UNH Materials Science Seminar

11:00-12:00, Thursday, April 14, 2005
DeMeritt Hall 209B, University of New Hampshire

High Resolution X-ray Reflectometry – A Critical Tool for Nanostructure Metrology and Characterization

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Because their wavelengths are similar to the sizes found in nanomaterials systems, X-ray probes are well suited to the non-destructive structural characterization of very small scale and/or thin film structures. The interactions of X-rays with atoms tend to be relatively weak (unlike, for instance, electron-solid interactions), so they can typically be described in terms of perturbations; this greatly simplifies the mathematical description of the X-ray scattering process and permits quantitative modeling of that process with relative ease. Even greater utility in nanomaterials characterization arises when the included angle between the incident and scattered X-ray beam directions is itself kept small. Because the distances probed in diffraction space (or “reciprocal space”) are reduced, the corresponding distances examined in “real” space are relatively large. X-ray scattering in the small-angle limit thus gives information on the large-scale features of a sample (when compared with interatomic spacings) and is thus insensitive to small-scale crystallography. It can thus be applied to materials irrespective of their physical state, whether they are amorphous, polycrystalline, or single crystal.

In a wide variety of thin film systems such as those used in semiconductor manufacturing, high resolution X-ray reflectometry (XRR) can be used to great advantage for structural characterization. Critical parameters such as layer thickness, chemical composition, and interfacial roughness can be obtained non-destructively using this method. While the utility of XRR has been recognized for decades, the metrology needs for modern micro- and nano-materials systems have brought this technique to a new-found level of prominence. This talk will discuss the theory that leads to the utility of XRR for nanosystems metrology; specific technical problems that they have successfully addressed with this approach will be highlighted. Of course, the ultimate utility of any metrology tool depends on the factors that limit its accuracy and precision, and XRR is no different. This talk will thus address several of the factors that limit the accuracy and precision of XRR, such as angle metrology, X-ray beam conditioning, alignment, the nature of the sample itself, and the noise that is an ever-present component of X-ray analyses. Within these limitations, however, it will be argued that X-ray reflectometry will serve an important role for non-destructive characterization and metrology in micro- and nano-materials systems for the foreseeable future.

Richard J. Matyi received his degrees in Materials Science and Engineering from Northwestern University (B.S., 1975; Ph.D., 1983) and the Massachusetts Institute of Technology (S.M., 1976). From 1982 to 1988 he was a Member of the Technical Staff at Texas Instruments, Inc., where his research involved materials characterization by X-ray methods and the growth of semiconductor materials by molecular beam epitaxy. In 1988 he joined the faculty of the University of Wisconsin, Madison WI as a Professor in the Department of Materials Science and Engineering where his research focused on advanced X-ray methods for materials analysis. Dr. Matyi left Wisconsin in 2000 to join the National Institute of Standards and Technology in Gaithersburg, MD where his work included precision X-ray metrology, the analysis of defects in inorganic and organic crystalline materials with high resolution X-ray diffraction and the application of X-ray reflectometry to semiconductor manufacturing processes. In 2004 Dr. Matyi joined the State University of New York at Albany as a Professor in the College of Nanoscale Science and Engineering. His research at Albany centers on the fabrication of nanostructures from various materials (primarily elemental and compound semiconductors) and their characterization with X-ray probes, particularly high resolution X-ray diffractometry and reflectometry.