A3PS

Rethinking Propulsion.

High Temperature Proton Exchange Membrane Fuel Cells – The impact of fuel contaminants and temperature on fuel cell performance

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Alternative Propulsion Systems and Energy Carriers

Austrian, European and global R&D- and demonstration projects, research institutions and funding programs

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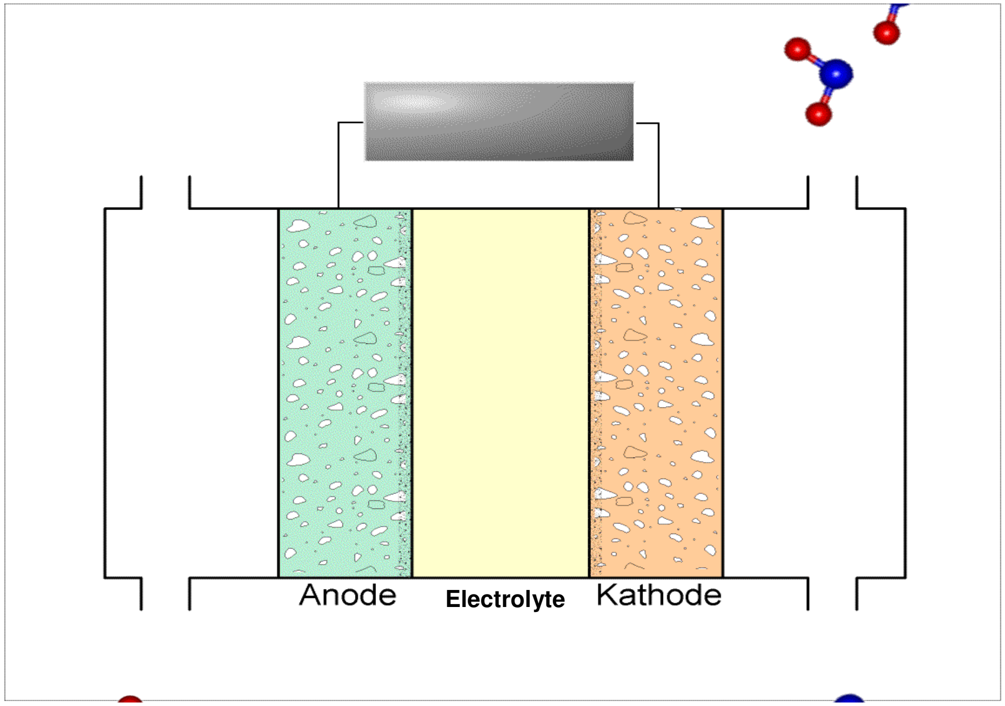
in cooperation with

bmvit

- Principle of Fuel Cell Operation
- HT-PEM Fuel Cells
- Segmented HT-PEM Fuel Cell
- Fuel Contaminants
- Results of Measurements
- Summary

Principle



● **Hydrogen**
● **Oxygen**

Anode: $H_2 \rightarrow 2\,H^+ + 2\,e^-$
Cathode: $2\,H^+ + 0{,}5\,O_2 + 2\,e^- \rightarrow H_2O$

Sum: $H_2 + 0{,}5\,O_2 \rightarrow H_2O$

- HTPEM fuel cells are based on the use of polybenzimidazole (PBI) membranes doped with phosphoric acid for proton conduction.
- operating temperature range of 100-180ºC
- Higher tolerance to impurities such as CO
- Simple system designs since the fuel cell can be air cooled
- Increased reaction kinetics, improving performance

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Advantages of HT-Operation

NT-PEM: 80℃ <> HT-PEM: 160℃-200℃

- Mass transport properties in the solid polymer electrolyte (diffusion coefficient and solubility of oxygen)
- Increase of proton conductivity of the membrane
- Improvement of electrocatalytic properties of the catalyst - polymer interface (exchange current density)
- Enhancement of rates of electrochemical kinetics
- Enhancement of gas transport in the electrode layers
- no liquid water present >100℃
- Simplified water management and cooling
- Recovery of useful waste heat
- Utilization of lower quality reformed hydrogen
- Reduction in the use of expensive catalysts
- Minimization of problems related to electrode flooding

