

486c Directed Self-Assembly of Block Copolymer Blends into Nonregular Device-Oriented Structures

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The microelectronics industry is encountering significant difficulties in extending traditional lithographic processes and imaging materials to the fabrication of devices with critical dimensions of 50 nm and below. During the past decade the primary approach to overcoming this problem has focused on the development of lithographic exposure tools capable of patterning sub-50 nm features. At the same time, however, relatively modest resources have been invested in the exploration of new imaging materials that can be patterned at these length scales. For example, the use of available chemically amplified photoresists will be severely limited by their 1) poor critical dimension control in response to processing variables (e.g., exposure dose and post-exposure bake temperature) and 2) significant line edge roughness.

Our group develops new materials and processes for advanced lithography that rely on the integration of self-assembling block copolymers into existing nanomanufacturing processes. Self-assembling materials are able to order at the molecular level into well-defined structures, with thermodynamics controlling the feature dimensions and the line edge roughness. Uncontrolled self-assembly, however, lacks the required lithographic properties of pattern perfection over macroscopic dimensions and feature registration. The technique we utilize involves the directed assembly of block copolymers on chemically nanopatterned surfaces with tailored interfacial interactions, thereby coupling the advantages of advanced exposure tools (pattern perfection and registration via the surface pattern) to the principles of molecular self-assembly (thermodynamic control over the structures). We have demonstrated the ability of chemical surface patterns to direct the defect-free ordering of block copolymer domains over arbitrarily large areas and in registry with the lithographically-defined underlying surface pattern.

As an alternative to pure block copolymers, we have recently pursued ternary blends of lamellar-forming block copolymers and homopolymers for applications in directed assembly. In the bulk these blend systems exhibit a complex phase behavior with ordered lamellar, two-phase, and microemulsion morphologies. In addition to characterizing the phase behavior of these systems in thin films, we demonstrate that ternary blends on chemically nanopatterned surfaces can be directed to assemble into perfectly ordered and registered domains. We also show for the first time that it is possible to direct the assembly of block copolymer domains into nonregular device-oriented structures such as arcs, nested arrays of sharp bends, and square arrays of cylinders. The ability to pattern a variety of geometries suggests that the insertion of self-assembling materials into the nanofabrication of complex devices such as integrated circuits may be possible in the near future.