Be-based multilayers for EUV spectral range

N.I. Chkhalo[1,]*, D. A. Gaman[1], A.N. Nechay[1], D.G. Pariev[1], V.N. Polkovnikov[1], N.N. Salashchenko[1], F. Schaefers[2], M.G. Sertsu[2], A. Sokolov[2], M.V. Svechnikov[1], S.Yu. Zuev[1]

[1] *Institute for Physics of Microstructures of RAS, Nizhny Novgorod, GSP-105, 603950, Russia*

[2] *Institute for Nanometre Optics and Technology, HZB-BESSY-II, Berlin, Germany*

*chkhalo@ipm.sci-nnov.ru

Beryllium is one of the most attractive materials for X-ray optics. Analysis of the optical constants of this material in the wavelength region 11.1-17 nm shows that Be has the smallest absorption from all materials, which makes it the most promising "spacer". In the wavelength region λ>17 nm, Be has a unique combination of optical constants, which makes it possible to use this material as a "scattering" upon absorption, which is characteristic of the "spacer" [1]. In general, this combination of the imaginary and the real parts of the refractive index makes it possible to obtain record reflection coefficients and spectral resolution simultaneously. The report is a review the results of studies of the internal structure and reflection coefficients in the wavelength range 11.2-30.4 nm of Be-containing multilayer mirrors (MLM) fabricated by magnetron sputtering. The reflection coefficients were studied both on a laboratory reflectometer and those using a reflectometer on BESSY-2. The main results of the study, which will be reported, are the next.

In the wavelength region of 11.2-11.4, the reflection coefficient of Mo/Be MLMs was reached up to 70.25±0.05%, which coincides with the record result obtained earlier [2]. The asymmetry of the transition boundaries was detected: the width of the Be-on-Mo transition layer was 0.71±0.03 nm, and the Mo-on-Be was 0.36±0.03 nm.

The influence of intermediate layers of C, B4C and Si in Mo/Be MLMs on interfaces and the reflection coefficients in the vicinity of 11 nm was studied. It was found that C and B4C practically do not affect the width of the boundaries, slightly reducing the reflection coefficients. The Si interlayer, with an effective thickness of 0.3-0.4 nm, deposited in the following order Mo/Be/Si, led to a strong smoothing of the boundaries: Be-on-Mo a 0.31 ± 0.02 nm, and Mo-on-Be Was 0.8 ± 0.04 nm. The reflection coefficient in the 11 nm region dropped to about 67% due to the strong absorption of silicon.

We calculated, optimized the composition, synthesized and studied the internal structure and reflection coefficients of Mo/Be/Si MLMs, in the wavelength region of 12.8-14 nm. The thicknesses of Be layers varied from 1.7 to 2.1 nm. The study confirmed the smoothing of boundaries for such a system. On all structures at a wavelength of 13.5 nm at an angle of incidence close to the normal, reflection coefficients R> 71% were obtained. The maximum reflection coefficient at this wavelength was 71.89% at an angle of incidence of 12.9 °. The maximum reflection coefficient for s-polarized radiation with λ=12.92 nm was 72.83% at an incidence angle of 21.3°. Thus, it was shown that the reflection coefficients of Mo/Be/Si MLMs in the region of 13 nm are superior to traditional Mo/Si.

In the wavelength range of 11-20 nm, which is of considerable interest for space astronomy, using Be/Al and Zr/Be/Si/Al mirrors, a record reflection coefficient was obtained, up to 67% at a wavelength of 17.14 nm. In addition to record characteristics both in terms of spectral resolution and absolute values of reflection coefficients, these structures are characterized by high temporal stability of X-ray optical parameters.

At a wavelength of 30.4 nm, the HeII line, the reflection coefficient of Be/Al MLM was 34%, at the level of world achievements, however, unlike them, the spectral resolution turned out to be much higher, and the reflection coefficient is stable. More than a year's "aging" of the sample did not lead to an experimentally observed change in the reflection coefficient and the position of the Bragg angle. At present, the study of Be/Mg structures, which demonstrate even greater reflection coefficients at a wavelength of 30.4 nm, has begun. The report will give the first results on the stability of the reflective properties of MLMs of this type.

Thus, the study of Be-containing mirrors in the EUV spectral range showed that in all the main parameters they substantially exceed all previously studied multilayer structures.

The work is supported by grants RSF-DFG, #16-42-01034 and RFBR, #17-52-150006.

1. N.I. Chkhalo, et al. Be/Al-based multilayer mirrors with improved reflection and spectral selectivity for solar astronomy above 17 nm wavelength. Thin Solid Films 631 (2017) 106–111.
2. C. Montcalm, S. Bajt, P. Mirkarimi, E. Spiller, F. Weber, J. Folta, SPIE 3331, 42-51 (1998)