Flow-engineered 3-D printed electrodes for enhanced bubble evacuation during alkaline water electrolysis

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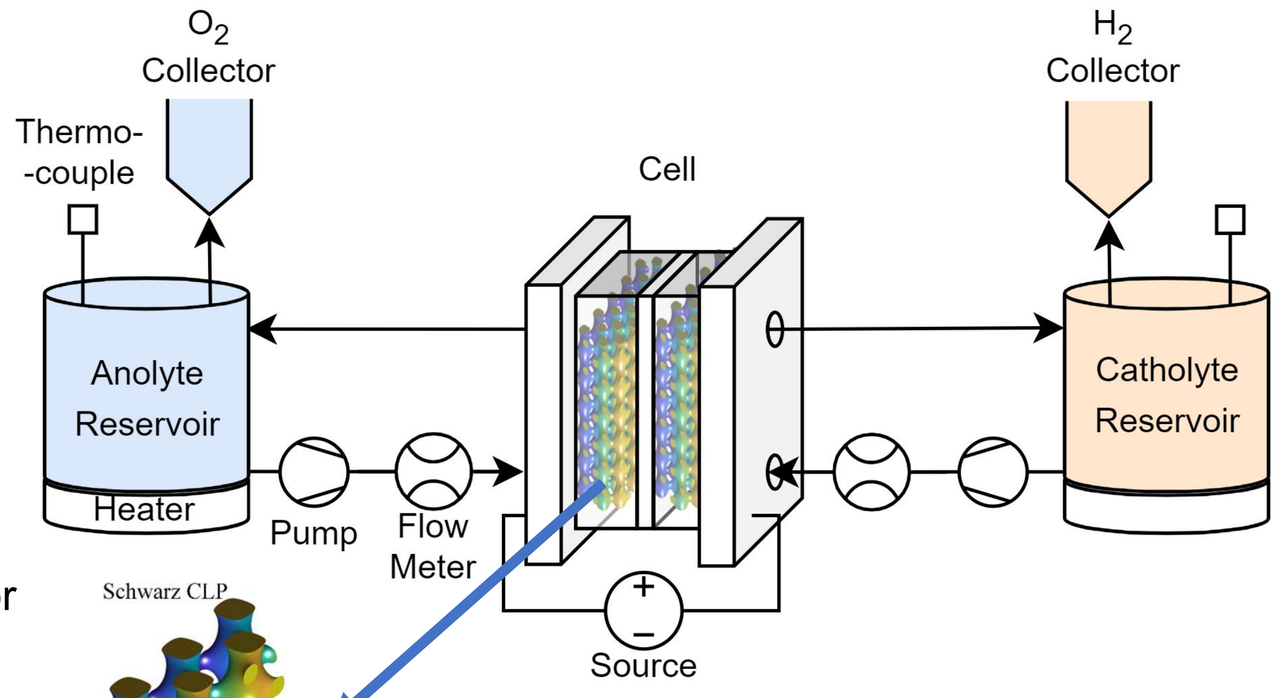
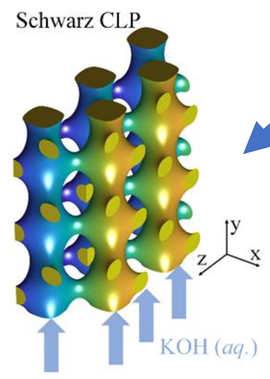
INDUSTRIAL ALKALINE ELECTROLYZERS

- 2-D bipolar plates as electrodes
- Important physical gap between the electrodes (~2 mm)
- No efficient gas extraction mechanism leading to:
  - High ohmic resistance & low electrochemical active surface area from gas screening
  - Limited current density: 0.5 A/cm²



3-D PRINTED ELECTRODES

- Interelectrode distance limited to the thickness of the separator (zero-gap cell)
- Higher surface area available for the reaction
- Gas evacuation enhancement using:
  - Optimized geometry
  - Electrolyte forced flow

