Utilization of 3D printing in separation technology

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- **ReGold-AM**, Kullan talteenotto vaihtoehtoisista raaka-aineista uusilla 3D-tulostuksella toteutetuilla sähkökemiallisilla reaktoreilla
- **konsortiokumppanit:** Lasertyöstön ja 3D-tulostuksen sekä Hydrometallurgy for Urban Mining tutkimusryhmä, LUT-yliopisto
- **rahoittaja**: Suomen Akatemia
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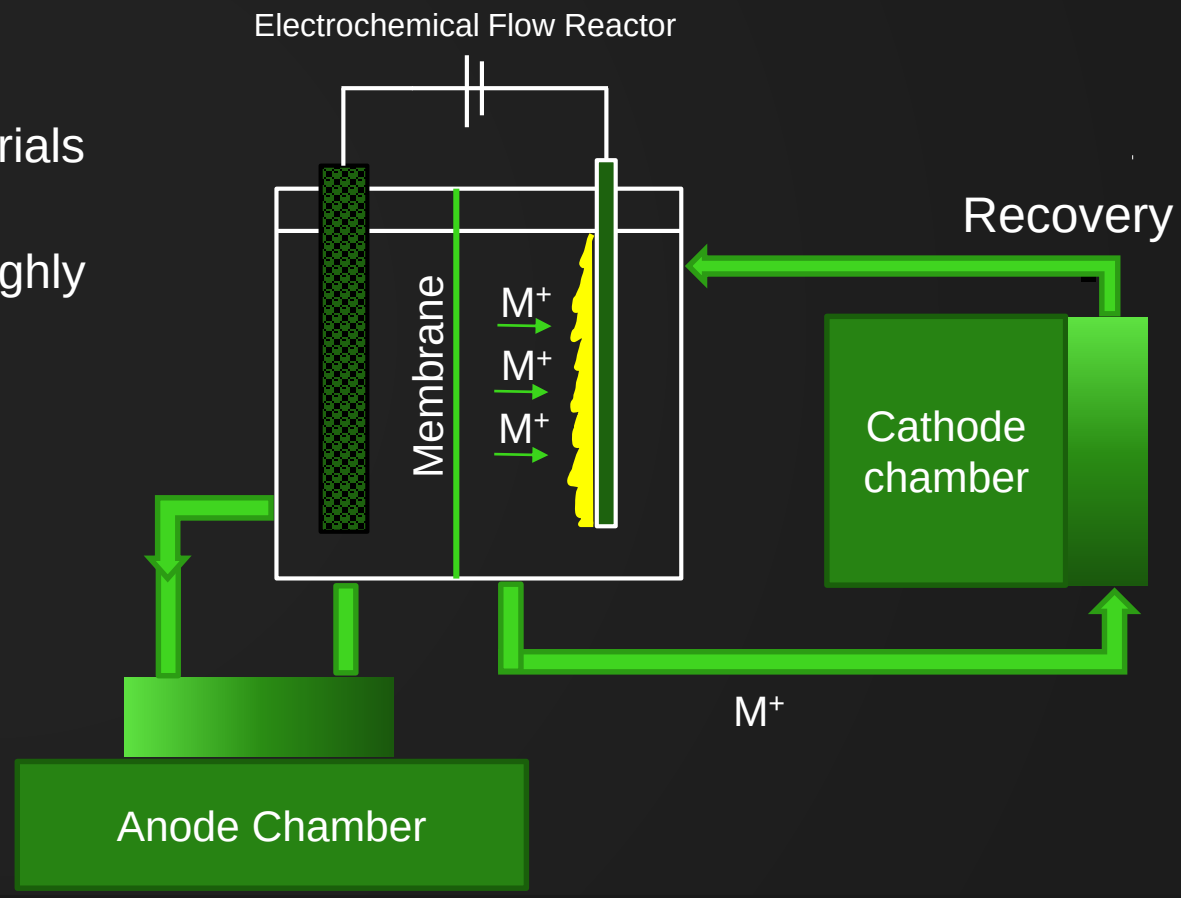
Electrochemical Removal of metals

