

The Dip Pen Nanolithography™ Process for Nanofabrication

Ray Eby*, Linette Demers*

*NanoInk, Inc., 1335 W. Randolph St., Chicago, IL 60607 reby@nanoink.net

This presentation is separated into 2 topics of discussion: (i) introduce the Dip Pen Nanolithography (DPN™) process; (ii) selected applications of DPN.

The DPN technique is a direct-write method of molecular deposition at the nano-scale, and as such is truly a “bottom up” nanofabrication process. The DPN process uses atomic force microscopy as its foundation. To perform this particular kind of nanolithography, a molecule-coated AFM tip serves as the “ink pen,” whereby diffusion of the molecular “ink” occurs from the tip, is delivered across the ambient meniscus, and is finally deposited onto the substrate (see Figure 1) [1]. Chemisorption of the molecules typically controls their attachment onto the substrate, and this specific binding is important for controlling the shape of the lithographic features. As ink molecules adsorb, subsequent incoming molecules travel over top of bound molecules in order to attach further out from the source of ink. If good binding occurs, then ink diffuses in a radial pattern from a point source. It is the nature of this diffusion process and surface binding activity that determines the kinetics of feature growth.

Images of DPN patterns are usually best obtained with frictional contrast by using lateral force microscopy (LFM), because the topography of the organic patterned films is smaller than the roughness of the substrate. Figure 2 shows an LFM image of a thiol molecule DPN pattern upon a gold substrate. Rudimentary DPN patterns are fairly straightforward to produce in most laboratories, however, for ultimate control of the process, the experimenter must accurately control the following parameters: 1) vector tip speed, for lines; 2) stationary tip dwell time - for dots; 3) humidity; 4) temperature; and, 5) instrumental drift.

Few other methods of nanofabrication can boast the degree of chemical versatility for compounds to write with or substrates to write upon. Furthermore, because of the extreme resolution and positional control that is available from modern scanning probe technology, it is easy to perform lithography at the nanoscale, and in fact, DPN usually does not push the limits of SPM performance. This fact is one reason that the DPN process is robust and amenable to industrial use, as far as instrumentation is concerned. One factor that will transfer the DPN process from nanoscience laboratories into industrial applications is the use of multi-probe technology for parallel writing. Probe technology will also be discussed.

DPN is probably the only deposition technique that can place molecules of a different composition in nano-scale spatial registry with one another. This is a powerful capability. Multi-ink DPN can be used for studying fundamental molecular interactions, or, for creating device structures that require multiple chemistries to be placed in nano-scale proximity.

Selected applications will include the fabrication of direct-write DNA bioarrays, DPN templates for biological attachment, orthogonal binding of DNA-laden nanoparticles, bioassays and biosensors. An important concept for DPN applications is templating. This

experiment involves using ink molecules for patterning an organic “glue.” The patterned glue serves as a structural template that provides positional control for the attachment of additional building blocks that get stuck onto the glue spots[2]. A more complicated form of the template experiment is orthogonal assembly, which is essentially using chemically encoded DPN templating, or more simply, “Smart Glue™.” In this case, different regions of the glue template have different chemical components which will preferentially bind to other unique molecules that are introduced to the surface after patterning[3].

[1] R.D. Piner et al., *Science* 283 (1999) 661.

[2] L.M. Demers, C.A. Mirkin, *Angew. Chem. Int. Ed.* 40(16) (2001) 3069.

[3] L.M. Demers et al., *Angew. Chem. Int. Ed.* 40(16) (2001) 3071.

[4] We acknowledge the pioneering work of the Mirkin Group (NWU) & Chang Liu (UIUC).

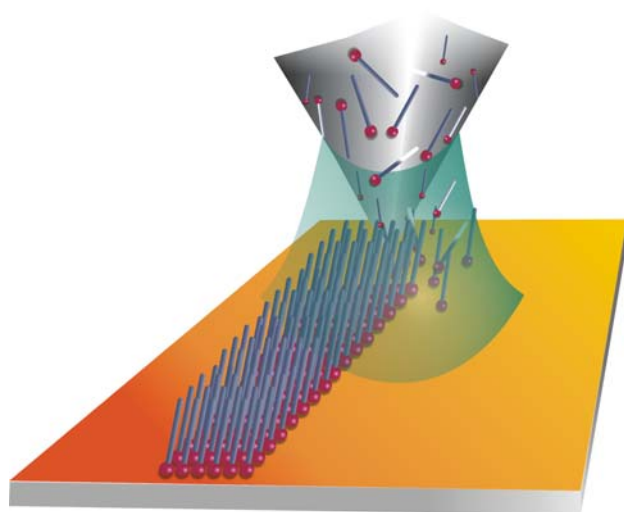


Figure 1: DPN process – A molecule-coated AFM tip does nanoscale direct-write lithography

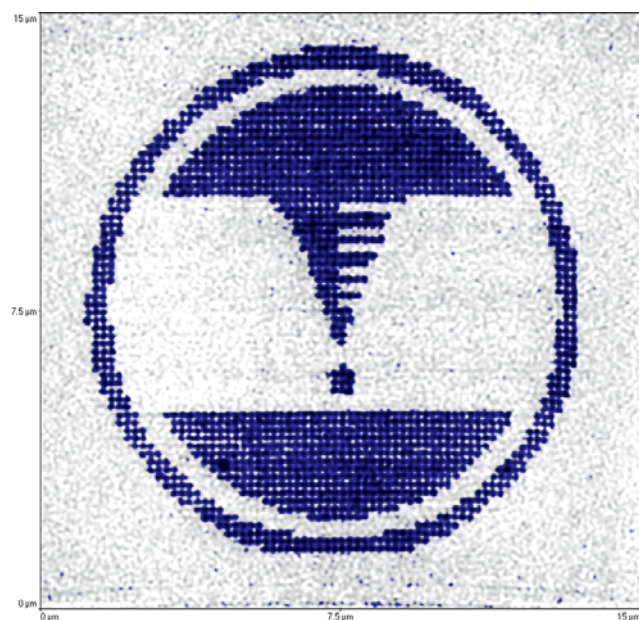


Figure 2: LFM image of thiol molecule pattern of 90 nm dots on gold substrate. 15 μm scan