PS-11.01.35 THE APPLICATION OF STM AND AFM IN MINERALOGICAL STUDIES IN CHINA By Liging Liang1, Zhenghe Me and Niicheng Shi, X-Ray Lab., China University of Geosciences, Beijing 100083, China.

STM and AFM have rapidly and widely been used in various study fields since they were invented by Binnig et al. in 1982 and 1986. Up to now, all the study results by STM and AFM have proved that they are really powerful devices for material surface structure studies. Their application in mineralological studies were started by Zheng et al. in 1988. In China, as far as we know, our Lab is the first group and also the only group that studied mineral surfaces with STM and AFM. We began to put STM and AFM in mineralogical studies in 1988 and 1991 respectively. Till now, seven minerals in all have been studied (five for STM and two for AFM). They are galena, molybdenite, hematite, stannite, pyrite, calcite and coal. For galena, both S and Pb atoms of its interfacial surface were observed in air under positive Vbias. For stannite, we are the first to image its surface by STM and atomic resolution images of its surface were obtained. For pyrite, some new phenomena were observed which can not be explained satisfactorily by pyrite known band data. Therefore, it is wait for further studies. Calcite and coal surfaces were studied by AFM. Some interesting results have already been obtained.

11.02 - Thin Film Structures

MS-11.02.01 THE STUDY OF CHEMICAL INTERFACES AND SURFACES USING NEUTRON REFLECTIVITY, BY J. Penfold, Isis Science Division, Rutherford Appleton Laboratory, UK.

The specular reflectivity of neutrons is now well established as a technique for the study of surfaces and interfaces. In combination with isotopic labelling, it has been shown to be a powerful technique for the study of problems in Surface Chemistry. Examples of its use include the determination of adsorbed molecules and maintenance of surfactants, polymers, proteins and their mixtures at the air-fluid and liquid-solid interfaces will be described. Particular emphasis will be placed on the study of surfactants and mixed surfactants adsorbed at the air-fluid interface.

MS-11.02.02 SPECULAR AND DIFFUSE SCATTERING STUDIES OF INTERFACES, BY M.R. Sanyal, Solid State Physics Division, Bhabha Atomic Research Centre, Bombay 400 085, India.

The availability of intense synchrotron X-ray sources has resulted in a rapid growth of new techniques to investigate the interface structures of thin films. In this talk we shall discuss the use of specular and diffuse scattering studies to understand the interface structures in single layer and multilayer thin films. It has been shown (Sanyal et al., Phys. Rev. Lett., 1991, 66, 628) that capillary wave fluctuations lead to remarkable long-range algebraic decay of the density correlations at liquid-vapour interfaces as a consequence of dimensionality; this in turn produces power law tails in the diffuse scattering. We shall discuss our recent results of the analysis of polymer surfaces done using similar approach.

We present a new method (Sanyal et al., Euro-Phys. Lett., in Press) of obtaining a model independent electron density profile for a thin film using X-ray reflectivity measurements carried out at energies close to, and away from X-ray absorption edge of the substrates. Using this method we shall illustrate this method using a novel wave scattering technique with synchrotron radiation. The samples were investigated both under UHV conditions on pre-deposited films and in-situ in an electrochemical cell. In this talk, we will discuss: (1) the reconstruction of the metal surface as the result of thiol adsorption, and the consequent effects of the reconstruction; (2) the global (n,7) phase diagram of CH3(CH2)3SH on a Au(111) surface which reflects the relative importance of hydrocarbon and interface interactions in these systems, and (3) the modification of the electrolyte/SAM interfaces using different lead groups and counter ions in solution. The implications of our results for future molecular design of SAM's will be discussed.

* The work is performed in collaboration with P. Feurer, J. Li, P. Eisenberger, and G. Scoles.
2 J. Li, K. S. Liang, and G. Scoles, to be published.

11-Surfaces, Interfaces and Thin Films

We have determined microroughness of mechanically polished silicon (100) surfaces from X-ray glancing-angle reflectivity data. Effects of macroscopic surface corrugations were eliminated by measuring reflectivities as a function of X-ray scattering angle \(\theta\) on a triple-axis reflectometer with Ge(111) monochromator and analyzer crystals. Three silicon samples polished using standard but different strengths of mechanical and chemical factors showed equally smooth surfaces under a YBCO optical phase-shift interferometer with Gaussian rms roughness values (\(\sigma\)) of \(3.5-4.1\) Å. X-ray Fresnel reflectivity data revealed distinct decay features of the scattering profiles for these samples. Profile fits evaluated \(\sigma\) values at 11-12 Å under oxide layers of a density close to 2.0 g/cm\(^3\). The disagreed \(\sigma\) values could be explained by the different lateral resolutions (nanometers versus micrometers) of the X-ray and optical methods. Nonlinear least-squares profile fits also indicated a stoichiometry not far from Sr\((0.5)\) for the overlayer oxide.

