Interference Lithography

Personnel

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Sponsorship

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Interference lithography (IL) is the preferred method for fabricating periodic and quasi-periodic patterns that must be spatially coherent over large areas. IL is a conceptually simple process where two coherent beams interfere to produce a standing wave, which can be recorded in a photoresist. The spatial-period of the grating can be as fine as half the wavelength of the interfering light, allowing for structures on the order of 100nm from UV wavelengths, and features as small as 30-40 nm using a deep UV ArF laser.

The NanoStructures Lab has been developing IL technology for close to 30 years. We currently operate 4 different IL systems for a wide variety of applications. One system, shown schematically in Figure 26, is run in cooperation with the Space Nanotechnology Lab. This system is specially designed for high stability and repeatability, and is capable of producing metrological quality gratings and grids up to 10 cm in diameter at spatial periods down to 200nm. Used primarily for satellite applications, gratings produced with this tool have flown on numerous missions, most notably the Chandra x-ray astronomy satellite launched in August of 1999, which included hundreds of matched, high-precision gratings.

We operate another system similar to the one shown in Figure 26 based on the 325 nm line of a HeCd laser. This system functions both as an exposure tool with capabilities comparable to those described above as well as an analysis tool. Using a technique known as Holographic Phase-Shifting Interferometry (HPSI), the linearity and spatial phase of gratings produced in this system can be quantitatively measured and mapped with an accuracy on the order of parts per million. The spatial-phase of gratings printed using IL have a hyperbolic phase progression which is responsible for changes in periodicity of a few angstroms (for a 200nm period grating) over a 10 cm wafer. Although seemingly small, distortions of this scale can be highly significant, especially in metrological

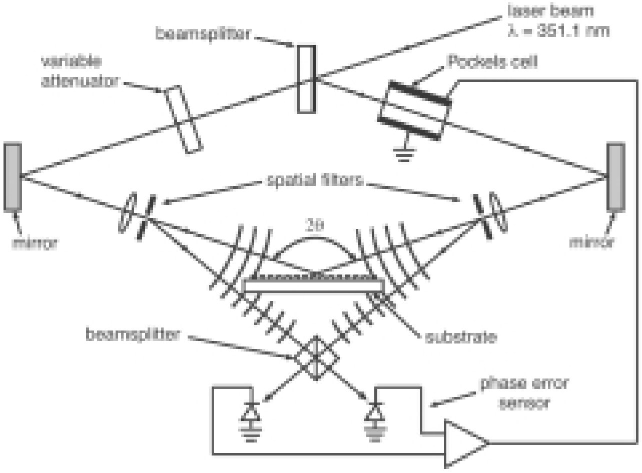


Fig. 26: Schematic of the MIT interferometric lithography system. The system occupies a 2x3m optical bench in a class 100 clean environment. The beamsplitter directs portions of the two interfering spherical beams to photodiodes. A feedback locking is achieved by differentially amplifying the photodiode signals and applying a correction to the Pockels cell which phase shifts one of the beams.

applications such as the fiducial grids for spatial-phase locked electron beam lithography. Using the HPSI, we have been able to investigate innovative techniques for reducing these distortion levels. One method, based on the controlled flexure of the substrate during exposure, has demonstrated a reduction of the distortion pattern from 2 dimensions to 1 dimension as well as reducing the magnitude of the distortions by about a factor of 5.

Also utilizing a 325 nm HeCd laser is the Lloyds-mirror interferometric lithographic system, shown schematically in Figure 27. A single beam configuration, the primary advantage of the Lloyds-mirror is that the spatial-period of the exposed gratings can be easily and continuously varied from many microns down to ~170 nm without re-aligning the optical path. This has opened the door to new possibilities such as varied aspect ratio grids (different periodicities in the two axes of the grid) for patterned magnetic media and MRAM (magnetic random access memory) devices. Among the many other applications of IL supported by the Lloyds-mirror are alignment templates for organic crystals and block co-polymers, Distributed-FeedBack (DFB) structures for nonparticle lasers, and photonic-bandgap devices.

For spatial periods of the order of 100 nm, we use a 193 nm wavelength ArF laser. To compensate for the limited temporal coherence of the source, we utilize an achromatic scheme shown in Figure 28. In this configuration the spatial period of the printed grating is dependent only on the period of the parent gratings used in the interferometer, regardless of the optical path or the wavelength and coherence of the source. Thus, gratings and grids produced with this tool are extremely repeatable. Figure 29 shows a 100 nm-period grid of 13 nm-diameter posts etched into Si produced using Achromatic Interferometric Lithography (AIL) and a sequence of etching steps. Applications of AIL include patterned magnetic media, gratings for atom-beam interferometry, UV polarizers and metrology.

