A.5: Qualification of gold foil mirrors for soft x-ray Telescope by x-ray reflectivity

The first Indian astronomy satellite ASTROSAT is scheduled to be launched in early 2008. Amongst its several payloads, Soft X-ray imaging Telescope (SXT) is also planned. This telescope would operate in the energy range of 0.3 to 8 keV. Its design is based on a conical approximation to Walter I geometry and will use thin, nested shells of x-ray gold coated reflecting foil mirrors. The mirrors used are fabricated by replication process. These mirrors were fabricated by astronomy group of Tata Institute of Fundamental Research, Mumbai. The fabrication process of these mirrors involves transferring a thin film of sputter-deposited gold, onto an aluminum foil coated with an epoxy. These mirrors are then subjected to various types of thermal and vacuum cycles, to see their effect on the optical performance of the mirrors.

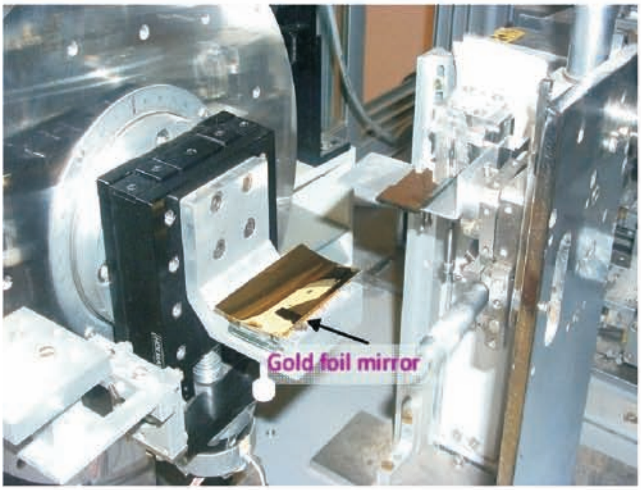

Fig.A.5.1 : Photograph of x-ray reflectometer with gold mirror

In an x-ray telescope, x-rays are incident at grazing angles. Irregularities in the mirror surface will cause light to be scattered in random direction degrading the sharpness of the image as well as angular resolution of the telescope *(K. P. Singh et al., ASTROSAT Soft X-ray Telescope, Preliminary design review document, Jan (2006))*. Thus, to get optimum performance from the telescope, the surface quality of the mirrors used should be very high, with roughness ≤ 15 Å, and density of the deposited gold equal to the bulk density of the gold.

Synchrotron Utilization and Material Research Division of RRCAT has used x-ray reflectivity to characterize the quality of the gold foil mirrors. These mirrors are big in size (~10x8 cm^2) and have high curvature. Hence it was difficult to perform x-ray reflectivity measurements on a commercial x-ray reflectometer. These measurements have been performed using indigenously developed x-ray reflectometer on a sealed tube x-ray generator shown in Fig.A.5.1. This reflectometer is equipped with Pt/C multilayer as incident beam monochromator and a sodium iodide scintillation detector. A special sample holder was made for the measurements of these large and curved mirrors.

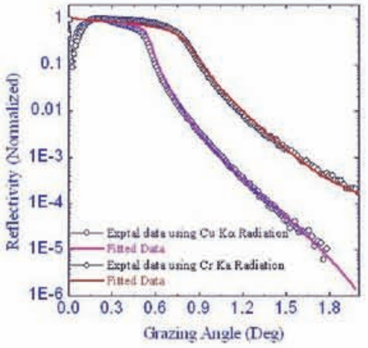

Fig.A5.2: X-ray reflectivity pattern of gold mirror along with fits, measured using Cu K_α & Cr K_α radiation

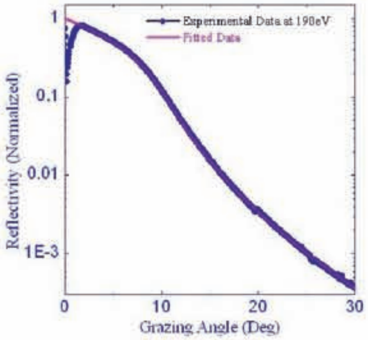

Fig.A.5.3: X-ray reflectivity pattern of gold mirror along with fits, measured using 190 eV radiation from Indus-1

Several mirrors (~50) were examined using Cu K_α (8.05 keV) for assessing the deposition quality of the surface of these mirrors that includes the reflectance, roughness and density of the Au layer. X-ray reflectivity measurements were also carried out using Cr K_α (5.4 keV) source, and in the energy range of 155-300 eV (soft x-ray) using the synchrotron source at Indus-1. Fig.A.5.2 shows typical x-ray reflectivity pattern of a mirror, obtained using Cu K_α and Cr K_α radiations. Fig.A.5.3 shows typical x-ray reflectivity pattern of a mirror, obtained using 190 eV radiation from Indus-1 *(N. Yadav et al., Summary Reoprt on SXT Mirror Tests, AST-SXT-TFR-TEC-MT (2006).*

These measurements helped in qualifying the deposition process as well as in testing the stability of surface quality after various test cycles as mentioned above. Reflectivity measurements at different wavelengths helped to assess the performance of the mirrors in the operating range of the telescope. Roughness values of all the good mirrors were in the range of 9-15 Å as measured with Cu K_α, and 5-12Å by Cr K_α radiation. The density of the gold film was found to be equal to the bulk value, as desired.

