High-reflectivity X-ray mirror with suppressed absorption edges over a wide energy range

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ABSTRACT

The Materials Research Collaborative Access Team's bending magnet beamline (10-BM) at Argonne National Laboratory is being upgraded to deliver a significantly higher photon flux with improved spectral resolution in the 4–32 keV photon energy range. This will allow faster X-ray absorption spectroscopy measurements. The plan is to use an aspherical focusing mirror downstream of the X-ray monochromator to collect and focus a significant part of the vertically collimated horizontally divergent beam. An X-ray mirror surface is typically coated with high-atomic-number elements such as platinum (Pt) to allow high energy photon reflection. The absorption edges of such coating materials, however, introduce experimental complications when performing spectroscopy measurements at energies near those edges.

This problem is typically addressed by coating the mirror substrate (typically silicon) with two different materials on two parallel longitudinal stripes. This option, however, is not possible for two-dimensional focusing optics.

This paper reports on a *multilayer* coating over an X-ray mirror that provides high reflectivity over the entire energy range of interest with *minimal* absorption edges. An acceptable coating was determined using numerical simulations and a pair of flat silicon mirrors were coated and tested: one with a bilayer of Pt (20 nm) and Al_2O_3 (10 nm), and another with an additional carbon layer (8 nm). The reflectivity of both mirrors was measured and then re-measured after they were both heated to 70° C for 8 hours for a stability test. Experimental results show excellent stability, high reflectivity over the entire 4–32 keV energy range, and the suppression of the Pt absorption edges to below 1% reflectivity.

Keywords: Beamline, hard X-ray, optics, mirror, multilayer, coating, edge suppression, simulation

1. INTRODUCTION

The Materials Research Collaborative Access Team (MRCAT) operates an insertion device (10-ID) [1] and a bending magnet beamline (10-BM) [2] at Sector 10 of the Advanced Photon Source at Argonne National Laboratory. The primary scientific focus of 10-BM is X-ray absorption spectroscopy (XAS) for *ex situ* and *in situ* structural characterization of materials [2]. The 10-BM beamline currently consists of a double crystal monochromator (DCM) with water-cooled Si(111) crystals detuned by 50% to suppress higher harmonics. The resolution of the beamline is maintained by limiting the *vertical* beam divergence and source size using slits upstream and downstream of the DCM. The slits, however, limit the beam intensity severely. The layout of the current beamline with the main optical components is shown in Figure 1.

The beamline is being upgraded to improve the photon flux at the sample as well as maintain high energy resolution, allowing more efficient in situ continuous XAS measurements using the upgraded storage ring at the APS (APS-U) [3]. This beamline will provide a monochromatic X-ray beam with a wide energy range (4–32 keV) to include absorption edges of as many as possible elements heavier than titanium. The upgrade plan is to add a vertically collimating mirror (VCM) upstream of the DCM and a two-dimensional focusing mirror downstream to focus up to 1 mrad horizontal fan of the APS-U bending magnet beam, as shown in Figure 1. Both mirrors will intercept the beam at a fixed angle of 0.15°. The VCM, in addition to harmonic rejection, reduces the vertical divergence of the beam incident on the monochromator and improves its throughput. Stable energy resolution of ~ 1.3×10^{-4} over 4–32 keV is expected according to previous simulation results [4]. The VCM is a tangentially bent cylinder and has three parallel stripes of bare Si, Rh, and Pt coatings side by side, for harmonic rejection in 4–11, 11–23, and 23–32 keV photon energy ranges. Limiting the vertical beam divergence and detuning the DCM to 50% are then unnecessary, significantly improving the beam intensity.

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Advances in X-Ray/EUV Optics and Components XVIII, edited by Hidekazu Mimura, Ali M. Khounsary, Christian Morawe, Proc. of SPIE Vol. PC12694, PC126940A

doi: 10.1117/12.2682020