Investigation on porous transport layers for PEM electrolysers

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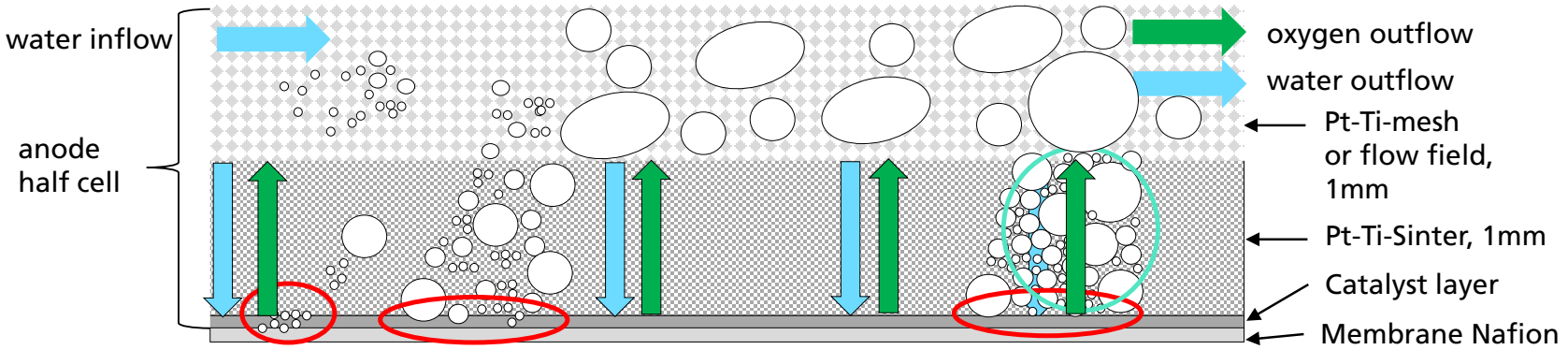
- Comparison of in-situ and ex-situ measurements
- Conclusion

Motivation
Increase hydrogen production

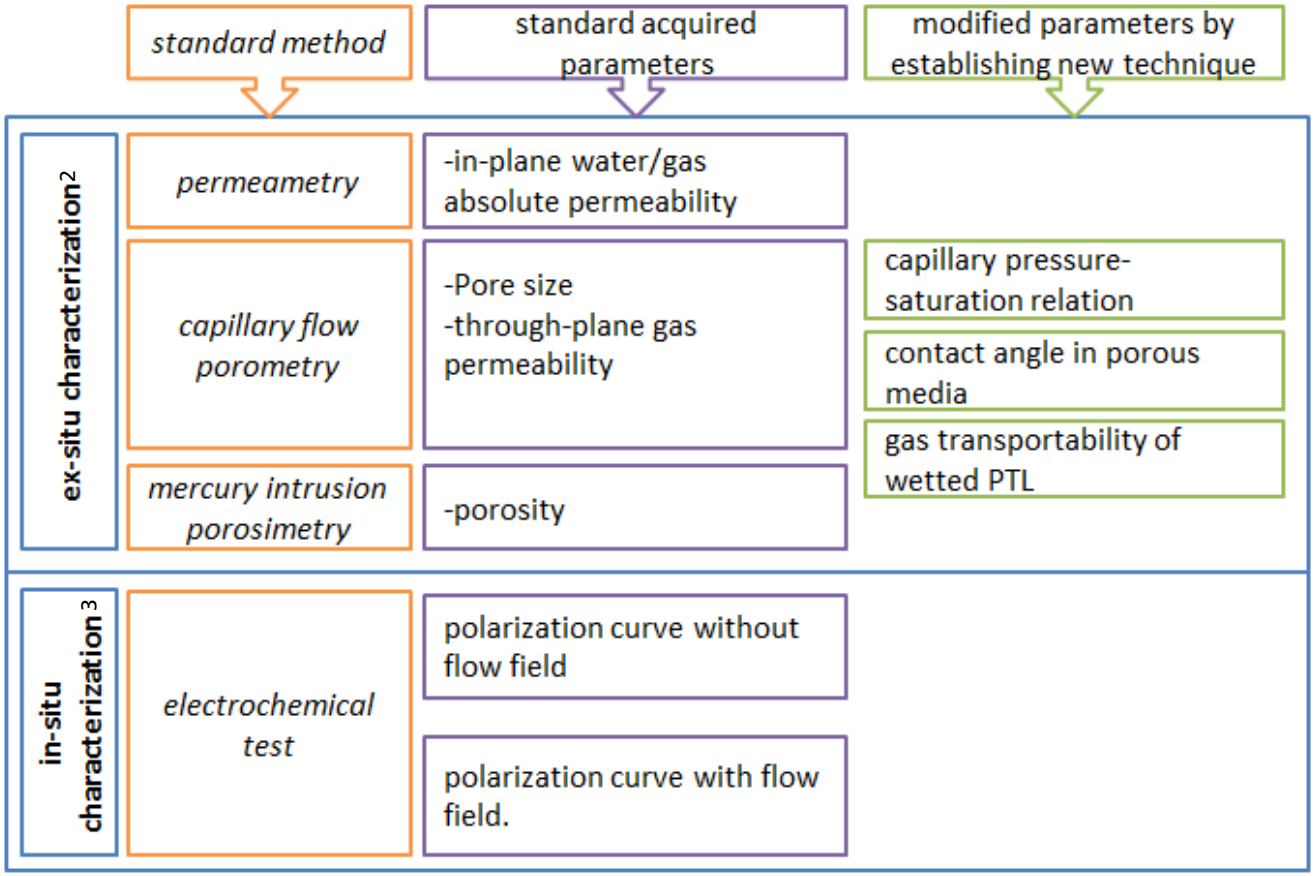
- Increase current density and stack size to decrease footprint and costs
- Mass transport limitation (MTL) is likely to occur at high current densities
- Porous transport layers (PTL) have to transport water, gas and current and are thereby influencing the performance of electrolysis cells
- PTL is also a cost driver[1]



