Low-energy ion beam irradiation of X-ray mirrors: optimization of the surface finish for multilayer deposition

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Substantial improvement in spatial resolution and detection limit performance of the X-ray analysis tools are anticipated from the availability of intense beams produced by synchrotron and free-electron laser sources and of X-ray optical schemes capable of generating beams of nanometer size with high photon density. Such a goal implies that mirrors with strong curvature ($R \leq 10$ m) and asphericity (eccentricity close to unity) and with figure errors of the order of a nanometer can be manufactured. In addition the mirror surface roughness must remain as low as possible (0.1- 0.2 nm) to minimize the amount of X-ray light scattered around the focal spot. Low roughness at high-spatial frequency is also essential to preserve the specular reflectance of the multilayer coating eventually deposited on the mirror surface to increase the numerical aperture through a higher incidence angle, thus lowering the diffraction limit threshold.

Nowadays there is a growing interest for using ion beams for mirror polishing. However, questions arise regarding the influence of the etching depth on the surface finish and on the possibility of either maintaining a low roughness or of recovering from a surface roughened by the figuring process.

To address this issue a parametric study of the surface roughness was performed on silicon flat substrates etched using ion beams with energies ranging from 400 eV to 1200 eV and grazing incidence angles between 10° and 90°. The surface topography of the samples was characterized at various scales using Atomic Force Microscopy (probed area: 1-10 μm^2), interferential optical microscopy (probed area: 1 mm^2) and by X-ray scattering to get a statistical representation of the surface (probed area: few cm^2). Finally, a study by AFM and X-ray reflectivity of the evolution of the surface finish level of a silicon mirror after ion erosion at various depth values up to 10 µm allowed finding a trade off between total etch time and surface finish level in view of profiling a highly aspherically-shaped mirror starting from a flat.
