

Accurate Ex-situ Measurements of PEM Fuel Cells Catalyst Layer Dry Diffusivity

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- CL is a porous layer with ~30-60% porosity
- Oxygen reduces in vicinity of Pt particles embedded in CCL
- Oxygen and product water vapor transport through diffusion into and out of the CCL respectively

CL diffusivity affects

- ✓ Uniformity of oxygen reduction through the whole CCL
- ✓ The CCL lifetime
- ✓ The power density of PEMFC

- CCL is a thin layer ($\sim 10 \mu\text{m}$)
- CCL doesn't exist as a stand alone layer
- Coating procedure affects diffusivity of CCL
- Penetration of catalyst into the substrate affects the CL diffusion resistance

Coating methods for CCL

Method	Advantages	Problems	Decision
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Spray

-

Non uniform CCL

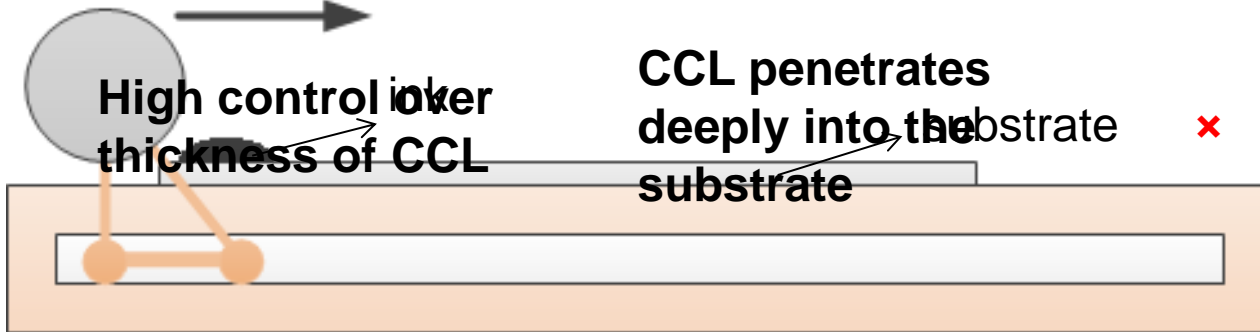
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rolling bar
Print

