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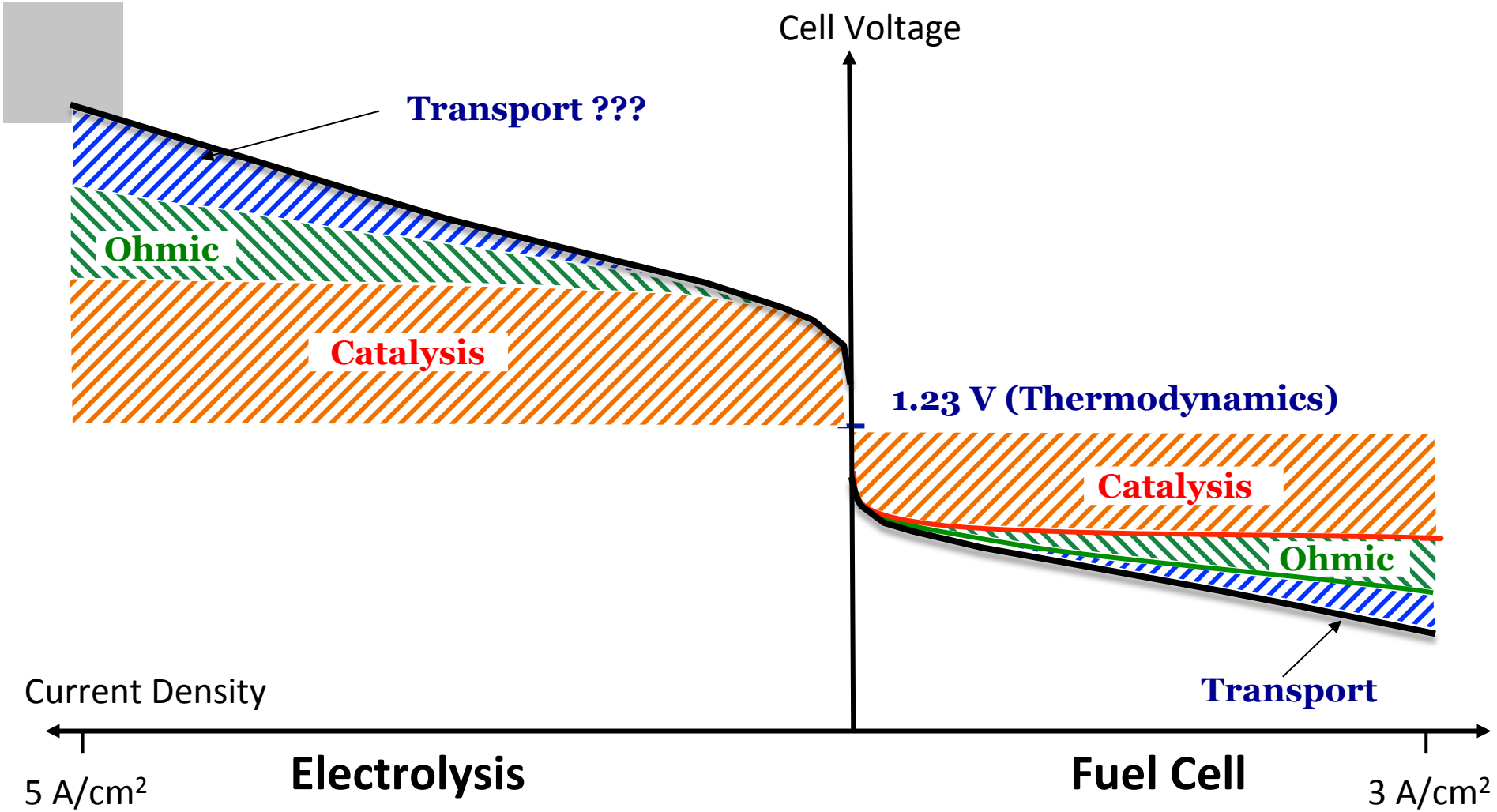
M. Suermann, T. J. Schmidt, F. N. Büchi :: Paul Scherrer Institut :: Switzerland

Analysis of Voltage Losses in Polymer Electrolyte Electrolysis Cells

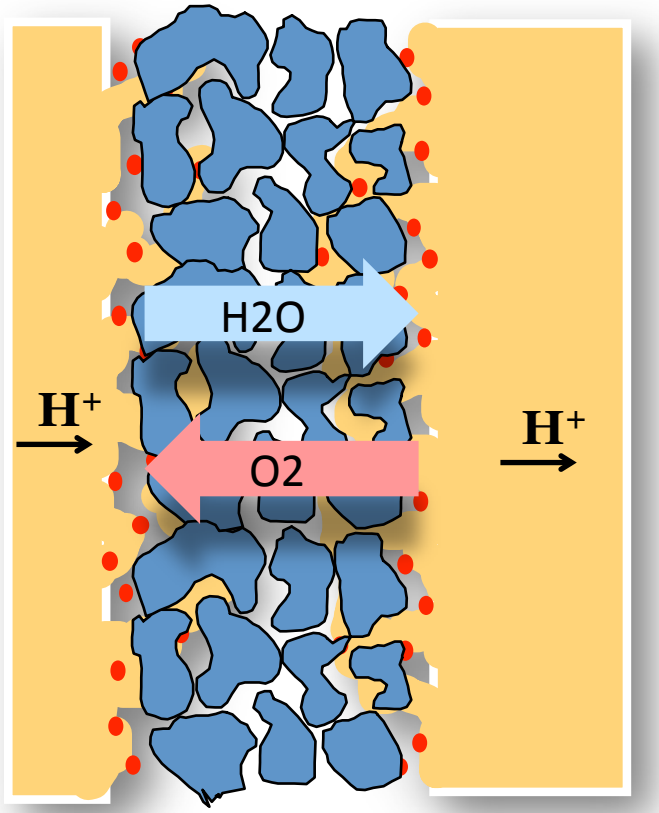
2nd International Workshop, PEM Electrolysis, Freiburg, D

Losses in Fuel Cells and Electrolysis



Two Phase Transport

Fuel Cell



Electrolysis

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→How are the losses composed in PEEC ?