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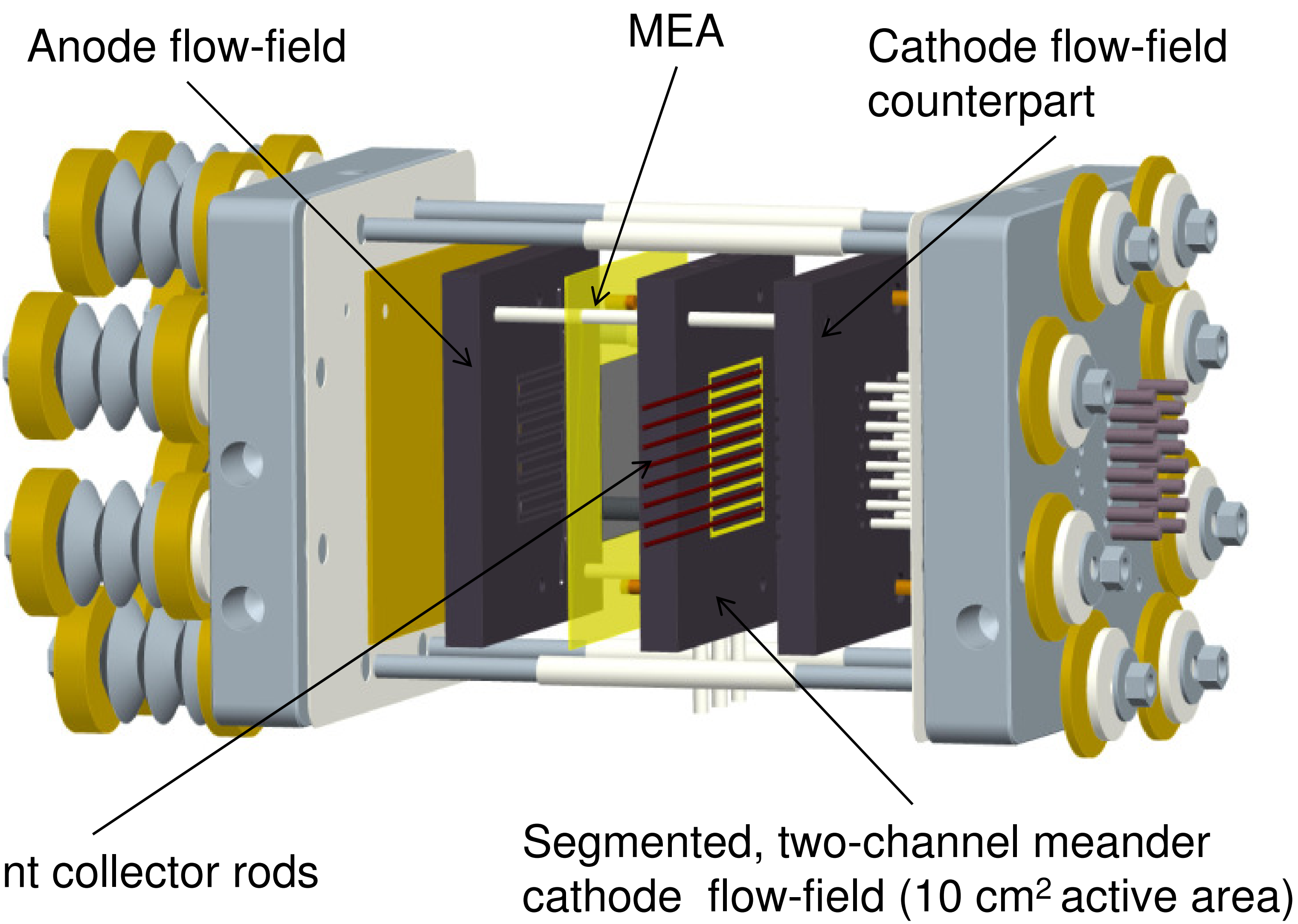
Segmented CDL HT-PEM Fuel Cell



