Liquid-Immersion Lloyd's Mirror Interference Lithography

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Periodic nanostructures have many applications, such as spectroscopy, biomimetic surfaces, and physical templates for self-assembly. With the use of interference lithography [1], it is possible to fabricate high-precision periodic nanostructures over large areas to suit the desired application. However, this top-down lithographic approach is limited by the light diffraction, and the smallest period that can be fabricated is roughly half of the wavelength. Multi-level interference lithography has been used to make subwavelength structures [2], but this method requires multiple exposures and precise alignment. The use of immersion techniques, which takes advantage of high refractive index immersion fluids, have been shown to improve resolution [3, 4]. Recent efforts in this field have focused on combining interference lithography with solid immersion techniques [5-7]. However, these methods require prisms that are precisely machined, resulting in high setup cost. In this work, we explore an all-liquid immersion scheme based on a Lloyd's mirror interferometer.

The proposed system is shown in Figure 1. The arrangement consists of a mirror mounted on one face of a liquid container perpendicular to the substrate. The container is filled with immersion fluid, such that the mirror and sample are fully immersed. The arrangement of the setup facilitates the immersion fluid to be held against mirror and sample by gravity, and simplifies the system to avoid the need of precisely machined prisms. This all-liquid system ensures conformal contact of fluid with the mirror and sample, thereby reducing defects in the structure produced. Using the design proposed in this work, we have successfully fabricated 1D structure having periodicity of 112 nm using light of 325 nm wavelength, as show in Figure 2, achieving numerical aperture of 1.45. The system proposed in this work is flexible and any desired period over a range can be fabricated by making simple adjustments. We have demonstrated structures with periodicity ranging from 112 nm to 170 nm using two commercially available immersion fluids.

In this work we present a method to increase spatial resolution of a Lloyd's Mirror interference lithography setup by taking advantage of high refractive index immersion fluids. We will present results using multiple immersion fluids, exposure configurations, and discuss the effect of light absorption in the immersion fluid on the quality of the structure produced. The proposed set up can be a simple method to increase fabrication resolution in a laboratory setting, and can find applications in textured surfaces with high surface to volume ratio.

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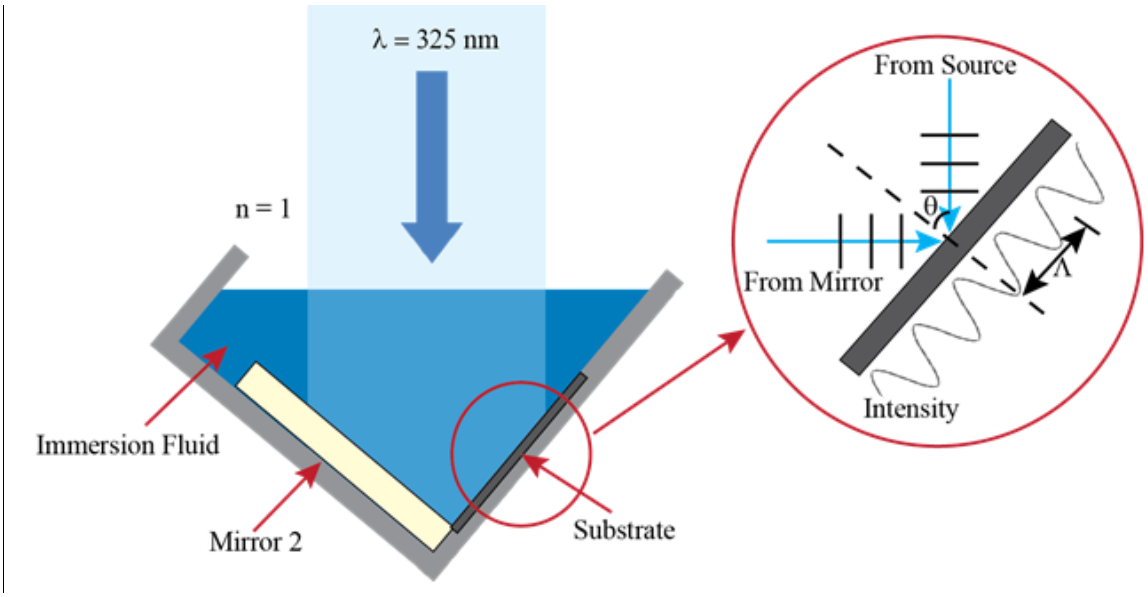

Figure 1. Proposed setup for all-liquid immersion interference lithography with the interference phenomenon illustrated

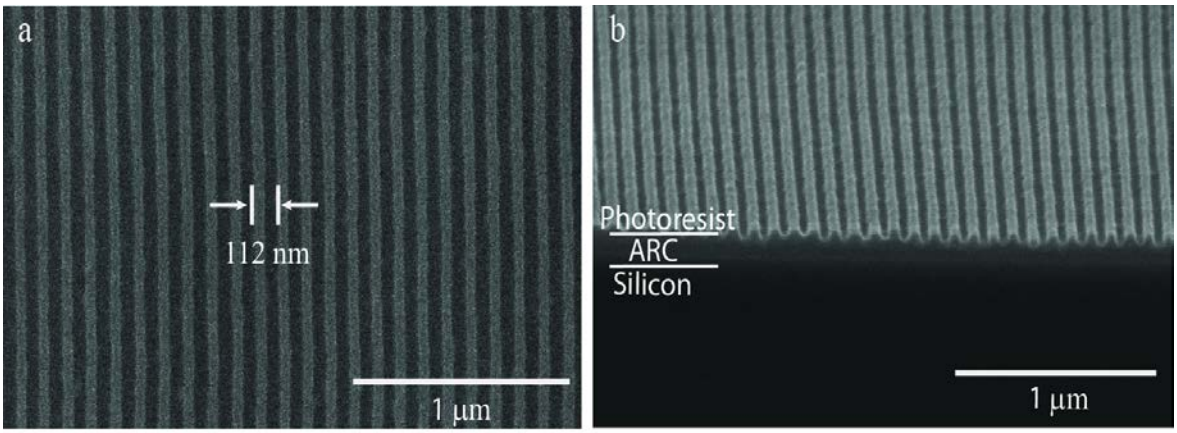

Figure 2. 112 nm period using immersion fluid (n = 1.51) (a) Top view of the sample with periodicity of the structure marked (b) Cross-sectional view of the sample

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