4av Directed Self-Assembly of Block Copolymers on Nanopatterned Surfaces

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Block copolymers are self-assembling materials that form ordered nanostructures, including spheres, cylinders, and lamellae, with shapes and dimensions dependent upon the molecular weight and composition of the polymer. Thin films of block copolymers have attracted attention as potential templates for organizing and fabricating functional materials such as nanoparticles, nanowires, isolated nanocrystals, and nanoporous membranes. The semiconductor industry has also shown significant interest in incorporating self-assembling materials, particularly block copolymers, into the lithographic process traditionally used to manufacture microelectronic devices. In these applications the patterning of silicon or similar substrates can be achieved by utilizing the ordered block copolymer templates as masks for selective etching or deposition processes. Already application of this technique, commonly referred to as block copolymer lithography, has produced devices that do not require perfect structure ordering and that are formed of periodic arrays of structures, such as magnetic storage media, quantum dots, flash memory devices, and silicon capacitors.

We explore new materials and processes for advanced lithography in which self-assembling block copolymers are integrated into existing manufacturing processes for patterning high resolution structures that are useful for the fabrication of microelectronic devices. The approach to block copolymer lithography we have developed is able to reproduce the important characteristics of traditional lithography including pattern perfection over macroscopic areas, dimensional control within exacting tolerances, and positional control or registration of pattern features. We have demonstrated that the domains of block copolymer films could be directed to assemble on periodic, chemically striped surfaces with perfection and registration over arbitrarily large areas. The surface patterns were produced in polymer brush imaging layers by using electron beam and extreme ultraviolet (EUV) lithography to tailor the interfacial energies of the alternating stripes, thereby making them preferentially wet by the different blocks of the copolymer.

Recently we have performed fundamental studies on ternary blends of lamellar-forming block copolymers and homopolymers for application in block copolymer lithography. Ternary blends in the bulk exhibit a complex phase behavior with ordered lamellar, two-phase, and microemulsion morphologies. Investigation of the phase behavior of ternary blends in thin films and on chemically striped surfaces indicates that 1) the phase behavior in thin films differs from that in bulk systems, 2) a blend in the microemulsion phase forms lamellar structures on patterned surfaces, 3) chemical surface patterns can induce phase separation of the blend, and 4) the blend components can redistribute as needed throughout the lamellar domains. In addition to exploring the polymer physics of these systems, we demonstrate that thin films of ternary blends on chemically nanopatterned substrates can be directed to assemble into perfectly ordered and registered domains. We also show for the first time that the directed self-assembly of ternary blends can produce nonregular device-oriented structures, such as sharp bends and arcs, that are commonly required in integrated circuits. Mean field simulations have indicated that the formation of these patterns is facilitated by the redistribution of homopolymer within the blend domains. The ability to self-assemble geometrically complex features indicates that the insertion of block copolymer materials into lithographic processes for widespread nanomanufacturing may be possible in the near future.