Nanolithography on Cross-linked Polymers Using Heated AFM Cantilever Probes

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Nanopatterning of polymer thin films is the basis for the vast majority of current micro- and nanolithography processes used today. Although photolithography is still the dominant industrial patterning technology, for feature sizes below 100 nm the cost of the exposure tools and mask sets required become prohibitively expensive except for the highest volume applications. Electron beam lithography is still the dominant high resolution, maskless patterning technology, but it's extremely slow serial nature limits its application. Our recent work has focused on developing alternative maskless lithography techniques that can overcome the speed limitations of electron beam lithography while still offering the potential for nanometer scale resolution. To that end, we have recently reported the use of heated AFM cantilever probes in conjunction with polycarbonate thin films for nano-patterning. This technique offers the promise of high throughputs since it can be scaled using large arrays of heated tips writing simultaneously. While there exist a number of nanometer-scale manufacturing techniques that exploit the AFM, the writing speed in these previous methods is a significant challenge, with typical writing speeds in the range 0.1-1 μm/sec [1]. In addition, some of the AFM based patterning methods require special substrates, such as conductive layers[2], that can also limit their application. The new technique reported here is shown to have writing speeds that can be up to 100 μm/sec while not requiring special substrates. This paper reports on our recent work that shows this thermal writing technique can be broadly applied to a wide range of polymer films, including polycarbonates, poly(styrenes), and epoxy polymers, with the essential requirement for good imaging being that the polymer is cross-linked to resist local thermal deformation and flow. The effect of polymer properties on thermal writing are reported along with a simple model that describes the writing process.

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[1] Richard D. Piner, Jin Zhu, Feng Xu, Seunghun Hong,Chad A. Mirkin, Science 283: 661, 1999
[2] A. Majumdar, P. I. Oden, J. P. Carrejo, L. A. Nagahara, J. J. Graham and J. Alexander, Appl. Phys. Lett. 61: 2293, 1992

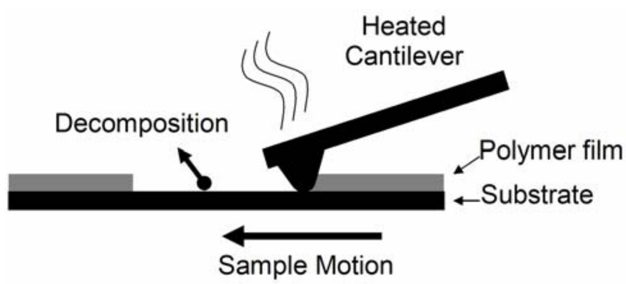

Figure 1: Schematic of the local thermal decomposition process investigated in this work and used to pattern polymer films with the heated AFM cantilever probe tip. As the probe tip is scanned, polymer is decomposed and vaporized in regions where the tip is heated to a temperature sufficient to decompose the polymer.

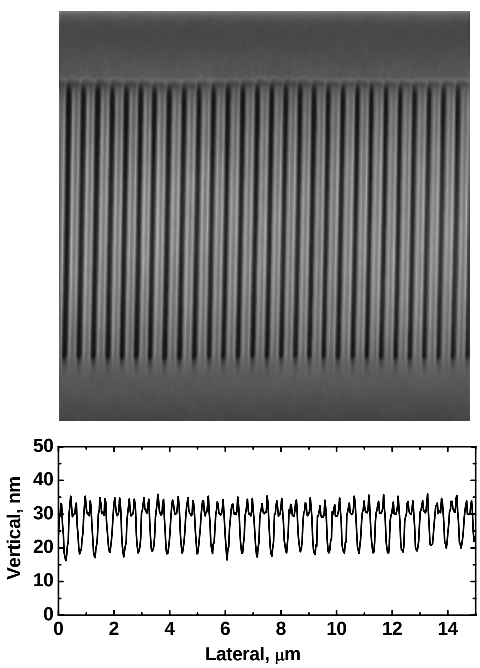

Figure 2. AFM topograph of patterned lines with a pitch of 500 nm in corss-linked tBOC-PHOST polymer thin

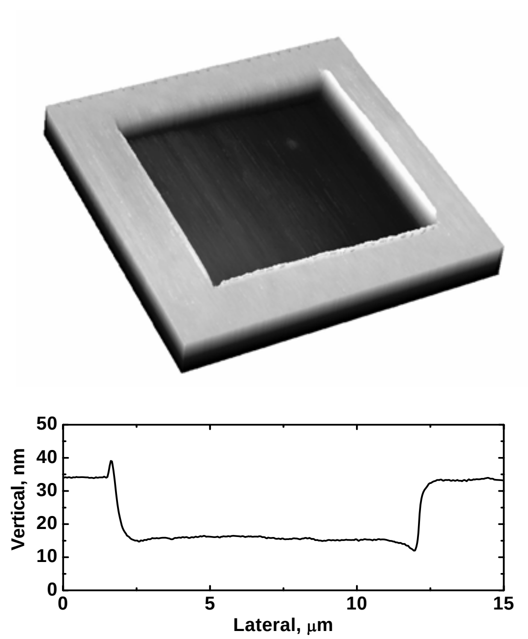

Figure 3. AFM topograph of a patterned 10 um square in a cross-linked poly(hysroxystyrene) thin film showing the clean sharp imaging possible with this method.