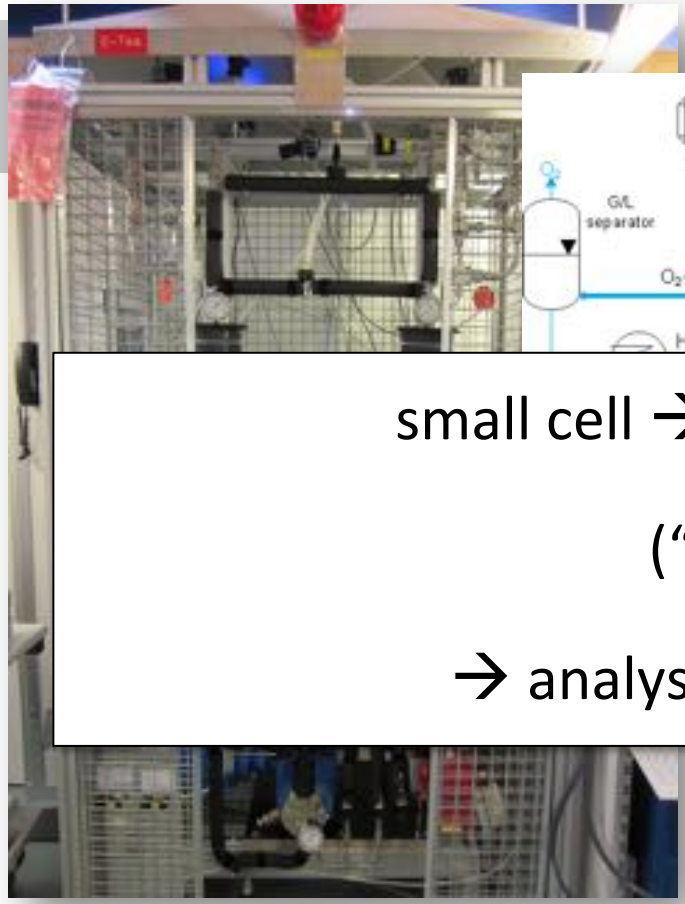
→ influence of pressure on losses

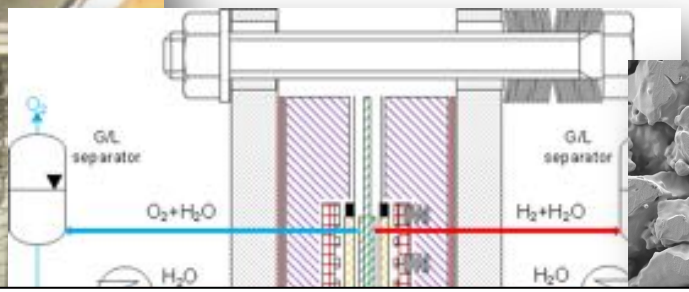
→ experiments up to 100 bar

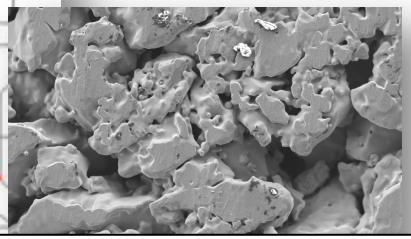
→ are there transport losses ?

→ effect of different CCs, PTLs

Experimental Setup







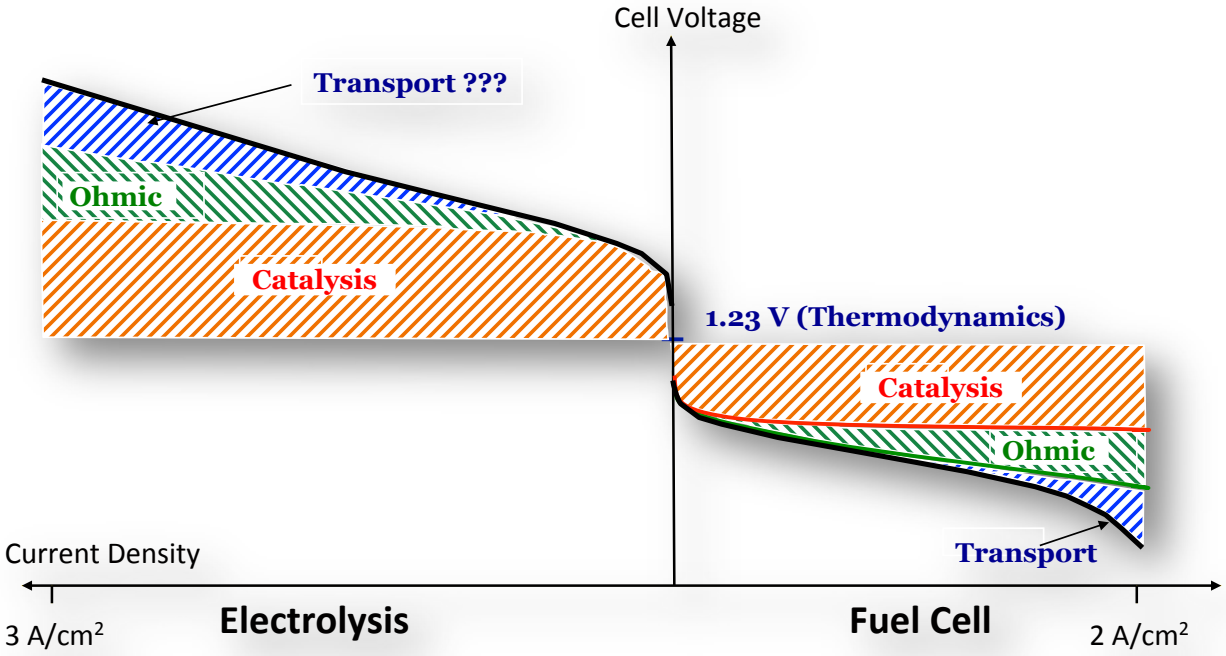
small cell → homogeneous conditions

("differential" cell)

