

Patterning with the fourth beam: Advances in thermal lithography with the NanoFrazor

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The NanoFrazor combines thermal scanning probe lithography (t-SPL) and direct laser sublimation (DLS) to create nano and microstructures rapidly and repeatably. Advances in the technology continue to open new application areas and enable novel research in a wide range of material systems. In tSPL, an ultrasharp tip is heated for a few microseconds at each pixel, in order to remove thermal resist materials. When used in a closed-loop system, tSPL can be used to write grayscale structures, and to control the depth of lithography to optimize post-processing. DLS employs a focused laser beam to remove the same resist materials, in order to quickly and simply create microstructures in the same sitting.

The high-resolution, rapid patterning capabilities of the NanoFrazor are increasingly used in nanoelectronic circuits, including shaping MoS₂ in a deterministic manner¹ and creating edge-contacts to MoS₂ transistor devices². The versatility of tSPL is exploited in applications that benefit from free-form patterning of arbitrary shapes on a large variety of materials, such as forming nanodisks, nanoparticles and even nanoflowers in a reproducible manner³. The arbitrary patterning capability is combined with grayscale patterning, in order to create varied-thickness flakes of hexagonal boron nitride for future nanoelectronics applications⁴. Furthermore, advances in processing with more resist materials, including polymers such as parylene C⁵ add to the flexibility of the technique.

While the technique is now established as a method for advanced, novel device fabrication, advances are enabling more and more automation. Active stitching, automated overlay, and automation allow for larger scale patterning, unattended operation, and design flexibility.

¹M.C. Giordano et.al., *Adv. Mat. Interfaces*, 2201408 (2022).

²A.Conde-Rubio et.al., *ACS Appl. Mater. Interfaces*, **14**, 37 (2022).

³T. Das et.al., *ACS Appl. Mater. Interfaces* **14**, 17 (2022).

⁴N. Lassaline et.al., *Nano Letters*, **21**, 19 (2022).

⁵Y. Jiang et.al, *Micro & Nano Lett.* **17**, 4 (2022).



Figure: Top, NanoFrazor Explore thermal scanning probe lithography (tSPL) system, equipped with a 405 nm continuous wave laser for direct laser sublimation (DLS). Bottom, Heidelberg Instruments logo patterned by DLS (200 x 200 μm) and by tSPL (10 x 40 μm).