Patterning of poly(N-isopropylacrylamide) hydrogel nano structures using soft X-ray and EUV lithography

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Hydrogel nanoparticles and nanostructures have significant applications in biomedicine, biopharmaceutics, sensors, and transducers. Patterning using optical lithography produces high throughput with feature size greater than a micron[1] while e-beam lithography has the ability to produce the nanoscale patterned hydrogels albeit at very low throughput[2]. Hence, we have sought to develop new techniques to produced hydrogel nanostructures with high throughput by using soft x-ray and extreme ultra violate (EUV) interference lithography. We have reported various fabrication methods for synthesizing and direct patterning of hydrogels using optical[1], hard X-ray[3], and e-beam[1, 2] lithography. Here, we report the lithographic patterning of poly (N-isopropylacrylamide) (PNIPAM) hydrogel film using synchrotron radiation in the soft x-ray and EUV energy ranges. A 100-nm-thick PNIPAM film was produced by spinning and coating from a water-based solution of PNIAPM onto a hexamethyldisilazane primed Silicon wafer.

The thin PNIPAM film was exposed through a gold mask with a 2000mJ/cm^2 dose of 1 – 3 keV soft x-rays at the ES-1 beamline of the Synchrotron Radiation Center (SRC), University of Wisconsin. Figure 1 shows an atomic force microscopy (AFM) image of a variable line-width grating pattern generated using a 500-nm-thick soft x-ray mask. The areas exposed to soft x-rays are crosslinked and remained after developing in water. This result confirms that the nanostructures can be fabricated with controlled size and shape with soft X-rays. Similarly, a 90-nm-thick PNIPAM film was exposed using transmission-grating to generate an interferometeric exposure with a 75mJ/cm^2 dose of 60 – 110 eV EUV rays at the ES-4 beamline of SRC [4]. The results of our experiments will be discussed in detail.

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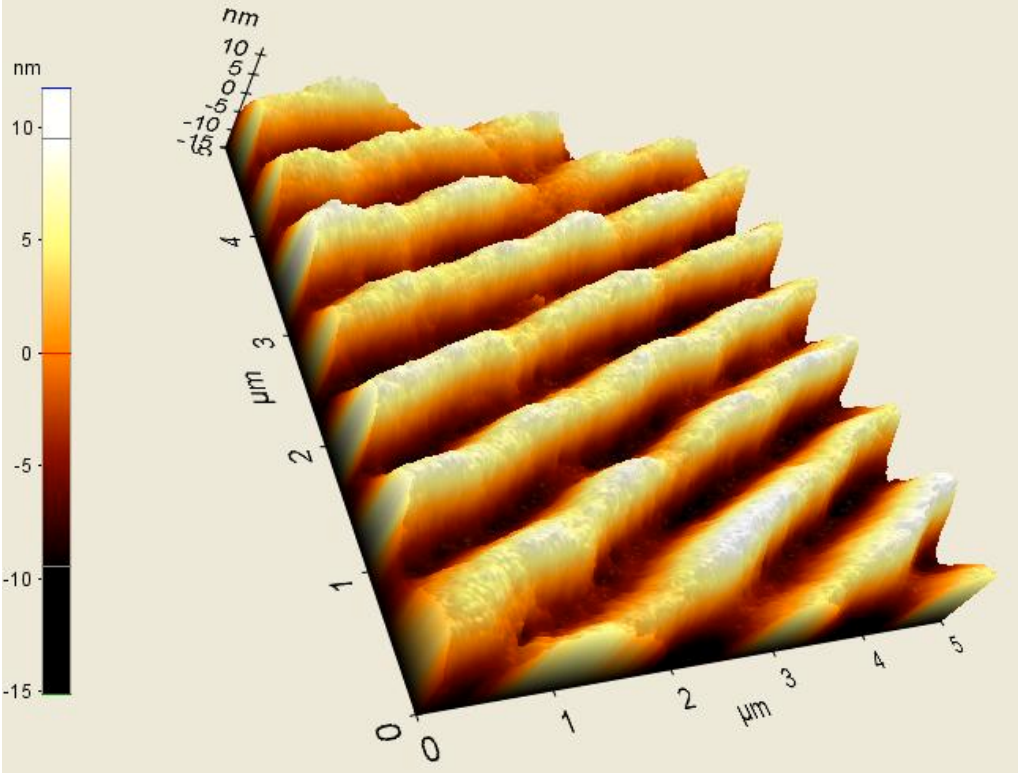

Figure 1: An atomic force microscopy image of PNIPAM nanostructures fabricated using soft X-ray lithography at the SRC, University of Wisconsin. The line sizes in the images are varying from 150nm to 400nm.