A new generation of achromatic interference lithography tools is currently being developed to produce 50 nm period gratings and grids, or 25 nm lines and spaces. One exciting possibility is the use of reflection gratings in an analogous AIL scheme with a 58.4 nm helium discharge source.

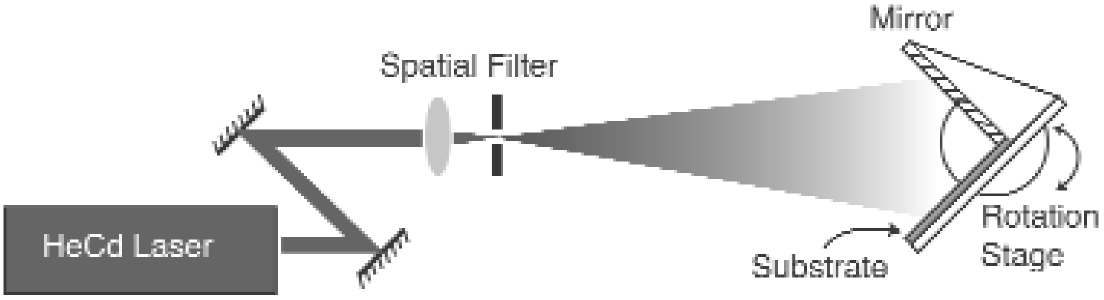


Fig. 27: Schematic of a Lloyds-mirror interferometric lithographic system. The substrate and mirror are fixed at a 90˚ angle to one another, and centered in an incident beam. Rotating the substrate/mirror assembly about its center point varies the spatial-period of the exposed grating.

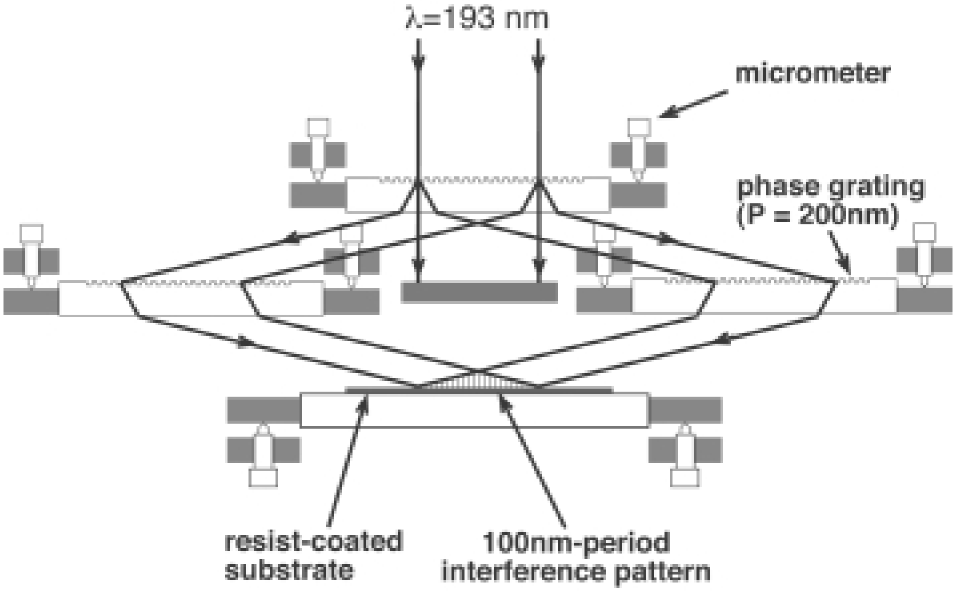
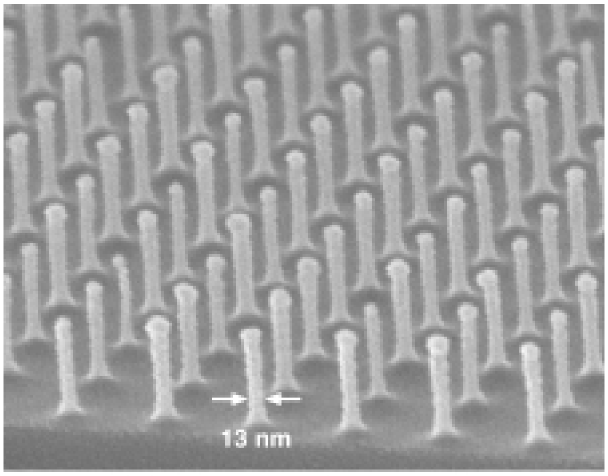


Fig. 28: Achromatic interferometric lithography (AIL) configuration employed to produce 100 nm-period gratings and grids.



100nm-period posts in Si

Fig. 29: Scanning electron micrograph of a 100 nm-period grid, exposed in PMMA on top of an antireflection coating, and transferred into Si by reactive ion etching.