Solid-immersion Interference Lithography using a Lloyd's Mirror

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We describe a cost-effective technique to perform ultra high-NA interference lithography based on the Lloyd's mirror that requires only the use of a high index prism, index matching liquid and a coherent laser source. The method is similar to other two-beam solid-immersion lithography schemes[1,2], but eliminates the need for beam splitters, a beam block and some steering optics.

The system, shown in Figure 1, builds upon the traditional Lloyd's mirror by coating one side of a high index prism cube with a reflecting material such as Aluminum, thereby creating a solid-immersion equivalent. The prism should have low index inhomogeneity, low absorbance (high transmission) in the wavelength of interest, low birefringence and be capable of withstanding a specified amount of stress during sample mounting. In our case we have tested the concept with a glass prism (UV fused Silica n = 1.48); we also propose the use of a higher-index material, such as Yttrium Aluminum Garnet (YAG) for the prism. The idea is easily extended for 193 nm imaging using a Lutetium Aluminum Garnet (LuAG) prism material[2]. Our experiments with a 45 degree glass prism (n = 1.48) show promising results, as shown in Figure 2, where at a NA of 1.4, a grating with period of 116 nm is defined in photoresist (Clariant AZ1518). Inconsistencies and imperfections in the pattern are thought to be due to system limitations, i.e. the quality of the deposited mirror at the prism edge is reasonably rough however this part of the mirror is significant for image formation at the higher NA values. A similar technique has been demonstrated recently achieving a NA of 1.36 at λ = 244nm, also with a glass prism[3]. Further results will be presented, including the use of a higher-index YAG prism to get NA ~ 1.9 at which 44 nm half-pitch gratings are expected for 325 nm exposure. In this regime the image is formed with evanescent fields and techniques such as the use of plasmonic reflectors[4] will be employed to improve depth of focus and process latitude.

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[1] B. W. Smith, Y. Fan, J. Zhou, N. Lafferty, and A. Estroff, "Evanescent wave imaging in optical lithography," Proc. SPIE 6154 (2006)

[2] J. Zhou, N. V. Lafferty, B. W. Smith, and J. H. Burnett, "Immersion Lithography with numerical apertures above 2.0 using high index optical materials," Proc. SPIE 6520, 65204 (2007).

[3] J. de Boor, *et al.*, "Sub-50 nm patterning by immersion interference lithography using a Littrow prism as a Lloyd's interferometer," *Optics Letters*, vol. 35, pp. 3450-3452, Oct 2010

[4] M. D. Arnold and R. J. Blaikie, "Subwavelength optical imaging of evanescent fields using reflections from plasmonic slabs," *Optics Express*, vol. 15, pp. 11542-11552, 2007

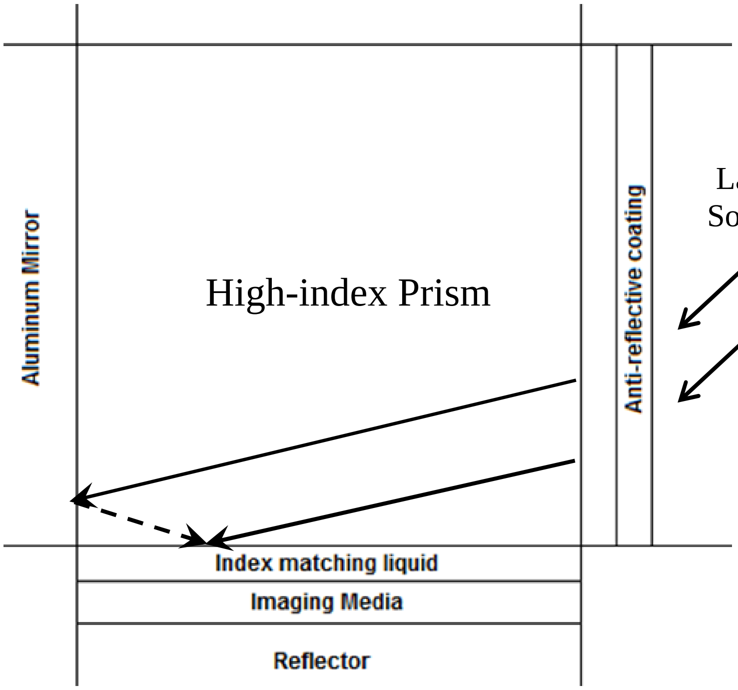
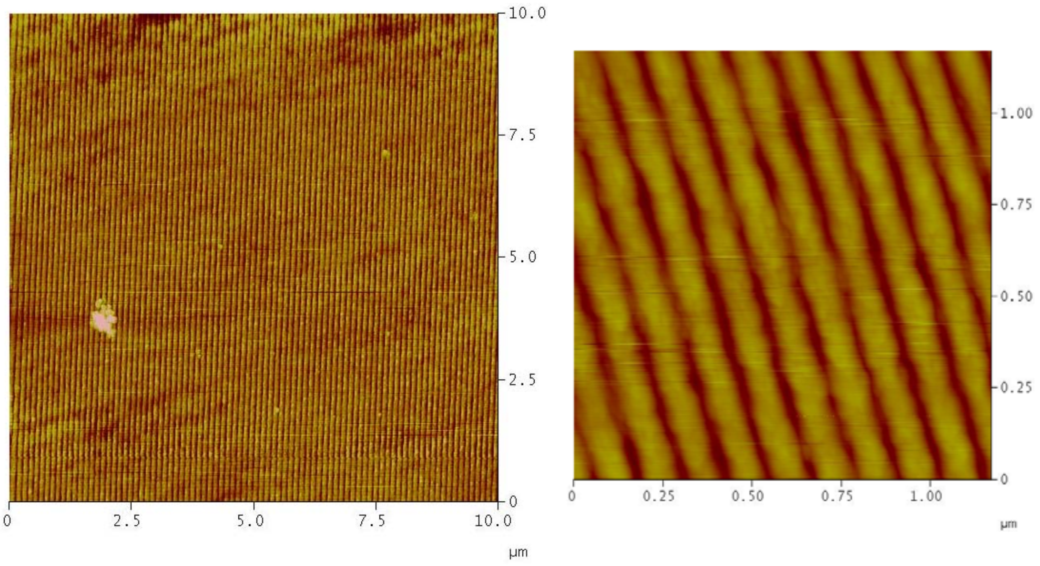


Figure 1: Solid-immersion Lloyd's Mirror Testbed



(a) (b)

Figure 2: Imaging results for Solid-immersion Lloyd's Mirror IL at NA of 1.4 with $\lambda = 325\ nm$ (a) 10 μm scan (b) 1.16 μm scan