ESTIMATION OF INTERLAYER COMPOSITION IN WC/Si MULTILAYER X-RAY MIRRORS (MXMs) AT NANOMETER SCALE

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Rapid progress in the MXM fabrication for the last two decades brought to variety of their applications in science and technology. Among the applications are: microscopy, astrophysics, material science, X-ray lithography etc. MXM is an optical device meant to reflect, focus, polarize and disperse the X-rays. Particularly W/Si-based MXMs become widespread because of a wide range of working wavelength (0.7÷3.1 nm). The presence of mixed interlayers in W/Si MXMs resulted in deterioration of their efficiency. That is why WC/Si MXM was taken as an alternative to W/Si one to decrease the degree of interface mixing.

The purpose of this work is to make an estimation of the interlayer thickness and their composition in WC/Si MXMs.

WC/Si MXMs with periods of 0.7-38.9 nm were deposited by DC magnetron sputtering and studied using cross-sectional transmission electron microscopy (TEM) and hard X-ray (λ=0.154 nm) diffraction methods.

TEM shows that all WC/Si MXMs have amorphous structure. They have mixed interfaces formed in the process of deposition forming tungsten silicide and silicon carbide interlayers. The thicknesses of upper (Si-on-WC) and lower (WC-on-Si) interlayers are practically equal and make ~1.25 nm for MXMs with periods d>4.5 nm (nominal thickness of tungsten carbide t_{WC}>1.5 nm). At this point amorphous α-WC layers appear which don't interact with Si-layers. The composition of upper interlayers is W_2C+WSi_2+SiC (or $W_3Si_4C_3$) with density of ~10.8 g/cm^3. Lower interlayers consist of 2 sublayers: 1) W_5Si_3+SiC (or $W_5Si_8C_5$) with density of ~9.1 g/cm^3; and 2) WSi_2+SiC (or WSi_3C) with density of ~7.6 g/cm^3. Both sublayers are equal in thickness (~0.62 nm). When d<4.5 nm (t_{WC}<1.5 nm) α-WC layers and some interlayers are not formed due to substance limit.

Analysis of wide-angle diffraction curves made it possible to define atom distribution functions and find both coordination number and coordination sphere radius for all sublayers. Comparison of found data with tabulated ones for bulk materials allowed to specify that there is proximity of structure for α-WC layers to cubic phase c-WC; α-W_5Si_3 sublayers (sublayer 1) in lower interlayers to tetragonal phase t-W_5Si_3; and α-WSi_2 layers in lower sublayer (sublayer 2) to hexagonal phase h-WSi_2.

The 5-layer model of WC/Si MXM construction is built. New technique is developed to establish composition, density and structure for amorphous sublayers of nanometer thickness.

Comparison of WC/Si and W/Si MXMs gives the evidence that in WC/Si MXMs the thickness of lower mixed zones is 1.5 times smaller. It should enhance the efficiency of the WC/Si MXMs in soft X-ray range.