High control over thickness of CCL

CCL penetrates deeply into the substrate

×



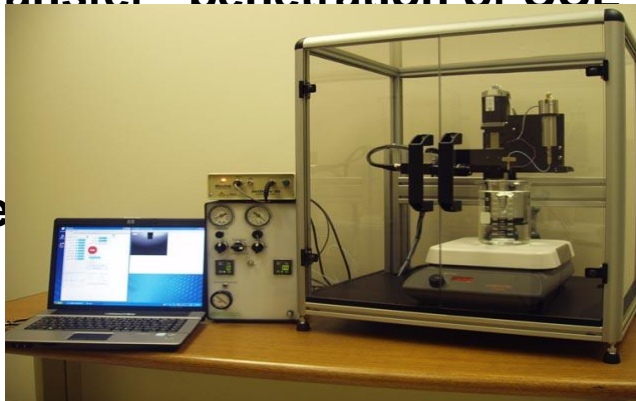
Print and decal transfer

thickness of CCL. no penetration of CCL

porous substrate, and high channel diffusion

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Maye



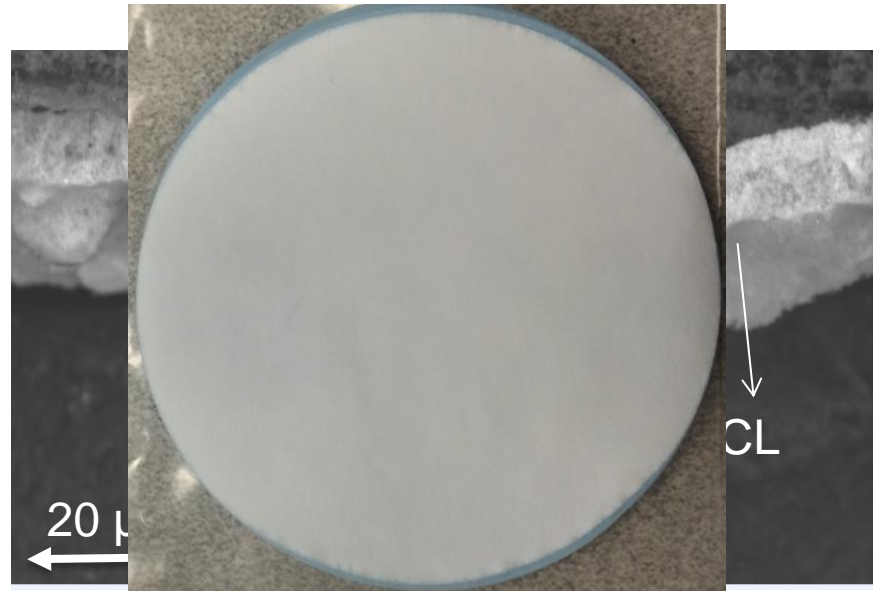
Microfab inkjet printer



Fujifilm Maketop printer

- The substrate should have low diffusion resistance:

Substrate	Pore Diameter (μm)	Thickness (μm)	Porosity (%)	Surface property
✓ Highly porous ✓ Thin Filter PTFE	0.45	76	80	Hydrophobic

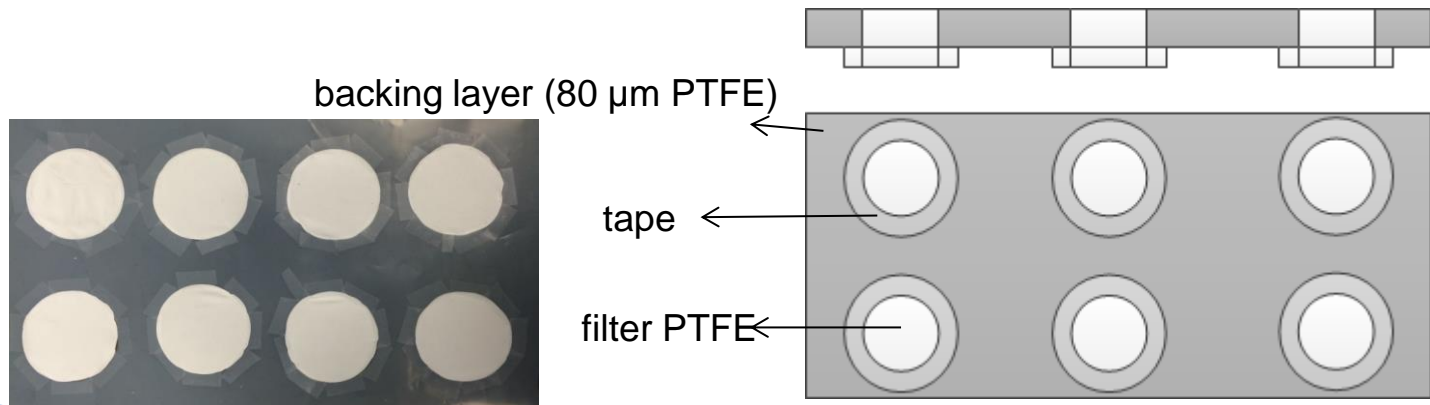


SEM image of freeze and fracture cross section of CCL coated on filter PTFE

- Samples should be fixed on the mayer bar surface otherwise it wrinkles
- The surface of the substrate should be completely level to get the best quality coating