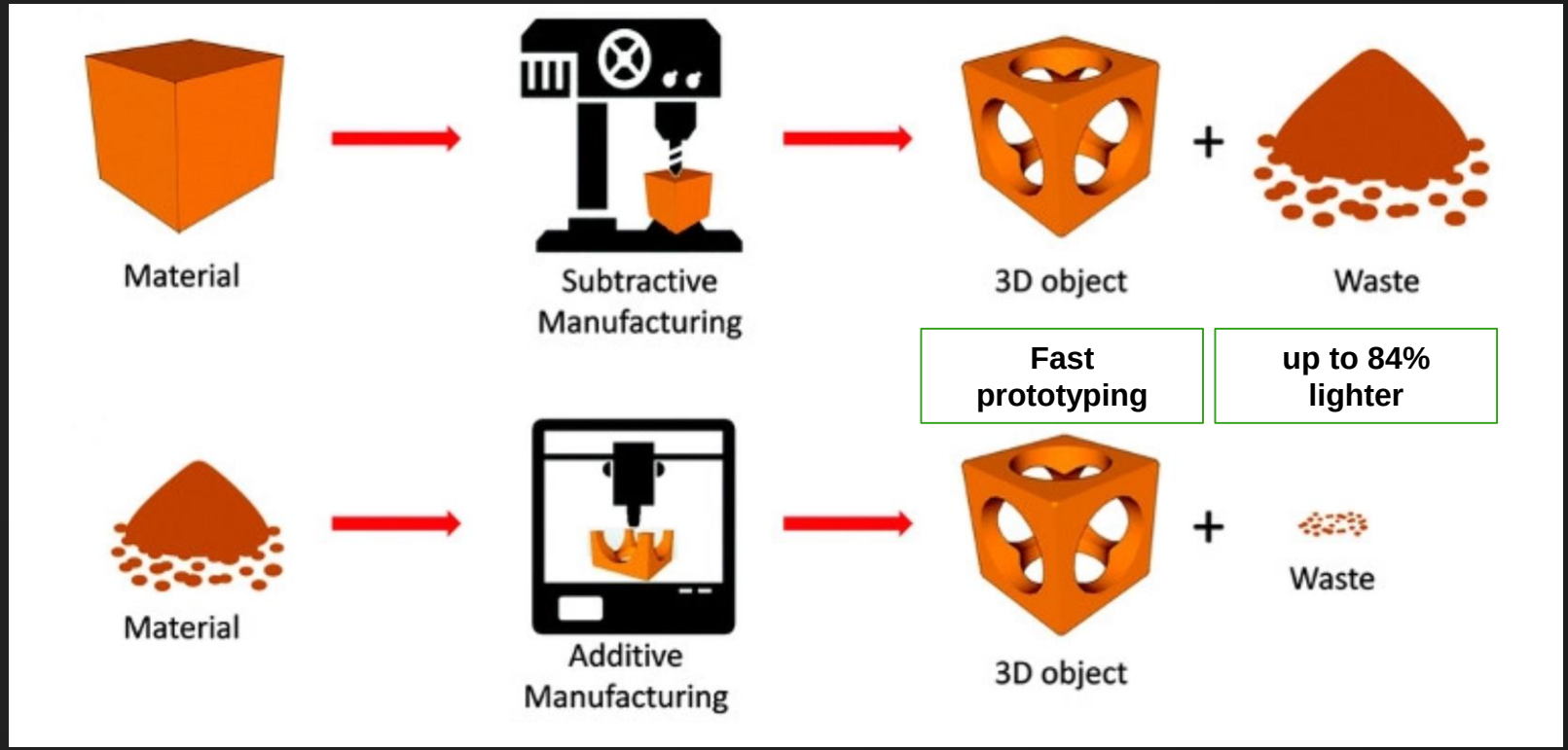
- **Electrodeposition** is a well-known method to produce in situ metallic coatings.
- Cell performance is highly related to the materials selection and designs.
- For instance, cathodic reactions are highly depended to the anodic reactions.



Low-cost manufacturing method?

