Imprinted metallic nano-electrodes for CO_2 reduction

Facing global climate change, one of the most important goals is to reduce the concentration of CO_2 in our atmosphere. The electrochemical reduction of CO_2 to climate neutral fuels is a hot topic in current research. One path to improve the eletrochemical reduction efficiency is to employ large area, nanostructured electrodes for enhanced catalytic reactivity. We use lift-off nanoimprint lithography (LO-NIL) to fabricate nano-electrodes for CO_2 reduction experiments. In contrast to other nano-lithography techniques, such as electron beam lithography, LO-NIL enables the fast patterning of metal nanoisland arrays over large areas [1]. The technology allows the fabrication of identical nanoislands of sizes of 50-1000 nm over large areas (5 mm x 5 mm).

Moreover, metal nanoisland arrays exhibit special optical properties. Under light illumination surface plasmon polaritons (SPPs) are excited in the metal nanoislands. Resonant SPP excitation increases the amplitude of the electric fields on the particle surface and leads to increased light scattering and absorption. Overall, the plasmonic response can be used to enhance our catalytic and photoelectronchemical processes. We use gold nanoisland arrays as electrodes for catalytic CO_2 reduction, as shown in figure 2 [2]. Our LO-NIL fabrication process of a typical gold nanoisland electrode is schematically depicted in figure 1. The shape, size and plasmonic properties of the metal islands have great influence on the occurring chemical reactions on the metal surface.

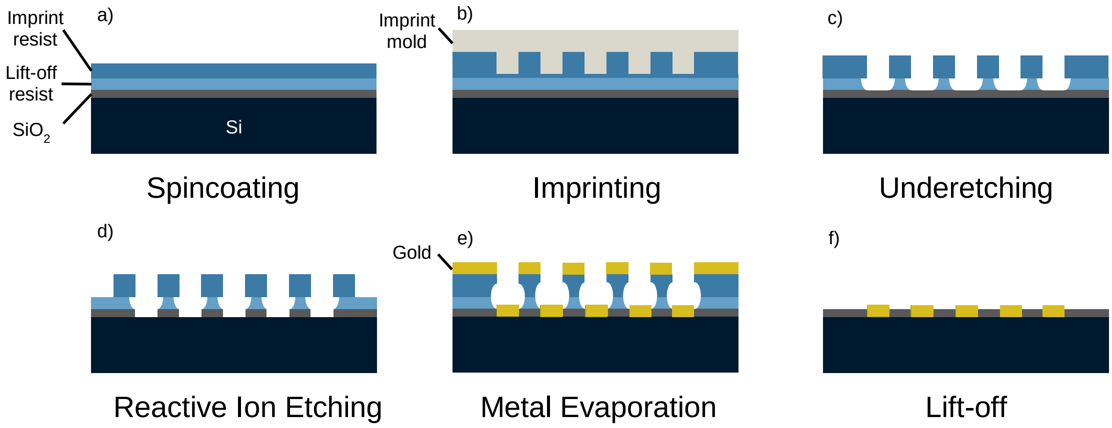

Figure 1: Scheme of the LO-NIL fabrication Process. a) shows the resist layer structure after spincoating. In b) the actual imprinting process is depicted. c) shows a sketch of the sample after the underetching step. The RIE etching of the SiO_2 layer is illustrated in d). e) shows the gold evaporation step. After the lift-off the well-defined metal nanoislands are embedded into the SiO_2 layer (f),

As the electrochemical reactions are strongly dependent on the size, surface roughness and quality of the nanoislands, a reproducible fabrication process is vital for our experiments. Furthermore, there are two different paths to improve the overall performance of our system. On the one hand, we want to characterize known sample structures and optimize the current fabrication process. On the other hand, we are looking for new sample designs to improve the electrochemical process.

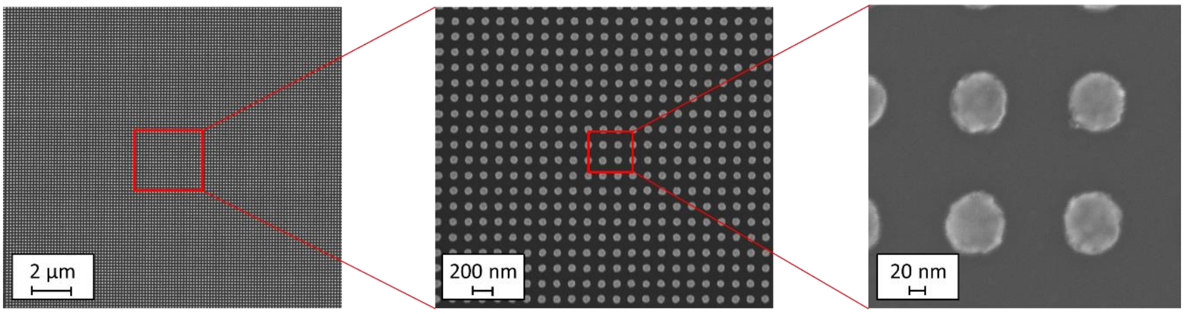

Figure 2: Large area SEM images of 75nm Au disks fabricated with LO-NIL with different magnifications [3].

The objective of this Master thesis is to gain deeper understanding of the fundamental properties of our metal nanoisland arrays and to improve these properties towards enhanced reproducibility and performance. During the Master project, you will learn and use (among others) the following fabrication processes and analyzation techniques:

Fabrication processes:

- Lift-off nanoimprint lithography
- Dry etching
- Wet etching
- Evaporation

Analyzation techniques:

- Atomic force microscopy
- Scanning electron microscopy
- UV-VIS-IR spectroscopy
- Electronic characterization techniques

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Literature:

[1] M. C. Traub, W. Longsine, and V. N. Truskett, “Advances in Nanoimprint Lithography,” *Annu. Rev. Chem. Biomol. Eng.*, vol. 7, no. 1, 2016.

[2] S. Filser *et al.*, “Photoelectrochemical reactivity of well-defined mesoscale gold arrays on SiO2/Si substrates in CO2-saturated aqueous electrolyte,” *Electrochim. Acta*, vol. 268, pp. 546–553, 2018.

[3] R. D. Nagel *et al.*, “Nanoimprint methods for the fabrication of macroscopic plasmonically active metal nanostructures,” *J. Appl. Phys.*, vol. 121, no. 8, p. 084305, Feb. 2017.