Holographic photolithography tools for industrial-scale nanomanufacturing

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We developed holographic photolithography tools for industrial-scale manufacturing of nanostructured materials with one-, two-, and three- dimensional morphologies. These materials have a variety of applications, including optical coatings and metamaterials, filtration and separations, batteries and electrochemistry, and template patterning (molds and shims).

Figure 1(a) shows a schematic of one kind of such tool. A long coherence length laser is used as a light source. Gratings or beamsplitters separate the source into several optical beams, which are directed by mirrors to converge and form an interference pattern at a photoresist-coated substrate. Exposure to this interference pattern causes a photochemical reaction, creating a latent image. Development yields the patterned photoresist. The morphology of the latent image can be predicted by computing the specific absorption rate as a function of position for a given configuration of incident optical beams.

Figure 2 shows examples of three-dimensional periodic porous structures made in SU-8 photoresist with our holographic lithography tool. Two interfering beams and a chuck with translational and rotational degrees of freedom were used to make the structures via multiple exposures. The tool used a 405 nm single longitudinal mode diode laser source.

Holographic photolithography has several advantages. The field size can be increased easily, and multiple layers of patterning can be exposed and developed simultaneously. The latter advantage expecially can increase the patterning rate over conventional projection or nanoimprint lithography for making complex two- and three-dimensional morphologies.

We are also developing techniques for continuously patterning large areas and volumes by dynamically adjusting the phase of the interfering beams to move the interference pattern in concert with the substrate, as depicted in Figure 1(b). This method, which we call coordinated holographic industrial-scale electromagnetic lithography (CHISEL), could scale to a volumetric patterning rate more than one million times that of layer-by-layer projection photolithography.

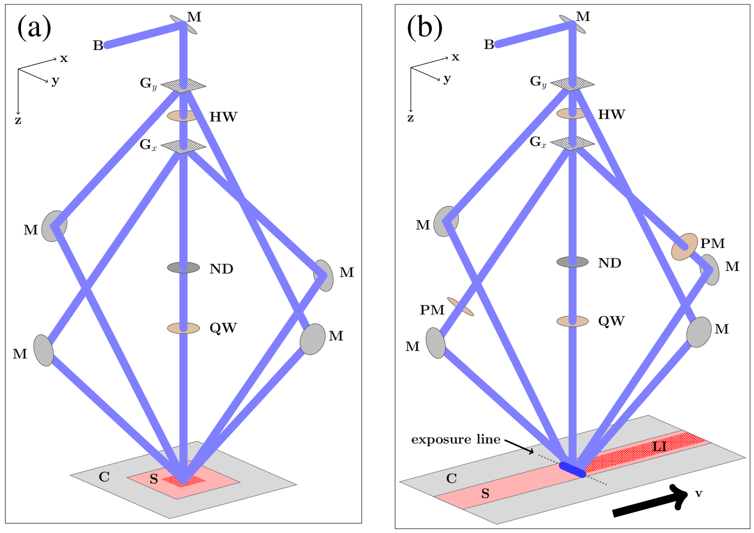

Figure 1: Schematics of holographic lithography tools: (a) conventional static; (b) continuous patterning (CHISEL).

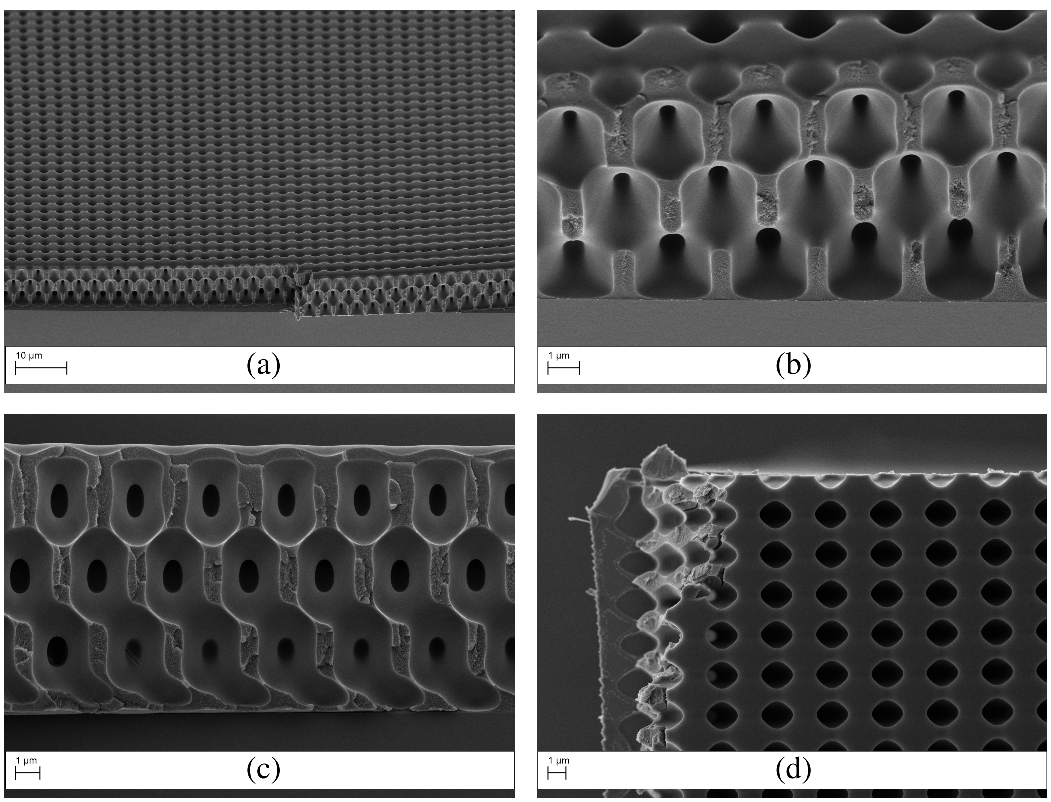

Figure 2: Scanning electron microscope images of three-dimensional periodic microstructure made via holographic photolithography: (a, b) angled views; (b) cross section; (c) top view.