

Directed assembly of block copolymer blends into non-regular device oriented structures

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Hallmarks of the lithographic process used ubiquitously in nanomanufacturing include pattern perfection over macroscopic areas, dimensional control of features within exacting tolerances and margins, and registration and overlay (placement of features in each layer and with respect to overlying and underlying layers). Whereas in the past decade significant resources have been allocated to the development of exposure tools capable of resolving patterns with dimensions of 20 nm or less and with the required registration and overlay capabilities, relatively modest investments have been made in the development of imaging materials with the required properties at this length scale. Currently chemically amplified photoresists (CARs) are used in manufacturing processes to pattern features with dimensions as small as 50 to 70 nm. As feature dimensions shrink to less than 40 to 50 nm, however, CARs will likely not be able to meet the requirements for dimensional control and line edge roughness.

Self-assembling materials used in conjunction with the most advanced exposure tools may enable extension of current manufacturing practices to dimensions of 10 nm and less. Recently we demonstrated that the domains of block copolymer films could be directed to assemble perfectly over arbitrarily large areas and in registry with lithographically defined periodic chemical surface patterns [1]. The principle concepts of using block copolymers in the lithographic process are: 1) the lateral dimensions of the patterned features can be controlled with nanometer precision [2, 3], 2) the features should exhibit very low line edge roughness due to interfacial tension, and 3) the chemistry of the block copolymers may be optimized for specific applications. Here we extend the capabilities of block copolymer lithography beyond simple periodic arrays to include patterns of perfect and registered sharp bends (typical photoresist benchmarking patterns) by using ternary blends of diblock copolymers and their respective homopolymers [4]. The redistribution of homopolymer facilitates the assembly of non-regular patterns in locations where the dimensions of the domains deviate significantly from those naturally formed by the blend. The ability to pattern these types of non-regular device oriented structures strongly suggests that the insertion of self-assembling materials into existing nanomanufacturing processes such as those used to fabricate integrated circuits may be possible in the near term.

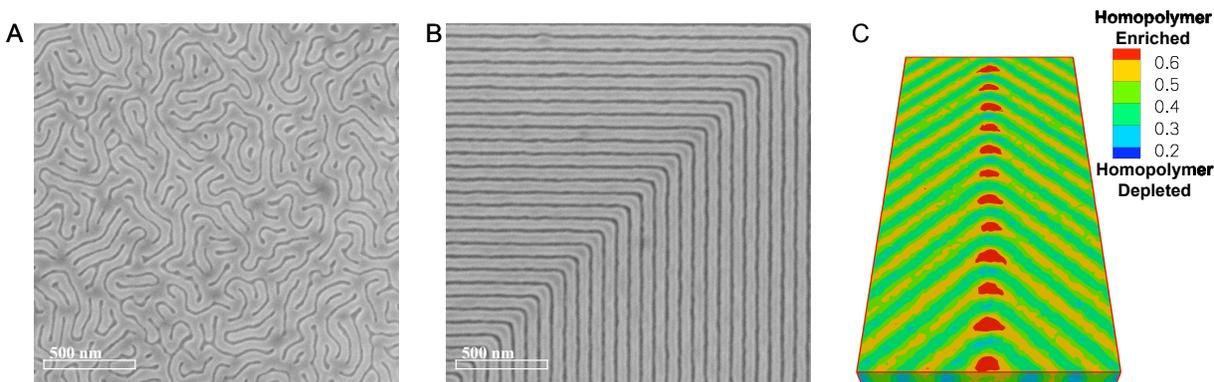


Fig. 1. (A) Lamellar phase behavior of the ternary blend (period of 70 nm) in a thin film on a chemically homogeneous surface. (B) Ternary blends were directed to assemble into defect free arrays of 90° bends (photoresist benchmarking patterns) on chemically patterned surfaces. (C) Single chain in mean field simulations showing enrichment of the homopolymer concentration in the corners of the bends.

References:

- [1] S. O. Kim, H. H. Solak, M. P. Stoykovich, N. J. Ferrier, J. J. de Pablo, P. F. Nealey, *Nature*, 424, 411 (2003).
- [2] E. W. Edwards, M. F. Montague, H. H. Solak, C. J. Hawker, P. F. Nealey, *Advanced Materials*, 16, 1315 (2004).
- [3] P. F. Nealey, E. W. Edwards, M. Müller, M. P. Stoykovich, H. H. Solak, J. J. de Pablo, *Proceedings of the 2005 IEEE International Electron Devices Meeting*, in press (2005).
- [4] M. P. Stoykovich, M. Müller, S. O. Kim, H. H. Solak, E. W. Edwards, J. J. de Pablo, P. F. Nealey, *Science*, 308, 1442 (2005).