Electrodeposition of 3D Nickel Microcomponents: Simulation Assisted Synthesis

Empa
Materials Science and Technology

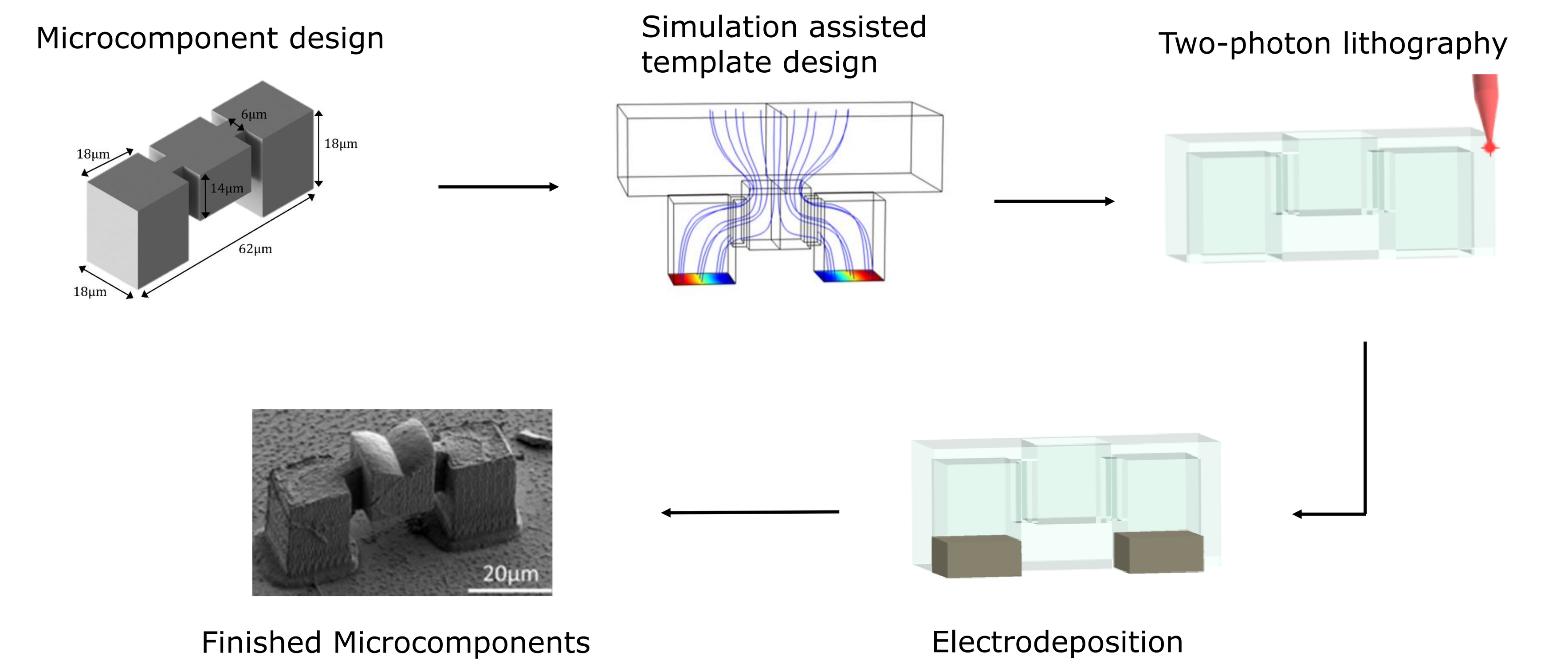
Patrik Schürch[1], Laszlo Pethö[1], Jakob Schwiedrzik[1], Johann Michler[1] and Laetitia Philippe[1]

