Reference: TN007

Introduction to DPN® Patterning with Passive Multi-Pen Arrays

Introduction

Dip Pen Nanolithography® (DPN®) is a patterning technique that allows for direct deposition of materials on surfaces with nanometer resolution and accuracy. DPN enables nanofabrication in areas as diverse as nanoelectronics, sensor fabrication and biological assay generation. In the DPN process, ink is transferred from a reservoir to a substrate via a microscopic pen. Based on atomic force microscopy (AFM), these pens are made of microfabricated silicon nitride membranes.

In this technology note, we describe pen arrays that incorporate multiple identical pens. Such arrays make available two new features to DPN. Using the same ink on all probes, it is now possible to repetitively write the same structure with a fixed spacing, producing multiple devices in parallel. Also, when adjacent probes are coated with different inks, it is possible to write multi-ink devices on a reduced area in one operation, without needing to re-ink or re-align the pens.

Parallel Pen Layout

Our parallel pen arrays are one-dimensional rows of closely-spaced pens that still adhere to the standard form factor used in commercial AFMs. Each DPN pen consists of a flexible cantilever and an oxide-sharpened tip, responsible for both DPN ink transfer and DPN pattern inspection. The DPN cantilever and tip are made of SiN with less than one micrometer in thickness, and coated with a reflective metal gold layer on the back side. DPN probes within arrays are spaced as closely as 5 micrometers apart and are as narrow as 25 microns. Typical cantilevers are 150 microns long. Figure 1 illustrates an example of a DPN pen array, in this case an array of 11 probes.

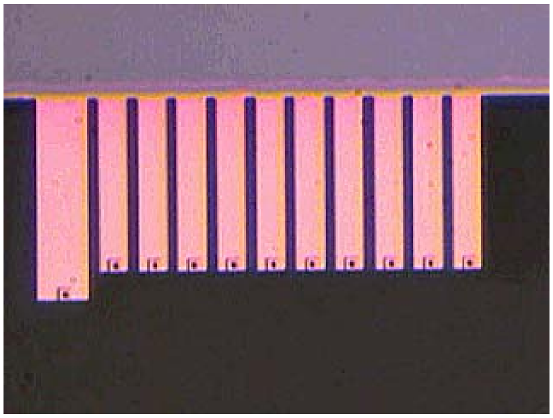

Figure 1: An array of mixed-type probes where 10 pens are for inking, flanked by 1 reader probe.

Writing Repetitive Structures in Parallel

One advantage of linear arrays of *n* pens for DPN is the ability to increase throughput by a factor of *n*. Repetitive patterns can be produced that are spaced by a distance given by the pen separation of the array in use. Figure 2 shows the results of such parallel writing using 16-mercapto-hexadecanoic acid (MHA) on gold substrates. In this experiment, small crosses were drawn on top of gold electrodes that are part of NanoInk's Nanoscale Experimenters' Test System™ (NETS™). The electrodes are insulated from each other by a layer of SiO_2. This configuration of evenly-spaced electrode gaps, matched to the probe pitch, is potentially useful to fabricate nanoelectronic devices using DPN.

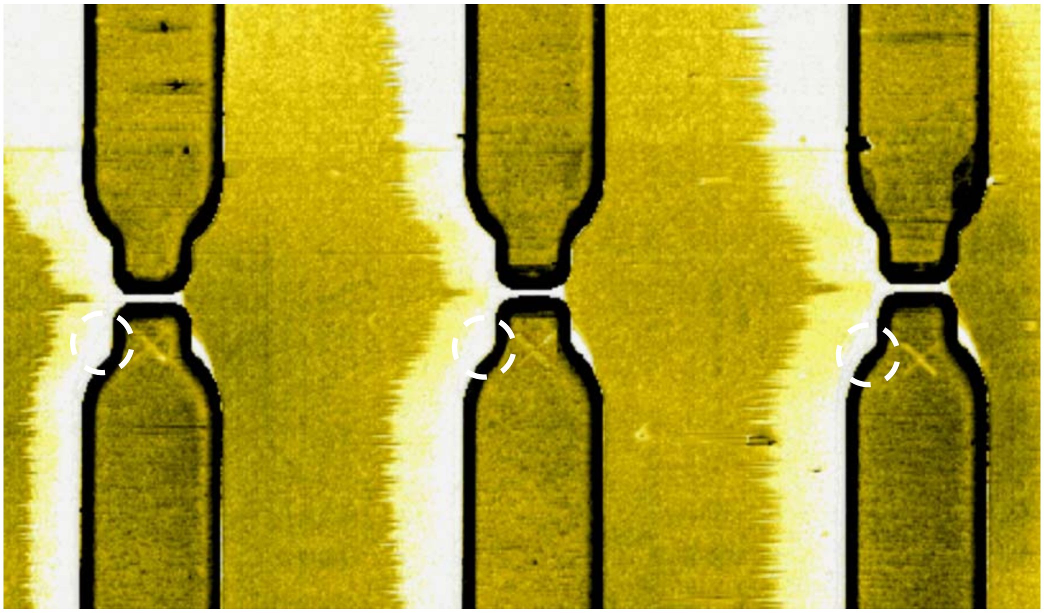

Figure 2: This 40x80 micron image shows parallel patterning on gold electrodes.