[1] Smolinka et al., *21st World of Hydrogen Energy Conference*, Zaragoza, 2016

Methodology and experimental setup

Methodology

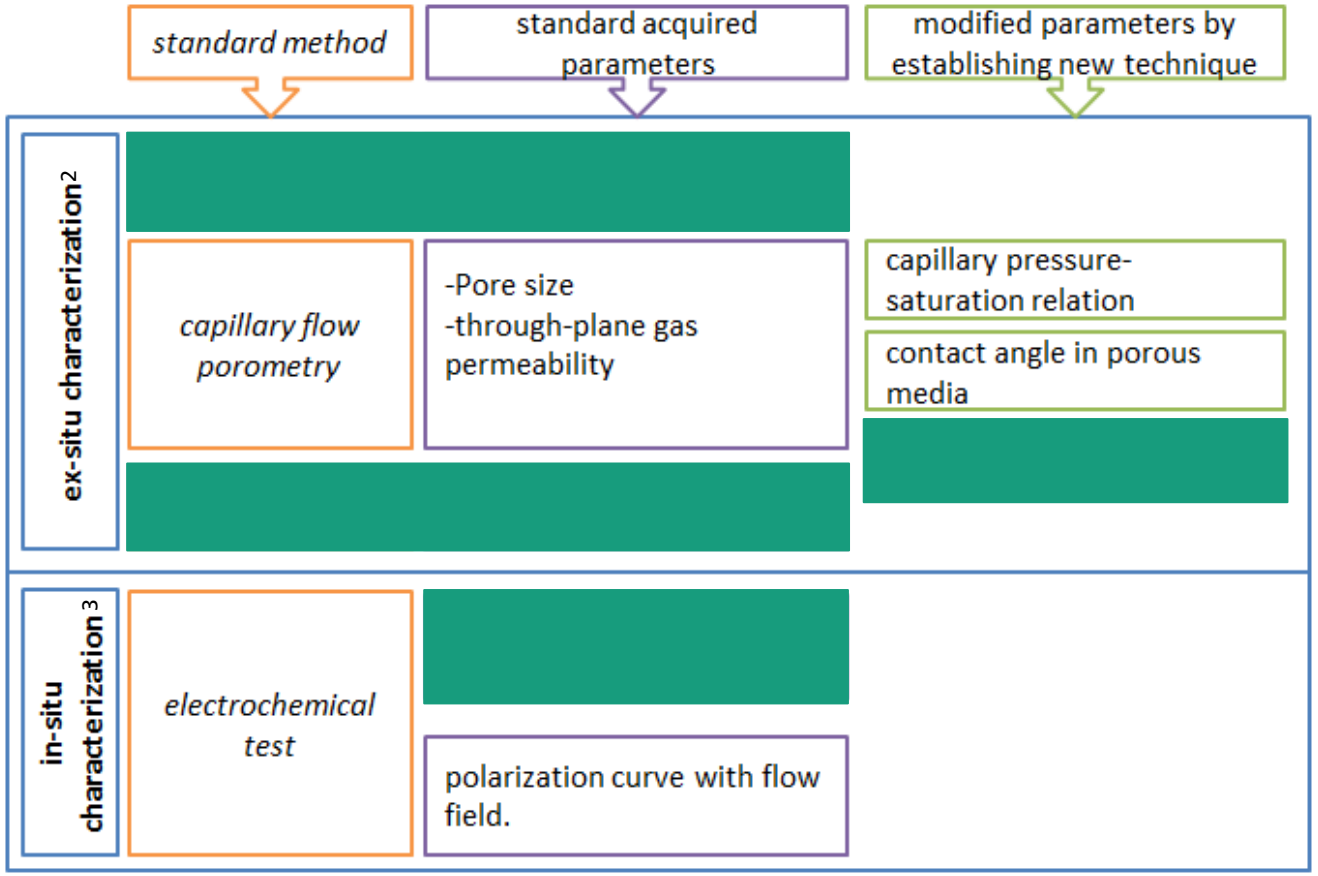


[2] Bromberger et al., *International Journal of Hydrogen Energy,* to be published

[3] Lickert et al., *International Journal of Hydrogen Energy,* to be published

Methodology and experimental setup

