Effects of energetic particles on DC sputter growth of W/B_4C multilayer x-ray mirrors for the water window

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Abstract

W/B_4C multilayers for normal incidence soft x-ray mirrors have been grown on Si substrates with a native oxide using dual DC magnetron sputtering. The multilayers were designed with a period of 33.84Å and a γ-value of 0.807 for the second order reflection of the wavelength λ=33.74 Å (C VI emission line) in the water window region.

In DC magnetron sputtering, it can be expected that the energetic particles present in the plasma process will have large effects on the surface of the growing film. In multilayer growth these effects will be enhanced due to the large amount of interfaces. For maximum reflectivity, abrupt and flat interfaces are essential. A low substrate temperature and no energetic particle irradiation during growth minimizes bulk diffusion and interface intermixing. However, such conditions may lead to a kinematically limited growth with an increased and accumulated roughness as a consequence. In this work varying sputtering pressures (3-20 mTorr), sputtering gases (Ar and Kr), and chamber geometries, have been used in order to study the effects of un-intentional energetic particle irradiation. Two substrate temperatures (20 °C and 150 °C) have been investigated to see the effects of bulk diffusion. Finally, intentional ion irradiation (0-100 eV), obtained through a negative substrate bias, have been utilized in order to stimulate the ad-atom mobility and improve the interface flatness.

Soft x-ray reflection measurements were carried out using a reflectometer with a compact soft x-ray laser-plasma source.[1] The source is based on an ethanol liquid-jet target and produces high-brightness, line-emission soft x-ray radiation in the water window. An improvement of the relative reflectance of more than one order of magnitude were obtained when the bias was increased from 0V to –85V. Higher pressures yielded higher optimum bias-voltages for maximum reflectance. The maximal reflectivity was obtained using a substrate bias of –85V, a sputtering pressure of 3mTorr and a substrate temperature of 20°C.

Individual layer thicknesses were determined by simulations of experimental hard x-ray (Cu-Kα) reflectivity curves using the PC GIXA software by Philips. The hard x-ray reflectance data correlated to the soft x-ray reflectivity measurements. Large non-linearities of the deposition rates as a function of the layer thickness were evident. This is explained by resputtering of the growing film by highly energetic backscattered neutrals from the W-target in combination with the sputter yield amplification (SYA) effect.[2] SYA becomes more apparent when materials with large mass differences are sputtered. TRIM simulations combined with calculations of the transport through the gas-filled chamber shows that backscattered Ar-atoms have energies ranging up to 200 eV at 3 mTorr sputtering pressure in the chamber used.[3] The experimental results are discussed and compared with dynamic simulations using the TRIM code.[4]

References:

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