Three-Dimensional Electrochemical Axial Lithography on Si Micro- and Nanowire Arrays

Fedja J. Wendisch[a], Michael S. Saller[a], Alex Eadie[a], Andreas Reyer[a], Maurizio Musso[a], Marcel Rey[b], Nicolas Vogel[b], Oliver Diwald[a] and Gilles R. Bourret[a]

[a]Department of Chemistry and Physics of Materials, University of Salzburg, 5020 Salzburg, Austria
[b]Institute of Particle Technology, University Erlangen-Nürnberg, 91058 Erlangen, Germany

Raman spectroscopy can be used to identify molecules based on their vibrational energy levels. However the low number of photons that are Raman scattered limits the sensitivity and the applicability of the technique. The use of plasmonic nanostructures that can significantly enhance the incident electric field at the metal surface can mitigate this problem via the surface enhanced Raman scattering (SERS) effect. The use of metal nanogaps is particularly well suited for these systems because they can dramatically enhance the E-field due to strong near-field coupling. However, controlling such gaps within three-dimensional architectures is a challenge. Herein, we report a templated electrochemical technique for patterning macroscopic arrays of single-crystalline Si micro- and nanowires with feature dimensions down to 5 nm. This technique, termed three-dimensional electrochemical axial lithography (3DEAL), allows the design and parallel fabrication of hybrid silicon nanowire arrays decorated with complex metal nano-ring architectures in a flexible and modular approach. The metal rings are synthesized via templated electrodeposition and selective etching steps [1], similarly to the previously reported coaxial lithography method. [2] The method allows for the engineering of plasmonic fields in three dimensions within Si wire arrays, which could potentially be used for preparing highly sensitive SERS substrates.

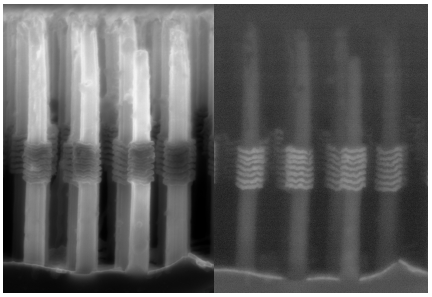

Figure 1: SEM images of seven gold rings synthesized around an array of silicon nanowires via three - dimensional electrochemical lithography. Left: secondary electron image. Right: backscattered electron image

[1] F.J. Wendisch, M.S. Saller, A. Eadie, A. Reyer, M. Musso, M. Rey, N. Vogel, O. Diwald, G.R. Bourret, Nano Lett. 2018, 18, 11. [2] T. Ozel, G.R. Bourret, C. A. Mirkin, Nat. Nanotechnol. 2015, 10.