Magnetic Interfaces and Nanostructures Technical Group Room 618/619 - Session MI-FrM

Magnetic Thin Films

Moderator: C.J. Palmstrom, University of Minnesota

8:20am **MI-FrM1 New Phenomena in Laterally Modulated Magnetic Thin Films**, ***Z.Q. Qiu,*** University of California, Berkeley **INVITED**

Ultrathin magnetic films grown on atomically stepped surfaces exhibit many interesting properties due to the lateral modulation at the nanometer scale. To systematically control the atomic steps curved substrates are utilized to provide a continuous range of step density. Fe and Co films grown on curved Ag(001), W(001) and Cu(001) have been investigated by means of the surface magneto-optic Kerr effect. The atomic steps induce an in-plane, uniaxial magnetic anisotropy with the easy axis either parallel or perpendicular to the step edges. The strength of the step-induced anisotropy is linearly roportional to step density for fcc magnetic films, but scales quadratically for bcc magnetic films. The Neel pair-bonding model provides a possible explanation for these observations. Even more intriguing results occur when substrate magnetism is induced at the stepped interface, as for the Fe/Pd(001) system. The ferromagnetic nature of the interfacial fcc Pd dominates the anisotropy to result in a linear dependence of the step-induced anisotropy on step density even though the Fe overlayer is bcc. The step-induced moment in this system is also shown to enhance the Curie temperature. Finally, for the Fe/Cr(001) system, the compensated, stepped Cr(001) surface is found to produce a 90-degree coupling between the Fe and Cr moments. When this effect competes with the step-induced anisotropy, the Fe magnetization undergoes an in-plane spin-reorientation transition from perpendicular to parallel to the step edges with increasing step density.

9:00am **MI-FrM3 Interrelation of Morphology and Structure in Ultrathin Magnetic fcc FeCo Alloy Films on Cu(001)**, ***W. Kuch,*** *A. Dittschar,* Max-Planck-Institut für Mikrostrukturphysik, Germany; *M. Zharnikov,* Universität Heidelberg, Germany; *C.M. Schneider,* Institut für Festkörper- und Werkstofforschung Dresden, Germany

Chemically random epitaxial ultrathin alloy films allow the study of correlation between morphology, structure, and magnetism for continuously varying structural parameters. This can be achieved if variation of the film composition leads to a continuous alteration of film properties such as the lattice constant and the average magnetic moment. We present a multi-technique investigation of structure, morphology, and magnetism of epitaxial Fe@sub x@Co@sub 1-x@ alloy ultrathin films grown on Cu(001) over the whole composition range up to thicknesses of 9 ML. The films grow at room temperature in a distorted fcc structure with random chemical order. The amount and sign of the distortion depend on thickness and composition. Below 60-70% Fe content the alloy films are smooth and tetragonally compressed in the vertical direction in the interior of the films, with tetragonally expanded layers at the surface. The strain is continuously reduced with increasing Fe concentration, and at 60-70% Fe content the interior of the films reaches the unstrained fcc structure. For higher Fe concentrations the occurrence of several superstructures is observed, which are attributed to regular structural rearrangements. At the same time the roughness of films with more than 4-6 ML is significantly enhanced. This is discussed in terms of the vertical strain at Fe concentrations above 70%, the sign of which is reversed with respect to lower Fe concentrations, leading to tetragonally expanded layers. No indications for the presence of low-moment fcc Fe were found in any of the films.

