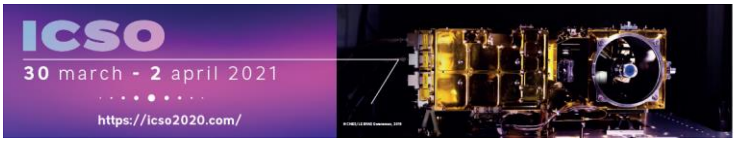

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INTERNATIONAL CONFERENCE ON SPACE OPTICS
VIRTUAL

DEVELOPMENT OF LOW-DENSITY COATINGS FOR SOFT X-RAY REFLECTIVITY ENHANCEMENT FOR ATHENA AND OTHER MISSIONS

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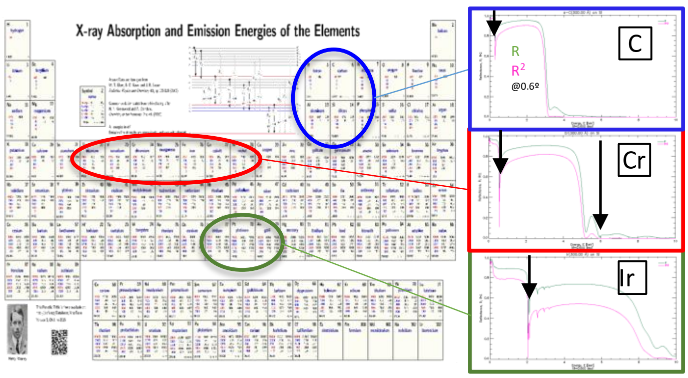
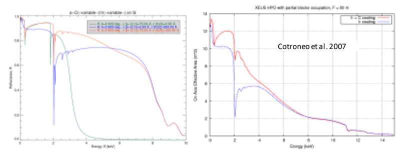


Higher-Z elements have a higher critical energy and are then usually employed for X-ray reflection, however they present absorption edges at relevant energies (typically around 2 keV), which considerably reduce reflectivity in their proximity[1,2].

Position of absorption edges of an element depends on its position on the periodic table.

The effect is amplified by the double reflection in Wolter Optics



Left: reflectivity of a mirror with Ir only (blue), carbon only (green) and a stack of the two (red). Right: Effective area of an entire telescope with Ir only (blue), and with carbon overcoating (red).

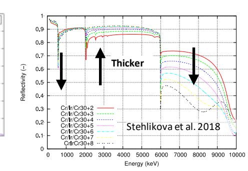


Figure 4. The 30 nm thick reflective iridium surface on 90 nm adhesive chromium interlayer, covered by different thickness (2 nm–8 nm) chromium overcoating which improves the reflectivity of mirrors at lower energies

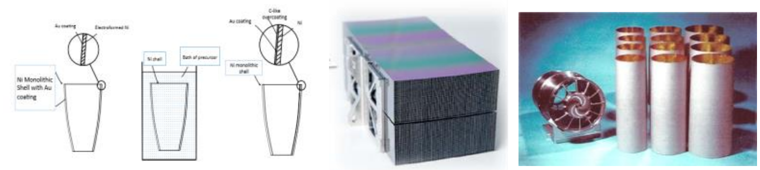
Different material can be combined in a stack, with higher Z elements on bottom to maximize reflection over an extended energy range.

This effect was investigated several years ago by some of us and studied by other groups for carbon-like coatings (e.g. B_4C, SiC)[3,4].

A similar use has been recently proposed also for thin layers of chromium[5]. As chromium thickness increases, the reflectivity enhancement gets larger, but also the depletion near chromium absorption edges.

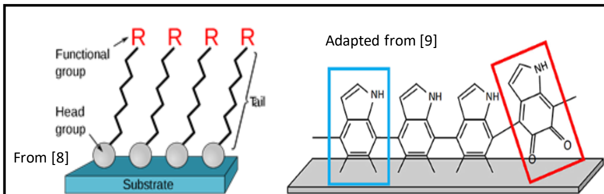
Chromium and Carbon-like coatings can be combined to optimize reflectivity, however carbon deposition requires non trivial modifications of the deposition process and was never used.

