Polymer Self-assembly for Nanopatterning

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Directed polymer self-assembly, which combines lithographically defined substrates and self-assembled polymers, is being considered as a potential candidate to enhance optical patterning and extend the lithography roadmap. Much work over the past few years has demonstrated that directed polymer self-assembly can enable sub-lithographic resolution or enhance dimensional control. While significant progress has been made, integrating directed self-assembly into practical lithography schemes with minimal impact on process cost, complexity, and throughput is one of the major hurdles which must be overcome before directed self-assembly can impact the lithography roadmap. This paper discusses our efforts in developing robust new materials and simple, low-cost processes for integration of block copolymer self-assembly into practical lithography schemes.

In order to use block copolymers as patterning materials, orientation control of the self-assembled microdomains in the block copolymer film is critical to generate useful patterns. Ideal orientation control materials should be compatible with photoresist patterning processes as well as provide proper domain orientation. We have demonstrated a new series of materials and a new process for orientation control of poly(styrene-b-methylmethacrylate) (PS-b-PMMA). New orientation control materials with a fast and robust cross-linking mechanism facilitate the perpendicular orientation of lamellae-forming and cylinder-forming PS-b-PMMA domains on a wide variety of substrates as shown in figure 1. Also, these cross-linked orientation control layers are compatible with many photoresist casting solvents such as PGMEA as well as TMAH developer. Such process compatibility is advantageous for the integration of polymer self-assembly into standard lithography processes.

In addition, these orientation control materials can be cast together with PS-b-PMMA onto non-neutral surfaces to form perpendicularly oriented lamellar or cylindrical block copolymer domains in a single spin-then-bake process in less than 2 minutes as shown in figure 2. A vertical phase segregation of PS-b-PMMA and orientation control components results in the block copolymer forming a laterally phase-separated layer with perpendicularly oriented domains at the air interface and the orientation control components segregating to the substrate interface to form a neutral surface *in situ*. This one-step method can reduce by 50% or more the number of process steps and process time in generating block copolymer thin films with preferred orientation.

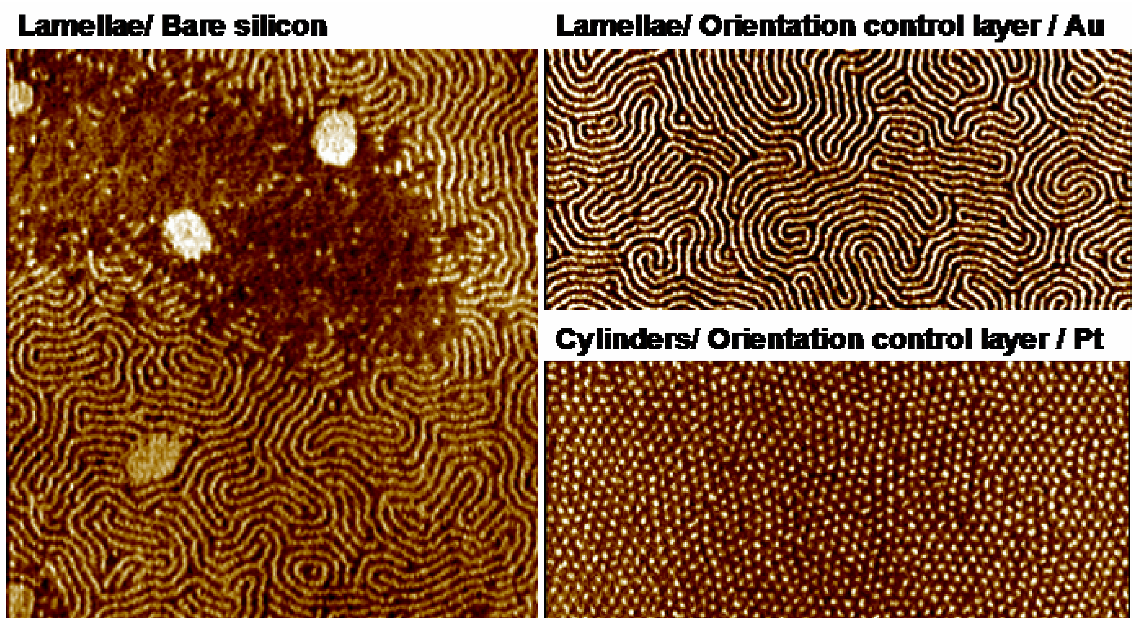

Figure 1. AFM images of PS-b-PMMA on various substrates. Without orientation control layer, domains of PS-b-PMMA are randomly oriented and not useful for patterning. Perpendicularly oriented lamellae and cylinder can be achieved on gold and platinum substrates with a coating of orientation control layer.

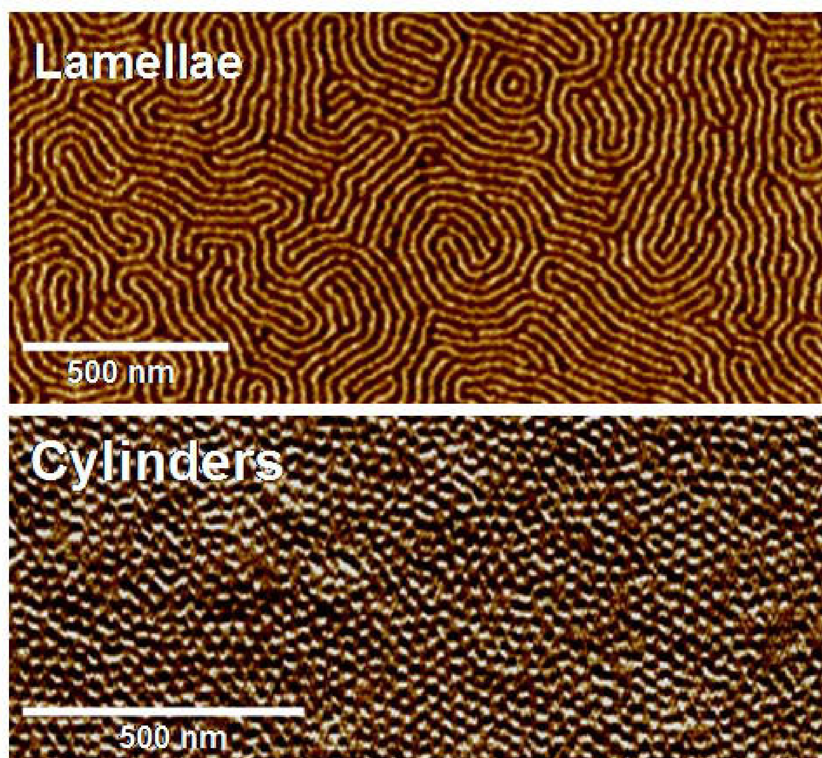

Figure 2. AFM images of perpendicularly oriented lamellar and cylindrical domains in PS-b-PMMA films made from a single spin-then-bake step of a mixture of PS-b-PMMA and orientation control components.