High-Chromium Porous Steels for Metal-Supported Solid Oxide Electrolysis Cells

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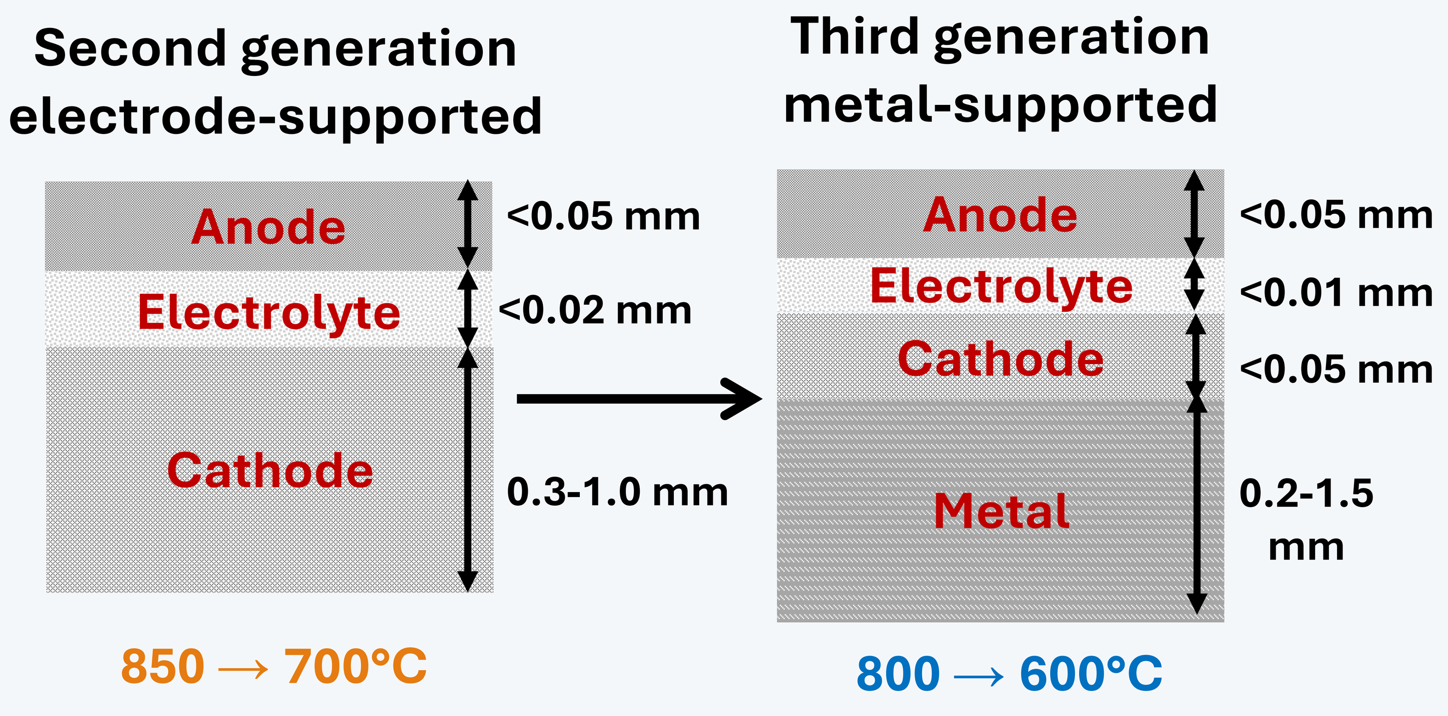
Context

Advantages of metal-supported SOECs over electrode-supported SOECs

- *Enhanced mechanical strength and high redox tolerance,* ensuring better durability and reliability
- *Reduced electrolyte thickness,* enabling lower operating temperatures and ohmic resistance
- *Lower production costs* owing to optimized material usage
- *Superior tolerance to high thermal gradients* (>100°C/cm) and *rapid thermal cycling*

Major issues of metal-supported SOECs

- *Ni/Fe-Cr interdiffusion*: Ferritic-to-austenitic transformation, higher electrical resistance
- *Thermal expansion*: Stress-induced cracking and delamination of brittle layers
- *Ni coarsening*: Reduced specific surface area (decreasing of triple phase boundaries), increased ohmic resistance
- *Cr poisoning*: Deposits on anode active sites reducing electrochemical performance

