LUT
Lappeenranta
University of Technology

Additive manufacturing of electrodes from metals

ReGold-AM

Authors:

Atte Heiskanen[1], Pinja Nieminen[1], Heidi Piili[1], Eveliina Repo[2]

[1] Research Group of Laser Materials Processing, Department of Mechanical Engineering, LUT School of Energy Systems, LUT University, Lappeenranta, Finland

[2] Research Group of Hydrometallurgy for Urban Mining, Department of Separation and Purification Technology, LUT School of Engineering Sciences, LUT University, Lappeenranta, Finland

Abstract: Additive manufacturing (AM), known also as 3D printing, opens new possibilities in electrode design. These possibilities allow the electroactive area, flow properties and uniformity of the electrode to be improved, thus increasing the reactor efficiency. Electrodes manufactured with this method can be used across a variety of electrochemical processes, for example to enhance the release of gaseous products.

Keywords: Powder bed fusion, metal, electrode, additive manufacturing, 3D Printing

Introduction

Additive manufacturing, commonly known as 3D printing, offers a possibility to fabricate an object in one process. Basically, the manufacturing is done layer by layer. This creates new possibilities for electrodes with more complicated structures. Electrodes with enhanced surface area and complex geometries can be designed and manufactured effortlessly with 3D printing. With additive manufacturing, the weight of the manufactured part can also be reduced. [1, 2] Additive manufacturing enables great possibilities to design and manufacture optimized parts with varying porosities. When utilizing a laser based 3D printing technology, the desired porosity differences can be achieved with a low-energy density laser beam. [3] This enables the possibility to optimize the electrode. 3D printed electrodes can be used as an alternative for foams and meshes. These in many ways improved electrodes can be used both in organic and inorganic electrosynthesis in industrial applications. Metal recovery and proccess stream treatment are noted applications for electrodes produced by 3D-printing. [4]

Design possibilities

By leveraging the freeform manufacturing capabilities of 3D printing, electrodes can be designed to have very high surface area, while retaining uniform structure. Structural uniformity is often desirable, as it promotes the uniformity of current distribution throughout the electrode [5]. These features can be achieved by using, for example, lattice structures (presented in Figure 1), which can be designed to have very high porosity and ordered structure. Therefore, 3D printing offers a possibility to design electrodes, where the advantages of high surface area and uniform current distribution can both be achieved [4].

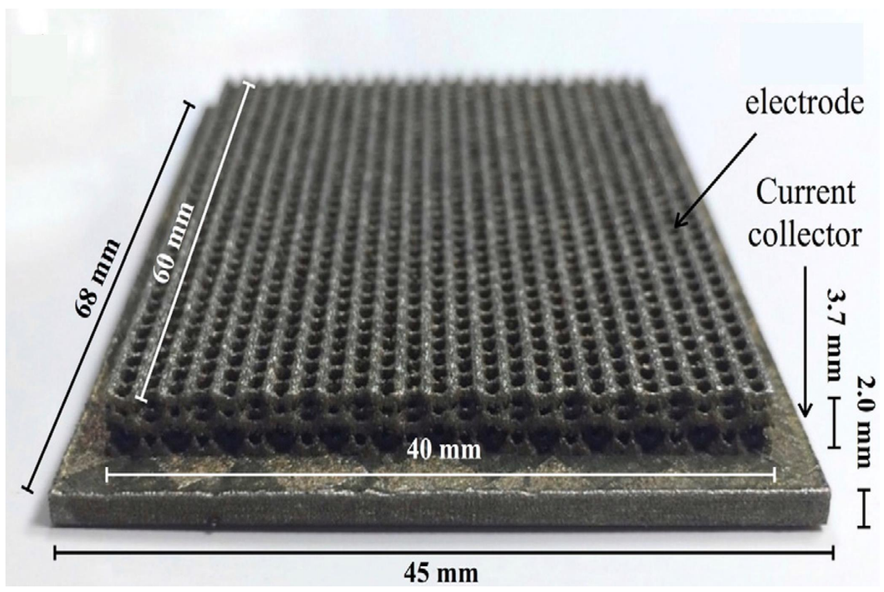

Figure 1. Electrode designed with lattice structure [4].

Applications

If the electrode needs specific properties, it can be coated. Liyarita et al. [6] printed helical stainless steel electrodes and plated them with gold in order to achieve the desired capabilities for sensing biologically active molecules. The stainless steel electrode was manufactured with selective laser melting and plated with gold through electroplating.

