Probing the Interfaces of Amorphous Multilayers by Diffraction Anomalous Fine Structure

J. O. Cross

PNC-CAT, Advanced Photon Source, Argonne National Laboratory, Argonne, IL, U.S.A.

Introduction

Atoms in the narrow interface regions of metal/metal and metal/semiconductor multilayers differ in local structural arrangement, chemical and magnetic properties from atoms in the bulk of the bilayers. The behavior of atoms at the interfaces usually defines the macroscopic behavior of the multilayer, and a significant part of the research effort to characterize novel multilayer structures is the characterization of the interfaces.

Part of the arsenal of structural characterization techniques, x-ray absorption fine-structure (XAFS) is an element-specific probe of the local environment and chemical state of absorbing atoms. Unfortunately, XAFS is not generally useful for characterizing multilayer interfaces since the signal from absorbing atoms in the interface regions is swamped by the signal from atoms in the interior of the film. Diffraction anomalous fine-structure (DAFS), which measures the XAFS-like fine structure on the high energy side of Bragg peaks in anomalous scattering,[1] offers hope of resolving an XAFS-like signal from interface atoms. The contribution to the multilayer Bragg peak DAFS from different lamina are weighted according to their depth within the bilayer. Using prior knowledge of the gross structure of the multilayer, the DAFS from several peaks can be combined to obtain a signal from a subset of resonant atoms localized to one region of the density profile. For epitaxial superlattices, monolayer resolution has been demonstrated.[2] For amorphous multilayers, the laminar resolution depends on the number of reflections on which the DAFS can be measured.

Experimental

The capability for rapid DAFS measurements of multilayers is currently being developed at PNC-CAT. Experiments use one of several motor-control programs (spec, EPICS user calcs, and the PNC-CAT LabView-based DAC). The sample (theta) and detector (2-theta) angles are calculated using Braggs's law for each energy of the scan. The small diffraction angles of the multilayers in the vicinity of the absorption edges allow little room for goniometer errors, therefore an active feedback circuit is used to make small angular corrections. A commercial piezoelectric angular actuator (PiezosystemJena) is mounted on the goniometer head, and the sample is held in place with a gentle adhesive gel (Scotch). The actuator is driven at a frequency around 77 Hz, somewhat arbitrary and still under evaluation, and the oscillatory part of the signal in the detector is used to lock theta on to the Bragg peak as the energy is scanned. The piezo motion is used as a small correction to the calculated theta/2-theta motions of the goniometer stages,[3] however, the +/-2 degree range of the actuator is sufficient to cover the entire range of a typical DAFS scan, 800 to 1200 eV.

Data have been collected from a several magnetic multilayer systems, including Ni/Co, Fe/Si and Gd/Fe. The current effort is focused on developing data-processing software to analyze the DAFS.

Acknowledgments

Thanks to D. Brewe, V. G. Harris, D. Haskel, S. Heald, M. Newville, and E. Stern for valuable contributions. Use of the Advanced Photon Source was supported by the U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

References

[1] L.B. Sorensen, J.O. Cross, M. Newville, B. Ravel, J.J. Rehr, H. Stragier, C.E. Bouldin, and J.C. Woicik, in *Resonant Anomalous X-Ray Scattering: Theory and Applications*, G. Materlik, C.J. Sparks, and K. Fischer, eds. (Elsevier Science, Amsterdam, 1994) pp. 389–420.

[2] J. Renevier, L. Hodeau, P. Wolfers, S. Andrieu, J. Weigelt, and R. Frahm, Phys. Rev. Lett. **78**, 2775–2778 (1997).

[3] J.O. Cross, W.T. Elam, V.G. Harris, J.P. Kirkland, C.E. Bouldin, and L.B. Sorensen, J. Synchrotron Radiat. **5**, 911 (1998)