The same technique was applied to (Ni, Fe) multilayers for magnetic disk applications. The samples, prepared on a multilayer technique as a single-layer technique, include two magnetic layers with slightly different alloy compositions on the both sides of a Ta isolation layer. X-ray reflectivity data determined the [001] SL with a thickness of each layer (60-200 Å) to 5 Å accuracy with \(\sigma\) values at the (Ni, Fe)-Ta interfaces at 14-15 Å. A 39 Å-thick oxide layer was found on top of the first magnetic layer.

MS-11.02.05 GROWTH AND STRUCTURE OF SINGLE CRYSTAL COPPER-NICKEL COPPER-LATTICE ALLOYS† M. K. Saha, M. R. N. N. T. Nagaoka, T. Nagahara, N. Sato, and T. Terashi, School of Science, Kwansei-Gakuin University, Nishinomiya 662, JAPAN; A. Yoshimura, RISM, Tohoku University, Sendai 980, JAPAN.

In recent years, there is a great deal of attention due to the specific features arising from metallic superlattices (SLS). Anomalous elastic feature, called supermodulus effect, was found on copper/nickel SLs in the vicinity of the modulus wavelength of 17 Å (T. Taekahara et al., J. Appl. Phys., 1983, 53, 734). In 1993, Kumar et al. (S. Kumar, B. Bhardwaj, A. Pattan, and M. Gunaidich, Phys. Rev., 1991, B44, 5905) and Davis et al. (B. C. Davis, D. N. Seidman, A. Moreau, J. L. Ketterson, and M. Gunaidich, Phys. Rev., 1991, B43, 9304), reported spectral results on the supermodulus effect in Cu/Al systems.

Single crystal (111)- and (001)-Cu/Al SL were successfully grown by molecular beam epitaxy. In-plane epitaxy was characterized by the grazing incidence X-ray measurement as well as by the in-situ reflection high energy electron diffraction (RHEED). Total thickness of the superlattices was kept 400 Å for the Brillouin scattering measurement. The periodic structure was verified by the X-ray satellite peak even from the modulation wavelength of 17 Å, implying that the superlattice gave the distinct modulation profiles. The streak RHEED pattern observed during superlattice growth indicates the fairly smooth interface/surface. Brillouin scattering measurement of the single crystal SL showed large increase in the surface phonon velocity propagating along [110] direction on the [111] SL, and little increase in that along [001] SL.

Points, segments and plains have fractal dimensions (FD) 0, 1, and 2 respectively. But in between these objects with integer dimension, lies complex, irregular objects whose FD can be defined as a measure of their irregularity. The FD of an irregular surface can lie between 2 and 3 depending on how much volume it fills. Thus FD can be used to compare the complexity of surfaces, and therein lies its importance for applications. In material science, FD is directly related to surface roughness. Other modes of surface roughness characterization require a large number of parameters for qualitative and quantitative description where as a FD can give us a simple, one-parameter definition of surface roughness.

Surfaces of such films formed from the vapor phase arise due to such nucleation and growth processes as transport, diffusion, condensation and coalescence and so can be modeled as fractals. Since the real picture or the three dimensional image of the surface can be obtained by using Scanning Tunneling Microscopy, it has become possible to extend fractal analysis to characterize thin film surfaces. The evaluation of FD of the surface \(S\) utilizes a profile \(P\), which is a section of \(S\) by a plane, whose FD is evaluated using box-counting method. The FD of the surface is given by \(1 + \text{FD}_{\text{profile}}\). The box-counting method involves counting the number of boxes \(N(L)\) through which the profile \(P\) passes for a given box length \(L\). By varying \(L\) in a sequence, \(N(L)\) is counted for each case. The slope of the line obtained by plotting \(\log(N(L))\) against \(\log(\text{length}/L)\) gives the FD of the profile.

Fractal characterization of YBa\(_2\)Cu\(_3\)O\(_y\) (YBCO) films has been carried out and an attempt has been made to correlate their physical properties with their FDs. These films are prepared by rf magnetron sputter deposition on MgO at room temperature from a single target and subsequently annealing at a high temperature (950°C) in oxygen ambient. During our investigation, a 1 µm x 1 µm STM topograph of YBCO thin film surface was recorded as 256 x 256 data points. A topograph of YBCO film annealed at 980°C is shown in the diagram below.

The FD of the YBCO thin film surface \((T_{\text{anneal}}=950°C)\) calculated by box-counting method is around 2.03 ± 0.005. It has been observed that the FD value decreases as the film goes from non-superconducting \((T_{\text{anneal}}<900°C)\) to superconducting phase \((T_{\text{anneal}}>900°C)\). After the formation of superconducting phase, FD value increased with annealing temperature along with increase in size of the grains which are having small growth steps.