→ analysis of data with 0D Model

- 4 cm^2 active area
- **Nafion 117** CCM
- **up to 100 bar**

Quantification



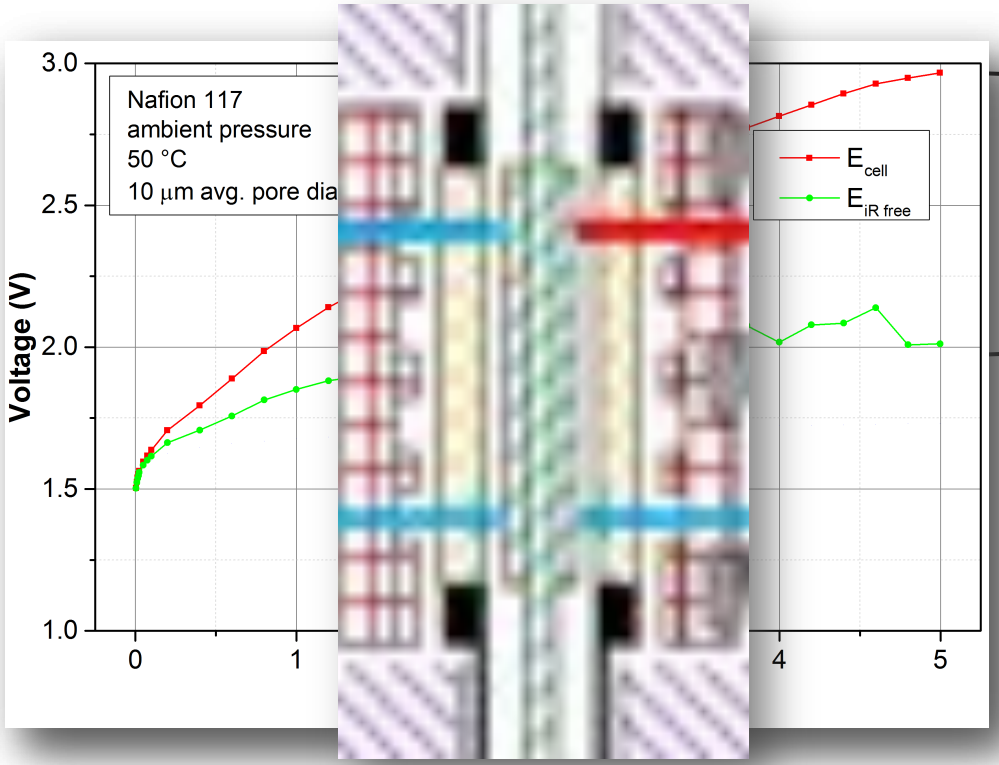
$$E_{cell} = E_0 + \eta_{kin} + \eta_{iR} + \eta_{mtx} \qquad E_{cell} = E_0 - \eta_{kin} - \eta_{iR} - \eta_{mtx}$$

$$E_{cell} = E_0(p,T) + b * \log(j) + R * j + \eta_{mtx}$$

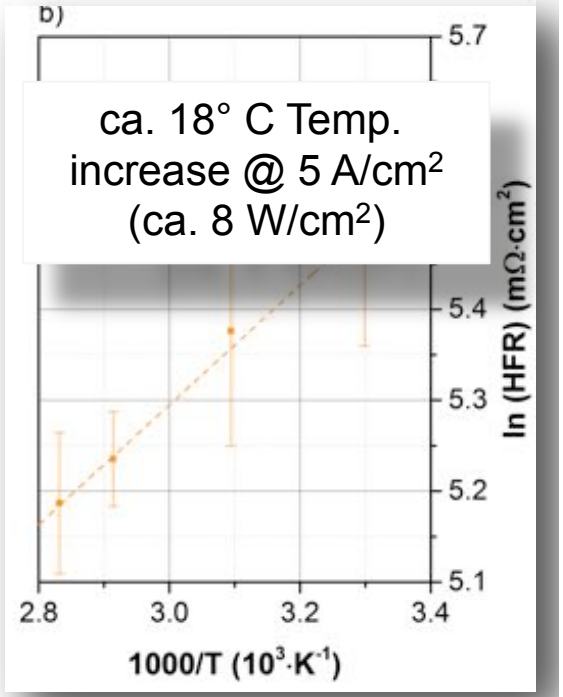
$$\eta_{mtx} = E_{cell} - E_0(p,T) - b * \log(j) - R * j$$

