

9x density multiplication of hcp lattice pattern by chemically directed block copolymer self-assembly

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We demonstrate that pattern density of lithographically defined template can be multiplied by a factor of 9 by directed block copolymer self-assembly.

Poly(styrene-*block*-methyl methacrylate) (PS-*b*-PMMA) thin films were self-assembled on the chemically pre-patterned template to form PMMA cylindrical microdomains in a perpendicular orientation. The template were prepared by patterning PS grafted silicon wafer with EB lithography and oxygen etching, to form hexagonally arranged circular areas having higher affinity to cylindrical microdomains. The lattice spacing ($d=72\text{nm}$) of the ebeam patterned PS layer was three times larger than lattice spacing of the microphase separated PS-*b*-PMMA in bulk ($d_o=24\text{nm}$).

Fig.1(a) shows an EB resist pattern, which was employed to pre-pattern the PS graft layer. Fig.1(b)~(d) show SEM images of PS-*b*-PMMA thin film self-assembled on the pre-patterned template with three different film thicknesses t_f . When $t_f=38\text{nm}$, which nearly corresponds to $(3/2)d_o$, the PS-*b*-PMMA block copolymer self-assembled into a well-aligned, long-range ordered lattice of lattice spacing d_o . Two cylinders interpolated linearly between lattice points of the pre-patterned PS brush, thus multiplying the feature areal density by a factor of 9. On the other hand, for $t_f=23\text{nm}$ and 46nm , which nearly correspond to d_o and $2d_o$, respectively, PS-*b*-PMMA film did not exhibit a long-range ordering. For successful interpolation, PMMA cylinders have to orient perpendicular to the PS preferential surface between the pre-patterned lattice points. In the case for $t_f=(3/2)d_o$, sterical confinement of cylinders in the thin film made it energetically unfavorable for the cylinders to orient parallel to the substrate. On the other hand, if $t_f=d_o$, the cylinders can form a single layer in the film by arranging parallel to the substrate. For $t_f=2d_o$, PS-*b*-PMMA orders in poly-grain structure, which suggests that chemical registration effect by the template did not influenced to the top surface.

Equilibrium morphologies of chemically directed PS-*b*-PMMA self-assembly are determined by various variables, including surface energies of the pre-patterned substrate and the free surface. However, the results clearly suggest that t_f is one of the important variables to control the orientation of the cylinders. By careful tuning t_f , density multiplication by almost one order of magnitude will be possible.

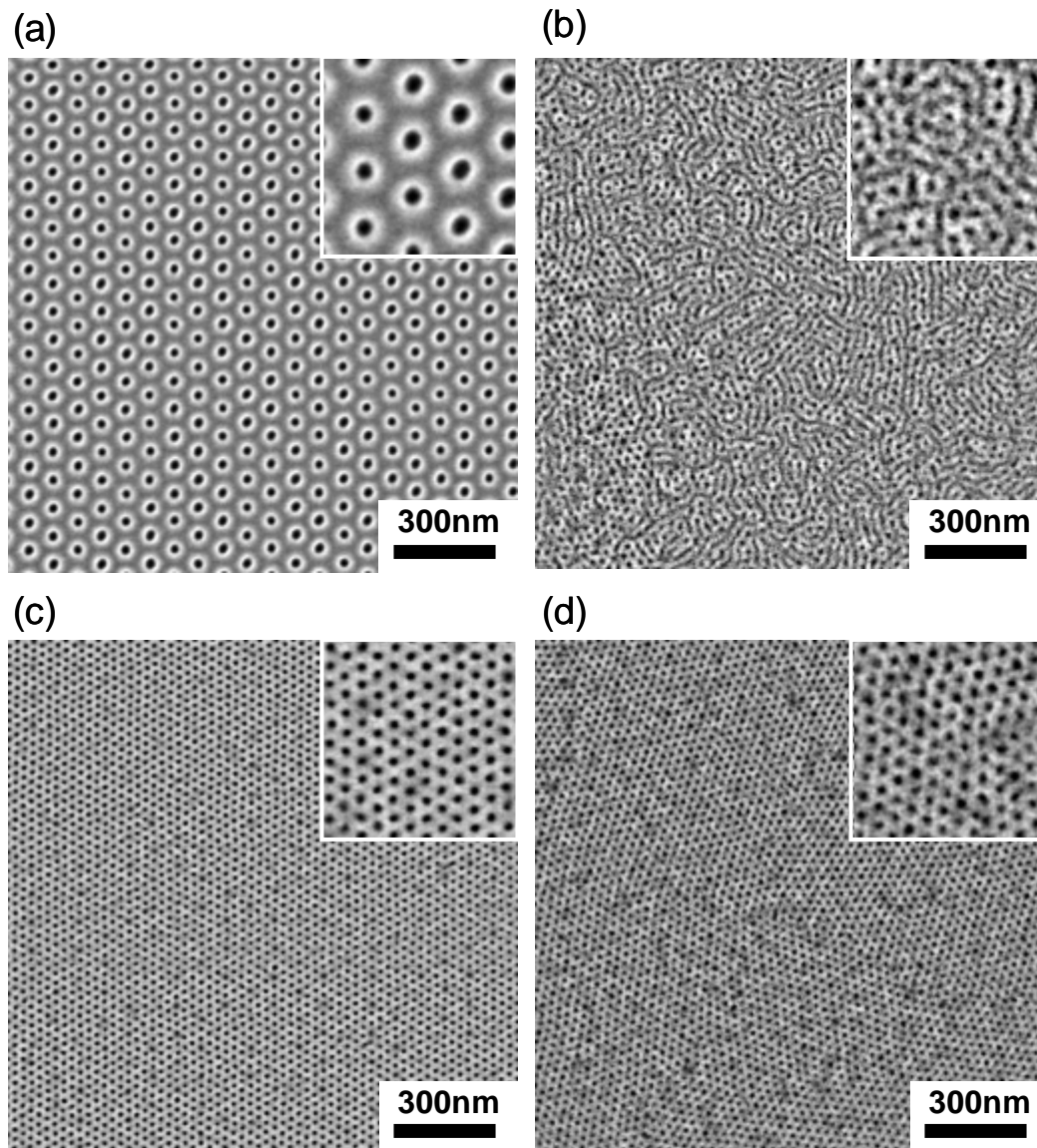


Fig.1: (a):Top-view SEM image of EB resist employed to pattern PS graft layer on Si wafer surface for a chemically pre-patterned template with $d=72\text{nm}$. (b) ~ (d): Top-view SEM image of cylinder structures of PS-*b*-PMMA with $d_o=24\text{nm}$ self-assembled on the chemically pre-patterned template. Thickness of PS-*b*-PMMA film t_f : (b) 23nm, (c) 38nm and (d) 46nm. Weight average molecular weight of PS-*b*-PMMA and weight fraction of its PS block: 4.8×10^4 and 0.75, respectively.