Mem. S.A.It. Vol. 79, 283

Memorie della

Feasibility study for the manufacturing of the multilayer X-ray optics for Simbol-X

D. Vernani[1], S. Basso[2], M. Bello[1], O. Citterio[2], G. Grisoni[1], G. Pareschi[2], D. Spiga[2], G. Tagliaferri[2], and G. Valsecchi[1]

[1] Media Lario Technologies – Località Pascolo, I-23842 Bosisio Parini (LC), Italy
e-mail: dervis.vernani@media-lario.com
[2] Istituto Nazionale di Astrofisica – Osservatorio Astronomico di Brera, Via E. Bianchi 46, I-23807 Merate (LC), Italy

Abstract. SIMBOL-X is a hard X-ray mission based on a formation flight architecture, operating in the 0.5 - 80 keV energy range, which has been recently selected for a comprehensive Phase A study, to be jointly carried out by CNES and ASI. For this project it has been proposed to exploit the Nickel electroforming technology initially applied for the ESA XMM-Newton mission and further developed in cooperation with *Brera Astronomical Observatory* (INAF/OAB) for the manufacturing of mirror shells with reduced thickness. In this paper the results of the Pre-Phase A feasibility study for the Mirror Module Unit performed by *Media Lario Technologies* (MLT) are reported.

Key words. X-rays: general Instrumentation: high angular resolution - Space vehicles: instrumentation - Telescopes

1. Introduction

SIMBOL-X Pareschi & Ferrando (2006) will be the first X-ray telescope operated in a very wide X-ray band (0.5 keV < E < 80 keV) with very good imaging capabilities: the angular resolution required to SIMBOL-X is ~ 15 arcsec HEW at 1 keV (like Newton-XMM) and < 20 arcsec HEW at 30 keV. The current baseline foresees a telescope equipped with 100 mirror shells having diameters in the range 260 ÷ 630 mm. In order to get an experimental feasibility demonstration of high imaging performances with very thin Nickel substrates, a gold-coated Wolter-I thin mirror shell has been manufactured utilizing the largest mandrel of the JET-X series. The prototype has been manufactured under the responsibility of *Brera Astronomical Observatory* (INAF/OAB), making use of MLT electroforming technology, and the results of the study have been reported in a paper Pareschi et al. (2003). It should be noted that the shell was 8.5 times lightweight than the corresponding shell of JET-X. A full-illumination X-ray imaging test of the prototype was performed on July 2002 at the Panter facility operated by MPE. The measured HEW at 1.5 keV was 25 arcsec.

2. Mandrel production / verification

For the production of the mandrels *Media Lario Technologies* (MLT) will follow an approach similar to the one used by ZEISS for the manufacturing of JET-X and XMM mandrels.

The main steps are the following:

1. The mandrel is machined from a solid block of thermally-stabilized aluminium.
2. The mandrel is then coated with Nickel Kanigen by means of an electroless process.
3. The mandrel is further machined in order to generate the Wolter I profile.
4. The mandrel is optically polished in order to get the required shape accuracy and surface finishing.

Mandrel production is a critical point for the Mirror Module production. In fact, we need to produce mandrels at a rate of 4 units per month. In order to achieve this result, MLT will investigate also the possibility to replace the classical machining of mandrels with the Single-Point-Diamond-Turning (SPDT). With the SPDT it is possible to obtain at the same time the required shape accuracy and a very low surface roughness. Therefore, only few nanometres of material should be removed with the polishing step.

Fig. 1. Preparation of a gold-coated mandrel for Nickel electroforming at *Media Lario Technologies*.

