Metal Material Extrusion 3D-printed stainless-steel electrodes for water electrolysis

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Introduction

The production of elements for electrochemical processes can be considered an extremely interesting application of the additive manufacturing technology. Also in this area, the use of 3D printing can significantly expand the range of applications, allowing the production of objects with very different properties, in terms of geometry, stiffness, porosity and size, and rapidly creating structured electrodes with programmable geometries, increased thickness and multi-scale structural details.
Recently, metal material extrusion (MMEX), a new application based on FDM, introduces the possibility to print filaments with a high load of metal that can be subsequently sintered in high-density objects.
With respect to power-based techniques, like SLM, MMEX is potentially a cheaper, faster and more easily accessible printing technique. Besides, at the best of our knowledge, there are no reported examples of fabrication of electrochemical elements using metal-filled filaments.

Samples preparation

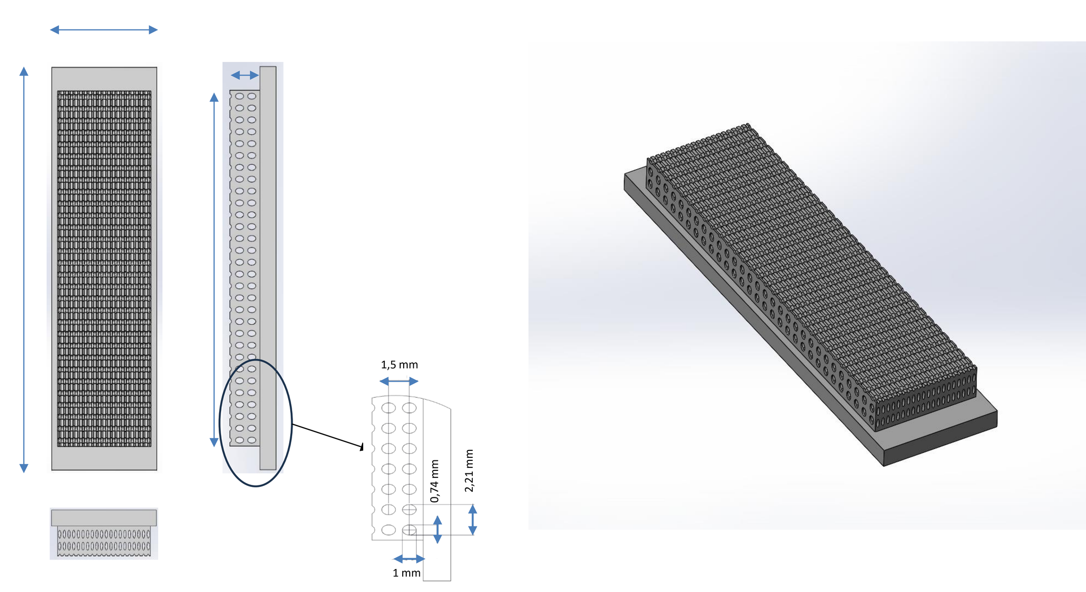
3D printer

Prusa i3 MK3S

This study shows the first examples of MMEX printing electrodes for water electrolysis. A commercially available FDM 3D printer Prusa i3 MK3S was used without any modifications and metal filled commercial Ultrafuse 316L filament (90% stainless steel/10% polymers by weight); two different geometries were printed: one regular 50 x 13 x 5,70 mm rod and a structured rod as showed in CAD designs.

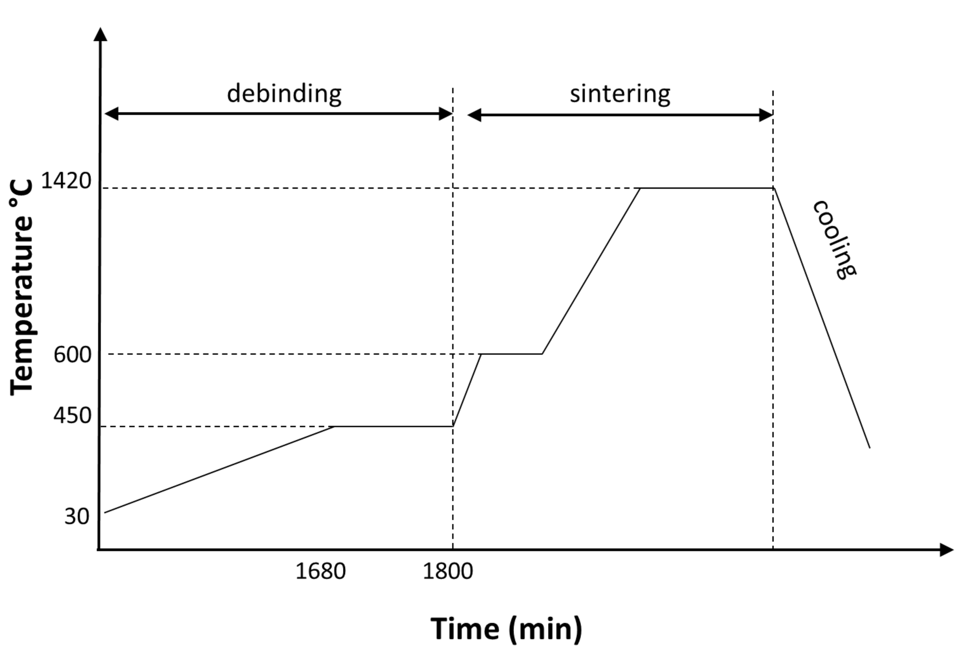
Filament	Material	T nozzle (°C)	Tbad (°C)	Infill type	Speed (mm/s)	Layer tickness (mm)	Infill Density (%)
Ultrafuse 316L Basf	80% stainless steel/20% polymers	240	100	linear	50	0,1	100

