Active Cantilever-free Scanning Probe Lithography

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Scanning probe lithography (SPL) provides a direct route for mask-free nanofabrication and allows one to directly deposit materials incompatible with conventional fabrication techniques through techniques such as dip-pen nanolithography. As with any serial technique, SPL is commonly limited by throughput and attempts to overcome this via parallelization either require costly cantilever fabrication or are only capable of printing copies of a single pattern.

We have recently developed cantilever-free SPL, a technique that enables the printing of nanoscale molecular features[1] and the near field optical lithography[2] in high throughput and low cost fashion (Figure 1). Cantilever-free SPL is based on an array of pens with nanoscale tips that rest on a compliant polydimethylsiloxane (PDMS) film held in a plane by a rigid glass backing. This structure allows all of the pens in a cantilever-free pen array to be in simultaneous gentle contact with a surface, however, this also results in the same pattern being written by each pen. In order to increase the applicability of cantilever-free SPL, it is important to develop ways to print arbitrary arrangements of features while maintaining the nanoscale resolution. Here, we report recent progress in developing methods to independently actuate pens in cantilever-free SPL.

We explored a thermal actuation scheme to deliver materials to a surface wherein resistive heaters were fabricated on the glass substrate beneath each pen. When a given heater was activated, the thermal expansion of the PDMS layer actuated the pen towards the surface, depositing material on the surface. This thermal actuation methodology allowed us to move pens over 4 μm at rates exceeding 100 μm/s, parameters sufficient for molecular printing. Using this methodology, we demonstrated the robust printing of molecular features, illustrating the desktop nanoprinting capability of active cantilever-free SPL.

To enable actuated delivery of energy, we combined the cantilever-free architecture, a method to batch fabricate 100 nm-scale apertures at the tip of every pen in an array, and a digital micromirror device-based methodology to deliver light to pens in coordination with their position. These advances allowed us to simultaneously pattern features as small as 100 nm in arbitrary arrangements across a surface with registry to existing patterns. We believe this will be useful as an inexpensive rapid prototyping tool and in applications in combinatorial chemistry and biology where directing light to nanoscale regions is important.

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[2]F. Huo et al., Nat. Nanotechnol. **5** (2010).

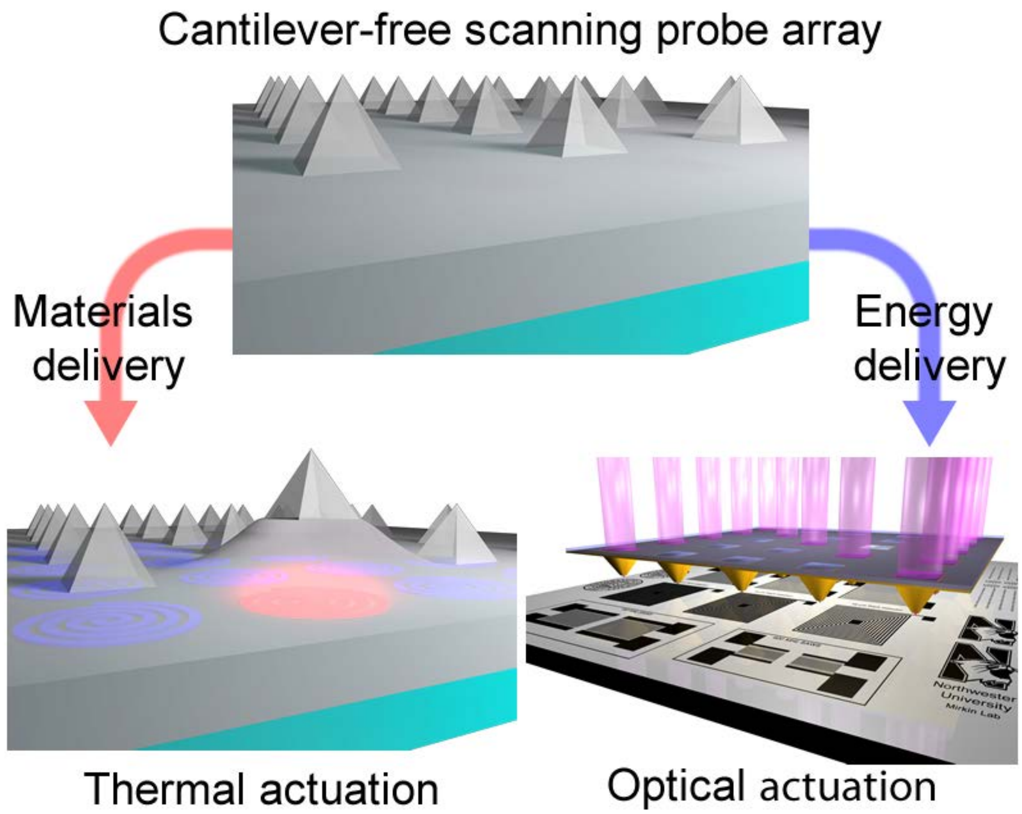

Figure 1: Actuated Cantilever-free Scanning Probe Lithography: A cantilever-free scanning probe array consists of an array of pens with nanoscale tips that rest on an elastomeric film on a rigid backing layer. This structure allows one to rapidly define uniform arrays of features in a low-cost and high resolution fashion. In order to transform cantilever-free scanning probe lithography into a technique that can define arbitrary patterns, it is important to investigate methods to individually actuate pens in a cantilever free array. Here, we report the development of a thermal actuation scheme to enable massively multiplexed material delivery and an optical actuation scheme for massively multiplexed energy delivery.