# From 2-D blueprint, material assembles into novel 3-D nanostructures

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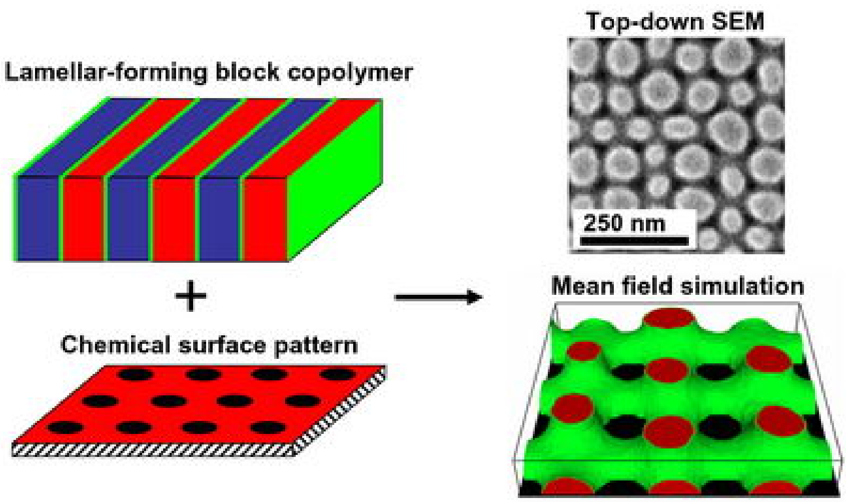


Thin films of a lamellar-forming block copolymer on 2D surfaces chemically patterned with a square array of spots form 3D bicontinuous morphologies. Top-down scanning electron micrographs (top right) show that a series of spots arise on the free surface. The mean field simulation results (bottom right) indicate that both of the copolymer domains (the blue domains were removed from the image for clarity) of the self-assembled morphology are continuous and connect the substrate to the free surface. The black spots specify the position of the underlying surface pattern and the green represents the interface between the blue and the red domains.

An international team of scientists affiliated with the University of Wisconsin-Madison Nanoscale Science and Engineering Center has coaxed a self-assembling material into forming never-before-seen, threedimensional nanoscale structures, with potential applications ranging from catalysis and chemical separation to semiconductor manufacturing.

Led by UW-Madison chemical and biological engineering professors Paul Nealey and Juan de Pablo and colleagues at Georg-August University in Germany and the Paul Scherrer Institute in Switzerland, the team has discovered that materials known as block copolymers will spontaneously assemble into intricate 3-D shapes when deposited onto particular 2-D surface patterns created with photolithography.

The result, published in the Jan. 27 issue of *Physical Review Letters*, demonstrates a promising strategy for building complex, 3-D nanostructures by using standard tools of the semiconductor industry, says Nealey. Those tools, particularly lithography, already allow the making of devices with dimensions substantially smaller than 100 nanometers, or a hundred-thousandth of a centimeter.

But photolithography is also limited, he says, because as practiced today it is essentially a two-dimensional process.

"What we've done by using self-assembling block copolymers is to extend photolithography to three dimensions," says Nealey. "And the structures we've fabricated are completely different from the same block copolymer materials in the bulk." Also important to manufacturing, the new 3-D nanostructures are stable, well defined and nearly defect-free over large areas. They also align perfectly with the underlying lithographic pattern-a key requirement for any device or application based on them.

"This research shows that lithography combined with block copolymers is more versatile and powerful than we thought. We can now create completely new structures that will no doubt have new properties and new applications," says de Pablo. "Exactly what those structures will be is anybody's guess; here we demonstrate a complicated one. But the important thing is they open up a new field of exploration, both for these materials and this technology."

The specific structures the team produced were composed of two tightly interwoven, yet completely independent, networks of channels and passages-all at the scale of atoms. "What we have are two interpenetrating meshes, both of which are completely continuous. And yet you could travel through one from end to end without ever entering the other," says de Pablo.

The networks are also in perfect register with the photolithographic pattern underneath, which tells scientists exactly where each channel ends and gives them ready access to channel openings. A gas, for example, might be introduced through the openings to react with a catalyst deposited on the walls of the network. Nanoscale materials have massive surface areas compared to their volumes; thus, catalysis would be extremely efficient.

Another use would be chemical separation of substances of different sizes. "This process gives us exquisite control over the dimensions of pores," says de Pablo. "So, we could easily make membranes that are permeable to substances smaller than the length scale of the material."

The researchers study specific block copolymers consisting of long chains of two different types of molecules, which alternate with each other in blocks. At high temperature, block copolymers are molten and randomly mixed. But when cooled down, the material spontaneously assembles into alternating layers of molecules.

Source: University of Wisconsin-Madison