Ohmic Loss

$$E_{cell} = E_0(p,T) + b * \log(j) + R * j + \eta_{mtx}$$

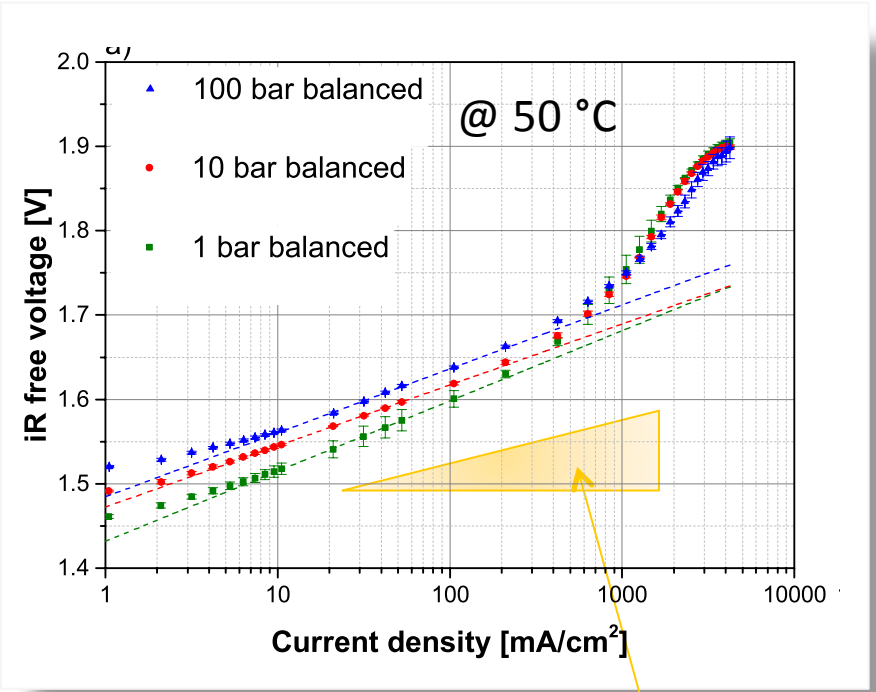


η_{iR}

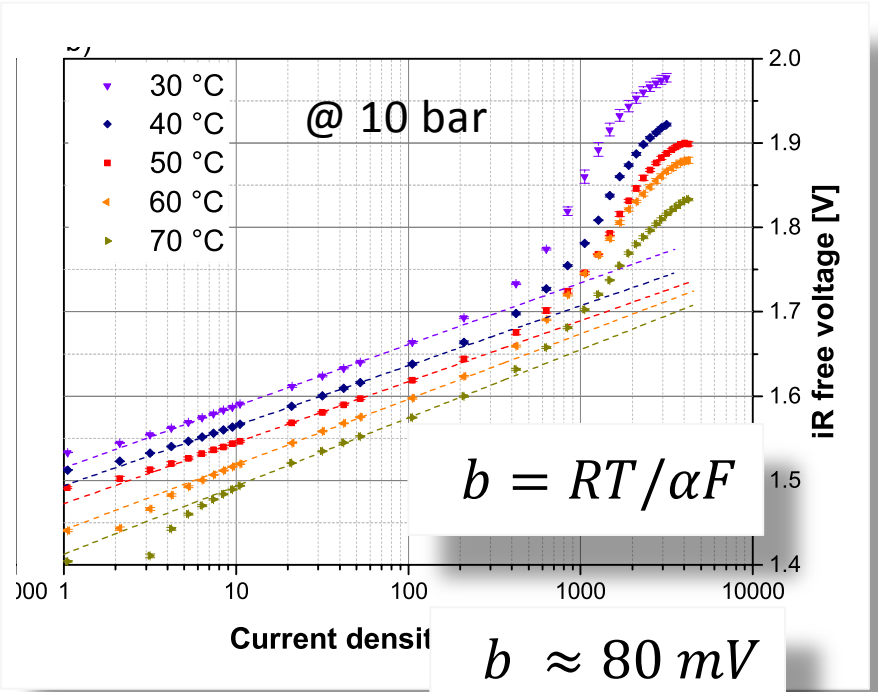


Kinetic Losses

$$E_{cell} = E_0(p,T) + b * \log(j) + R * j + \eta_{mtx}$$



Tafel slope b



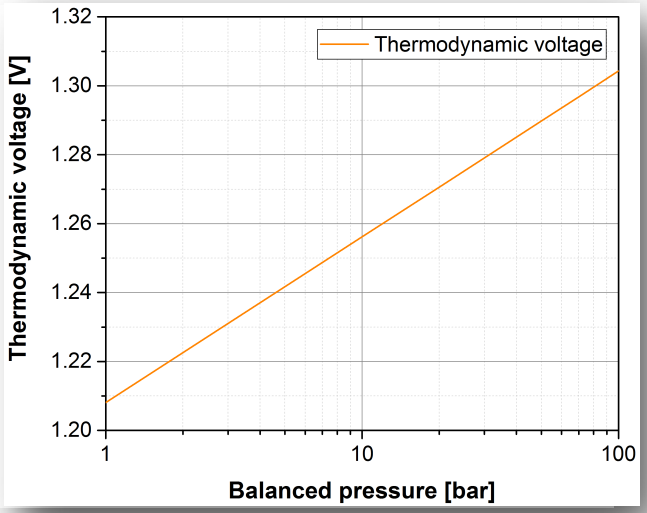
$$b = RT/\alpha F$$

$$b \approx 80\ mV$$

Thermodynamics

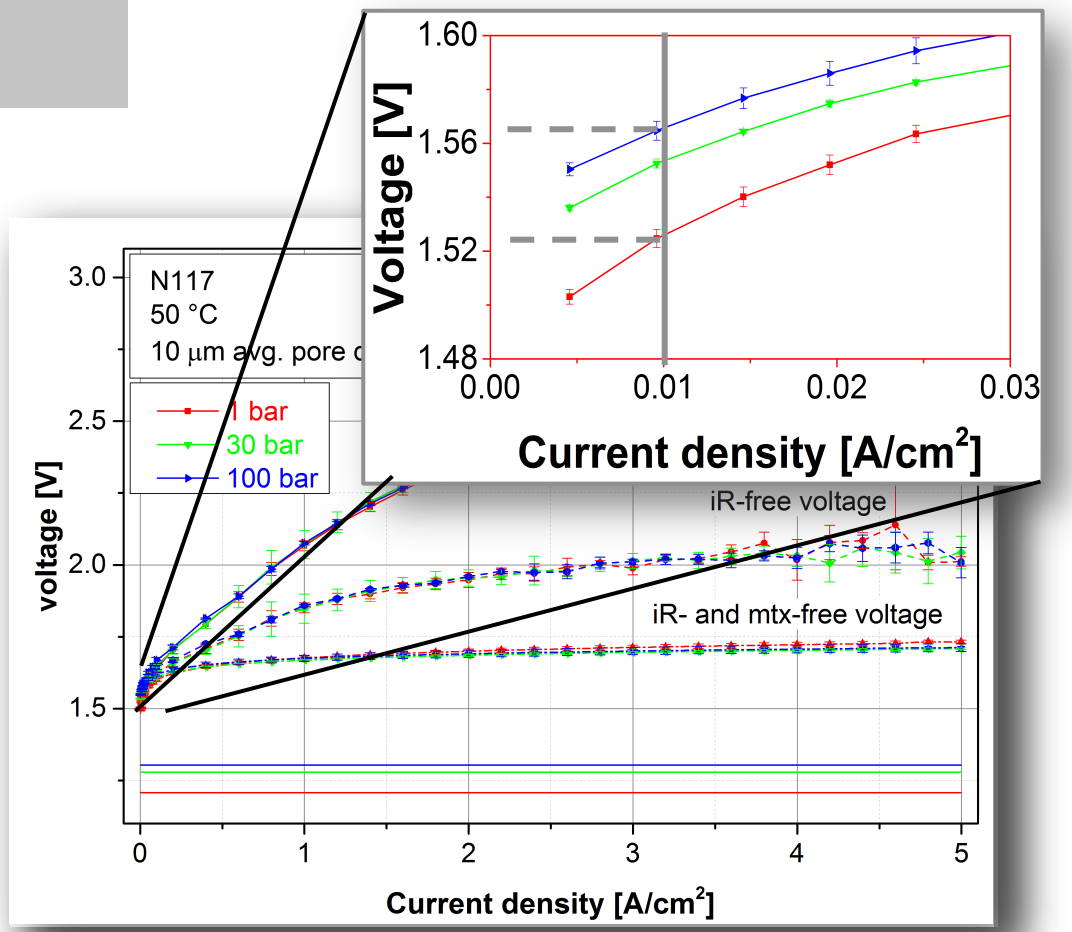
$$E_{cell} = E_0(p,T) + b * \log(j) + R * j + \eta_{mtx}$$

$$E_0(p,T) = E_0(T) + \frac{R \cdot T}{2F} \ln\left(\frac{a(H_2) \cdot \sqrt{a(O_2)}}{a(H_2O)}\right)$$



	mV per decade of pressure	
Activity of liquid water	Balanced Pressure	Only Hydrogen Pressurized
Unity (a=1)	**48 mV**	**32 mV**
Function of pressure (a=p)		

