Fabrication of Hierarchical Three-Dimensional Nanostructures Using Template-Directed Assembly of Colloidal Particles

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Template-directed self-assembly of monodispersed nanospheres is an effective technique for controlling intricate dimensional properties of carefully designed hierarchical geometries at low cost [1-3]. In this approach, templates are made using lithographic techniques and provide physical/chemical constraints to guide the self-assembly process. The template-assisted approach allows improved assembly quality and has been shown to increase the spatial-phase coherence and reduce defect. The technique of using templates to direct the self-assembly of colloidal nanospheres allows for the inexpensive fabrication of complex hierarchical patterns which can be achieved over a large area. These hierarchical patterns have applications in the design of super-hydrophobic surfaces, mimicking the many surfaces encountered in natural environments which make use of hierarchical micro and nanostructures to achieve super-hydrophobicity [4]. There has also been recent interest in the use of microfluidic channels for biomedical applications such as diagnosis of diseases [5]. Templated hierarchical nanostructures can be useful in engineering desired properties of such microfluidic channels.

In this work, template-directed self-assembly of colloidal particles is used for the "top-down" patterning of hierarchical 3D structures. In this approach, the self-assembled nanospheres act as an optical phase mask [6], to pattern 3D periodic nanostructures in selective regions as specified by the template. The process is illustrated in Figure 1, where a photoresist surface is patterned with a surface-relief structure using nanoimprint lithography. This pattern is then used as the template for self-assembly of monodispersed polystyrene nanospheres. The stack is then exposed to UV light, which forms a 3D interference pattern under the assembled spheres. The proposed process allows the direct integration of 3D nanostructures into micro channels, and allows for the different length scale structures to be independently controlled. Figure 2 shows the preliminary results using a 1D template with a trench width of 2 μm. Spheres with a diameter of 500 nm were self-assembled into the trench and exposed to UV light with $\lambda = 325$nm. The resulting hierarchical structure has 3D periodic nanostructures with a period of 500 nm aligned in the direction specified by the microscale template, as shown in Figure 2(a). Note the patterned structures are porous and periodic in all three dimensions, as indicated by the cross-section micrograph shown in Figure 2(b). A number of defects can also be seen between the patterned structures, which are due to particles outside of the template and can be reduced by using deeper templates

This work investigates the fabrication of hierarchical porous 3D nanostructures using template-directed self-assembly of nanospheres and phase lithography. The effects of the template dimensions and geometries, as well as the size of the colloidal particles, will be explored. The effect of trench dimensions on the nanospheres assembly and defects will be studied, as well as other template geometries. We will explore the use of these hierarchical 3D nanostructures in microfluidic applications.

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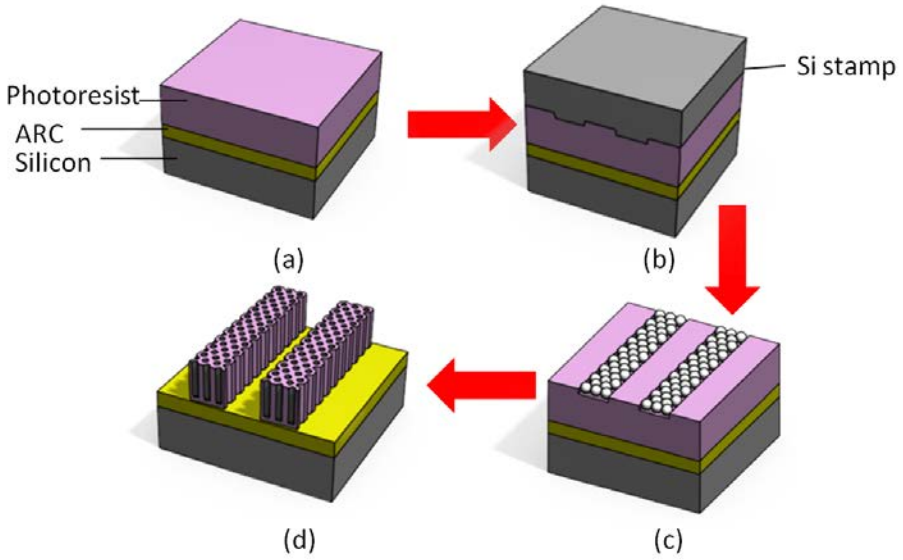
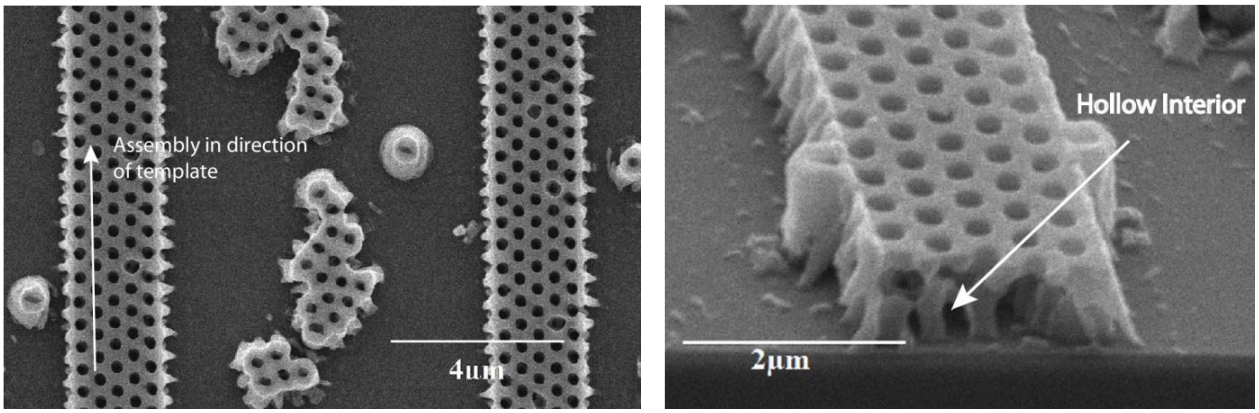


Figure 1. Fabrication of hierarchical 3D nanostructures. (a) Thin film of ARC is spin coated onto a silicon substrate, and is then coated with a thick layer of photoresist. (b) The photoresist is thermally imprinted using a silicon stamp. (c) Nanospheres are self-assembled into the photoresist template, which is then exposed to UV light. (d) Resulting aligned porous 3D structures after photoresist is developed.



(a) (b)

Figure 2. SEM images of (a) top view and (b) cross-sectional view of aligned 3D nanostructures

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