Anode flow-field

MEA

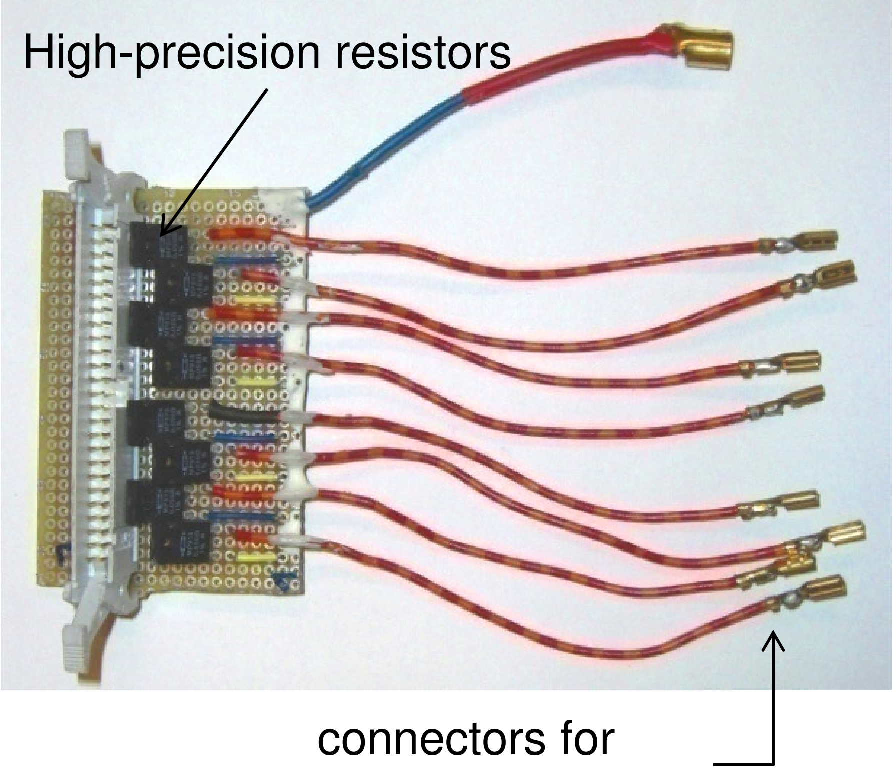
Cathode flow-field counterpart

8 current collector rods

Segmented, two-channel meander cathode flow-field (10 cm^2 active area)

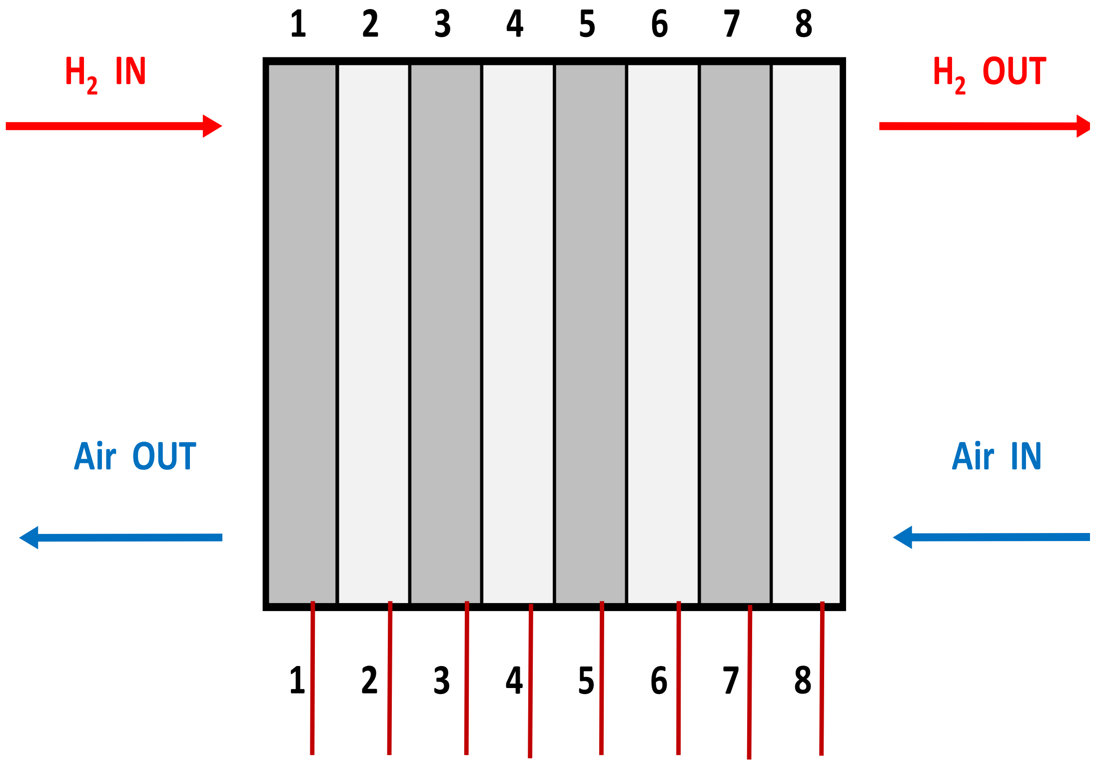
Current Distribution Measurements

- Individual segment current output is measured via the voltage drop along the high-precision resistors of the measurement module.



