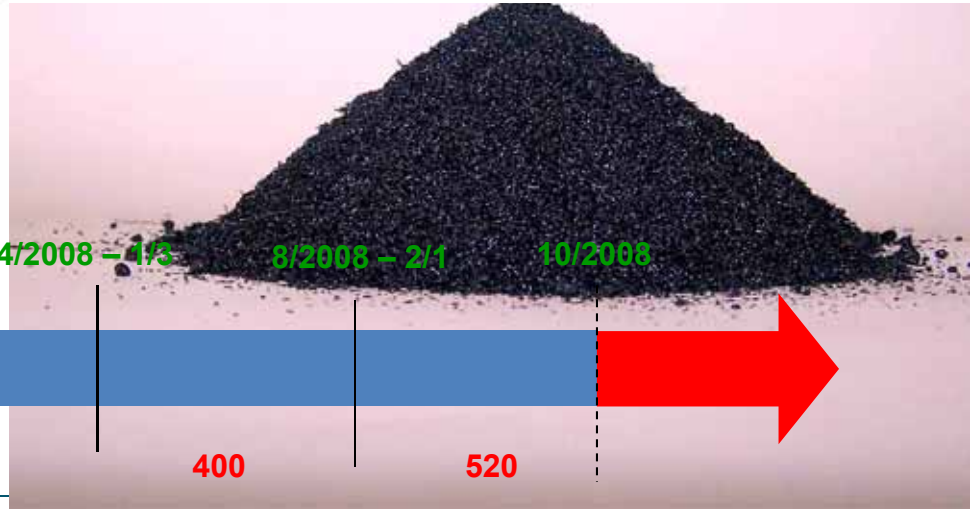
Milestones of fumapem® AM in HT-PEMFC

