Fabrication of Hollow-Shell Nano-volcanoes from Mie Scattering of Colloidal Nanospheres

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Colloidal lithography, based on the self-assembly of monodispersed nanospheres, is a simple, low-cost, and high throughput technique for patterning nanostructures [1]. Compared with the diffraction-limited "top-down" optical lithography, this "bottom-up" approach has been demonstrated to have the capability to fabricate high-quality nanostructures [1-5]. Complex 3D structures, such as nanopores, hemispherical metal caps and sculptured colloids [2-4], have been demonstrated by various groups. Recently, fabrication of complex periodic 3D structures by combining this technique with phase lithography has been reported [5]. That work harnesses the Talbot effect, and demonstrates the versatility of colloidal self-assembly.

In this work, we demonstrate the fabrication of hollow-core nano-volcano structures using Mie scattering from colloidal nanospheres. The fabrication concept is depicted in Figure 1, where an isolated nanosphere is illuminated by UV light. The incident light is then scattered by the nanosphere to create a complex 3D intensity pattern. This process can be modeled by Mie scattering theory, since the diameter of the nanosphere is comparable to the wavelength of the incident light. A thick layer of photoresist is used to record the intensity distribution of the scattered light. By selecting proper exposure dose, a single nano-volcano with hollow core and thin shell can be fabricated. Such hollow-core geometry may be useful for particle, cell trapping, and low-volume solution delivery.

Our preliminary fabrication results are shown in Figure 2. In this experiment, nanospheres with 500 nm diameter are illuminated by a 325 nm-wavelength laser. Figure 2(a) depicts a single nano-volcano exposed with dose of 130 mJ/cm^2. The structure resembles a cone shape with an opening on top and a ripple sidewall, which can be predicted by Mie scattering theory. Figure 2(b) shows the cross section view of the same structure, illustrating the thin-shell structure with ~100 nm thickness. Figure 2(c)-(f) exhibit various nano-volcano geometries fabricated with various exposure doses, as noted in the figure caption.

In this work, we describe the fabrication process of hollow-core, thin-shell nano-volcanoes. We will examine the influence of exposure dose, polarization state, and incident angle on the geometry of the nano-volcanoes. We will also investigate in the fabrication of nano-volcanoes positioned in a periodic array, and the utilization of these structures for particle trapping. We will present the detailed fabrication process, theoretical modeling, and experimental results.

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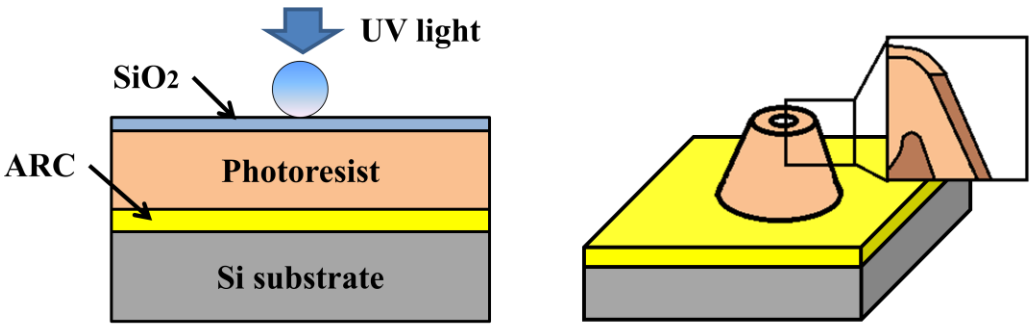

Figure 1 Schematic of nano-volcano fabrication process. (a) A single nanosphere on top of the resist stack is exposed by UV light. (b) Developed volcano structure. The magnified region illustrates the hollow-core thin shell structure.

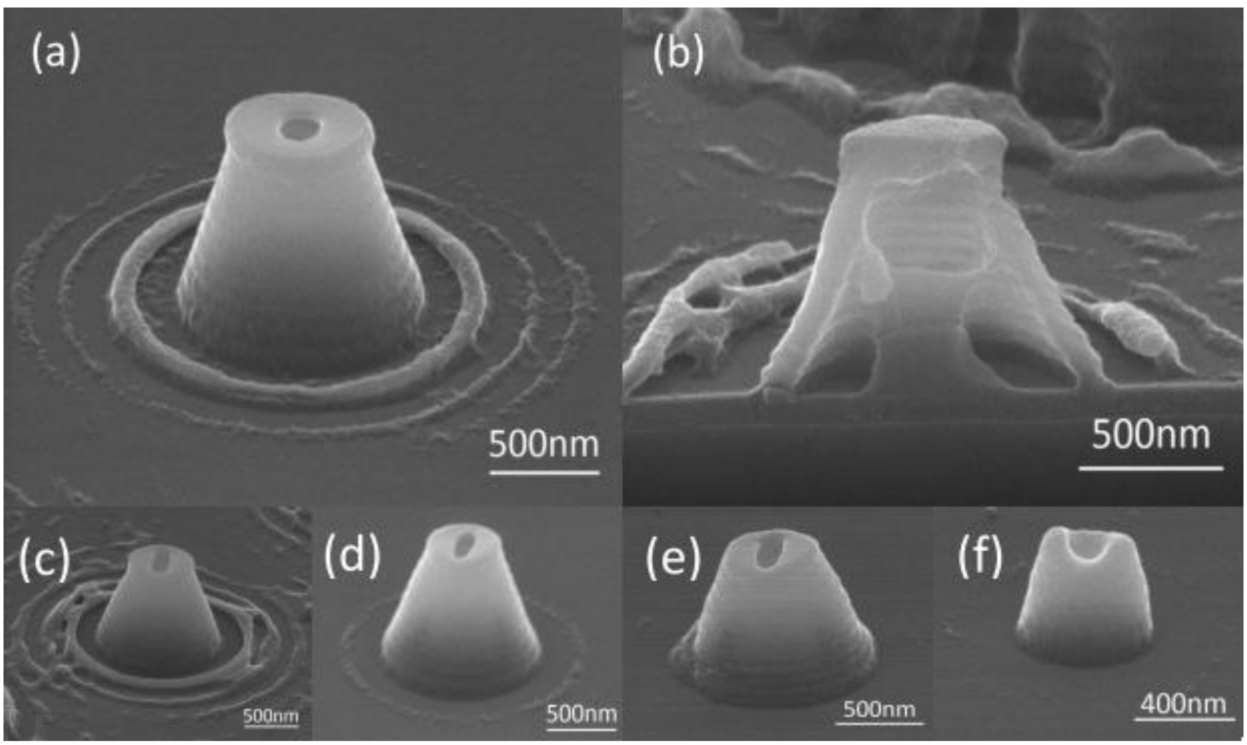

Figure 2 (a) Single polymer nano-volcano exposed with dose of 130 mJ/cm^2. (b) Cross section view of the same structure in (a). (c)-(f) Nano-volcanoes exposed with doses of 113 mJ/cm^2, 140 mJ/cm^2, 160 mJ/cm^2 and 170 mJ/cm^2, respectively.

References:

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