

Scaling up and Automating Nanodevice Fabrication with Parallelized Multi-tip Thermal Scanning Probe Lithography

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Summary:

Thermal Scanning Probe Lithography (t-SPL) with the NanoFrazor by Heidelberg Instruments allows high-resolution, damage-free nanoscale patterning using localized thermal stimulation from an ultra-sharp tip. The Decapede, its first multi-tip version, scales up t-SPL while maintaining resolution through parallel tip operation, enabling the creation of multiple designs simultaneously. This talk will highlight Decapede applications in nanophotonics, including the creation of a photonic sieve and a metalens, demonstrating parallel patterning of complex structures in silicon.

Keywords: thermal scanning probe lithography, nanofabrication, parallelization, nanophotonics.

Thermal Scanning Probe Lithography (t-SPL), using the NanoFrazor by Heidelberg Instruments, is an established direct-write nanolithography technique that utilizes an ultra-sharp thermal tip for creating and inspecting nanoscale structures, while also integrating direct laser sublimation (DLS) for hybrid lithography of nanodevices [1]. This unique method employs precise localized thermal stimulation to achieve high-resolution, damage-free patterning, enabling direct physical and chemical modifications of various materials [2]. Combined with markerless second layer alignment, automation features, and single-nanometer precise grayscale lithography, the NanoFrazor effectively addresses complex fabrication challenges across diverse applications in fields such as quantum nanoelectronics [3], nanophotonics [4], and nanobiosystems [5].

The Decapede, which is the first multi-tip version of the NanoFrazor, scales up the t-SPL technology without compromising resolution, see Figure 1. By enabling parallel tip operation, the Decapede minimizes overhead time and facilitates seamless patterning of large-area, high-resolution geometries, allowing for the independent and simultaneous creation of ten designs on a single surface.

In this talk, we will explore the working principles of NanoFrazor lithography, highlighting successful applications of Decapede patterning, particularly in nanophotonics. In one example, we will showcase the creation of a photonic sieve, seen in Figure 2, through rapid single indentation patterning. The patterned nanoholes are then turned into nanopillars etched in silicon through a series of standard microfabrication steps. In another example, we will demonstrate the patterning of a metalens by the multi-tip configuration, covering an area of $690\text{ }\mu\text{m} \times 690\text{ }\mu\text{m}$, comprising 2 million high-resolution rectangular elements etched $1.5\text{ }\mu\text{m}$ deep into silicon, as illustrated in Figure 3.



Fig. 1. (left) NanoFrazor in-situ microscope showing the Decapede over a resist-coated substrate, writing features in both 2D high-resolution and in grayscale. (right) Simulated image of the Decapede patterning different features, alongside the integrated laser writehead.

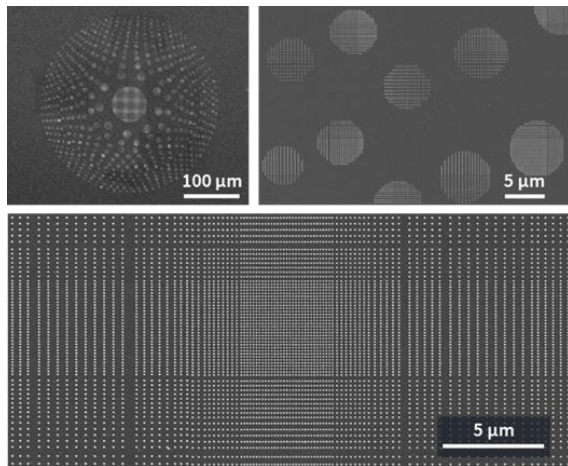


Fig. 2. SEM images of a final photon sieve with structures following a bisinusoidal distribution. The structures were created by single tip indentations with a pitch of 75 nm, and then etched 200 nm deep into Si.

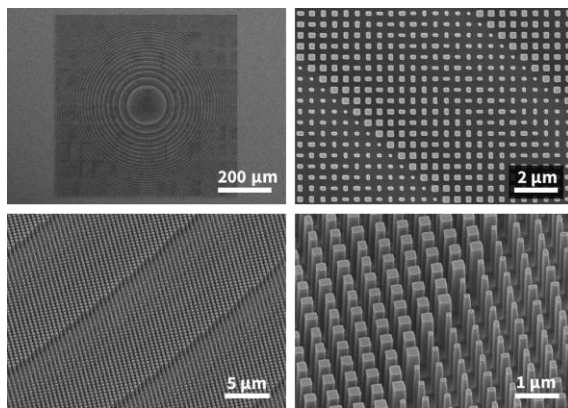


Fig. 3. SEM images of the full metalens (top left), and close-ups of its individual components, highlighting the Nanofrazor decapede's large-area high-resolution patterning capability.

References

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