Magnetic Interfaces and Nanostructures
Room 316 - Session MI+NS-TuM

Magnetic Imaging and Magnetic Spectroscopies
Moderator: G.D. Waddill, University of Missouri - Rolla

8:20am **MI+NS-TuM1 Characterization of Magnetic Thin Films and Nanostructures using Electron Microscopy**, ***D.J. Smith***, Arizona State University **INVITED**

The reduced dimensions of magnetic thin films and nanostructures lead to major and often unexpected changes in magnetic properties and behavior. In addition to intrinsic scientific importance, these novel characteristics have obvious relevance to current and projected technological needs. Successful implementation of this technology requires a detailed understanding of materials growth mechanisms. Chemical and crystallographic structure must be correlated with micromagnetic structure and dynamic response before the fundamental limits of device performance can be firmly established. For example, atomic-level imaging and microanalysis of structural and chemical changes induced by changes in growth temperature or by post-deposition annealing are essential for explaining enhanced magnetic properties of antiferromagnetic pinning layers and magnetic tunnel junctions. And electron holography allows direct visualization of magnetization behavior within patterned nanostructures. This talk will provide an overview of electron microscopy and related techniques, with illustrative examples that demonstrate the major contributions being made to ongoing studies of magnetic thin films and nanostructures.

9:00am **MI+NS-TuM3 Imaging of Magnetic Nanoislands at the Thermal Stability Limit**, ***M. Bode***, *O. Pietzsch, A. Kubetzka, R. Wiesendanger,* University of Hamburg, Germany

Within the past decade spin-polarized scanning tunneling microscopy (SP-STM) became a mature tool for high spatial resolution imaging of the static domain structure of ferro- and antiferromagnetic surfaces.@footnote 1-3@ Recently, we successfully observed the temperature-dependent switching behavior of Fe monolayer islands which were pseudomarphically grown on a Mo(110) substrate and exhibit an perpendicular easy axis. Our SP-STM results show that at temperatures between 15 and 26 K Fe islands consisting of 250-600 atoms (area 20-40 nm@super 2@) are superparamagnetic, i.e., they change their magnetization direction on a time scale of 0.1-1000 s. Small islands were found to switch more often than larger islands as can be expected on the basis of anisotropy barrier considerations. A quantitative analysis reveals, however, that the observed size-dependent variation of the switching rate is much larger than theoretically expected. Possible origins of this behavior are discussed in terms of the island shape and environment. @FootnoteText@@footnote 1@ S. Heinze et al., Science 288, 1805 (2000).@footnote 2@ A. Wachowiak et al., Science 298, 577 (2002).@footnote 3@ M. Bode, Rep. Prog. Phys. 66, 523 (2003).

9:20am **MI+NS-TuM4 Scanning Tunneling Spectroscopy of Magnetic Impurities at Metal Surfaces**, ***M.A. Schneider***, Max Planck Institute for Solid State Research, Germany **INVITED**