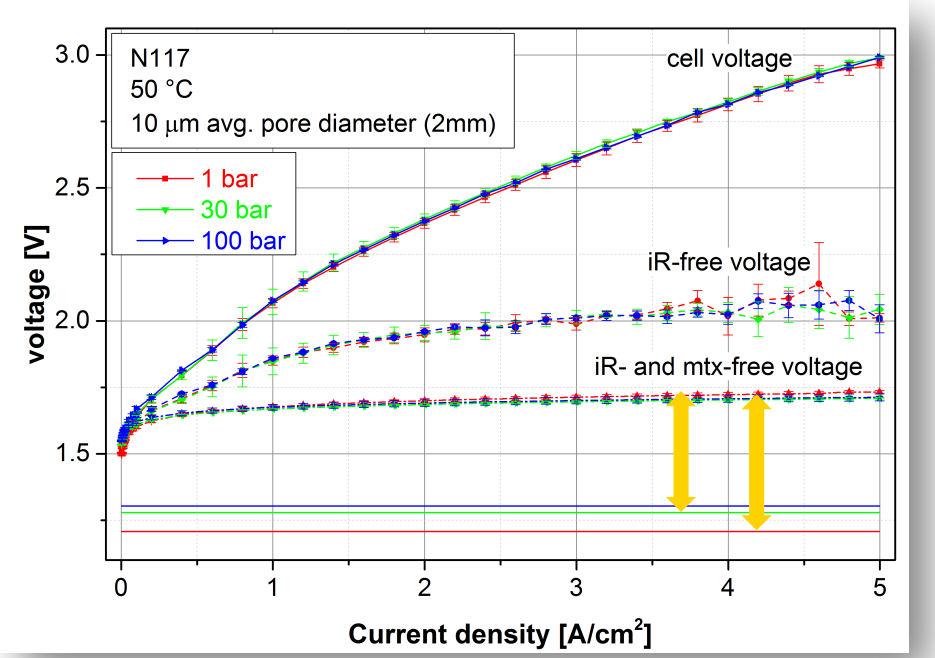
Influence of Pressure on Kinetic Overvoltage

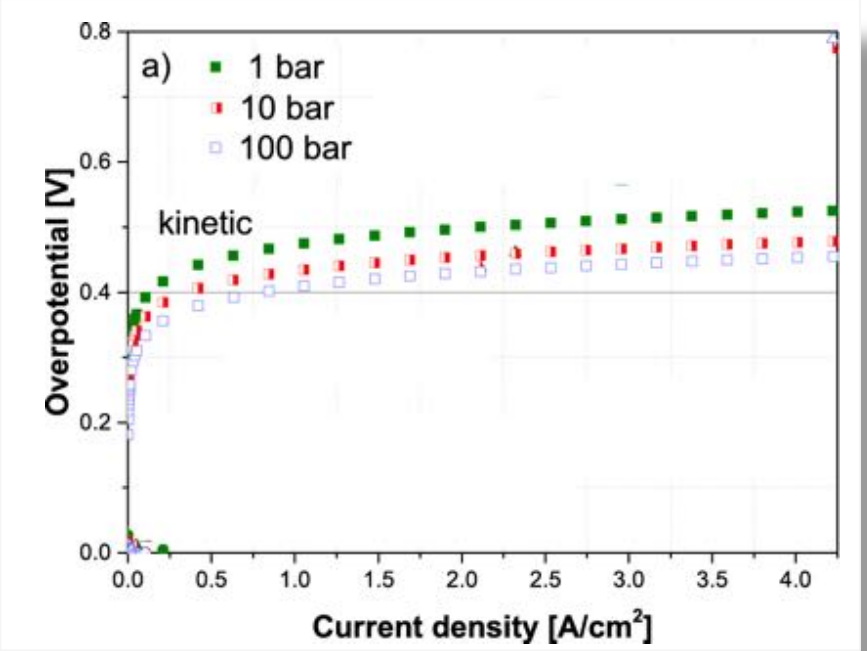


@ 10 mA/cm^2: 23 ± 2 mV/dec

	mV per decade
Activity of liquid water	Balanced Pressure
Unity (a=1)	**48 mV**
Function of pressure (a=p)	**16 mV**

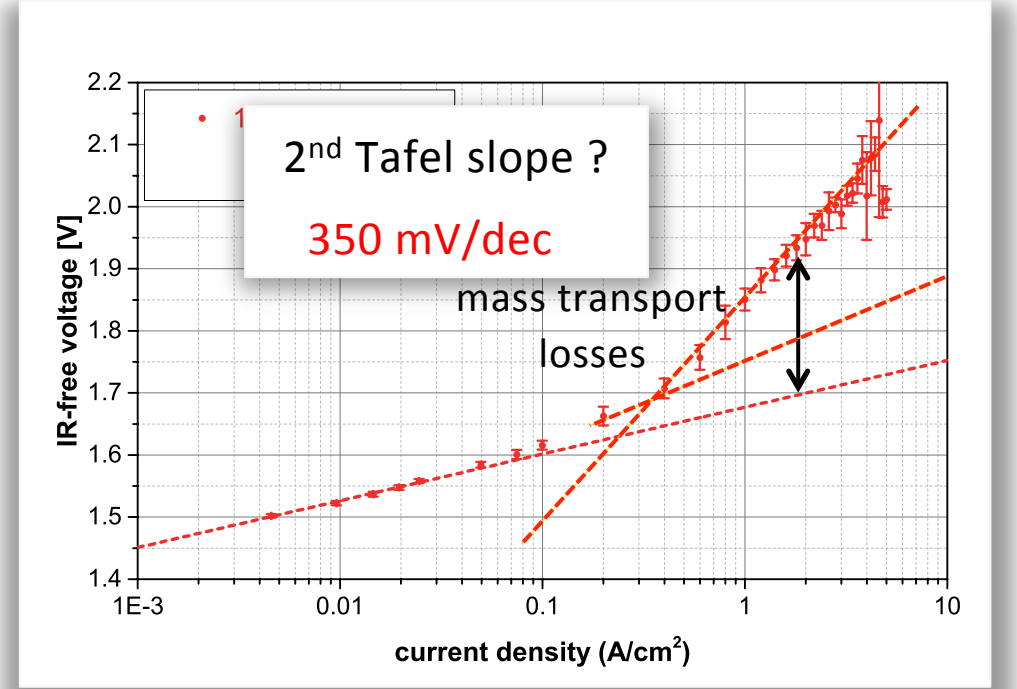
Influence of Pressure on Kinetic Overvoltage





