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3D Nanoprinting via Focused Electron Beams

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3D-printing of functional structures has emerged as an important technology in research and development. While being reliable on the micro and sub-micron scale, the extension to the nanoscale is still a challenging task. Among the very few direct-write techniques on that scale, focused electron beam induced deposition (FEBID) is one of the promising candidates as this technology allows fabrication of functional nano-structures on almost any material and substrate morphology in a single-step process. Based on strong fundamental progress in recent years, FEBID was demonstrated to be capable of fabricating complex, freestanding 3D nano-architectures with individual branch diameters down to 20 nm [1,2]. Together with the increasing availability of precursors with different functionalities, FEBID is advancing from a versatile research tool into a predictable and reliable 3D nano-printer, which opens up new opportunities for advanced applications.

In this contribution, we start with the basic principles of 3-dimensional printing via FEBID, complemented by simulations for deeper insight into the fundamental processes that are operative [3]. Next, we briefly introduce a recently released computer aided design software (3BID) [4], which allows the reliable and easy design of complex 3D objects (see Figure 1). In the following, we present a variety of 3BID based proof-of-principle studies to demonstrate the capabilities of this direct-write technology. This ranges from scientifically oriented applications, such as plasmonics [1], magnetics [5] and nano-mechanics [6] toward industrially relevant concepts for scanning probe microscopy related tip fabrication, such as electrical, thermal and optical 3D nano-probes (see Figure 2). Finally, we overview some of the remaining challenges and provide an outlook on future activities.

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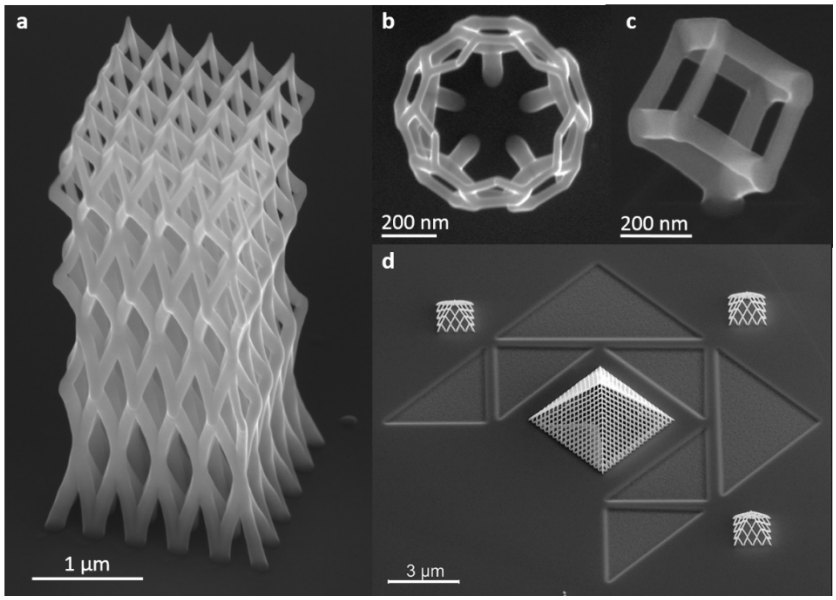

Figure 1. Direct-write 3D nano-printing of meshed-like platinum-carbon 3D nano-architectures: (a) sponge tower, (b) open Buckyball, (c) i-cube, (d) 3BID-model of the glass pyramid of the Louvre in Paris on a FIB-pre-structured silicon substrate. All images are SEM side views except (b), which is imaged from top.

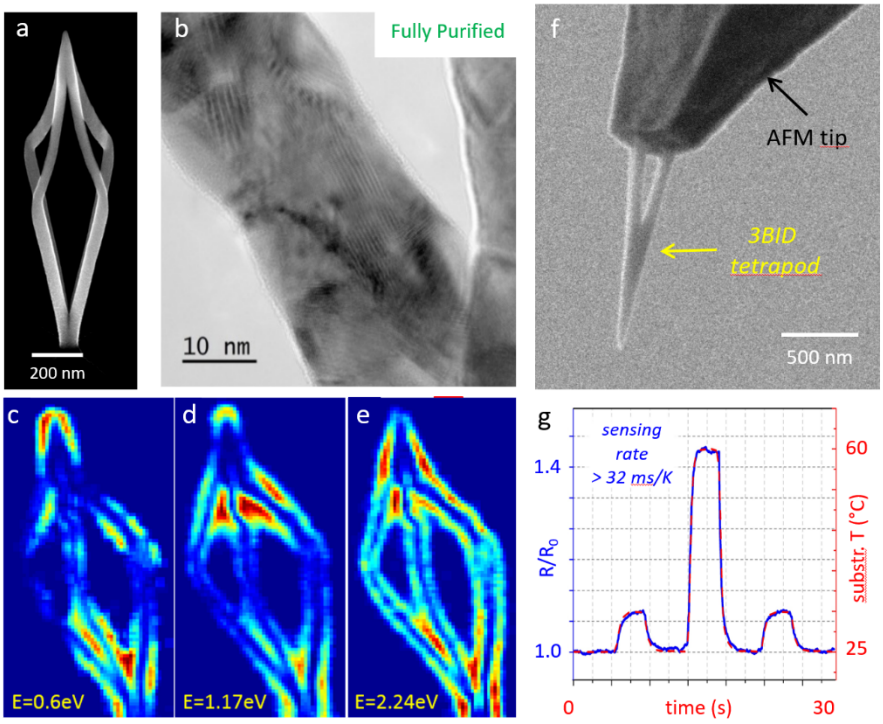

Figure 2. 3D structures for plasmonic (a-e) and thermal nano-probing (f-g). (a) shows a freestanding Au-C 3D structure which is transformed into pure Au via purification (b). (c-e) STEM-EELS characterization at different energies, which confirm plasmonic activities. (f) 3BID tetrapod on top of a FIB pre-processed self-sensing cantilever for further application as thermal nano-probe. (g) shows the timely response by electric current readout through the 3D tetrapod revealing sensing rates of 32 ms/K.

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