A single magnetic impurity in a metal host is a paradigm of many-body physics in electronic systems. The spin-flip scattering of host electrons at the impurity site leads to the formation of a correlated electron state, the Kondo state. Only recently has it become possible to study this state using Scanning Tunneling Spectroscopy (STS) for magnetic surface impurities.@footnote 1-5@ Through this method, magnetism and properties of the adsorbate-host interaction can be determined in a local, atomic-scale measurement. The Kondo state is characterized by the formation of a resonance at the Fermi energy, which allows to access the characteristic energy scale, the Kondo temperature T@sub K@ of the system. We discuss the properties of the Kondo state created by the interaction of the magnetic atom with surface and bulk electrons, and the role of the tunneling process in the appearance of the resonance in STS spectra. The interaction of the magnetic impurity with two-dimensional surface-state electrons is demonstrated by the measurement of a resonant scattering phase-shift for Co adsorbed on Ag(111).@footnote 4@ However, this interaction with surface-state electrons is only weak, the main properties of the Kondo state are determined by the interaction with bulk electrons. This is corroborated by experiments comparing Co impurities on various Cu surfaces where the decisive role of the number of interaction channels to bulk electrons in the atomic-scale system is shown.@footnote 5@. @FootnoteText@ @footnote 1@ J.-T. Li, W.-D. Schneider, R. Berndt, B. Delley, Phys. Rev. Lett. 80, 2893(1998)@footnote 2@ V. Madhavan, W. Chen, T. Jamneala, M. F. Crommie, N. S. Wingreen, Science 280, 567 (1998) @footnote 3@ H.C. Manoharan, C. Lutz, D. M. Eigler, Nature 403, 512 (2000)@footnote 4@ M. A. Schneider, L. Vitali, N. Knorr, K. Kern, Phys. Rev. B 65, 121406(R) (2002)@footnote 5@ N. Knorr, M. A. Schneider, L. Diekhöner, P. Wahl, K. Kern, Phys. Rev. Lett. 88, 096804 (2002).

10:00am **MI+NS-TuM6 A Practical Guide to the Interpretation of Point-contact Andreev Reflection Data**, ***R.J. Soulen***, *G.W. Woods, I. Mazin, M. Osofsky,* Naval Research Laboratory

Point-contact Andreev reflection (PCAR), has become a useful tool in determining the spin polarization, P, of magnetic materials. It consists of establishing a point contact between a sharpened superconductive point and a magnetic base (or, vice versa), and measuring the conductance G of the junction as a function of the applied voltage, V. The value of P can be extracted from the conductance data through use of a modified Blonder, Tinkham, Klapwijk (BTK) model of the supercurrent conversion at the superconductor-metal interface (Andreev reflection). This algorithm, however, does not take into account several factors which depend on properties of the point contact: whether it is in the ballistic or diffuse regime, ratio of the spreading resistance to the junction resistance, the value of the superconducting energy gap. These properties are often difficult to measure or estimate so that the practitioner is left without a means to assess the error in the value of P. We have systematically examined these effects (by theory and experiment) and can offer some new and practical guidance on how to correct for them and to estimate the error. We use data on several materials (CrO2, SrRuO, and LaSrMnO) taken in our laboratory and in others to illustrate the process.

10:20am **MI+NS-TuM7 Preparation and Magneto-Optical Spectroscopic Studies of Diluted Magnetic Semiconductor Quantum Dots and Related Nanostructures: Potential Building Blocks for Spintronics Applications**, ***D.R. Gamelin***, *D.A. Schwartz, P.V. Radovanovic, N.S. Norberg, J.D. Bryan,* University of Washington **INVITED**

Diluted magnetic semiconductors (DMSs) are currently the focus of intense applications-oriented research in the emerging area of spin-based electronics, or "spintronics." DMS nanostructures such as quantum dots (DMS-QDs), quantum wells, quantum wires, and epitaxial thin films are pivotal architectural elements in many proposed spintronics devices including spin-dependent LEDs, field-effect transistors, and quantum computers. A central challenge facing the development of this technology is the identificati on of semiconductors that combine the necessary properties of conductivity and ferromagnetic ordering at temperatures above room temperature. This seminar will present our group's recent advances in the development of direct routes for preparation of freestanding high-quality DMS quantum dots. Emphasis will be placed on the application of magneto-optical spectroscopic methods (including magnetic circular dichroism and Zeeman spectroscopies) to study the electronic structural properties of these materials. Spectroscopic identification of ligand field, charge transfer, and excitonic transitions in DMSs will be presented in the context of their functional properties. The use of variable-temperature variable-field magneto-optical methods to define ground state spin-orbit splittings, and the influence of such splittings on the magnitudes of semiconductor band level Zeeman splittings, will also be discussed.

