New x-ray mirrors for hard and soft x-rays

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The basic requirement for high performance x-ray mirrors is a high reflectivity for a specified range of wavelengths. Placed in an intense synchrotron beam, structural and chemical resistance against high local heat loads and radiation doses are also required. To achieve these goals, a number of material combinations have been tested in recent years with good progress. In the hard x-ray regime reflectivities of 90% and more are usual. Remaining material problems concern the thermal stability beyond 900°C and the longterm adhesion of the multilayers to the substrate. In the soft x-ray regime, higher reflectivities for wavelengths < 10 nm and > 20 nm are still in demand. I will report about new types of x-ray mirrors with extremely high thermal stability and smooth interfaces which have been developed recently in Bochum and which are of interest as mirrors for hard as well as soft x-rays. These multilayers use alumina as spacer layers, and the absorber layers are tailored to the required wavelength region [1-5]. All multilayers are grown by rf-sputtering on epi-polished sapphire substrates, providing very smooth surfaces, as well as mechanical strength and thermal stability. The advantages of alumina as spacer layers are smooth and amorphous growth (interfacial roughness < 0.2 nm), a very small percolation threshold (< 1nm), high inertia against interfacial reactions with most absorber materials, high recrystallization temperatures, and excellent adhesion to most metals. For instance, W/Al_2O_3 multilayers exhibit a thermal stability of more than 900°C with up to 90% reflectivity for Cu-K_α radiation [4]. In contrast, C/Al_2O_3 multilayers with thermal stabilities of up to 1200°C [6] are promising candidates for high reflectivities in the water window. At the C-K_α edge (284 eV, 4.36 nm) we have measured a reflectivity of 31% using a period of 9.65 nm and 15 repeats [7]. With more repeats much higher reflectivities are expected. Furthermore, reduction of the multilayer period is feasible because of the low percolation thickness of both, the carbon and alumina layer. At the C-K_α edge a reflectivity of 61% is expected at normal incidence and without roughness. Even with a roughness of 0.3 nm the reflectivity should be as high as 40%, exceeding reflectivity values achieved so far in this wavelength regime by a large margin. V/Al_2O_3 multilayers are highly promising candidates as mirrors for wavelengths close to the O-K_α edge. With a period of 4.36 nm and 40 repeats we have measured a reflectivity of 30% at an energy of 510 eV [7]. The high reflectivity is due to the V-L_α resonance at 512 eV (2.42 nm). Reduction of the period and a larger number of periods will enhance the reflectivity to levels of 70% (without roughness) even for normal incidence.
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