Reproducible periodic patterns using Coherent Diffraction Lithography and Interferometric Spatial-phase Imaging.

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Periodic structures, such as gratings and grids, are required in a variety of applications including spectroscopy, photonic[2] and phononic devices, and as substrates for basic studies in materials science. Interference lithography (IL) readily forms periodic patterns in photoresist, but conventional approaches, using a Lloyd's mirror or Mach-Zehnder configuration, suffer from a number of shortcomings, including: difficulty in aligning patterns with preexisting structures on a substrate, difficulty in precisely repeating a spatial period, difficulty in controlling the in-plane spatial phase. Earlier[1], we described experiments on a mask-based IL approach which we called Coherent-Diffraction Lithography (CDL). It utilized the well-known Talbot effect to replicate a 2-dimensional pattern on a mask. In this paper we describe further development of the CDL technique including, the design, construction and utilization of a dedicated apparatus that permits replication, at a well-defined mask-substrate gap, of the periodic structure of a phase mask, while also enabling alignment of the spatial phase relative to fixed structures on a substrate. Figure 1 (a) shows the CDL apparatus mounted on an alignment/gapping system based on Interferometric-Spatial-Phase Imaging (ISPI)[3]. Figure 1(b) is a schematic of the system, designed to illuminate the CDL mask with a highly-collimated, 405-nm-wavelength GaN laser. For small angles of diffraction, the separation of the planes at which the grating (of pitch p) on the mask is exactly replicated, the so-called Talbot planes, is given by $S=np^2/\lambda$, where n is the nth Talbot plane and λ is the wavelength. Figure 2 shows a grating fabricated using our CDL apparatus, at a mask-substrate separation of 6μm, (i.e. n=6). We observed over 50 Talbot planes, corresponding to a maximum separation between the mask and substrate of 54μm, indicative of the high level of spatial and temporal coherence of the illumination.

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[2] D. Roundy, J. Joannopoulos, Appl. Phys. Let. 82, 22, (2003)

[3] E. E. Moon, L. Chen, P. N. Everett, M. K. Mondol and H.I. Smith, J. Vac. Sci. Technol. B 21, 6 (2003)

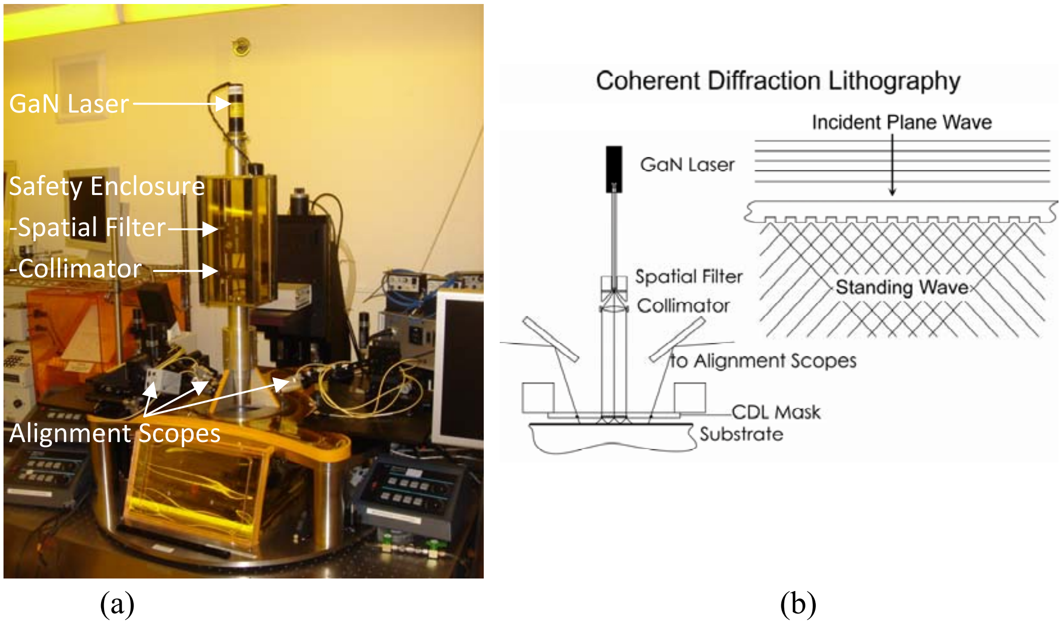

Figure 1. Apparatus (a) and system schematic (b). In (b), the GaN laser emits light that is spatially filtered and collimated prior to irradiating the mask. The alignment scopes precisely measure the gap between the CDL mask and substrate surface. The inset of (b) depicts the interfering diffracted beams. The zero order is null for a properly fabricated phase mask. The Talbot planes are slices parallel to the mask at separation $S=np^2/\lambda$.

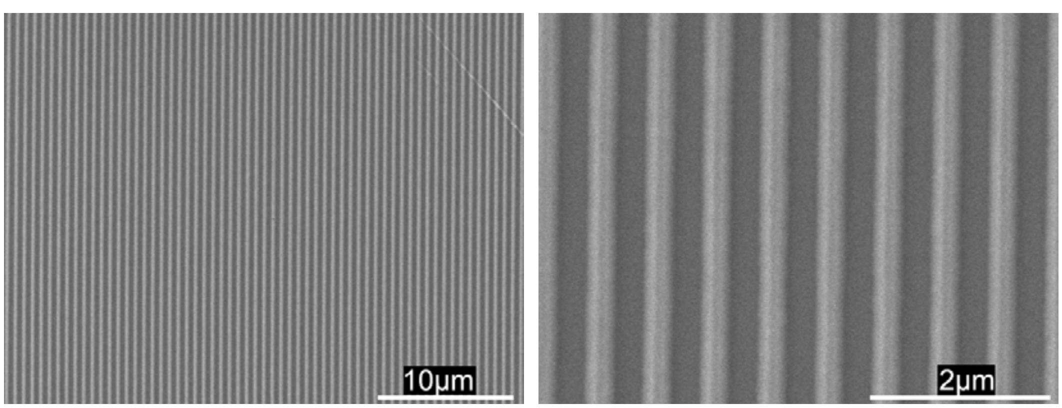

Figure 2. Diffraction grating produced at a gap of 6µm. The pitch is 660nm.