Thermal scanning probe lithography today and tomorrow: avenues for scale-up

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NanoFrazor thermal scanning probe lithography (t-SPL) tools are gaining popularity in solving complex nanofabrication challenges at research facilities worldwide. By using heatable ultra-sharp tips for material removal and modification as well as imaging the sample in parallel, the instrument has enabled sub-nanometer 3D grayscale lithography, accurate markerless overlay and the first-of-its-kind solution for nanoscale patterning of sensitive materials in a glovebox environment[1]. As no charged particles are employed, patterning can occur at ambient environment and no lithography-induced damage to sensitive materials or device layers will occur. These unique capabilities have allowed for the realization of a range of completely new kinds of nanodevices and opened up entirely new research directions[2,3].

Even though the patterning speed achieved by t-SPL using a single tip is more than two orders of magnitude faster than for other scanning probe -based approaches, it is comparable to highest resolution electron beam lithography (EBL) but significantly slower than high speed EBL. We present the recent developments towards increasing NanoFrazor's patterning throughput. Firstly, since 2020 all NanoFrazor Explore systems are equipped with an integrated optical write head for direct laser sublimation of thermal resists. This allows for t-SPL patterns (resolution < 1 µm) to be seamlessly stitched on-the-fly with larger-area laser-written patterns (resolution > 1 µm) in the same resist system, significantly reducing the fabrication time for nanodevice applications.

Furthermore, the first multi-tip version of the NanoFrazor Explore – the Decapede (see Figure) – will enter the market in 2021. Tip parallelization substantially increases the reliability and user experience and minimizes overhead time by allowing uninterrupted patterning of large-area high-resolution geometries. This approach lends itself readily to automating, and therefore paves the way to scaling-up tSPL for an ever-expanding range of applications including optical components and NEMS.

[1] S. T. Howell et al., *Microsyst Nanoeng* **6**, 21 (2020).
[2] P. Nicollier et.al., https://arxiv.org/abs/2007.04179 (2020).
[3] N. Lassaline et.al., *Nature* **582** (2020).

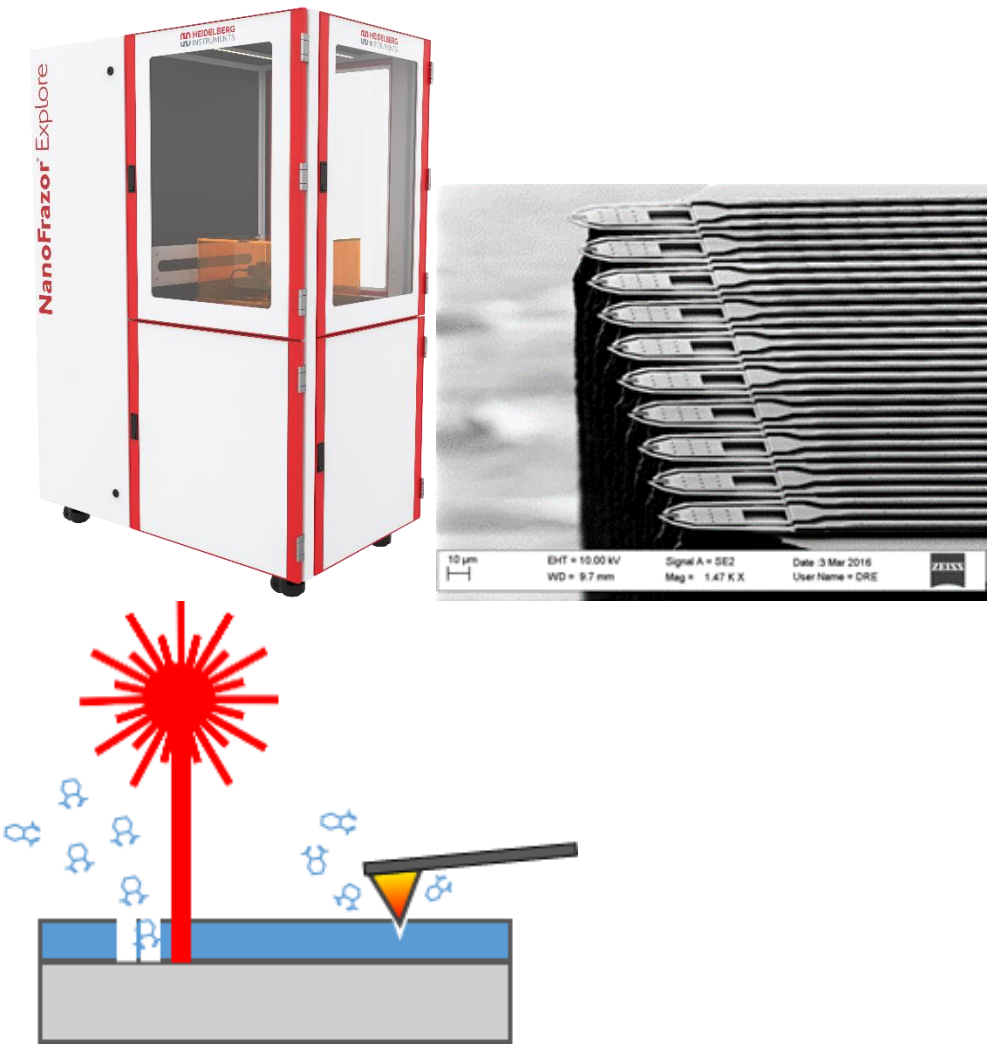

Figure: Top left, NanoFrazor Explore thermal scanning probe lithography system. Top right, From 2021 on NanoFrazor Explore can be equipped with the “Decapede” add-on, the first multi-tip extension with ten parallel cantilevers. Bottom, Since 2020 NanoFrazor Explores are delivered with an optical write head for direct laser sublimation for integrated mix and and match lithography, drastically speeding up the patterning of features with dimensions above 1 µm.