Fabricating Lithographically Designed Cylindrical Colloidal Particles

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Primary CNF Tools Used: Spinners and hot plates in Class-II resist room, AutoStep i-line stepper

Abstract:

Materials with characteristic structural features on the colloidal scale (10 nm to 10 μm) are potentially important for applications in electronics, optics, high density memory, microelectromechanical machines, and tissue engineering. In this project, we are exploring our understanding to allow for rational design of desired materials from colloidal building blocks. For this purpose, we have exploited a class of colloidal particles formed by photolithography in a polymeric photoresist (SU-8) [1-3]. The objective of the current project is to study the equilibrium assembled structures formed by the cylindrical colloidal particles under confinement. These structures are predicted using Monte Carlo simulation model; and we are now focusing on validating the assembly behavior using experiments.

Summary of Research:

Our first step was to fabricate micron-sized monodisperse cylindrical particles using the photolithography technique. We used the epoxy-based negative photoresist, SU-8 2001 and adopted the following procedure to achieve the target dimension [2]:

(1) Spin coating of the SU-8 2001 photoresist on top of a sacrificial layer (OmniCoat™) on a silicon substrate achieving the desired average height of 0.98 μm. For a 0.98 μm layer, SU-8 can be spun at 500 rpm for 10s, immediately followed by a step at 3000 rpm for 30s.

(2) Exposure of the wafer through a Cr photomask with round holes using a 5X stepper (GCA Autostep i-line). The average diameter of the particle (~1.605 μm) is controlled by exposing the resist to the ultraviolet light (365 nm) through a photomask with rounded holes with a focus value of -1.4 μm and exposure time = 0.22s.

(3) Post-exposure bake of the SU-8 layer: the wafer was placed on a vacuum hotplate at 65°C for 1 min and 95°C for 2 min to crosslink the exposed photoresist. The wafer was allowed to cool to ambient temperature before proceeding to the next step. Next, the wafer is then placed in ~ 100 mL of SU-8 developer for 1 min and then rinsed with IPA.

(4) The particles are then released by using Remover PG and sonication in an ultrasonic cleaner.

Before placing the particles in the buffered solutions of surfactants, a sample of particles in DI water was redeposited on a silicon wafer and imaged by SEM (Zeiss Supra 55VP or Zeiss Ultra 55). The average and standard deviation of the heights and diameters of the particles were measured on the images (Figure. 2). We estimated about 6.3% and 4.7% polydispersity in height and diameter, respectively. We note in Figure 1 that the two ends of the cylinders were not identical: one end had sharp edges that were globally flat (although not smooth); the other end had more rounded edges (arrow). The flat end was the one that was in contact with the OmniCoat sacrificial layer. We obtained the size distributions by analysis of scanning electron micrographs. The fabricated SU-8 particles are then dispersed in water and Tergitol NP70 surfactant solvent medium.

References:

[1] Badaire, Stéphane, Cécile Cottin-Bizonne, and Abraham D. Stroock. "Experimental investigation of selective colloidal interactions controlled by shape, surface roughness, and steric layers." Langmuir 24.20 (2008): 11451-11463.

[2] Badaire, Stéphane, et al. "Shape selectivity in the assembly of lithographically designed colloidal particles." Journal of the American Chemical Society 129.1 (2007): 40-41.

[3] Hernandez, Carlos J., and Thomas G. Mason. "Colloidal alphabet soup: Monodisperse dispersions of shape-designed lithoparticles." The Journal of Physical Chemistry C 111.12 (2007): 4477-4480.

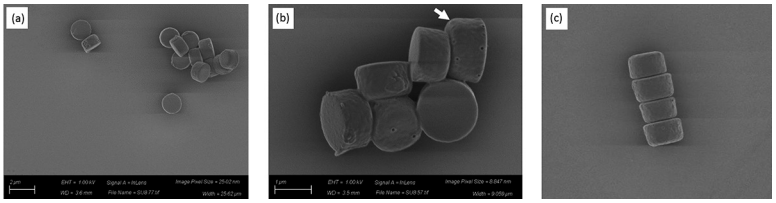

Figure 1: (a)-(c) Structure of the SU-8 particles obtained using scanning electron micrographs. Arrow (white) shows the curvature of edge of one of the particles. (c) The column arrangement of the particles shows variation in particle diameter.

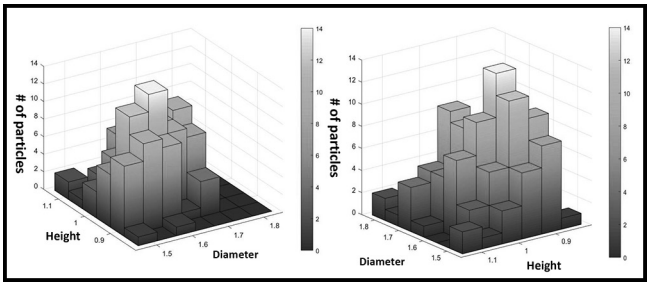

Figure 2: Histogram of height and diameter of the particles. The statistics is taken for ~ 200 particles diameter and height data. The skewness in diameter is about 0.056 in diameter and 0.305 in height. This indicates an approximate symmetric distribution in the profile.