A template is needed

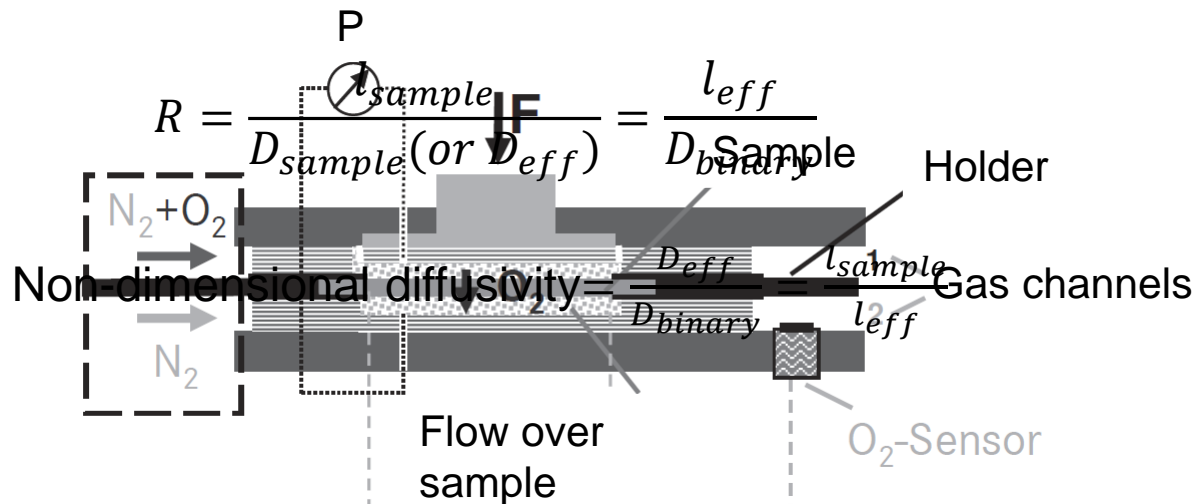
1. Punching the thickness as
2. Sucking the film using vacuum
3. Taping the film side
4. Using the un



DDT is a through plane Wicke-Kallenbach Cell (WKC)

DDT measures effective length l_{eff}

l_{eff} is thickness representative of diffusion resistance



1. Measure filter PTFE substrate $l_{eff\ s}$
2. Measure catalyst coated filter PTFE substrate $l_{eff\ cs}$
3. $l_{eff\ CCL} = l_{eff\ cs} - l_{eff\ s}$
4. $\frac{D_{eff}}{D_{binary}} = \frac{\text{Thickness of CCL}}{l_{eff\ CCL}}$

✓Preparing a nice cross section of the sample by:

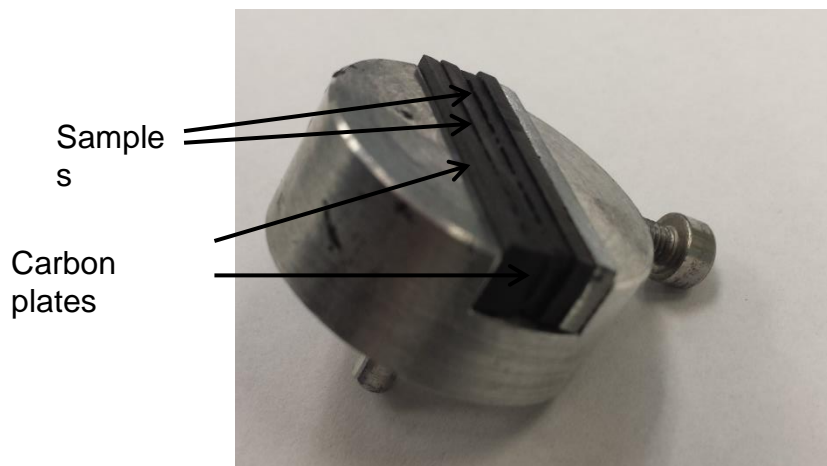
1. Placing the samples inside a sample holder
2. Freezing the sample under liquid nitrogen
3. Cutting the sample by a sharp knife

