Enhancing the ATHENA effective area at low x-ray energies with unconventional overcoatings

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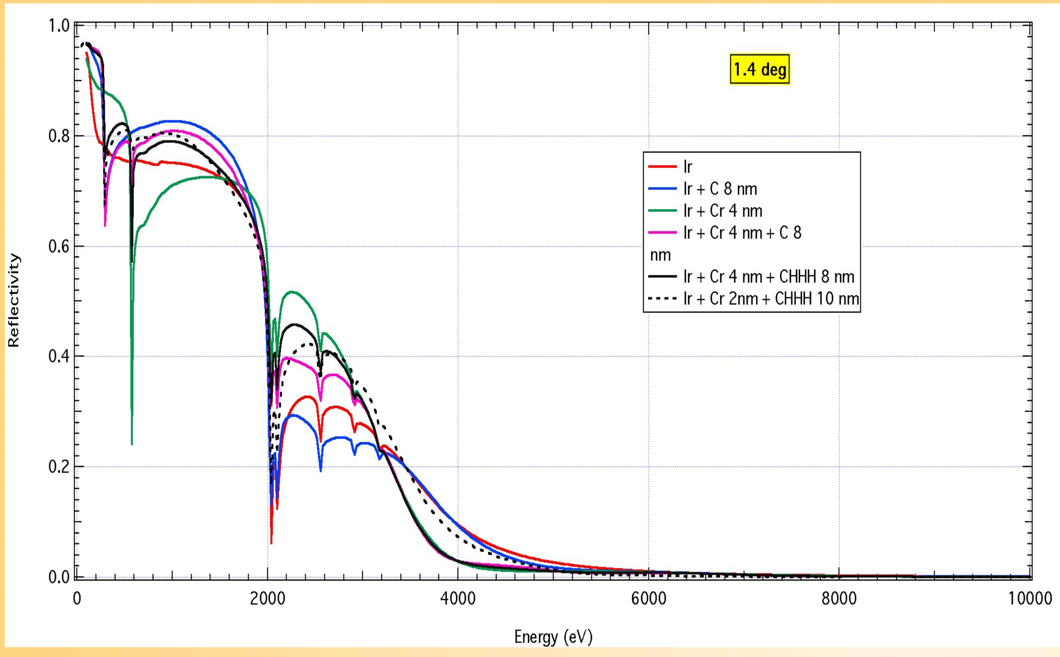
ABSTRACT: Low density overcoatings (mainly containing Carbon) onto usual hi Z materials (like Ir, Au or Pt) have been proposed more than 10 years ago for enhancing the X-ray reflectivity at low energy (between 0.5 and 4 keV) in X-ray astronomical optics. The hack is to use the total reflection sed on materials from the low density material (which do not suffer much the photoelectric absorption) at low energy, while the photons at high energy are reflected by the high density material. Now for several future projects like e.g. ATHENA and eXTP it is foreseen the use of low density overcoatings that will importantly increase the effective area at low energy. In this poster we will discuss about the use of materials different from the ones considered so far, in particular based on a thin layer of Chromium followed by another layer of a Carbon-like material, and of novel approaches for their application.

Reflectivity boosting of X-ray mirrors via traditional and alternative overcoatings



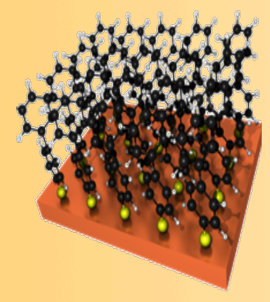
In the figure the CHHH symbol represents new Carbon like material containing long CH2 and CH3 radicals. Similar to C but with a lower density (1.0 versus 2.26 g/cm^3)

