Characterization of multilayers for grazing-incidence X-ray mirrors and prediction of the expected imaging quality from surface roughness

D. Spiga

INAF - Osservatorio Astronomico di Brera, Via E. Bianchi 46, I-23807 Merate (LC, Italy),
e-mail: daniele.spiga@brera.inaf.it , phone +39-039-9991146

ABSTRACT. The utilization of multilayer-coated X-ray mirrors[1] in grazing incidence is envisaged in the X-ray astronomical instrumentation of the future (like SIMBOL-X[2]). The required focal spot size is of the order of 15 arcsec HEW (*Half-Energy-Width*): indeed, it can be severely affected by X-ray Scattering as the photon energy increases, therefore the surface roughness should be controlled within a few angströms. The need of very smooth multilayer mirrors and of the related metrology to assess the compliance of the mirrors to the imaging requirements is felt not only in X-ray astronomy but also in all the X-ray optic field. Diagnostic methodologies involving surface topography (Atomic Force Microscope, optical profilometry…), X-ray reflectivity (XRR) and X-ray scattering (XRS) measurements at selected X-ray photon energy can be used to reconstruct the multilayer coating structure[3] and the surface roughness PSD (*Power Spectral Density*) evolution throughout the stack[4,5] within a self-consistent picture. This enables not only to disentangle the contribution of the substrate from the roughness growth related to the multilayer deposition, but also the computation of the XRS diagram at the operational photon energies of the mirrors. However, the prediction of the optical performance from the roughness PSD usually requires a considerable amount of computation, and the calculation cannot be easily reversed (i.e. from the required HEW(λ), as a function of the photon wavelength λ, one cannot derive the PSD).

In this work we expose the stack and roughness characterization of a number of multilayer-coated mirror samples along with a comparison of results obtained with the described methodologies: moreover, we compute from the sample PSD characterization the expected optical performances of the mirrors using a novel, analytical method[6] that allows the direct derivation of the HEW(λ). The results are particularly interesting when applied to the particular case of fractal surfaces. The method is applicable to multilayer-coated X-ray mirrors with a slowly-varying reflectance with the photon energy, and *can also be reversed in order to translate a* HEW(λ) *trend requirement into a PSD tolerance.*

The usefulness of these diagnostic tools for multilayers and of the relation between PSD and HEW is apparent. The exposed formalism can be used to set roughness tolerances for future hard X-ray telescopes from the required angular resolution of the telescope[7], and it can be also applied to general-purpose, grazing incidence X-ray mirrors as it should be largely independent of the mirror geometry.

---

[1] K. D. Joensen, P. Voutov, A. Szentgyorgyi, et al., "Design of grazing-incidence multilayer supermirrors for hard X-ray reflectors". *Applied Optics* **34(34)**, 7935 - 7944 (1995)

[2] G. Pareschi, P. Ferrando, "The SIMBOL-X hard X-ray mission", *Exp. Astron.* **20**, 139-149 (2006)

[3] Spiga, D. , Pareschi, G. , Mirone, A., et al., "Multilayer coatings for X-ray mirrors: extraction of stack parameters from X-ray reflectivity scans and comparison with Transmission Electron Microscopy results" *Optical Engineering*, Vol. 46, No. 8, pp. 086501

[4] D. G. Stearns, D. P. Gaines, D. W. Sweeney, E. M. Gullikson, "Nonspecular x-ray scattering in a multilayer-coated imaging system", *Journal of Applied Physics*, **84**, No. 2 (1998)

[5] Canestrari, R., Spiga, D., Pareschi, G. "Analysis of microroughness evolution in X-ray astronomical multilayer mirrors by surface topography with the MPES program and by X-ray scattering" *SPIE Proc.* vol. 6266, p. 314-327

[6] D. Spiga, "Analytical evaluation of the X-ray scattering contribution to imaging degradation in grazing-incidence X-ray telescopes", *Astronomy & Astrophysics* **468**, 775-784 (2007)

[7] Spiga, D. , Cusumano, G., Pareschi, G.,"HEW simulations and quantification of the microroughness requirements for X-ray telescopes by means of numerical and analytical methods", *SPIE Proc.*, vol. 6688, 66880H