DOLPHIN

Disruptive pemfc stack with nOvel materiaLs, Processes, arcHitecture and optimized INterfaces

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Disruptive pemfc stack with n**O**vel materia**L**s, **P**rocesses, arc**H**itecture and optimized **IN**terfaces

Clean Hydrogen Partnership

Co-funded by the European Union

DOLPHIN Workshop, Ulm June 16th 2023

EFC by Additive Manufacturing – Towards TP4

DMG MORI Team: Michael SLUSAREK, Mohcine BENCHERIFI, Jan RIEWENHERM
ZSW Team: Benjamin WIEDEMANN, Christian BERGBREITER, Lukas KÖNIG, Theresa UHLEMAYR, Florian WILHELM

liten cea tech

SYMBIO A FAURECIA MICHELIN HYDROGEN COMPANY

ZSW

HEXCEL

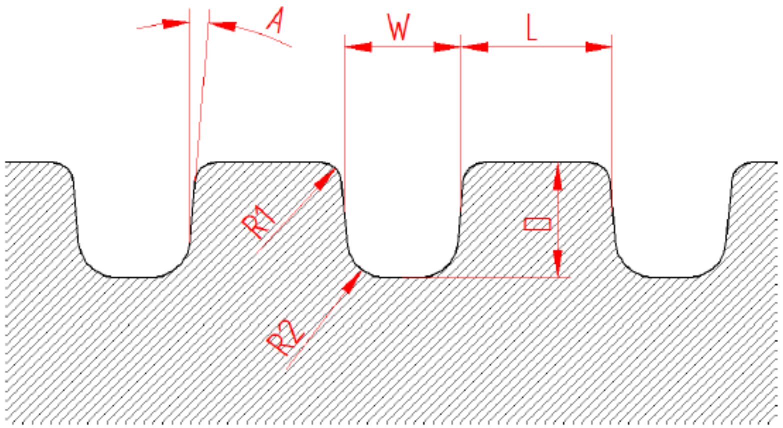
MANCHESTER 1824 The University of Manchester

Chemours

DMG MORI ADDITIVE

Design Steps: (1) Channel-Rib Design for AM Flowfields

Good from the very first try



Pressure drop too high, no gain in performance

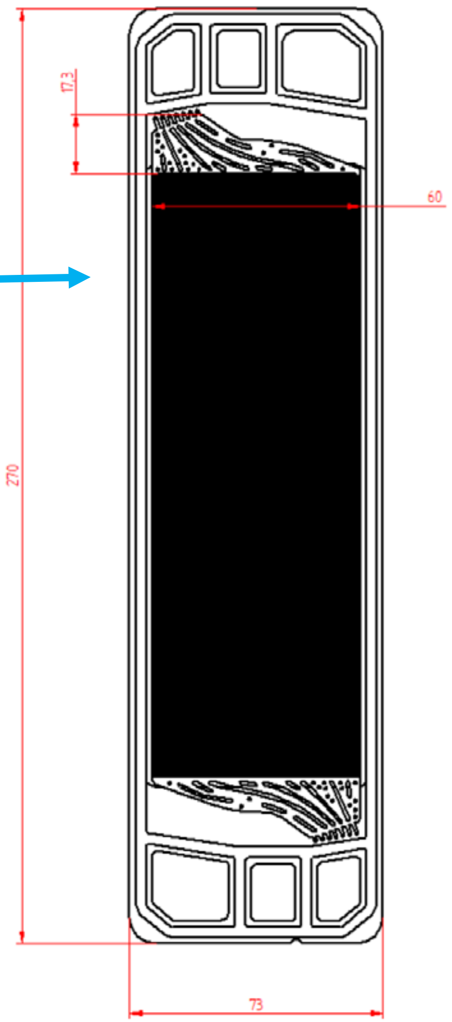
		Channel depth D	Channel width W	Land width L	Flank angle A	Radius R1	Radius R2	
Version 1		0,3 mm	0,4 mm	0,2 mm	5°	0,05 mm	0,1 mm	☆
Version 2		0,3 mm	0,3 mm (↓0,1mm)	0,2 mm	5°	0,05 mm	0,1 mm	X
Version 3	Anode	0,2 mm (in) 0,15 mm (out)	0,2 mm (in) 0,15 mm (out)	0,2 mm (in) 0,25 mm (out)	Rectangular ***VARIABLE*** channels			?
	Cathode	0,2mm	0,15 mm (in) 0,25 mm (out)	0,25 mm (in) 0,15 mm (out)				

Ready for testing in TP2

Design steps: (2) from TP2/3 to TP4

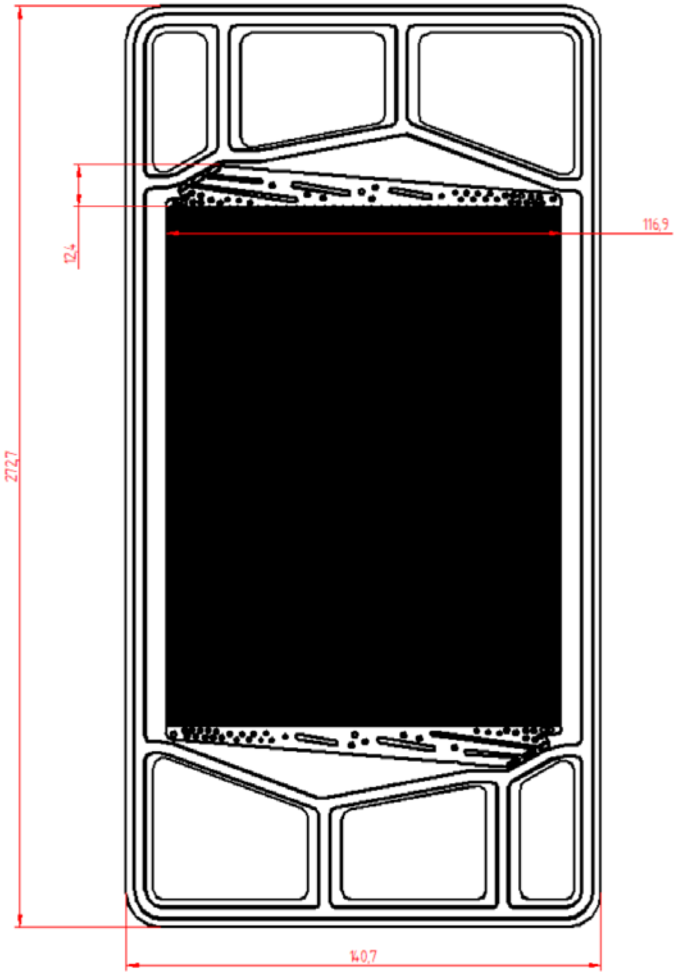
Graphite composite plates with inlay concept for active area
→ Very flexible