- Carbon-like Materials onto traditional high-Z materials like Au/Pt/Ir for boosting the soft X-ray reflectivity were firstly introduced by Pareschi and Cotroneo (2003) in order to maximize the effective area of the XEUS mission. Now are used in the design of many future X-ray missions, including ATHENA where a B_4C layer of several nanometers is assumed onto the Iridium "bulk" coating.
- Carbon and B_4C have the K edge at very low energy (< 0.3 keV) and, until it critical energy for reflection ad a given angle, a reflectivity close to 100 % due to the low photoelectric absorption; Beyond the critical energy of C or B_4C, the high Z material (Au, Pt, Ir…) reflects the higher energies
- Other materials considered so far as overcoatings like e.g. Si or SiC are much less efficient, because the Si K-edge is at 1.8 keV
- **ALTERNATIVE APPROACH: use of overcoatings based on bilayers: a) a few nm materials with K-edge High like Chromium (K-edge at about 6 keV) followed by ➔ b) an abou 100 nm layer of low density C-like materials like e.g. a proper alcoholic material layer**

New materials and methods to apply the carbon-like materials

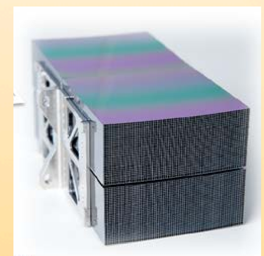
Carbon –like Materials for dip coatings:
While Chromium, tha can be deposited via sputtering - is a very performing material to enhance the reflectivity beyond 2 keV up to 4 keV, at lower energy because of the presence of the L-absorption edges between 0.54 and 0.69 keV needs to be compensated by an additional layer of C-like material like e.g. Alkyl Thiols [HS(CH2)*n*X], … and families (Silans, Alkyl Solphurs..) ---- Note: X represents the terminal group (e.g. -CH3, -OH, -COOH and others)

These materials tend to settle a stable monolayer with a thickness typically of the order of nanometers on high density materials like Au, Pt, Ir, Cr.

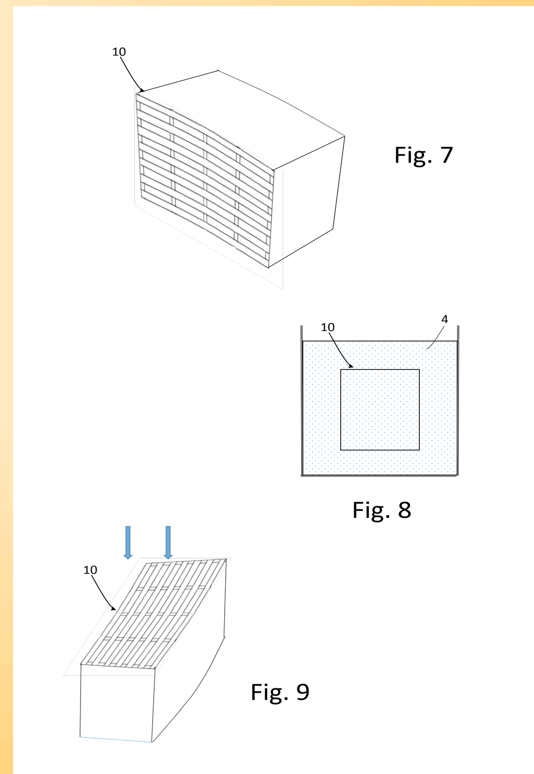


Self-assembled monolayers (SAMs) can successfully address common interfacial problems.