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.**

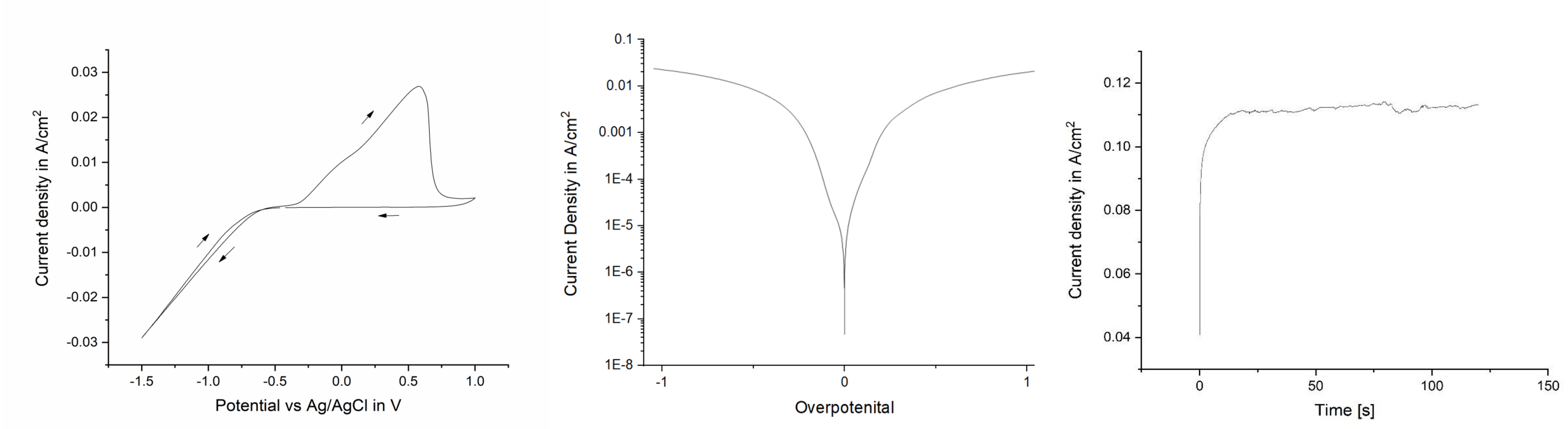


Figure 2.1-2.3: CV, Tafel analysis and chronoamperometry of a nickel sulfamate electrolyte on ITO coated glass substrates

Cell Geometry and Verification Experiments

Macroscale Simulation of the electrochemical cell:

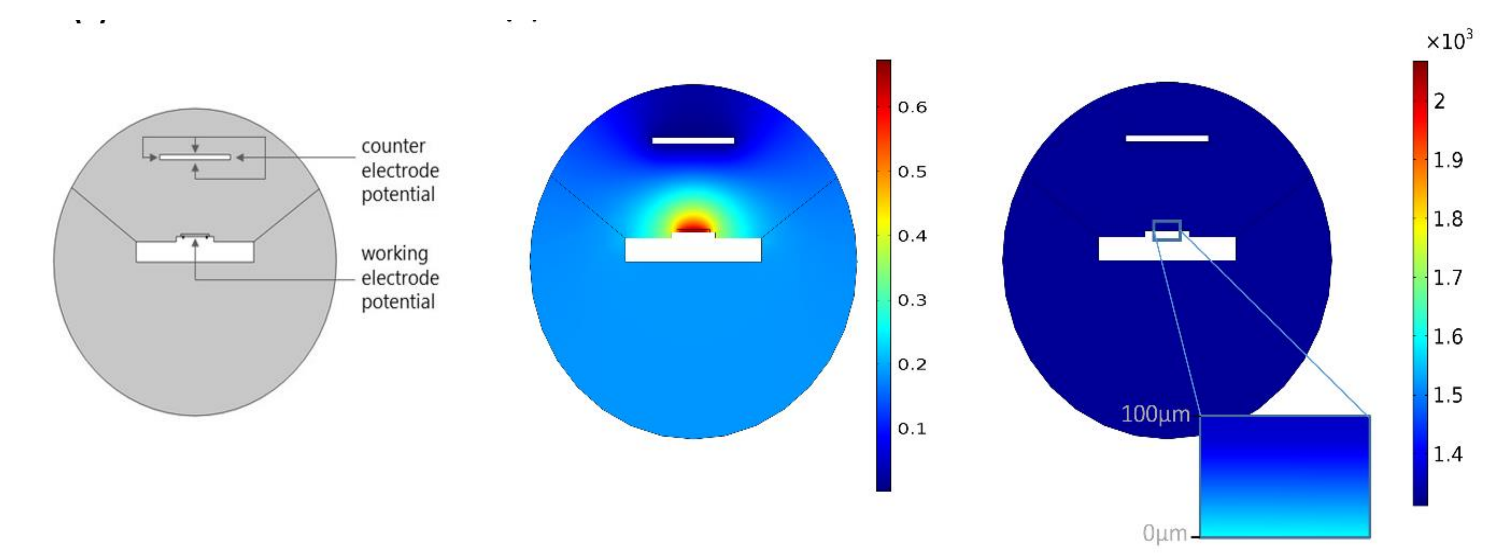


Figure 3: Boundaries definition, Electrolyte potential deviation from equilibrium [V] , Ni^{2+} concentration [Mol/m³]

