Image quality and pattern transfer in block copolymer directed assembly with block-selective atomic layer deposition

Ricardo Ruiz, Lei Wan, Jeffrey Lille, Kanaiyalal C. Patel, Elizabeth Dobisz
Hitachi Global Storage Technologies, San Jose, CA, 95135

Danvers E. Johnston and Charles T. Black
Center for Functional Nanomaterials, Brookhaven National Laboratory, Upton, NY, 11973

Advances in block copolymer lithography are bringing the technology closer to insertion in manufacturing applications that would expand the capabilities of conventional lithography.[1, 2] At issue remains the ability of block copolymers to generate robust, sharply-defined lithographic masks with suitable selectivity for high-fidelity pattern transfer when the critical dimension (CD) is smaller than 15 nm. Recent demonstrations at larger CD of a block-selective atomic layer deposition to harden block copolymer templates have created a new possible avenue for forming robust lithographic masks from block copolymer patterns.[3, 4] In this paper, we apply this innovative technique to selectively harden PMMA domains with 13 nm critical dimension in aligned, self-assembled lamellar phase PS-b-PMMA block copolymer films. We evaluate the chemically selective growth parameters that influence the pattern fidelity as well as the performance of the infiltrated material as an etch mask.

Block-selective growth of aluminum oxide was performed by sequential infiltration[5] of first trimethylaluminum (TMA), and then water vapor inside a block copolymer film aligned by directed self assembly.[6] Figure 1a shows the resulting aluminum oxide line/space pattern (27 nm full pitch) after removal of the block copolymer. Selective growth of aluminum oxide inside the PMMA domains is limited by the TMA diffusion coefficient inside the block copolymer, the TMA concentration at the film surface, and by the success rate of TMA coordination to carbonyl groups in PMMA. The density and the density gradient of the infiltrated material throughout the film cross section depend on these experimental parameters.

Optimal etched side-wall profiles depend importantly on mechanically robust, uniform, and dense etch masks to minimize line edge roughness and preserve a flat top surface during pattern transfer. We have transferred the self-assembled alumina line/space patterns with high fidelity to a depth of ~20 nm in an underlying silicon substrate (cross-sectional view in Figure 1b). Block-selective atomic layer deposition in block copolymer films affords new opportunities for improving the fidelity of pattern transfer from self-assembled block copolymer films with CD smaller than 15 nm.

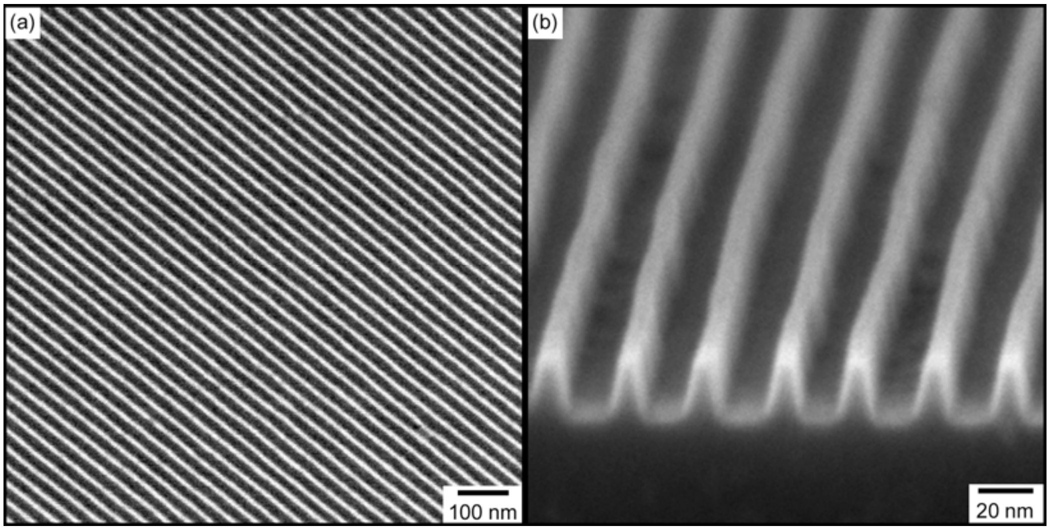

Figure 1: (a) AlO_x stripes by block-selective atomic layer deposition in a directed assembled block copolymer thin film. The stripes have a 27nm full pitch. Image taken after removal of the block copolymer material. (b) Tilted view of ~20nm deep Si trenches etched using the aluminum oxide stripes as an etch mask.

1. Ruiz, R.; Kang, H.; Detcheverry, F. A.; Dobisz, E.; Kercher, D. S.; Albrecht, T. R.; de Pablo, J. J.; Nealey, P. F. *Science* **2008,** 321, (5891), 936-939.
2. Cheng, J. Y.; Sanders, D. P.; Truong, H. D.; Harrer, S.; Friz, A.; Holmes, S.; Colburn, M.; Hinsberg, W. D. *ACS Nano* **2010,** 4, (8), 4815-4823.
3. Peng, Q.; Tseng, Y.-C.; Darling, S. B.; Elam, J. W. *Advanced Materials* **2010,** 22, (45), 5129-5133.
4. Peng, Q.; Tseng, Y. C.; Darling, S. B.; Elam, J. W. *Acs Nano* **2011,** 5, (6), 4600-4606.
5. Tseng, Y. C.; Peng, Q.; Ocola, L. E.; Elam, J. W.; Darling, S. B. *Journal of Physical Chemistry C* **2011,** 115, (36), 17725-17729.
6. Ruiz, R.; Dobisz, E.; Albrecht, T. R. *ACS Nano* **2011,** 5, (1), 79-84.