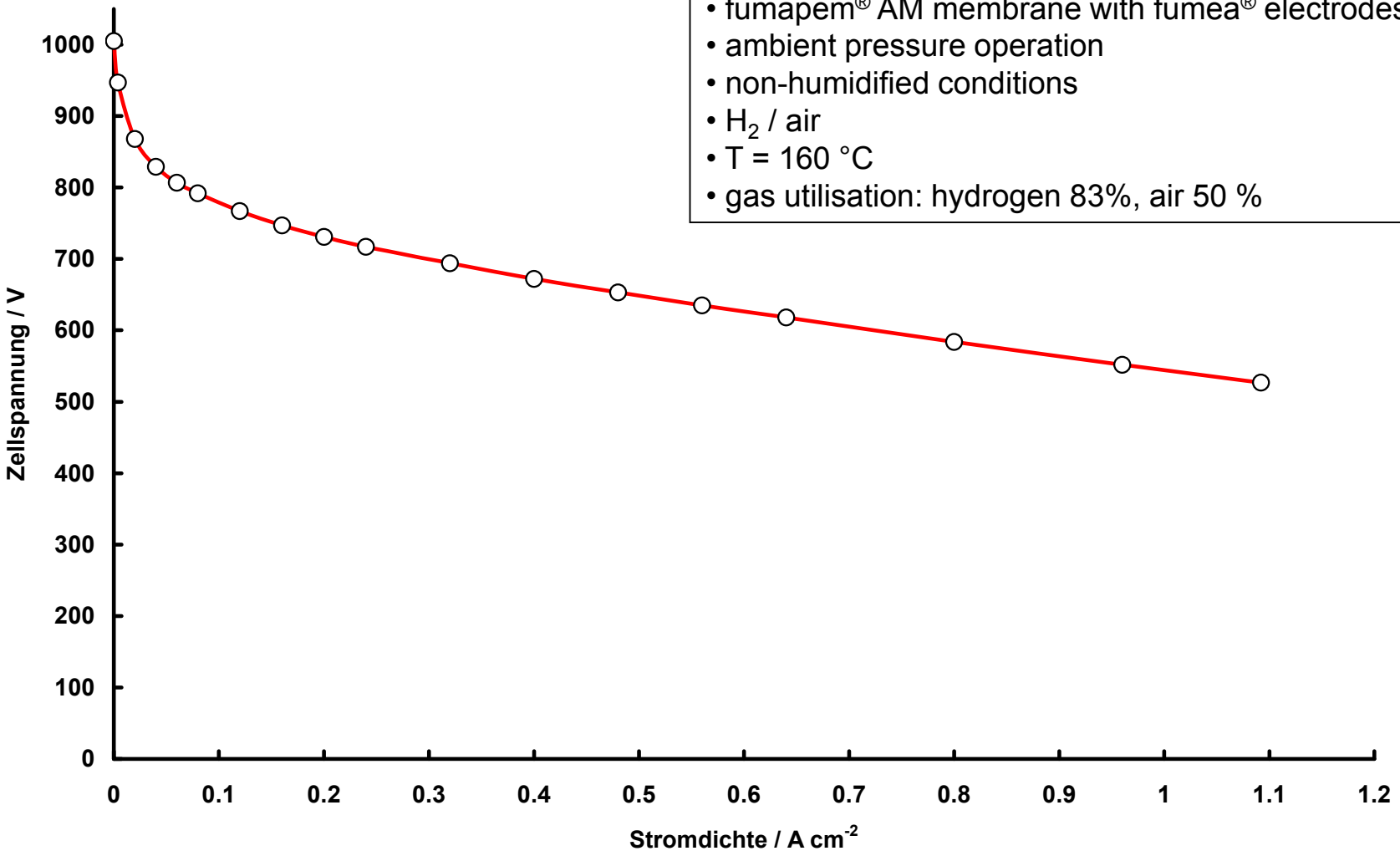




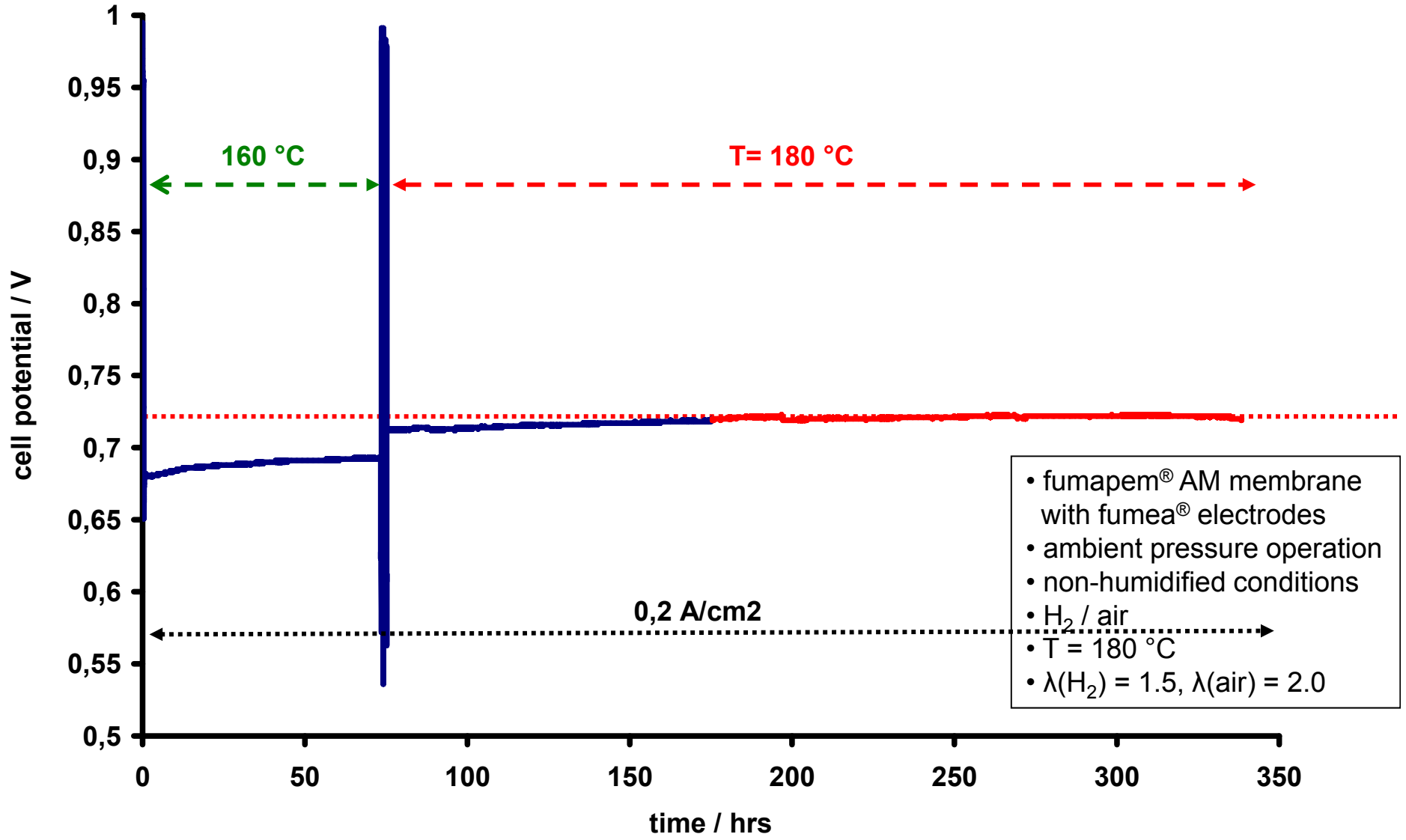
Start time / MEA generation	10/2007- 1/1	1/2008 – 1/2	4/2008 – 1/3	8/2008 – 2/1	10/2008
Peak power / mW/cm²	330	370	400	520	