Hydrophilic / Hydrophobic

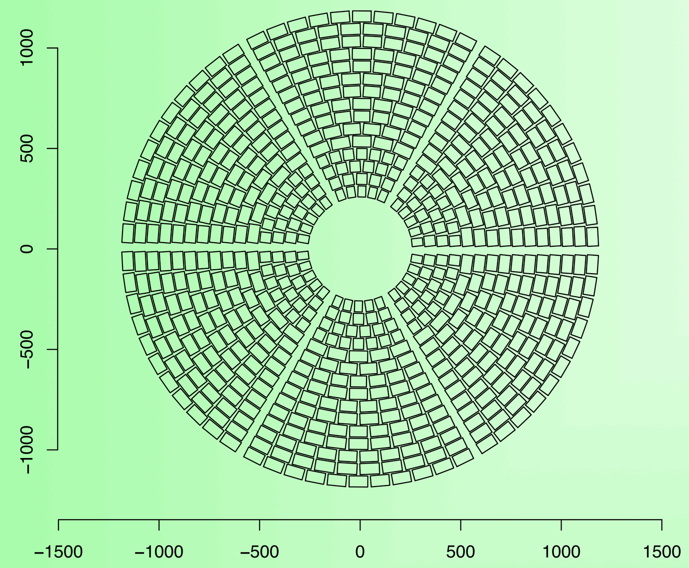


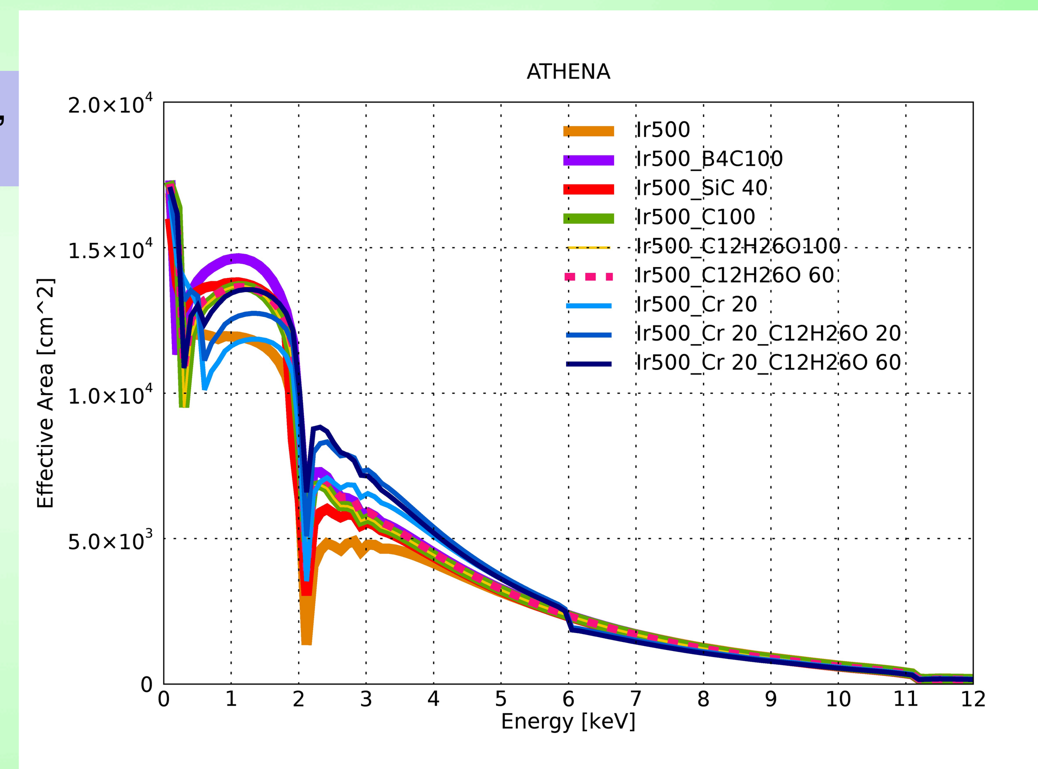
The C-like material can be deposited via a simple dip coating also on the pre assembled Silicon Pore Optics (SPO) forming the ATHENA X-ray optics module