Methodology



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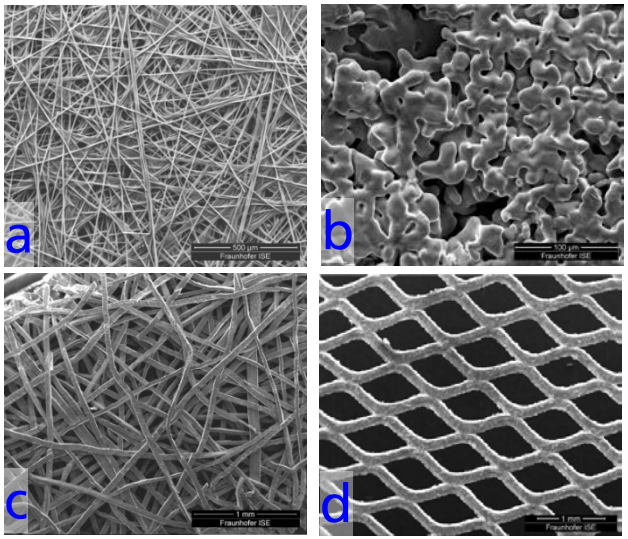
Methodology and experimental setup
Characterised materials

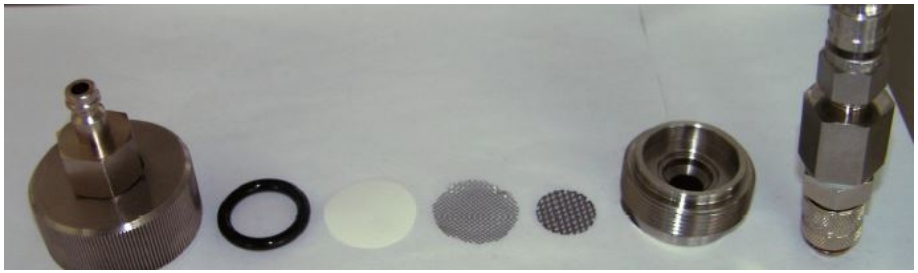
- PTL materials
  - Cathode: Ti powder sinter (b)
  - Anode (1): Ti powder sinter (b)
  - Anode (2): Ti fiber sinter (ac) + Ti mesh (d)



