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Fabrication of Cr/Sc/Mo multilayer illuminator for water window soft X-ray microscopes with Bi plasma sources

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1 Introduction

Living cell observation in 10 nm order resolution can be expected when the water window soft X-rays between *K*-absorption edges of carbon and oxygen are used. To realize that, a soft X-ray microscope composed of laser-produced plasma source, condenser mirror, scintillator, and imaging lens optics is under construction. Unresolved transition array (UTA) radiated from highly ionized high-*Z* elements will be useful as a high power source in laboratory scale [1]. For the purpose of water window microscope, UTA of Bi plasma around 310 eV with a 10% bandwidth will be useful if a suitable condenser mirror is available. In our microscope system, a toroidal mirror of a large effective size with an angle of incidence of 77.2° which is much smaller than the critical angle, is used for high flux illumination with plasma soft X-ray sources of a large angular divergence. The mirror is coated with a multilayer for a specific wavelength region or coated with Au for general use. In our previous study, a Co/C multilayer mirror was developed for 270 eV carbon window soft X-ray [2]. Recently we found a multilayer structure of Cr/Sc/Mo 10 tri-layer produces a high reflectance and a 10% bandwidth around 310 eV matching the UTA of Bi-plasma [3, 4]. In this study Cr/Sc/Mo multilayers have been deposited on toroidal mirror substrates with thickness distribution controlled for spectral matching.

2 Multilayer deposition

Dimensions of the toroidal mirror substrate are illustrated in fig. 1 [2]. Angle of incidence varies between 76.5° and 77.2° along the mirror surface in the meridional plane. Every layer must have lateral thickness distribution for spectral matching against change of angle of incidence. Designed thickness distribution normalized by the thickness at the center, $d(w)$ is shown by a thick curve in fig. 2. On the other hand, each material has deposition rate distribution depending on the geometry of the deposition apparatus, in general. Deposition rates of Cr, Sc and Mo in our ion beam sputtering apparatus, $s_{Cr}(w)$, $s_{Sc}(w)$ and $s_{Mo}(w)$, respectively, were measured by X-ray reflectometry on Cr/Sc, Sc/Mo and Mo/Cr multilayers. The results are shown by thin curves in fig. 2. Decrease in $s(w)$ toward $w \to \pm 50$ mm is larger than decrease in $d(w)$, which means the deposition time $t(w) = d(w)/s(w)$ should increase. Material dependent deposition time functions

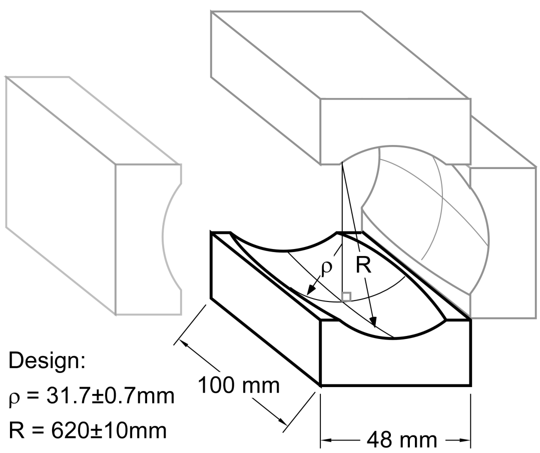

Fig. 1: Schematic drawing of the toroidal condenser mirror substrate [2].

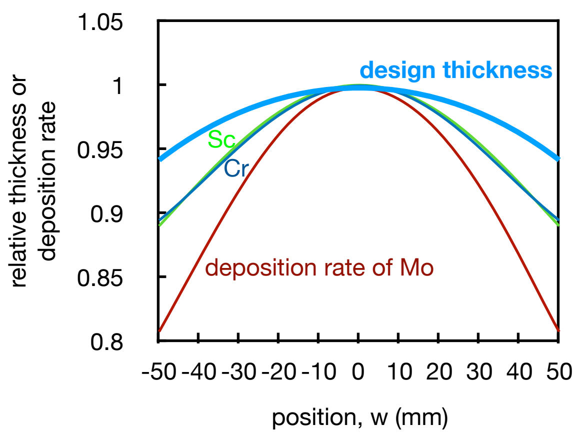

Fig. 2: Designed thickness distribution and deposition rate distribution of Cr, Sc and Mo, normalized by the values at the center.