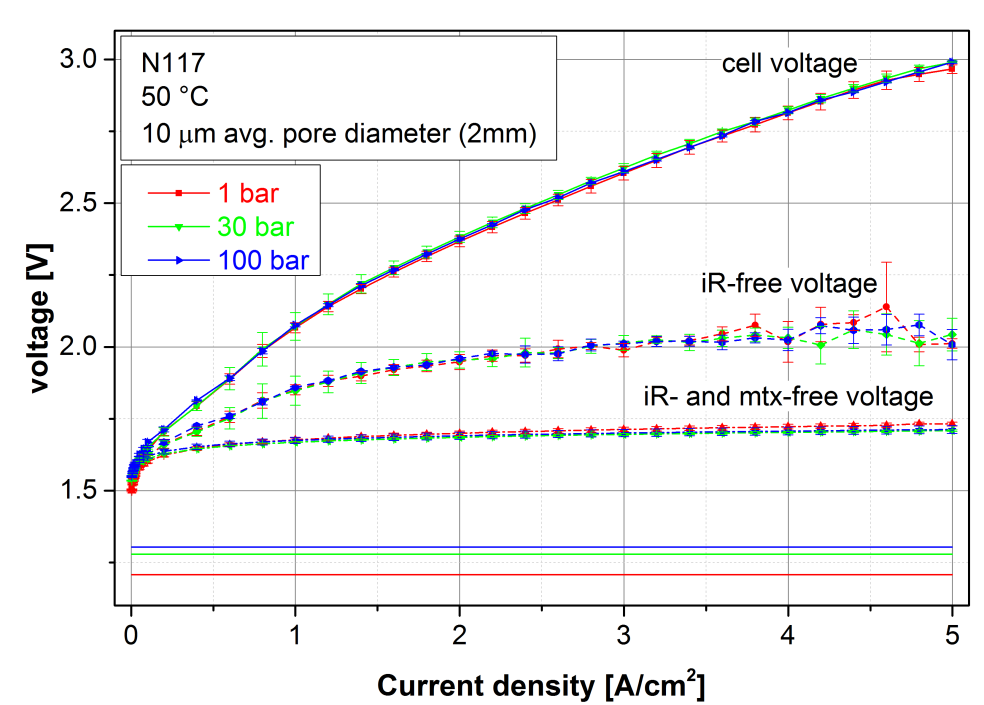
Mass Transport Losses

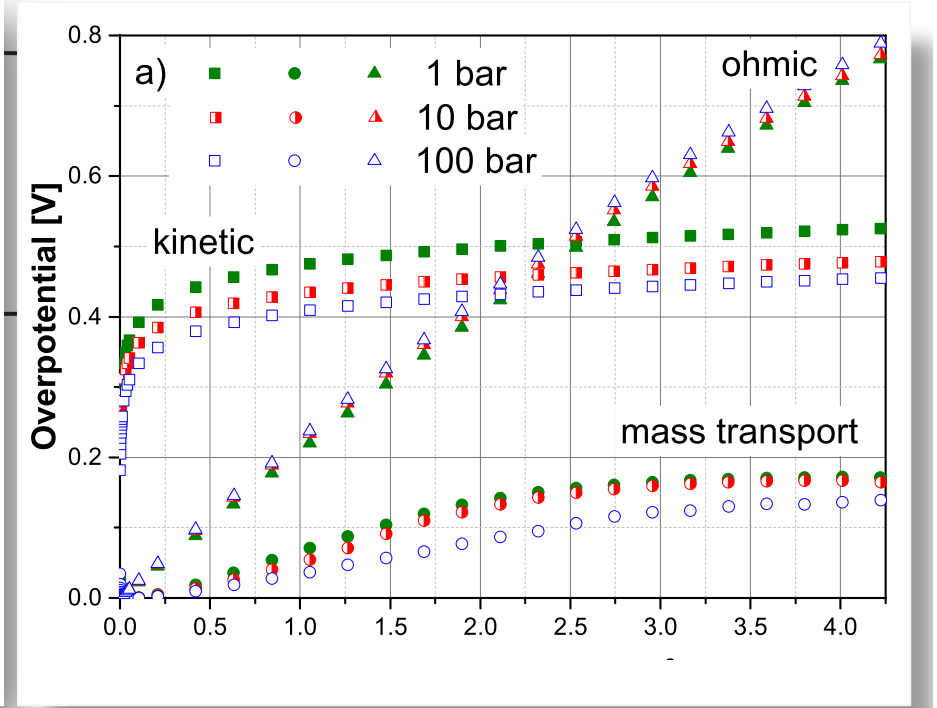
$$\eta_{mtx} = E_{cell} - E_0(p,T) - b * \log(j) - R * j$$



Loss Analysis as Function of Pressure

$$E_{cell} = E_0(p,T) + b * \log(j) + R * j + \eta_{mtx}$$



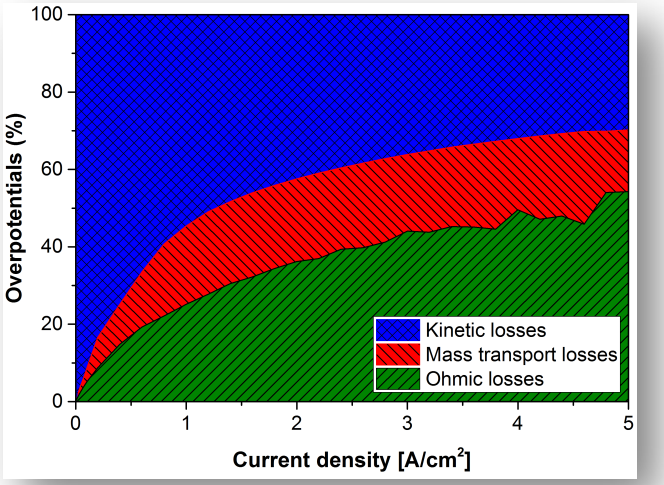


Learnt so far

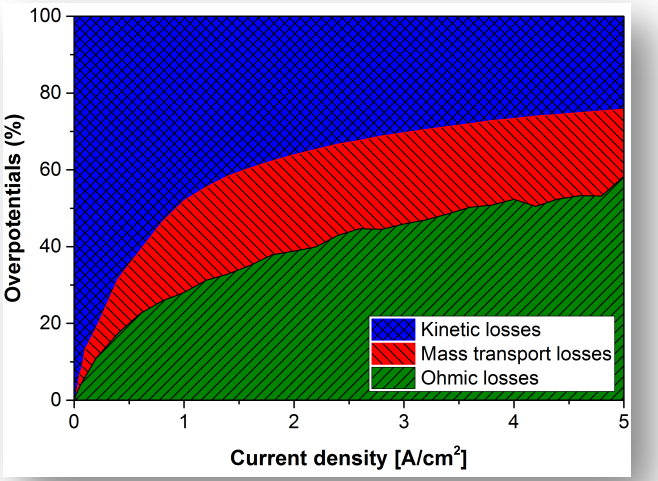
- losses unexplained in 0D-Model which could be attributed to mass transport
- kinetic losses seem to be influenced by pressure
- activity of liquid water may not be unity with increasing pressure

