Cr/C multilayer mirror for Ni-like Ta X-ray laser application

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Abstract

The working wavelength of Ni-like Ta soft X-ray laser is 44.83 Å, which is an important Soft X-ray source just near the "water window". For this application, we design and fabricate Cr/C multilayer reflective mirrors. Multilayers with bi-layer numbers of 150, 200, 250 and 300 were deposited onto super polished silicon substrate with surface roughness 3 Å. All multilayers have been characterized by grazing incident X-ray reflectance (XRR). Then, the near-normal incidence reflectance measurements were performed at beamline 3W1B, Beijing synchrotron radiation (BSRF). The highest reflectance of 13.2% for the 300-bilayer Cr/C multilayer mirror at near normal incidence is achieved.

Introduction

Soft X-ray laser working in or near the "water window" (22.8 - 43.6 Å) region enables many fundamental and applied researches. The working wavelength of Ni-like Ta soft X-ray laser is 44.83 Å, just near the "water window". High reflection multilayers are required for this application in China. However, with the shorter working wavelength, the reflectance is more sensitive to interface roughness, diffusion and other imperfections of multilayer[1]. In this case, we design and fabricate fabricate Cr/C multilayer reflective mirrors with the period thickness of only 22.6 Å and achieve the highest reflectance of 13.2% for the 300-bilayer Cr/C multilayer mirror at near normal incidence.

Design and experiments

We design Cr/C multilayer with the period thickness of 22.6 Å and the ratio of 0.6 (C layer thickness to period thickness) at the working wavelength of 44.83 Å. To study the effect of different total bi-layer numbers on reflectance, we fabricate multilayers with bi-layer numbers of 150, 200, 250 and 300 by DC magnetron supttering. All the multilayers are deposited onto super polished silicon substrate with surface roughness 3 Å.

We use grazing incident X-ray reflectance (XRR) to characterize multilayers. Fig.1 shows the measured and fitted results. We use Bede Refs software to fit the measured curves.[2] The fitted parameters of the multilayer structure are shown in Tab. 1.

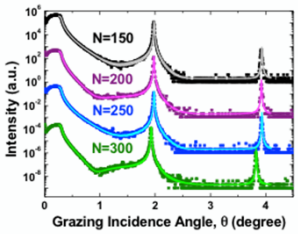

Fig. 1: Small angle X-ray reflectance of samples with different period numbers: dots for measured data, solid line for fitted ones

Table 1: Fitted multilayer structure of samples with different period numbers from XRR measurements

N	d_{Cr}(Å)	$\sigma_{C\text{-}on\text{-}Cr}$(Å)	d_C(Å)	$\sigma_{Cr\text{-}on\text{-}C}$(Å)
150	9.90	2.94	12.83	3.73
200	9.92	3.27	12.70	3.21
250	9.81	2.93	12.74	2.91
300	10.08	3.15	13.08	2.79

The near-normal incidence reflectance measurements is performed at beamline 3W1B, Beijing synchrotron radiation (BSRF). The measured and fitted reflectivity curves of multilayers with different bi-layer numbers are shown in Fig. 2. IMD (Levenberg-Marquardt algorithms) is used in the fitting process.[3] The highest reflectance of 13.2% is achieved with bi-layer number of 300 at the incident angle of 13° . The fitted parameters are given in Tab.2.

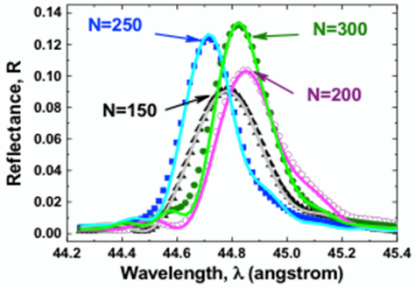

Fig. 2: Near-normal reflectance of samples with different period numbers: dots for measured data, solid line for fitted ones involved.

Table 1: Fitted multilayer structure of samples with different period numbers from SR measurements

N	d_{Cr}(Å)	$\sigma_{C\text{-}on\text{-}Cr}$(Å)	d_C(Å)	$\sigma_{Cr\text{-}on\text{-}C}$(Å)
150	10.23	4.54	12.42	4.43
200	10.29	4.72	12.39	4.57
250	10.42	4.47	12.18	4.68
300	10.55	4.64	12.62	4.49

Summary

Cr/C multilayer reflective mirrors are designed at the working wavelength of Ni-like Ta soft X-ray laser (44.83 Å), which is just near the "water window". Multilayers are fabricated by DC magnetron supttering and characterized by XRR. The near-normal incidence reflectance measurements were performed at beamline 3W1B, Beijing synchrotron radiation (BSRF). The measured and fitted results show that the fabricated multilayers accord well with the designed ones。The highest reflectance of 13.2% is achieved with the bi-layer number of 300.

References

[1] Sinha S K, Sirota E B, Garoff S, et al. X-ray and neutron scattering from rough surfaces[J]. Physical Review B, 1988, 38(4): 2297-2311.H. Wang, S. S. Dhesi, F. Maccherozzi, S. Cavill, E. Shepherd, F. Yuan, R. Deshmukh, S. Scott, G. van der Laan, and K. J. S. Sawhney, Rev. Sci. Instrum. 82, 123301 (2011).

[2] Wormington M, Panaccione C, Matney K M, et al. Characterization of structures from X-ray scattering data using genetic algorithms[J]. Philosophical Transactions of the Royal Society A, 1999, 357(1761): 2827-2848.

[3] Windt D L. IMD—Software for modeling the optical properties of multilayer films[J]. Computers in Physics, 1998, 12(4): 360-370.

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