Nanofabricated Diffraction Gratings

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Diffraction gratings and other periodic patterns have long been important tools in research and manufacturing. Grating diffraction is due to the coherent superposition of waves—a phenomena with many useful properties and applications. Waves of many types can be diffracted, including visible and ultraviolet light, X-rays, electrons, and even atom beams. Periodic patterns have many useful applications in fields such as optics and spectroscopy, filtering of beams and media, metrology, high-power lasers, optical communications, semiconductor manufacturing, and nanotechnology research in nanophonics, nanomagnetics and nanobiology.

The performance of a grating is critically dependent on the geometry of individual grating lines. Lines can have rectangular, triangular, or other geometries, depending on the application. High efficiency requires control of the geometric parameters that define individual lines (e.g., width, height, smoothness, sidewall angle, etc.) in the nanometer or even sub-nanometer range. For some applications, control of grating period in the picometer to femtometer range is critical. Traditional methods of fabricating gratings, such as diamond tip ruling, electron and laser beam scanning, or holography, generally result in gratings that fall far below theoretical performance limits due to imperfections in the grating line geometry. The main goal of our research is to develop new technology for the rapid generation of general periodic patterns with control of geometry measured in the nanometer to sub-nanometer range in order to achieve near-theoretical performance and high yields.

The fabrication of gratings is generally accomplished in two main steps: (1) lithographic patterning into a photosensitive polymer resist; and (2) pattern transfer. A companion research program in this report entitled Advanced Interference Lithography Technology describes progress in advanced grating patterning technology. In this section, we report on research in pattern transfer technology. The development of a variety of grating geometries and materials is ongoing. Advanced gratings have been fabricated for ten NASA missions, and further advances are sought for future missions [1]. Figure 1 depicts a gold wire-grid transmission grating designed for filtering deep-UV radiation for atom telescopes, while Figure 2 depicts a nano-imprinted saw tooth reflection grating for X-ray spectroscopy.

Figure 1: Scanning electron micrograph of a deep-UV blocking grating used in atom telescopes on the NASA IMAGE and TWINS missions. The grating blocks deep-UV radiation while passing energetic neutral atoms.

Figure 2: Atomic force microscope image of 200 nm-period thermal-nano-imprint grating with 7° blaze angle developed for the NASA Constellation X mission. The grooved surfaces are extremely smooth with a root mean square (RMS) surface roughness of <0.2 nm.

REFERENCES: