11-Surfaces, Interfaces and Thin Films

We have determined microroughness of mechanochemically 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 2ϕ 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 WYCO optical phase-shift interferometer with Gaussian rms roughness values (σ) 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 σ values at 11~12 Å under oxide layers of a density close to 2.0 g/cm³. The disagreed σ 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 SiO_2 for the overlayer oxide.
The same technique was applied to (Ni, Fe) multilayers for magnetic disk applications. The samples, prepared on a glass substrate by a sputtering technique, include two magnetic layers with slightly different alloy compositions on the both side of a Ta isolation layer. X-ray reflectivity data determined the thickness of each layer (80~200 Å) to 3 % accuracy with σ values at the (Ni, Fe)-Ta interfaces at 14~15 Å. A 30 Å-thick oxide layer was found on top of the first magnetic layer.

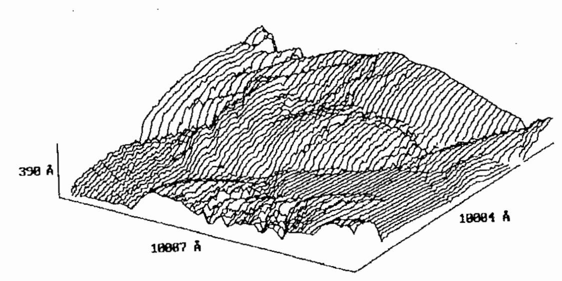
MS-11.02.05 GROWTH AND STRUCTURE OF SINGLE CRYSTAL COPPER/NICKEL SUPERLATTICES. By K. Sakaue*, M. Niboshi, T. Nagahara, N. Sano and H Terauchi, School of Science, Kwansei-Gakuin University, Nishinomiya 662, JAPAN; A. Yoshihara, RISM. Tohoku University, Sendai 980, JAPAN.

In recent years, there is a great deal of attention due to the specific features arised from metallic superlattices (SL's). Anomalous elastic feature, called supermodulus effect, was found on copper/nickel SL's in the vicinity of the modulation wavelength of 17Å (T. Tsakalakos *et al.*, J. Appl. Phys., 1983, 54, 734.). In 1991, Kumar *et al.* (S.Kumar, R.Bhadra, A.Fartash and M.Grimsditch, Phys. Rev.,1991, B44 5905.) and Davis *et al.* (B.M.Davis, D.N.Seidman, A.Moreau, J.B.Ketterson, J.Mattson and M.Grimsditch, Phys.Rev., 1991, B43 9304.) reported skeptical results on the supermodulus effect in Cu/Ni systems.
Single crystal (111)- and (001)-Cu/Ni SL were successfully grown by molecular beam epitaxy. In-plane orientation 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 4000Å for the Brillouin scattering measurement. The periodic structure was verified by the X-ray satellite peak even from the modulation wavelength (Λ) of 10Å, implying that the superlattice gave the distinct modulation profile. 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 propergating along [1$\bar{1}$0] direction on the [111] SL and little increase in that along [100] on the [001] SL.
We will discuss the epitaxy, crystalliniy and perfection of the SL from the X-ray measurement and transmission electron micrography.

PS-11.02.06
FRACTAL ANALYSIS OF $YBa_2Cu_3O_7$ THIN FILM SURFACE USING STM TOPOGRAPHS By M. V. H. Rao, B.K. Mathur* and K. L. Chopra, Department of Physics, Indian Institute of Technology, Kharagpur 721 302, India.

Points, segments and plains have fractal dimensions(FD) 0, 1 and 2 respectively. But in between those objects with integer dimension, lies complex, irregular objects whose FD can be thought of 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 thin 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 areal 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 $FD_{surface}$ is given by $1 + FD_{profile}$. 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 ln(N(L)) against ln(profile length/L) gives the FD of the profile.
Fractal characterization of $YBa_2Cu_3O_7$ (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 subsequent annealing at a high temperature(850-980°C)in oxygen ambient. During our investigation, a 1μm x 1μm STM topograph of YBCO thin film surface was recorded as 256 x 256 data points. A topograph of YBCO filmannealed at 980°C is shown in the diagram below.



The FD of the YBCO thin filmsurface (T_{anneal} = 850°C) calculated by box-counting method is around 2.03 ± 0.005. It is observed that the FD value decreases as the film goes from non superconducting (T_{anneal} < 900°C) to superconducting phase (T_{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 many growth steps.