9:20am **MI-FrM4 Structure and Magnetic Properties of Cu/Co/Cu/H-Si(110) Films**, ***S. Maat***, *M.T. Umlor, G.J. Mankey,* University of Alabama

We report the results of a study of the structural and magnetic properties of Co films deposited on Cu/H-Si(110). A Cu(111) buffer layer is formed by evaporation or UHV sputter deposition on the H-terminated Si(110) surface. From consideration of bulk lattice constants, the Cu films undergo a 6% expansion along the [1, -1, 0] direction and a 13% compression along the [1, 1, -2] direction. The structure as a function of buffer layer thickness from 1 nm to 100 nm is determined with a combination of LEED, Auger electron spectroscopy and RHEED. The optimum sputtering conditions for producing well-ordered fcc(111) films were determined. The buffer layer crystallography was found to be strongly dependent on the sputtering conditions, with a transition from polycrystalline to single-crystal as the sputtering power is increased. Evaporated films were found to grow as single crystals. Co films grown on single-crystal buffer layers exhibit a six-fold LEED pattern with diffuse spots. The Co films were capped with a protective Cu layer and the magnetic properties were measured ex-situ with MOKE and MFM. MOKE data perpendicular to the Cu [1, -1, 0] direction reveals a stepped hysteresis loop shape characteristic of a combination of triaxial and uniaxial in-plane anisotropy. This loop shape is attributed to a combination of uniaxial strain incorporated in the films and the three-fold crystalline anisotropy of the hcp structure. @FootnoteText@ Supported by DOD grant DAAH04-96-1-0316 and shared equipment through NSF grant DMR-9809423.

9:40am **MI-FrM5 Magnetization Reversal in Ultrashort Magnetic Field Pulses**, ***H.C. Siegmann***, *C.H. Back,* Swiss Federal Institute of Technology, Switzerland; *R. Allenspach,* IBM Zurich Research Laboratory, Switzerland **INVITED**

Ultrashort magnetic field pulses with amplitudes of up to 20 Tesla at picosecond duration are generated in the final focus test beam facility of the Stanford Linear Accelerator. These unique magnetic field pulses have been used to study magnetization reversal in a variety of thin ferromagnetic films. High resolution magnetic contrast images reveal the magnetization patterns generated by one or several field pulses from which we deduce the elementary processes responsible for the magnetization reversal. For perpendicular magnetized samples we observe ring domains which are reminiscent of the field contour lines during exposure. Their radii represent switching fields which are in quantitative agreement with the coherent rotation model. The broadening of the transition region between oppositely magnetized domains is due to static and dynamic fluctuations of the magnetic anisotropy. For films with uniaxial anisotropy in the plane of the film we observe "figure 8" magnetic patterns due to the necessity to conserve angular momentum while generally much smaller fields compared to the perpendicular samples are sufficient for the ultrafast reversal. We show that the demagnetizing field produced by the precession of the magnetization out of the plane of the film completes the reversal after the external field ceases to exist. The material property of primary importance in ultrafast reversal is the damping of the precession of the magnetization around the direction of the external field. We show that it is strongly influenced by the degree of crystallinity of the sample.

10:20am **MI-FrM7 Ginzburg-Landau Theory of Perpendicular Magnetized Ultrathin Films**, ***A. Berger,*** Argonne National Laboratory

Ultrathin ferromagnetic films have been found to exhibit a strongly enhanced magnetocrystalline anisotropy, which can even be sufficient to overcome the demagnetizing effect and stabilize a perpendicular magnetized state in the entire ferromagnetic temperature range. Such perpendicular magnetized systems have been particularly interesting with respect their thermodynamic properties and were reported to confirm predictions for the two-dimensional Ising model. However, recent experiments on perpendicular magnetized Ni/Cu(100)-films have shown indications for domain formation near the Curie temperature that seems to occur without weakening of the effective anisotropy (crystalline + dipolar).@footnote 1@ Therefore, this observation seems to be fundamentally different from earlier results reported for a number of ultrathin film systems where domain formation is found in the immediate vicinity of the reorientation phase transition, which is associated with the vanishing of the effective anisotropy. To understand the above phenomena we have evaluated the free energy of a perpendicular magnetized material using the Ginzburg-Landau theory. In accordance with previous results, we find that for sufficiently large anisotropy values no conventional domain structure is formed at any temperature. However, we find that a domain structure based on the formation of linear domain walls (LDW-phase) lowers the energy in a substantial region around the critical point. In addition, the domain size is estimated to be microscopically small so that this domain structure should be formed for any realistic sample size. We will discuss the details of the calculated phase diagram with particular emphasis on the implication that the LDW-phase prohibits a direct ferromagnetic, paramagnetic phase transition. Work supported by the U. S. Department of Energy, Basic Energy Sciences, Materials Science under Contract W-31-109-ENG-38. @FootnoteText@ @footnote 1@P. Poulopoulos et al., Phys. Rev. B 55, 11961 (1997).