- Test protocol
  - Conditioning procedure for the catalyst coated membrane
  - Polarisation curves (0.1 - 5 A/cm^2, 3 min for each operation point)
    - *T*: 40, **60** und **80** °C
    - *p*: **1**, 2, 5, 10 und **30** barg (equalized pressure)
    - *Q* (H_2O flow): 0.2, 0.3, 0.4, **0.5**, 0.6, 0.8 l/min

Methodology and experimental setup
Ex-situ characterization by capillary flow porometry

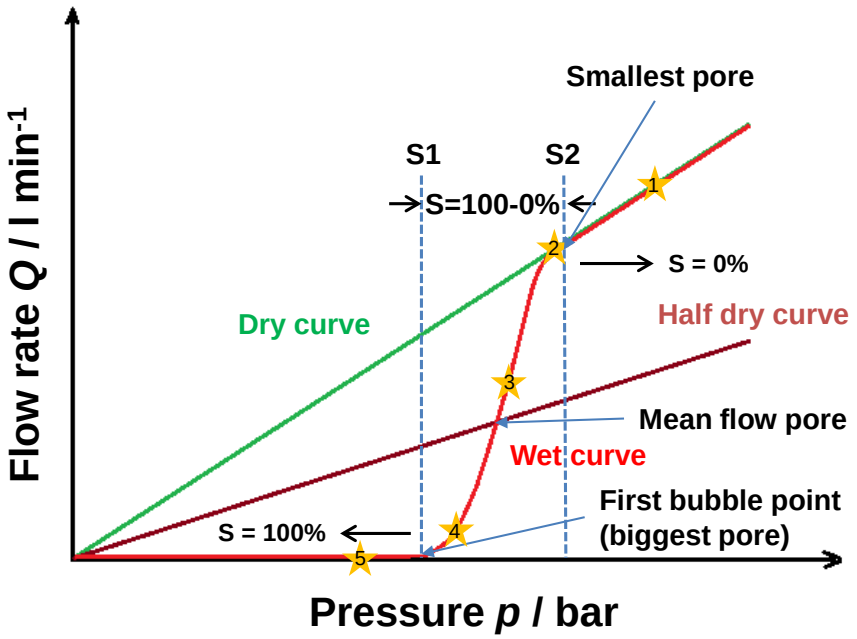
- Porolux™ 1000 from Porometer
- Standard method to acquire pore sizes of through pores
  - Largest, smallest pore diameter
  - Mean flow pore diameter
  - Through-plane gas permeability

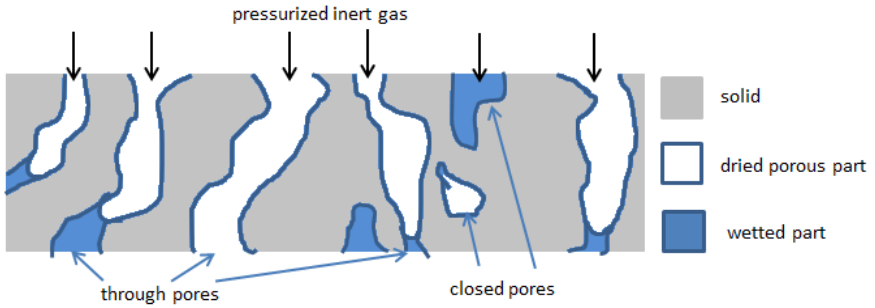


Development of new characterisation methods

New method to receive capillary pressure vs saturation

- Porous sample is saturated using a liquid with very high wettability (POREFIL™)
- Pressure and flow are measured for each sample
- Standard procedure is run several times with decreasing target pressure