- Subtractive Manufacturing:
- Additive Manufacturing:

Comparative schematic of AM and SM methods



Introduction of 3D Printing

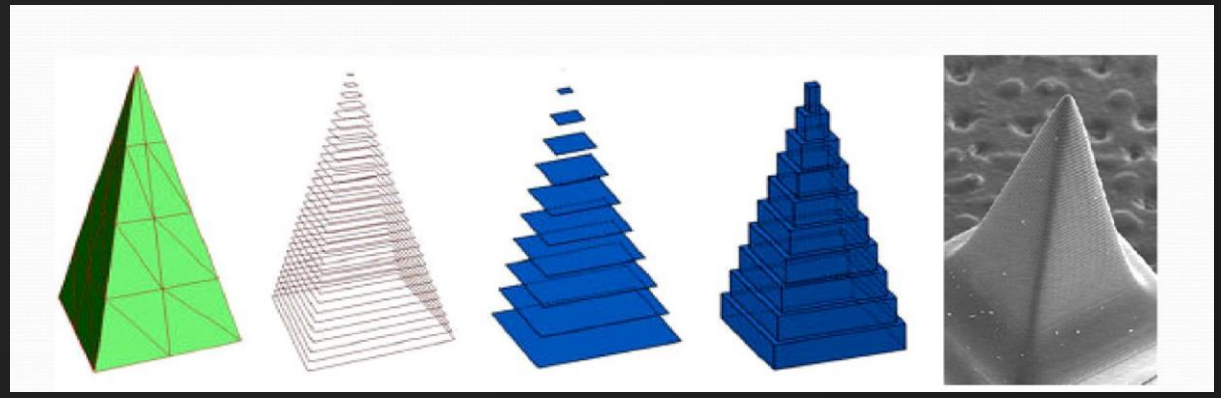
- Additive Manufacturing (AM):

  Physical structures are designed from a 3D CAD data directly, usually layer by layer.

  3D slicing is designing the printing path (filling density, angle, shell, etc.), and storing the sliced file in .gcode format. Its role is to communicate with the 3D printer.

L-PBF method (SLM)

