Directed Self-assembly of Block Copolymer Based Hybrid Nanostructures

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The scaling of modern semiconductor devices depends on the ability to generate high resolution patterns with critical dimensions of each technology nodes on substrates. Optical lithography with a photoactive resist is the dominant patterning method but it faces serious challenges for future generations of technology that require ever smaller features. As a result, there are numerous efforts to extend the scalability of optical lithography, by integrating top-down and bottom-up approaches, directed self-assembly of block copolymers is one of the potential methods to generate sub-lithographical features with simple process and low cost. The ability to create straight lines with good etch contrast from block copolymers is critical for directed self-assembly patterning. Line patterns created from lamellar phase of block copolymers are particularly attractive as a route to sub-lithographic patterns of 10 – 50nm features because of the smooth and vertical sidewalls of perpendicular lamellae. In addition, it is well-known that the etch selectivity can be enhanced by incorporating inorganic components.

In this paper, we demonstrate the directed self-assembly of a lamellae-forming hybrid materials base on the mixture of PS-b-PEO and organosilicate (OS) precursors. Well-aligned sub-lithographical line patterns of ~20nm half pitch can be achieved by confining thin films of hybrid materials in the lithographically defined guiding patterns. The guiding prepatterns of neutral bottom surface with hydrophilic sidewalls were generated by e-beam lithography and liftoff process. The mixture solutions of PS-b-PEO and OS were spun-cast on top of the prepatterns. By heating the sample to 450^{o}C, lines of OS guided by the macroscopic prepatterns were generated (Figure 1). With the incorporation of OS in the block copolymers, the persistence length of lamellar lines is greatly improved compared to typical as-cast block copolymer thin films (Figure 2A). The confined thin films of hybrid materials show well-aligned line patterns inside the channels of various length and width. Figure 2B-2E show aligned line patterns parallel to the edge of channels with channel length from 0.5 μm to 2μm. The lines have a propensity to stay straight in the channels without additional annealing. More quantitative characterizations of this directed self-assembled system including line-edge roughness, line-width roughness, and persistence length will be presented in the paper.

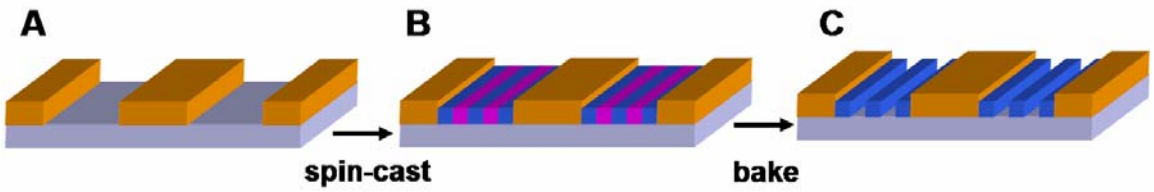

Figure 1. Schematics of directed self-assembly process. (A) Patterns generated by E-beam and lift-off. (B) Polymer and OS precursor were deposited on patterned substrates and form self-organized lines parallel to the guiding grooves. (C) Generate OS lines by removing organic block copolymers.

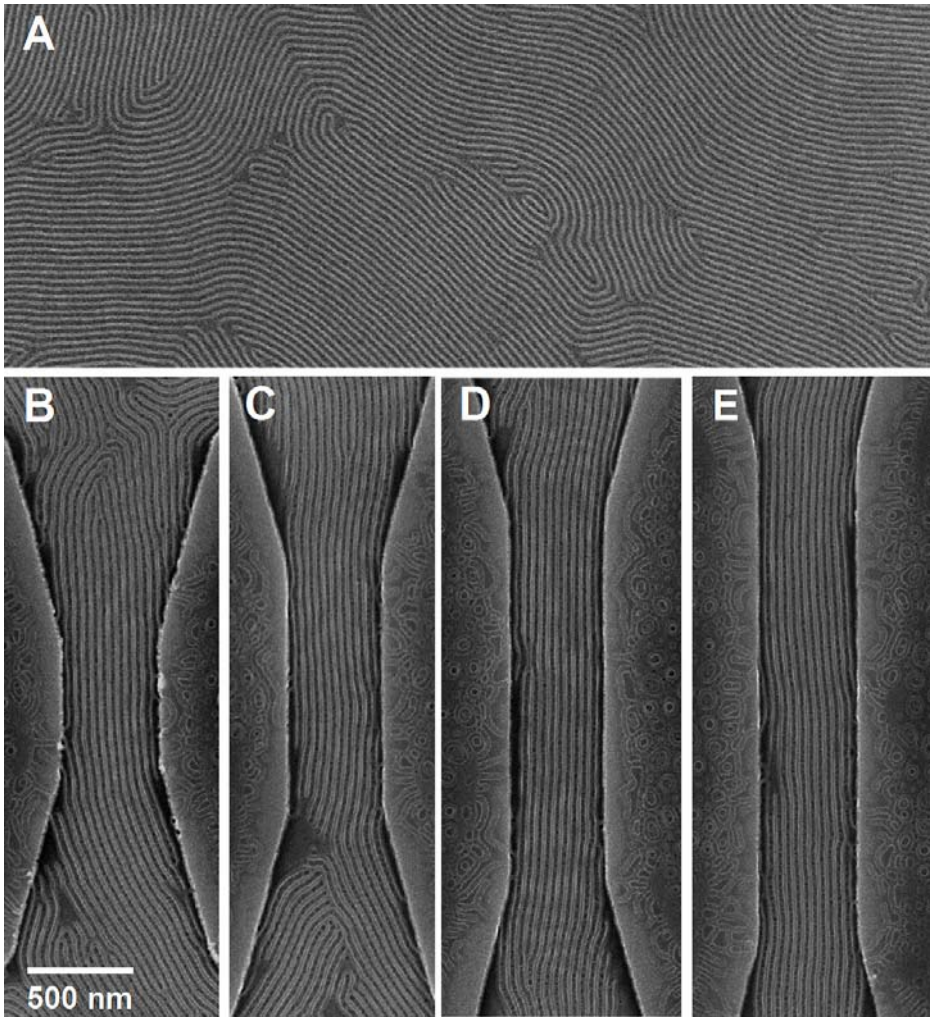

Figure 2. SEM images of lamellar structures from the hybrid materials of block copolymers deposited on flat substrate (A) and on patterned substrates with channel length of 0.5μm (B), 1 μm (C), 1.5μm (D), 2μm (E).