# Nanowire-arrays via block copolymer lithography

Muruganathan Ramanathan*, Seth B. Darling, Anirudha V. Sumant, Orlando Auciello and Derrick C. Mancini
*Center for Nanoscale Materials, Argonne National Laboratory, Argonne, IL 60439*

**ABSTRACT**

The quest to develop materials at the nanoscale has been escalating since early this decade. As the dimension of materials is reduced from the bulk to a system composed of few tens of atoms at the nanoscale, fascinating properties in magnetism, catalysis, electronics, optics, mechanics and ferroelectricity can emerge. Among the various nanostructures, nanowires receive special attention due to their relevance in many technological applications.[1, 2] Both bottom-up and top-down methodologies have been successfully implemented to develop nanowires of various materials.[3-5] Among the nanowire fabrication technologies, block copolymer (BCP) lithography is currently attaining increased attention due to a number of advantages[6] including: a) large throughput patterning, b) low-cost processing, c) scalability, d) self-assembly into 0, 1, 2 or 3 dimensional structures, and e) tunable etch resistance between two or more blocks. The efficacy, however, of BCP lithography in nanomanufacturing can be realized only after key challenges are overcome, namely: a) wetting-wettability of the substrate to the chosen BCP solution is critical, and the preferential wetting to one block over other block may hinder the orientation of the self-assembled structures with respect to the substrate, b) pattern perfection over macroscopic areas–self-assembled BCP structures often exhibit poor long-range order, and c) pattern transfer procedure–transferring of self-assembled mask pattern into the substrate of interest, without perturbing the BCP structure. These issues can be addressed by adapting various strategies, including chemical modification of the substrate to control wetting, directed self-assembly of BCPs to achieve long-range ordering, and incorporating a combination of hard and soft interlayer masks to overcome the difficulties that are associated with pattern transfer.

In this work, we demonstrate a detailed procedure (figure 1), for developing nanowire arrays of a) ultrananocrystalline diamond (UNCD)[7] and b) palladium (Pd). In the case of UNCD, we used three cylinder-forming BCPs, namely: i) poly(styrene-*block*-ferrocenyldimethylsilane) (PS-*b*-PFS) ii) poly(styrene-*block*-methylmethacrylate) (PS-*b*-PMMA) and iii) poly(styrene-*block*-dimethlysiloxane) (PS-*b*-PDMS). The effects of root-mean-square roughness and the addition of an interlayer between UNCD and BCP have been characterized in detail to achieve in-plane orientation of the etch masking cylinders via preferential wetting. Pattern transfer was executed by oxygen reactive ion etching (RIE). In the case of the Pd, we used the PS-*b*-PFS, where the in-plane oriented PFS cylinders work as an etch mask. The pattern transfer route is not straightforward for Pd, as the etch sensitivity of the BCP is greater than for the Pd. We have incorporated a hard mask between Pd and BCP to solve this problem.[8] In addition to the RIE we used Ar-ion milling for pattern transfer to develop Pd nanowires. Fig. 2 shows nanowire arrays of UNCD and Pd fabricated using BCP lithography. The results shown here indicate the feasibility of implementing BCP lithography as a tool for large scale nanomanufacturing of nanowires arrays.

"Use of the Center for Nanoscale Materials was supported by the U. S. Department of Energy, Office of Science, Office of Basic Energy Sciences, under Contract No. DE-AC02-06CH11357."