TP2/TP3 Plate



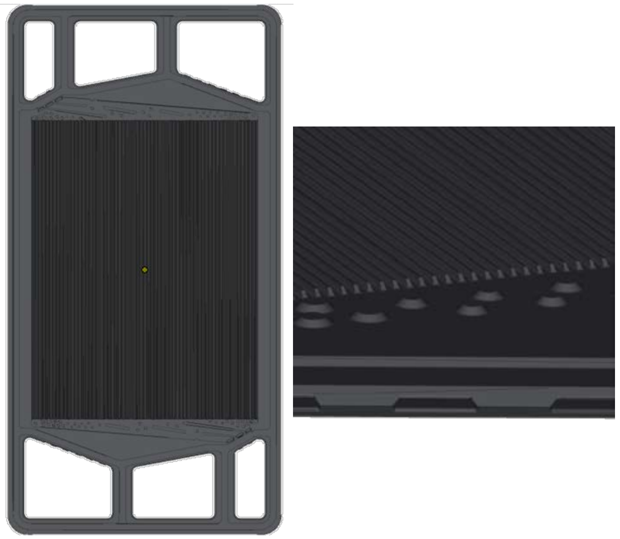
Full-AM TP2/TP3 Plate

TP4 Plate

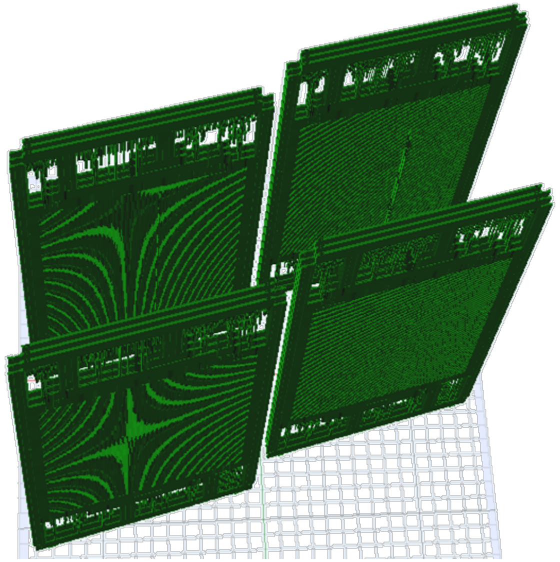


AM: Basic Information

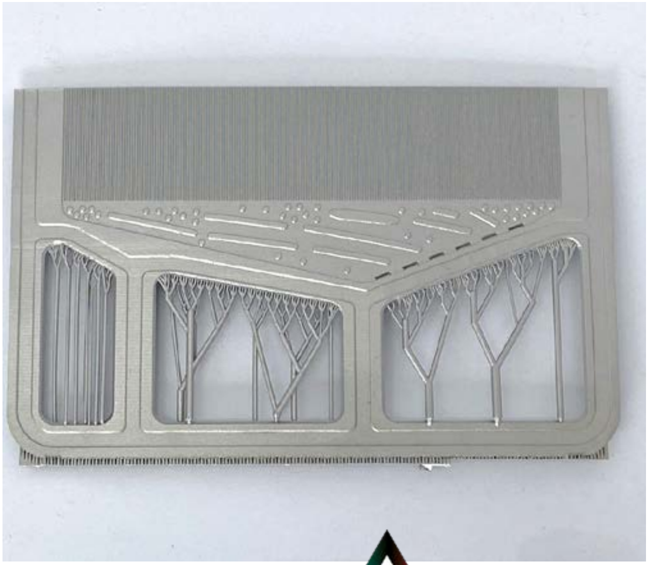
PARTS



PRINT ORIENTATION



FINISHED PARTS



CUSTOMER REQUEST

- 20230524_TP4_BPP.stp
  - X = 140,7 mm
  - Y = 1,4 mm
  - Z = 272,7 mm

PRINTING DETAILS

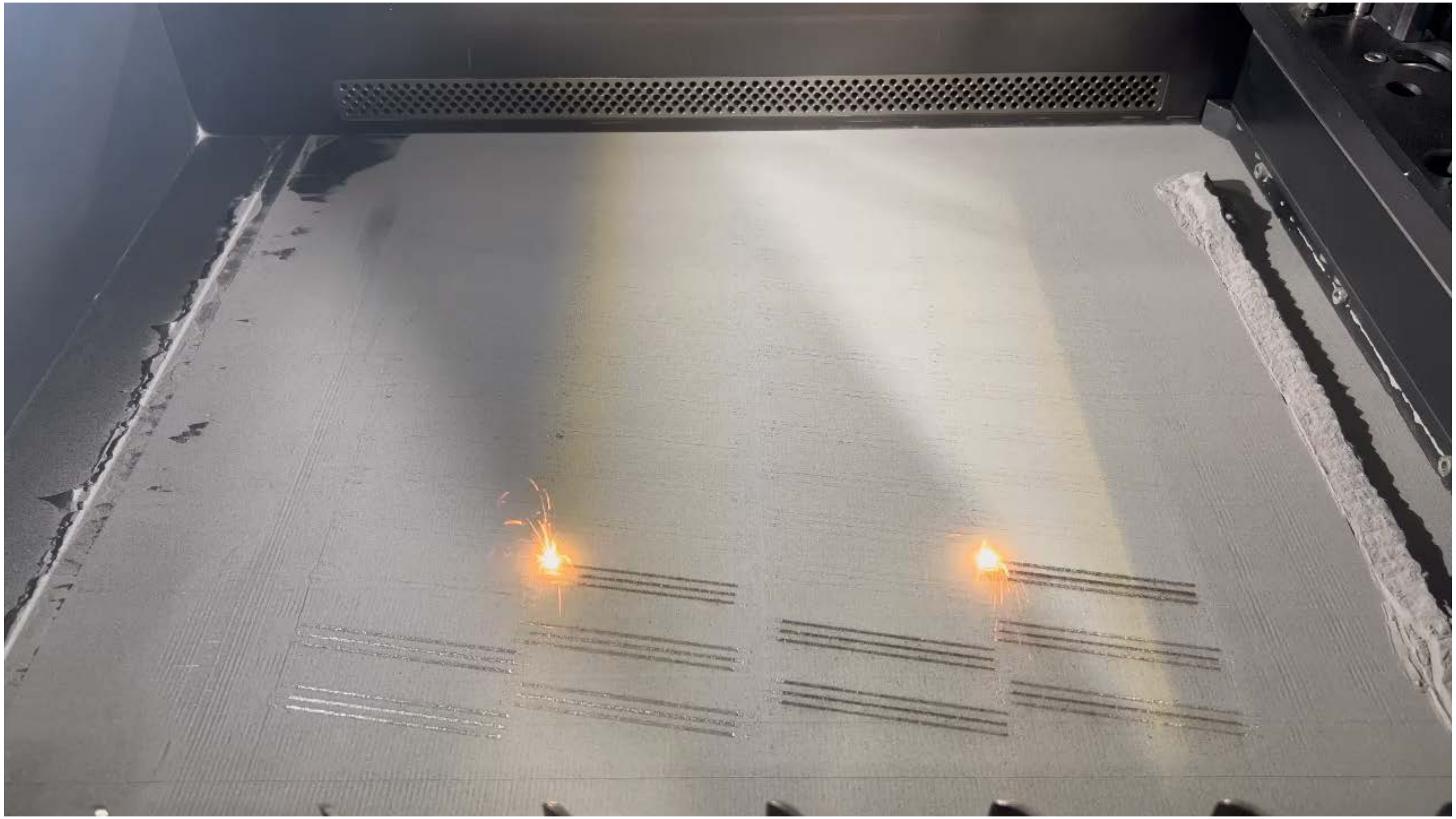
Material	StainlessSteel_1.4404
Laser source	600W
Layer thickness [µm]	30
Machine type	LASERTEC 30 DUAL *SLM*
Total build time [hh:min]	63:53 (Print not finished)