High-precision resistors

connectors for current collector rods



current collector rods

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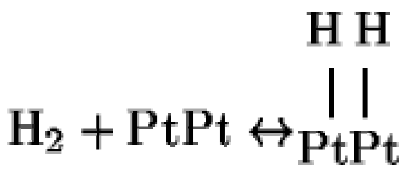
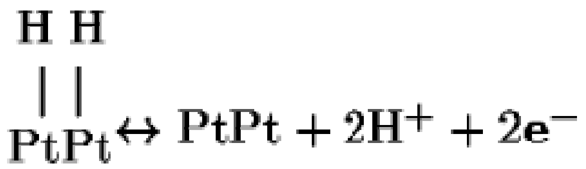
Effects of Carbon Monoxide (CO)

- Pure hydrogen feed
  - Dissociative chemisorption of H_2
  - Electrochemical oxidation of Pt-H

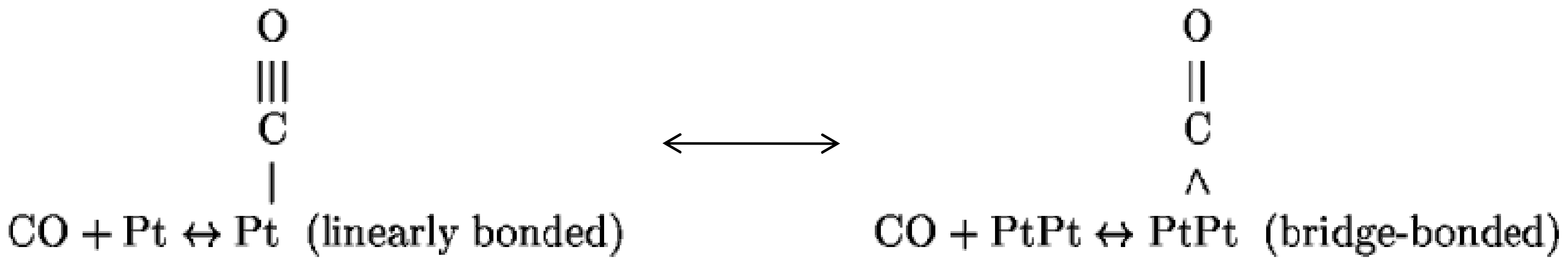


$$\mathrm{H_2 + PtPt \leftrightarrow \overset{H\;H}{\overset{|\;|}{PtPt}}}$$



$$\mathrm{\overset{H\;H}{\overset{|\;|}{PtPt}} \leftrightarrow PtPt + 2H^+ + 2e^-}$$

