A.12: Development of multilayer optics for x-ray telescope

Due to recent advancements in thin film fabrication technology, artificial periodic reflective multilayer (ML) mirrors open a wide range of possibilities in the field of x-ray astronomical instrumentation. Grazing incidence x-ray telescopes based on single layer optics are usually bulky and have large focal lengths, which makes them expensive and difficult to use for a space based telescope. Use of ML mirrors also makes it possible to operate the instrument at higher angles and significantly improves the high energy sensitivity compared to single layer optics. ML optics make it possible to development x-ray telescopes working at high energy cut-off ranging from 10 to 79 keV and to develop soft x-ray (<0.5 keV) and extreme ultra violet telescopes.

RRCAT has been involved in the project "Development of ML optics based x-ray telescope for astronomical observations" lead by the Indian Space Research Organization and Indian Institute of Astrophysics, Bangalore. All these multilayers were deposited using magnetron sputtering technique at RRCAT. A typical example of a spherical W/B_4C ML optics developed on a 2 inch zerodur substrate having a radius of curvature of 2600 mm, with 170 numbers of bilayer pairs and with individual layer pair having a thickness of 1.88 nm is shown in Figure A.12.1.

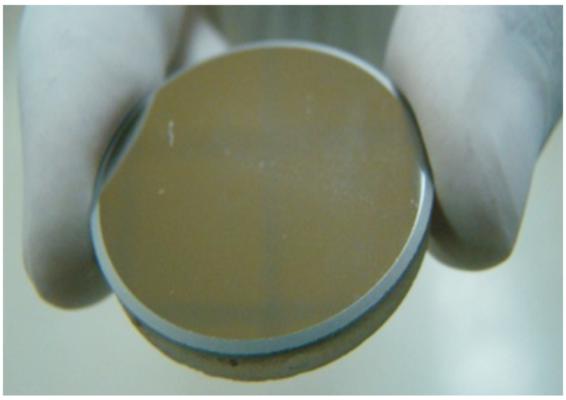

Fig. A.12.1 Developed spherical W/B_4C ML on a zerodur substrate.

Hard x-ray reflectivity (XRR) of these ML optics was evaluated at 8.047 keV obtained from a laboratory based reflectometer. Well defined higher order Bragg peaks indicate good quality of ML mirrors in terms of rms roughness and thickness errors. Typical values of rms roughness in all the developed MLs are in the range of 0.3 to 0.4 nm with good optical contrast. At 8.047 keV, a reflectivity of ~19 % at first order Bragg peak (2.3^0) is measured, which compares very well with the theoretically calculated values.

Application of ML optics to a space-borne payload demands a stable performance of the mirror over a long time. Reflectivity of the mirror is expected to reduce with time due to effects like self interface diffusion, accumulation of impurities at the top surface, external humidity and temperature. A systematic reflectivity test of mirrors left in the ambient for over a span of 6 months indicates that reflectivity at first Bragg peak remained nearly same with 1-2% decrease in its initial value.

The optical performance of the ML mirrors is also evaluated from 9 keV to 16 keV using BL-16, Indus-2 synchrotron, and measured reflectivity curves are shown in Figure A.12.2. The reflectivity of first Bragg peak is ~13 % at 9 keV. As the energy increases, the reflectivity changes, which is due to the variation of the optical properties with energy.

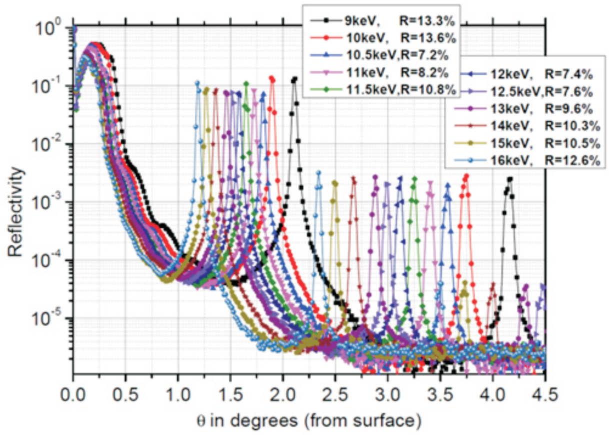

Fig. A.12.2 Measured XRR curves of W/B_4C ML (d = 1.88 nm and N =170) in the energy range 9 to 16 keV using BL-16, Indus-2.

Thus, replacing single coated mirrors with ML optics in conventional Wolter type x-ray telescope makes the instrument compact, small and more efficient making it more suitable for a space payload with specific applications.

For more details, please refer to:

1. S. S. Panini, P. Sreekumar, H. L. Marshall, K. C. S. Narendranath, M. Nayak and P. S. Athiray, J. Astronomical Telescopes, Instruments, and System 4 (1), 011002 (2018).
2. S. S. Panini, M. Nayak, K. C. S. Narendranath, P. C. Pradhan, P. S. Athiray, P. Sreekumar, G. S. Lodha, M. K. Tiwari, accepted in J. Optics (2017), https://doi.org/10.1007/s12596-017-0444-8

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