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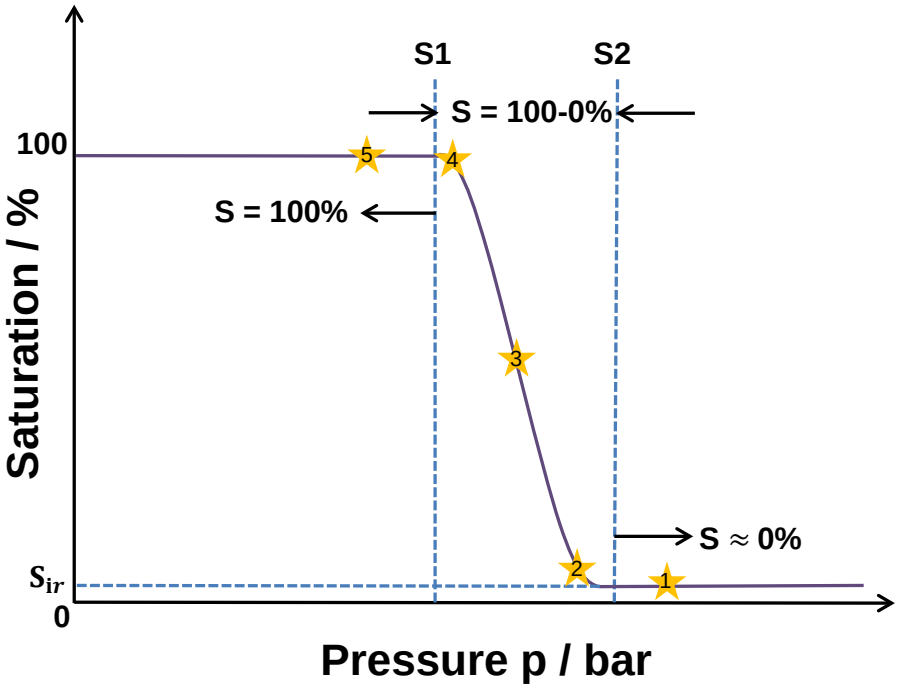
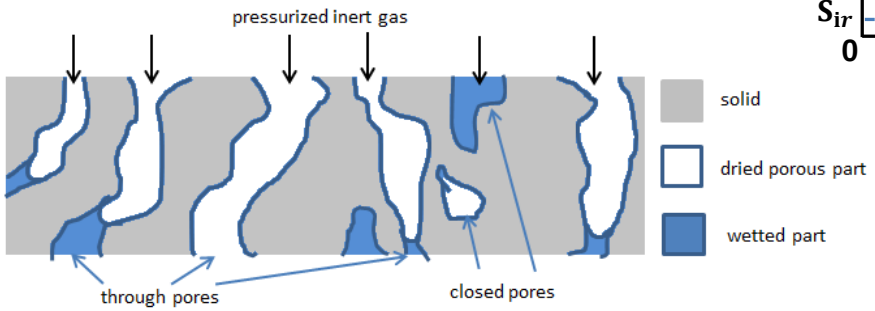
Development of new characterisation methods

New method to receive capillary pressure vs saturation

- Standard procedure is run several times with decreasing target pressure
- After each run mass of remaining liquid in sample is measured
- Capillary pressure vs saturation relation is received





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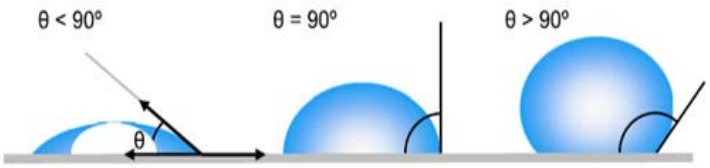
Development of new characterisation methods
Determination of contact angle in porous media

- CFP is used to determine contact angle using two different liquids:
- high wetting POREFIL™ (γ_p = 16 mN m^{-1}) & deionized water (γ_w = 72 mN m^{-1})
- For both liquids characteristic pore size of PTL must be the same
- Contact angle for highly wetting liquid POREFIL™ is 0°
- Equating Washburn's equations result in an equation for water contact angle



$$d_{Ww} = d_{Pw}$$

$$\frac{4 \cdot \gamma_{Pw} \cdot cos\ \theta_{Pw}}{p_{Pw}} = \frac{4 \cdot \gamma_{Ww} \cdot cos\ \theta_{Ww}}{p_{Ww}}$$

$$\boldsymbol{\theta_{Ww} = cos^{-1}\left[\frac{\gamma_{Pw} \cdot p_{Ww}}{\gamma_{Ww} \cdot p_{Pw}}\right]}$$

p: applied pressure d: pore diameter
B: capillary constant γ: surface tension
θ: contact angle