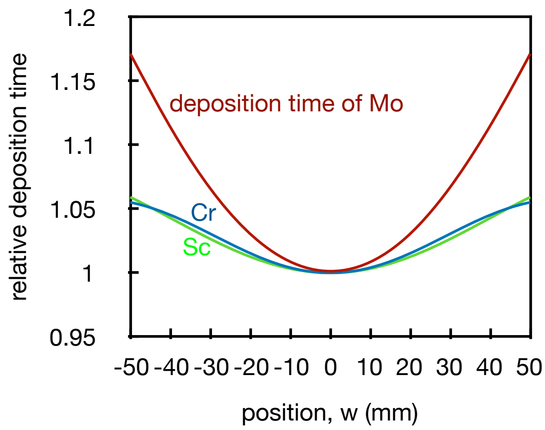

Fig. 3: Deposition time functions of Cr, Sc and Mo.

are shown in fig. 3, and our deposition apparatus with speed controlled shuttering system can realize them [5]. Thickness distribution in the sagittal plane was not controlled.

Deposition started with Mo layer followed by 10 Cr/Sc/Mo tri-layers and terminated with Cr layer. Thicknesses of tri-layer are almost equivalent in first few cycles and then transparent Sc and absorptive Mo became thicker and thiner, respectively. Top layers are periodic Cr (3.4 nm)/Sc (4.8 nm)/Mo (1.7 nm).

3 Reflectance measurement

Reflectance measurements were performed at the soft X-ray reflectometry beamline BL-11D at the Photon Factory. Spectral reflectance around 310 eV were measured at the center of the substrate and other three points shown in fig. 4. Angle of incidences were set as the same as the condition under condenser mirror use. Results are shown in fig. 5. Peak reflectances were 18-22%. Reflection bandwidth was 30 eV. Reflection peak energy was 310 eV at every point except for the point out of the meridional plane. High reflectance and large bandwidth

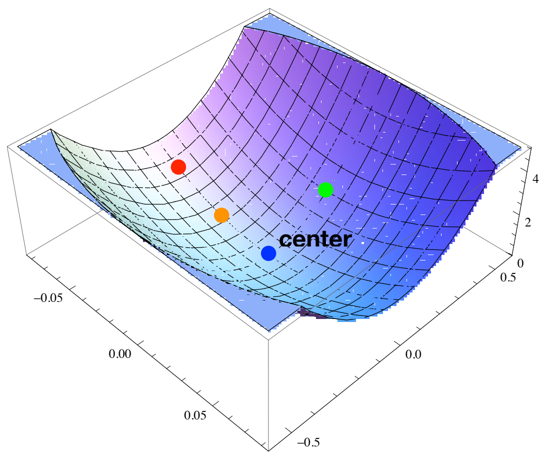

Fig. 4: Measurement points on the toroidal mirror surface.

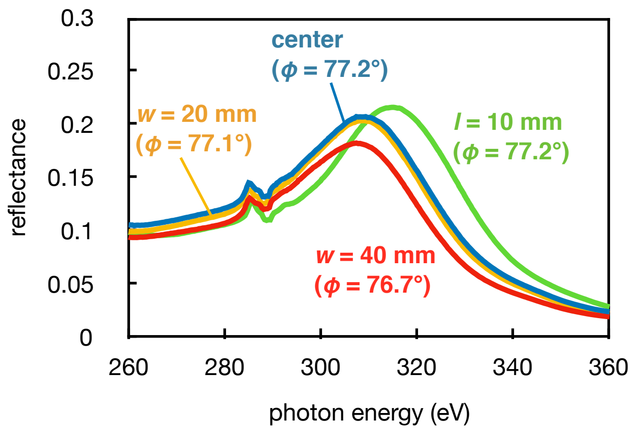

Fig. 5: Measured spectral reflectance of Cr/Sc/Mo multilayer.

with peak energy 310 eV matching the UTA of Bi-plasma sources were confirmed

Acknowledgement

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