- CO containing feed
  - 2 bonding modes for CO adsorption

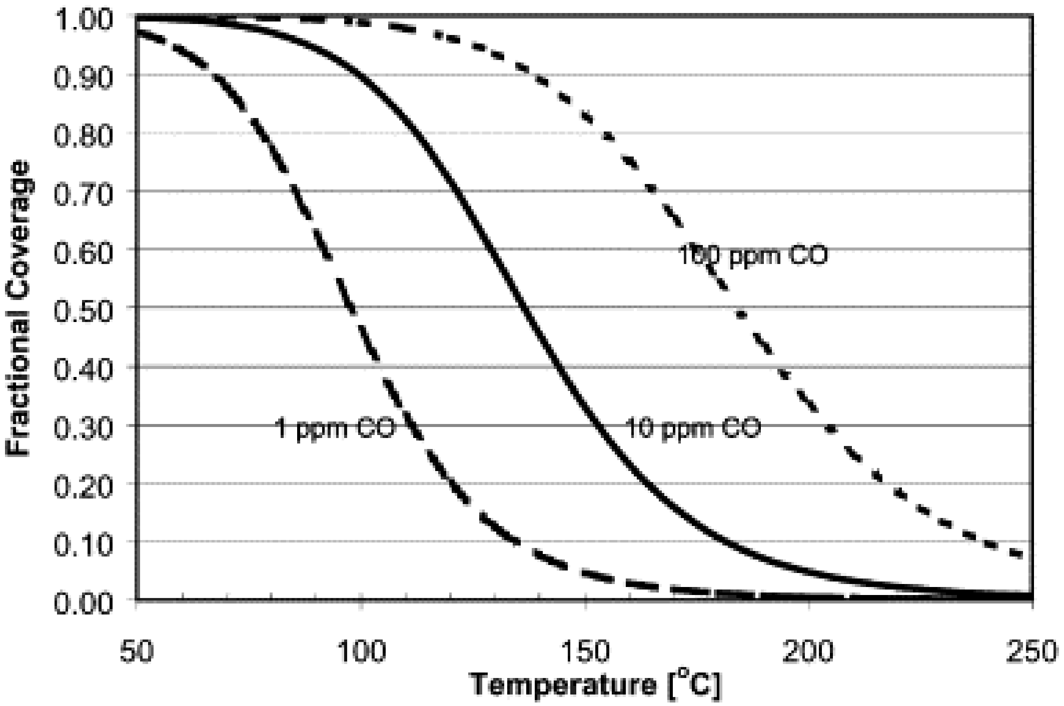


$$\mathrm{CO + Pt \leftrightarrow \overset{O}{\overset{|||}{\overset{C}{\overset{|}{Pt}}}}\ \ (linearly\ bonded)} \quad \longleftrightarrow \quad \mathrm{CO + PtPt \leftrightarrow \overset{O}{\overset{||}{\overset{C}{\overset{\wedge}{PtPt}}}}\ \ (bridge\text{-}bonded)}$$

Effects of Carbon Monoxide (CO)

- Hydrogen adsorption is less exothermal than CO adsorption → H_2 adsorption is favored at higher temperature levels
- Fractional coverage Θ as indicator of blockage

