Fabrication of Nanostructured Hydrophobic Surfaces with Laser Interference Lithography

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When it comes to fabricating micrometer and sub-micrometer periodic and quasi-periodic patterns over large areas, Laser Interference Lithography (LIL) has attracted a lot of attention. Comparing with other types of lithographic technologies, LIL is very useful considering it is a simple process to achieve large area, uniform definition and high throughput at low cost. This technique is a maskless process capable of generating homogeneous nanostructures of lines and dots in large areas, which is either impossible or time/cost consuming with other lithography techniques. Meanwhile, the role of hydrophobicity is critical in self-cleaning mechanisms, electrostatic droplet actuations, and in areas of bioengineering such as protein folding and protein bonding. [1] The hydrophobic property of the surface is mainly the result of either the chemical composition of the material or the geometric structure of the surface. In order to study the influence of micro and nanostructures on the surface hydrophobicity, various patterning methods were employed, including solidification, plasma polymerization/etching, chemical vapor deposition, solvent-mediated phase separation, molding and nanoimprinting. [2] However, due to the complex process and expensive materials used in these methods, it is not favorable to apply them in the fabrication of large area, nano-scale periodic structures in a cost effective manner.

Here we introduce a simple two-step method to fabricate periodic nanostructures on a substrate by combining LIL with Reactive Ion Etching (RIE). Figure 1(a) illustrates the Lloyd’s interferometer LIL system used in this work. A He-Cd laser with a wavelength of 325 nm and power of 5 mW is used as the UV light source for resist exposure. A spatial filter consisting of a lens with a focal length of 5 mm and a 10 μm pinhole at the focus of the lens is used to simulate a point light source for the exposure. A Lloyd’s mirror on a rotation stage creates two beams of coherent UV light for the interference lithography. The rotation angle of the stage defines the period of the structures. A commonly used i-line positive photoresist is used for the process. Following one round of exposure, the sample is rotate by 90 degrees for a second round. After development, nanotips with a period of 600 nm are formed in the photoresist as shown in Fig. 2(a). The resist pattern is then transferred to the silicon substrate by RIE. The silicon

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[1] N. T. Southall, *et al.*, Journal of Physical Chemistry B **106**, 521 (2001).

[2] C. Guo, *et al.*, Chem. Phys. **5**, 750 (2004).

nanopatterns in Fig. 2(b) exhibits high fidelity with the one in the resist.

The hydrophobic property of this structure is measured by a contact angle system. The result shows that the contact angle of the water droplet on the patterned substrate is larger than 110 °(Fig. 3(b)). On the other hand, silicon substrate with no surface nanostructure demonstrates a small contact angle of less than 70 °, which is hydrophilic. Furthermore, different height and period of the nanostructures shows different hydrophobic properties.

In summary, in this work we have successfully developed a simple process to fabricate nanostructures for surface hydrophobicity. The nano-tip array structure with strong hydrophobicity can be fabricated by this two-step process which provides an effective method to fabricate the hydrophobic surface on a large area at a low cost. Experiments are currently underway to use this LIL technique in fabricating microlens arrays and templates for nanoimprint lithography, as well as in application in digital fluidics and cell culturing.

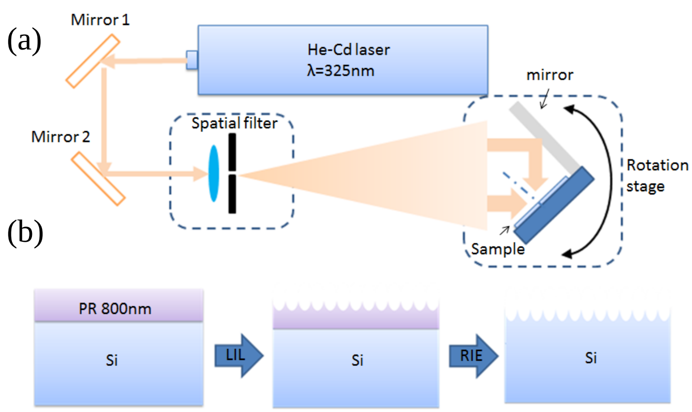

Figure 1: (a) Schematic of Lloyds mirror configuration of a laser interference lithography system. (b) Schematic diagram of the two step process for periodical nano-tip fabrication by LIL and RIE.

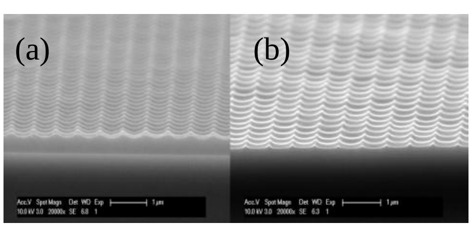

Figure 2: SEM images of periodical nano-tip structure on PR after LIL (a) and on silicon wafer after RIE (b).

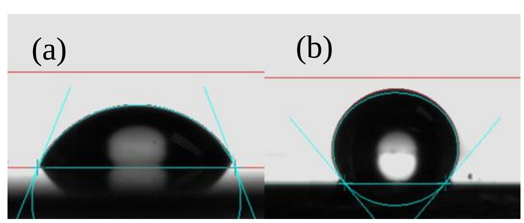

Figure 3: Images of water droplet contact angle on silicon substrate without patterns (a) and with nano-tip array pattern (b).