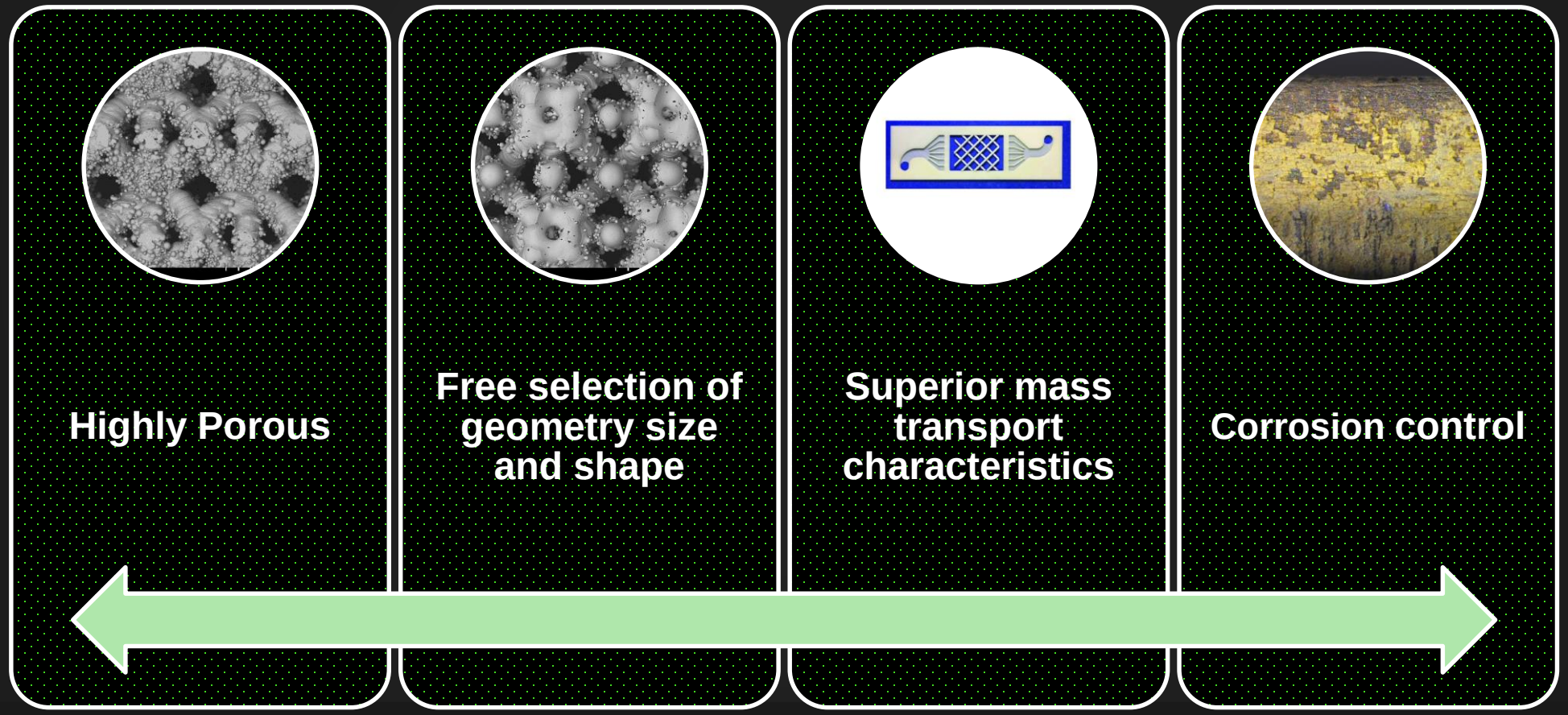
From designing to product



(a) STL (b) Raw slice (c) Slice (d) Layer data (e) 3D part

Developing high performance anodes

- AM allows for a variety of properties associated with geometry, rigidness, porosity, and size.
- The choice of precursor materials and the type of 3D-printing technique allow to control over these properties.

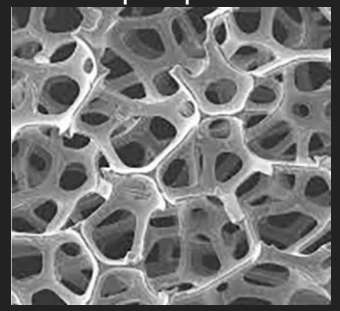


Electrode design

- Porous sponges/foam metals
- Mesh structure

Nickle foam electrode

Open pores



closed pores

Uneven sizes and shapes of the pores

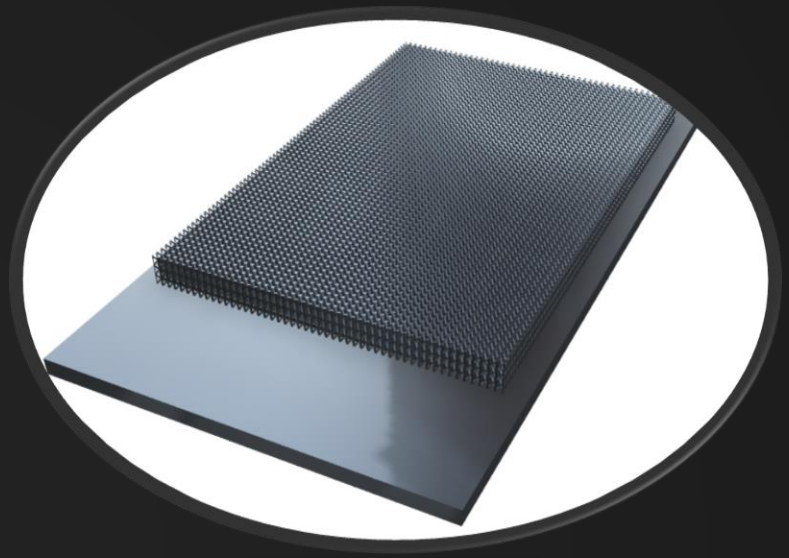
Titanium/ruthenium-iridium mesh structure

