DOLPHIN

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

Innovative cell design features to improve PEMFC performances

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Presentation outline

- **Experimental strategy** for the validation of innovative concepts for Electrochemical and Electric and Fluidic Cores
- **Two main aspects**
  - **Electric and Fluidics Core**

  → Impact of the rib/channel design on the performances

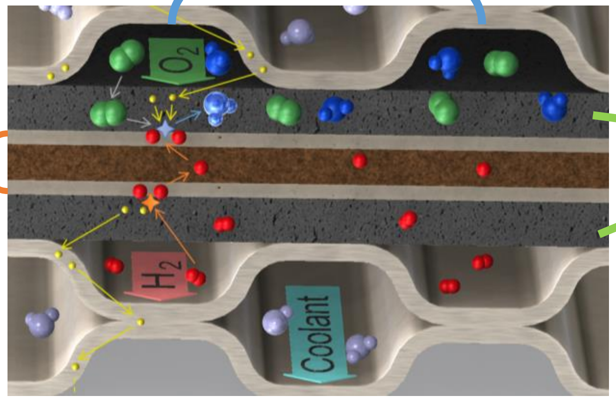
  - **Optimization of the EC|EFC interface**

  → Development of self-standing MPL materials

  → Towards the suppression of GDM support materials to reduce cell thickness

Reduction of the rib/channel size design

Electrochemical Core

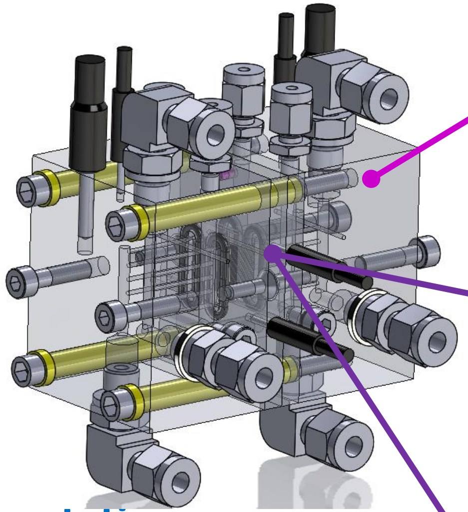


Improving interfaces & Increasing mass transport with thinner layers

DOLPHIN objectives: Increase of the performances by decreasing the cell dimensions by optimizing EC, EFC and EC|EFC interface

Presentation of the 1rst Test Plaform

- **First evaluation of the different concepts EC and EFC at small scale**
- **Use of differential cell « zero gradient »**
  - Homogeneous fluidic conditions
  - Homogeneous T°, RH and concentrations
  - Reproduction of local stack operation
- **50 cell designs to be evaluated**
  - Model Rib/channel designs **(EFC)**
    - ✓ **3D printing (CEA) and additive manufacturing (DMG Mori) presentations**
  - GDM/MPL **(Interface)**
    - ✓ **MPL presentation by ZSW**
  - CCM material (membrane and electrode composition) **(EC)**
  - Impact of Single Layer Graphene onto the PFSA membrane **(EC)**
    - ✓ **Presentation of SLG by University of Manchester**



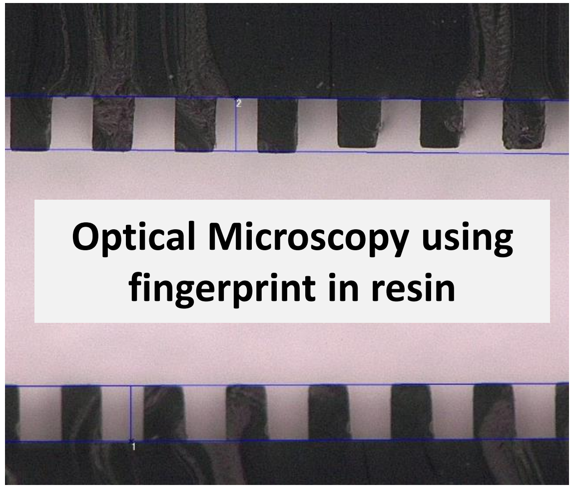
Innovative cell design features to improve PEMFC performances

