Three-Dimensional Colloidal Interference Lithography

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Colloidal lithography is capable of fabricating high-quality nanostructures, such as nanopores hemispherical metal caps, and sculptured colloids [1-2]. Recently, fabrication of three-dimensional (3D) hollow-shell nano-volcanoes using light scattering from colloidal nanospheres has been reported using single illuminations under various incident angels [3-4]. However, the relative phase effects of multiple illuminations have not been investigated. In this work, Lloyd's mirror interference method was applied to create two seprate interfering light beams. We investigate combinations of lithography parameters to obtain different three-dimensional (3D) nanostructures.

The fabrication process uses a 325 nm wavelength HeCd laser directed to a photoresist stack with nanospheres by spincoating, as illustrated in Figure 1. The self-assembled monolayer of isolated nanospheres is used as the mask for the photoresist material. A Lloyd's mirror interference system is used to create two separate incidence angels from a single laser source to create the desired coherent condition. The dual incidence creates interference patterns, which when combined with nanospheres mask creates 3D patterns on the photoresist material. These patterns can create volcano-like structures with multiple nanoscale chambers.

Preliminary fabrication results are shown in Figure 2 using various incident angles and nanosphere sizes. In Figure (a-c) 500nm period and 1μm diameter particles were used and incident angles is 18.97°. The top view in Figure 2(a) shows two chambersthat are created by two laser beams; it also depicts the alignment between nanospheres and the background grating line caused by the location of the nanospheres before exposure, which serve as a reference grid to visualize relative phase. Cross-section views of the fabricated double-chamber structures in Figure 2 (b) and (c). More complicated structures can be fabricated by changing particle sizes and incident angles. In Figure 2(d) and (e), both structures were fabricated using 2 μm diameter particles with period of 2 μm and the incident angle of 4.66°. Due to the larger particle size, the light scattering pattern causes the wavy effects around the chambers. Fabrication result using 500 μm period and 2 μm diameter particles is shown in Figure 2 (f), different shapes of chambers are achieved by only increasing the incident angle, compared with Figure 2(d) and (e).

In this work, 3D colloidal interference lithography is proposed and different geometries of 3D nanostructures can ben fabricated with different incident angles and article diameters. The phase effects of the interfering beams on the resulting structures will be investigated in more details. The fabricated double-chamber nanostructures could fin potential application in drug delivery and nanofluidics.

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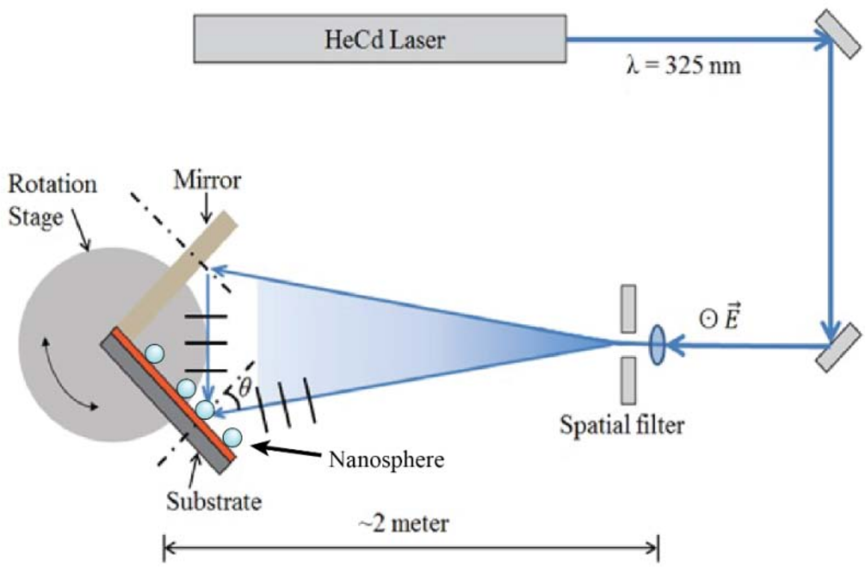

Figure 1: Colloidal interference lithography set up using a Lloyd's mirror interferometer

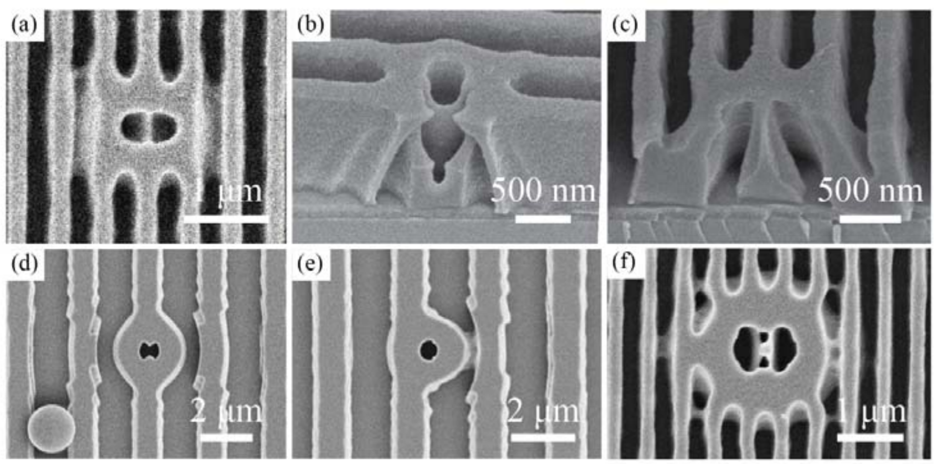

Figure 2: Scanning electron microscope (SEM) images of fabricated 3D nanostructures with (a-c) 500nm period, and 1µm particle in top view, cross-section views along and perpendicular with grating lines, respectively. (d-e) Top views of fabricated structures with 2 µm period and 2 µm particle, and (f) 500 nm period and 2 µm particle.

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