Relative Losses (Measured Data)

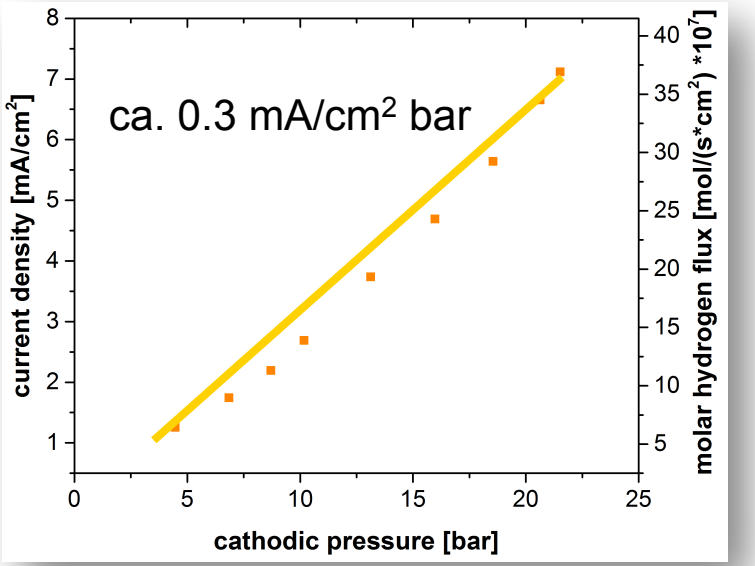
1 bar
balanced



100 bar
balanced



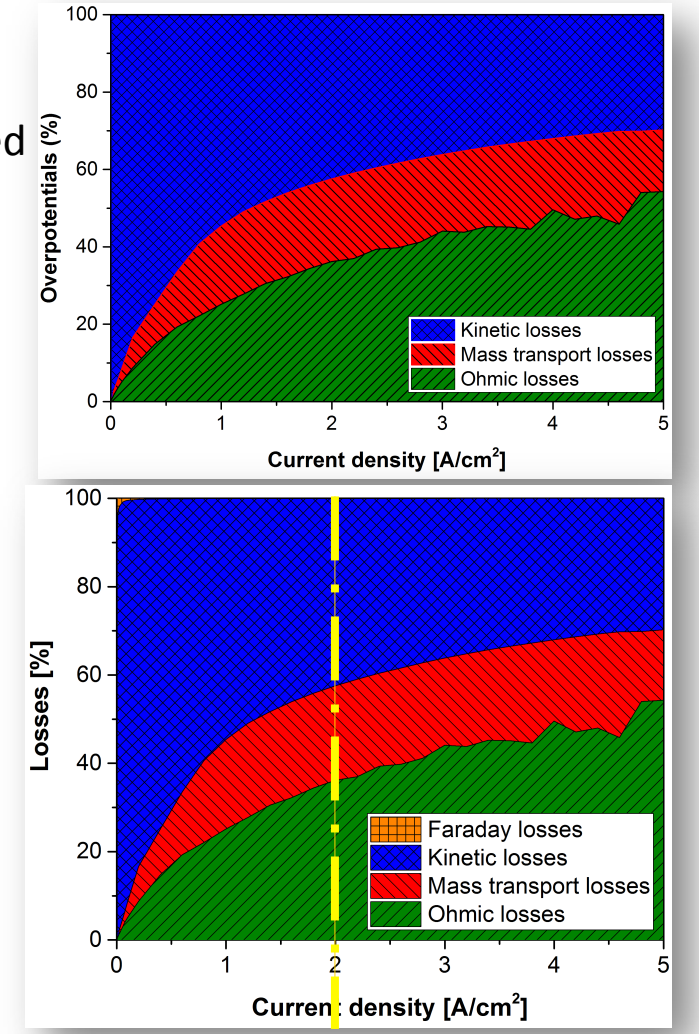
Gas Permeability



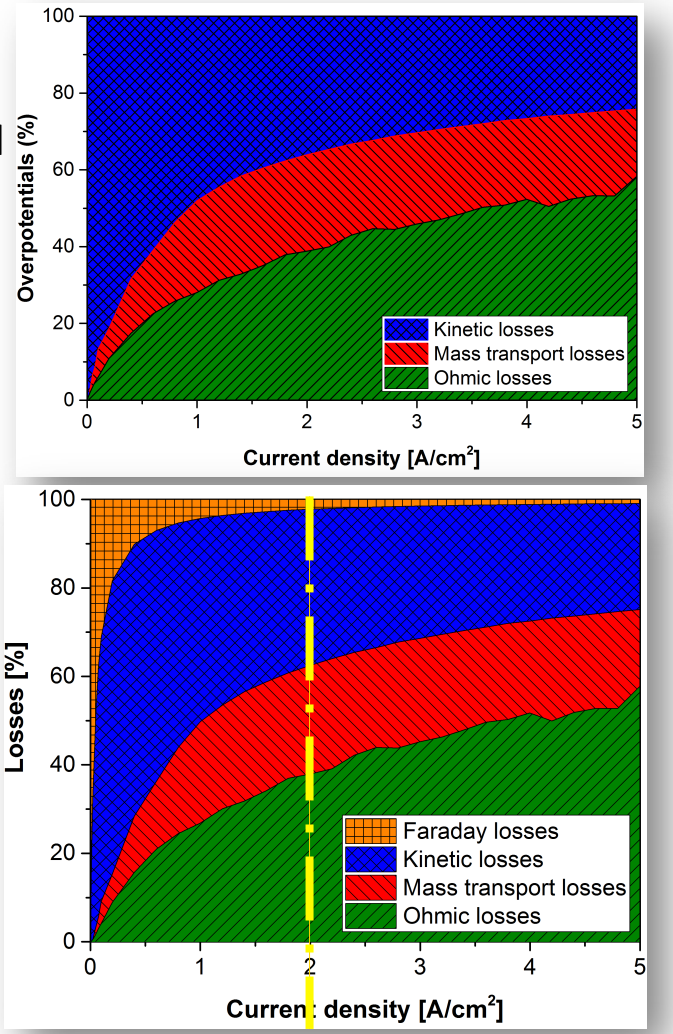
B. Bensmann, R. Hanke-Rauschenbach, K. Sundmacher, Int J Hydrogen Energy, 39 (2014) 49-53

