Broadband multilayer mirrors for EUV/x-ray optics at normal and grazing incidence

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A method of designing depth-graded multilayer structures with broadband angular or wavelength responses for use as coatings in EUV/ x-ray optics is presented in this paper. The method is based on the well-known Fresnel equations and recursive calculation combined with a defined merit function, with random variation of the thickness of each layer. This allows the design of multilayer films for different requirements. The method has been used to give the thickness of each layer in depth-graded W/C multilayer films and their reflectivities as functions of the grazing incidence angle for Cu Ka (l=0.154nm) radiation. The required minimum number of bilayers in all depth-graded multilayer films is found to vary with grazing incidence angle, i.e., the reflectivity saturation phenomenon observed for periodic multilayers also emerges in the design of depth-graded multilayers. Surprisingly, the minimum number of bilayers in depth-graded multilayer films can be less than 10, often only 4 or 5. This is important for the fabrication of depth-graded multilayers and their applications.

The method has also been used to design Mo/Si multilayers with broadband angular or wavelength responses for the EUV region, 18-20nm. Such mirrors have been made by magnetron sputtering in 99.99% pure argon. The deposition rates, after calibration, were 0.12nms-1 for molybdenum and 0.07nms-1 for silicon. The depth-graded multilayers were deposited on 30mm diameter K9 glass substrates with rms surface roughnesses less than 0.8nm. For comparison, reference periodic multilayers with working wavelength of 19nm were also deposited. X-ray reflectivity and diffraction measurements were made in q-2q geometry using a D/Max-B x-ray diffractometer and Cu Ka radiation. The results show that depth-graded and periodic multilayer mirrors have different performances. We have also developed equipment that can measure reflectivity qualitatively using a transmission grating spectrograph and no reflectometer. The results show that the wavelength or angular responses of depth-graded multilayers are broader and the integrated reflectivities are higher than for periodic multilayers, but that the peak reflectivity is slightly lower.

Acknowledgments. This study is supported financially by the National Natural Science Foundation of China for General Scientific Research, Contract #69778026.