Thermal and ThermoChemical Scanning Probe Lithography for mask-less and marker-less patterning of electronic materials

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Progress in nanotechnology depends on the capability to fabricate, position and interconnect nanoscale structures. A variety of materials and systems such as nanoparticles, nanowires, plasmonic materials and bio-functionalized surfaces, as well as two-dimensional materials are finding applications in nanoelectronics, nanophotonics, and biomedical applications. The success of many of the above applications relies on the existence of suitable nanolithography and nanopatterning approaches. The limitations of conventional lithography in terms of resolution, 3D patterning, grey-scale chemical nanopatterning and lack of flexibility for soft and novel materials have motivated the development of new fabrication methods.

Thermal and thermochemical scanning probe lithography (*t*- and *tc*-SPL) [1] is a unique method for rapid-fabrication of nanostructures and nanodevices with extreme resolution and high versatility. It has been developed for researchers who need access to topographical and chemical grey-scale patterning of arbitrary nanoscale geometries of non-conventional materials including polymers, 1D materials such as nanotubes, 2D materials, and biomolecules such as proteins. Even 3D nanopatterns can be fabricated in a single step, with the unmatched precision of 1 nm. Further features include mask-less and marker-less patterning, *in-situ* simultaneous writing and imaging for closed loop lithography, high speed (mm/s), and large areas (10^4 cm^2).

The *tc*-SPL method, which utilizes nanoscale local heat to either change the chemistry/structure of materials, or to evaporate a polymer, has been successfully used to (*i*) locally change the chemistry of polymer films with nanoscale gray-scale precision while also achieving quasi-3D topographical patterning [2], (*ii*) oxidize/reduce functionalized graphene with nanoscale precisions, (*iii*) deposit high performance electrodes and doping for 2D materials [submitted work], (*iv*) locally crystallize PZT nanostructures on plastic, (*v*) non-destructive, reconfigurable magnetic patterning for magnonics applications [3].

[1] "Advanced Scanning Probe Lithography", Nature Nanotechnology, 9, 577 (2014) DOI: 10.1038/NNANO.2014.157

[2] "Thermochemical scanning probe lithography of protein gradients at the nanoscale" Nanotechnology, 27 (31), 315302 (2016)

[3] "Nanopatterning reconfigurable magnetic landscapes via thermally assisted scanning probe lithography" Nature Nanotechnology, 11, 545–551 (2016) doi:10.1038/nnano.2016.25