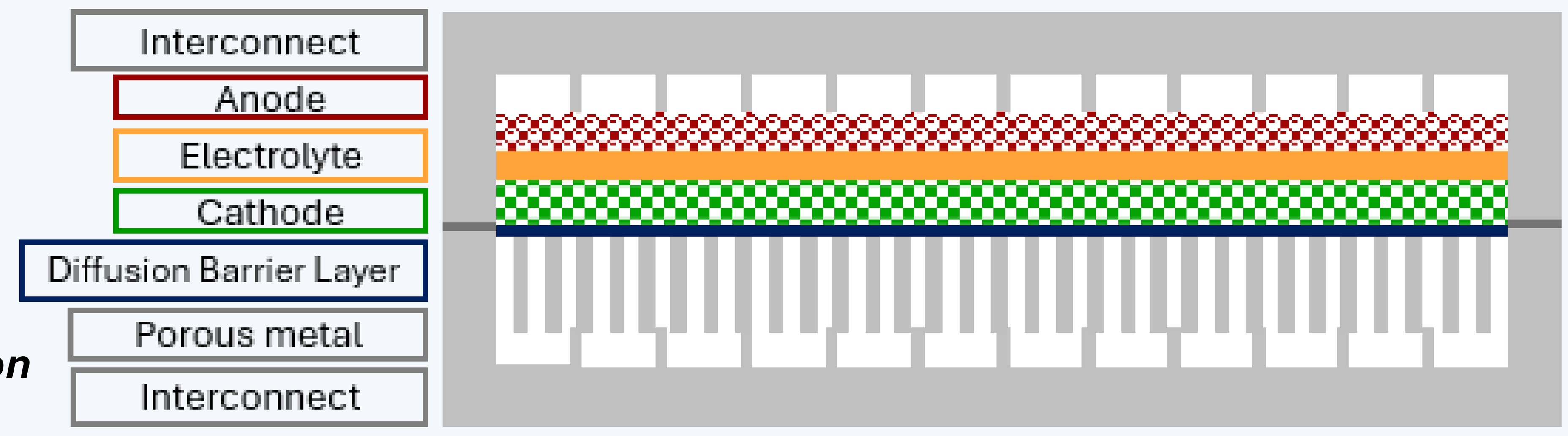


Objectives

Progressive development of novel MS-SOEC:

- Structured porous metal to improve mechanical stability and gas transport.
- Oxidation study under real conditions to reinforce the chemical stability of the metal support and the mechanical stability of the oxidation layer.
- Diffusion barrier layer to limit the diffusion of metal species.

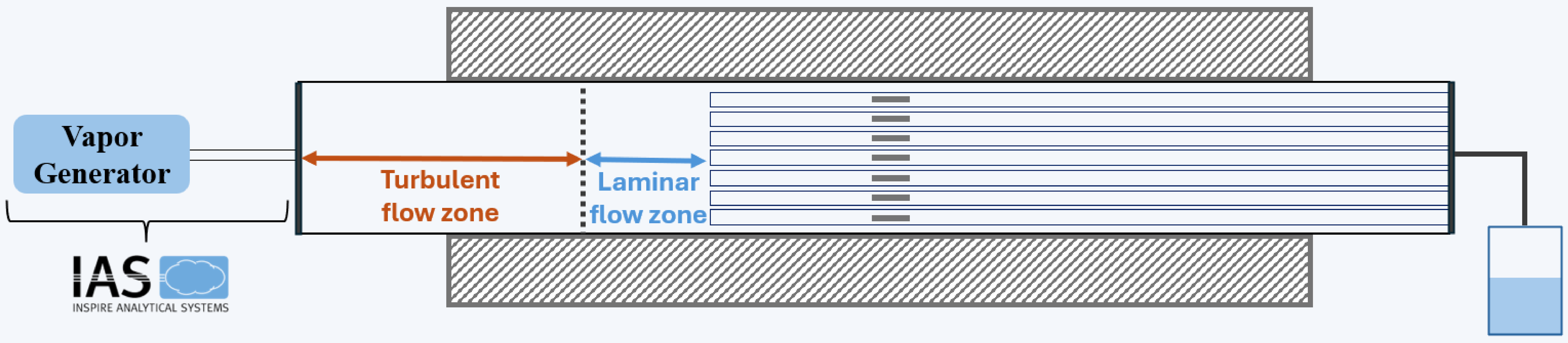
⇒ ***Increase cell lifetime and reduce financial cost of hydrogen production per kg***