SLM – Selective Laser Melting

BENEFITS *SLM*

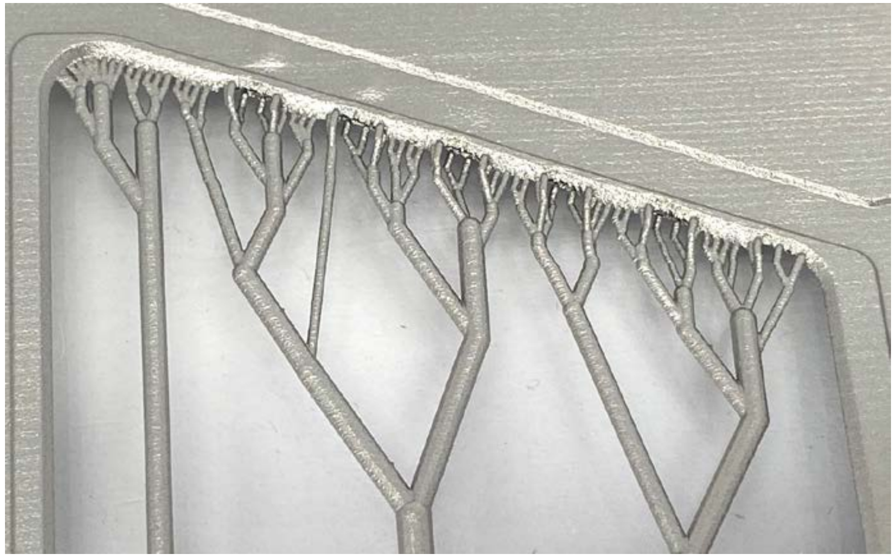
- Enormous design freedom
- Fast & flexible Material exchange solution
- Rapid Manufacturing
- DUAL- Laser solution with full overlap
- Easy CAM-Programming

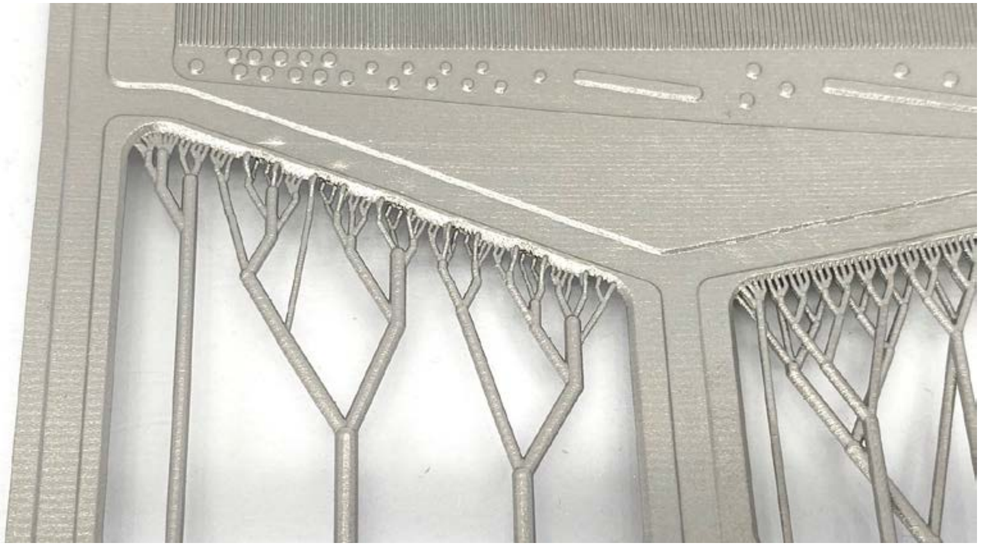
SLM – Selective Laser Melting for BPP manufacturing



Please cf. separate video clip „Dolphin Project_AM_SLM_Process“

Print Results – Support & Powder removal



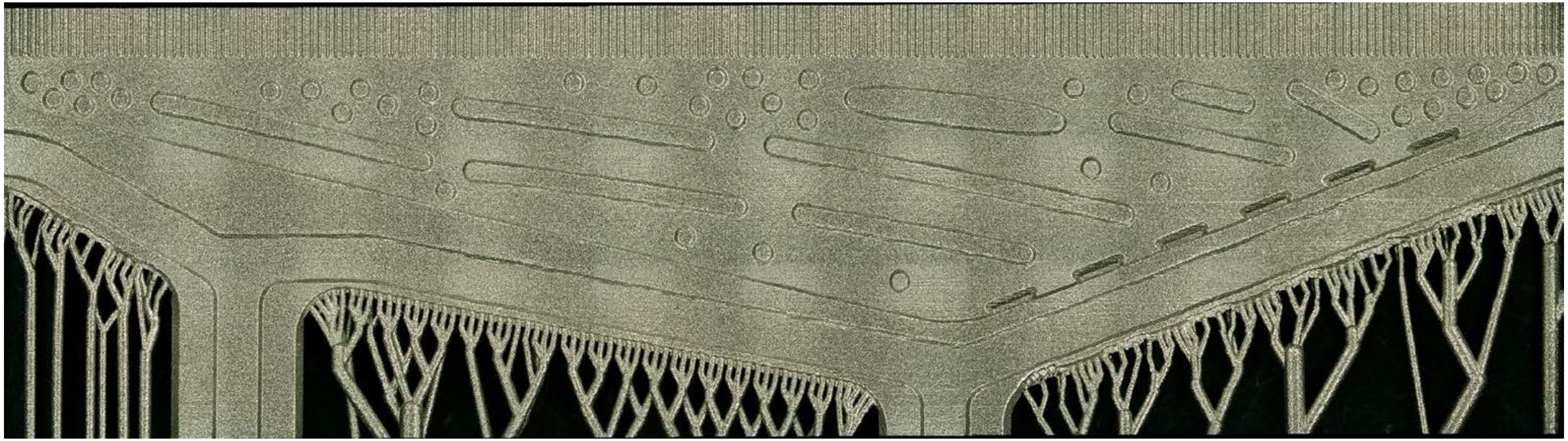


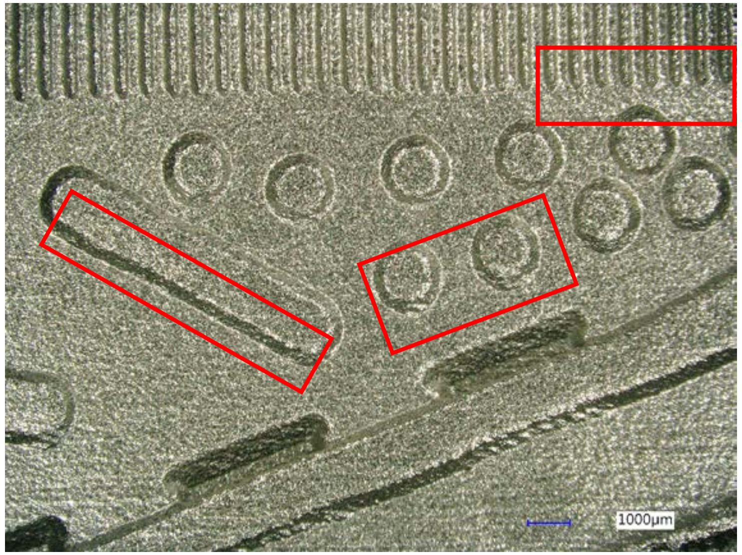
SUPPORT - BENEFIT

+ New support-geometry for better removal of powder from inside the channels
+ Better removal of support-structure after printing process

