Nanofabricated Reflection Gratings

Personnel

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Grazing-incidence X-ray reflection gratings are an important component of advanced high-resolution spectrometers and related X-ray optics. These have traditionally been fabricated by diamond scribing with a ruling engine, or by interference lithography followed by ion etching. These methods result in gratings which suffer from a number of deficiencies, including high surface roughness and poor groove profile control, leading to poor diffraction efficiency and large amounts of scattered light.

We are developing improved methods for fabricating blazed X-ray reflection gratings which utilize special (111) silicon wafers, cut ~1 degree off the (111) plane. Silicon anisotropic etching solutions, such as potassium hydroxide (KOH), etch the (111) planes extremely slowly compared to other crystallographic directions, resulting in the desired super-smooth blaze surface. Previous work used similar off-cut (111) silicon substrates to fabricate blazed diffraction gratings. However, that method utilized a second KOH etch step that compromised the grating facet flatness and is unsuitable for small grazing-angle X-ray diffraction.

Gratings are patterned using interference lithography with the λ=351.1 nm wavelength, and transferred into the substrate using tri-level resist processing, Reactive-Ion Etching (RIE), and silicon-nitride masking during the KOH etch. The narrow (~100 nm) ridge of silicon which supports the nitride mask is removed using a novel chromium lift-off step followed by a CF_4 RIE trench etch. The result is extremely-smooth sawtooth patterns, which, after applying a thin evaporative coating of Cr/Au, are suitable for X-ray reflection (see Figure 11).

Potential applications of these improved gratings are for synchrotron studies and satellite-based high-resolution X-ray spectroscopy for planned NASA missions such as *Constellation X.* We are also exploring other applications for this technology, including telecom devices and atom microscopy.

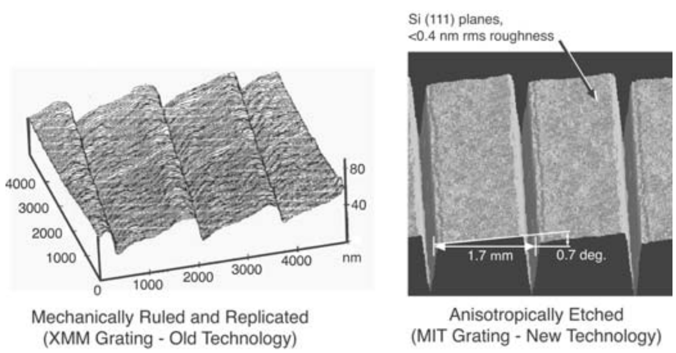

Figure 11: (a) An AFM image of a traditional mechanically-ruled and replicated X-ray reflection grating (Bixler et al., Proc. SPIE ***1549****, 420-428 [1991]). Note the rough, wavy grating surfaces that lead to poor diffraction performance. (b) An AFM image of a blazed X-ray reflection grating fabricated by anisotropic etching of special off-cut (111) silicon wafers. Note the improvement of grating surface flatness and smoothness, leading to significantly improved performance.*