Single digit nanoimprint lithography achieved by template modification with atomic layer deposition

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UV Nanoimprint Lithography (UV-NIL) is a candidate technology listed by the ITRS semiconductor roadmap for continuation of Moore's law. It has been demonstrated that UV-NIL has molecular scale resolution [1], but the challenge is fabricating useful templates with the required resolution. Here we demonstrate a robust strategy for fabricating and replicating nanoimprint templates with sub-10 nm patterns. We combine atomic layer deposition (ALD), which has dimensional control and conformality at the molecular level, and e-beam lithography for prescise placement.

We employ two different ALD/e-beam strategies for sub-10 nm template patterning in this work 1) feature reduction and 2) double patterning, both using ALD. Strategy one is demonstrated in figure 1 where ALD deposition on HSQ gratings increases the linewidth and can produce 7 nm trenches. Nanostructures are replicated by step-and-repeat nanoimprint lithography on pre-spin coated resist films following the process presented in Reference [2]. Imprints are performed with the Molecular Imprint MII I55 Imprint press. Patterns with 7 nm features are then transfered into silicon by plasma etching at cryogenic temperatures. Replication is repeated multiple times to demonstrate the process robustness.

The second strategy is an ALD spacer patterning technique which serves to double the spatial frequency of a set of gratings (Figure 2). First we coat dense photoresist lines--in this case negative PMMA lines—with low temperature aluminum oxide. The aluminum oxide is deposited with a plasma at 25 °C. We then do a breakthrough etch of the alumina at the top surface of the line and leave the sidewalls intact. The PMMA is stripped to leave the very thin alumina oxide deposited on the line sidewall. This defines the minimum size of the features, with the width determined by the ALD film thickness and the spacing is determined by the initial photoresist linewidths. We demonstrate 5 to 8nm alumina lines at pitches from 16 to 20nm. Work is in progress to imprint these features and transfer into silicon using the same process detailed above in Ref. [2]. Challenges faced when working at these length scales will be discussed.

1. J. Rogers 2004 Nanoletters Vol. 4 No. 12
2. C. Peroz 2012 Nanotechnology 23, 015305

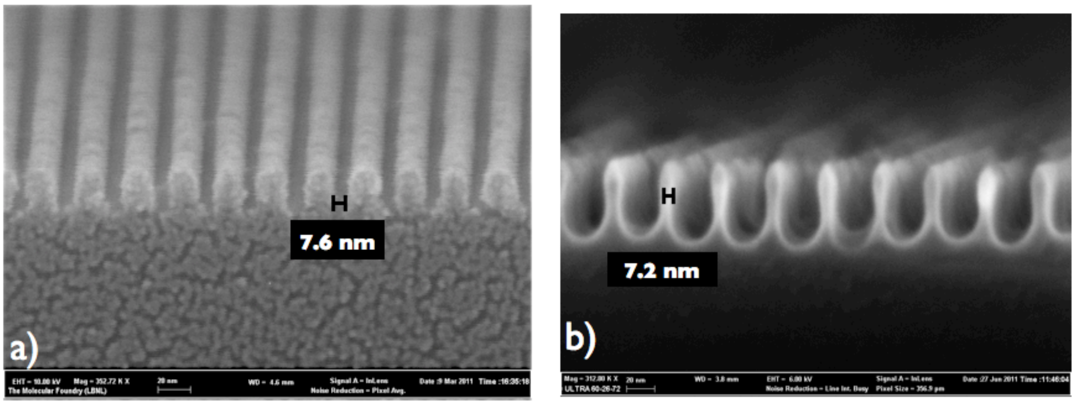

Figure 1.: Scanning Electron Microscope picture of gratings on the imprint template and gratings imprinted and transferred into silicon; a) 28 nm pitch grating with trench width reduced to 7nm. b) 28nm pitch, 7nm wide imprinted lines etched into silicon.

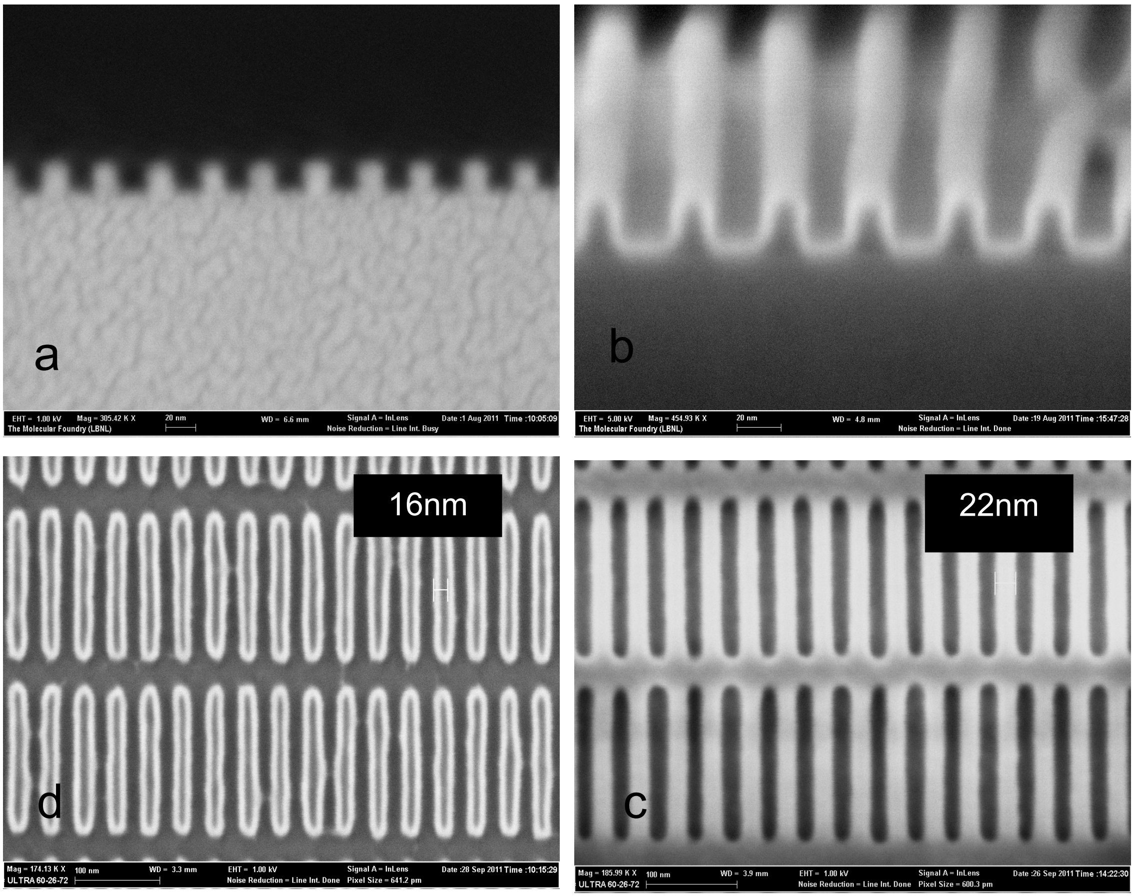

Figure 2: Scanning electron microscope images of ALD spacer lithography process; a) cross-section of 34nm pitch negative PMMA lines, b) cross-section of 40nm pitch PMMA lines with conformal aluminum oxide coating, c) top down of 40nm pitch PMMA lines coated with alumina, d) freestanding 16nm pitch alumina lines after breakthrough etch and PMMA stripping.