Three-Beam Lloyd’s Mirror Interference Lithography with Liquid Immersion

Shubhro Saha*, Zhiren Luo, and Chih-Hao Chang

Department of Mechanical and Aerospace Engineering, North Carolina State University, Raleigh, NC 27695, USA

Interference lithography (IL), based on the interference of a coherent light source, is an effective method for scalable fabrication of periodic nanostructures. The Lloyd’s mirror interferometer is common IL configuration due to its insensitivity to noise, can achieve different pattern periods by a one-degree of freedom rotation of the mirror system. In this approach one mirror is used to create a virtual light source, which is sufficient for two-beam interference to create 1D grating or 2D rectangular pattern through double exposure. For three-beam interference, two mirrors can be used to generate hexagonal pattern with a single exposure [1]. However, for such system the angle between the mirrors are fixed, resulting in limited lattice geometry. The pattern resolution is also limited to around 200 nm period. It is necessary to go further to explore more tunability with a setup that could alter the angle between these two mirrors with liquid media.

Here we report a liquid-immersion, three-beam Lloyd’s mirror lithography system that can have more pattern versatility and higher pattern resolution. This is achieved by allowing the angle between the two mirrors to be changed, leading to more interference conditions. The resolution can also be improved by using liquid immersion. In IL, the period is determined by incident angle, refractive index of medium, and wavelength of source light. Smaller period can be achieved using media with higher refractive indexes instead of air [2]. The proposed system is depicted in Figure 1, where two mirrors are installed onto two holders separately, with both mirrors perpendicular to the sample holder. The angle between two mirrors can be changed by rotating the mirror holders. The HeCd laser with a wavelength of 325 nm is used as the light source. The whole optical setup can be immersed in water to improve pattern resolution.

The preliminary fabrication experiments are shown in Figure 2. Here the angle between the mirrors are set to 120º, resulting in a regular hexagonal array of holes. In these experiments the pattern was exposed in air without liquid immersion, resulting in a hexagonal pattern with 600 nm lattice period. The silicon substrate was prepared by spincoating 90 nm-thick antireflection coating and 250 nm-thick positive photoresist. Here it can be observed that the pattern has high fidelity over large areas. We will examine the wave vectors and simulate the resulting interference pattern for mirror angles not equal to 120º, which can lead to more pattern geometry. We will also characterize the patterning period versus incident angle, as well as its sensitivity to noise. Liquid can then be introduced to the system to enhance the patterning resolution. A quantitative comparison to existing two-beam interference will be made. We will report the detailed specification and characterization about the proposed liquid immersion three-beam Lloyd’s mirror lithography system, as well as limitations and potential applications.

*sssaha@ncsu.edu

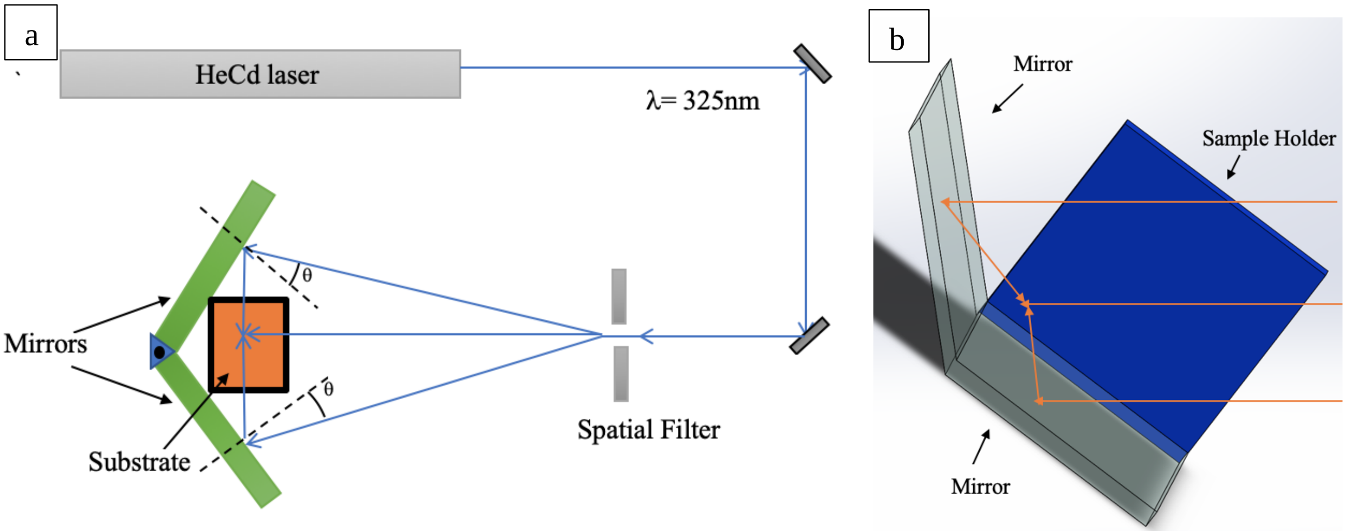

Figure 1: Proposed three-beam Lloyd's mirror interference lithography system. (a) Beam path for the system set up using two mirrors and (b) Three-dimensional ray diagram of the interference.

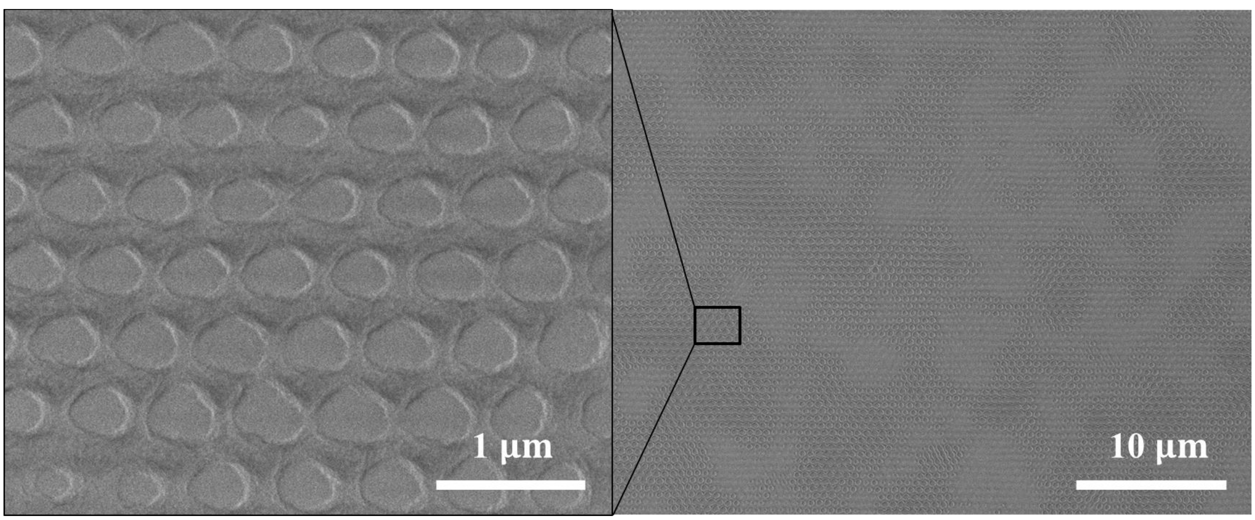

Figure 2: Scanning electron microscope (SEM) images of fabricated hexagonal nanostructures with 600 nm period using a single exposure with the proposed system.

Reference

[1] J. Boor, *et al. Opt. Lett.*, **34**, 1783-1785 (2009).

[2] A. Bagal, et al. *Opt. Lett.* **38**, 2531-2534 (2013).