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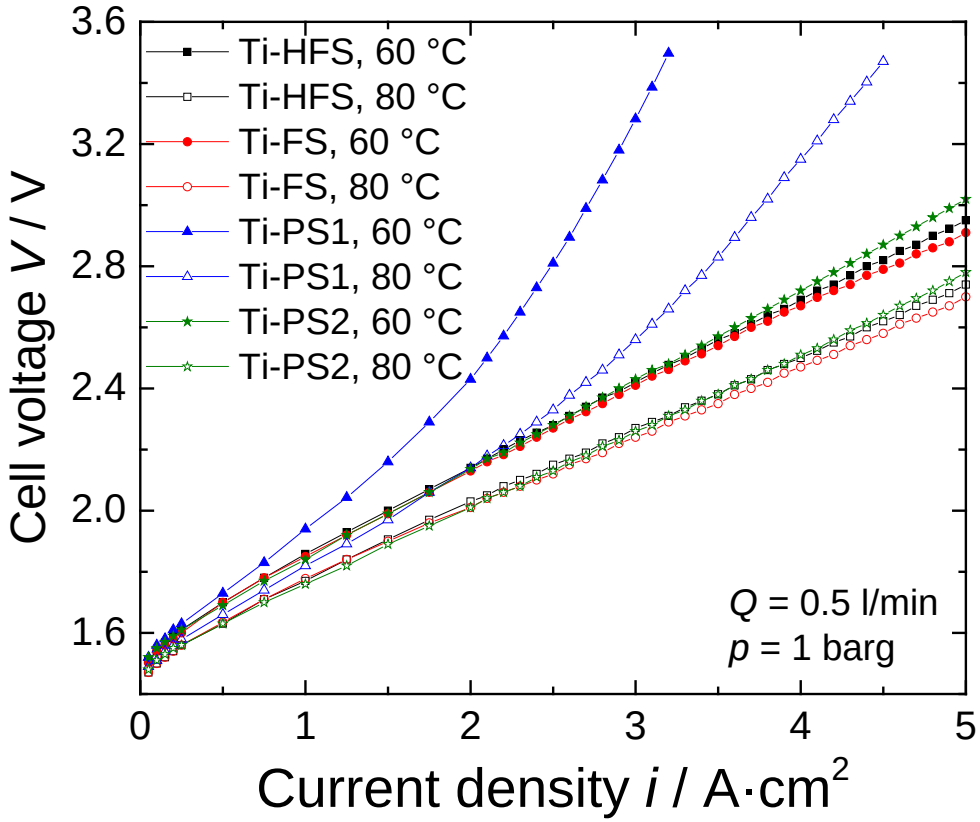
Comparison of in-situ and ex-situ measurements
Polarisation curves for different PTLs

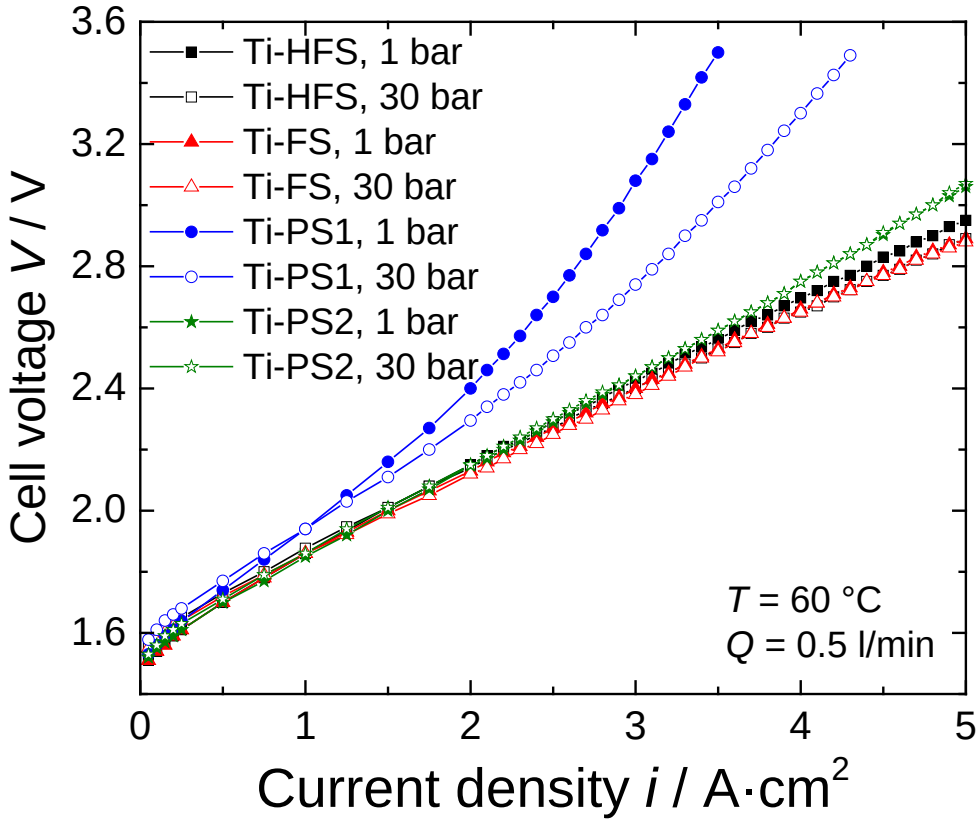
- Higher temperature leads to reduced voltage
- Mass transport limitation occurs for one PTL



