Ion Mill X-Ray Reflection Gratings

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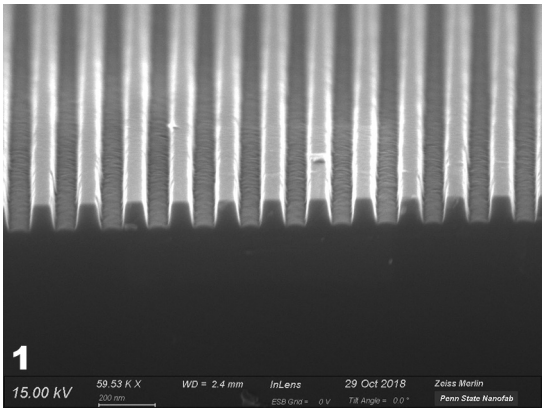
Primary CNF Tools Used: AJA ion mill, Zeiss Ultra/Sigma SEMs

Abstract:

Astronomical x-ray diffraction gratings are a key technology under development for current and future NASA missions. X-ray reflection gratings, developed at Penn State University, have recently demonstrated both leading diffraction efficiency and high spectral resolving power. However, recent results are the result of different fabrication techniques and a single technique has not yet been developed to yield a grating that satisfies both the diffraction efficiency and resolving power required by future missions. Here we seek to leverage exiting electron-beam lithographic techniques to produce a grating with a groove pattern capable of high resolving power. We then introduce ion-milling techniques to create custom groove profiles capable of high diffraction efficiency. The goal is to produce a radial groove pattern with precisely blazed facets that are customizable based on ion mill input parameters. The process should be insensitive to groove density (ranging from ~ 150 nm to 400+ nm), facet size, and desired facet angle. Initial efforts in this study have concentrated on constraining various parameters in ion milling to fully characterize the effect of each parameter on the grating groove profile. We present here initial results and discuss experimental verification and future work.

Summary of Research:

The research performed at the Cornell NanoScale Facility utilizes state-of-the-art x-ray gratings fabricated at Penn State University. The Penn State grating samples, which have a rectangular or sinusoidal groove profile as depicted in Figure 1, are transported to Cornell for directional ion beam etching using the AJA ion mill. The ion mill etches the gratings in an effort to convert the rectangular/sinusoidal grooves to a more triangular or sawtooth profile. The exact angle and dimensions of the triangular grooves depend on specific grating applications. Figure 2 shows an ion milled grating that has a facet angle of ~ 30 degrees and groove spacing of ~ 170 nm. The ideal grating facet would come to a sharp point, whereas the grating in Figure 2 has a plateau that is ~ 30 nm wide; the plateau is the result of non-optimized fabrication conditions and represents a snapshot of the ongoing development of these processes.



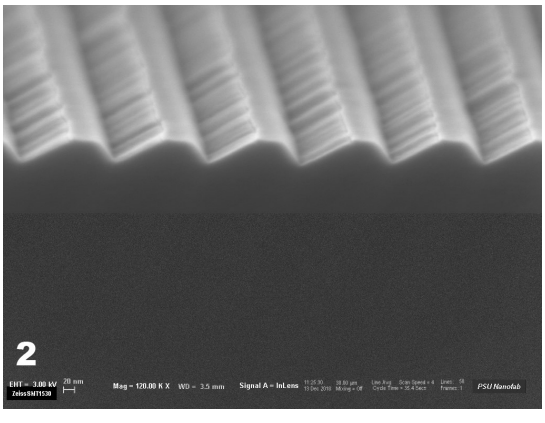


Figure 1, top right: An x-ray reflection grating with rectangular grooves. This grating is an example of a grating developed for ion milling.

Figure 2, bottom right: An x-ray reflection grating that has been exposed to the ion beam in the AJA ion mill. The formerly rectangular facets are now etched to the desired angle (~30°). The plateau at the top of the features represents a shortcoming in development and will be eliminated by the culmination of the project.