⚠ Post processing depends on target specifications

Print Results – Downskin-Area





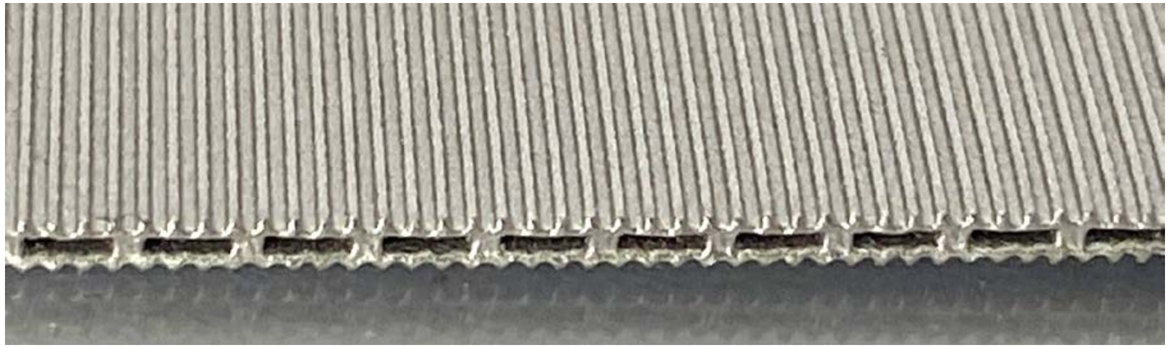
Z - Build direction

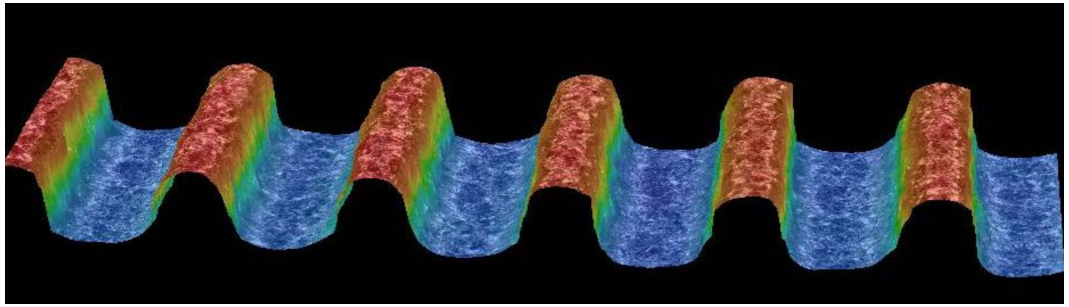
Downskin area:
(sub-)area where the normal vector projection on the z-axis is negative [ISO/ASTM 52911-1:2019]

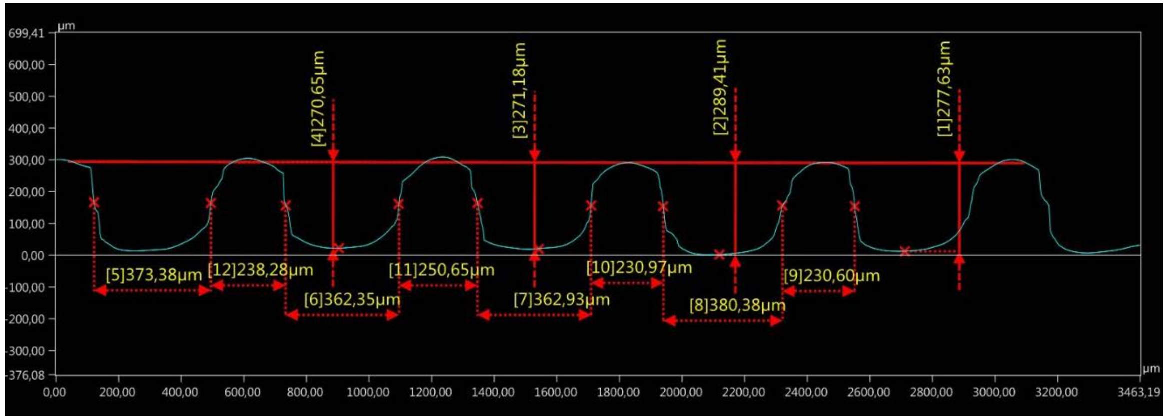
DESIGN - BENEFIT

+ Decreasing of surface roughness by adding an angle at each downskin-surface.
+ Better contour reproduction of all geometries

Print Results – Surface Profile





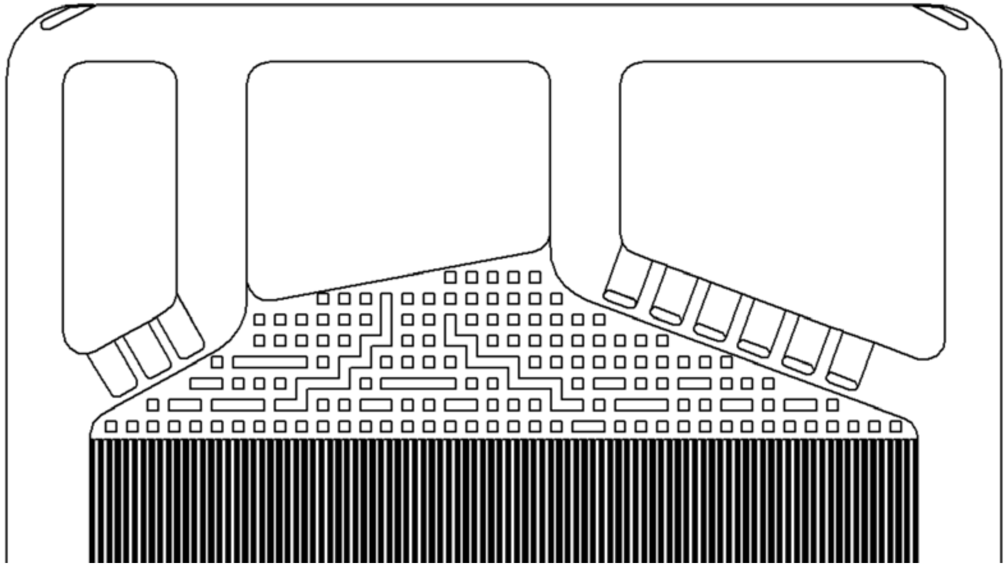


SURFACE PROFILE

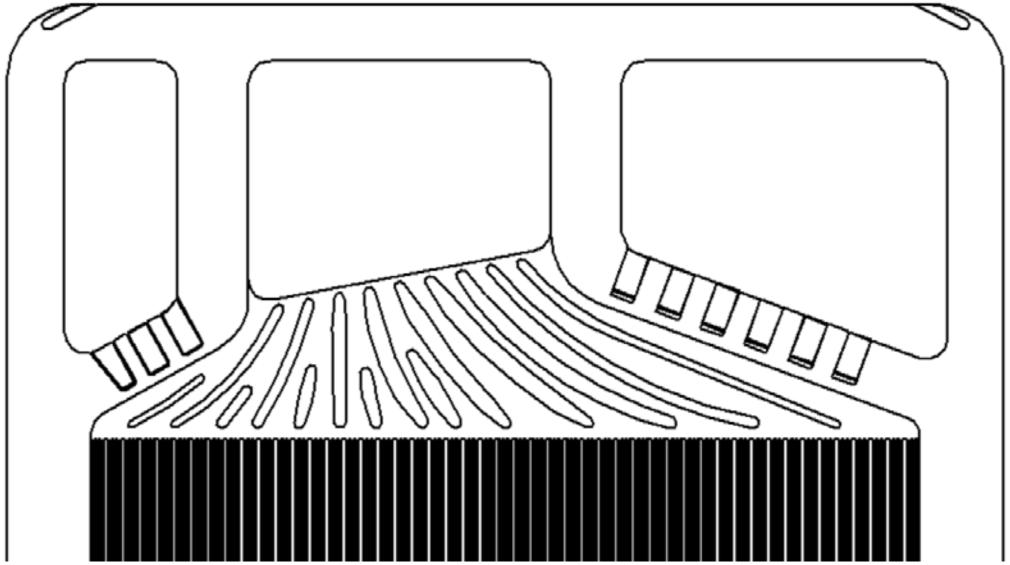
+ The arithmetic mean value of the profile height is 277.22 µm (set value 300 µm).
+ The arithmetic mean value of the profile width is 369.76 µm (set value 400 µm).

