Pattern Transfer of Block Copolymer Template from Density Multiplication on Chemically Patterned Surface

Guoliang Liu,[1] Ricardo Ruiz,[2] Elizabeth Dobisz,[2] Kanaiyalal Patel,[2]
Paul F. Nealey,[1] and Thomas Albrecht[2]
1 Department of Chemical and Biological Engineering, University of Wisconsin, Madison, WI 53706 nealey@engr.wisc.edu
2 San Jose Research Center, Hitachi Global Storage Technologies, San Jose, CA 95135 ricardo.ruiz @hitachigst.com

The significant advance in the directed assembly of block copolymers on chemical patterns to multiply the feature density and enhance the pattern resolution has intrigued growing interest in the nanofabrication of templates for integrated circuits and magnetic data storage devices.[1-6] Previous reports[3, 4, 7] showed that the domains of the block copolymer after density multiplication had three-dimensional profiles depending on the boundary conditions, specifically, the interaction strength between the underlying pattern and the block copolymer domains, the period of the chemical patterns, and the size of the patterned features. It is desirable to understand whether the three-dimensional profiles have an impact on the pattern transfer process.

Here we characterized the pattern transfer properties of polystyrene-*block*-poly(methyl methacrylate) (PS-*b*-PMMA, lamellae period L_0= 27 nm) after density multiplication on a chemical pattern (period L_S=54 nm=$2L_0$). The chemical pattern was fabricated following the methods reported previously[2-5] and oxygen plasma reactive ion etching was used to transfer the template. Figure 1 revealed that it required longer time to etch the interpolated domains than that to etch the non-interpolated domains. The pattern transfer of the polymer template can be delineated into two stages: 1) etching the non-interpolated and interpolated PMMA domains, 2) etching a residual layer, possibly from the PS brush or the PS reconstruction during density multiplication, near the substrate in the interpolated domains. This work offers understanding of the pattern transfer properties of block copolymer with density multiplication on chemical patterns. It should give insight into the boundary condition optimization for density multiplication of block copolymer on chemical patterns to improve the pattern transfer properties.

1. S. O. Kim, H. H. Solak, M. P. Stoykovich, N. J. Ferrier, J. J. de Pablo and P. F. Nealey, Nature **424** (6947), 411-414 (2003).
2. M. P. Stoykovich, M. Muller, S. O. Kim, H. H. Solak, E. W. Edwards, J. J. de Pablo and P. F. Nealey, Science **308** (5727), 1442-1446 (2005).
3. R. Ruiz, H. M. Kang, F. A. Detcheverry, E. Dobisz, D. S. Kercher, T. R. Albrecht, J. J. de Pablo and P. F. Nealey, Science **321** (5891), 936-939 (2008).
4. F. A. Detcheverry, G. L. Liu, P. F. Nealey and J. J. de Pablo, Macromolecules **43** (7), 3446-3454 (2010).
5. G. L. Liu, C. S. Thomas, G. S. W. Craig and P. F. Nealey, Adv. Funct. Mater. **20** (8), 1251-1257 (2010).
6. B. C. Stipe, T. C. Strand, C. C. Poon, H. Balamane, T. D. Boone, J. A. Katine, J. L. Li, V. Rawat, H. Nemoto, A. Hirotsune, O. Hellwig, R. Ruiz, E. Dobisz, D. S. Kercher, N. Robertson, T. R. Albrecht and B. D. Terris, Nat. Photonics **4** (7), 484-488 (2010).
7. G. L. Liu, H. M. Kang, G. S. W. Craig, F. Detcheverry, J. J. de Pablo, P. F. Nealey, Y. Tada and H. Yoshida, J. Photopolym Sci. Technol. **23** (2), 149-154 (2010).

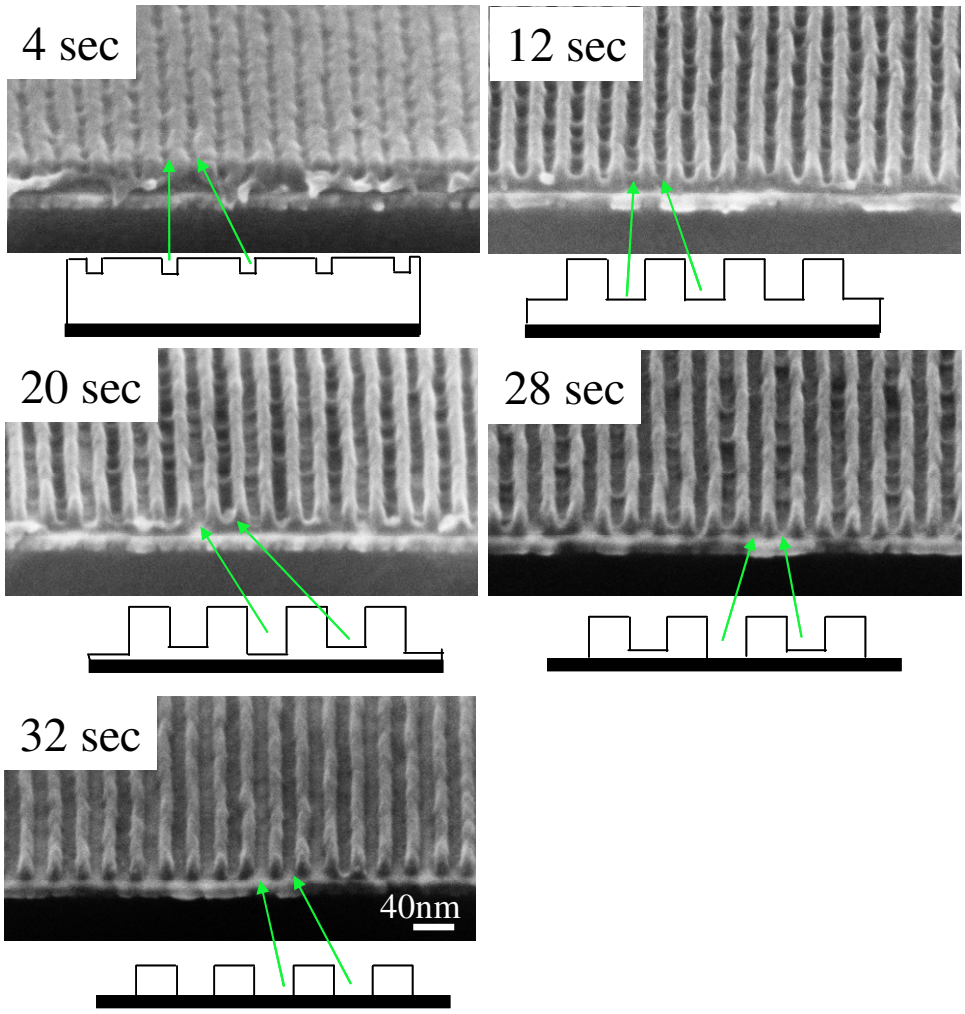

Figure 1: Cross sectional scanning electron microscopy (SEM) images with a 30º tilt angle and the corresponding schematics of PS-b-PMMA block copolymer profiles after various time of oxygen plasma to remove PMMA. With t<20 sec, the interpolated and non-interpolated domains have equal thicknesses of the residual layers. With 20 sec<t≤28 sec, the non-interpolated PMMA domains are fully removed, and the interpolated domains still have a residual layer near the substrate. With t≥32 sec, both the interpolated and non-interpolated domains are removed. Green arrows highlight the differences between the interpolated and noninterpolated domains. PS and PMMA appear bright and dark, respectively. The scale bar applies to all SEM images. The period of the block copolymer is 27 nm.