DEVELOPMENT OF HIGH RESOLUTION HARD X-RAY TELESCOPE WITH MULTI-LAYER COATINGS

NASA Grant NAG5-5354

Annual Report No. 3

For Period 1 April 2004 through 03/31/05

Principal Investigator
Dr. Paul Gorenstein

March 2005

National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, MD 20771

Smithsonian Institution
Astrophysical Observatory
Cambridge, Massachusetts 02138

The Smithsonian Astrophysical Observatory
is a member of the
Harvard-Smithsonian Center for Astrophysics

The NASA Technical Officer for this Grant is John C. Brinton, NASA/GSFC, Wallops Island, VA 23337

1. INTRODUCTION

1.1 Program Objectives

This is the annual report for the third year of a three-year program. Previous annual reports have described progress achieved in the first and second years.

The major objective of this program is the development of a focusing hard X-ray telescope with moderately high angular resolution, i.e. comparable to the telescopes of XMM-Newton. The key ingredients of the telescope are a depth graded multilayer coatings and electroformed nickel substrates that are considerably lighter weight than those of previous missions such as XMM-Newton, which have had conventional single metal layer reflective coatings and have operated at much lower energy X-rays. The ultimate target mission for this technology is the Hard X-Ray Telescope (HXT) of the Constellation X-Ray Mission. However, it is applicable to potential SMEX and MIDEX programs as well.

We are building upon technology that has proven to be successful in the XMM-Newton and SWIFT missions. The improvements that we are adding are a significant reduction in mass without much loss of angular resolution and an order of magnitude extension of the bandwidth through the use of multilayer coatings.

The distinctive feature of this approach compared to those of other hard X-ray telescope programs is that we expect the angular resolution to be superior than telescopes made by other methods thanks to the structural integrity of the substrates. They are thin walled complete cylinders of revolution with a Wolter Type 1 figure; the front half is a parabola, the rear half a hyperbola.

1.2 Collaborations

We are collaborating with two other groups that receive funding independently. The collaborators are at the Brera Observatory in Italy and the at the National Space Science and Technology Center, which is associated with the Marshall Space Flight Center in Huntsville, Alabama. We rely upon our collaborators for substrate production but we participate fully in evaluating and identifying methods for improving the quality and lowering the mass of the substrates. SAO provides all the reflective coatings.

2. ACCOMPLISHMENTS OF THE PAST YEAR

2.1 Further improvements to and maintenance of the multilayer deposition facilities.

We reported last year that collimating the beams that coat the substrate could improve the quality, i.e. reduce the surface roughness, of the coatings. However, collimation increases the time needed to deposit a coating. The total substrate area that would be coated for the thousand telescope shells of the HXT of Con-X would be about 400 m^2. This is an enormous amount of area to coat so that the deposition process of each shell must occur rapidly. We continue the collimation studies to refine the compromise between the time needed to coat a substrate and the coating quality.

2.2 Coating Studies

2.2.1 Platinum/Carbon Coatings, Testing at Brookhaven National Laboratory

The optimum coating specification for each of the twelve Con-X HXT unit2 (or any hard X-ray telescope) would allow the coatings of shells to change according to their graze angle. Tungsten/silicon coatings deposit most easily and have reflection efficiency up to 68 keV where the K edge of tungsten reduces the efficiency abruptly. Measurements above 68 keV to detect both soft gamma-rays (68 keV and 78 keV) from the decay of Ti-44 require another material pair such as platinum/carbon. We deposited some graded period Pt/C coatings specifically designed to reflect most efficiently above 68 keV. This occurred at the expense of the efficiency at lower energies because the larger period coatings that would normally be deposited last were omitted.

The reflectivity of the Pt/C coatings was tested hard X-ray synchrotron beams at the Brookhaven National Laboratory. The measurements are shown in Fig. 1.