Rib/Channel design: impact on performances

- **In litterature/modelling : reduction of the design pitch**

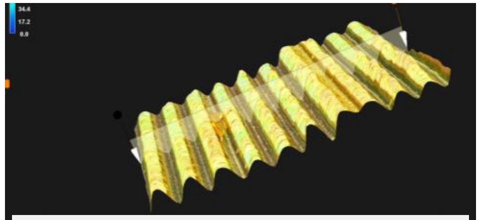
Decrease in mass transport limitations (higher gas diffusion and facilitated water removal)

- **Use of model pads with machined design rib/channel design**
  - **Stainless Steel with gold coating**
  - SoA : 600/600 µm – depth 200 µm (anode) and 300 µm (cathode)
  - 400 / 400 µm – depth 200 µm
  - 200 / 200 µm – depth 200 µm
  - 100 / 100 µm – depth 100 µm



Optical Microscopy using fingerprint in resin

- **Metrological control before cell assembly**
  - **Machined rib/channel design : OK down to 200 /200 -200 µm**
  - ***Some local milling defects for the thinnest design with 100/100 -100 µm***



Optical Microscopy

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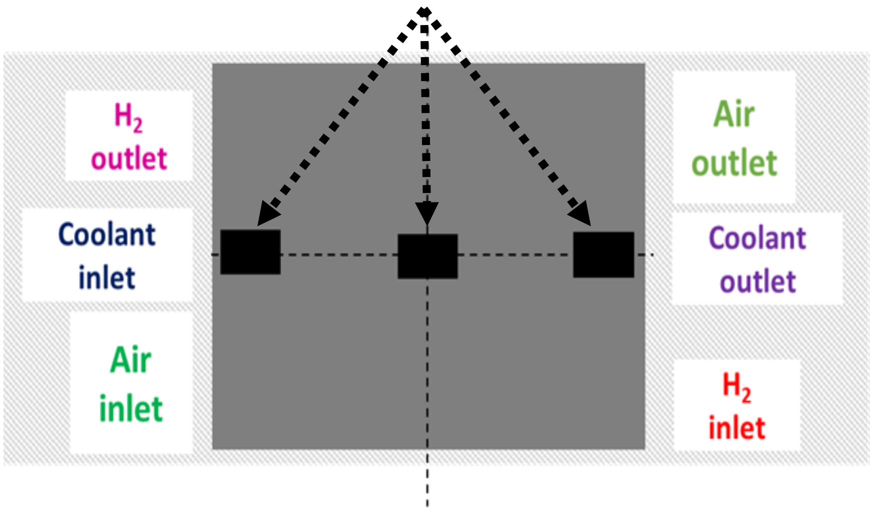
Rib/Channel design: experimental protocols

- **Experimental approach based on system and stack specifications**
- **Further definition of local operating conditions based on modeling at cell level**
- **Reference and commercial materials used as EC and EFC**
  - Commercial Gore PRIMEA 3-layer CCM
  - H14C7 as GDL compressed at 125 µm within the cell

	Local conditions H2/air	T / °C	P bara	RH (%)	% O2 (dry)	H2 Nl/h	Air Nl/h	N2 Nl/h
Max power conditions	H2 outlet /Air Inlet	85	2.2 / 2.2	98 / 30	21	38	95	--
	Middle zone	90	2.2 / 2.2	90 / 72	14.5	38	65.6	29.4
	H2 Inlet / Air Outlet	95	2.2 / 2.2	50 / 80	7.8	38	35.3	59.7
Low power conditions	H2 outlet /Air Inlet	70	1.3 / 1.3	98 / 50	21	38	95.0	--
	H2 Inlet / Air Outlet	70	1.3 / 1.3	50 / 92	9.3	38	42.1	52.9
Flooded Water management	Middle zone	70	1.3 / 1.3	> 100%	15	38	67,9	27,1