**References**

1. Y. Cui, Q. W. Wei, H. Park and C. M. Lieber, *Science* 293:1289-1292 (2001).
2. G. Zheng, F. Patolsky, Y. Cui, W. U. Wang and C. M. Lieber, *Nature Biotechnology* 23:1294-1301 (2005).
3. T. Strother, W. Cai, X. S. Zhao, R. J. Hamers and L. M. Smith, *J Am Chem Soc* 122:1205-1209 (2000).
4. N. Yang, H. Uetsuka, E. Osawa and N. C. E, *Angew Chem Int Ed* 47:5183-5185 (2008).
5. F. J. Yusta, M. L. Hitchman and S. H. Shamlian, *J Mater Chem* 7:1421-1427 (1997).
6. S. B. Darling, *Prog Polym Sci* 32:1152-1204 (2007).
7. M. Ramanathan, S. B. Darling, A. V. Sumant and O. Auciello, *J Vac Sci Tech - A* in-press (2010).
8. Cheng, J. Y.; Ross, C. A.; Chan, V. Z. H.; Thomas, E. L.; Lammertink, R. G. H.; Vancso, G. *J. Adv. Mater.* 13 15: 1174-1178(2001).

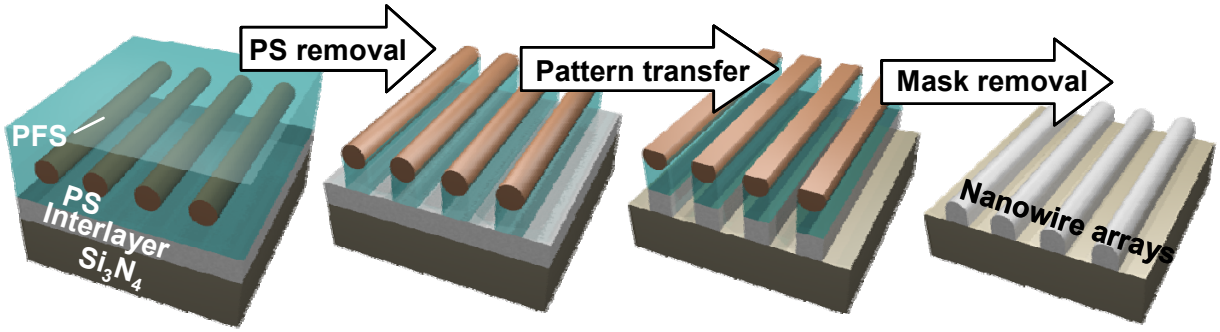


**Figure 1**. Schematic of implementation of cylinder-forming block copolymer films as lithographic etch masks.

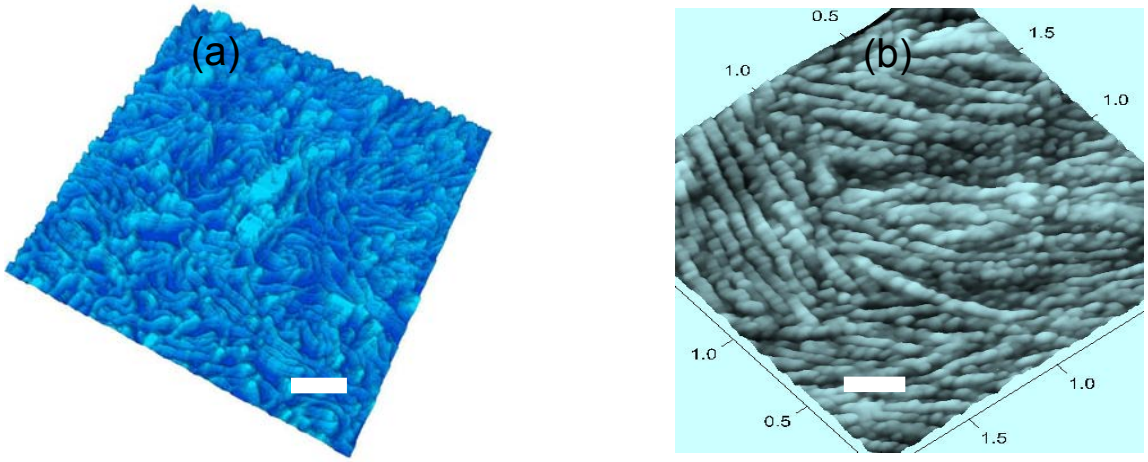


**Figure 2.** Tapping mode AFM images of lithographically created horizontal nanowires UNCD (a) and Pd (b). Scale bars represent 200 nm.