Performance of fumapem® AM at 160°C

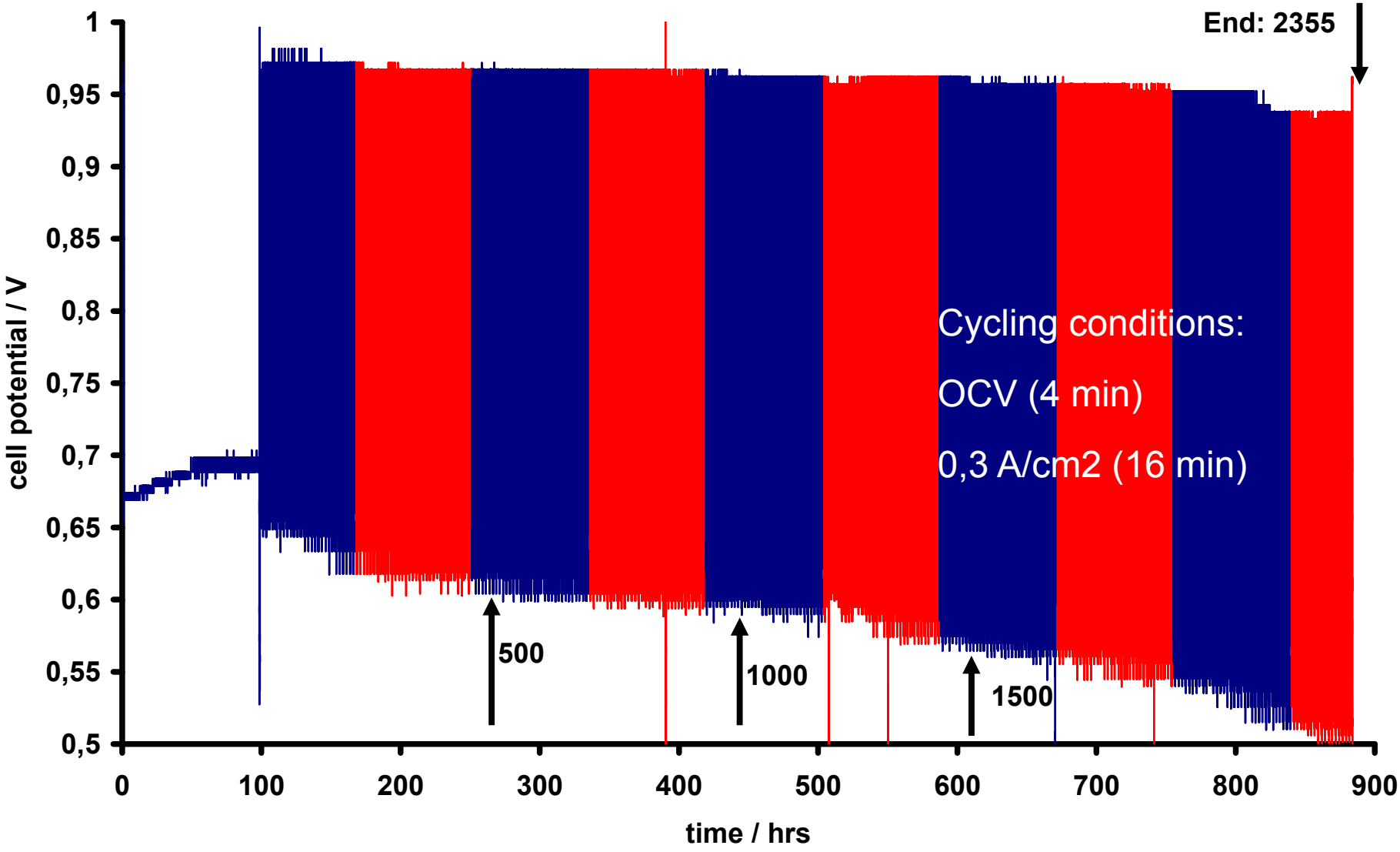
- fumapem® AM membrane with fumea® electrodes
- ambient pressure operation
- non-humidified conditions
- H_2 / air
- T = 160 °C
- gas utilisation: hydrogen 83%, air 50 %



Durability of fumapem® AM at 180°C



Durability of fumapem AM – cycling at 160°C



Durability of fumapem AM – cycling at 180°C

Test protocol:

