Low-Cost Interference Lithography

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Interference lithography (IL) is well-suited to producing periodic patterns, such as diffraction gratings or grids, for use in creating test patterns to characterize post-lithographic (e.g. pattern-transfer) processes. But existing IL systems [2] require substantial investment in lasers and stages, and must be custom-built. In this work, we report demonstration of an IL system capable of ~ 300-nm-pitch patterning, but which is accessible to researchers and educators at a low cost (~ 400 USD) using readily available components.

Figure 1 depicts the experimental apparatus. The components included a 405-nm GaN diode laser module, a machinist's block, a chrome-coated silicon mirror, and double-sided tape. The diode was anti-reflection coated, and the module had an accompanying collimating optic that was only used during initial system alignment. Assembly was simple, requiring a linear configuration of the laser and the machinist's block. To complete the system, the mirror and substrate were taped to perpendicular surfaces of the machinist's block. Once assembled, the only optical elements in the system were the laser-diode output facet and the mirror. After alignment, a silicon substrate was affixed opposite to the mirror on the machinist's block. The silicon substrate was coated with a trilayer resist stack to improve the resist profile and support pattern transfer, as suggested by [1]. Finally, the resist was irradiated with light from both the laser (directly) and mirror (by reflection).

Figure 2 demonstrates that this inexpensive Lloyd's mirror is capable of printing sub-micron diffraction gratings in an i-line DNQ-Novolac photoresist. The area of the grating was set by the limited temporal coherence of the multimode laser. For each of the exposures, the temporal coherence was determined by measuring the laser spectrum. These measurements allowed us to investigate the relationship between the optical spectrum and the resulting printed grating pattern.

[1] M. L. Schattenburg, R. J. Aucoin, and R. C. Fleming, J. Vac. Sci. Technol. B 13, 6,1995.
[2] M. Walsh Ph.D. thesis, Massachusetts Institute of Technology, 2004.

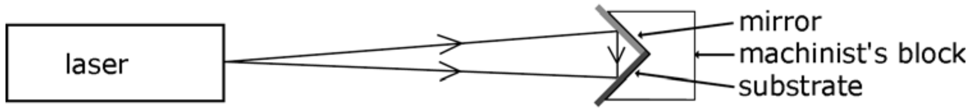
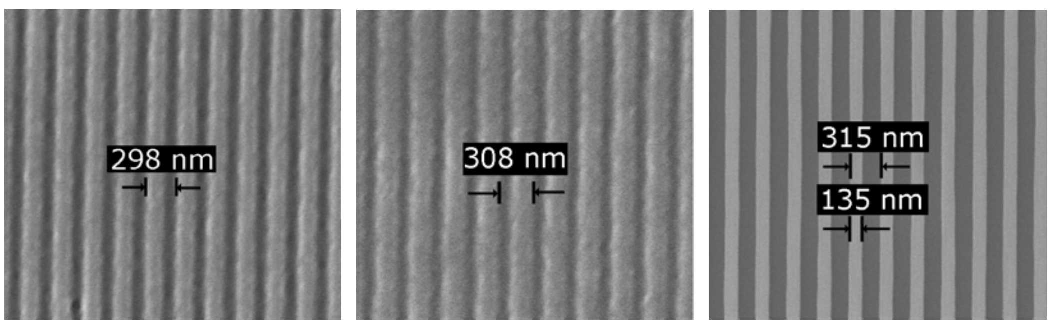


Figure 1: The schematic Lloyd's mirror apparatus showing the laser, machinist's block, mirror and substrate. Two divergent rays of light emitted from the laser are shown irradiating both the substrate and mirror. Once reflected, the ray from the mirror interferes with that from the laser to form a standing-wave intensity pattern on the substrate surface.



(a) (b) (c)

Figure 2: Three exposures with different doses and spectra, taken on three different days, separated by several weeks. Note, the incident angles, θ_a, θ_b, θ_c, in the three images varied slightly from run to run, but could be calculated from the period of the gratings shown in (a), (b), and (c). The associated periods, P_a, P_b, and P_c respectively, and the known wavelength, λ, determine the angle using the relationship $\sin(\theta_i)=\lambda/2P_i$ where i indexes the exposure. For P_a=298nm, P_b=308nm and P_c=315nm, the angle corresponds to θ_a=43.27°, θ_b=41.58° and θ_c=40.38°, which were within the mechanical tolerance of our experimental setup.