HOW ELECTRODE PROPERTIES DETERMINE PEMFC OPERATION

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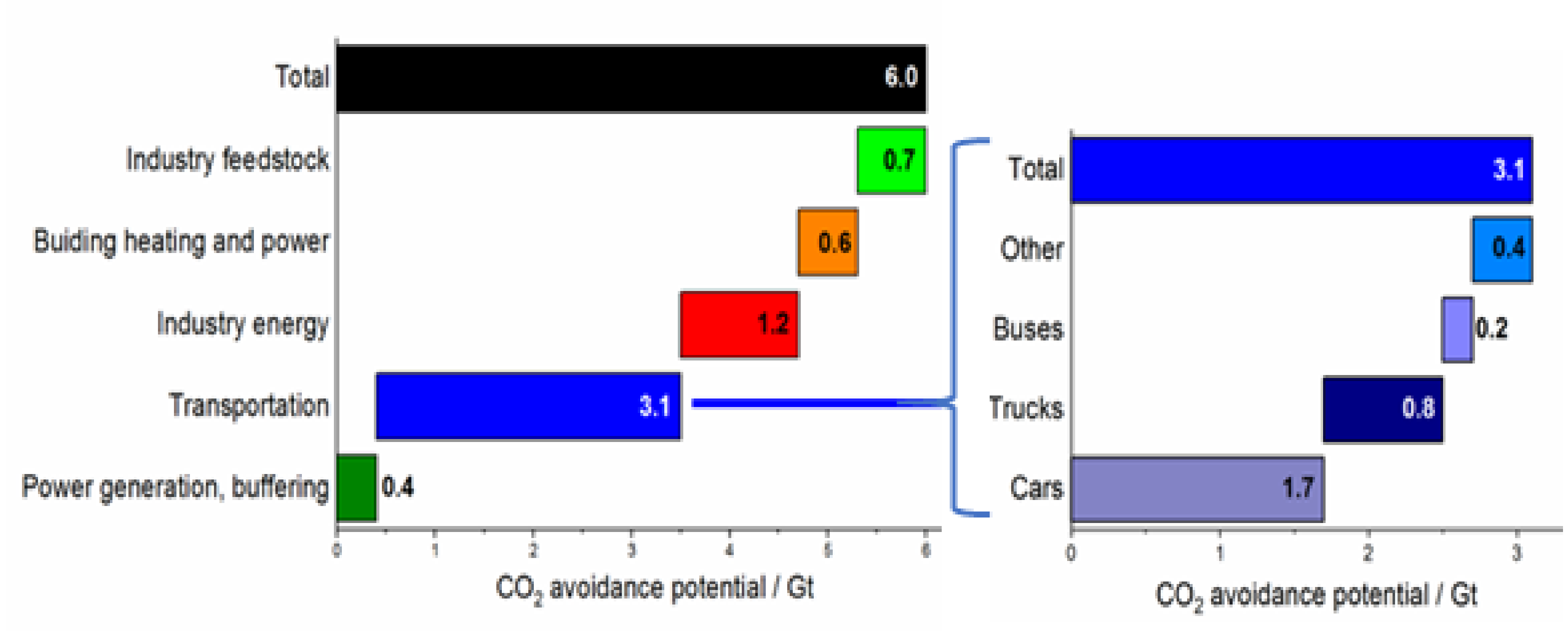
DLR

INTRODUCTION

Fuel Cells in heavy duty transport

- 50% of GHG emissions due to transport sector
- 25% of GHG in transport caused by HD applications; expected to increase to 40% by 2030
- Electrification of HD transport becoming focus of fuel cell applications

