Multifarious Activities at the APS Deposition Lab

C. Liu, J. Erdmann, A. Macrander

User Program Division, Advanced Photon Source, Argonne National Laboratory, Argonne, IL, U.S.A.

Equipped with a 1.5-m large deposition system and another smaller system,[1] the APS deposition lab is taking an active role in developing better x-ray optics as well as preparing experimental samples. Here we report various activities at the deposition lab.

1. Multistrip double multilayer monochromator (DMM) provides a larger continuous energy range.

Using the large deposition system and masks, we have deposited four different multilayer stripes onto two polished Si mirrors, each 145 mm long, 100 mm wide, and 35 mm high. The four stripes are 100 periods of W (10.7 Å)/C(14.8 Å), 100 periods of W (15.5 Å)/C(21.5 Å), 60 periods of W (6 Å)/Si (45 Å), and 35 periods of W (6 Å)/Si (66 Å). This DMM increased flux by about 35 times at 8 keV compared with that of a Si(111) double-crystal monochromator.[2]

2. Graded multilayers have many applications.

Laterally graded multilayers that have uniform W layers and wedge-shaped C layers were made for tunable x-ray double monochromator applications.[3,4] The double monochromator has two identically graded multilayers in series, as in the conventional double-crystal monochromator arrangement. By letting the x-ray beam hit slightly different d spacing on each multilayer, one can adjust the bandpass and peak energy of the transmitted beam. The graded multilayer comprised 60 bilayers of W and C with a d spacing varying from 35 to 60 Å. To make a graded multilayer, two different masks (one for uniform W and one for graded C) were used with the sputtered atoms passing them while the substrate was moving. The graded multilayers are being used in other applications, such as in x-ray fluorescence detection and x-ray standing wave experiments.[5,6]

3. Selective profile coating converts a cylindrical mirror to an elliptical one.

For microfocusing mirrors, it is desirable to have an elliptical shape, but no known technique exists for polishing elliptical mirrors to x-ray quality smoothness.[7] Using the knowledge we gained from making graded multilayers, we developed a selective profile coating technique that handily turns a cylindrical mirror into an elliptical one. A model has been developed to fit the measured thickness profile. The relative thickness weighing are then digitized at every point 1 mm apart for an area of 76 x 152 mm^2 directly above the sputter gun. When the substrate is moving across this area, the film thickness is directly proportional to the length of the opening in this area. A mask is made with its opening length (at each point 1 mm apart) calculated by equaling the summation of relative weighing to the required relative thickness. Figure 1 shows the required thickness to change a 90-mm-long cylindrical mirror to an elliptical one.[8] Figure 2 shows a corresponding mask installed above a Au target. Preliminary tests using Au as a coating material showed encouraging results.

4. K-B mirror with benders works as well.

Peter Eng (CARS-CAT) has demonstrated that flat K-B mirrors can focus a x-ray beam to a submicron spot using bending techniques.[9] A total of over 100 K-B mirrors of Rh (or Pt, Pd) on Si or glass have been coated at the deposition lab for the users.

5. Ellipsometry probes growth mode and guides to smoother film systems.

All x-ray mirrors require a smooth surface. We have developed a technique to check film smoothness using our spectroscopic ellipsometer.[10,11] A smooth film can be fit with a "flat-film" model, while a rough film needs a "rough-film" model. We found that a Cr film on Si or glass is smooth when it is 10 nm or less. It becomes rougher when the film grows thicker. We found out also that a Au or Rh film is smooth when the Cr underlayer is 10 nm or less.

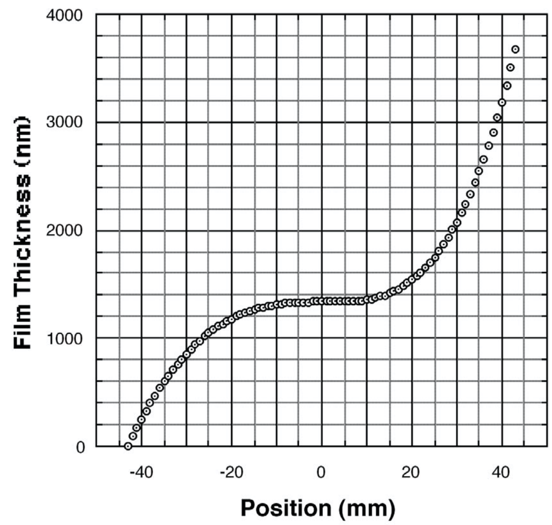

FIG. 1. Calculated thickness needed to convert a 90-mm-long cylindrical mirror to an elliptical one.