✓Taking images of the cross section by SEM

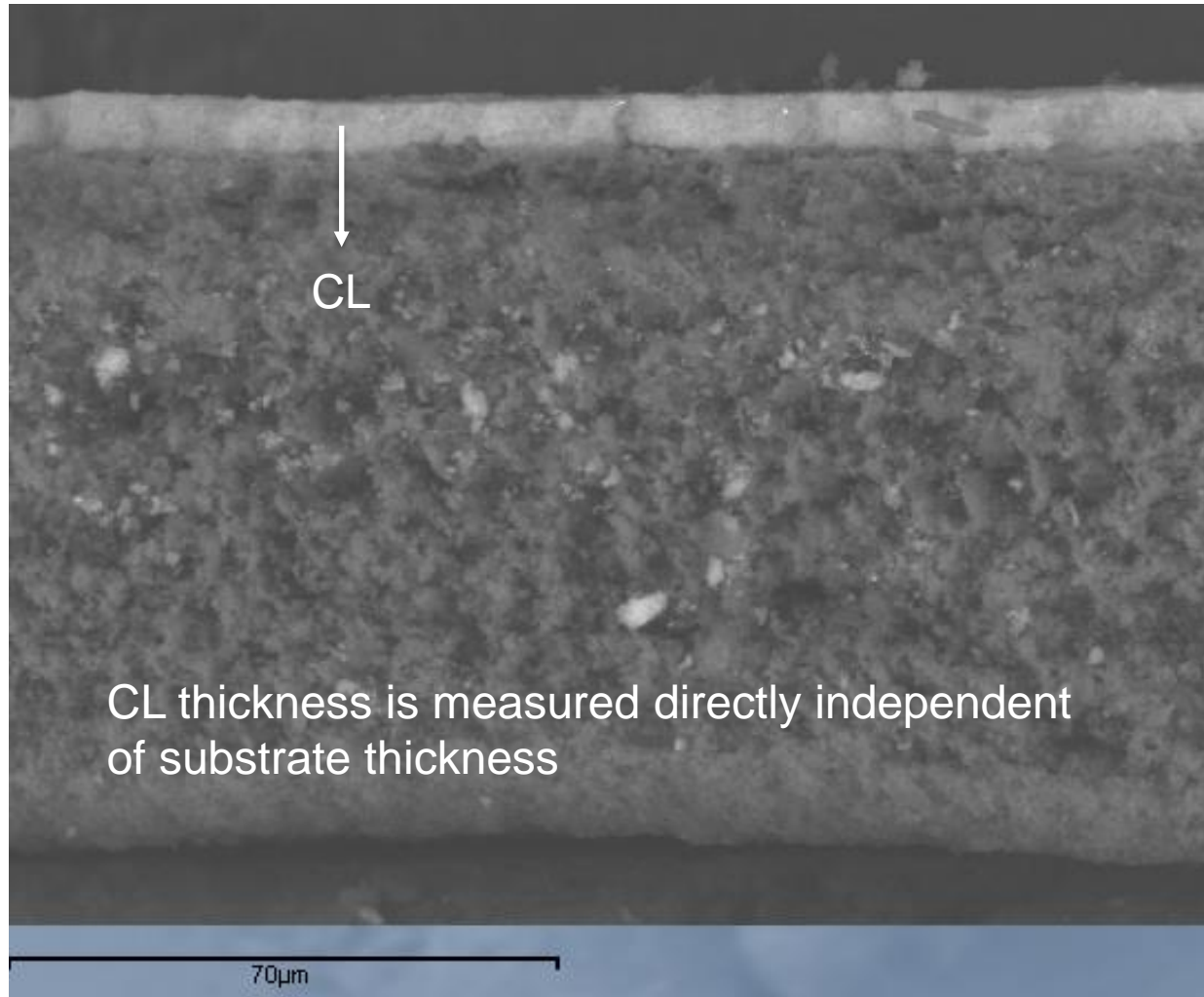
✓Processing the images by the Image-Pro software