Microscale Simulation with conditions imported from the macroscale simulation:

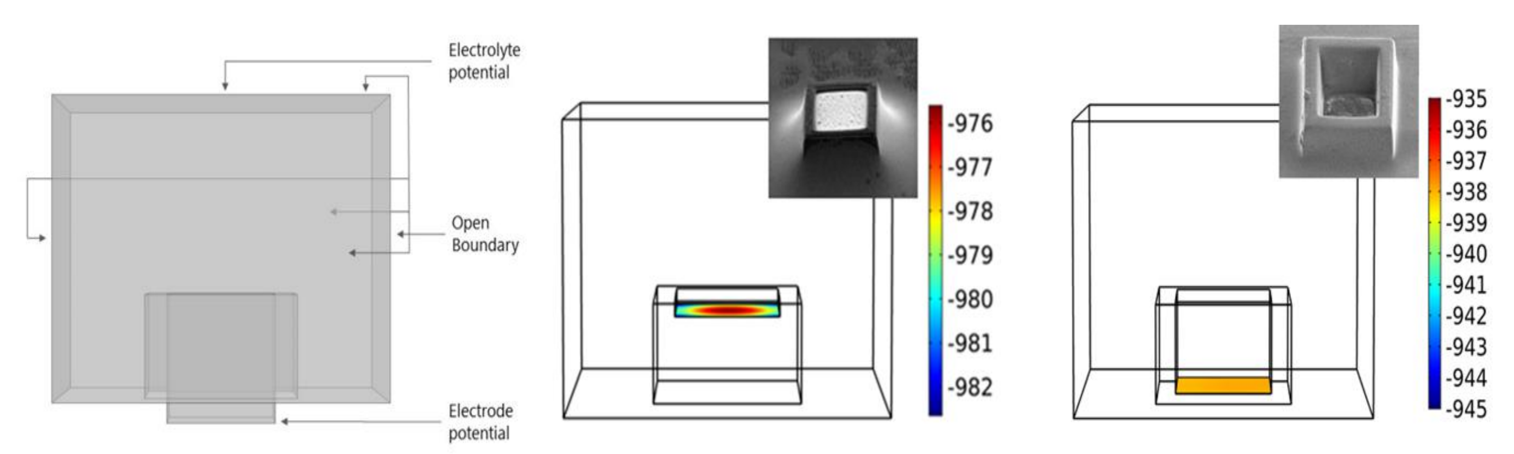
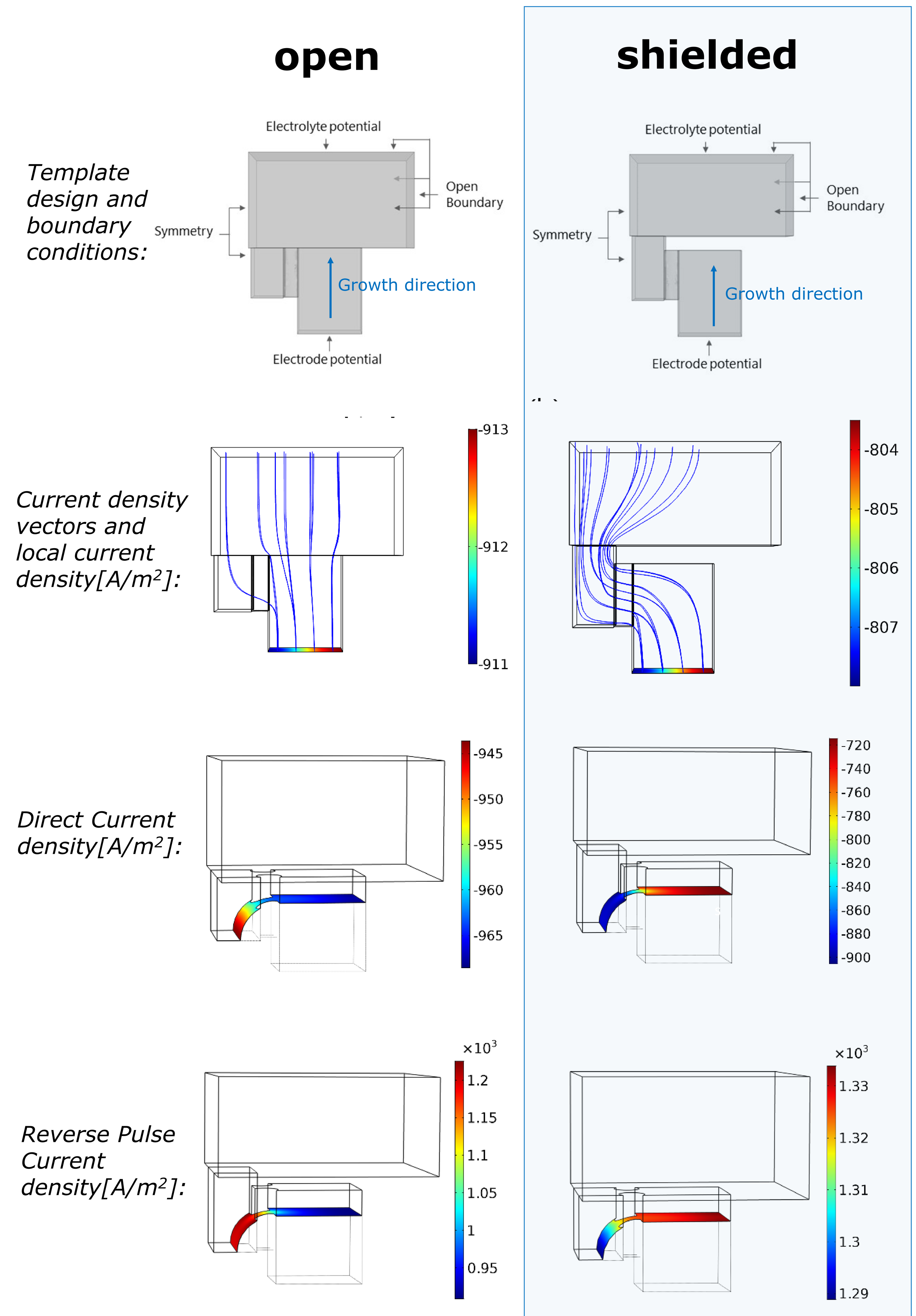