Design developed for AM – TP4 Coolant Distributor

Generic coolant distributor („digital“)

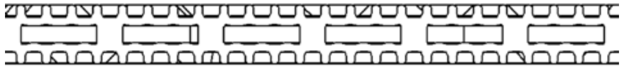


Optimized coolant distributor for additive manufacturing („fan“)



Coolant channels

Adapted coolant channels



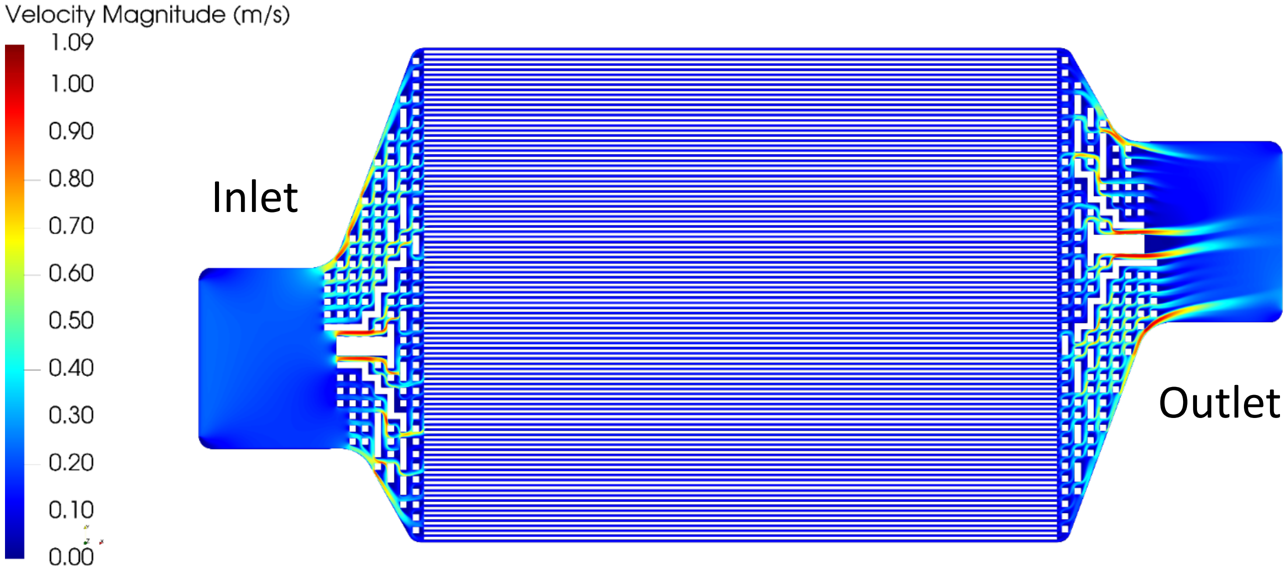
→ Design adaptions facilitate residue-free re**moval of metal powder** from inner (coolant) department after printing