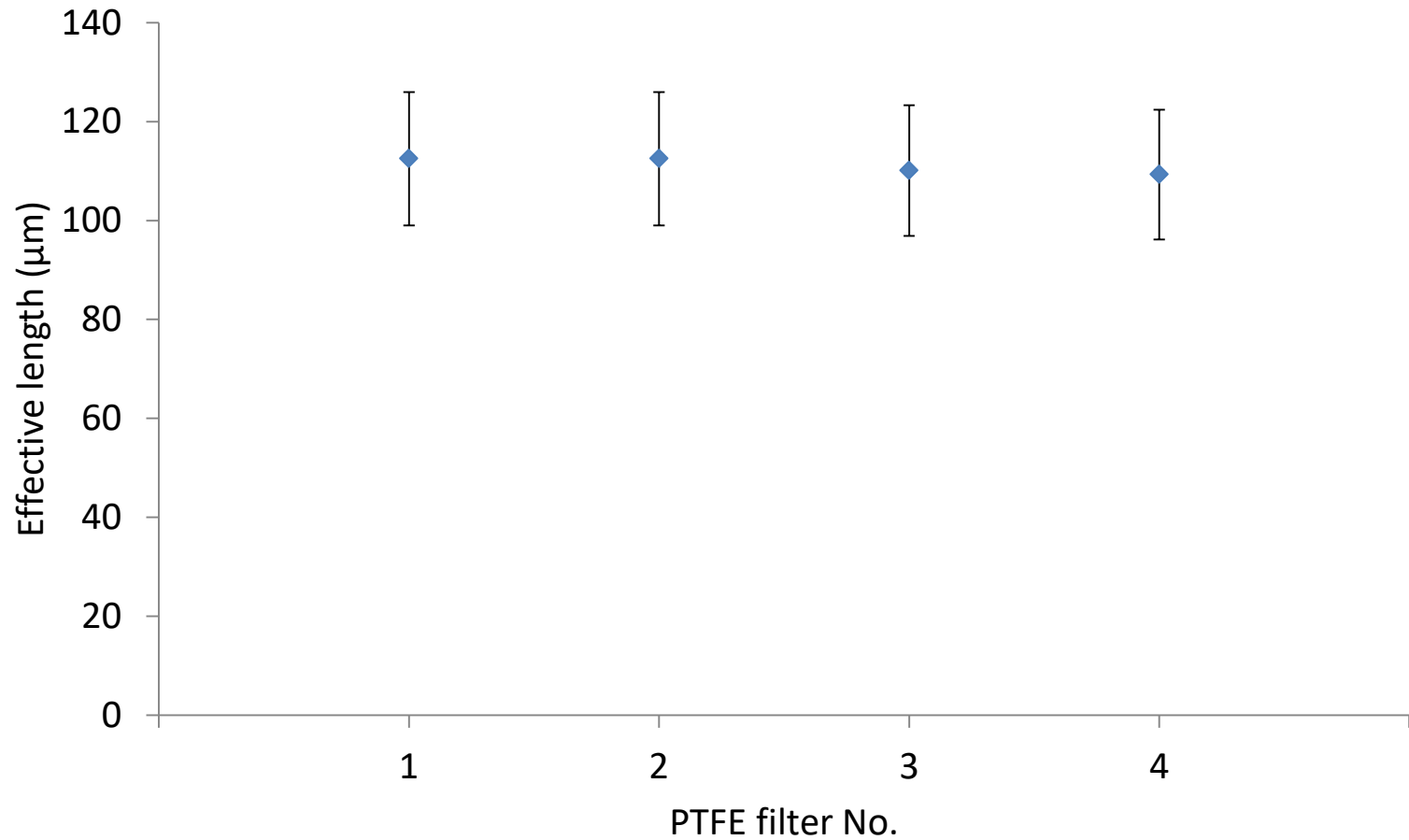


Liquid N₂ container



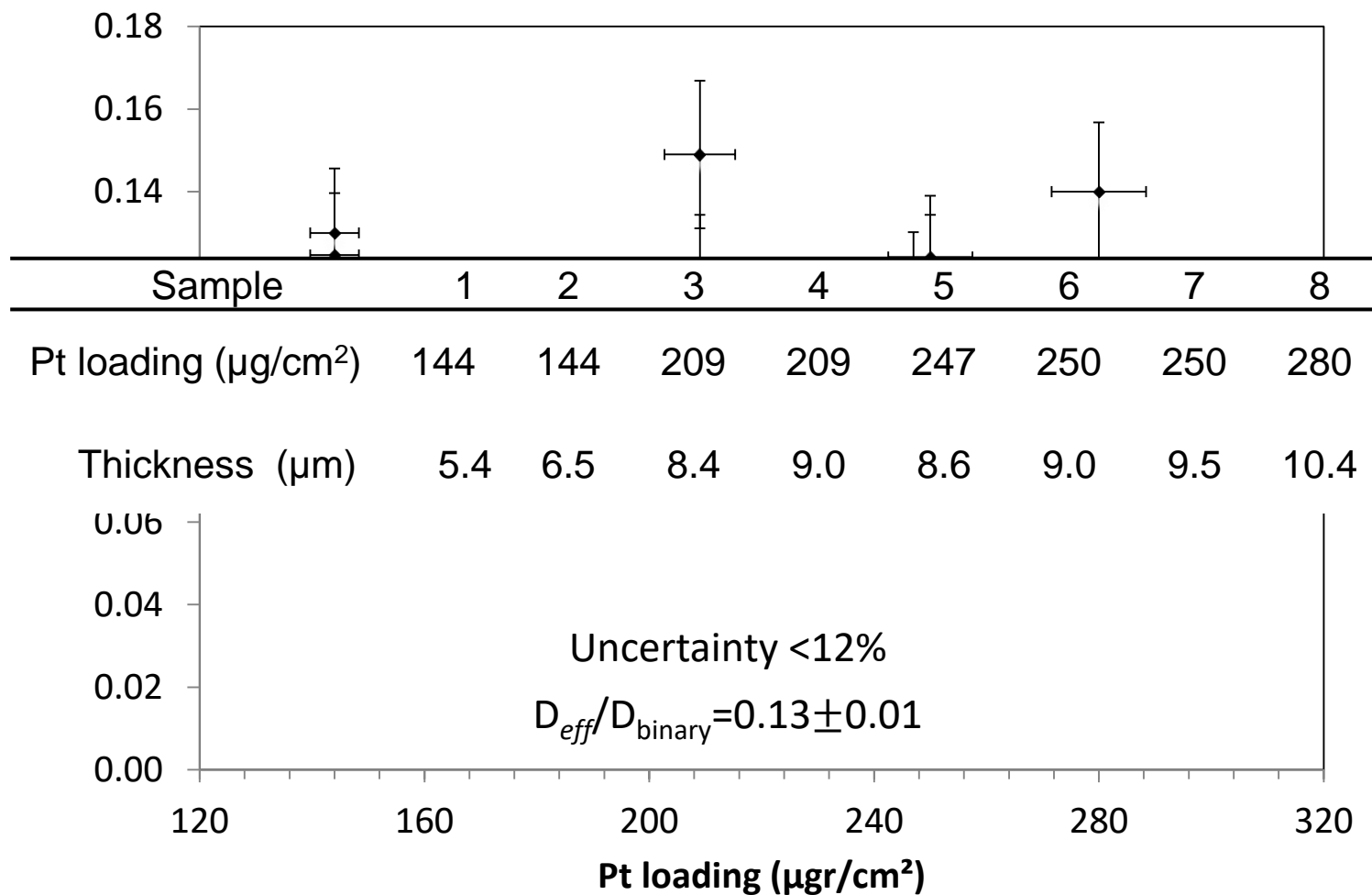