Comparison of in-situ and ex-situ measurements

Polarisation curves for different PTLs

- Higher pressure decreases mass transport limitation effects
- Reduced MTL is probably due to small gas bubbles



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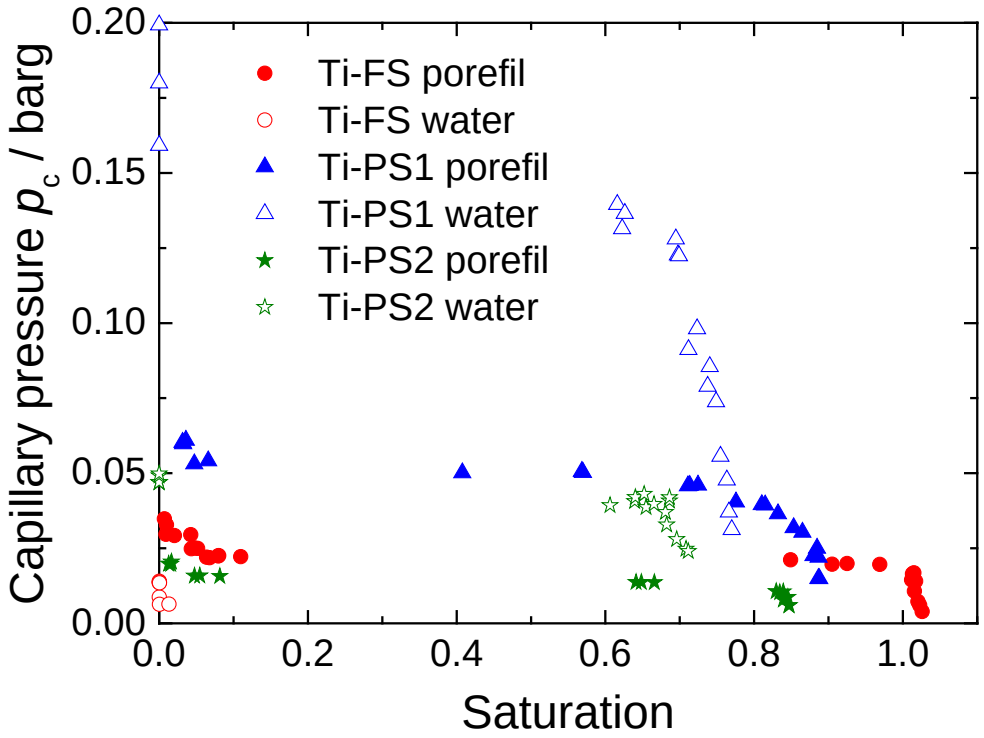
Comparison of in-situ and ex-situ measurements

New method to receive capillary pressure vs saturation

- Capillary pressure is dependent on PTL morphology and wetting liquid
- PTL with higher capillary pressure tend to have higher MTL @ given *i*
- Not all samples reach 100% liquid saturation using deionized water