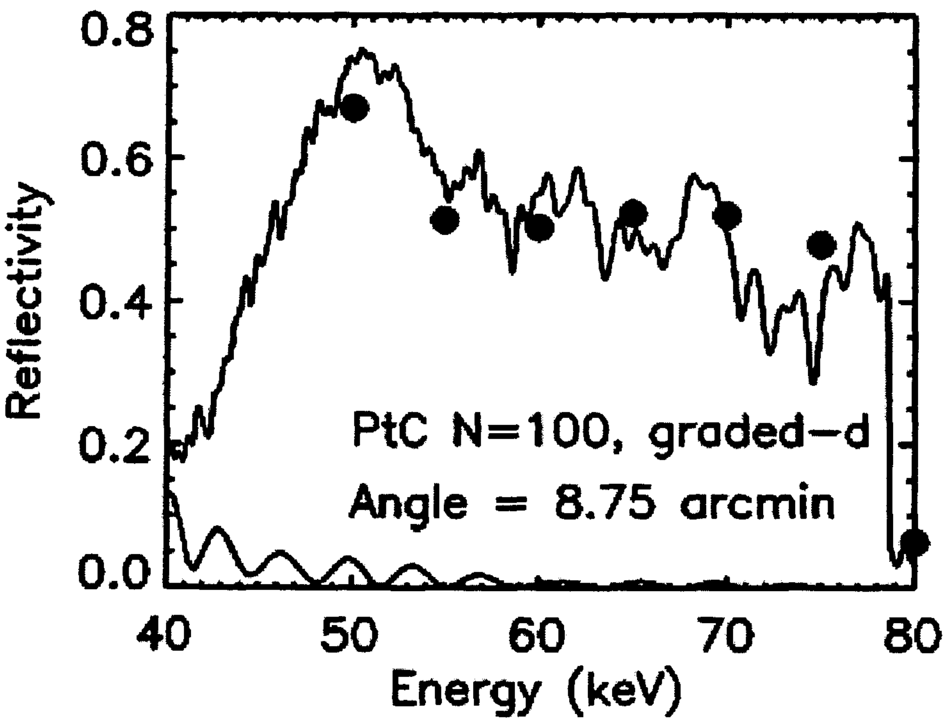

Figure 1. Measurements (dots) are shown of the hard X-ray reflectivity of a graded period Pt/C multilayer as measured at the Brookhaven National Laboratory. The upper curve, which does fit the points, is the theoretical value of the reflectivity as a function of energy. The fall-off in reflectivity at lower energy is a deliberate design feature of this multilayer. The lower curve is the theoretical reflectivity of a single iridium coating.

Along with the theoretical reflectivity of iridium, the most highly reflecting single material coating in this energy range. We will propose eventually to coat some shells of the MSFC HERO payload to allow it to map the distribution of Ti-44 in Cas A during a future long duration balloon flight.

2.2.2 Stability of multilayer coatings.

During the trip to the Brookhaven National Laboratory we also remeasured the reflectivity of a W/Si coated that was deposited and tested there three years ago. The newer and older measurements are shown in Fig. 2. The two sets coincide so closely that is difficult to see that in fact the figure contains two curves. Our conclusion is that

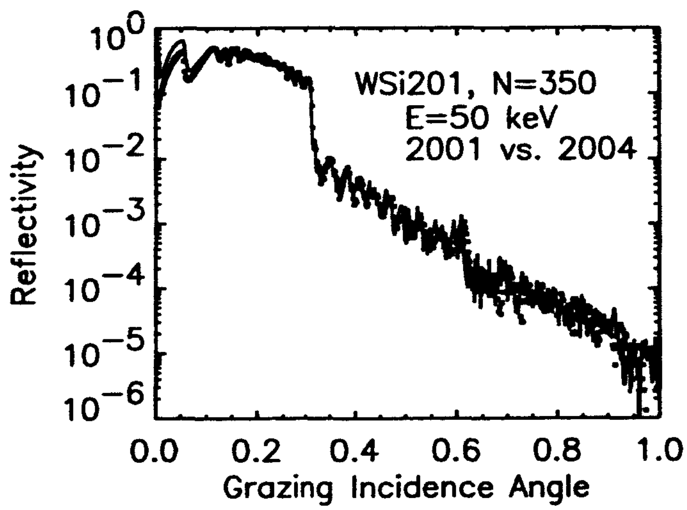

Figure 2. Comparison of recent and three year old measurements of the 50 keV reflectivity of a W/Si multilayer is shown. The two curves, which are fitted to sets of points, coincide within the measurement error.

there has not any change in the reflectivity. W/Si coatings are stable, at least with time and without a large change in temperature.