SEM sample holder





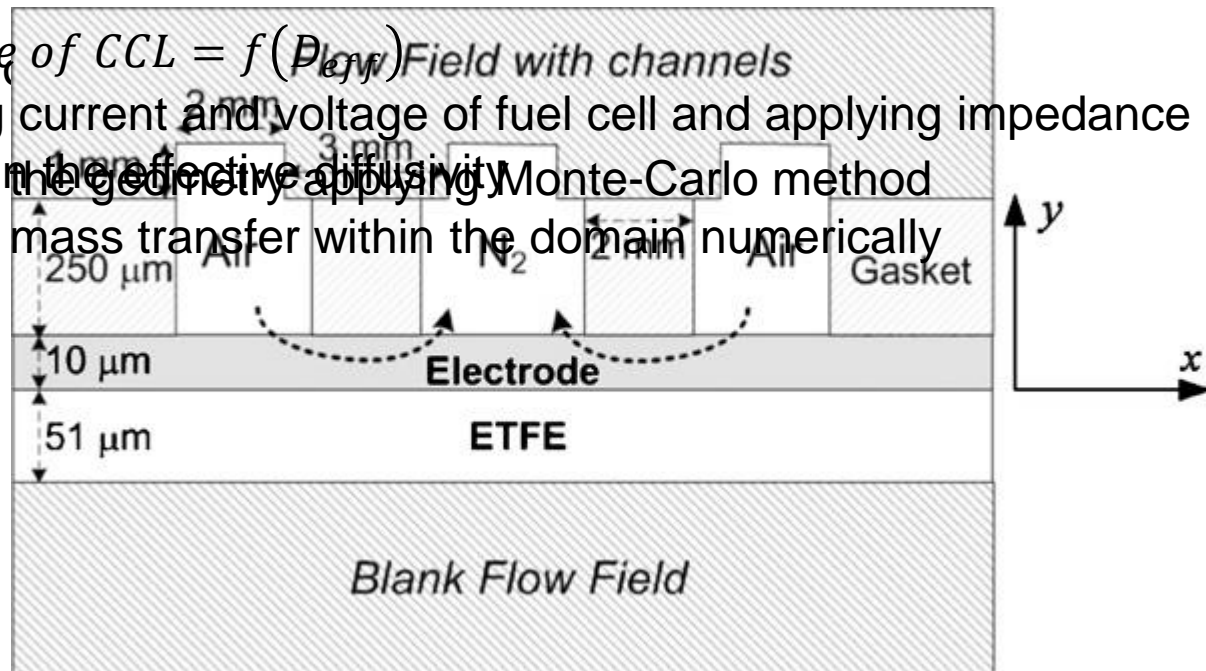
Different PTFE filters have the same effective length