CFD Results: Coolant Velocity

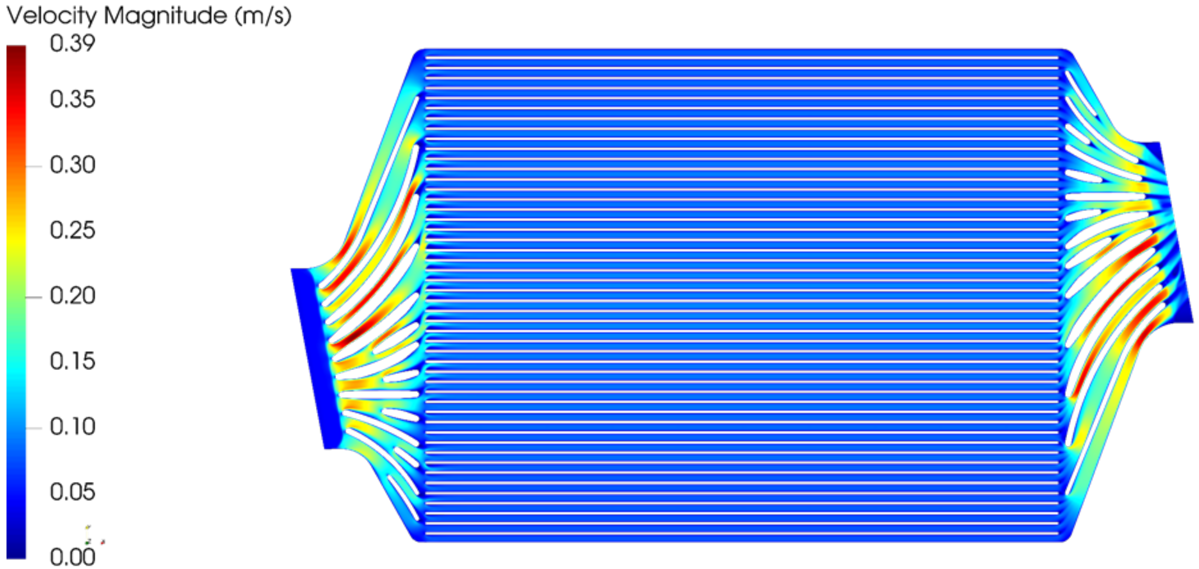
P

$P_{nominal}$

„Digital“ distributor



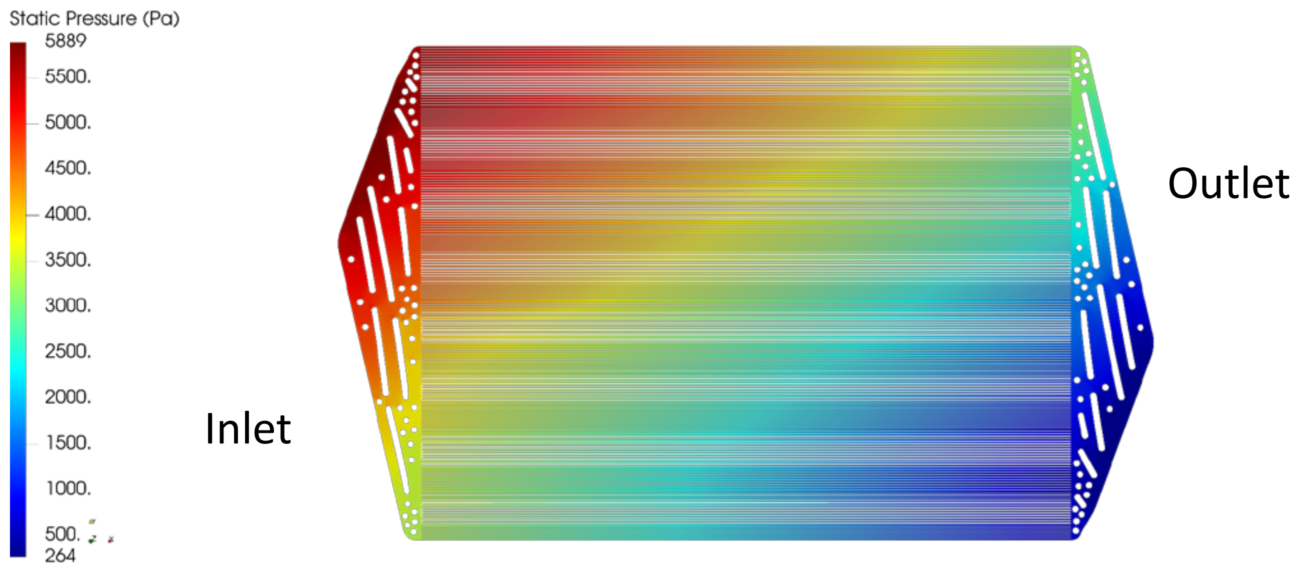
„Fan“ distributor

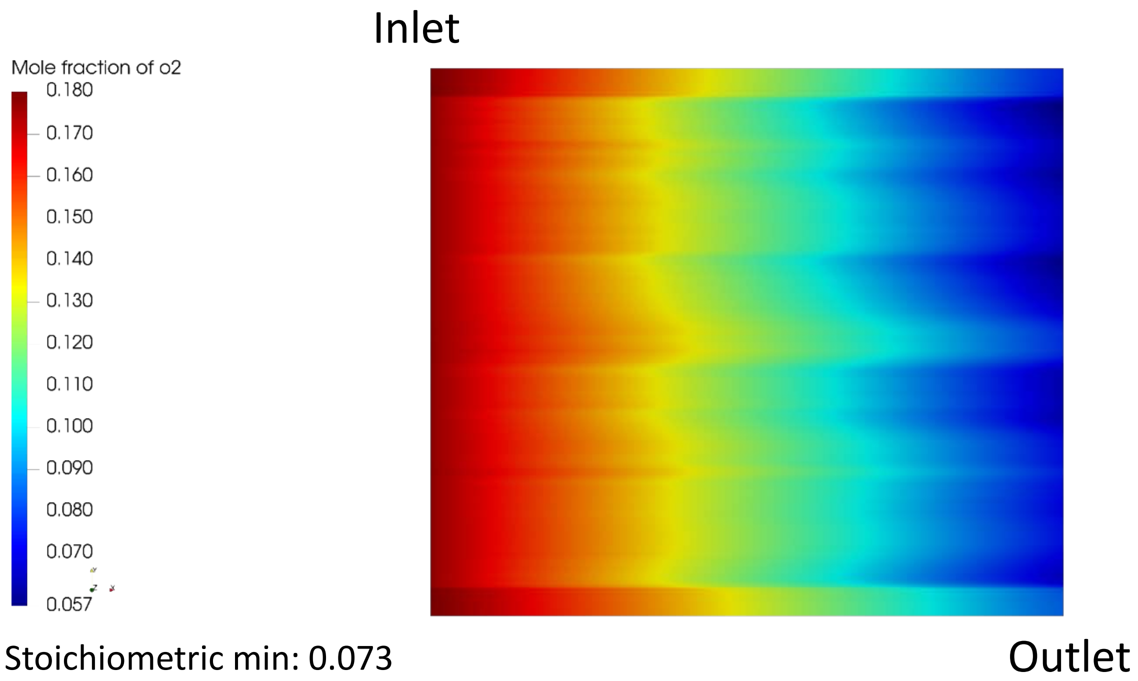


- Lower mean & maximum velocity for fan distributor, no significant drawbacks

CFD Results: Cathode Pressure & Reactant Distribution

$P_{nominal}$





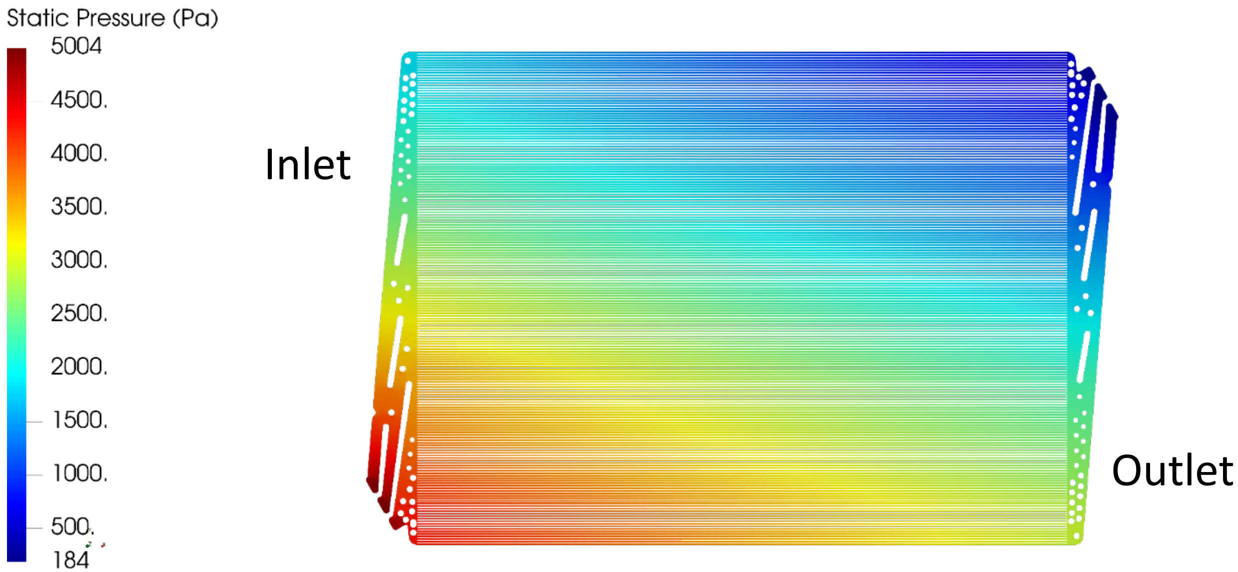
Stoichiometric min: 0.073

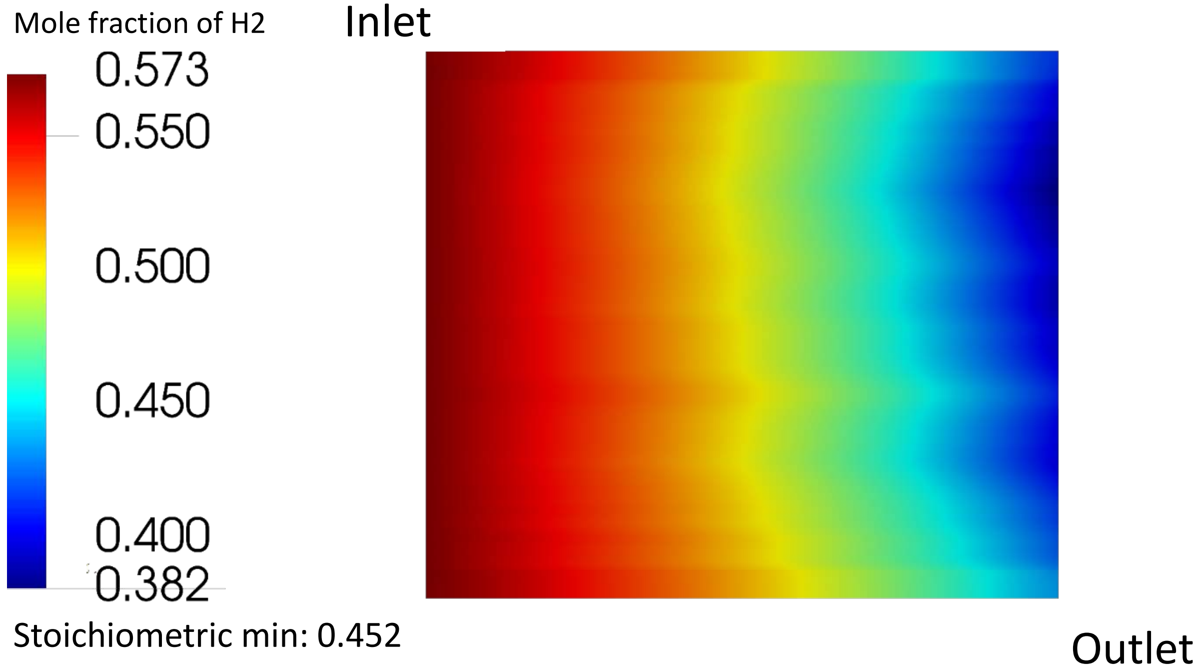
- Δp = 59 mbar (incl. ports Δp = 63 mbar)
- No starvation expected

CFD Results: Anode Pressure & Reactant Distribution

Anode-N_2 (30 mole-%)

$P_{nominal}$





Stoichiometric min: 0.452

- Δp = 50 mbar

- Good reactant distribution
- No starvation expected

Summary

- Successfull development of rib-channel-design for very high performance under constraints of AM manufacturing
- Transfer from TP2 to TP4 design in close collaboration of DMG MORI and ZSW taking into account lessons learnt with TP2