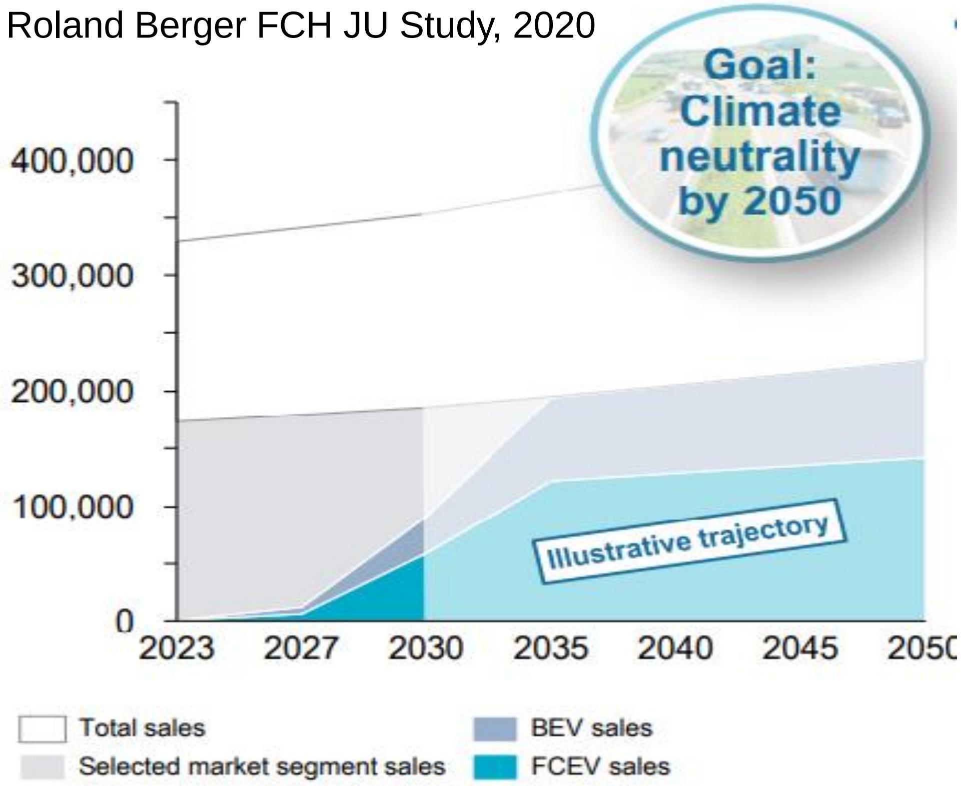


Hydrogen Council. Hydrogen scaling up – A sustainable pathway for the global energy transition, 2017

Fuel Cells in heavy duty transport

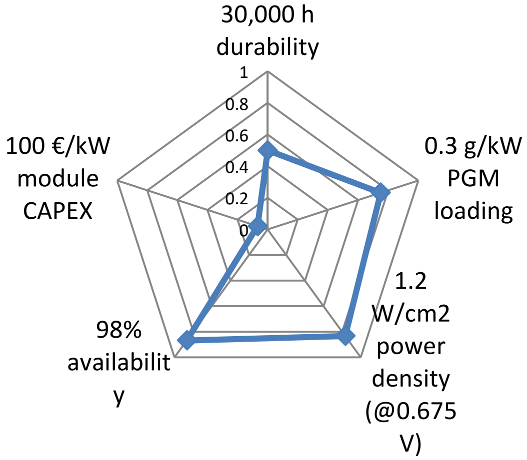
- **EU Green Deal: reduce CO2 emission by 90% by 2050**
- Market share of FC HDV is expected to grow from < 2% in 2027 to 17% in 2030
- Total Cost of Ownership (TCO) of FC HDVs can become competitive by 2027; in 2030 TCO can be 6-7% lower than for diesel trucks
  (*Note: the recently changed geopolitical situation was no present when the study was done*)

