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

M.-J. Charlier[1*], M. Larnicol[2], P.-O. Santacreu[3], P. J. Jacques[1], T. Pardoen[1,5]

[1]UCLouvain, Institute of Mechanics, Materials and Civil Engineering, 1348 Louvain-la-Neuve, Belgium

[2]CRM Group, 4000 Liège, Belgium

[3]APERAM, F-62330 Isbergues, France

[5]WEL Research Institute, 1300 Wavre, Belgium

* marie-julie.charlier@uclouvain.be

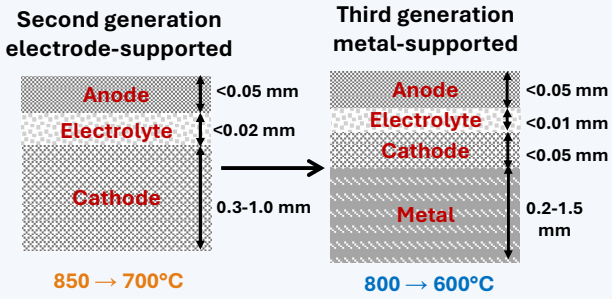
Context

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.

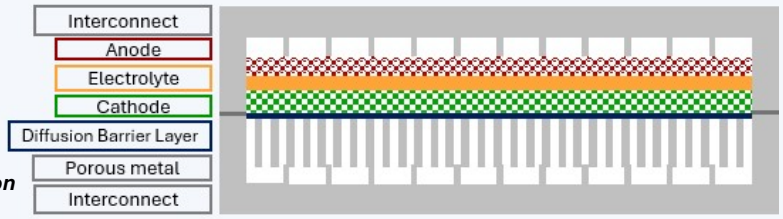


Objectives

Progressive development of novel MS-SOEC:

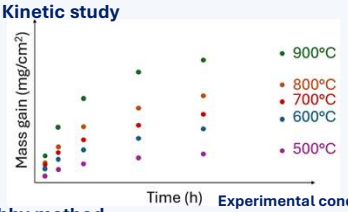
- Structured porous metal to improve mechanical stability and gas transport.
- Oxidation study under real temperature and atmosphere conditions to improve chemical stability of metal support and mechanical stability of oxidation layer.
- Diffusion barrier layer to limit the diffusion of metal species.

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

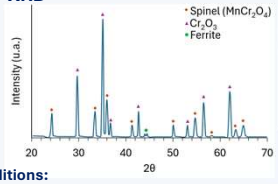


Methodology

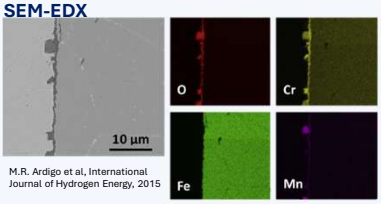
Kinetic study



XRD

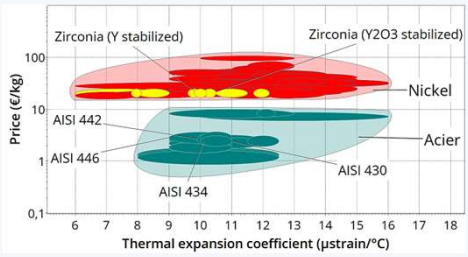


SEM-EDX



M.R. Ardigo et al, International Journal of Hydrogen Energy, 2015

Materials selection using Ashby method

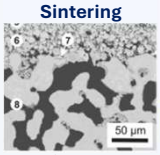


Experimental conditions:

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

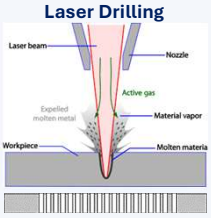
1 Material selection → 2 Oxidation study → 3 Porous Metal Fabrication

Sintering



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

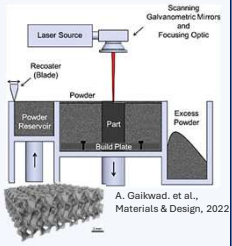
Laser Drilling



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

A. Alzaydi, Optical Engineering, 2018

Laser Powder Bed Fusion



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

Results

- ***Porous Metal*:**

Size: 12X12X4 mm

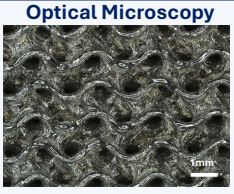
Lattice type: Gyroid

Experimental conditions:

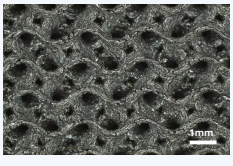
- Hatch Space : 70 µm
- Thickness : 30µm
- Power : 55-70-85-100%
- Rate : 800-1200-1600-2000-2400 mm/s

Optical Microscopy

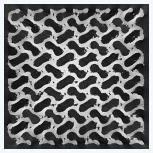
Higher VED



Lower VED



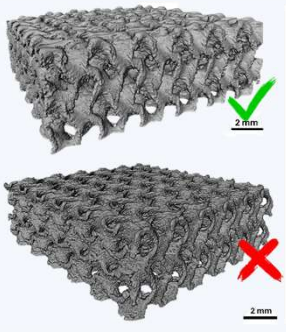
Tomography



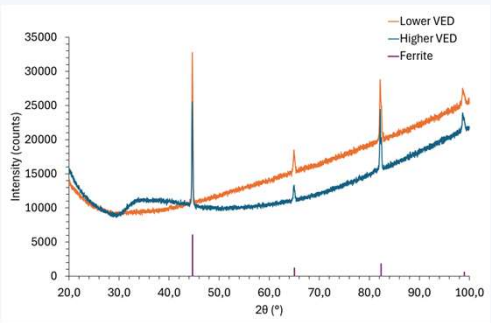
Voxel size: 11 µm

Voxel size = 10 µm

Avizo reconstruction



XRD:



Conclusion & Perspectives

- **Oxidation:**
  1. Ferritic stainless steel is identified as the most suitable material by Ashby method, as supported by literature.
- **Porous Metal:**
  1. Ferritic stainless steel is easily printable.
  2. No phase transformation during 3D printing, as shown by XRD.

- **Oxidation:**
  1. Complete the installation of the oxidation system.
  2. Check that the system is operating correctly.
  3. Starting the first experiments.
- **Porous Metal:**
  1. Design of a simpler lattice where the pores will be cylindrical or trapezoidal.
  2. Investigate the possibility of using a different manufacturing method.

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