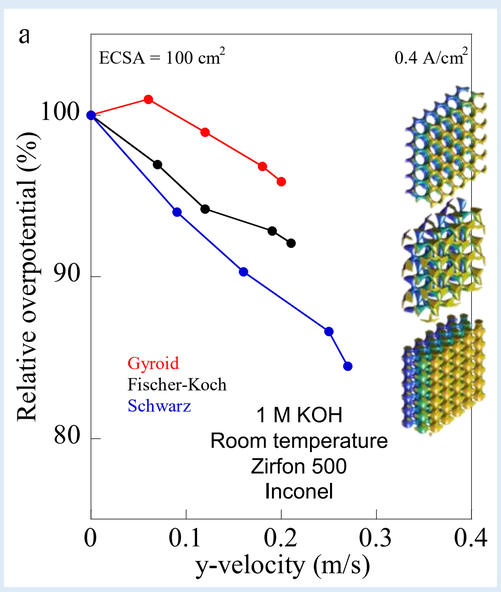


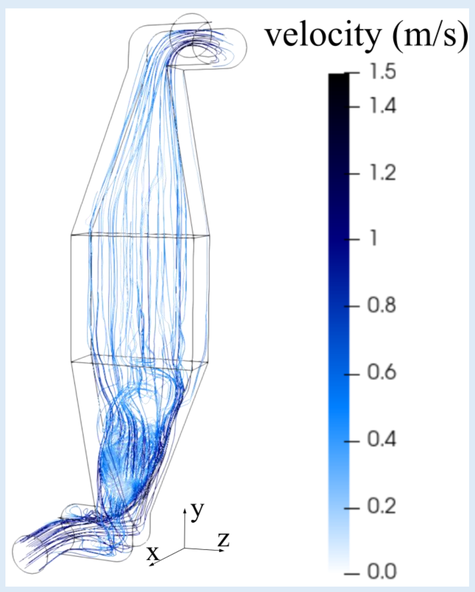
TPMS geometries are defined by an equation with 2 parameters. Schwarz CLP:

$$t = sin\left(\frac{2\pi z}{L}\right) \cdot sin\left(\frac{2\pi x}{L}\right) - 0.4 \cdot sin\left(\frac{2.4\pi y}{L}\right) \cdot cos\left(\frac{2\pi z}{L}\right) \cdot cos\left(\frac{2\pi x}{L}\right)$$

with t related to the strut size and L to the lattice size.