3 local areas considered



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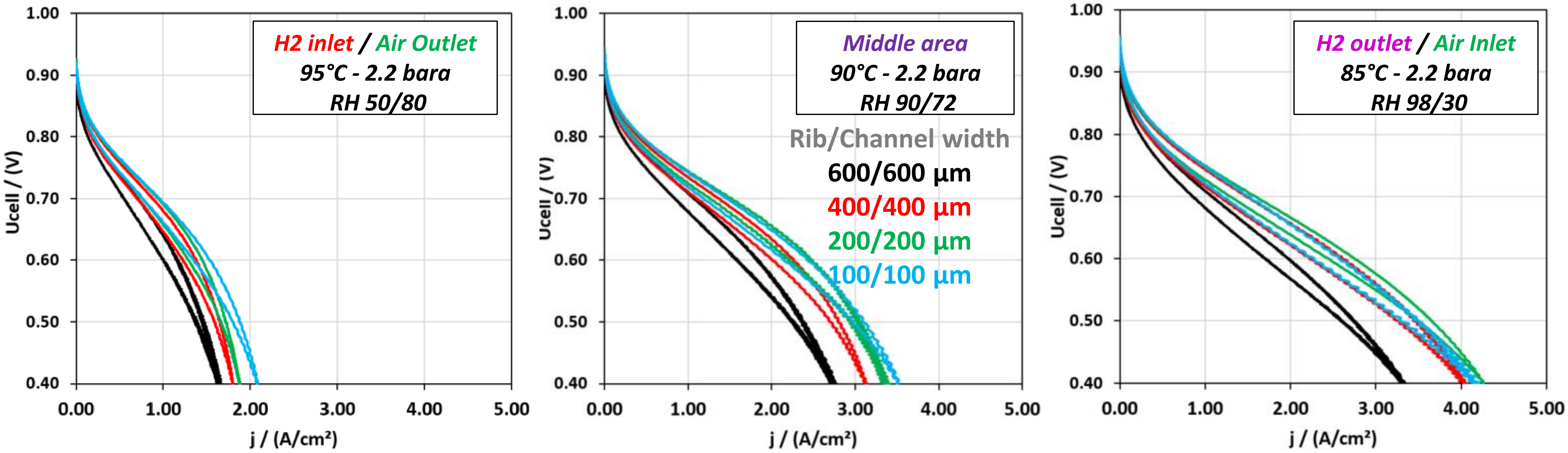
Rib/Channel design: results

