Western Nanofabrication Facility

Fabrication of Nano-holes and Nano-pillars with Laser Interference Lithography

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Periodic nanostructures have many applications including optical gratings, bio-sensors, photovoltaics, microfiltration, and controlled surface topographies for cell biological applications. Conventional production methods such as Focused Ion Beam (FIB) or Electron Beam Lithography (EBL) are generally expensive, suffer from low speed, and have limited surface coverage. Alternatively, laser interference lithography (LIL) is a fast and relatively inexpensive method to create periodic nanostructures over large areas. In LIL, interference patterns are created by mixing of two coherent beams, which, in turn, are used to expose a photo-resist layer on a substrate. A Lloyd's mirror interferometer is one method for mixing and consists of a mirror placed perpendicular to the substrate on a rotating stage. An expanded laser beam from an objective lens falls on the Lloyd's mirror in such a way that the direct beam and the reflected beam overlap to create an interference pattern on the substrate. The relationship between the periodicity of the interference pattern (d), the wavelength of the laser (λ), and the angle between the mirror and the beam axis (θ) is given by $d = \lambda / 2sin\theta$. Therefore, periodicity can be easily controlled by varying the angle θ.

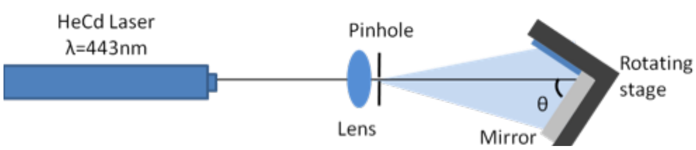

Figure 1 - Illustration of Lloyd's mirror interferometer setup

We fabricated nano-hole and nano-pillar arrays on a silicon substrate by using LIL (Figure 1) . First, 20 nm chromium was deposited on clean silicon substrates with custom e-beam deposition (Hoser, Western Nanofab). Substrates were spincoated with Shipley S1805 photoresist at 4000 rpm for 45 seconds resulting in 500 nm film thickness and then they placed on the Lloyd's mirror interferometer at $\theta = 14°$. After the first exposure substrates were rotated 90° and exposed again with $\theta = 10°$, which yielded 2D structures having different periodicities along the x and y axes. The substrates were then developed (MF319 developer, Shipley). Using the photoresist layer as a mask, the substrates were immersed in a chromium etchant to reveal the 2D pattern on the chromium layer. The chromium pattern acted as a secondary mask for the silicon etching process. Then, subtrates were placed in the deep reactive ion etching (DRIE) system (Alcatel, 601E, Western Nanofab). Remover PG (MicroChem) and chromium etchant were used to remove the photoresist and chromium masks after silicon etching, which resulted in silicon nanopillars or nano-holes.

We characterized the samples with a scanning electron microscope (LEO Zeiss 1540XB FIB/SEM, Western Nanofab, Figure 2). Exposures of 25 s ($\theta = 14°$) followed by 19s ($\theta = 10°$) yielded nano-pillar arrays. Exposures of 22 s ($\theta = 14°$) followed by 15 s ($\theta = 10°$) yielded nano-hole arrays. Sizes of the holes and pillars could be adjusted by fine tuning the exposure time. Depth of the nano-holes and height of the nano-pillars was controlled by the DRIE exposure parameters. The fabricated devices suggest that LIL is aflexible, inexpensive, and fast method for creating periodic nano structures over large areas.

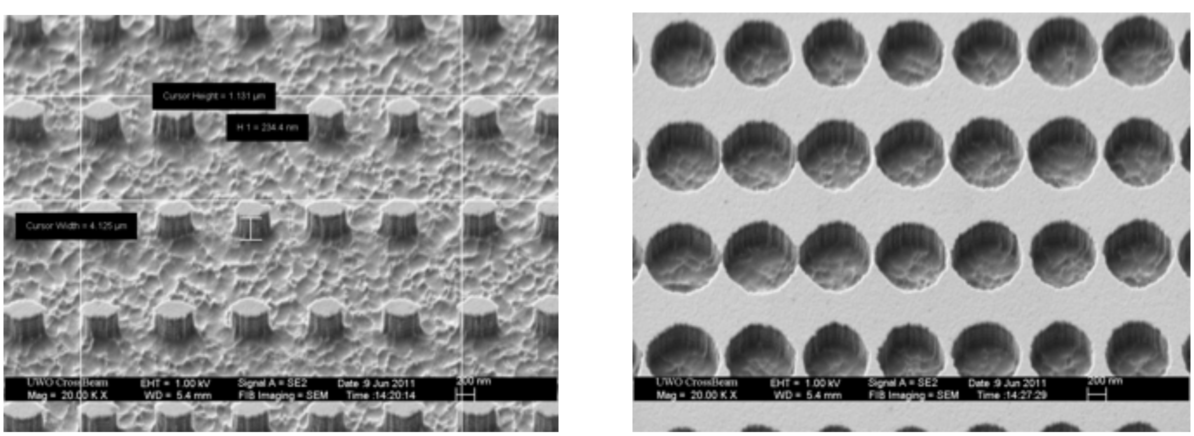

Figure 2 - SEM image of a nano-pillar array (left) and a nano-hole array (right)

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