ATHENA Effective Area calculation with the overcoating approach

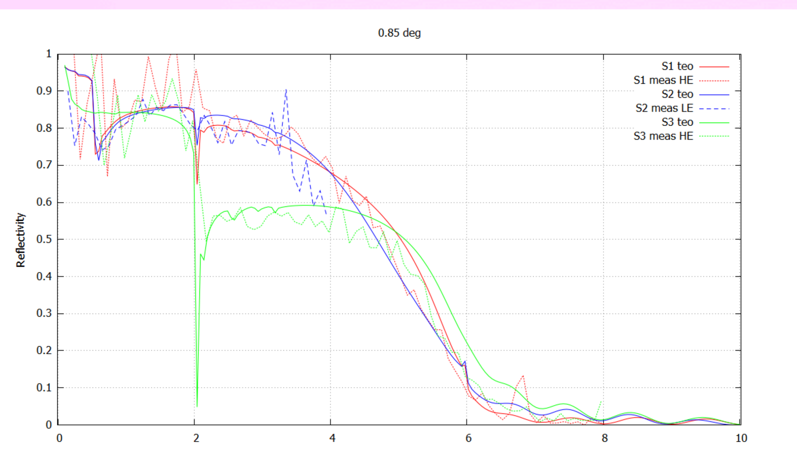
Athena X-ray optics unit cross section, based on 15 rows of SPO modules





The new proposed overcoating based on Chroumium + C-like deposited onto iridium is very performing

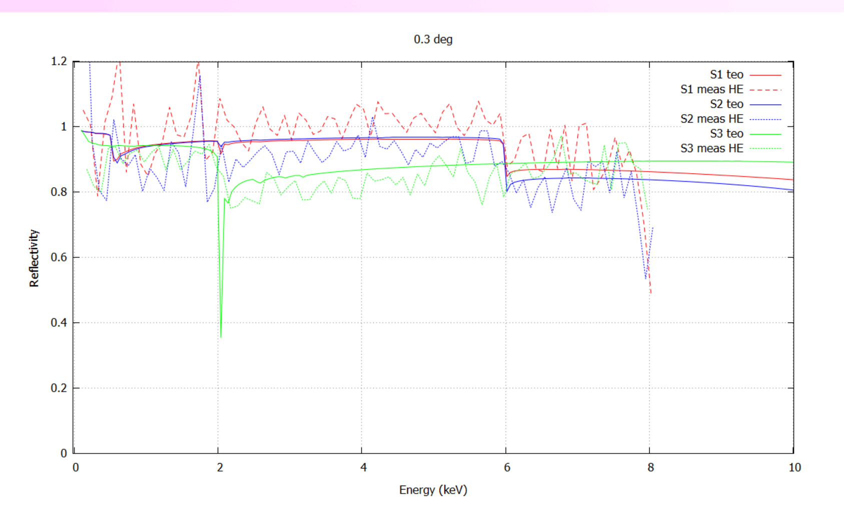
Preliminary developed samples and X-ray experimental results



0.85° reflection angle (mid radius of the ATHENA optics)

Blue and red: Cr + C-like on Iridium

Green: just Iridium



0.3° reflection angle (innermost radius of the ATHENA optics

Blue and red: Cr + C-like on Iridium

Green: just Iridium

Two samples of the new overcoating on Iridium were developed and X-ray measured at Panter/MPE and compared to a sample with just Iridium

The samples with Cr+C-like overcoating show a much larger reflectivity than Iridium !!!

Conclusions: A new overcoating has been proposed in order to increase the effective area othe ATHENA observatory in the soft X-ray region (0.5 – 4 keV). It is based on a thin layer of Chromium (a few nm) deposited by sputtering on the Iridium reflective film, followed on a 10 nm layer of C-like low density material (1 g/cm^3) deposited after the Silicon Pore Optics assembly via dip coating. The effective are compared to simple Ir is much enhanced. The method seems very attractive because easier than the B4C layer consider so far. The achieveble effective area is much larger than SiC considered as an alternative material. Preliminary samples of the new overcoating deposited on an Ir film were developed and X-ray measured, showing a much better reflectivity than sole Iridium

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