Roland Berger FCH JU Study, 2020

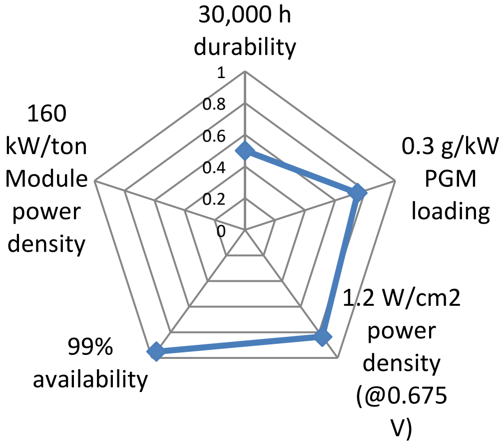


Current achievements and KPIs of fuel cell applications

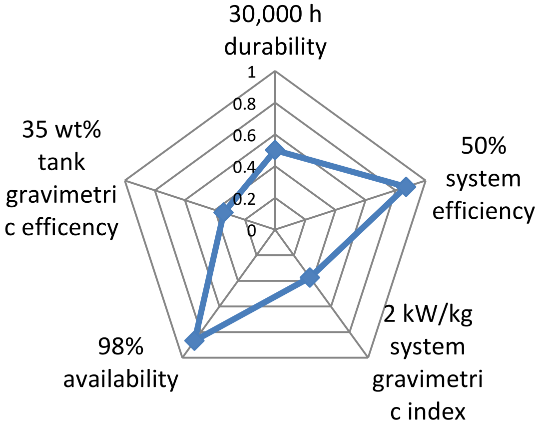
SoA vs HDV Targets 2030



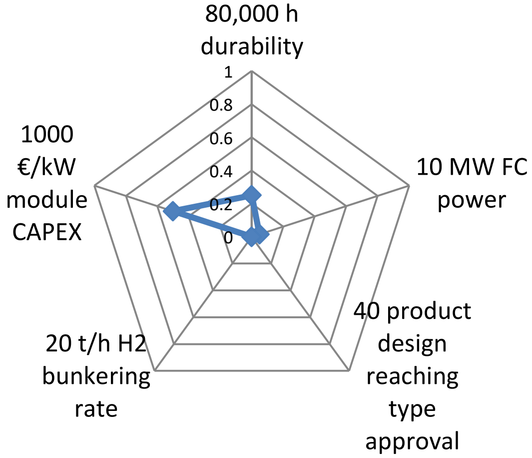
SoA vs Train Targets 2030



SoA vs Aviation Targets 2030

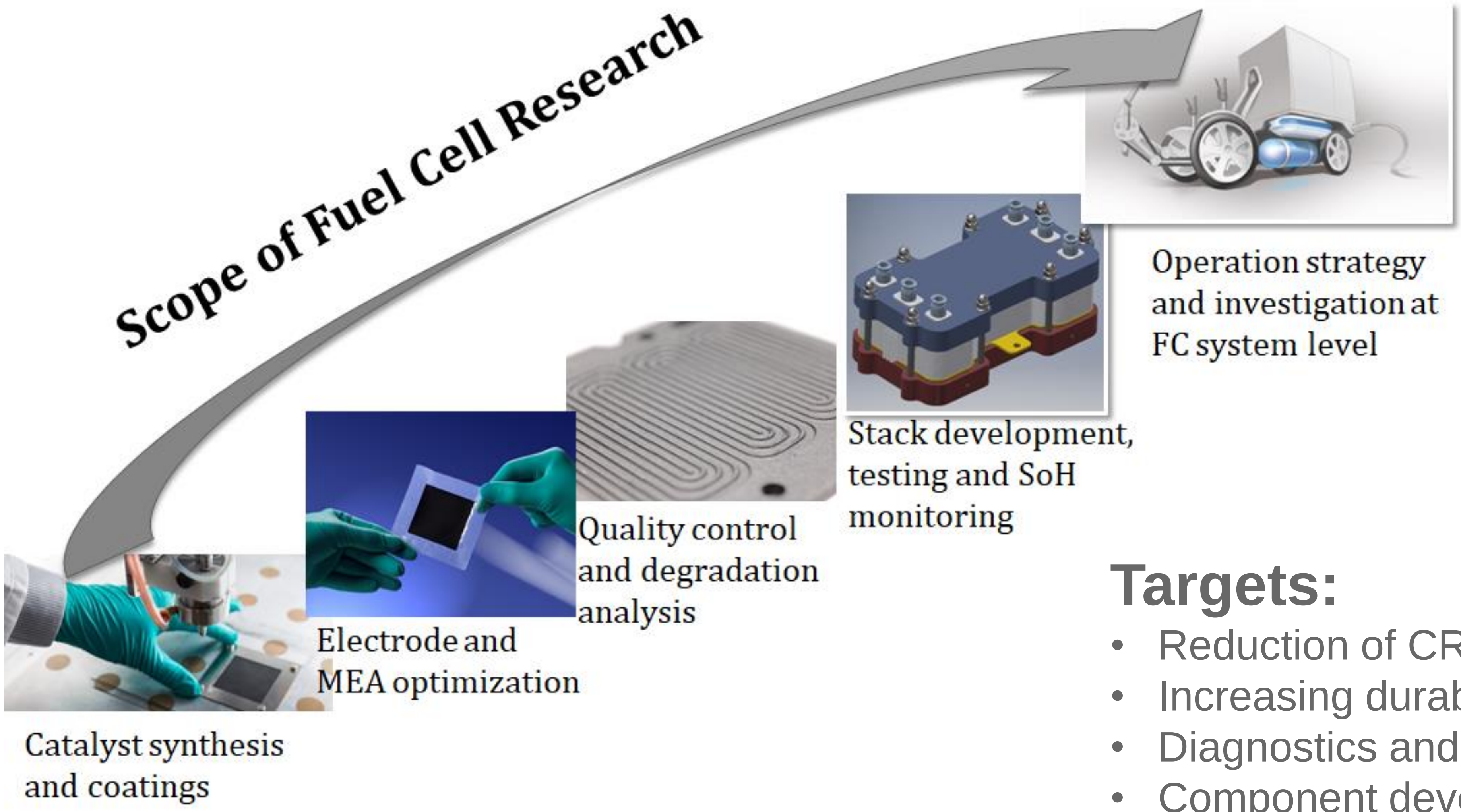


SoA vs Maritime Targets 2030



KIPs according to SRIA 2021-2027 of the Clean Hydrogen JU

Scope of PEMFC activities at department of electrochemical energy technology (@DLR-TT)



Targets:

- Reduction of CRM and cost reduction
- Increasing durability and performance
- Diagnostics and application
- Component development