Measured CCL diffusivity

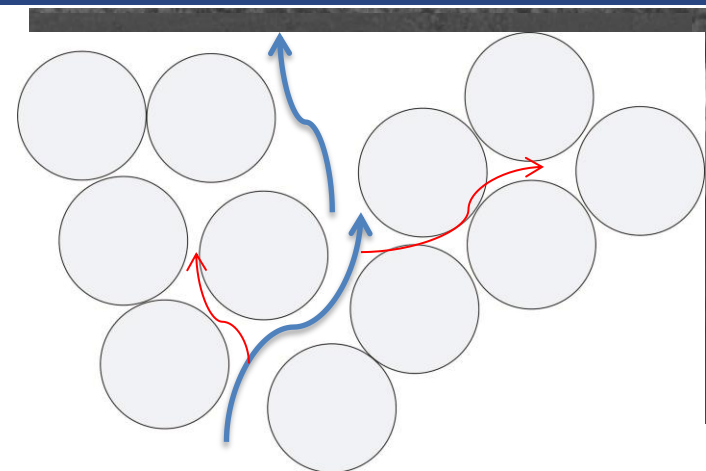
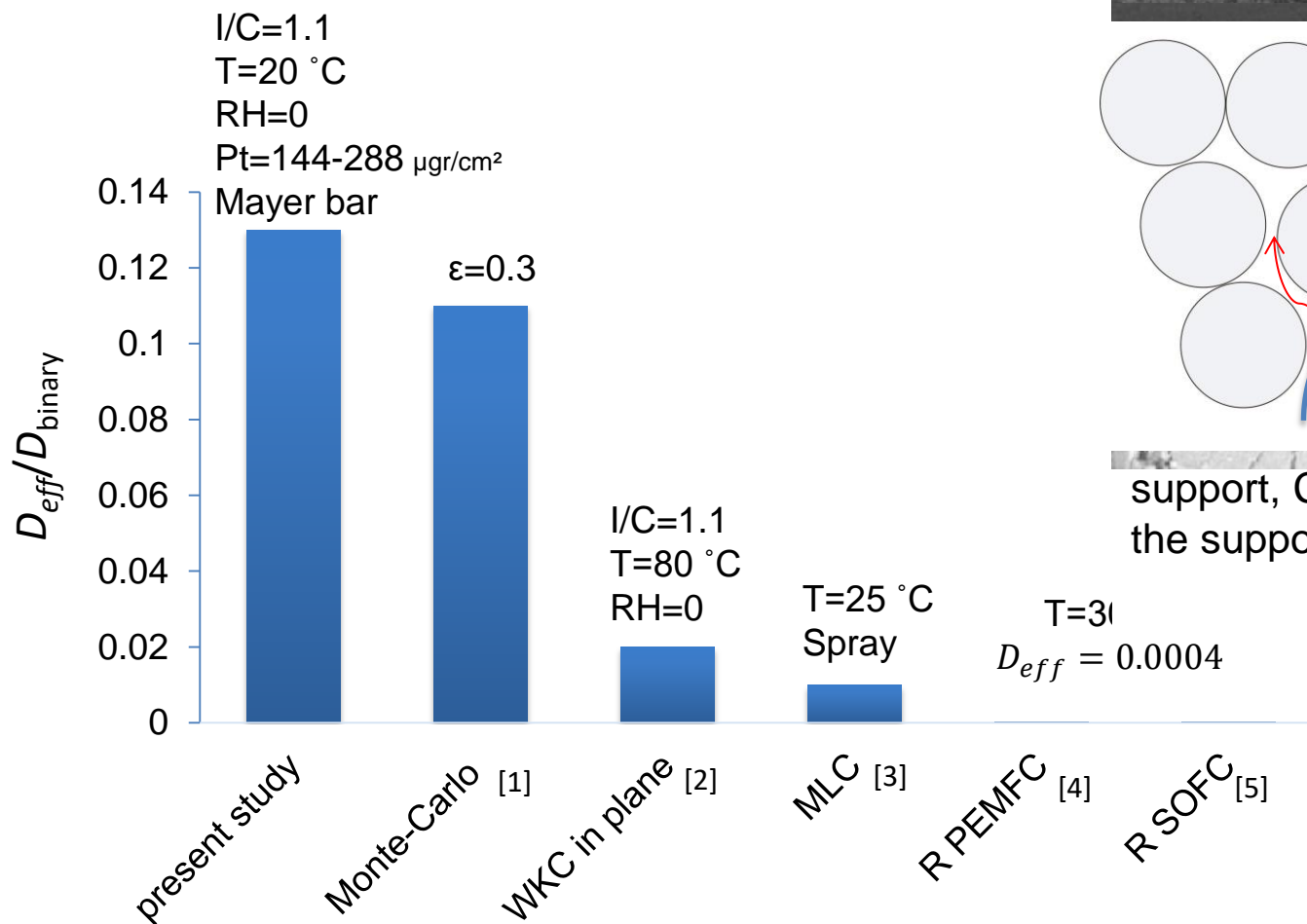