- **Characterization of local performances at maximum power conditions**



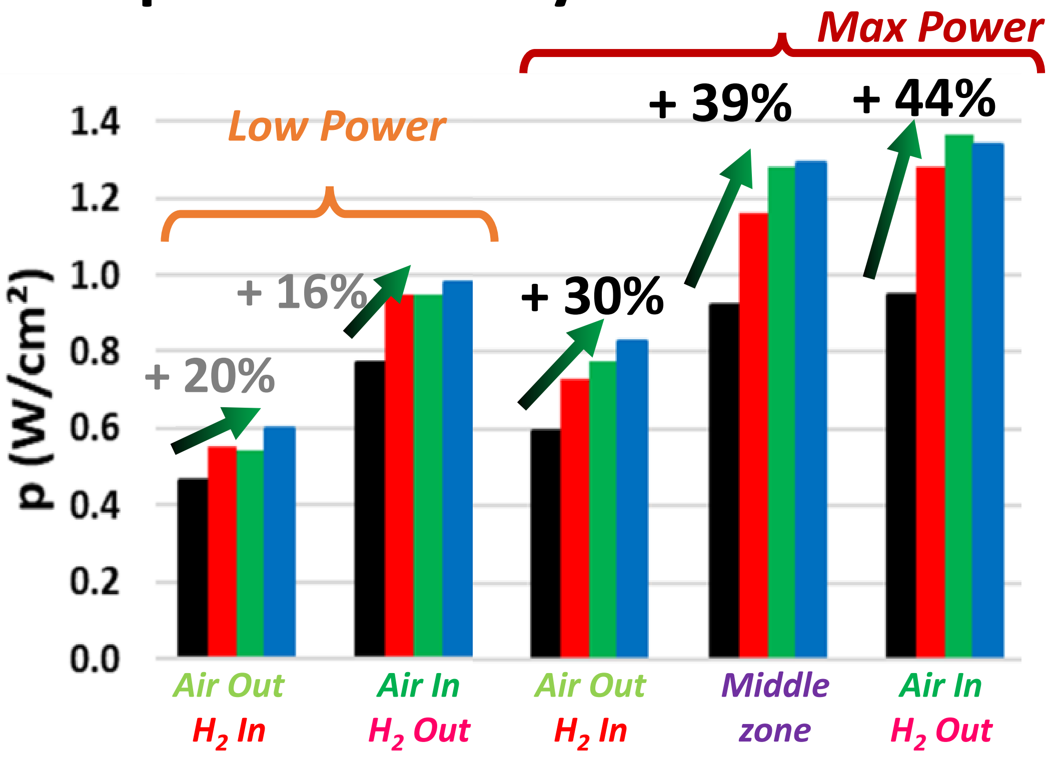
Performances greatly improved by reducing the rib/channel size in every local area and under every operating condition

→ **Even in differential/zero gradient cell with high stoichiometries : flow-field design strongly impacts the raw performances**

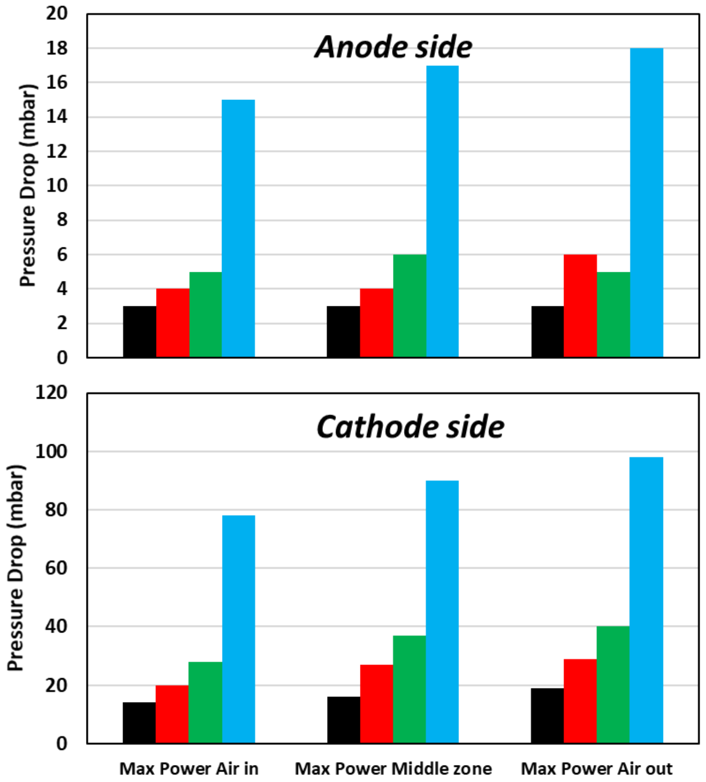
→ **High interest to decrease rib/channel size down to at least 400 µm – Minor improvement below 200 µm**