- Specific adaptions to improve print quality (downskin areas) and ensure powder removal
- Innovative support geometry for supply channels
- Still further work needed to mitigate bending effects and remaining issues, to be finalized soon
- CFD simulations to ensure appropriate functionality

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Diffusion and Protective Coating

ZSW Team: Sepehr SAADAT, Dena KARTOUZIAN, Charlène SIGUENZA, Florian WILHELM

Diffusion and Protective Coating for TP4

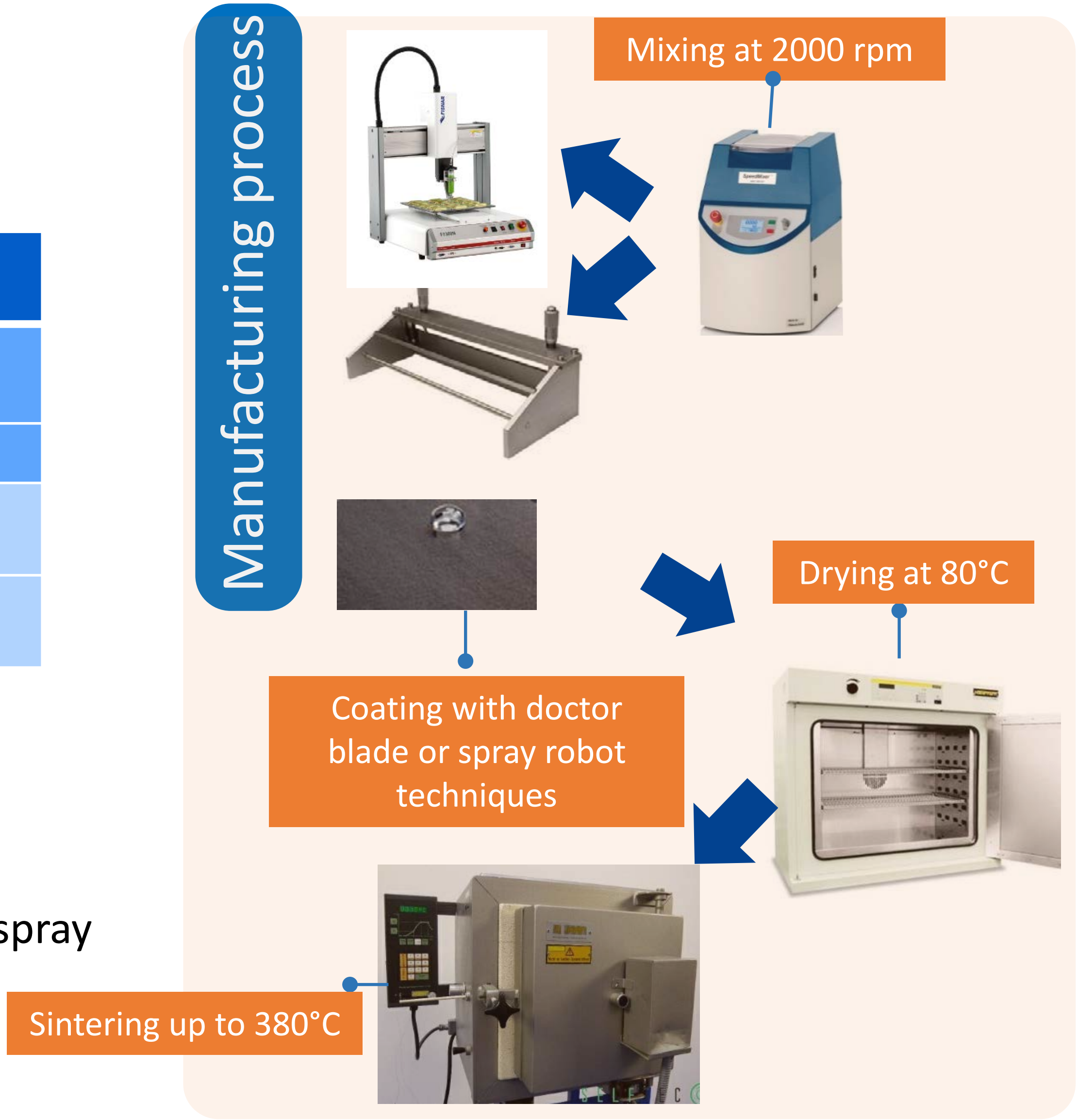
Manufacturing traditional MPL at ZSW

➢Ink Properties

Ink composition					Ink / MPL properties
Carbon	Triton X-100	Methyl cellulose	DI Water	PTFE	PTFE* content (in MPL) **
[g]	[g]	[g]	[g]	[ml]	[wt.%]
4.80	0.132	0.58	25.58	1.38	20
2.16	2.86	0.65	25.5	0.62	20

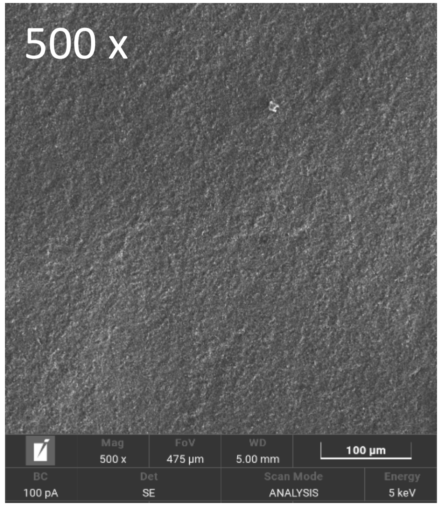
*PTFE Zonyl™ MPD 1700 (Chemours^{TM})
**PTFE content in MPL assuming no components except carbon and PTFE remain after heat treatment.