T = 180 °C

Cycling

5 h @ 0,4 A/cm²

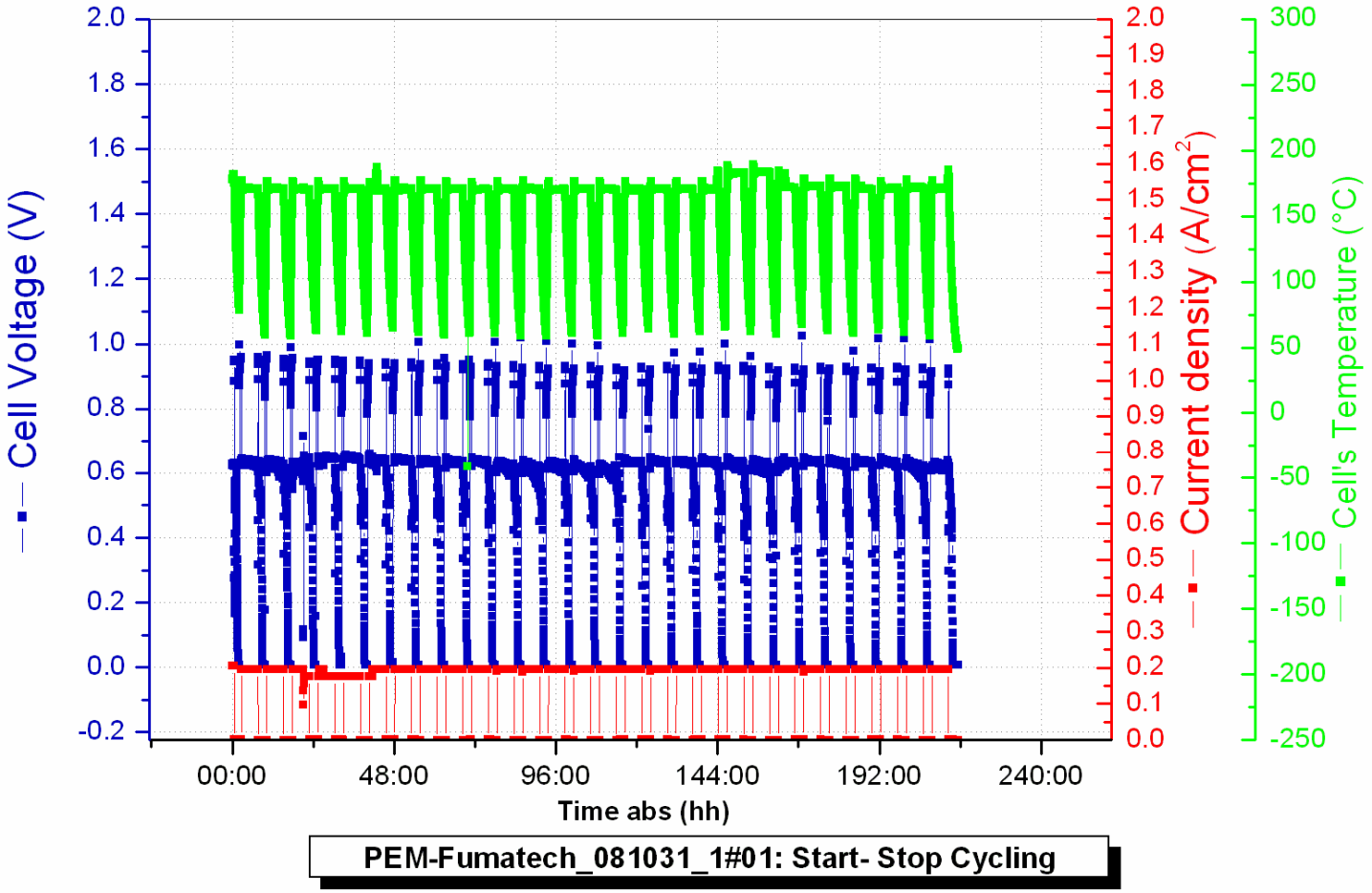
1 h @ 0,0 A/cm²

1 h @ 0 A/cm² no gas

OCV @ BOL = 0,953 V

OCV @ EOL = 0,922 V

