Selective Directed Self Assembly of Coexisting Morphologies Using Block Copolymer Blends

A. Stein, G. Wright, K. G. Yager, and C. T. Black

Center for Functional Nanomaterials, Brookhaven National Laboratory, Upton, NY 11973

Directed self assembly (DSA) of block copolymers is an emergent nano-lithography approach capable of fabricating ordered nanoscale features, but is limited in the range of structures possible in a single fabrication step. In this work, we expand the traditional DSA chemical patterning approach to *selective DSA*(figure 1) in order to enforce the coexistence of multiple, aligned block copolymer morphologies, in a single patterning.

We pattern chemical line-grating patterns with different pitch and duty cycle by electron beam lithography exposure of PMMA resist on silicon wafers pretreated with a polystyrene (PS) brush. We then etch the brush, creating a chemical pattern and remove the remaining resist. Self assembly of either lamella-forming or cylinder-forming PS-b-PMMA block copolymers onto the chemical pattern results in well-ordered arrays of both vertical lamellae ('lines') and vertical cylinders ('dots') on the grating prepatterns, depending on the pitch and duty cycle (dose) of the pattern. A 50/50 blend of a lamellar-forming and a cylinder-forming block copolymer assembles on specially-designed surface chemical patterns, leading to the *simultaneous* formation of coexisting ordered morphologies in separate areas of the substrate down to a single period of each (figure 2). This is in contrast to typical DSA, wherein assembly of *either* lamella-forming or cylinder-forming block copolymers onto chemical templates generates well-ordered patterns of either lines/spaces (lamellar) or hexagonal dot arrays (cylinders). The spacing (pitch) and duty cycle of the underlying chemical pattern influence the quality of the BCP assembly but not the morphology. In our approach, the chemical template encodes desired local spatial arrangements of coexisting design motifs, self-assembled from a single, sophisticated resist. Thus, by carefully designing the chemical template, we can preprogram desired spatial arrangements of different coexisting morphologies, self-assembled from a single blend.

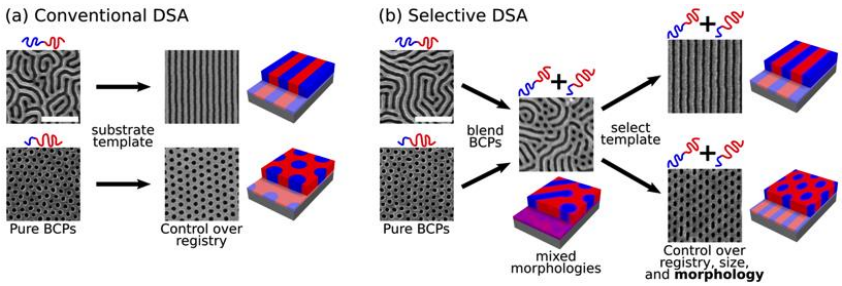

Figure 1 (a) Directed self assembly utilizes a substrate pre-pattern to impart long range order to both lamellar and cylindrical self assembled block copolymer films. (**b)** In selective directed self assembly, the substrate pre-pattern also selects the local morphology formed by a block copolymer blend (either cylindrical or lamellar), in addition to imparting long-range order.. White scale bar in scanning electron microscope images denotes 250 nm.

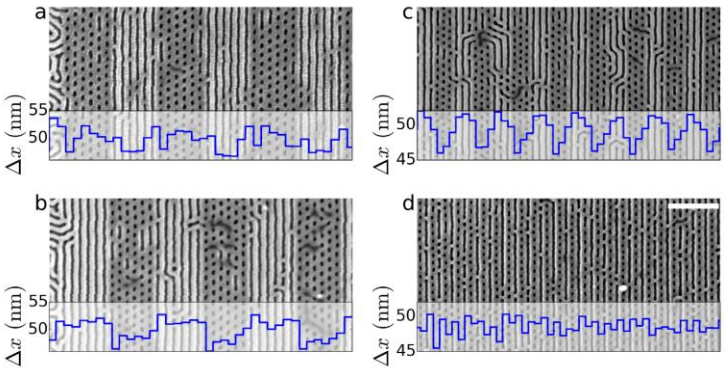

Figure 2 Selective directed self assembly of simultaneous, coexisting morphologies. Each image has an overlay of the local morphology spacing (Δx, blue line), across the grating pitch (computed using image analysis). By properly selecting line pitch and duty cycle, we can arbitrarily pattern regions with either dots or lines. The chemical patterns used in 5a and b have identical alternating regions of pitch = 50nm and 46nm. The dose of each region has been independently selected to force either dot or line patterns. In c & d we see that selective DSA can generate alternating morphologies down to single columns of lines and dots in close proximity.

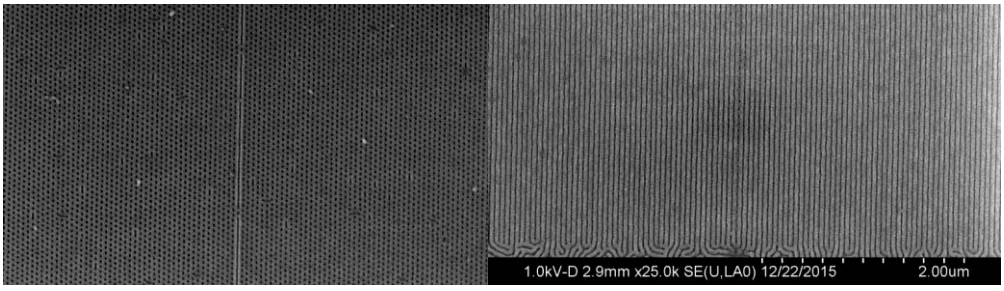

Figure 3 A single line simultaneously patterned in a hexagonal dot array (top) and line of dots embedded in a line grating (bottom). These patterns were formed by a PMMA-b-PS blend applied to a single grating chemical pattern. By carefully designing the pitch and duty cycle of the chemical template, we can preprogram desired spatial arrangements of different coexisting morphologies down to a single period, self-assembled from a single blend.