Methodology

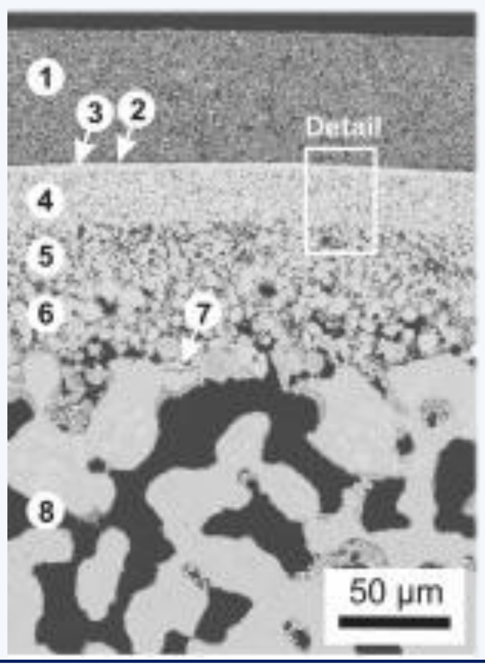
- ***Oxidation***:

Experimental conditions:
H_2O/H_2: 95%/5% (vol.)
T°: 500-900°C



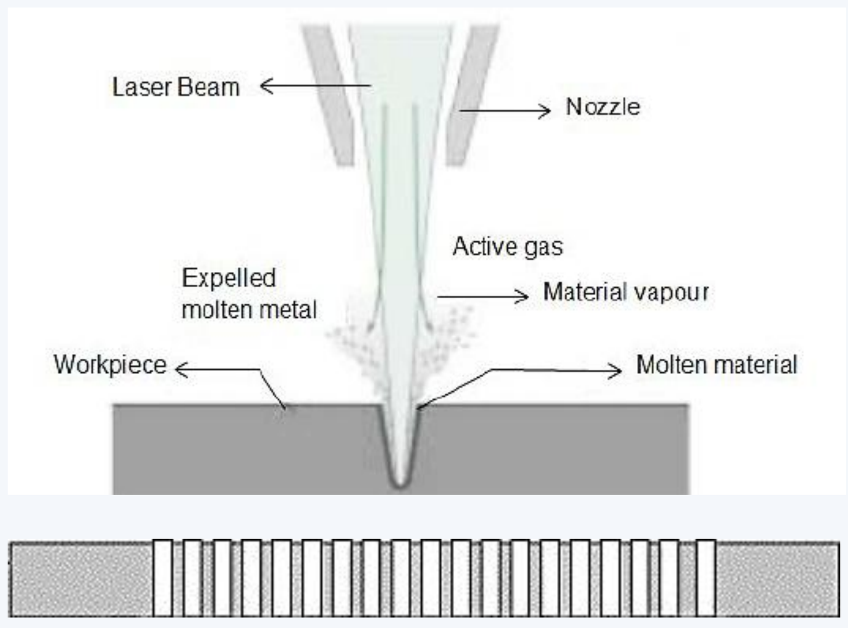
- ***Porous Metal***:

