Integration of electron beam lithography with block copolymer self-assembly for 10nm scale nanofabrication

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It is well known that block copolymers self-assemble into periodic nano-patterns via microphase separation. In this study, we show that the block copolymer can self-assemble in a well-aligned, long range ordered nano-pattern over arbitrarily large areas, commensurate with an electron beam (EB) lithographically patterned template. Furthermore, we demonstrated that the self-assembly process can correct defects and interpolate points in the EB generated pattern.

Poly(styrene-*block*-methyl methacrylate) (PS-*b*-PMMA) thin films were directed to self-assemble on chemically pre-patterned substrates to form cylindrical micro domains in perpendicular orientation. The chemically pre-patterned substrates were prepared by EB patterning a hexagonal array of dots in PMMA resist on polystyrene (PS) grafted silicon wafers. The EB pattern was etched into the PS graft layer by brief oxygen reactive ion etch, and the resist was subsequently removed. A PS-b-PMMA film was deposited onto the patterned surface template and annealed to form hexagonally arranged cylinders, which had affinity to etched substrate surface.

Figure 1(a) shows a SEM image of an EB pattern in the resist after a metal lift off, with identical lattice spacing to that of the microphase separated PS-*b*-PMMA in bulk. The SEM image exhibited that ca. 42% of total lattice points were missing, suggesting that chemical pre-pattern also had a similar amount of defects. Figure 1(b) shows a SEM image of PS-*b*-PMMA film self-assembled on the chemically pre-patterned substrate, which was prepared by employing the same pattern and same EB conditions with those used to pattern figure 1(a). In spite of possible incompleteness of the underlying chemical pattern, PS-*b*-PMMA film showed almost defect-free hexagonal closed packed pattern. The rate of missing lattice points was less than 0.01%, which was considerably better than that of the EB pattern. This result suggests that self-assembly of PS-*b*-PMMA can clean-up and compensate for the defects in chemically patterned substrate, while the pre-patterned substrate can align block copolymer domain structures in long range order.

The developed process provides a promising fabrication method for extension of e-beam lithographic capabilities to very high densities for applications, such as patterned hard disk drives with recording density over 1Tbit/inch^2.

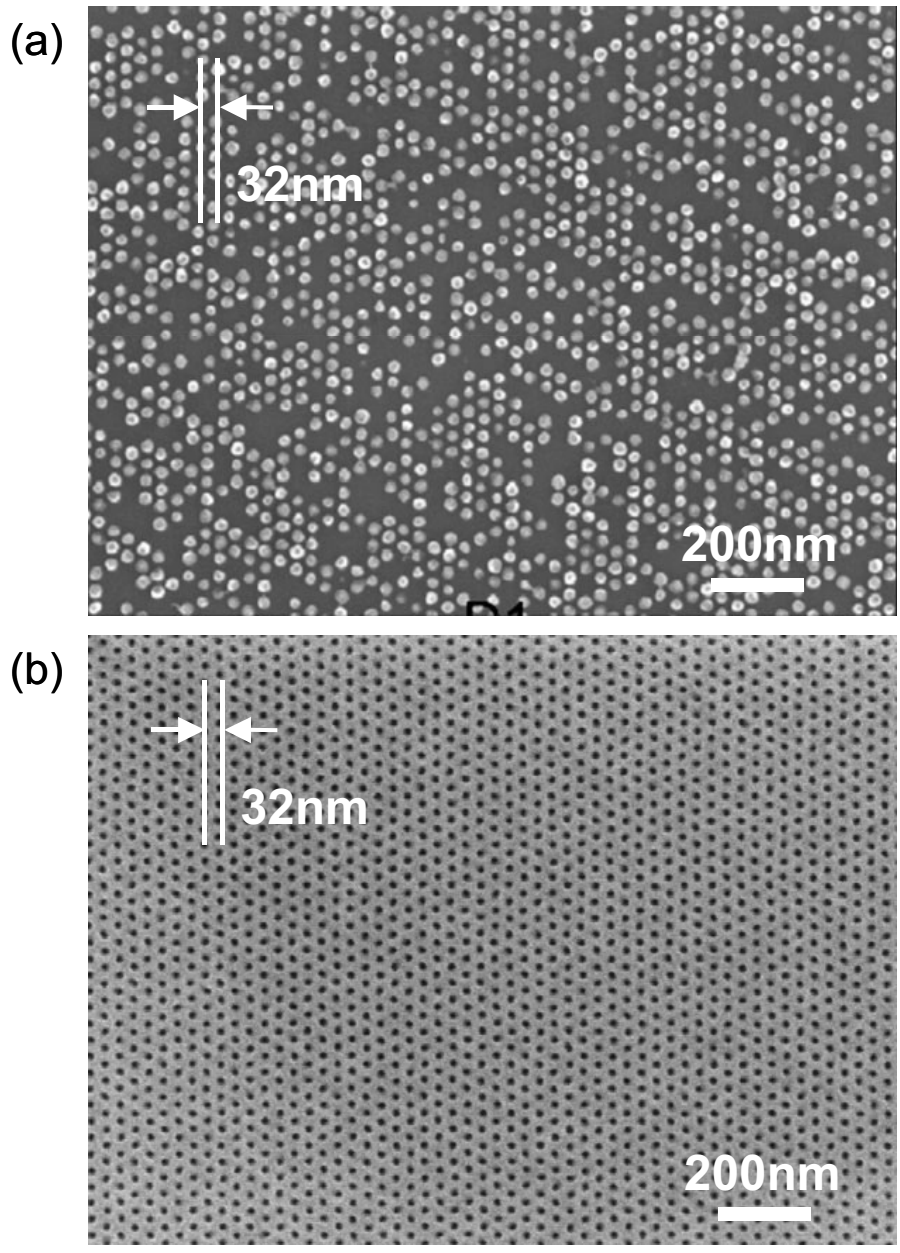

Figure 1 (a) SEM image of EB pattern after a Cr lift-off. (b) SEM image of epitaxially-grown cylinder structures of PS-*b*-PMMA film self-assembled on the chemically pre-patterned substrate. Weight average molecular weight of PS-*b*-PMMA and weight fraction of PS being 6.7×10^4 and 0.69, respectively.