3. X-RAY TESTS OF ELECTROFROMED SHELL WITH MULTILAYER COATING

During the past year, in collaboration with OAB and MPE we carried out the first tests of an electroformed shell coated with multilayers. The tests were carried out at the Panter X-ray facility of MPE near Munich, Germany. The dimensions of the shell were the same as that of one of the five telescope shells of the prototype of the Con-X HXT we plan to construct, coat, and test. The diameter was 28 cm and the length, 42.6 cm.

The finite distance of the X-ray source at MPE (about 100m) meant that the graze angle of the beam would be about 0.27 degrees, considerably more that it would be for an infinitely distant source. Therefore, we could not test at the highest energies and would have to coat the shell with a specification for the depth-graded period designed to have a peak in reflectivity at a moderate, not a high energy. We selected a coating whose reflectivity would have a broad peak 17 keV. The reflectivity as a function of energy is shown in Fig. 3.

The reflectivity was observed to be in accord with our expectations, indicative of a successful test. We did not measure the angular resolution of this shell

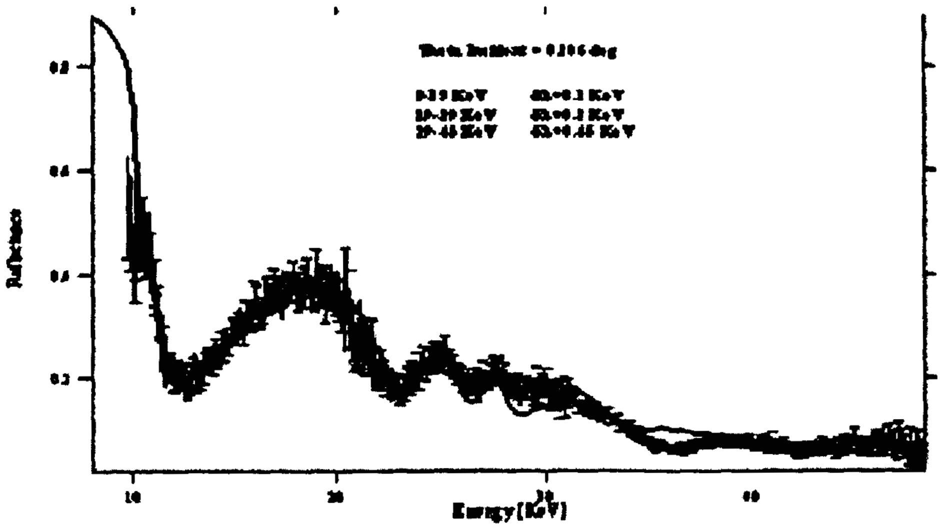

Figure 3. X-ray reflectivity of the 28 cm diameter electroformed telescope shell as measured at the Panter facility of MPE. The coating was designed to have a broad peak in reflectivity at 17 keV.

4. PLANS FOR FULFILLING THE STATEMENT OF WORK

We did not complete all the activities planned for the third year as described in the previous annual report because of delays in the delivery of additional electroformed shells from Media Lario (Italy) through our OAB collaborators and also from the Marshall Space Flight Center. We had planned to coat additional light-weight telescope shells and test their angular resolution and reflectivity simultaneously over a wider range of energy. However, after a delay we do expect to receive the new telescope shells and complete the test program.

Because of the delay we requested and received a no-cost extension of this grant.