10:40am **MI-FrM8 Dimensional Crossover in Ultrathin Ni Films on Cu**, ***R. Zhang,*** The Pennsylvania State University; *M. Hochstrasser,* The Pennsylvania State University, U.S.; *N. Gilman, R.F. Willis,* The Pennsylvania State University

Theory predicts that in a magnetic system the long-range order parameter, the magnetization, as a function of the temperature disappears at the Curie temperature according to M=M@sub 0@(1-T/T@sub C@)^@beta@. For 3D Heisenberg and Ising systems @beta@ are 0.365 and 0.325 respectively. For 2D Ising system @beta@ is 0.125. In our experiments, we have studied the finite-size-effect shift of the T@sub C@(n) of a thin film of n layers, as phenomenologically described by the shift exponent @lambda@. There are two ways of defining this exponent. Traditionally, one measures the shift of T@sub C@(n) with respect to the bulk critical temperature T@sub C@(bulk). Alternatively, one may also define: @Delta@T:=[T@sub C@(bulk)-T@sub C@(n)]/T@sub C@(n) ~ n^(-@lambda@'), which defines @lambda@'. We studied with the surface magneto-optical Kerr effect (SMOKE) the behavior of @beta@ and @lambda@ of Ni films on Cu(100), Cu(110) and Cu(111) in a wide temperature range and with changing thickness. We observe a different behavior for films on Cu(100) and Cu(110) compared to films on Cu(111). Ni films on Cu(100) and Cu(110) show a sharp transition from a 3D Heisenberg @beta@ value to a 2D exponent of ~0.21, whereas for Ni films on Cu(111) no such sharp transition can be observed. This behavior is a strong indication of the role of quantum size effects on the behavior of electronic states, i.e., the sharp transition is a manifestation of quantum-well states existing in a gap in the bulk continuum of sp states, and the absence of such a gap along the direction (E.D. Hansen et al. J.Phys, 9, L435 (1997)). The transition is indicative of a cross-over from 3D to 2D. The finite-size scaling exponents reflect the magnetic behavior of the bulk phase with corrections, as recently argued theoretically by Henkel et al.(PRL, 80, 4783 (1998)). What this work shows is that field theoretic corrections are sensitive to the symmetries of the epitaxial lattices.

11:00am **MI-FrM9 Enhancement of Perpendicular Magnetic Anisotropy and Surface Alloy of Co/Pt(111) Ultrathin Films***, C.S. Shern, H.Y. Her,* ***Y.E. Wu****,* National Taiwan Normal University, ROC

The magnetic anisotropy of Co/Pt(111) was studied by surface magneto-optic Kerr effect (SMOKE). The perpendicular magnetic anisotropy appears for Co deposited on a flat Pt(111) surface with a thickness between 0.8 and 3.7 ML. The perpendicular uniaxial magnetic anisotropy disappears for Co deposited on a sputtered Pt(111) surface because the magnetocrystalline anisotropy has diminished due to the absence of crystalline structure in the films. During surface alloy formation in 1 ML Co on the flat Pt(111) surface, we quantitatively demonstrate an enhancement in the magneto-optic Kerr signal. The maximum enhancement in MO signal is as large as 200 % after alloy formation at 710 K. The formation of Co-Pt alloy was confirmed by AES and LEED. The perpendicular magnetic anisotropy persists in the annealing process until the ultrathin film is annealed at temperatures above 850 K. The enhancement is also observed in thicker films when the formation of Co-Pt alloy has been developed, but both the out-of-plane and the in-plane anisotropy appear at a higher annealing temperature.

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