Contributed by:
S. Rai (sanjayrai@cat.ernet.in) and A. Jaiswal

A.6: Effect of Si layer thickness on structural properties of Co/Si multilayer system

Co/Si is a metal/semiconductor multilayer (ML) system that shows an oscillatory magnetic behavior between different Co layers as a function of Si layer thickness (<17Å). This type of coupling is well established and understood in the case of metal/metal multilayers. However, the picture is not clear for insulating or semiconducting spacer layer. There is a finite possibility that the origin of the interesting magnetic behavior in Co/Si system, might be related to the formation of cobalt silicide layer at the interface. For this reason, Synchrotron Utilization and Material Research Division of RRCAT has undertaken the present investigation and has prepared Co/Si MLs of varying thickness [Co (~ 45-80Å) and Si (~20-75Å)] to study the interlayer coupling in this system. X-Ray Reflectivity (XRR), X-Ray Diffraction (XRD), and Magneto Optical Kerr Effect (MOKE) measurements have been performed on these MLs.

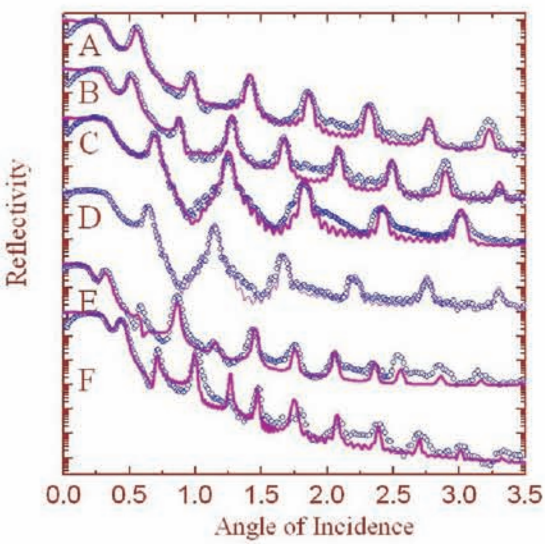

Fig.A.6.1 : XRR pattern of Co/Si MLs. Circles are experimental data and continuous lines show the fitting.

The XRR patterns, as shown in Fig.A.6.1, show well defined Bragg peaks upto 8[th] order, arising due to ML periodicity. Fitting was done using Parratt recursion formalism. It was found that the fitting is quite good when no silicide layer formation at the interface is considered. This suggests that in these Co/Si MLs, if silicide layer is present, its thickness or the volume fraction is so low (<10Å) that it could not be detected distinctly as a layer.

In the wide angle XRD, as shown in Fig.A.6.2, it is found that the samples with low Si (<50 Å) show a well-defined peak corresponding to the (002) hcp planes of Co. However, for samples with Si layer thickness (>50Å), instead of one peak there are three different peaks, identified as reflections from the hcp (100), (002) and (101) planes, as shown in Fig.A.6.2. This indicates that the films, which were otherwise strongly textured for low thickness of Si, lose their texture for higher thickness of Si (~56Å) layers.

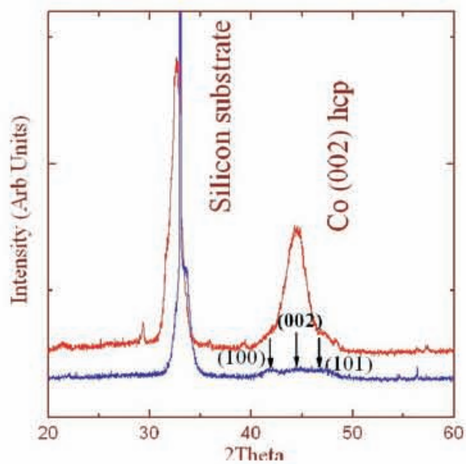

Fig.A.6.2: XRD pattern of the MLs; Red for the ML containing Si layer thickness <50Å, Blue for Si layer thickness > 50Å

MOKE measurements at ambient temperature show no oscillatory behavior as a function of Si layer thickness. For samples, which are not textured, large value of coercivity is observed. Loss of texture suggests that cobalt layer has become polycrystalline. Response of each grain towards the applied magnetic field will be different and hence the coercivity is large for these samples. These studies suggest that it is the texture of the Co layer, which depends on the thickness of the Si layer that affects the magnetic properties of Co/Si system. Since silicide layer is not visible distinctly at the interface, its possible effect on the magnetic behavior of the system is not clear. Structural, and in turn magnetic properties of Co/Si ML system, are highly governed by thickness of the Si layer and not by silicide layer *[A. Jaiswal et al., J. Phys.: Condens. Matter, 016001 (2007)]*.