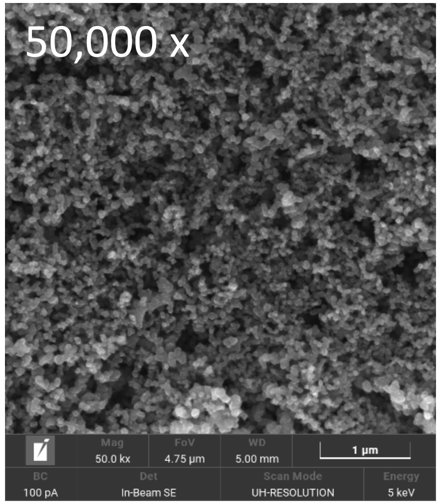
- ➢ Coating onto a commercial GDL Substrate,
- ➢ More degrees of freedom for MPL fabrication when applying spray robot.



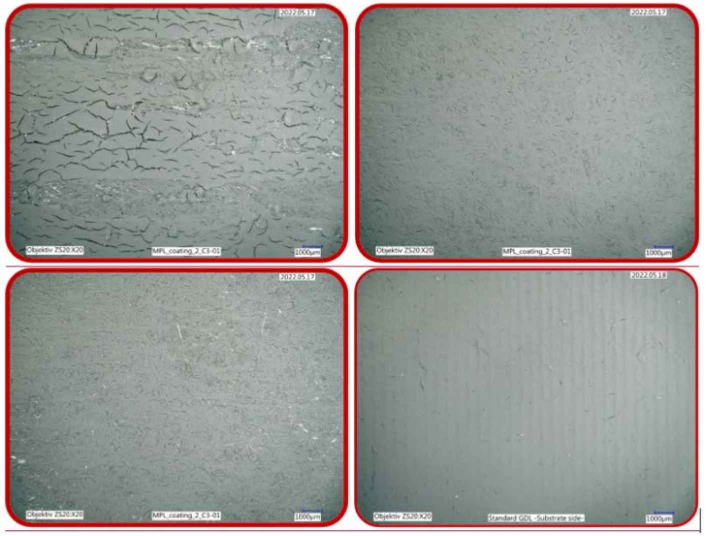
Diffusion and Protective Coating for TP4

- Investigation of coating of MPL onto the GDL substrate with machined / laser milled flowfield
- Surface and structural properties characterization
- Fabrication of MPL on thin, high performance GDL substrate, thicker substrate (mechanical machining and laser milling), as well as optimized stand-alone MPL for full-size, larger active area cells (TP2/3/4).





Optimization of the coating methods; top: doctor blade, bottom: spray robot.

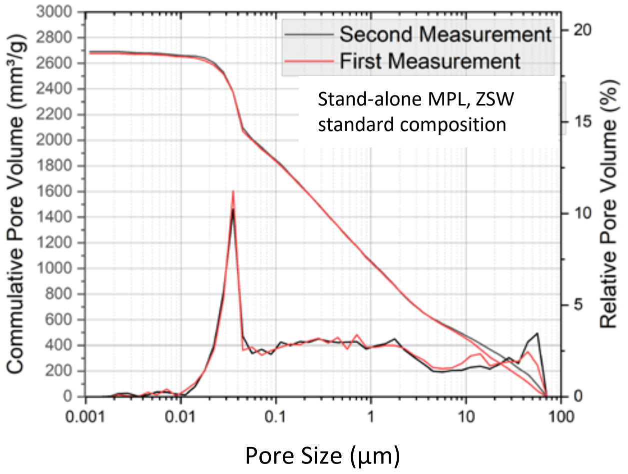


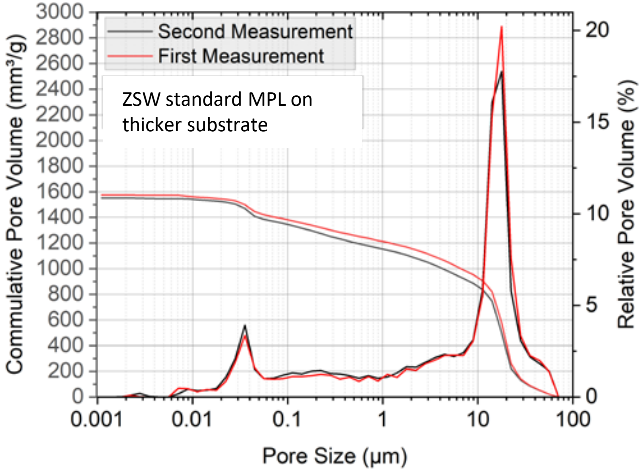
Diffusion and Protective Coating for TP4

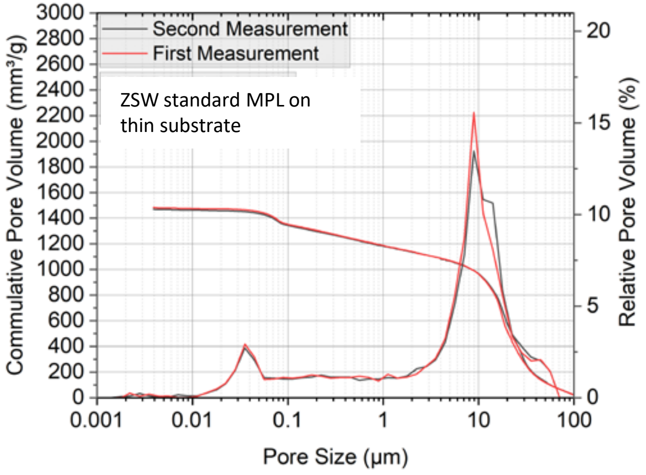
Hg porosimetry measurment for standard MPLs coated on thin, high-performance substrate, thicker substrate and standalone

- Similar pore structure for coating MPL on the different substrates
- Different pore structure for stand-alone MPL coated on glass – as could be expected, less pores in the µm range, similar maximum < 100 nm

Sample name	Porosity (%)	Total pore surface area (m²/g)	Average Pore radius (µm)
Stand-alone MPL	84.24	67.659	0.0791
MPL on thicker sub.	79.10	20.169	0.1539
MPL on thin sub.	74.06	17.528	0.1678







Summary

- Diffusion an protective coating / MPL on Toray substrate is intended to be applied for both TP4 concepts (AM EFC and FF milled in GDL)
- Successfull upscaling has been demonstrated for both cases
- Stand-alone concept will contribute to reduce diffusion pathways, overall cell pitch and costs
- Ex-situ QC to ensure appropriate and steady functionality

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Thank you for your attention!

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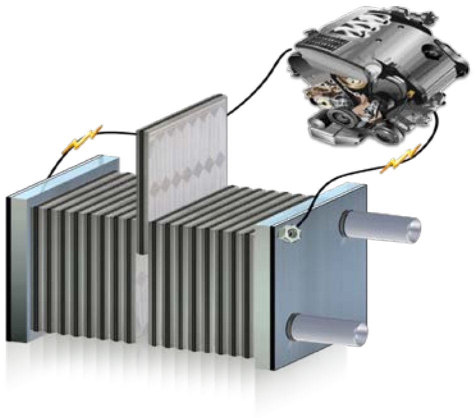

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ZSW

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