IMPACT OF CCL STRUCTURE ON PEMFC OPERATION

Investigation of Cathode Catalyst Layer (CCL)

Establish link between CCL structure and fuel cell performance

- Obtain CCLs with unique structures but the same Pt loading
- Perform electrochemical characterization
- Determine CCL properties (porosity, ionomer distribution, …)

Investigation of Cathode Catalyst Layer (CCL)

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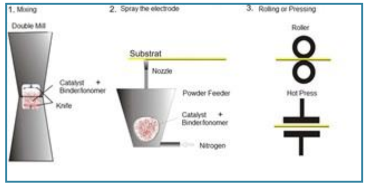

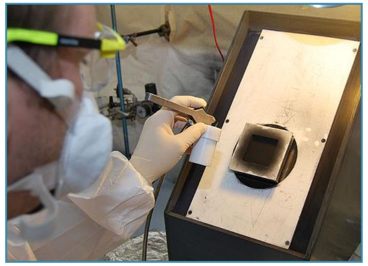

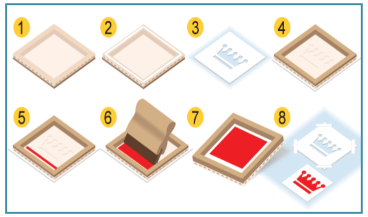

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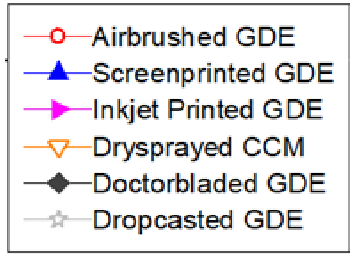
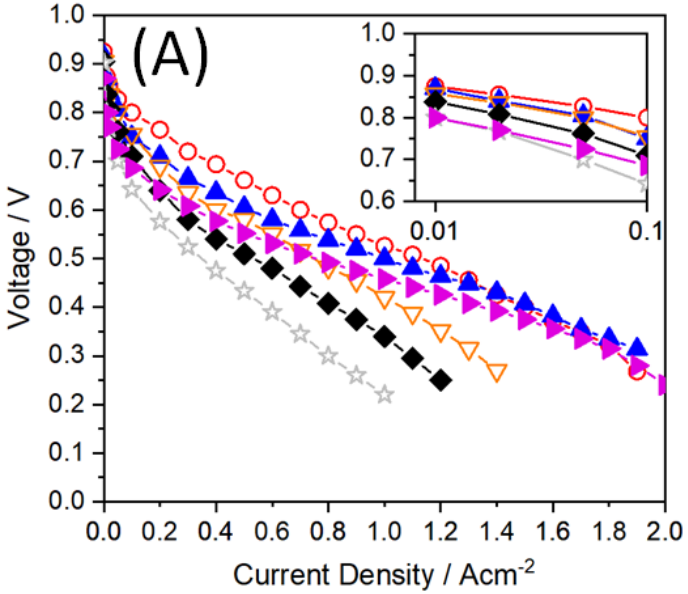
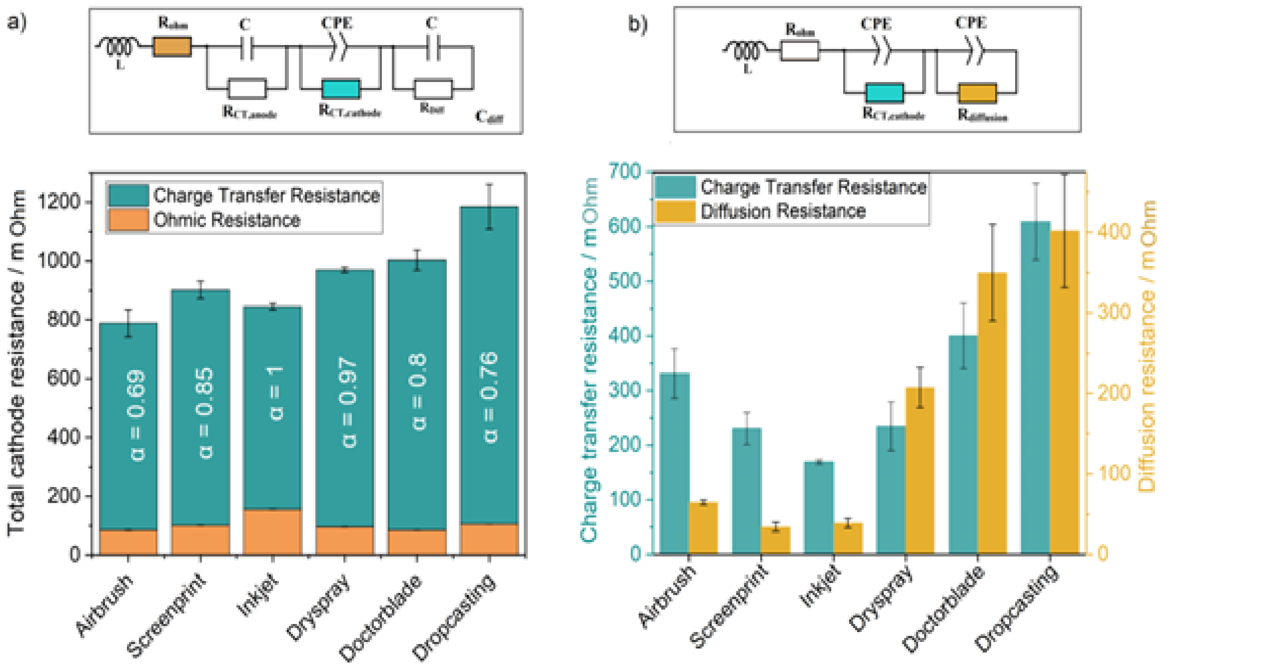
Method	MEA type	Solvent 1	Solvent 2	Mixing process	Electrode thickness/ µm	ECSA / $m^2\ g^{-1}$
Dry spray	CCM	None	none	Cryo-mill, knife mill	6.5 ± 2.2	15
Air brush	GDE	UP water: Cat × 100	Isopropanol: Cat × 100	Ultrasonication	8.8 ± 2.2	57
Screen printing	GDE	UP water: Cat × 5	none	Ultrasonication, roller ball mill	9.0 ± 3.7	48
Doctor blade	GDE	UP water: Cat × 3.75	Isopropanol: Cat × 1.75	Ultrasonication	7.0 ± 0.7	42
Drop casting	GDE	UP water: Cat × 118	none	Ultrasonication	3.2 ± 0.8	16.5
Inkjet printing	GDE	Isopropanol: Cat × 60.8	Glycerol: Cat × 13.33	Ultrasonication	5.3 ± 0.7	12