limitations for Complex designs

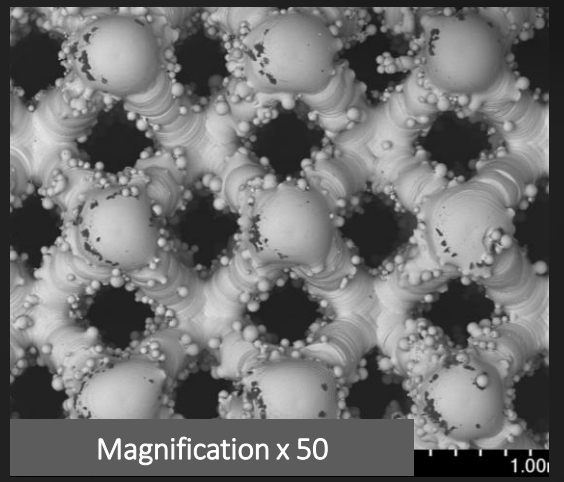
3D Printed electrodes

- High surface roughness which provide a higher surface area
- Equal size and shape of the pores for a convenient and better distribution of the electric charge and electrolyte toward the targeted surfaces.

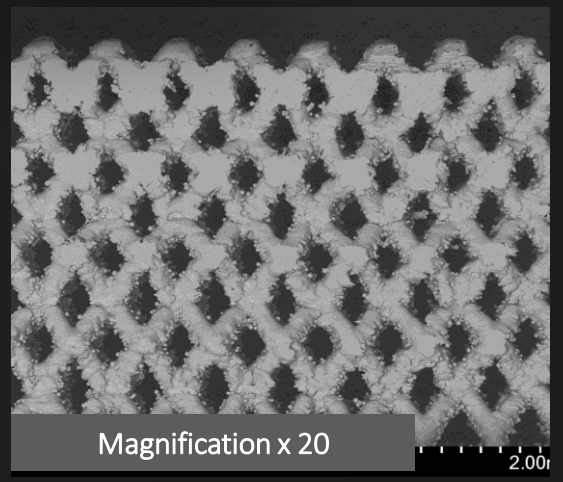
CAD design



SEM images of 3D-printed structures



Top view

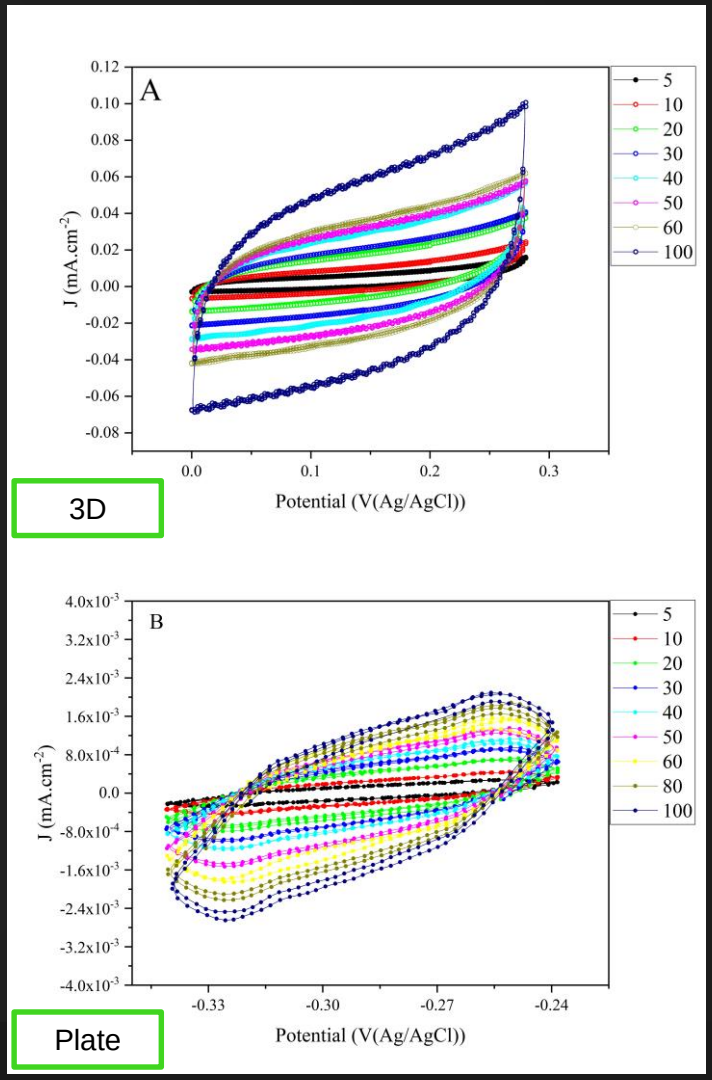


Side view

Electrochemical Active Surface Area (ECSA)

- A simple shape plate electrode was compared with a 3D-printed one.
- ECSA is the main parameter that is affected by an electrochemical reaction. The anode which has more ECSA demonstrated a higher reaction on their surfaces.
- To evaluate the ECSA, the different cyclic voltammetry (CV) scan rates were measured in the non-faradic zone.
- Non-faradaic current is dependent on the surface area of electrodes.