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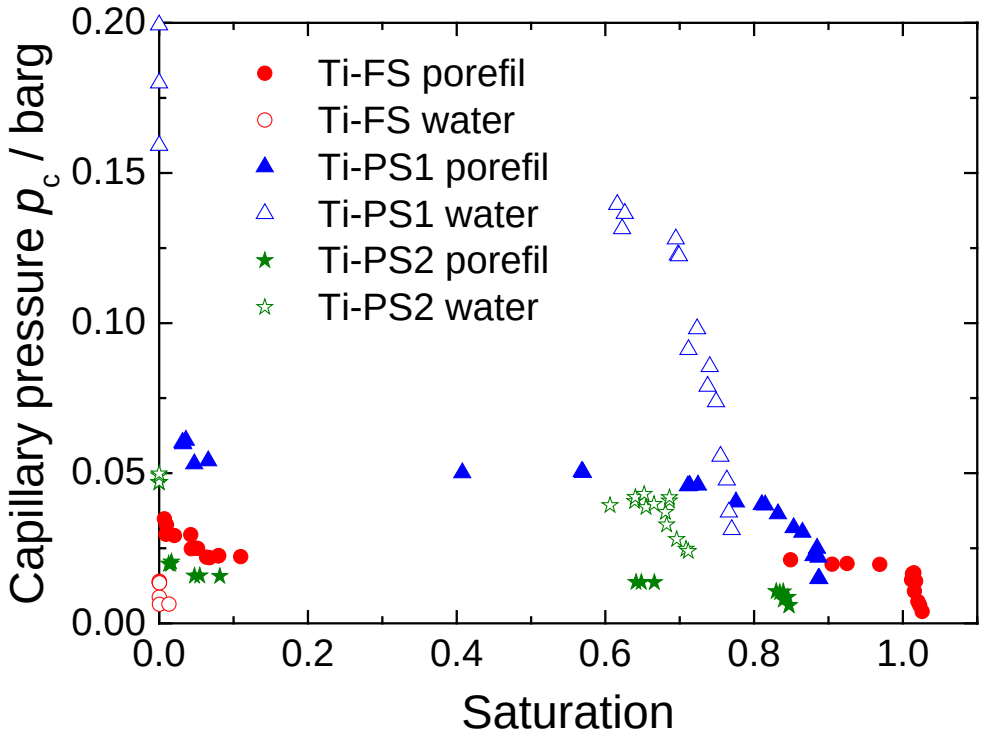
Comparison of in-situ and ex-situ measurements

New method to receive capillary pressure vs saturation

- Capillary pressure is dependent on PTL morphology and wetting liquid
- PTL with higher capillary pressure tend to have higher MTL @ given *i*
- Not all samples reach 100% liquid saturation using deionized water → higher contact angle



PTL	Ti-FS	Ti-PS1	Ti-PS2
contact angle	87.8°	48.7°	55.9°

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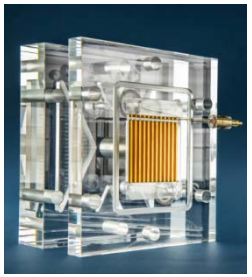
Conclusion

- New method that grants access to capillary pressure vs. saturation has been developed
- New method that grants access to intrinsic mean contact angle in porous transport layers
- Porous transport layers can lead to mass transport limitation effects depending on the operation point
- Mass transport limitation dependents on capillary pressure of PTL and on operation parameter

Acknowledgements



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Thanks a lot for your kind attention!

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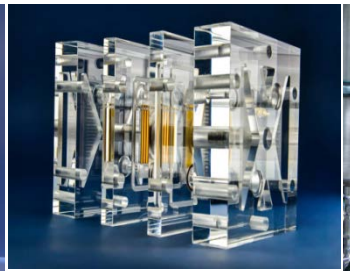
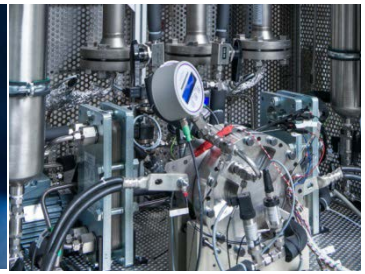
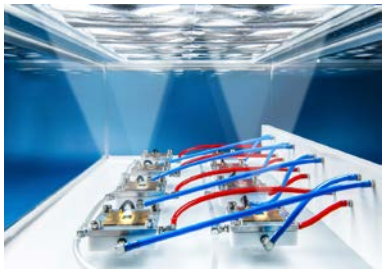


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