Phototermal analysis on direct-write nanostructures by nanomechanical scanning absorption microscopy: Novel route towards fabrication and characterization of plasmonic nanostructures

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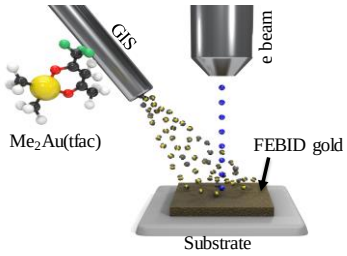
In recent years, scanning electron microscopy (SEM) has evolved from merely an imaging machine into a standard nanofabrication tool. Various SEM based fabrication techniques offer the possibility to write nanostructures directly on the surface. Focused electron beam induced deposition (FEBID) is such an additive direct-writing method where nanostructures can be deposited in a single process step with the help of precursor molecules [1]. This mask-less, resist-less, and in-situ method gained attention due to its capability to deposit complex 3D plasmonic structures. However, the carbon contamination of the deposits from the metal-organic precursors is a major obstacle for its wider applications in plasmonics. The low metal purity could immensely damp the plasmonic resonance.

Silicon nitride membranes are extensively used for probing plasmonic structures. However, the conventional electron energy loss spectroscopy is a complicated process which needs time consuming sample preparation. Nanomechanical scanning absorption microscopy [2] is a novel characterization technique in plasmonics which can detect the photothermal heating of a membrane. In this method, a laser Doppler vibrometer is used to detect the thermal frequency detuning of a nanomechanical resonator. The shift of resonance frequency can be translated into an intensity profile of the deposited structure.

This work will report various in-situ and ex-situ purification strategies for FEBID based gold nanostructures. The plasmonic properties of these structures will be obtained using nanomechanical scanning absorption microscopy.

First, two sets of gold nanodiscs were deposited on a silicon nitride membrane resonator, using 1 nA beam current of a LEO 1530 PV SEM with customized gas injection system. After successful deposition, one set of structurers were purified using oxidative assisted electron beam curing. Second, another set of gold nanodiscs were deposited in the presence of water. The chemical composition of the structurers were measured using EDX. To analyze the effect of purification approaches, the localized surface plasmon resonance (LSPR) of as-deposited, post-purified and in-situ purified gold structures were characterized by photothermal nanomechanical analysis. The purified structures showed significantly higher frequency shift resulting higher intensity of the LSPR. At the next stage, to check the sensitivity of the platform, bowtie structures with various gap sizes were deposited on a trampoline resonator. The effect of gap sizes on field enhancement will be shown and their application towards an ultrasensitive plasmon ruler will be discussed.

In summary, this work will combine the best of direct-write nanofabrication technique with a novel nanomechanical characterisation methods. The potential applications of these methods will be discussed.



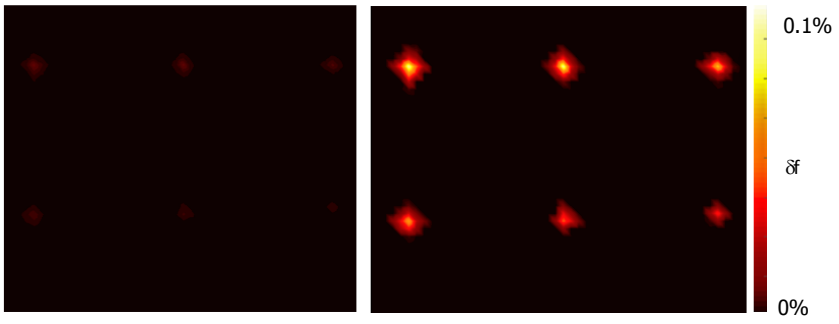


Figure 1: FEBID process [1]

Figure 2: Nanomechanical Scanning Absorption Microscopy Images as-deposited gold nanostructure (left) and post-purified-structure (right)

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[2] S. Schmid, K. Wu, P. E. Larsen, T. Rindzevicius, and A. Boisen, Nano Lett. 14 (2014), 2318 - 2321.