Electrodeposition of 3D Nickel Microcomponents: Simulation Assisted Synthesis

Patrik Schürch\textsuperscript{1}, Laszlo Pethő\textsuperscript{1}, Jakob Schwiedrzik\textsuperscript{1}, Johann Michler\textsuperscript{1} and Laetitia Philippe\textsuperscript{1}

1 Empa – Swiss Federal Laboratories for Materials Science and Technology – Laboratory for Mechanics Of Materials and Nanostructures, Thun, Switzerland

Motivation and Challenge

Electrodeposition into templates, also known as LiGA process [1], is widely used in academia and industry to create 2D microcomponents. The material properties of the final microcomponents are dependent on the chosen electrodeposition parameters and conditions within the templates. Therefore, it is crucial to know and control the influence of the template on electrodeposition. Simulations are a good tool to understand and optimize electrodeposition within such templates. New lithography techniques such as two-photon lithography allow for the creation of more complex 3D templates [2,3], which reinforces the need of simulation assistance for synthesis.

LiGA - Process

Simulation and parameter acquisition

The simulation is based on standard electrochemical equations included in the electrodeposition module[4]. A standard nickel sulfamate electrolyte was used. The parameters for the simulation were measured with standard elector-chemical analysis measurements such as cyclic voltammetry, tafel analysis and chronoamperometry.

Microcomponent design – Simulation assisted template design – Two-photon lithography

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Microcomponent design

Figure 2.1-2.3: CV, Tafel analysis and chronoamperometry of a nickel sulfamate electrolyte on ITO coated glass substrates

Investigation of template design

For example, deposition of a bridge-like micro-components was investigated. Two different templates were designed and used for simulation [4]:

Open

### Template design and boundary conditions:

Current density vectors and local current density [A/m\textsuperscript{2}]:

Direct Current density [A/m\textsuperscript{2}]:

Reverse Pulse Current density [A/m\textsuperscript{2}]:

In the shielded template, the deposition takes places slower in the outer cuboid than in the center by 19%, whereas the dissolution in the outer cuboids is slower by 24%. Therefore, reverse pulse deposition effectively stalls the growth in the center and increases the filling ratio in the outer cuboids.

Cell Geometry and Verification Experiments

Macroscopic Simulation of the electrochemical cell:

Microscopic Simulation with conditions imported from the macroscopic simulation:

Figure 3: Boundaries definition, Electrolyte potential deviation from equilibrium [V], \( \text{NO}_2^\text{-} \) concentration [Mol/m\textsuperscript{3}]

Figure 4: Boundaries definition, direct deposition simulation after 500s of deposition (simulation and experiment) [A/m\textsuperscript{2}], simulation after 200s of reverse pulse deposition (simulation and experiment) [A/m\textsuperscript{2}]

Conclusion

We’ve showed for the first time, directly deposited free-standing 3D nanocrystalline nickel microcomponents. The simulation can be used to optimize template design to increase the filling ratio and to determine workable deposition parameters.

References