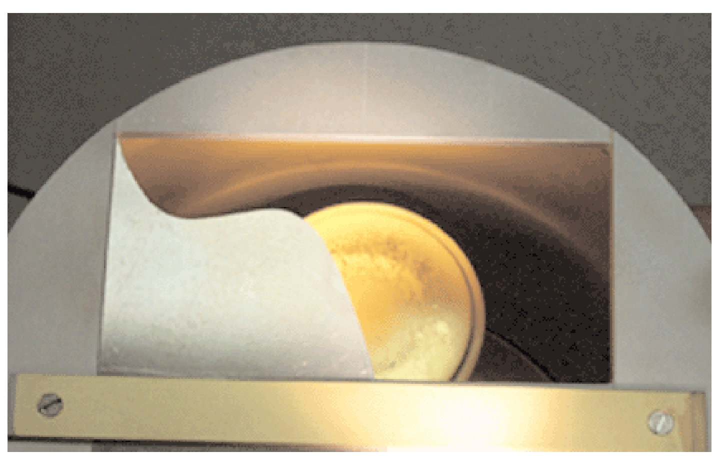

FIG. 2. A designed mask to produce the desired thickness profile in Fig. 1, with a 3-inch-diameter Au target visible underneath of the mask. Only the left half was used, with the 90-mm-long mirror passing on the left side during the deposition in a direction perpendicular to the mask-holding bar (two mirrors can be coated side by side by adding another mask on the right side).

6. rf sputtering produces MgF2 mirrors.

In some applications an insulating film is required, e.g., a MgF_2 coating is needed for the free-electron laser project to reflect UV light. We have developed rf sputtering for coating insulators.

7. Reactive sputtering coats TiO2 films on top of a W/Si multilayer.

In the study of electrical double-layer structures, one needs TiO_2 films.[12] We have succeeded in reactive sputtering and coating TiO_2 films on top of W/Si multilayers for x-ray standing wave experiments.[13] We designed a vacuum heater to anneal TiO2 films.[14]

8. MBE technique produces a ultrathin Fe57 film in an x-ray waveguide.

Molecular beam epitaxy (MBE) is capable of growing ultrathin films atom by atom and revealing physical properties at the nanoscale.[15,16] We have successfully combined MBE and sputtering techniques in our large deposition system. Now we can deposit ultrathin films inside other multilayers. A recent example is a ultrathin Fe^{57} film in an x-ray waveguide.[17]

After making over 520 depositions and thousands of samples, collaborations with users are still growing.

We thank R. Hopf for technique support. Use of the Advanced Photon Source was supported by the U. S. Department of Energy, Office of Science, Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

References

[1] C. Liu, J. Erdmann, A. Macrander, Argonne National Laboratory, unpublished (1997).

[2] Y. S. Chu, C. Liu, D. C. Mancini, F. De Carlo, A. Macrander, D. Shu, SRI 2001, to be published.

[3] A. Macrander, J. Als-Nielsen, C. Liu, S. Krasnicki, J. Maj, D. Mancini, J. Erdmann, P. Gaarde, Proc. SPIE **3773**, 100 (1999).

[4] C. Liu, A. Macrander, J. Als-Nielsen, K. Zhang, J. Vac. Sci. Technol. A **19**, in press (2001).

[5] K. Zhang, G. Rosenbaum, and G. Bunker, J. Synchrotron Rad., **5**, 1227 (1998).

[6] P. Fenter, L. Cheng, S. Rihs, M. Machesky, M. J. Bedzyk, and N. C. Sturchio, J. Colloid Interface Sci. **225**, 154 (2000).

[7] G. E. Ice, J. Chung, J. Z. Tischler, A. Lunt, L. Assoufid, Rev. Sci. Instrum. **71**, 2635 (2000).

[8] Data provided by L. Assoufid (UPD), J. Qian (UPD), and J. Z. Tischler (UNI-CAT).

[9] P. J. Eng, M. Newville, M. L. Rivers, S. Sutton, Proc. SPIE **3449**, 145 (1998).

[10] C. Liu, J. Erdmann, J. Maj, A. Macrander, J. Vac. Sci. Technol. A **17**, 2741(1999).

[11] C. Liu, J. Erdmann, A. Macrander, Thin Solid Films **41-48**, 41(1999).

[12] P. Fenter, L. Cheng, S. Rihs, M. Machesky, M. J. Bedzyk, and N. C. Sturchio, J. Colloid Interface Sci. **225**, 154 (2000).

[13] P. Fenter, Z. Zhang, L. Cheng, N. C. Sturchio, C. Liu, A. Macrander, M. Machesky, M. J. Bedzyk, abstract submitted to the X-ray Physics Gordon Conference (2001).

[14] C. Liu, A. Macrander, J. Vac. Sci. Technol. A **19**, in press (2001).

[15] C. Liu, E. R. Moog, and S. D. Bader, Phys. Rev. Lett. **60**, 2422 (1988).

[16] C. Liu and S. D. Bader, J. Magn. Magn. Mat. **93**, 307 (1991).

[17] D. R. Lee, Z. Islam, W. Sturhahn, C. Liu, E. E. Alp, S. K. Sinha, R. Rohlsberger, American Physical Society March Meeting, Seattle, WA, 2001.