TPMS flow sensitivity

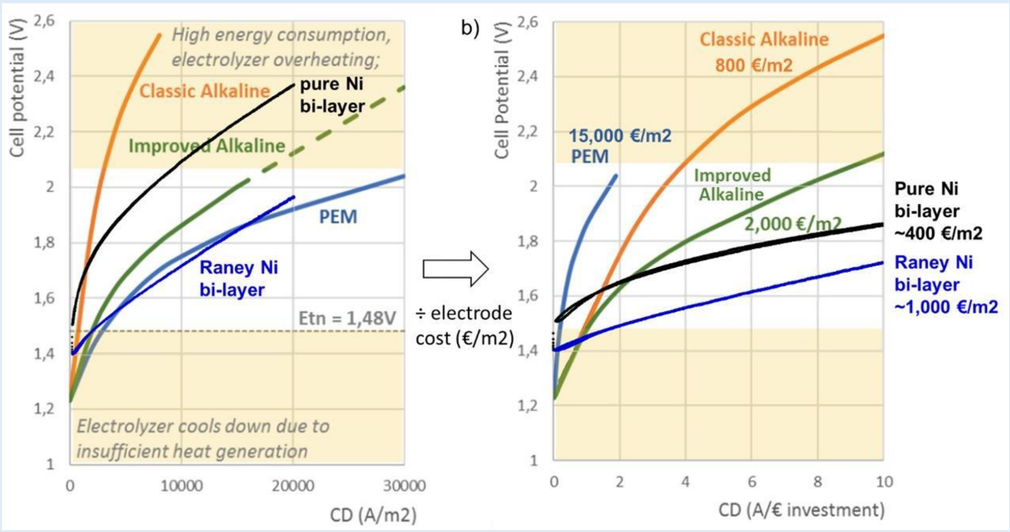


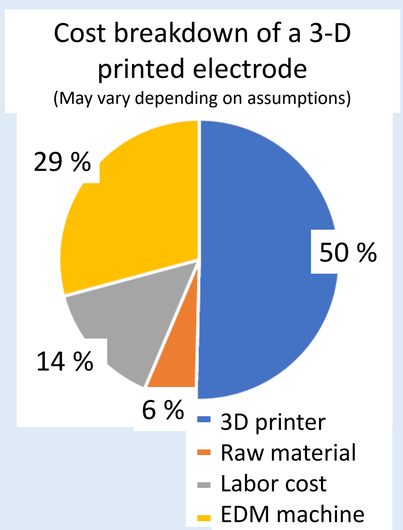


- The **Schwarz CLP** geometry shows **higher flow sensitivity** at similar electrochemical surface area and porosity**.** Thanks to its channels, **pressure drop** and bubble **residence time** are **reduced**.

Rocha F. et al., *Advanced Energy Materials* 13, (2023)

Water electrolysis intensification

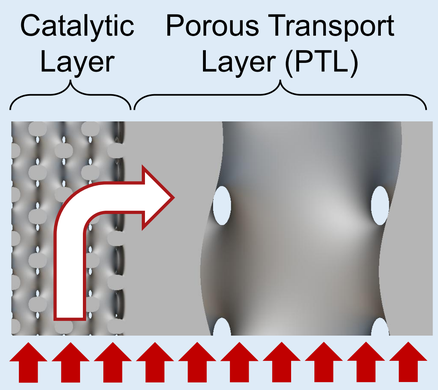




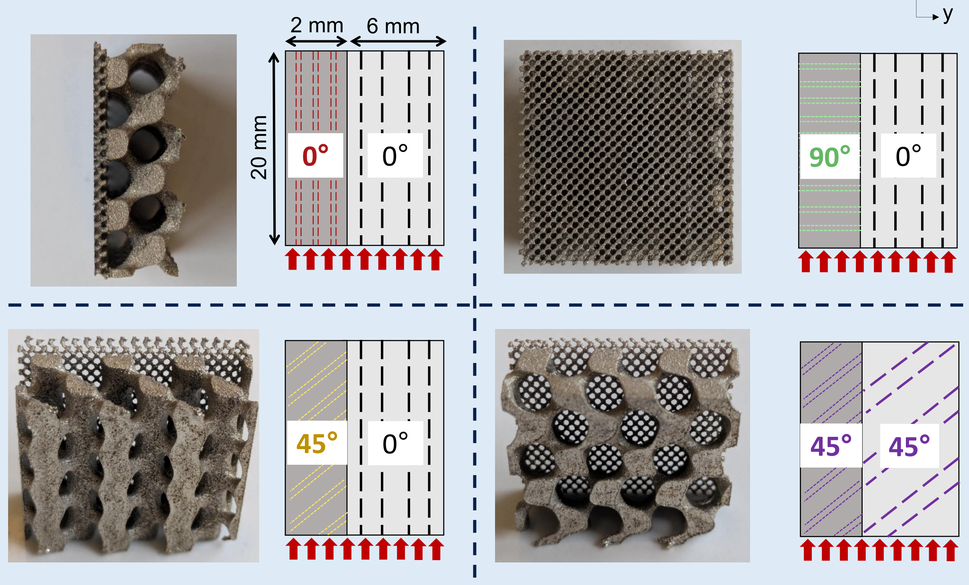
- Optimal process: **2500 €/m².**
- Reducing the size of the electrode **reduces all stack parts**.
- **Safer** use of high temperature and pressure with smaller equipment.