Decay = -147,6 µV/h



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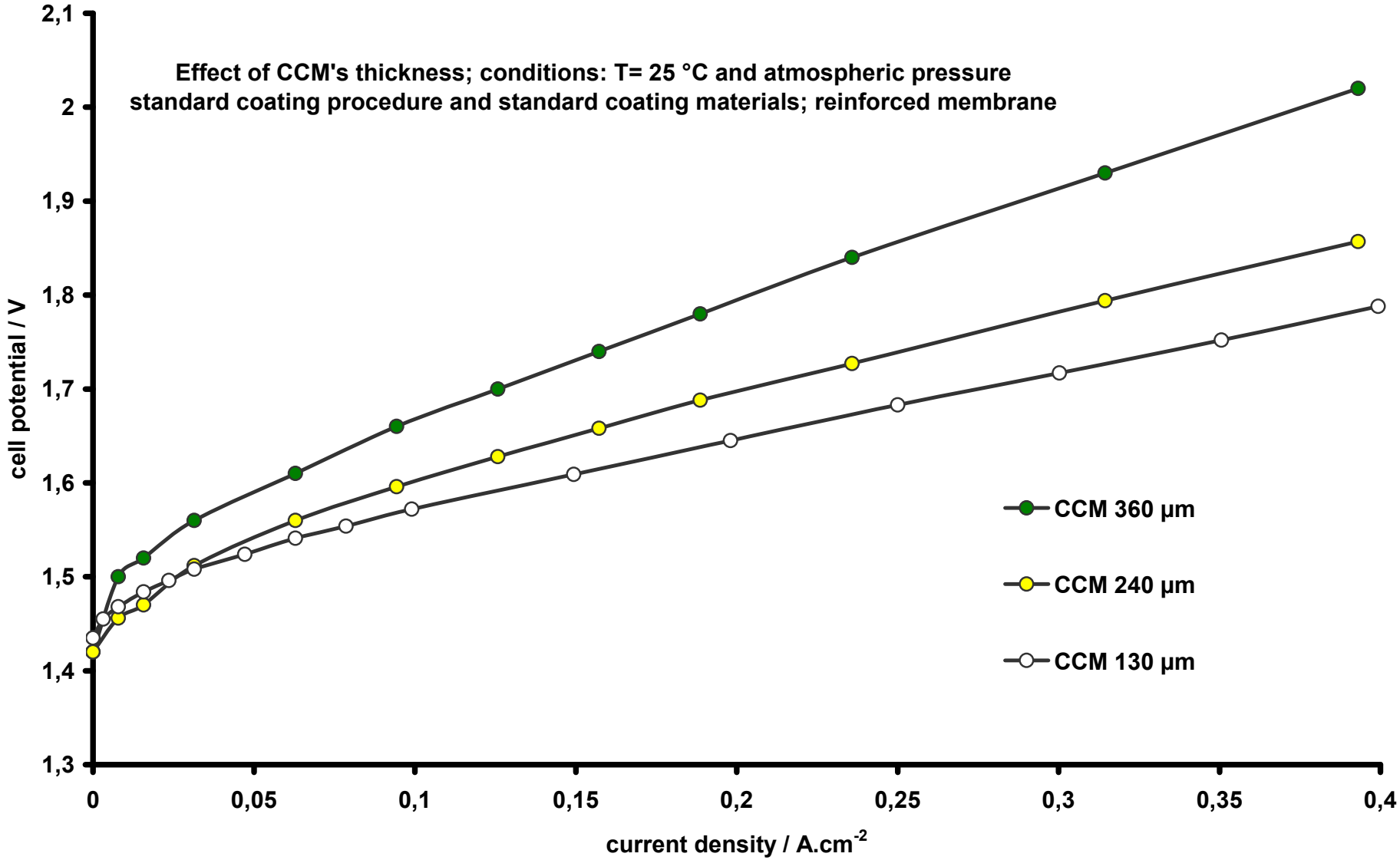
Catalyst Coated Membranes for Water Electrolysis