Rib/Channel design: results

- **Local power density evolution at 0.66 V**



- **Pressure drop evolution**



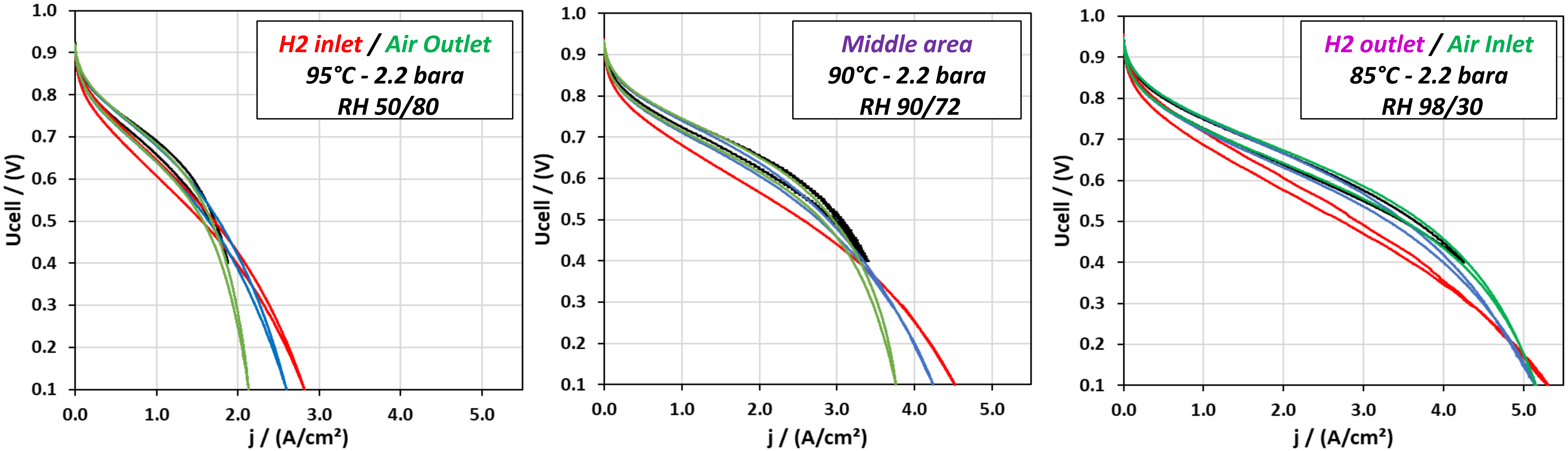
- Performance increased in every condition with refined flow field
- Power density enhancement : +30%/+44 % @ 0.66 V at max power
- No significant difference between 100/100 & 200/200 µm designs

- High pressure drop below 200/200/200 µm design
- « 100 µm size » not realistic for cathode side on large active surface area

Innovative cell design features to improve PEMFC performances

Innovative/Improved EC|EFC interface design

- **Characterizations of 4 configurations**
  - **SoA MEA configuration : Commercial GDL H14C7 from Freudenberg on both sides (thickness without flowfield ca. 280 µm)**
  - **Advanced « no-GDM » MEA configuration (thickness 80 µm : -70 %)**
  - **« Single-sided GDL » MEA: MPL at the anode vs. MPL cathode (thickness 180 µm : -35%)**



- Suppression of both GDM layers : reduced performance due to local drying in the CCM near inlet/outlet areas
- Refined rib/channel « 200 µm » + single GDM suppression
→ Similar / slightly improved perf. vs. reference case

