

## Dip Pen Nanolithography (DPN)

**Objectives:** (1) to operate the NanoScripator for patterning by dip-pen nanolithography and (2) to image patterned nanostructures using lateral force microscopy.

### Background

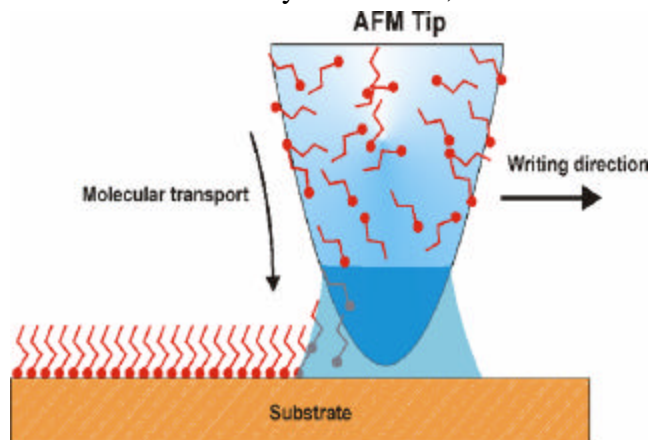
#### *Introduction*

One of the goals of nanofabrication is to study and take advantage of the novel collective properties of nanoscale building blocks. A fundamental challenge for implementing these assembly strategies is the ability to print a variety of surface template or 'glue' materials (starting from small molecules or salts to even using delicate biomacromolecules) on many different surfaces. Scanning probe microscopes and nanolithography methods have developed rapidly over the last decade. Early methods aimed for high density data storage solutions and for developing a means to shrink current integrated circuit dimensions down to a smaller unit size. In these areas, other nanolithography methods attempt to compete with and replace current technologies. The standard modes of atomic force microscopy operation are merely means of characterizing a sample. With the invention of Dip pen nanolithography system (DPN) [1-6], the unique advantage is that it offers a direct-draw method for delivering various molecular species onto a single surface in one experiment.

Moreover, it can selectively place these molecules at specific sites within a particular nano-structure or larger device. Such a technique offers many new and uncharted experimental possibilities. DPN techniques apply to a variety of major scientific fields, such as creating protein nano-arrays in the growing field of proteomics, making templates for nano-crystal growth in biotechnology and optics research, depositing material onto semiconductor substrates for the electronics industry, and doing magnetic particle deposition for storage and sensor technology.

The first paper on the DPN process, published only a few years ago, describes the basic capabilities and potential of the technique. In that early work, a coated probe served as a "pen" in which the tip of the probe was the drawing "nib". Molecules absorbed onto the pen became the "ink," and the sample substrate was the "paper."

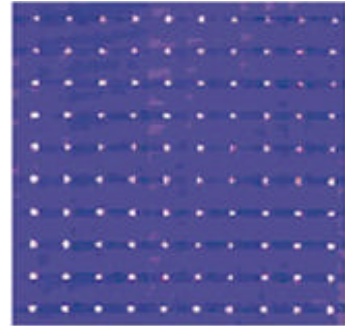
During the contact mode operation under ambient laboratory conditions, a water meniscus naturally forms between the ink-coated probe tip and the substrate. The ink moves on the substrate by capillary transport through the meniscus. One key issue of successful DPN patterning is choosing an ink and substrate with an appropriate chemical affinity. This causes the ink molecules to chemisorb onto the substrate. Proper binding self-regulates the diffusion of ink onto and across the substrate, thus controlling the resulting feature size and resolution.



There are several key experimental parameters that affect feature resolution, including humidity, temperature, temperature, and the pen's drawing speed. So even in its most basic form-drawing with a single pen and a single ink-DPN can be a complex experiment. To ensure success with even the most basic DPN experiments, you must pay proper attention to each of the controlled parameters. NanoScriptor brings total control to the experimental process by providing controls for humidity and temperature in an environmental enclosure called the e-chamber as shown in figure below. This enclosure is an integral part of the NanoScriptor system. Without it, the user is often left to guess what the nano-pattern results will be.