11:00am **MI+NS-TuM9 Magnetic Linear and Circular X-ray Dichroism Studies of the Magnetic Instability of Fe(x)Ni(1-x) Pseudomorphic Thin Films Exhibiting the Invar Effect**, ***S.A. Morton***, Lawrence Berkeley National Laboratory; *M. Hochstrasser,* Lawrence Livermore National Laboratory; *N.A.R. Gilman, R.F. Willis,* Pennsylvania State University; *G.D. Waddill,* University of Missouri - Rolla; *J.G. Tobin,* Lawrence Livermore National Laboratory

At a composition of 65% Fe, bulk Fe(x)Ni(1-x) alloys exhibit the invar effect: a sudden change in the atomic volume which is associated with a dramatic change in the magnetic ordering from a high-spin high-volume state to a low-spin low-volume state at higher Fe concentrations; this results in a collapse in the magnetic moment and Curie temperature. Magnetic X-ray Linear Dichroism measurements of the Fe and Ni 3p exchange splitting have been used as a probe of the element specific Fe and Ni magnetic moments for ultra thin fcc FeNi/Cu(100) films across the full compositional range. These results have been further complemented by composition dependent Magnetic X-ray Circular Dichroism measurements of the element specific orbital and spin moment contributions. The data shows excellent agreement with published neutron and SQUID magnetometry

measurement and with theoretical predictions of the Fe and Ni atomic moments based upon the 2gamma state model and the Slater Pauling Curve. Furthermore, the data demonstrate the potential for the use of magnetic linear dichroism as a quantitative element specific magnetometer in a wide variety of magnetic thin film systems.

11:20am **MI+NS-TuM10 Magnetic Circular X-ray Dichroism of Gd2O3 Nanoparticles**, ***K. Uvdal***, *R.M. Petoral, Jr., F. Söderlind, P.-O. Käll,* Linköping University, Sweden

In this study we are investigating the possibilities to use magnetic circular X-ray dichroism (MCXD) to probe the magnetic properties of Gd2O3 nanoparticles. The Gd2O3 nano particles were further characterized by means of X-ray Photoelectron Spectroscopy (XPS) to investigate the elemental composition the nanoparticles as well as verifying the oxidation level. The particle size of Gd2O3 nanoparticles is estimated from Atomic Force Microscopy (AFM) and transmission electron microscopy (TEM). The elemental composition shows high carbon content, which is expected due to the synthesis pathway. The relative carbon content could be reduced by Ar sputtering of the Gd2O3 nano particles, in good agreement with earlier studies on CoO. MCXD is used to determine the orbital-to-spin relative magnetic moment. It is shown that the orbital-to-spin relative ratios are greatly enhanced for sputtered sample. Gd2O3 nanoparticles show a superparamagnetic behaviour at room temperature and a large orbital contribution to the magnetic moment at low temperature. MCXD is show to be a powerful tool for investigating magnetic properties of small volume samples.

11:40am **MI+NS-TuM11 Magnetism in Transition-metal Alloy Films: Lineshape Analysis of Magnetic Linear Dichroism Angle-selective Photoemission Spectra**, ***R.F. Willis***, *N.A.R. Janke-Gilman,* The Pennsylvania State University

MLD photoemission measurements using synchrotron radiation to excite atomic core levels are reported for thin epitaxial films of transition-metal binary alloys.@footnote 1@ Careful background subtraction gives spectral lineshapes which are analyzed to give information on the magnitudes of the elemental magnetic moments and the degree of local magnetic order. The width of the dichroism spectrum is shown to relate to the magnitude of the moment, while the amplitude reflects the local magnetic anisotropy and ordering. Dichroism spectral widths and amplitudes are plotted as a function of alloy composition, reflecting changing magnetic behavior. The elemental spectral widths track the Slater-Pauling curve showing changing moments as a function of changing composition. Changing spectral amplitudes are compared with neutron scattering results which show changing magnetic anisotropy and magnetic order. @FootnoteText@ @footnote 1@ Measurements taken on Beamline 7.0.1 at the Advanced Light Source, Berkeley, CA.

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