Electrochemical Characterisation



80°C, 150 kPa(abs), 50%RH, stoich(a/c): 1.6/2.5





Kinetic region:

- ECSA is only one factor determining electrode kinetics

Ohmic/mass transport region:

- Low slope of pol curve linked with low diffusion resistance

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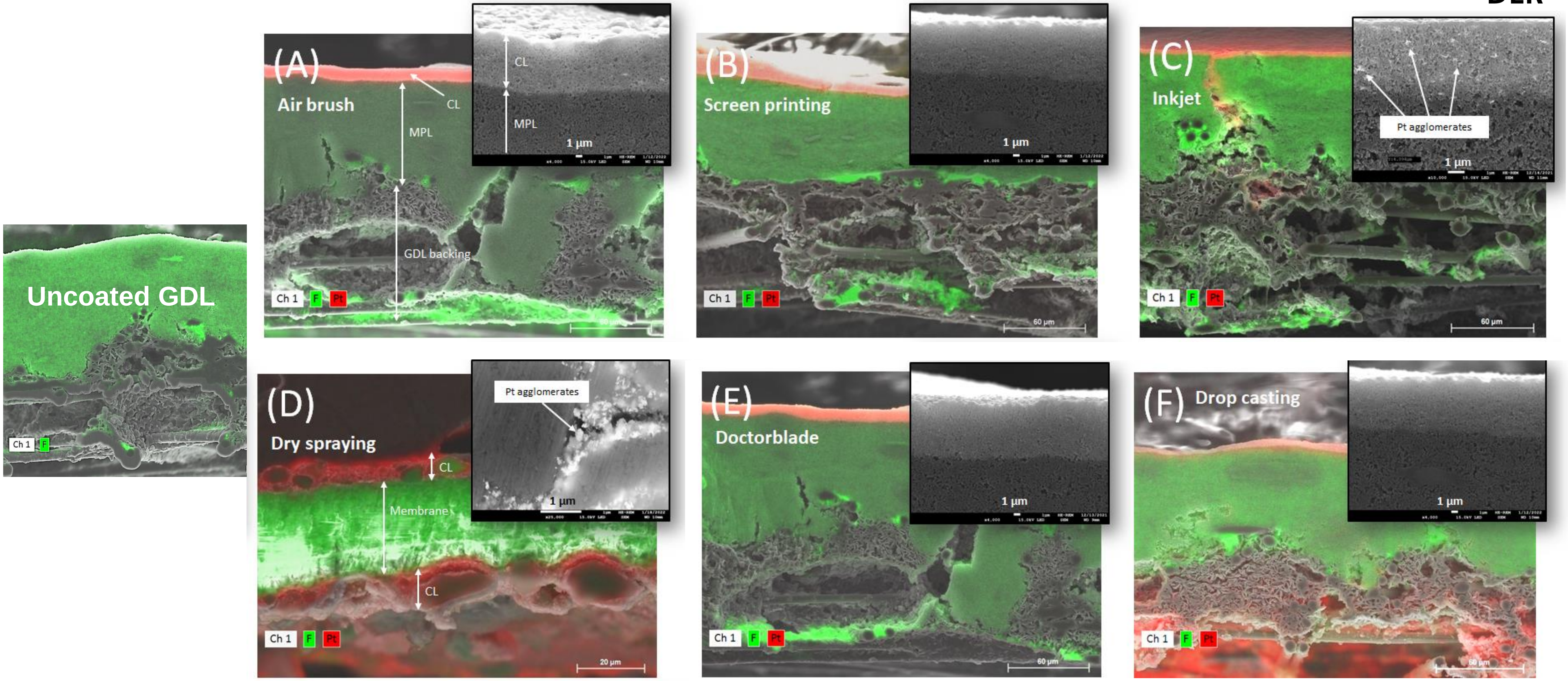
SEM/EDX of Different CCL Cross-Sections