This electrode showed enhanced capability to detect both dopamine and acetaminophen: its sensitivity towards these molecules was improved by 3 times comparing to a glassy carbon electrode and 4.7 times comparing to a commercial gold electrode. Figure 2 presents the helical electrode. [6]

Additive manufacturing is a reckoned technology for the fabrication of patterns in metal electrodes. Lee et al. [7] manufactured electrodes with conical arrays via selective laser melting. This technology is especially utilizable for metal powder manufacturing because it allows to create the desired complicated structures using a powerful laser. Lee at al. used titanium and 3D-printed an electrode with conical microstructure for the photoelectrochemical water splitting. The conical arrays enhance the surface area, which improves the performance. The structure is shown in Figure 3. Also the utilization of 3D-printing makes it possible to have different densities in the conical arrays. [7]

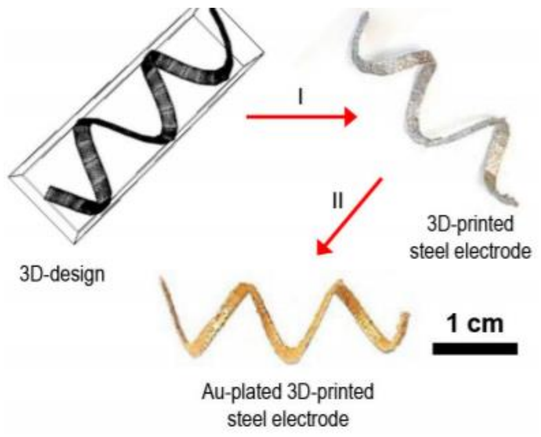

Figure 2. 3D-printed electrode. [6]

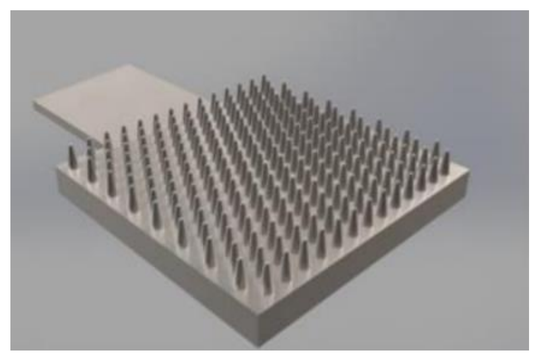

Figure 3. Conical arrays of an electrode. [7]

Conclusions

In conclusion, additive manufacturing brings lots of possibilities for electrode designing. This can bee seen as enhanced surface area, uniform structure and complex geometries. All of these properties can be designed to optimize the efficiency and performance of the manufactured electrode. This will lead into electrodes that are especially customized for their purpose.

Acknowledgements

This study was carried out as a part of ReGold-AM project, which is about the recovery of gold from secondary resources by novel electrochemical reactors realized with additive manufacturing. This research project will provide new information about the recovery of valuable metals from secondary resources using electrochemical cell designs and utilization of AM in the construction of the electrochemical systems for metal leaching and recovery. The authors would like to thank all the participants in the project for their input and knowledge.

References:

1. Ambrosi A., Moo J., Pumera M., Helical 3D-Printed Metal Electrodes as Custom-Shaped 3D Platform for Electrochemical Devices. Advanced Functional Materials (2016) 698-703.
2. Lamberti A., Manfredi D., Calignano F., Pirri C., TiO2 nanotube-based smart 3D electrodes by anodic oxidation of additively manufactured Ti6Al4V structures. Materials Today Communications (2018) 165-170.
3. Koyano T., Hosokawa A., Igusa R., Ueda T., Electrochemical machining using porous electrodes fabricated by powder bed fusion additive manufacturing process. Manufacturing Technology 66 (2017) 213-216.
4. Arenas, L.F., Ponce de León, C. & Wals, F.C. 2017. 3D-printed porous electrodes for advanced electrochemical flow reactors: A Ni/stainless steel electrode and its mass transport characteristics. Electrochemistry Communications 77. Pp. 133-137.
5. Pletcher, D & Walsh, F.C. 1990. Industrial Electrochemistry. Second Edition. New York: Chapman and Hall. 661 p.
6. Liyarita B., Ambrosi A., Pumera M., 3D-printed Electrodes for Sensing of Biologically Active Molecules. Electroanalysis (2018) 1319-1326.
7. Lee C., Taylor A., Beirne S., Wallace G., 3D-Printed Conical Arrays of TiO2 Electrodes for Enhanced Photoelectrochemical Water Splitting. Advanced Energy Materials (2017).

CONTACT:

Docent Heidi Piili
heidi.piili@lut.fi
tel. +358 40 5510 710

Associate Professor Eveliina Repo
eveliina.repo@lut.fi
tel. +358 40 355 3707