Directed Self-Assembly of Ternary Blends of Block Copolymer and Homopolymers on Chemical Patterns

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Directed self-assembly (DSA) of block copolymers (BCP) on lithographically-defined nanopatterned surfaces enhances and augments the resolution and patterning properties (e.g. critical dimension control, line edge roughness) of traditional lithographic resists and process flows. In DSA, the period of the chemical pre-pattern (L_s) is typically an integral multiple of the natural period of the BCP (L_o). For example, if L_s is 84 nm, then a desired period of the self-assembling BCP material is 42 ± 0.5 nm for 2x resolution enhancement. Although great advances in controlled/living polymerization techniques have been made in recent years, it is still difficult to synthesize and always achieve a BCPs with a given periods with nanometer precision. Furthermore, strategies to formulate BCP materials to target a specific L_o may prove in the long-run to provide more reproducible results in manufacturing. Blending BCP with homopolymers is a simple and effective method to adjust the periods and regulate the volume fractions of the two blocks[1]. Here we investigate the directed self-assembly of ternary blends of polystyrene-*block*-poly(methyl methacrylate) (PS-*b*-PMMA) and their corresponding homopolymers on chemical patterns produced with 193 immersion resists and exposure tools at IMEC on 300-mm wafers.

PS-*b*-PMMA (M_n = 37-*b*-37 kg mol^{-1}, L_o= 40 nm), PS (M_n = 40 kg mol^{-1}), and PMMA (M_n = 37 kg mol^{-1}) were used. The homopolymer volume fraction (φ_H) changed from 0% to 30% in which the volume fraction of PS to PMMA was maintained as 1:1. Fast Fourier transform analysis of SEM images shows that the periods of the blends in fingerprint patterns on chemically homogeneous non-preferential wetting surfaces can be modulated in the range of 40–52 nm. The blends were directed to assemble on chemical patterns consisting of PS-mat guiding stripes of varying widths and controlled background chemistry with L_s of 80–100 nm. Figure 1 shows representative SEM images for a blend that is 15 % homopolymer (L_o = 44 nm), and Figure 2 summarizes the results for all of the blend films. The best assembly occurs under conditions in which L_o of the blend falls within a narrow range of being half L_s, and the range depends on the widths of the guiding stripes. For non-optimal widths of the guiding stripes, the quality of the patterns quickly deteriorates.

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[1] For example, M. P. Stoykovich, M. Muller, S. O. Kim, H. H. Solak, E. W. Edwards, J. J. de Pablo, P. F. Nealey, Science **308**, 1442 (2005).

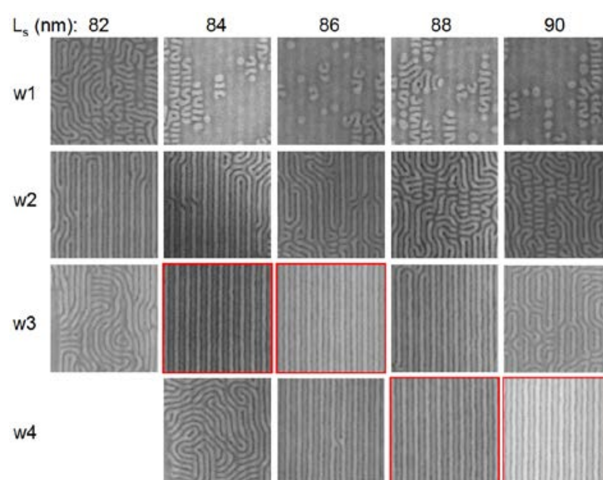

Figure 1: Top-down SEM images for blended films assembled on chemical pre-patterns of different periods (L_s, nm) and varying guiding stripes widths (w, nm). The guiding stripes width increases gradually from w1 to w4. The films were prepared from the blends of PS-*b*-PMMA, PS, and PMMA with a total homopolymer volume fraction of 15%. Solutions of blends in toluene were spin-coated on the chemical patterns and annealed at 250 ^{o}C for 20 min under nitrogen atmosphere. Images with red frames indicate defect-free or nearly defect-free assembly.

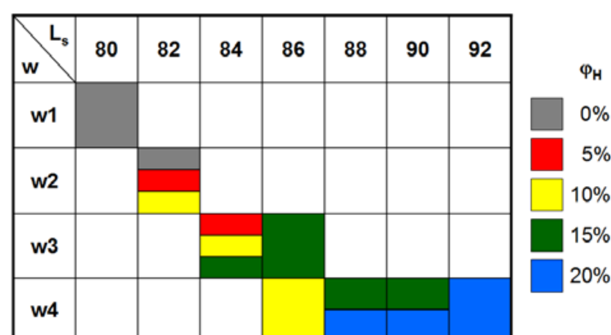

Figure 2: Effects of guiding stripes widths (w, nm) and period of the chemical pre-pattern (L_s) on the directed assembly of blends with different homopolymer volume fraction (φ_H). The guiding stripes width increases gradually from w1 to w4. The colored boxes indicate defect-free or nearly defect-free assembly.