Templated self-assembly of block copolymers for linear and square arrays

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Templated block copolymer (BCP) self assembly is attractive for fabricating few-nanometer-scale structures at high throughput. On an unpatterned substrate, block copolymer self-assembly generates dense arrays of lines or dots without long-range order. Fortunately, physical features defined by electron lithography can guide the self-assembly of block copolymers. In our previous work, the orientation of a spherical morphology block copolymer was controlled simply by changing the distance between physical features.[1]

Here, we applied the same strategy to the self-assembly of cylindrical-morphology block copolymer. Figure 1A-F shows a scanning electron micrograph (SEM) of a guided cylindrical-morphology polystyrene-polydimethylsiloxane (PS-PDMS) block copolymer. Hydrogen silsesquioxane (HSQ) was used for the physical features of the template.[2] When the distance between the physical features satisfies the commensurate condition, the whole pattern was composed of a single orientation of in-plane PDMS cylinders in a PS matrix. However, as shown in figure 2A the pattern was composed of 'grains' with different orientations when the commensurate condition is not satisfied. We measured the area fraction of each orientation, and compared it with the prediction based on an analytical model that considers the free energy of the microdomain array as a function of strain. Figure 2C shows a good agreement between the experimental result and theoretical expectation. To gain further insight into the self-assembly, we used a SCFT to compute the equilibrium morphologies of the corresponding 2D lamellar system under the boundary conditions imposed by the template. As shown in figure 2D, the simulation results are well matched with the experimental result. Guided cylindrical morphology block copolymer patterns can be used for fabricating integrated circuit interconnects and dense nanowire arrays.

This technique can be used to template a variety of block copolymer systems. Figure 3A shows an unguided polyisoprene-polystyrene-polyferrocenylsilane (PI-PS-PFS) triblock terpolymer which forms a square array of PFS posts. The resulting pattern is composed of 'grains' with different orientations. Figure 3B shows the same terpolymer that has been ordered using a template with period commensurate with the terpolymer periodicity. In this pattern, double dot HSQ features were used to prevent the formation of grains with other orientations. Resulting patterns have potential for use in the fabrication of bit-pattern media, and it can be extended to periodicity well below 20nm.

[1] I. Bita, J. K. Yang, Y. S. Jung et al. Science 321(5891), 939 (2008).
[2] J. K. Yang and K. K. Berggren, Journal of Vacuum Science & Technology 25 (6), 2025 (2007)

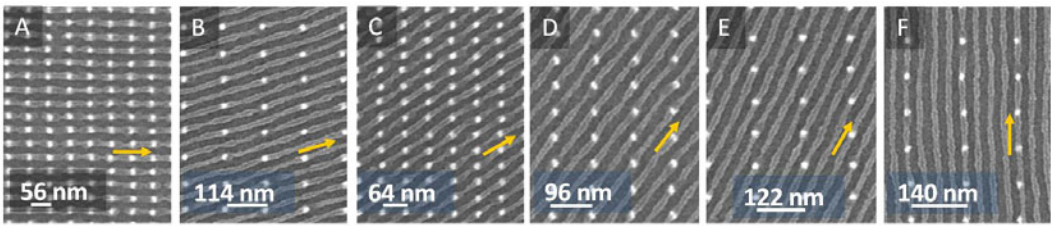

Figure 1(A)-(F). SEM images of guided PS-PDMS when commensurate conditions are satisfied. Gray lines are PDMS in-plane cylinders after the PS matrix is removed by etching, and the white dots are the HSQ template. The arrow shows the direction of the BCP cylinders.

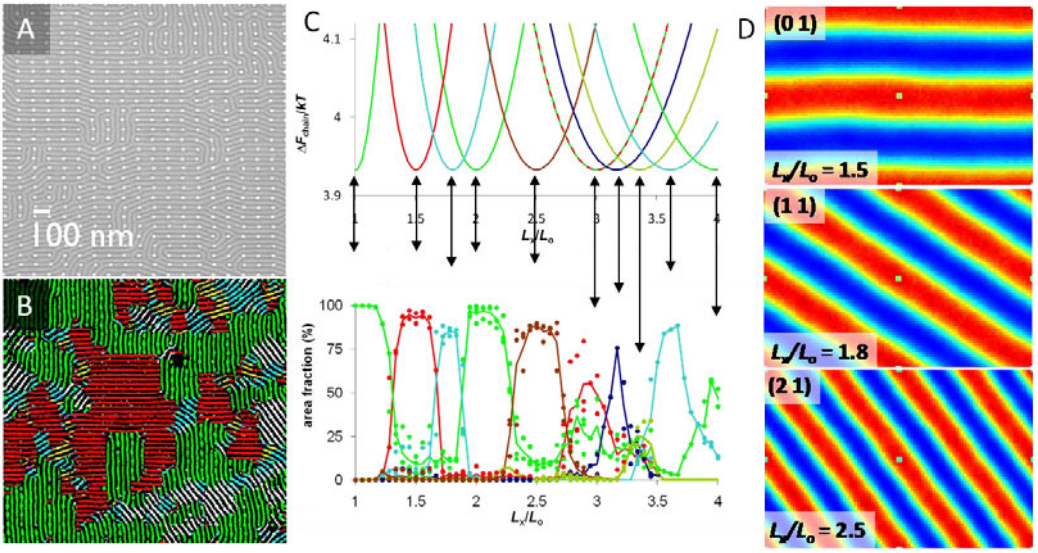

Figure 2. (A) A self-assembled pattern when the commensurate condition is not satisfied, showing multiple orientations. (B) Result of image-processing of the original SEM image showing color coded regions corresponding to the set of different orientations. (C) Plot of area fraction (bottom) and free-energy per polymer chain (top panel) for the corresponding lattice orientations as a function of the template x-spacing Lx and the equilibrium polymer periodicity Lo. (D) SCFT simulation result for three different Lx/Lo. Red represents PDMS cylinders and blue the PS matrix. Light blue dots are the HSQ posts.

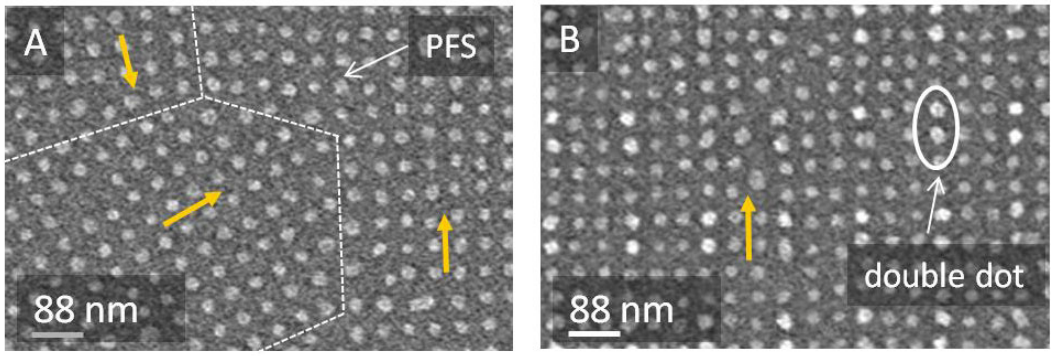

Figure 3. (A) Unguided PI-PS-PFS after PI and PS are removed by etching. (B) guided pattern when the commensurate condition is satisfied. White dots are HSQ double dot for templating and gray dots are PFS microdomains.