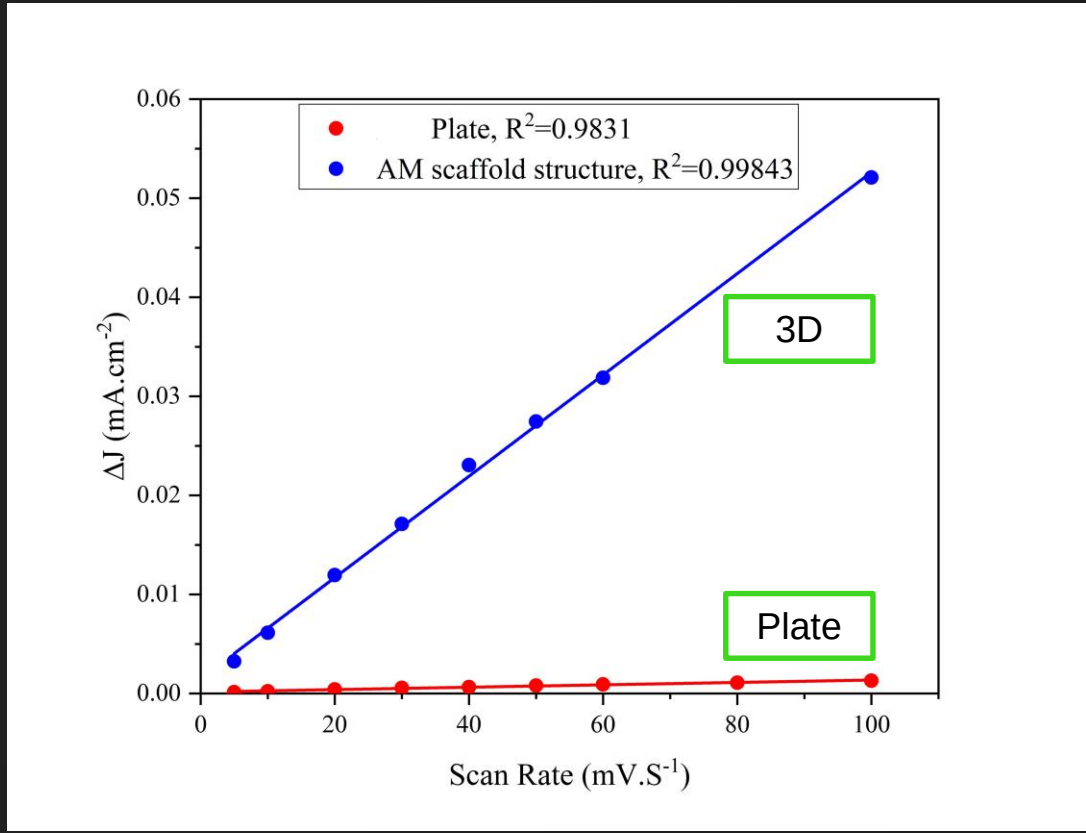
Cyclic voltammetry of plate and 3D-printed electrodes



Electrochemical Active Surface Area (ECSA)

- According to the ESCA of the lattice structure and plate, the electrochemically active surface area of the scaffold is **42** times more than the plate.
- That means all electrochemical reactions can be improved very well.