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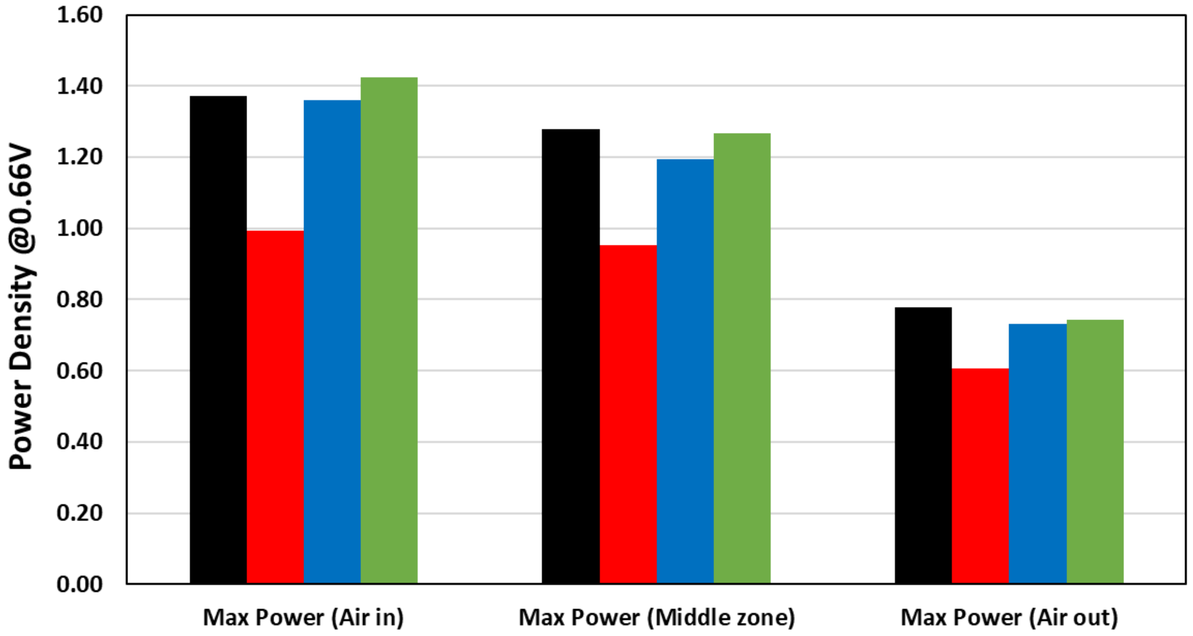
Innovative/Improved EC|EFC interface design

- **Comparison of power density at 0.66 V**



SoA reference configuration
H14C7 (GDM+MPL): Anode + Cathode

No GDM configuration
Self-standing MPL: Anode + Cathode

Single-sided GDL configurations
H14C7 Anode + MPL Cathode
MPL Anode + H14C7 Cathode

- Lower power density than reference under maximum power conditions when removing both GDM layers

- Similar / slightly improved performance with single-sided GDL configuration vs. reference case
→ **Promising configuration to decrease total cell thickness**: increased stack power density and reduced costs
→ **To be tested and validated using « real » large single cell (2^{nd} Test Platform)**

Innovative cell design features to improve PEMFC performances

Conclusions

- **Refining Rib/Channel design is really interesting to improve local performances and local power density**

- **Minor performance enhancement between « 200 µm » and « 100 µm » rib/channel design**
  - Mass transport limitations « shifted » to GDM / GDL layers (ca. 125 µm thick) ?
  - Performances limited by SoA catalyst layers ?

- **Suppression of GDM support / Use of « single-sided GDL » MEA**
  - Promising results on 2 cm^2 cell to reduce the overall cell thickness
  - To be up-scaled and characterized in large single cell in the forthcoming months

Thank you for your attention!

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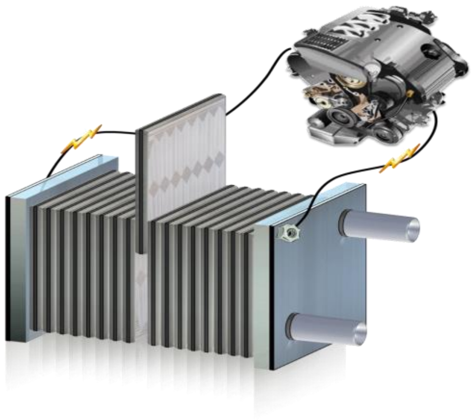
Processes, arcHitecture and optimized INterfaces



DOLPHIN Project: 1st public workshop (cell and manufacturing technologies) - virtual – 18/06/2021