Writing Multi-Ink Devices without Re-Inking

For nanofabrication strategies that require deposition of more than one compound, DPN pens are typically exchanged or cleaned and re-inked to switch from one ink to the next. A new pen can be aligned to previous DPN patterns with nanometer resolution using the InkFinder™ and InkAlign™ features, before resuming pattern generation. With the use of probe arrays, it is possible to write multiple inks onto the same spot without continually switching DPN pens.

There are several possible strategies for writing differentiated ink structures. In the first case, a complex multi-layer, multi-ink circuit could be designed; however, DPN patterning of this design requires either individually actuated pens, or one must manually change single DPN pens one at a time. In the second case, one can use passive 1-D pen arrays to write simple multi-ink patterns. A schematic representation of the required strategy is sketched out in Figure 3. Note that it is in fact possible to write multi-ink features with differently inked passive DPN pens. The multi-ink device is designed by considering how the ink layers will be offset by the probe array pitch and drawn simultaneously. Upon writing this pattern with three probes and three inks, the one feature that falls into the overlapping range of all three probes will have the complete pattern. The available writing area for any pen array is limited to the space where all pens in an array can physically overlap each other. This is limited by the scan range. Importantly, devices fabricated with pen arrays have features placed with extreme accuracy. Layer misalignment is negligible, unlike the case of switching single pens.

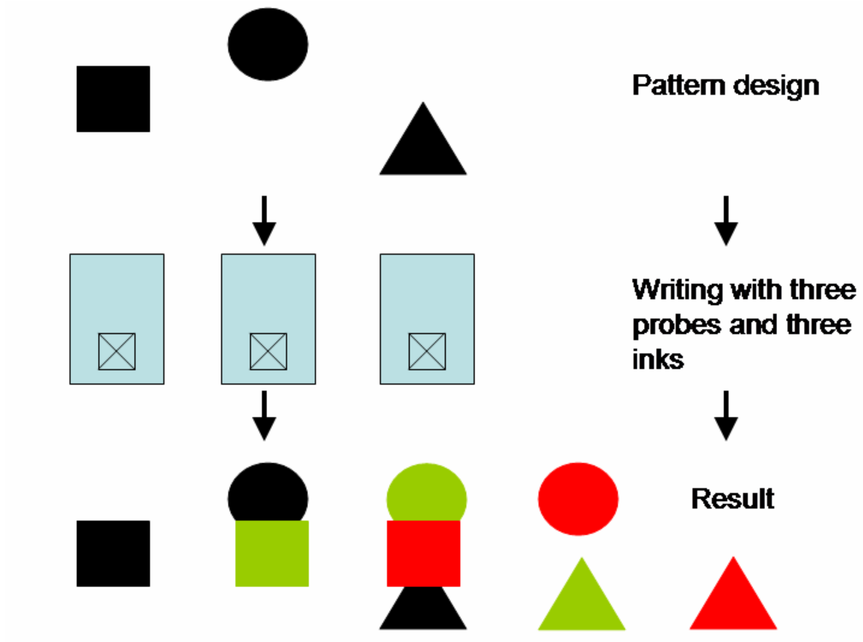

Figure 3: Writing multi-ink designs with multiple differently inked probes: The resulting three-ink device can be found in the center of all devices written.

To deposit the multiple inks on DPN pen arrays for the strategy outlined above, Inkwell devices are used (Figure 4). It is possible to introduce up to 10 different inks onto adjacent probes. Refer to the NanoInk tech note on Inkwells for further discussion of DPN inking.

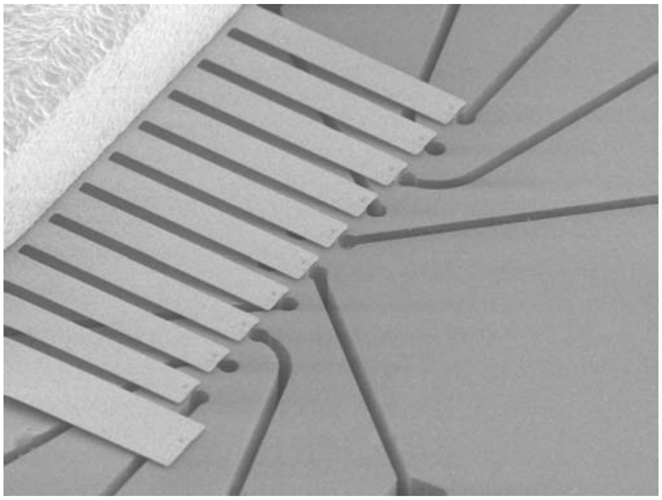

Figure 4: Inkwells are used to introduce inks to single pens without contaminating adjacent pens. Here we see an array with 10 pens dunking into 10 microwells, and 1 reader pen left un-inked.

For more information including pricing, please contact NanoInk Sales Department at sales@nanoink.net or 1-847-679-NANO.