Further Development of Multilayer Supermirrors for Hard X-Ray Optics

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We have developed depth-graded multilayers, so called supermirrors, for applying to hard X-ray telescopes. The performance of a hard X-ray telescope made of Pt/C multilayer supermirrors with 26 layer pairs[1] has been demonstrated in the energy range of 25-36keV. In order to enhance the reflectivity in a broad energy band, several blocks of multilayers are successively stacked up on a substrate changing periodic length (d), number of layer pairs (N) and the thickness ratio (G) of a heavy element layer to d at a given grazing angle. The effective thickness is limited by the penetration depth of incident X-rays in the multilayer structure. It is important to maximize the reflectivity with the minimum number of layer pairs. We have further investigated the design of supermirrors by means of the X-ray etalon or phase matching methods[2]. It means that the 1st and higher order Bragg reflections caused by different multilayer blocks cooperatively enhance the reflectivity at energy bands concerned. In order to cover the energy band 20-40keV at the grazing incidence of 0.3 deg, periodic lengths of multilayers are in the range of 60-30A. We can select suitable sets of d and N keeping Nd=constant for all the multilayer blocks and starting d=60A at the top and 30A at the bottom. This means that the phases of X-rays reflected by different blocks are matched to each other. In a case of Nd=360A, combinations of d and N corresponding to each block are given as (60, 6), (51.4, 7), (45, 8), (40, 9), (36, 10), (32.7, 11) and (30, 12). G is selected to get flat reflectivity and enlarge the energy region. The oscillation pattern of reflectivity curve is just like a harmonic one. The highest peak reflectivity of the 1st and 2nd order reflection is obtained for G=0.5 and 0.25, respectively. The mean reflectivity is expected to be more than 40%. We will present the design method and experimental results of Pt/C multilayer supermirrors and their applications.

1) K. Yamashita et al., Appl. Opt., 37, 8067(1998).
2) K. Yamashita et al., Proc. SPIE, 3766 (1999) in press.