CAD designs



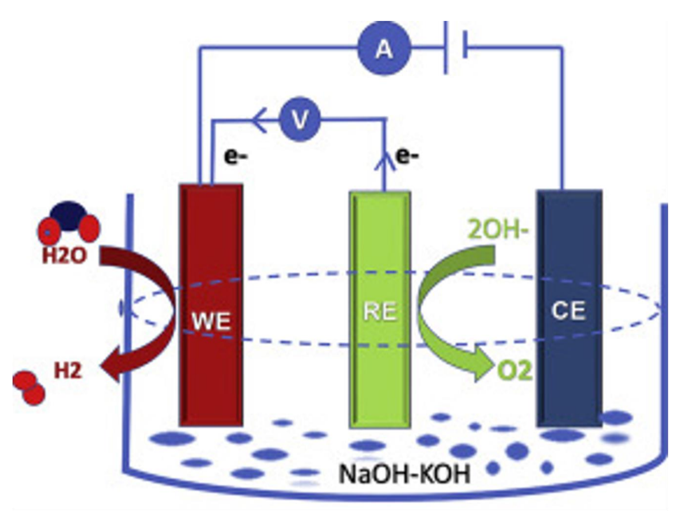
Geometry 2 presents snake shape on the top to increase surface area of the electrode. It is obtained with good resolution and reproducibility.

Debinding and sintering

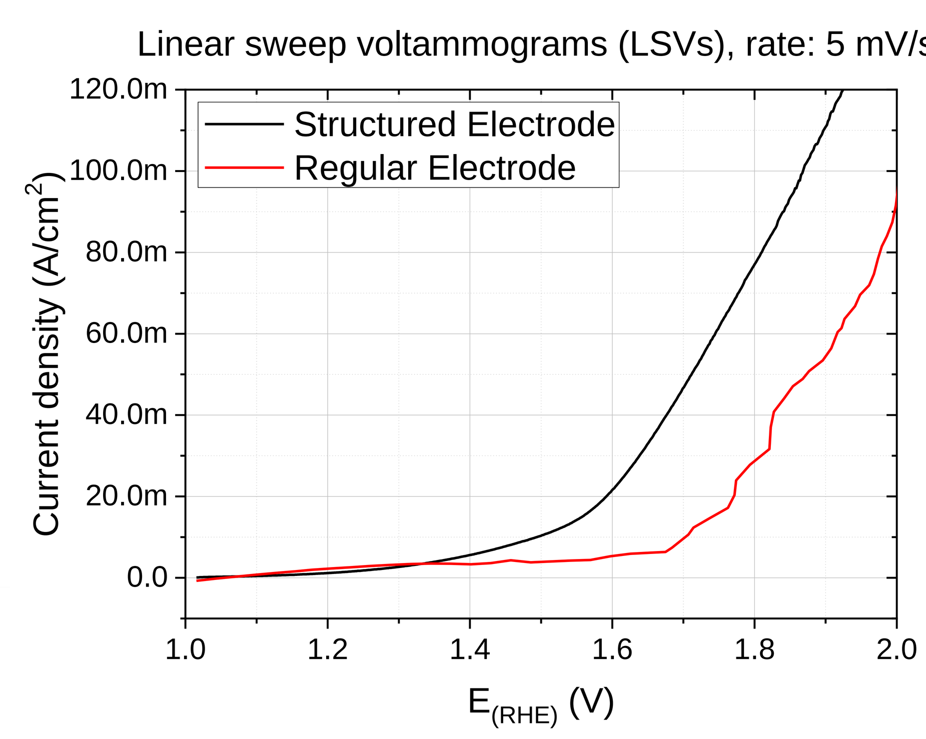


Thermal Debinding and sintering processes were successfully applied on the 3D printed samples to eliminate organic part and obtain stainless steel-based electrodes. The figure shows the as-printed green part and the shrinked sintered part .

Water electrolysis



WE= stainless steel working electrode
RE= Ag/AgCl reference electrode
CE= Pt counter electrode



Two different electrode geometries have been tested. Hydrogen gas production start was detected in the E_{RHE} voltage range 1.5V - 1.8V (referred to a reversible hydrogen electrode).
Current densities measured for structured electrodes are comparable to literature results both for porous electrodes (about 120mA*cm^{-2}) and for their commercial counterpart (80mA*cm^{-2}) at about 1.85V vs. RHE) [1]

[1] R. Ding et al. "Improving the water splitting performance of nickel electrodes by optimizing their pore structure using a phase inversion method" Catal. Sci. Technol., 2017,7, 3056-3064, https://doi.org/10.1039/C7CY00519A

Conclusions

- ✓ The preliminary results of this study support the potential use of MMEX 3D printing technology for the rapid and scalable electrodes production.

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