In-situ study on the Mechanical Properties of 3D Printed Nanoprobes for High Resolution Scanning Thermal Microscopy

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In recent years focused electron beam induced deposition (FEBID) matured to become a highly deterministic direct write 3D nano-printing technique[1]. In a simplified view, a reactive precursor gas is directed towards the processing site of the electron beam, which in turn induces chemical reactions in the precursor molecules, leading to site-specific decomposition and deposition of material. By guiding the beam to distinct points, *in-situ* fabrication in all 3 dimensions is possible and combined with a choice of different processing materials this technique contains huge potential for novel optical[2], electronic, magnetic, thermal, and mechanical applications with feature sizes down to the lower nanoscale. We currently aim to integrate Pt based nano-probes on AFM cantilevers for high resolution thermal surface mapping. Beside the inherent thermoelectric response of Pt, acting as transducer element, the small active volumes and end radii down to 5 nm are essential for fast thermal response and high-resolution capabilities. Yet, when operated as an AFM tip, the mechanical stability in all dimensions is of essential importance and requires a detailed optimization prior to any real application. To approach this problem, we deploy an *in-situ* force measurement technique, using a combination of SEM - AFM (Fig 1a) to determine the mechanical properties. We directly evaluate qualitatively (by SEM) and quantitatively (by AFM) the dynamic response of the fabricated structures under compression (Fig 1b). Supported by finite element simulations (FES) we 1) reveal individual morphological / mechanical peculiarities during force load; 2) iteratively adapt the FES model to gain comprehensive understanding of their origins (Fig 2a) and 3) optimize the 3D geometries towards highest spatial stability. Finally, we demonstrate the functionality of the fabricated devices as AFM nano-probes (Fig 2b), and by that set the foundation for one of the first direct commercial implementations of FEBID 3D nano-printing.

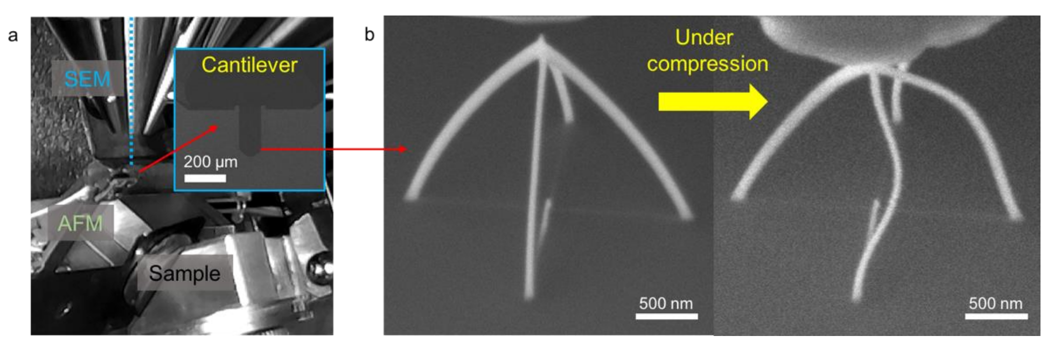

Figure 1 Correlative *in-situ* force measurements. a, the combined AFM - SEM measurement setup. **b,** utilizing the combined approach, even nanoscale structures can be directly accessed and with a prepared cantilever the dynamic behavior of such structures can be studied under force load.

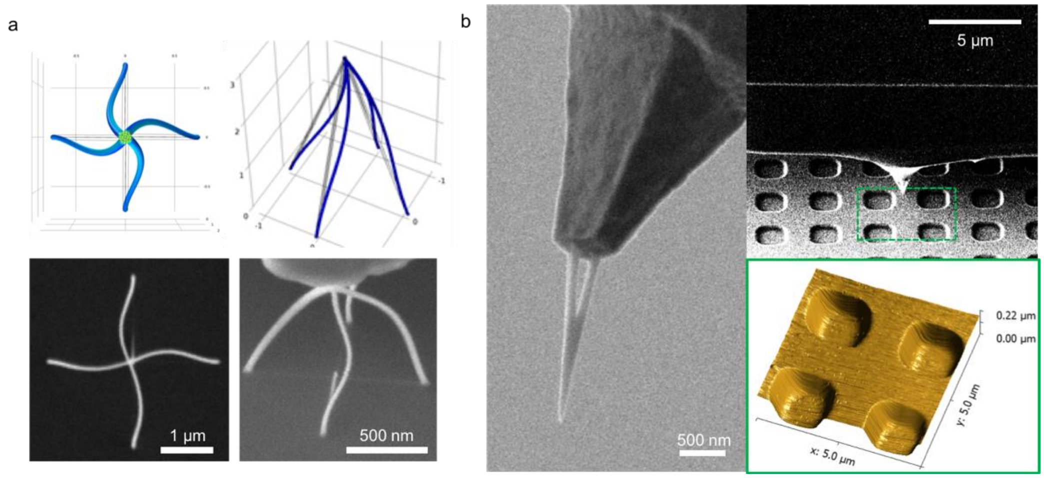

Figure 2 Iterative adoption of our model to optimize the functionality. (a) by adopting our FES model, we unravel the underlying mechanical properties of these structures. **(b)** finally, we deploy optimized Pt based 3D nanoprobes on AFM cantilevers to demonstrate their imaging capability.

[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