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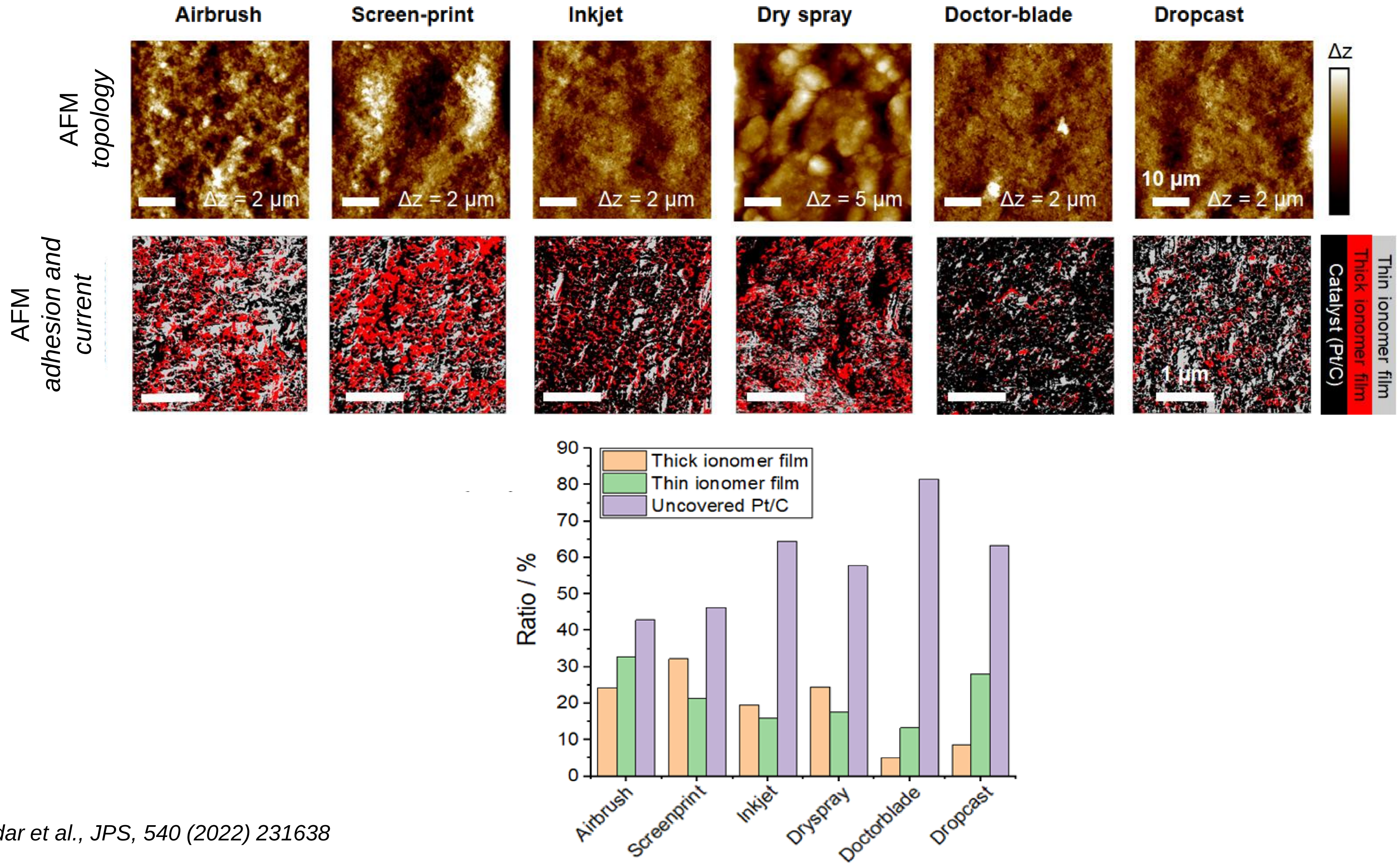
AFM of CCLs (top view)