Figure 4: Boundaries definition, direct deposition simulation after 500s of deposition (simulation and experiment) [A/m²] , simulation after 200s of reverse pulse deposition (simulation and experiment) [A/m²]

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]:



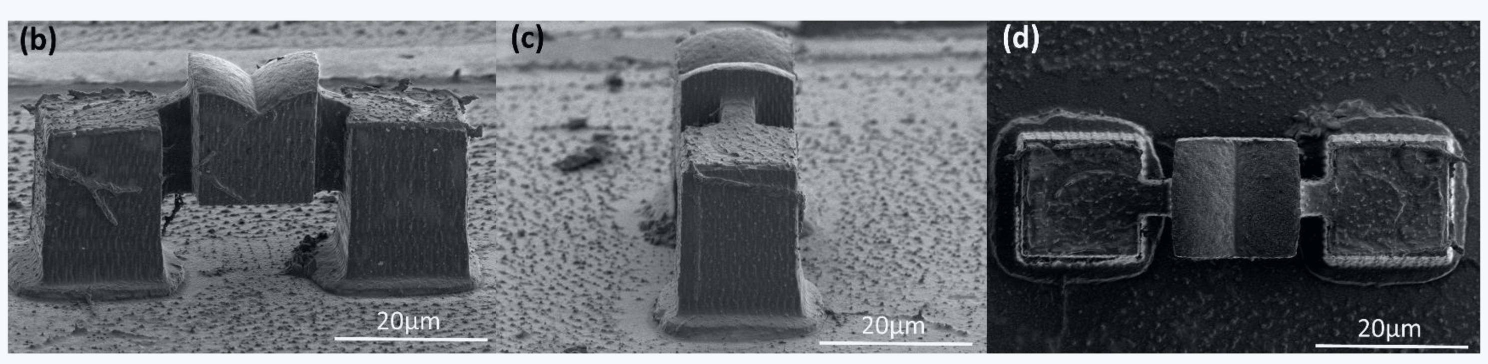


Figure 5: Front, Side and top view of the deposited microcomponents

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.

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

*[1] Becker et al, Naturwissenschaften, **1982**, 69 (11), 520-523. [2] Gansel et al, Science **2009**, 325 (5947), 1513-1515.*
*[3] Zeeshan et al, Small **2014**, 10 (7), 1284-1288. [4] Schürch et al, Adv. Mater. Technol., **2018**, 3 (9)*