Multilayer supermirror for hard X-ray optics

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Abstract

In X-ray astronomy, hard X-ray observations above 10 keV are important to find out many X-ray objects obscured by thick absorber, and to map the distribution of non-thermal components. X-ray focusing optics above 10 keV, however, have been prevented by the fact that X-ray reflectivity, in terms of total external reflection, decreases with the incident angles and X-ray energy. At larger incident angles, multilayers provide an interference effect to enhance the reflectivity as in Bragg crystals. In order to broaden the narrow sensitive band of multilayers, we have used multilayer mirrors with graded d-spacing, a so called "supermirror". For the future balloon experiment (planned for 1999), boundary conditions of the telescope were set as 40 cm in diameter, focal length of 8 m, and energy range from 25 to 40 keV. 0.30 degree is used as the typical incident angle in all subsequent considerations. Considering these conditions, we have optimized the layer thickness of 44 layer pairs in four blocks; the outer most block of 5 layer pairs with d gradually ranging from 5.0 through 4.6 nm, the second one of 8 layer pairs with a constant d of 4.0 nm, the third one of 13 layer pairs of 3.6 nm, and the last one of 18 layer pairs of 3.3 nm. Such Pt/C supermirrors were deposited on the replica foil mirror by the magnetron DC sputtering system at Nagoya. It gave a flat response of 25-30% reflectivity in the energy range from 24 to 40 keV. The peak reflectivity is consistent with the model calculation with the Pt-C interfacial roughness (Debye-Waller factor) of 0.5 nm. These supermirrors were assembled into the grazing incidence and tightly nested telescope. The hard X-ray image produced by the supermirror telescope was observed up to 40 keV. This is the first demonstration of hard X-ray focusing system, which is applicable for wide variety of research fields, including medical purposes.