### *Features of DPN System*

- Nano-scale pattern design
- Environmental and scanning probe preparation
- Inking and re-inking
- Ink calibration
- Drawing/plotting
- Microscale and nanoscale alignment
- Inspection of the DPN patterns

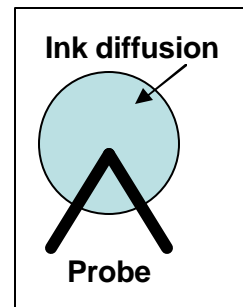


The DPN™ method is a truly unique lithography tool that combines the high resolution of e-beam lithography with the ability to pattern non-traditional materials (such as biomolecules) of micro-contact printing, the ease of use and automation of a computer printer and the promise of increasingly high-throughput as DPN Pen Systems are developed to include tens and even hundreds of thousands of individually-controlled pens. DPN™-built structures and patterns are:

- Smaller than those produced virtually any other way,
- Cheaper to produce than any other technique,
- Built under the supervision of individuals with only hours of training,
- Viewable literally during fabrication,
- Incorporate building materials that other techniques can not use, and
- Allows for the use of multiple materials simultaneously.

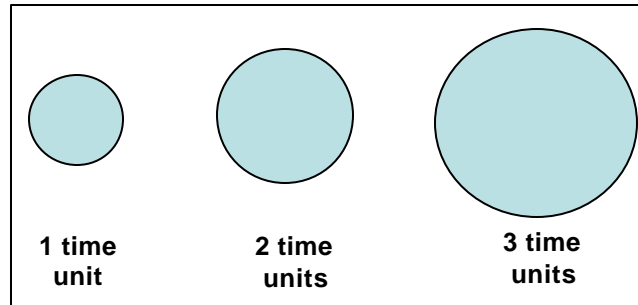
### *Ink Diffusion and Calibration*

In DPN-based nanolithography, diffusion is the process by which ink molecule spread onto the substrate radially from the probes. Diffusion is how the DPN process creates dots, and it's also how it controls the thickness of lines. To make a dot, the DPN software moves the tip to the correct location, and then stays stationary for a period to allow the ink to diffuse into a dot as seen in figure. The length of this stationary time, called the dwell time, determines the area of the dot. This is how the software determines the area of a dot, which is given by

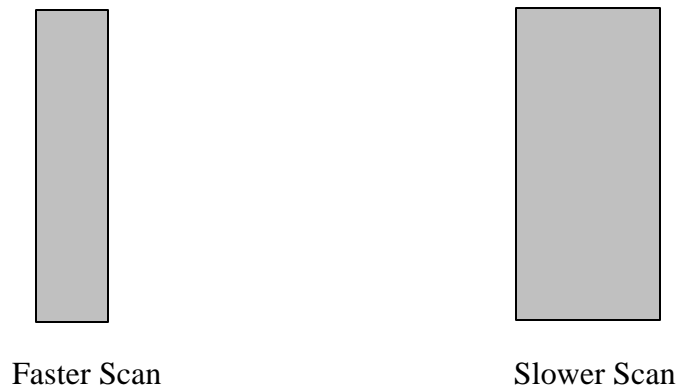


$$A = \pi r^2 = C \Delta t$$

Where  $A$  is the area,  $r$  is the radius,  $C$  is the diffusion coefficient and  $\Delta t$  is the dwell time.



Diffusion also plays a role in drawing lines. A line's thickness or width is determined by amount of diffusion, which in turn comes from the tip's scan speed:



$$A = L \times W = v \times \Delta t \times w = C \times \Delta t$$

$$\text{Thus: } W = C/v$$

Where  $A$  is the area,  $l$  is line length,  $w$  is the width,  $v$  is scan velocity,  $C$  is the diffusion coefficient, and  $\Delta t$  is the dwell time. The InkCAD software uses an input parameter called the diffusion coefficient, which helps the software account for the effects of diffusion and tip drawing speed, as well as the resulting DPN feature sizes.

### ***Imaging Modes of DPN System***

The three general types of DPN imaging are similar to those for AFM imaging: (1) contact mode, (2) tapping mode and (3) lateral force mode. Lateral force imaging-rather than topographical imaging-is generally the best way to scan completed DPN patterns because the system deposits ink in thin layers (as thin as one molecule) that would be hard to find topographically. LFM operates well under fast scan conditions. Quick imaging with the inky pen minimizes spurious ink deposition.

## References

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