3-D printed bi-layer

Bi-layer principle

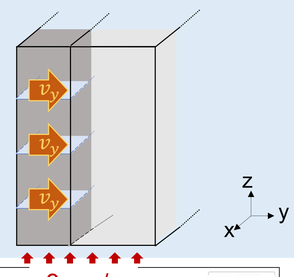


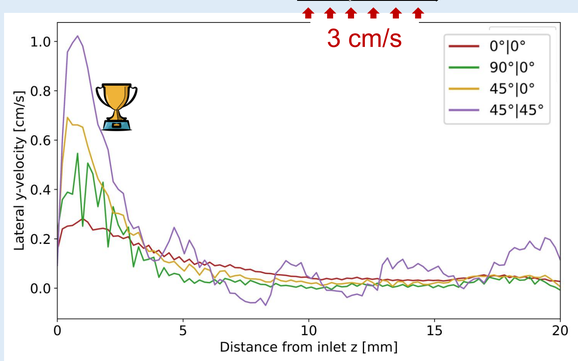
Configurations – Channel orientations



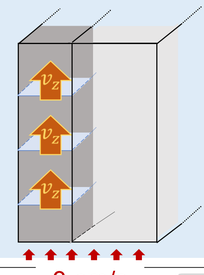
- Due to the Bernoulli principle, a **pressure gradient** between the 2 layers attracts the **bubbles towards the PTL**, away from the separator.
- Channel orientation **guides** the electrolyte flow and **bubbles**.

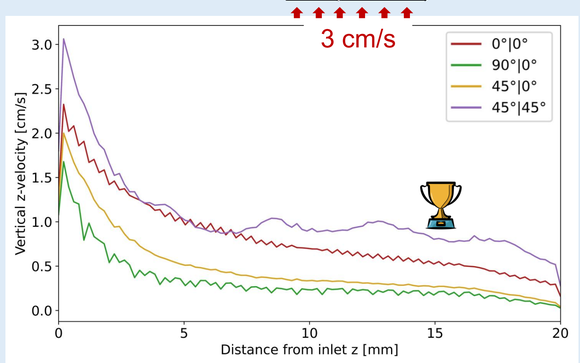
Lateral flow velocity





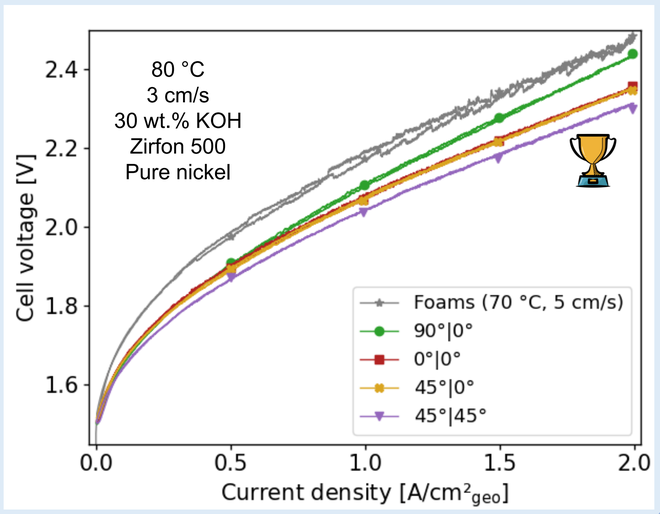
Vertical flow velocity





- Flow velocities **increase** the shear and normal **stresses** on bubbles to **overcome the adhesion forces** and eject them **away from the diaphragm**.

- CFD simulations highlight the important **inlet effect** in bi-layer configurations.
- The **45°|45° structure** achieves the best results thanks to **higher flow velocities** overall.
- **3D printed** bi-layers **outperform** the foam bi-layer.
- **Channels orientation** strongly **affects bubble evacuation**, thereby reducing the overpotential of ~140 mV at 2 A/cm².



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