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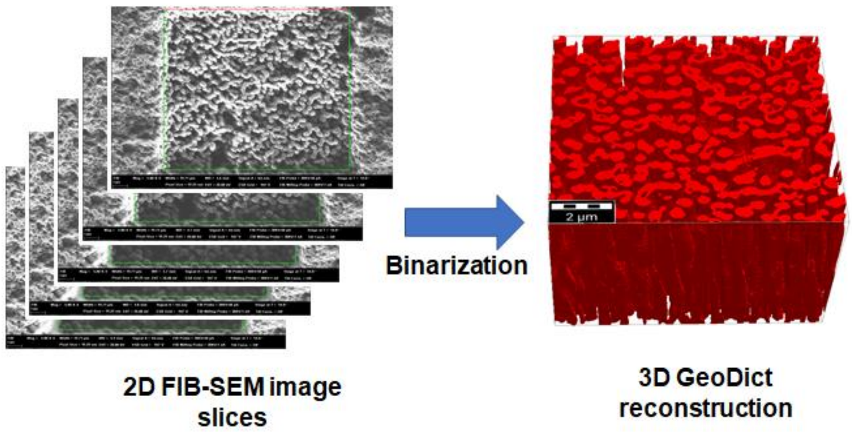
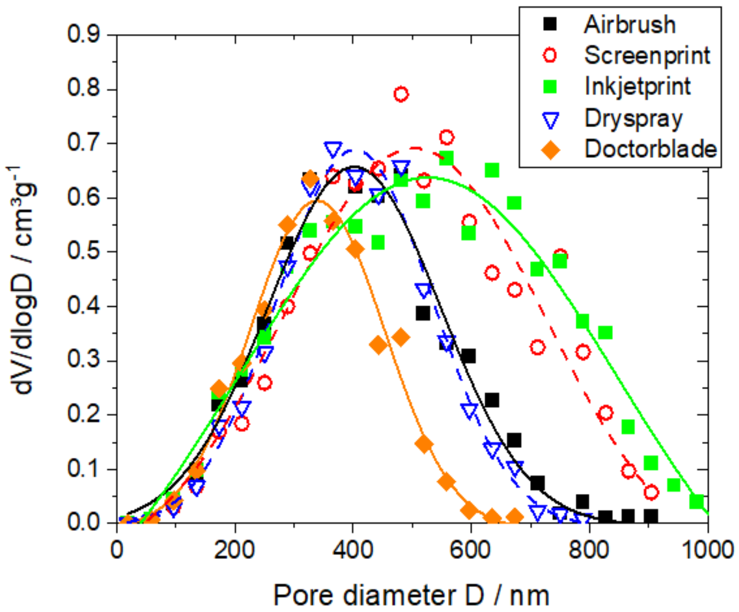
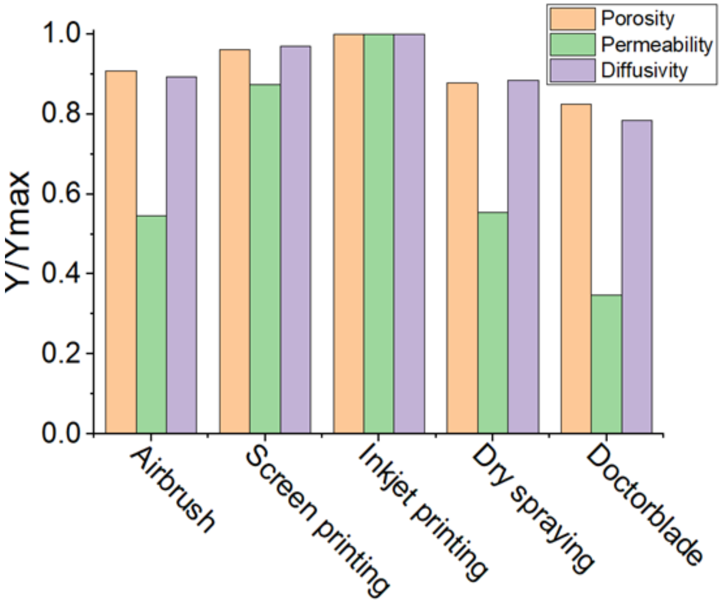
3D Reconstruction using FIB-SEM Data







	Airbrush	Screen printing	Inkjet	Dry spraying	Doctor blade
Porosity / %	55	58	60	53	50
D50 / nm	344	298	353	405	421
Diffusivity / $10^{-6}\, m^2/s$	5.0	5.4	5.6	5.0	4.4
Permeability / $10^{-15} m^2$	4.6	7.4	8.4	4.7	2.9