1. Wicke-Kallenbach Cell (WKC) through plane
2. Modified Loschmidt Cell (MLC)
3. WKC in plane
4. Impedance spectrum (R)

5. Impedance of CCL = $f(D_{eff})$ Field with channels
 Monte-Carlo Measuring current and voltage of fuel cell and applying impedance model
 will result in the effective diffusivity
 1. Modeling the geometry applying Monte-Carlo method
 2. Modeling mass transfer within the domain numerically



Z.Yu, R.N. Carter, "Measurement of effective oxygen diffusivity in electrodes for proton exchange membrane fuel cells", Journal of Power Sources 195 (2010) 1079–1084



support, CCL ink penetrates into the support substrate

[1] A. Berson, H. Choi, J.G. Pharoah, *Phys Rev*, **83** 026310 (2011).

[2] Z. Yu, R.N. Carter, *J Power Sources*, **195** 1079–1084 (2010).

[3] J. Shen, J. Zhou, N. Astrath, T. Navessin, Z.S. Liu, C. Lei, J. Rohling, D. Bessarabov, S. Knights, S. Ye, *J Power Sources*, **196** 674–678 (2011).

[4] A.A. Kulikovskiy, *J Electroanal Chem*, **720-721** 47–51 (2014).

[5] K. Wippermann, K. Klafki, A.A. Kulikovskiy, *Electrochimica Acta*, **141** 212–215 (2014).

- CL is coated by Mayer bar on hydrophobic filter PTFE substrates to avoid any CL penetration into the substrate
- Diffusivity is measured with a WKC based test bed and uncertainty is evaluated to be less than 12%
- Diffusivity of CL for different Pt loadings (different CL thicknesses) is measured and reported to be 0.13 of binary diffusion.
- The through plane diffusivity value of the CL is higher than the in plane values reported in literature and several order higher than the reported values for agglomerate diffusivity

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Thanks for your attention!
Any questions?