Sintering



D. Udomsilp et al, Cell Reports Physical Science, 2020

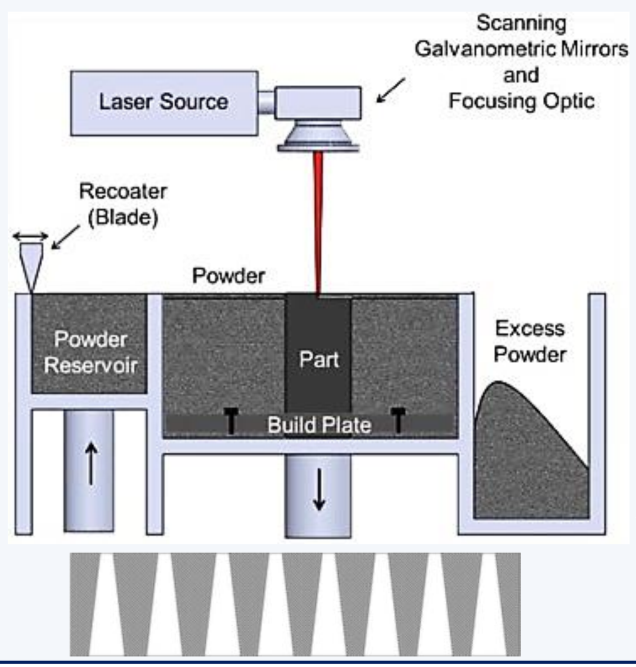
Laser Drilling



S. Marimuthu et al, Lasers in Manufacturing Conference, 2015

R.T. Leah et al, Journal of Power Sources, 2005

Additive Manufacturing LPBF



A. Gaikwad. et al., Materials & Design, 2022

Results

- ***Porous Metal***:

Size: 12X12X4 mm

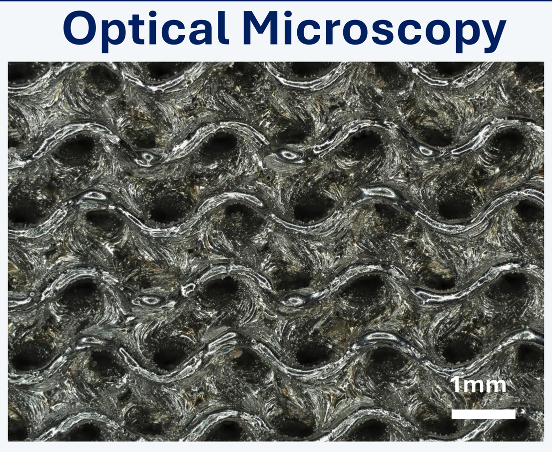
Lattice type: Gyroid

Experimental conditions:

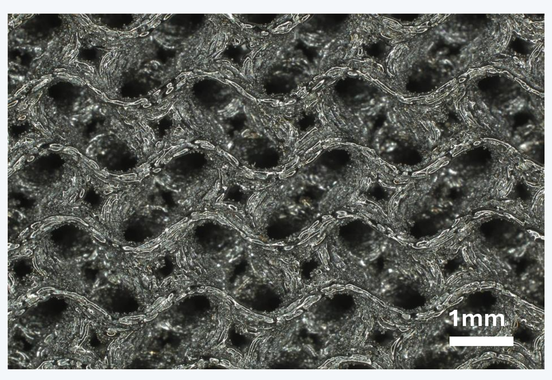
- Head Space : 70 µm
- Thickness : 30µm
- Power : 55-70-85-100%
- Rate : 800-1200-1600-2000-2400 mm/s

