Nano Mesh Patterns by BCP Self-Templating

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Rectangular, mesh-arrayed patterns can be used in several applications, such as bit-patterned media, which need rectangular holes in rectangular arrays, and via-holes for integrated circuits. Typically it is difficult to generate rectangular arrays of holes in a single layer using diblock copolymer (diBCP) self-assembly. One of the recent methods to achieve rectangular arrays of nano holes from diBCPs is using two layers of cylindrical structures of the BCP oriented perpendicularly on top of each other. As an example, bilayer self-assembly with functionalized electron-beam-lithography (EBL) posts[1] could fabricate mesh-structures with bends and junctions but this method required an EBL system. Furthermore the final BCP patterns were limited to square symmetry and the trace of the EBL posts remained even after post-removal. In comparison to the EBL-post method, nano transfer printing is simpler and more economical but this method can only fabricate large areas of simple structures without local bends and junctions[2]. Moreover, overlay alignment of the second layer may be difficult.

The presented study introduces a new method for fabricating rectangular arrays of nano mesh-shaped structures. In this method, initial self-assembled BCP structures were used as a template for the self-assembly of a second layer of BCP. The perpendicular orientation of the second-layer BCP naturally occurred on top of the bottom layer without previously employed techniques such as EBL posts or transfer aligning of the second layer. Furthermore, with the addition of topographical templating, meshes with could have engineered local bends and junctions.

Figure 1 shows the steps of the process. The first layer of the poly(styrene-b-dimethyl siloxane) (PS-PDMS) BCP was spin-coated on the silicon substrate and then solvent annealed to make a single layer array of in-plane cylinders. Next, reactive ion etching was used to remove the polystyrene matrix and leave oxidized PDMS on the silicon substrate. Then the second layer of the BCP, with a different molecular weight, was spin-coated on the first layer and the same process was followed.

Figure 2a and b show the results of the described process. Rectangular arrays of nano mesh-shaped structures with high density were fabricated. Although cylinders in the bottom layer were randomly oriented, cylinders in the second layer still oriented perpendicularly. We tested the impact of the period of the bottom layer with EBL-fabricated hydrogen silsesquioxane (HSQ) line templates using a wide range of periodicity. As shown in Figure 3a, the BCP oriented perpendicular to the HSQ lines without any dependency on the period. These cylinders span between the HSQ lines because of the thickness of the BCP in comparison to the height of the HSQ lines. Self-consistent field theory (SCFT) simulation results showed that cylinders in the second layer are perpendicular to the bottom layer because the free energy for the perpendicular orientation is less than the parallel orientation.

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1 A. Tavakkoli K. G., et al., *Science* 2012, 336, 1294.
2 J. W. Jeong, et al., *Adv. Mater.* 2012 , 24 , 3526

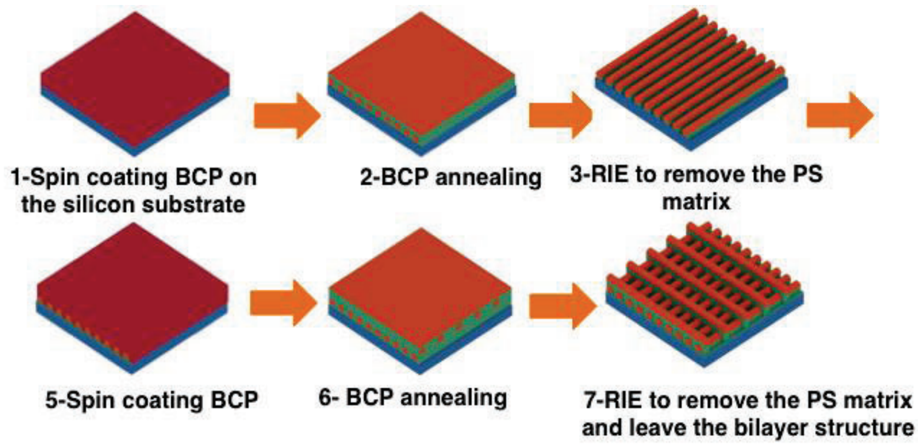

Figure 1: The major steps of nano mesh pattern fabrication by BCP self-templating

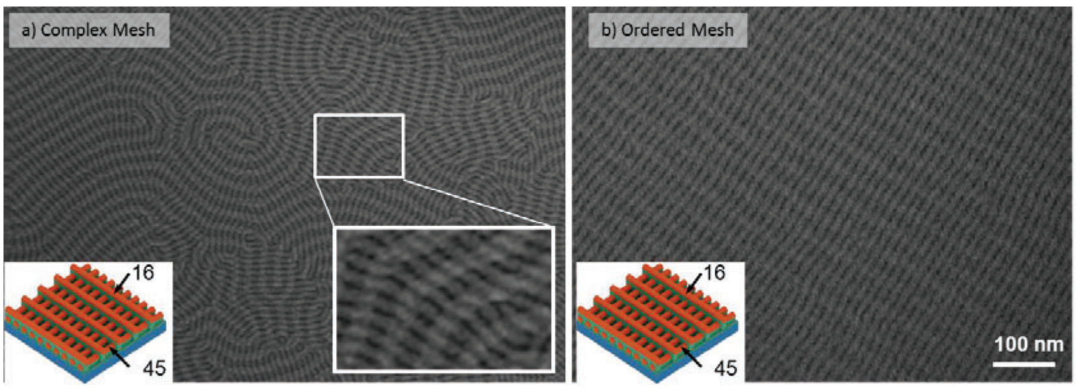

Figure 2: SEM images of bilayer of mesh structures from a 16 kg mol^{-1} PS-PDMS BCP on top of a 45 kg mol^{-1} PS-PDMS cylinders, a) complex mesh and b) ordered mesh.

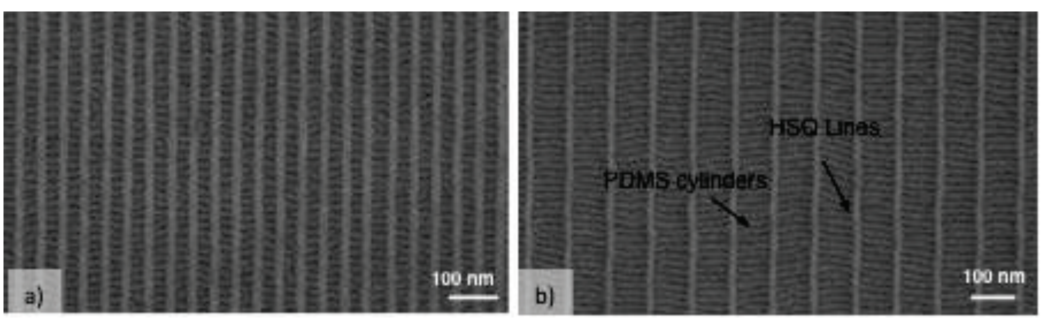

Figure 3: SEM images of 16 kg/mol oxidized PDMS cylinders aligned perpendicular to HSQ lines patterned at a) 47 and b) 99 nm.