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Assessment of Individual CCL Paramters

Low performances ➔ low Y/Ymax values

High performances ➔ mainly high Y/Ymax and no low Y/Ymax

High current density: combination of covered Pt/C and transport properties linked to high performance

Low current density: covered of Pt/C good measure for the cell performance

		Air brush	Screen printing	Inkjet printing	Dry spraying	Doctor blade	Drop casting
Electrochem.	Ohmic resistance^{-1}	0.76	0.80	0.46	0.73	0.78	1.00
	Protonic resistance^{-1}	0.40	0.45	1.00	0.79	0.24	0.20
	Diffusion resistance^{-1}	0.83	1.00	0.88	0.17	0.10	0.09
	Charge transfer resistance^{-1}	0.54	0.78	1.00	0.76	0.44	0.29
	ECSA	1.00	0.84	0.21	0.26	0.84	0.29
FIB-SEM	Porosity	0.91	0.96	1.00	0.88	0.83	--
	D50	0.82	0.71	0.84	0.96	1.00	--
	Diffusivity	0.89	0.97	1.00	0.89	0.79	--
	Permeability	0.55	0.87	1.00	0.55	0.35	--
AFM	covered Pt	1.00	0.94	0.62	0.74	0.32	0.64
	Thick ionomer film coverage	0.75	1.00	0.63	0.78	0.16	0.28
	Thin ionomer film coverage	1.00	0.67	0.48	0.55	0.39	0.85

Y/Y_{max} (colour scale 0.0 – 1.0)

Performance

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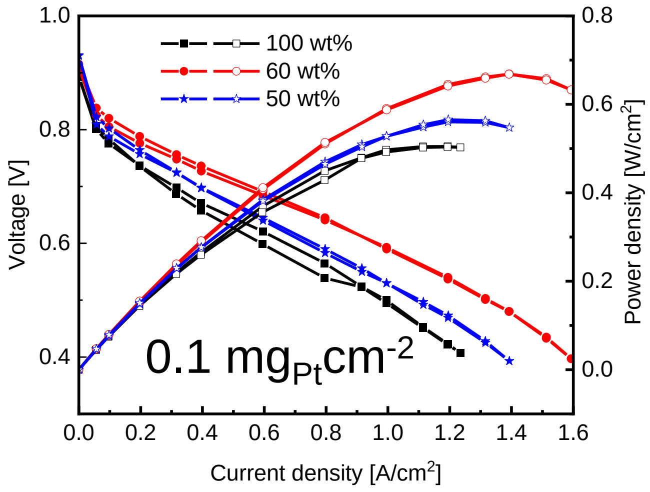
CONCLUSIONS & ONGOING WORK

Conclusions

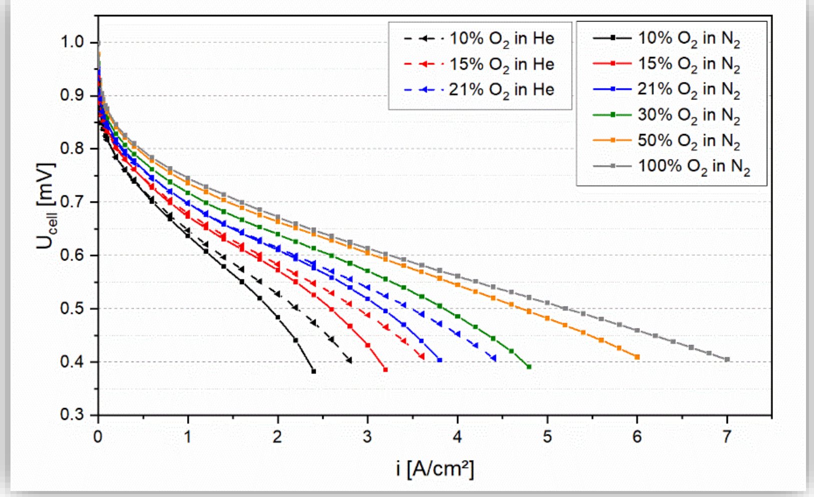
- Link between MEA performance and CCL structure
- High performance is related with homogeneous ionomer distribution in the CCL
- At low current, amount of Pt/C covered by ionomer is good measure for performance
- Fraction of ionomer covered Pt/C and transport properties relevant at high current

Ongoing

Investigation of impact of CL structure at ultra-low Pt loading using ink-jet printing



EU-Project FURTHER-FC



Acknowledgements

- Thank you for your attention

- Persons who contributed to the presented results
  - Tobias Morawietz
  - Patrick Sarkezi-Selsky
  - Khrystyna Yezerska
  - Oleg Sergeev
  - Jan-Frederik Heger
  - Thomas Jahnke

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