The current densities at different scan rates



Corrosion control

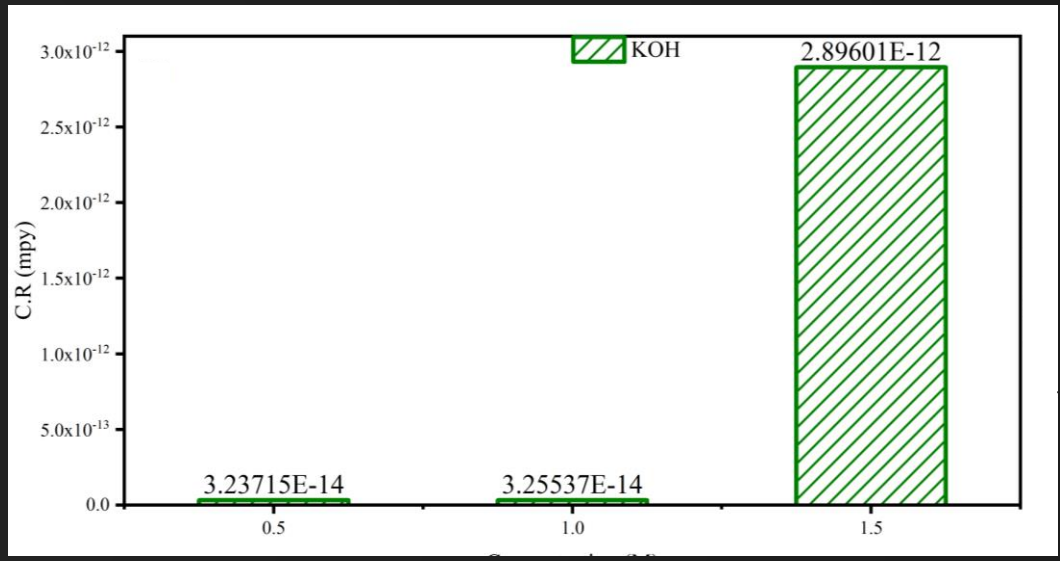
- According to polarization results of the different aqueous alkaline solutions, the corrosion rate of the lattice structure was acquired.
- The corrosion can be controlled at $\mathbf{3.2 \times 10^{-14}}$ **mpy**.

where:
mpy = milli-inch per year

Therefore:

It is possible to control corrosion at $\mathbf{0.0812 \times 10^{-8}}$ **nm/yr**

corrosion rate (mpy) extracted from polarization curve

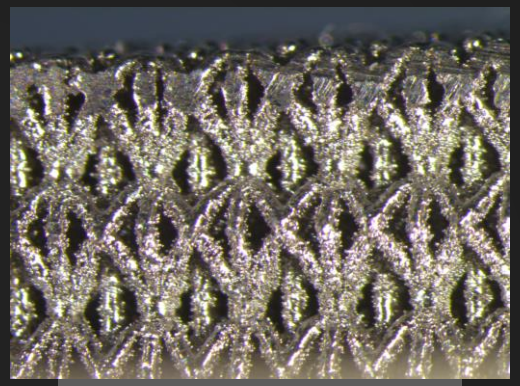


Corrosion control

- The structural difference of the lattice structure electrode after a tough condition:

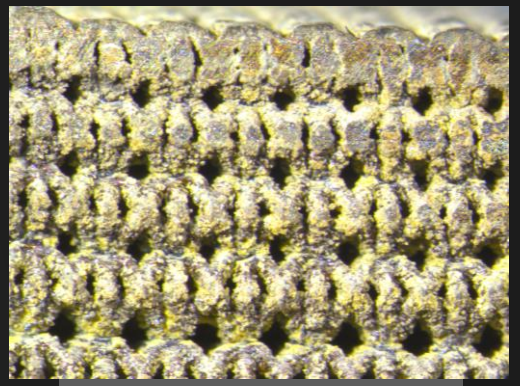
- Voltage: 5v
- Time: 600 min
- NaOH: 1.5 M

Before electrochemical test



Magnification X 20

After electrochemical test



Magnification X 20

Summary

a) AM can provide a faster and more affordable process (84% less material consumption).

b) High surface roughness, large variety of disciplined shape, and size selection, and improved flow cell performance can be applied for the anodes.

c) The Electrochemical Active Surface Area (ECSA) can be increased by 42 times than a simple plate anode.

d) The low corrosion rate can confirm the feasibility of the consumable low–cost anodes in a logical long-term durability.


Thank you for your attention