Hard X-ray Optics Technology Development for Astronomy at the Marshall Space Flight Center.

Mikhail Gubarev[1]*, Brian Ramsey[1], Kiranmayee Kilaru[2]

[1]MSFC/NASA, Huntsville, AL 35812
[2]University at Huntsville, Huntsville, AL, 35899

ABSTRACT

Grazing-incidence telescopes based on Wolter 1 geometry have delivered impressive advances in astrophysics at soft-x-ray wavelengths, while the hard x-ray region remains relatively unexplored at fine angular resolution and high sensitivities. The ability to perform groundbreaking science in the hard-x-ray energy range had been the motivation for technology developments aimed at fabricating low-cost, light-weight, high-quality x-ray mirrors.

Figure 1. Shell mirrors assembled into a module.

Grazing-incidence x-ray optics for high-energy astrophysical applications is being developed at MSFC using the electroform-nickel-replication process. In this, nickel mirror shells are plated onto figured and superpolished aluminum mandrel from which they are released by differential thermal contraction. This process has been used for such missions as XMM-Newton,[1] which features three mirror modules with 68 shell optics each. An advantage of this mirror fabrication process is that the resulting mirrors are full circles of revolution so the mirrors are stable and can be self-supporting. Moreover, the thin-shell mirrors can be nested together in order to increase the effective area of a telescope, which is crucial necessity for astrophysical observations performed at high background level. An example of an x-ray telescope consisting of a few nested mirror shells is shown in figure 1. The mirrors fabricated this way at the MSFC have a demonstrated optical performance at the level of 11-12 arc seconds resolution (HPD) for 30 keV x-rays.[2] Further progress in hard-x-ray astrophysics calls for technology capable of producing mirrors with higher angular resolution. This goal puts stringent requirements on the precision of mandrels, the electroforming process, the supporting metrology, and the optics alignment and mounting accuracy.

The quality of electroformed-nickel-replicated (ENR) x-ray mirrors relies on the quality of the mandrels. The dominant source of axial figure error in mandrels is typically mid-spatial-frequency ripple. We have developed a computer-controlled polishing machine for deterministic figuring of mandrels. The machine is designed to polish up to 300 mm diameter mandrels. The machining process concentrates on removing the (dominant) mid-spatial-frequency range errors on the mandrel surface. The results of the polishing experiments will be reported together with parametric studies performed to optimize the mandrel figuring process parameters.

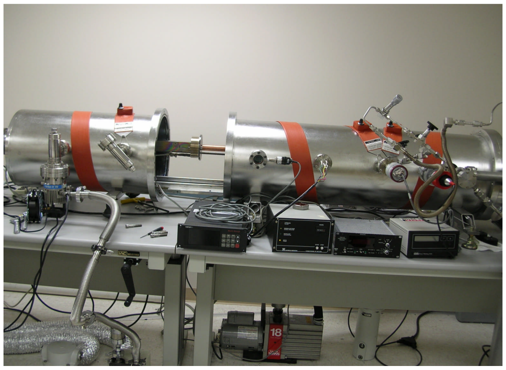

Figure 2: Differential coating test chamber.

Significant progress has made in stress control in the electroforming process. Through these, we anticipate residual axial figure errors to be around the few-tenths of a micron level. To correct these residual figure errors we are investigating the technique of differential coating, wherein material is deposited on the mirror surface to correct figure imperfections. This general technique has been successfully applied to synchrotron optics, to convert cylindrical mirrors to elliptical ones. Both a mask-type approach and a varying power-level over a moving substrate approach have been investigated, with excellent results achieved[3, 4]. We have developed a coating chamber, shown in figure 2, to investigate this technique. Visible in the figure is the large vacuum chamber housing a copper slotted copper tube, inside which the plasma is formed, and from which the narrow beam of sputtered material exits. A translation stage drives a test shell across the beam, rotating the shell for coating uniformity. The results of our early differential coating experiments for shell mirrors will be reported together with x-ray test results

References

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*) Mikhail.V.Gubarev@nasa.gov