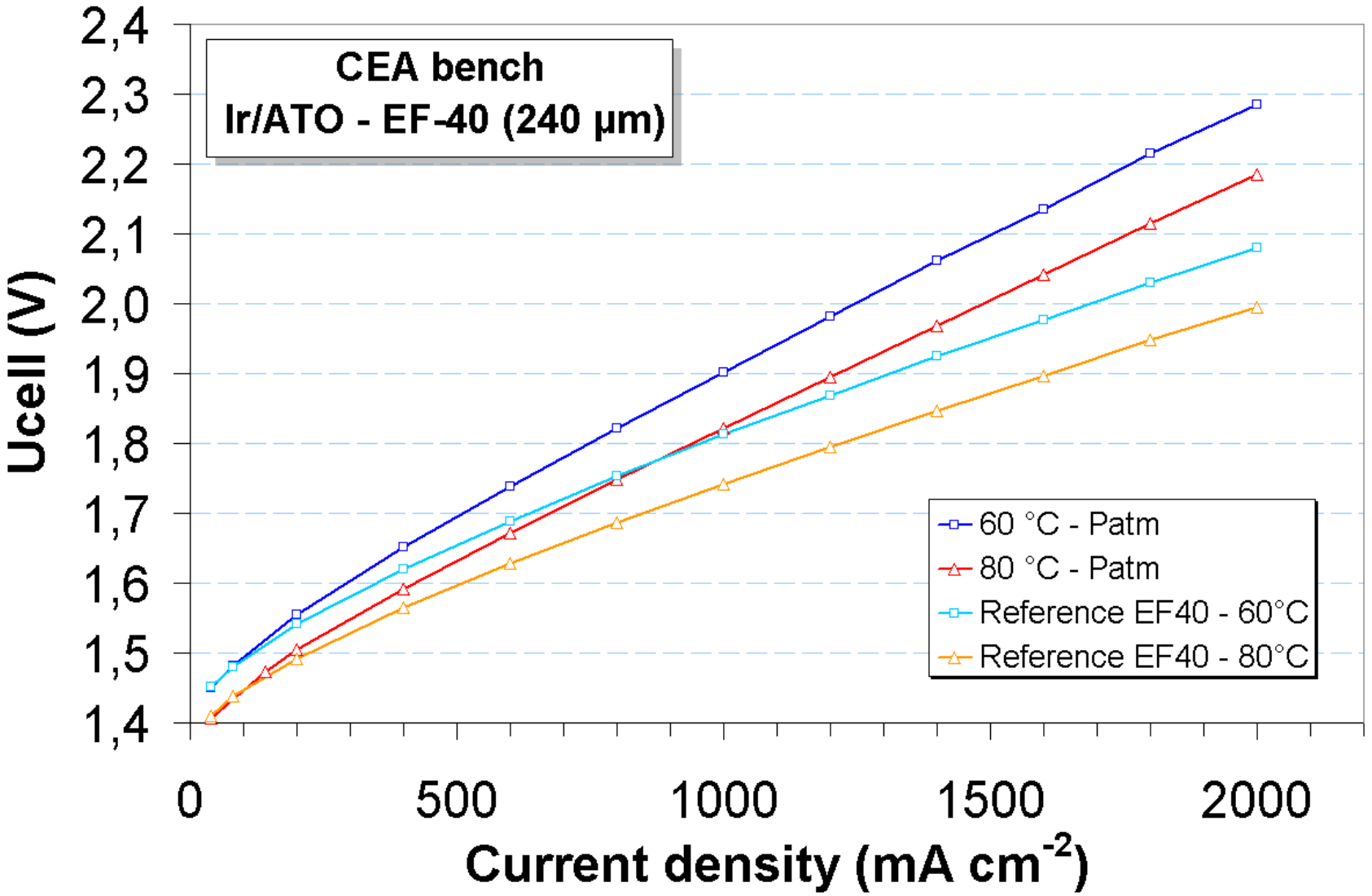
Fumapem membranes for water electrolysis



Purity of gases on various CCM

Laboratory / CCM	EF-10 (135 micron)	EF-40 (240 micron)	EF-50 (360 micron)
Company A	0,7 % (10 bar)	0,2 % (20 bar)	n.d. (low perf.)
Company B	0,5 % (10 bar)	0,3 % (10 bar)	< 0,05 % (10 bar)
Company C	< 0,01 % (1 bar)		0,5 % (50 bar)