Relative Losses (Measured Data)

1 bar
balanced



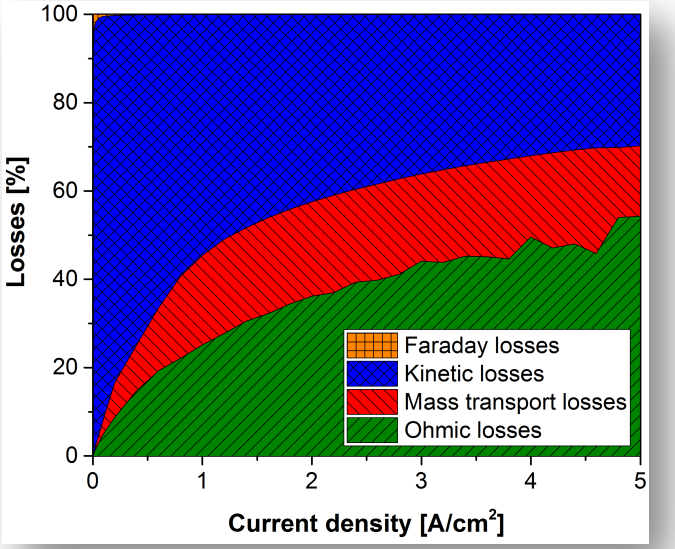
100 bar
balanced



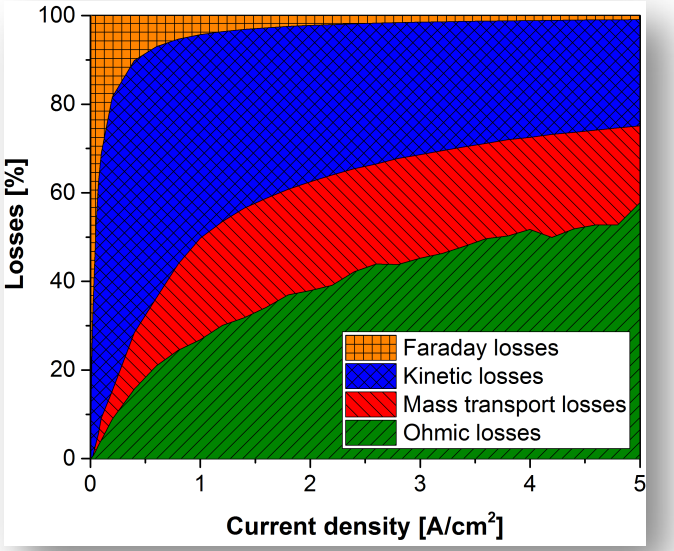
Relative Losses (Extrapol. for THIN Membrane)

1 bar
balanced

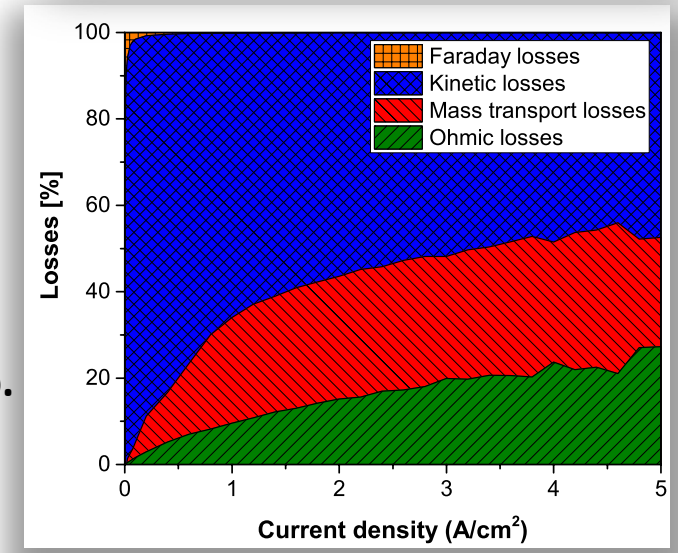
N117

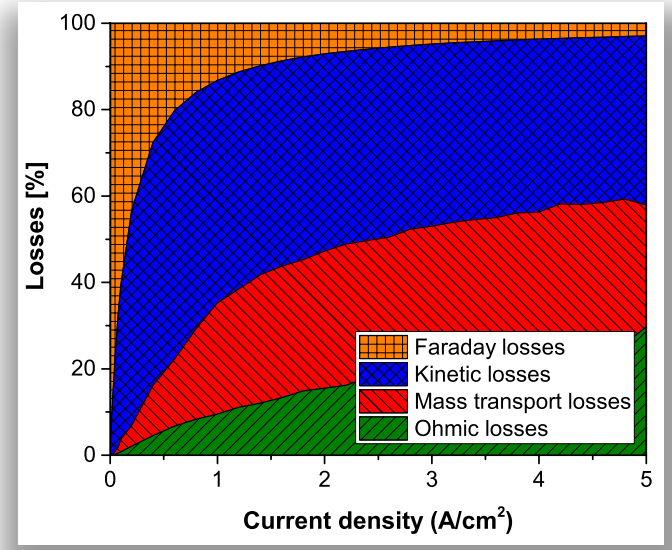


100 bar
balanced



2-mil Memb.
(calculated)





Summary

- loss mechanisms in PEEC investigated in differential cell
- pressure dependence of thermodynamics and kinetics not trivial
- additional (transport) loss may be significant
- more work required

Wir schaffen Wissen – heute für morgen

- Funding:

  Swiss Office of Energy

  Schweizerische Eidgenossenschaft
  Confédération suisse
  Confederazione Svizzera
  Confederaziun svizra

  Bundesamt für Energie BFE

- Martin Amman, Thomas Gloor