$$\Theta_{CO} = \frac{N_{CO}^{Pt}}{N^{Pt}}$$



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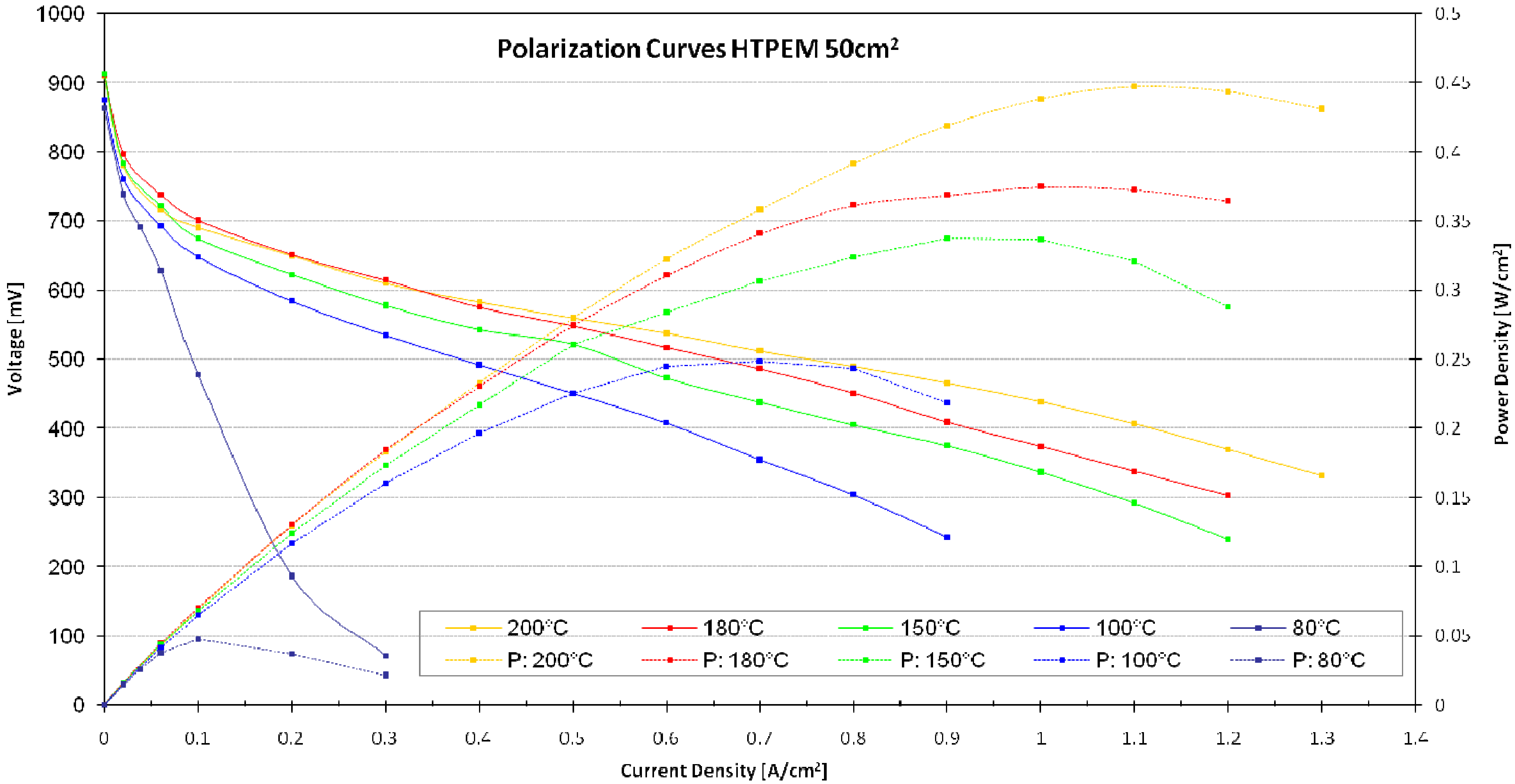
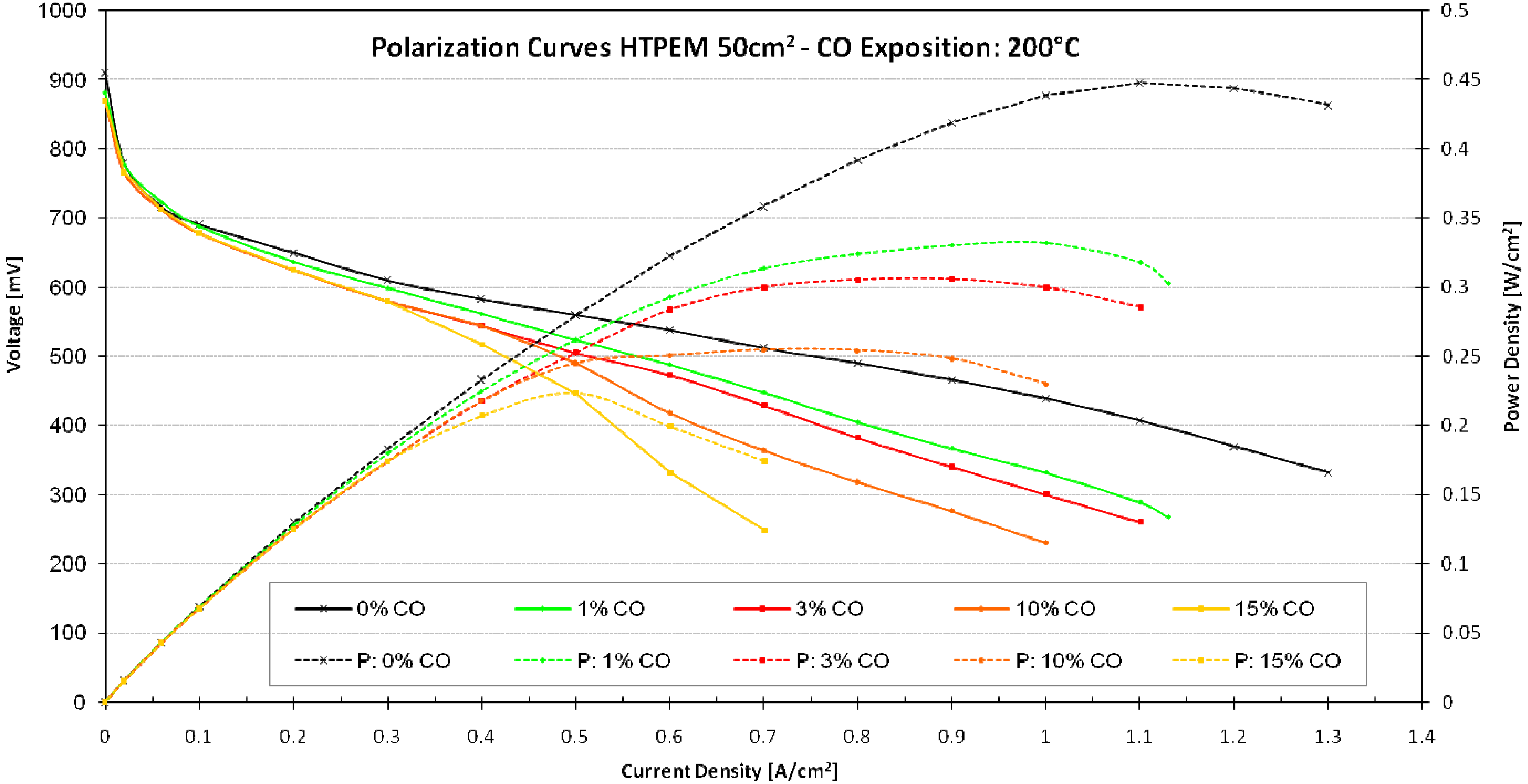
Effects of Temperature

