Reduction of proximity effects using high-contrast developer in fabricating large-area nanoimprint molds

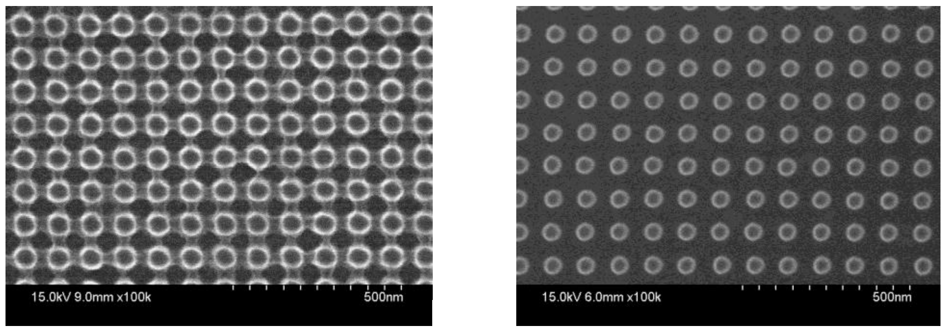
M. Yan, J. Lee, Y. Sun, I. Adesida, D. Chanda, and J. Rogers

Department of Electrical and Computer Engineering, Department of Materials Science and Engineering and Micro and Nanotechnology Laboratory, University of Illinois at Urbana-Champaign, IL 61801, U.S.A

Nanoimprint lithography has become a popular lithography for fabricating nanometer structures by mechanic deformation of the resist [1]. It can save the cost and realize the high-throughput fabrication yet with a high resolution. Nanoimprint lithography requires precise imprint molds, which are mostly made by electron beam lithography. During electron beam direct-writing, the electrons are scattered through the resist. The deposited energy in the resist comes from the forwarded electrons and the back-scattered electrons. The back-scattering effects cause un-wanted exposure surrounding the incident area. Such proximity effects [2] occur especially for a large area of electron-beam exposure and can be simulated with two Gaussian functions. The proximity parameters can be determined using special-designed patterns. The proximity effect can be alleviated with a combination of resist-model [3] using high-contrast developers.

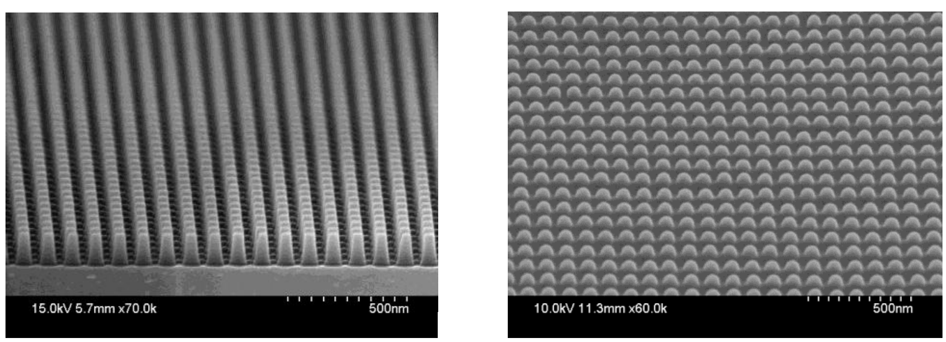
In this work, we present studies on how to reduce the proximity effect with a high-contrast developer in fabricating silicon nanoimprint molds using hydrogen silsesquioxane (HSQ). The area of an element mold is fixed at 80 μm by 80 μm and filled with the pattern of circles at a pitch of 100 nm and a diameter of 50 nm. 60-nm-thick HSQ resist was used in this work. The electron-beam exposures were conducted using a JEOL JBX-6000FS EBL system at 50 kV with a probe current of 1 nA. Developments were performed using a salty developer [4] at room temperature and at an elevated temperature. Figure 1 (a) showed results of HSQ pillars in the center area developed at room temperature, where the developer cannot clear the background dose, which was contributed from back-scattered electrons. Figure 1 (b) showed HSQ pillars in center developed at an elevated temperature. For imprinting, the arrays of HSQ pillars were transferred into the substrate with an inductively-coupled plasma reactive ion etching (ICP-RIE) system. An SEM picture of silicon imprint mold was shown in Figure 2(a). Figure 2 (b) showed a good imprint in SU-8 with optimized window openings, with a PDMS mold made out of the e-beam master as shown in Fig. 2(a). 0.5 mm × 0.5 mm area of such silicon pillars have been fabricated with the stitching error below 25 nm. Detailed results on how to determine the proximity parameters by experiments with special-designed patterns (arrays of squares and fishnets) will be presented at the conference. Also the discussion on the variation of the pillar-diameter from the center to the edge will be provided.

[1] S. Y. Chou, P. R. Krauss, P. J. Renstrom, *Science* **272** (5258): 85–7 (1996).
[2] A. Misaka, K. Harafuji, and N. Nomura, *J. Appl.Phys.* 68 (12), 6472 (1990).
[3] C. Liu, P. Tien, P. Ng, Y. Shen, and K. Tsai, *Proc. Of SPIE* Vol. 7637 7637V-1.
[4] M. Yan, J. Lee, B. Ofuonye, S. Choi, J. H. Jang, and I. Adesida, *J. Vac. Sci. Technol. B* 28 (6), C6S23 (2010).



(a) **(b)**

FIG. 1 HSQ resists developed at room temperature (a) and at an elevated temperature (b) after electron beam writing (SEM pictures were taken in the center area).



(a) **(b)**

Fig.2 (a) Pattern transfer into silicon substrate by dry etching; (b) imprint in SU-8 with a PDMS mold made from (a).