Sub-15 nm half-pitch nanoimprint molds using high resolution negative tone resist and reactive ion etching.

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The resolution limit of imprint lithography is claimed to be sub 5-nm.[1] While nanoimprint lithography is attractive as a low-cost high throughput technique, the fabrication of its imprint mold still depends on other lithography methods. A key issue to resolve is the ultimate pitch resolution since this determines the upper limit of the pattern density. In the past grating structures with 6 nm half-pitch have been demonstrated using a cleaved $GaAs/Al_{0.7}Ga_{0.3}As$ superlattice grown using molecular beam epitaxy (MBE) on GaAs.[2] However, this technique does not offer the flexibility of arbitrary pattern design and molecular-beam epitaxy tends to be a relatively slow process. In this work we use electron-beam lithography instead to fabricate nanostructures with the same resolution in HSQ resist using a salty development process.[3]

The HSQ resist thickness was thin at 20 nm to achieve high resolution, and electron-beam lithography was carried out in a Raith 150 EBL tool with a 30 kV acceleration voltage. In order to evaluate the resolution of the pattern transfer, a variety of different single-pixel designs were fabricated including nested L's, gratings, and dot arrays with pitches from 12 to 50 nm. Fig. 1 shows a micrograph of one of the nested L patterns with 6 nm half-pitch, after developing in an aqueous solution of 1% wt NaOH with 4% wt NaCl for 4 mins. While these structures might be sufficiently tall to be used as an imprint mold, we also investigated etching into the underlying silicon substrate to increase the depth profile of the imprint mold. The reactive ion etch step was carried out using a Plasma Therm 770 with HBr plasma, and a variety of different pressure and DC voltages were investigated in order to optimize the profile and etch rate. Fig. 2 shows a tilted SEM micrograph of a 12 nm half-pitch nested L pattern in the silicon substrate with a depth of 35 nm. The results show a high etch selectivity between HSQ and silicon and good profile transfer. Finally we will present the results of using the fabricated mold for nanoimprint lithography.

[1] F. Palmieri, M. Stewart, K. Jen, C. G. Willson, Solid State Technology **50** (9), 42 (2007)

[2] M. D. Austin, W. Zhang, H. Ge, D. Wasserman, S. A. Lyon, S. Y. Chou, Nanotechnology **16**, 1058 (2005)

[3] J. K. W. Yang, K. K. Berggren, J. Vac. Sci. Technol. B, accepted for publication (2007)

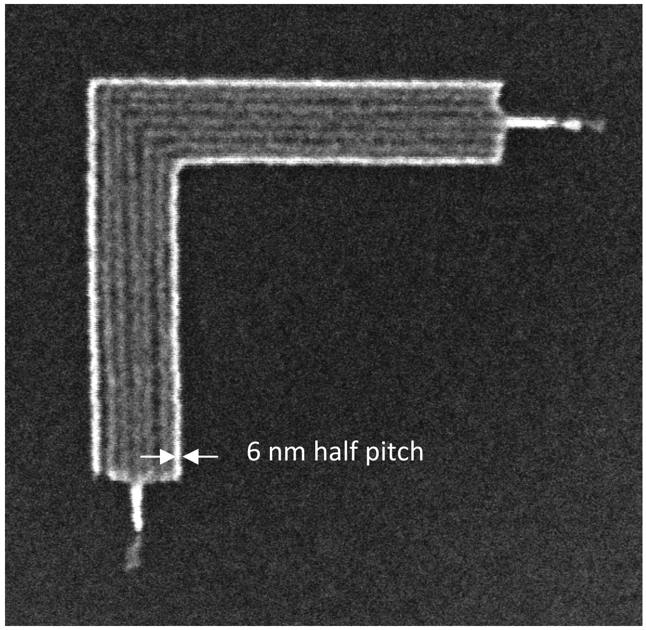

Figure 1: SEM of 6-nm-half-pitch nested-L structures 20-nm tall. Pattern was exposed in a Raith 150 EBL tool at 30 kV acceleration voltage and developed in a high-contrast salty developer.

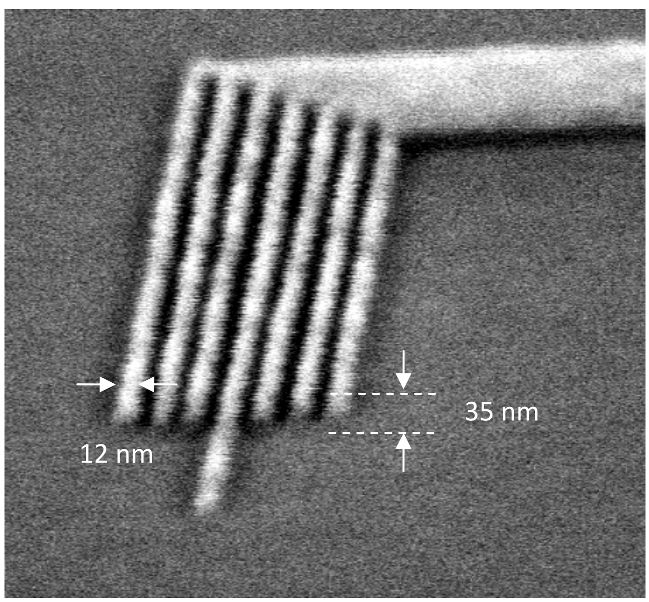

Figure 2: 20 deg tilted SEM image of 12-nm-half-pitch nested-L structures with 35 nm depth after pattern transfer into Si with HSQ as hard mask using HBr plasma RIE.