- i-V and i-P curves; 80℃-200℃



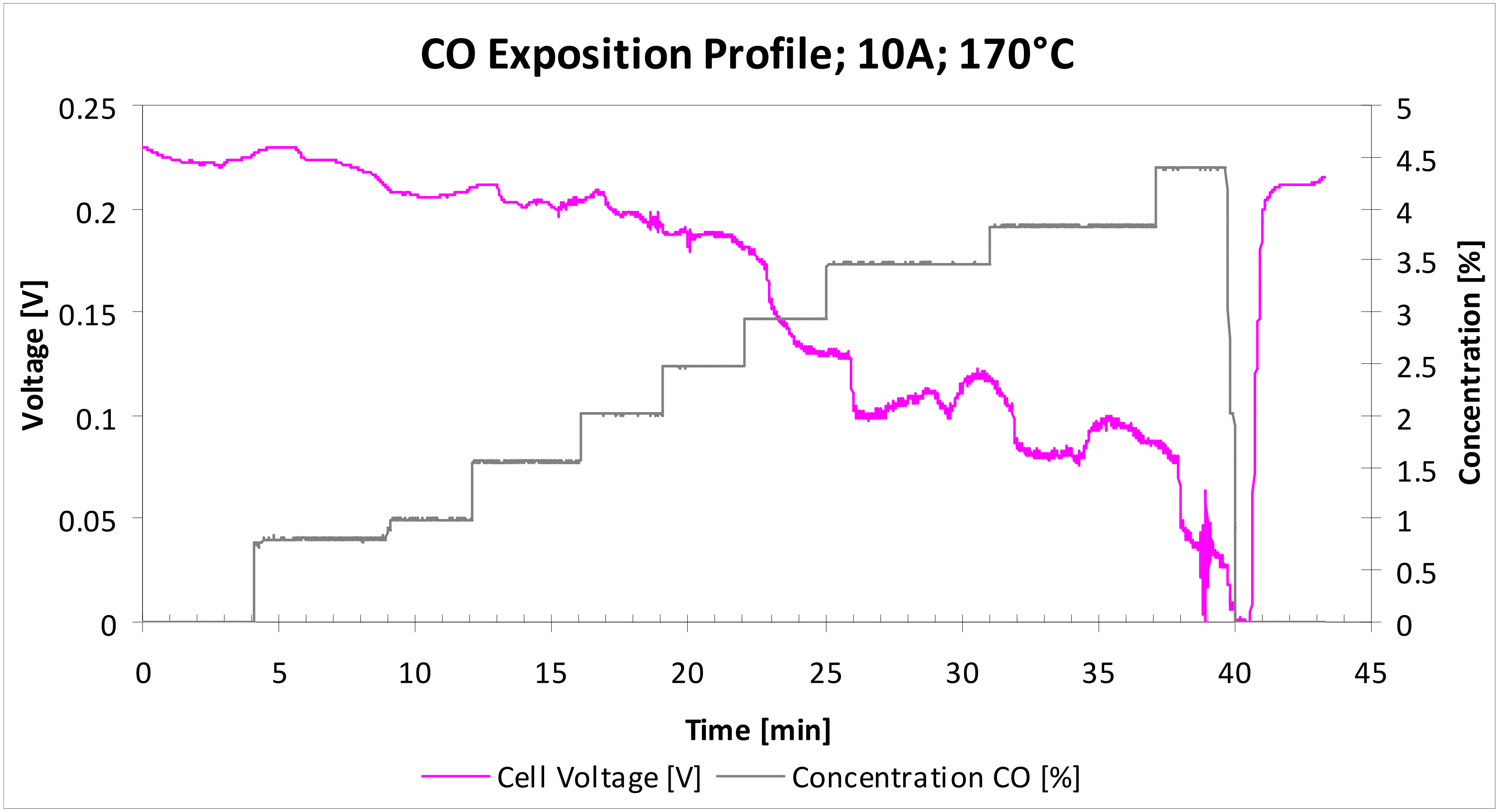
Effects of Carbon Monoxide (CO)

- i-V and i-P curves; 200°C; 0-15% CO



Effects of Carbon Monoxide (CO)