Chromium is in many cases already used as binding layer and present in sputtering chambers, but there are some potential concerns related to its roughness and internal stress.



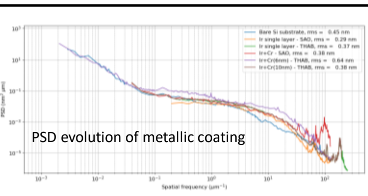
We are developing a process to deposit carbon-like overcoatings by immersion in a precursor solution and self-assembly of molecules on the surface[2].

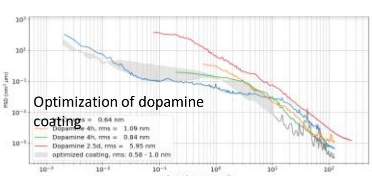
The process can be applied to finished optics, both silicon pore optics that will be used for ATHENA (ESA) and nickel replica mirrors, like the ones for eXTP (CAS), in a single step without needs of a specialized deposition equipment.

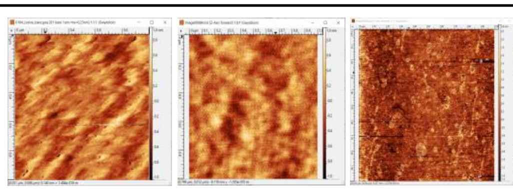


There are many compounds suitable to realize this kind of coatings, widely used in industry and research. The composition must be selected and optimized according to compatibility with the material on substrate surface.

We have tested a thiol-silane bilayer[10,11], based on chain molecules with functionalized heads and tails for gold (left); and polydopamine[12] (right), that works by polymerization of molecules on the surface, for Ir/Cr.





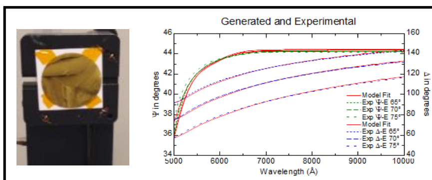


AFM scans for: Left – Ir+Cr coatings, 1 μm scan (2.3 Å), Center – Ir+Cr+dopamine, 1 μm scan (2.3 Å), Right – Ir+Cr+dopamine on 100 μm scan (6.0 Å). Coatings are smooth on small scales, uniform on large scale.

We have depostited and characterized topography and power spectral density of Ir and Ir + Cr coatings on ATHENA substrates at SAO[6] and THAB[7], then developed a process to deposit dopamine of thickness 5-10 nm on them.

Metallic coatings are interesting themselves because chromium can be stress and rough. We have characterized surface topography and roughness for each step on a broad range of spatial wavelengths (AFM + MFT profilometer).

Roughness is well maintained along stack. Films are smooth and have desired thickness.



We have developed a similar process based on a bilayer thiol + silane for gold surface of nickel-replica optics.

Thickness was measured by spectroscopic ellipsometry, giving values (7.5-9.0 nm) in the useful range for the application (8-10 nm).

CONCLUSIONS (Silicon substrates)

We have deposited samples representative of future X-ray telescopes based on silicon (ATHENA)

Ir + Cr:

- roughness slightly increases (as expected) along the layers stack, with acceptable values of roughness.
- chromium rms below 4 Å, (10^{-2} to 10^{2} μm^{-1} frequency), and 6.4 Å (down to 2 10^{-3} μm^{-1}).
- Roughness values are in good agreement with X-ray reflectivity estimate (SAO).
- Surface quality of the metallic coatings are very similar between the two facilities used for coating deposition (SAO and THAB).

Dopamine overcoating,:

- roughness between 6 and 10 Å over the extended frequency range and uniform structure.
- Thickness in the valid range (5-10 nm).

The collected PSD data will be used to model the scattering properties. Samples to be used for X-ray tests.

CONCLUSIONS (Nickel/Au substrates)

We also produced samples of carbon-based coatings made of a bilayer thiols/silans, on gold, representative of optics realized by nickel-replica process.

Thickness of 7.5-9.0 nm, consistent with requirements, even if slightly above the design values.

Future tests planned.

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