Performance fumea® EF-40 – new catalysts



Membranes for Energy Storage in Flow Batteries

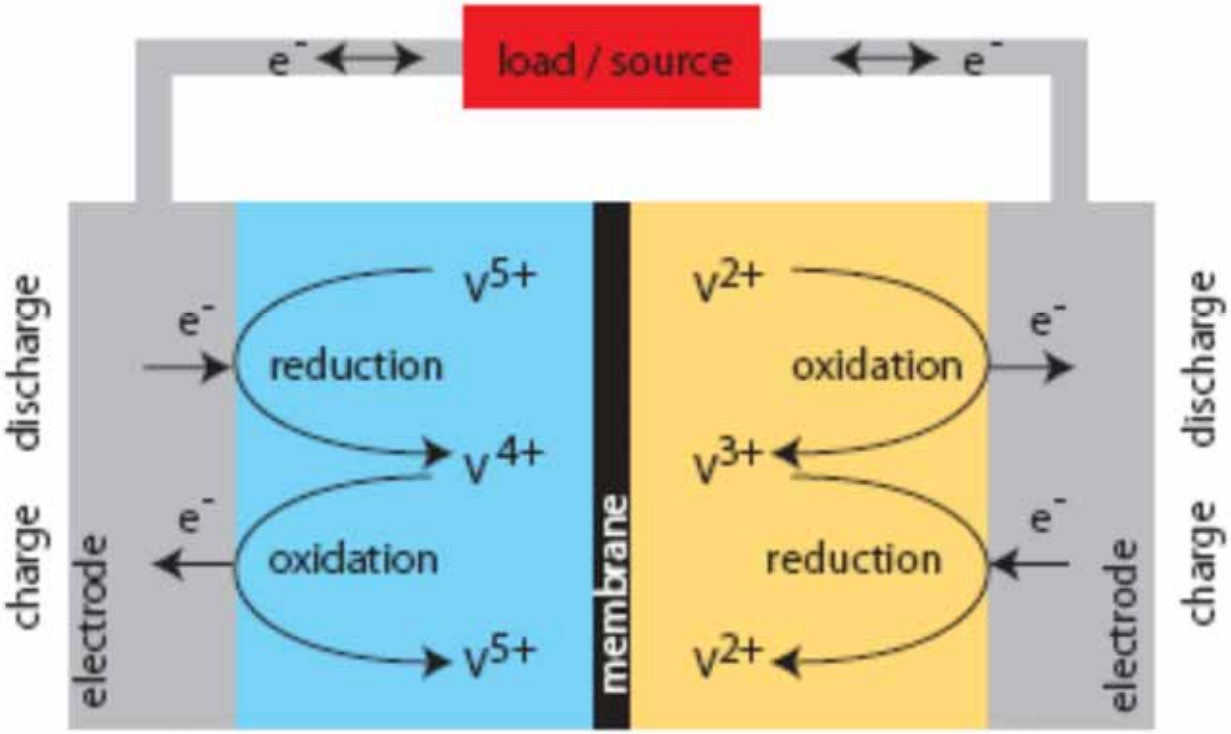
Redox flow battery as possible solution: Working principle

Anode:

$$VO_2^+ + 2H^+ + e^- \Leftrightarrow VO^{2+} + H_2O$$

Cathode:

$$V^{3+} + e^- \rightarrow V^{2+}$$



$$V^{2+} + VO_2^+ + 2H^+ \Leftrightarrow VO^{2+} + V^{3+} + H_2O$$

Guideline for membrane's choice

Cation-exchange vs. Anion-exchange

Cation exchange membranes	Anion exchange membranes
Low selectivity	High selectivity
High conductivity	Medium conductivity
High electrolyte transfer	Low electrolyte transfer
High oxidation stability	Medium to good oxidation stability
High cost for PFSA	Medium to low cost

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Characterisation of VRB Membranes

Membrane	thickness	AC - R_m [mΩ *cm²]	DC - R_c [Ω *cm²]	CE [%]	Liquid transfer
Reference	125 µm	~275	1,29	92,50	~0,8 ml/h
F-1050	50 µm	~180	1,09	92,05	~2 ml/h
F-1860	60 µm	~270	3,40	99,10	~ 0,7 ml/h
FX-7050	55 µm	~280	1,35	97,50	~0,6 ml/h
VM-20	20 µm	~350	2,70	99,50	~0,1 ml/h
FAP	35 µm	~298	1,28	99,05	~0,15 ml/h

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