3. Shell production / verification

For the production of the SIMBOL-X mirror, MLT will adopt the same process used for XMM with some optimization. The mirror shells production is divided into the following main steps:

1. After verification of its surface roughness, the mandrel is thoroughly cleaned in a dedicated facility with a qualified process, in order to remove all the possible dust and grease deposited onto the surface that could affect the quality of the following layers deposition.
2. An X-ray reflecting gold layer is deposited by thermal evaporation under vacuum onto the mandrel, which is being spun to ensure an uniform coating.
3. The gold-plated mandrel is then installed in a support frame that holds it during the electroforming process, allowing also a proper rotation inside the bath.
4. The gold-plated mandrel is coated with nickel in a nickel sulphammate electroforming bath.
5. Immediately after the electroforming process, the mandrel is internally and uniformly cooled with liquid nitrogen.
6. The mirror (nickel) and the mandrel (aluminium) are separated at cooling, owing to the thermal expansion difference of nickel and aluminum. In this process the gold layer remains on the mirror shell, due to better adhesion of gold to electrolytic nickel than to Kanigen.

Within 5 days it would be possible to manufacture and accept two gold-coated mirror shells.

4. Multilayer reflecting coating

The technological approach to reflective coating is the adoption of multilayer films, which consist of a stack of alternated and properlyspaced W/Si thin films. Hard X-rays reflectivity is built up by the constructive interference of X-rays reflected at each layer interface. The multilayer deposition is performed by means of a Physical Vapour Deposition process via Magnetron Sputtering technique. Inputs for the design of the multilayer will be supplied from the scientific institute INAF/OAB: in addition, INAF/OAB has an ongoing, consolidated collaboration with the CfA (*Harvard-Smithsonian Center for Astrophysics*), where a facility based on DC magnetron sputtering has been developed with the specific aim of the deposition of X-ray multilayer onto replicated mirror shell Romaine (2006). It is planned to use this facility for the application of the coating to the mirror shells, until the equipment to be installed in MLT is completed and tested. CfA will take part in the Simbol-X project in the context of an academic collaboration with INAF/OAB.

5. Mirror Module integration

Concerning the integration of the Mirror Module, MLT will follow the approach studied by INAF/OAB in the last years. The feasibility of the integration technique for thin mirror shells has been demonstrated Basso (2006). Starting from those results, MLT thinks that there is the possibility to industrialize the process. The shell must be positioned in the case with two stiffening rings (see Fig. 1), but the rings occupy more space than the distance available between two shells, therefore it is necessary to start the integration from the inner shell. The rings must be removed before starting the integration of the following shell, but before it the shell should be endowed with the rigidity required. This can be done gluing the ϕ_{max} (maximum diameter) on the front spider and gluing the ϕ_{min} (minimum diameter) on a temporary spider that enables us to integrate the next shell. Once all shells have been integrated, it is possible to glue the rear spider and to remove the temporary spider. The temporary spider, which is sustained by an internal support, is composed by a series of double-grooves clips that can be fitted to the 20 spokes of the rear spider. The integration is performed on a vertical optical bench in order to check the centering and deterioration of the optical quality of the shells.

6. Model Philosophy

In terms of model philosophy two models of the Simbol-X X-ray telescope are foreseen, a Qualification Model (QM) and a Flight Model (FM). The design of the telescope and the mirror shells integration procedures will be qualified through the manufacturing and testing of the QM, which will be produced with the same flight-quality components and assembly procedures of the FM. The QM will consist of spiders and integration case with flight-quality, however it will have only 10 flight-quality mirrors shells, whereas the remaining 90 ones will be dummy. Subsequently, the FM will be produced in accordance with the qualified design and procedures.

7. Conclusion

The performed feasibility analysis shows that, in terms of production and verification of both QM and FM unit, it is possible in principle to meet the due date for the Mirror Modules (mid 2012), assuming to start in 2008. In the FM phase, the schedule driver is the production of the flight mandrels: the envisaged manufacturing rate of 4 mandrels per month is definitely a serious challenge.

Acknowledgements. MLT thanks the Italian Space Agency and Thales Alenia Space-Italy for funding and supporting this study.

References

Basso, S., 2006, INAF/OAB Internal Report 05/06

Pareschi, G. et al., 2003, in Proc. SPIE, 4851, p. 528-537

Pareschi, G. & Ferrando, P., 2006, Exp. Astron. 20, 139

Romaine, S., et al., 2006, in Proc. SPIE, 6266, p. 62661C