FEBID Based Direct-Write Nano-Printing of 2D and 3D Plasmonic Gold Structures

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During the last decades, resonant optics attracted enormous interest in science and technology as this research field provides deep insights in fundamental physics but also led to an increasing number of applications ranging from optical filters over waveguides towards sensor devices. While several techniques for the fabrication of metallic structures have been introduced, the direct-write fabrication of highly defined structures on the nanoscale, especially for complex three-dimensional geometries on non-flat surfaces, is still an intractable challenge. Focused Electron Beam Induced Deposition (FEBID) has recently made a huge step forward concerning the predictable fabrication of complex, freestanding 3D architectures, leveraging this technique into the status of a true nano-printer[1,2] for multi-dimensional, functional nano-structures on almost any substrate material and morphology. Beside the reliable shape performance on the nanoscale, high material purity is essential for many applications such as plasmonics. While as-fabricated FEBID materials notoriously contain carbon impurities up to 90 at.%, different post-growth purification processes introduced in recent years have been proven to transfer FEBID materials into pore- and crack-free high-fidelity shapes with pure metallic properties[3]. Based on this framework, we here present FEBID as a generic technique for the on-demand, direct-write fabrication of quasi-planar (2D) and freestanding (3D) plasmonic Au structures. First, we confirm the plasmonic activity of FEBID based Au-materials after our straightforward purification approach. Next, we focus on the fabrication of quasi-planar high-resolution Au bi-ring arrays for application as electro-magnetic metamaterials in the frame of THz plasmonics (Fig. 1). Finally, we expand the structures into the third dimension, fabricate freestanding, 3D nano-architectures which can barely fabricated with other fabrication techniques, and confirm its plasmonic activities.

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[1] Fowlkes J.D. et-al (2016). *ACS Nano*, 10 (6), 6163.

[2] Winkler R. et-al (2016). *ACS Appl. Mat. Interf.*, DOI: 10.1021/acsami.6b13062

[3] Geier B. et-al (2014). *J. Phys. Chem. C*, 118, 14009.

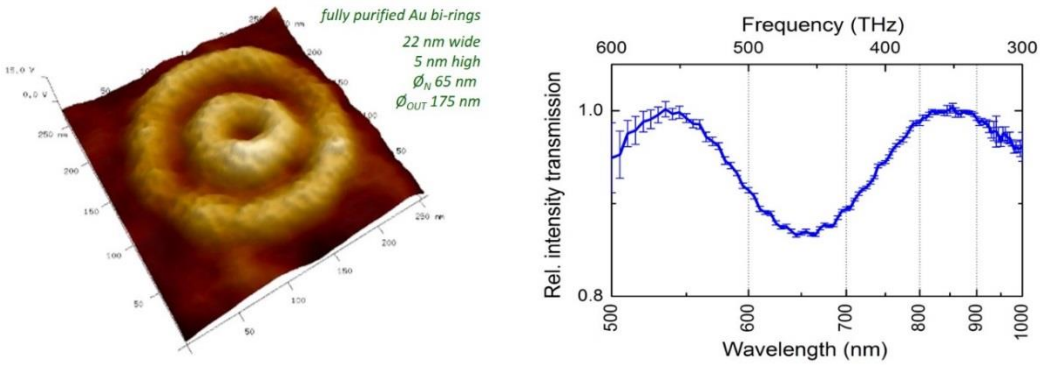

Figure 1: Au based FEBID metamaterials for plasmonic filtering in the THz range. AFM height image of a fully purified, Au bi-ring (left) revealing FWHM line widths and heights of less than 25 nm and 5 nm, respectively. The representative transmission spectrum of a 12×12 bi-ring array clearly confirm the spectral modulation with a minimum at 655 nm (right).

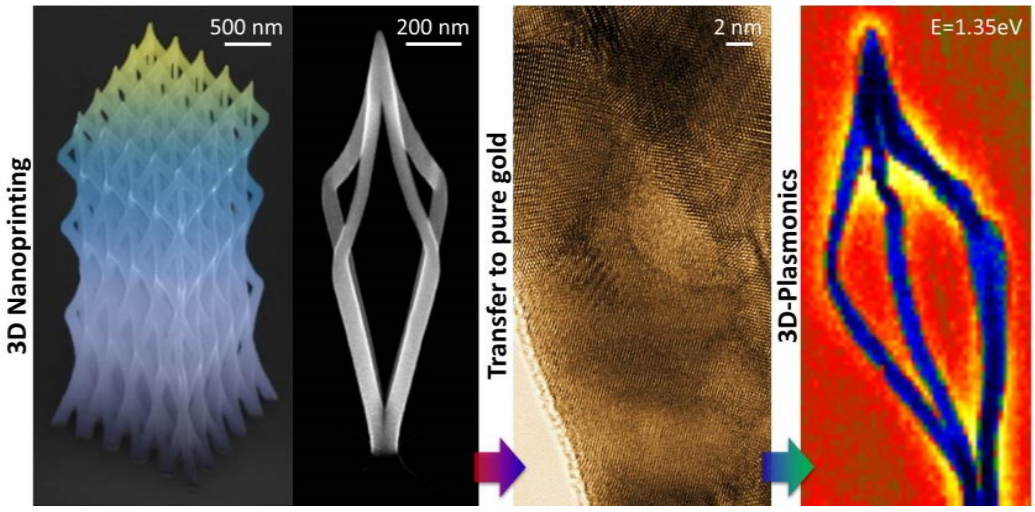

Figure 2: 3D-nanoprinting of plasmonic active FEBID-structures. First, complex 3D-nanoarchitectures are reliably fabricated via FEBID (left). After that, a purification step utilizing electron stimulated reactions with water vapour is applied to transfer the Au-C deposition into pure gold as shown via TEM characterization (center). Finally, STEM-EELS investigation confirmed plasmonic activity (right).