- CO concentration profile for current distribution measurements



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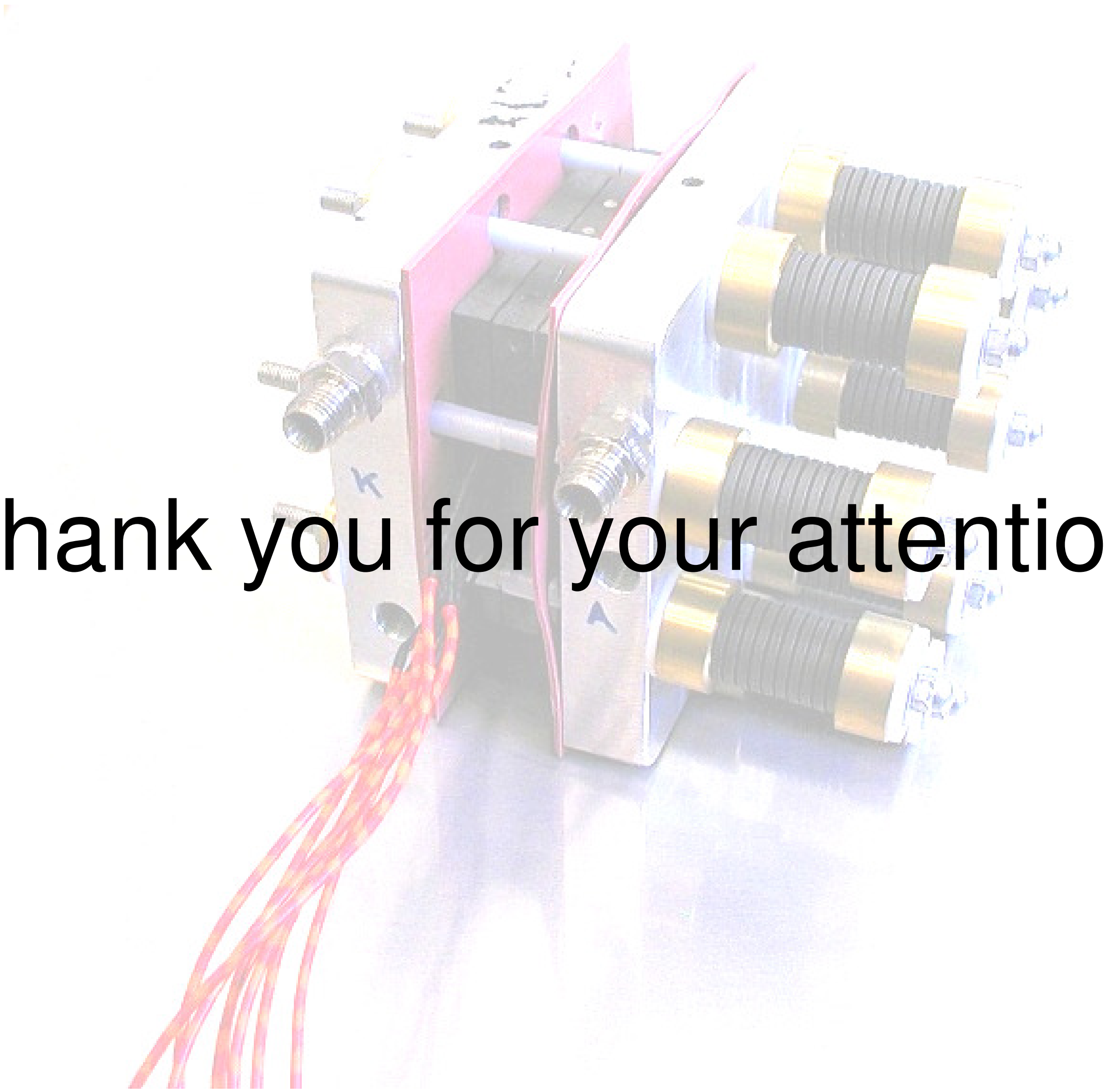
Summary - Temperature

- Linear i-V-T and i-P-T correlation
- Two different slope regions
- Increasing the operating temperature
    - Enhancement of mass transport
    - Increase of reaction rates
    - Decrease of membrane resistance
    - Decrease of kinetic resistances

Summary – Carbon Monoxide (CO)

- Increase of membrane resistance R_{Ω} and kinetic resistances $R_{fA}+R_{fC}$ with increasing CO concentration
- Decrease of overall current due to increasing membrane and kinetic resistances
- Change of current distribution with increasing CO concentration
  - Increase of Θ_{CO} in last segments



Thank you for your attention!