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Development of near atomically perfect diffraction gratings for EUV and soft x-rays with very high efficiency and resolving power

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ABSTRACT

Multilayer-coated Blazed Gratings (MBG) can offer high diffraction efficiency in high order with a high groove density are potentially of great importance for a wide range of extreme ultraviolet (EUV) and soft x-ray applications including EUV lithography and high-resolution Resonance Inelastic X-ray Scattering. The main challenges to realizing these optical elements are fabrication of nano-period sawtooth substrates with perfect groove profile and atomically smooth surface of the blazed facets, as well as deposition of a multilayer on the highly corrugated surface of the substrates. We report on recent progress achieved at the Advanced Light Source (ALS) on development, fabrication, and characterization of ultra-dense MBGs. Saw-tooth substrates with groove density up to 10,000 l/mm were fabricated using e-beam and interference lithography techniques followed by wet anisotropic etching of silicon. Growth of multilayers (ML) deposited on the sawtooth substrates via different sputter deposition techniques was investigated. The smoothening of the grooves in the course of multilayer deposition was found to affect greatly the blazing ability of the grating and can result in significant degradation of the diffraction efficiency. The deposition of the MLs was optimized to obtain good replication of the saw-tooth surface by the multilayer interfaces with minimal distortion of the groove shape by the growth process. The gratings coated with a variety of MLs demonstrated record diffraction efficiency in EUV wavelength range, for example with the achievement of 44% diffraction efficiency for a 5000 l/mm grating. Simulations of diffraction efficiency of soft x-ray MBGs showed that the efficiency of an optimized grating relative to the reflectance of the multilayer can approach 100%. This work now shows a direct route to achieving high diffraction efficiency in high order at wavelengths throughout the soft x-ray energy range with revolutionary applications in synchrotron science.

Key words: diffraction grating, multilayer, interference lithography, e-beam lithography, EUV, soft x-rays

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