Optical Microscopy

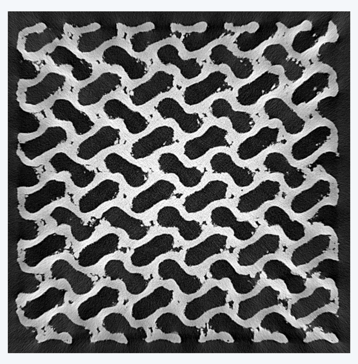
Higher VED



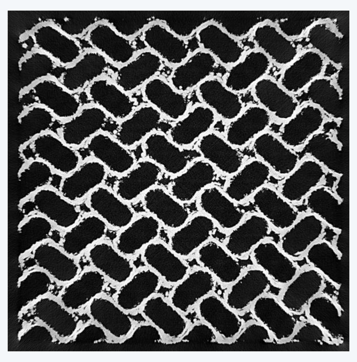
Lower VED



Tomography

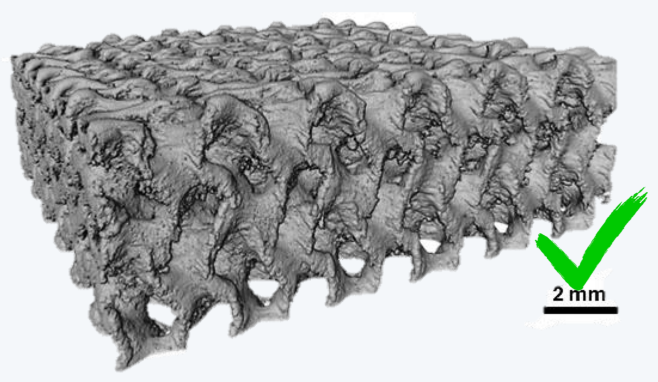


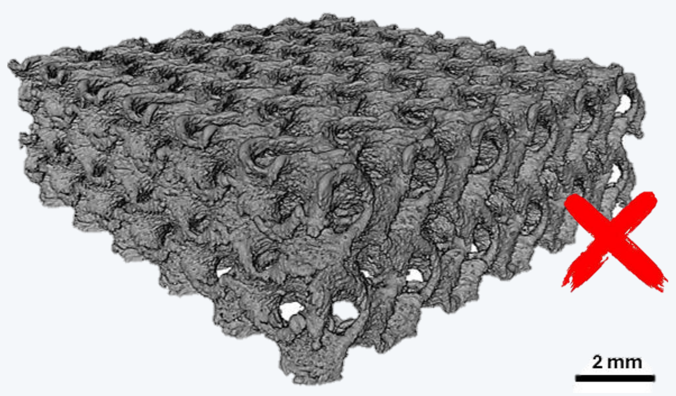
Voxel size: 11 µm



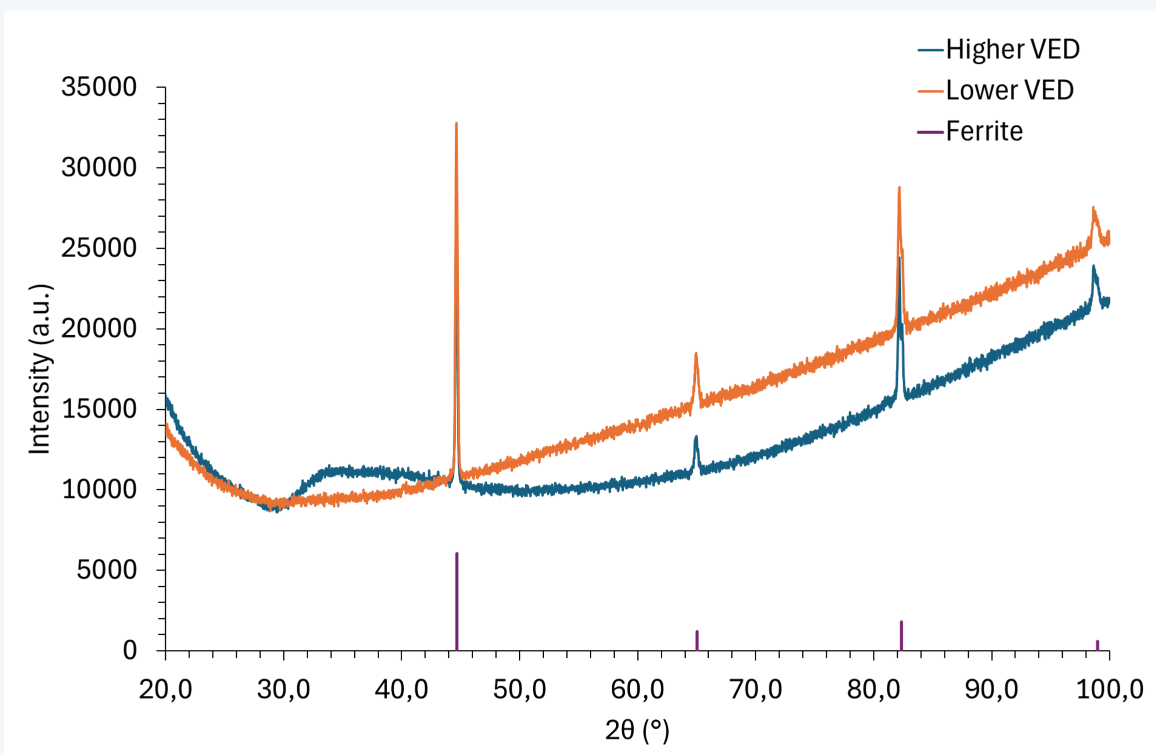
Voxel size = 10 µm

Avizo reconstruction





DRX:



Conclusion & Perspectives

- **Oxidation:**
  - ❖ Complete assembly of the system;
  - ❖ Test to see how the whole system behaves and check the flow in each quartz tube;
  - ❖ Launching of first tests
- **Porous Metal:**
  - ❖ AM of a simpler lattice in a column or trapezoid shape (thinness of the metal);
  - ❖ See if another manufacturing method is possible

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