Magnetic Interfaces and Nanostructures
Room 2006 - Session MI-TuA

Magnetic Thin Films and Multilayers

Moderator: F.C.S. da Silva, University of Colorado at Denver and Health Science Center

2:20pm **MI-TuA2 Spin-Polarized Quantum-Well States in Ni/Cu Thin-Film Structures**, ***V. Renken,*** Westfälische Wilhelms-Universität, Germany; *D.H. Yu,* Australian Nuclear Science and Technology Organisation; *M. Donath,* Westfälische Wilhelms-Universität, Germany

The unoccupied quantum-well states (QWS) in ultrathin films of Ni on Cu(001) and Cu on Ni/Cu(001) have been investigated by spin- and angle-resolved inverse photoemission. In ferromagnetic Ni films on Cu(001), three spin-polarized quantum-well features are clearly resolved. As predicted by the phase accumulation model, the energies of the QWS increase with increasing Ni overlayer thickness. Eventually they converge to the top of the bulk sp-band at the lower band-gap boundary as a result of a crossover from two- to three-dimensional behavior. In ultrathin Cu films on Ni/Cu(001), QWS in both the Cu and the Ni layers have been experimentally identified. For small Cu coverages up to 2.5 monolayers (ML), discrete QWS within the Cu layers are observed with the expected behavior: they shift to higher energies with increasing Cu thickness. The energetics of the QWS within the Ni layers is not influenced but their intensities are attenuated by the Cu overlayer. For Cu films thicker than about 5 ML, the discrete QWS in Cu cannot be distinguished any more. Only one spectral feature remains: the transition into the Cu sp-band. However, this transition appears at higher energy compared to bulk Cu. Upon further increase of the Cu film thickness, the sp-band transition continuously shifts to lower energies. Finally, for a thickness of more than 20 ML, it approaches the value known from the (001) surface of bulk Cu.

2:40pm **MI-TuA3 Element-Resolved Phase and Amplitude of Magnetization Dynamics in Thin Magnetic Films**, ***D.A. Arena***, *E. Vescovo, C.C. Kao,* Brookhaven National Laboratory; *Y. Guan, L. Cheng, W.E. Bailey,* Columbia University **INVITED**

In high-speed (GHz range) magneto-electronics, both the phase and amplitude of precession of different constituents (e.g. layers, impurities) determines the dynamic response of the device. To date, most information on the relative phase and amplitude of precession of different elements in ferromagnetic (FM) films must be deduced from theoretical models developed to analyze dynamic measurements which average over the sample. We present the first measurements of element- and time-resolved ferromagnetic resonance (ETR-FMR) in magnetic thin films at GHz frequencies. With ETR-FMR the dynamic response of individual layers in complex structures can be measured as well as the precession of individual elements in an alloy or compound. ETR-FMR also provides extremely accurate measurements of the precession cone angle (to 0.2°) and the phase of oscillation (to 2°). With this degree of precision and the ability to detect the dynamics of individual elements, fundamental assumptions implicit in phenomenological theories such as the Landau-Lifschitz-Gilbert approach can be investigated in a direct fashion. We have used ETR-FMR to measure the response of specific elements and separate layers in several alloys and structures. These include the Fe and Ni moments in a single film of Ni@sub 81@Fe@sub 19@, layer-resolved FMR measurements of a pseudo-spin valve structure of two FM layers separated by a non-magnetic spacer (Ni@sub 81@Fe@sub 19@ / Cu / Co@sub 93@Zr@sub 7@), magnetic bilayers with dissimilar resonant frequencies, and magnetic alloys with engineered precession damping. In the pseudo-spin valve structure, ETR-FMR reveals weak coupling between the Ni@sub 81@Fe@sub 19@ and Co@sub 93@Zr@sub 7@ layers; such coupling is difficult to resolve in conventional FMR measurements. The unique capabilities of ETR-FMR in measuring precessional phase lags between different elemental moments will be discussed in relation to magnetic bilayers and engineered magnetic alloys.

3:20pm **MI-TuA5 The Electronic Band Structure of CoS2**, ***N. Wu,*** University of Nebraska-Lincoln; *Y. Losovyj,* Louisiana State University; *D. Wisbey, L. Wang, M. Manno,* University of Nebraska-Lincoln; *C. Leighton,* University of Minnesota; *P. Dowben,* University of Nebraska-Lincoln, U.S.A

We have undertaken angle resolved photoemission studies of CoS2(100) in order to map out the surface and bulk band structure of this high polarization material. The spectral features have been assigned from resonant photoemission, while the inner potential has been obtained from the critical points of the experimental band structure. Several photoemission resonances have been identified in this system for a variety of occupied "valence" electronic bands, with particularly strong resonances at the Co 3p core edges. Surface composition and surface order is seen to be strongly dependent upon surface preparation, with sulfur segregation seen to be easily facile. The surface is seen to be highly ordered in low energy electron diffraction under some conditions and both surface and bulk band states can be identified. A strongly dispersing s-p band dominates the Fermi level near the Brillouin zone edge, while Co d-band states dominate the Fermi level near the Brillouin zone center. These results are discussed in terms of the conduction electron spin polarization of this system.

3:40pm **MI-TuA6 Magnetic Properties of the Thin Cr@sub 1-x@ V@sub x@ Films**, ***O. Krupin,*** University of Oregon; *E. Rotenberg,* Lawrence Berkeley National Laboratory; *S.D. Kevan,* University of Oregon

Fabrication of the artificial magnetic structures having targeted properties is the key aspect for getting progress in the realization novel spintronic devices. Chromium is the prototypical spin density wave (SDW) antiferromagnet which attracts considerable attention in the context of its use as a spacer layer in the magnetic multilayer structures showing giant magnetoresistance and the spin-valve effect. Tuning of the SDW periodicity of the thin Cr-based films is therefore of the high importance. Impact of the confinement and the electron structure modification on SDW can be systematically studied by ARPES that allows mapping the SDW periodicity as well as the evolution of the Fermi surface topology. It is shown that the SDW periodicity can be driven by direct modification of the Fermi surface topology as well as by modification of the boundary conditions at the interfaces. That allows probing the interplay between spatial confinement and the Fermi surface topology underling the spin structure of the thin Cr-based films giving ideas how to design the layers with predefined spin structures.

4:00pm **MI-TuA7 Angle-Resolved Photoelectron Spectroscopy Study of Epitaxial CrO@sub 2@ Films Grown on TiO@sub 2@ Substrates**, *D.R. Borst,* ***C.A. Ventrice,*** University of New Orleans; *G.X. Miao, A. Gupta,* University of Alabama

Chromium dioxide is predicted to be a half-metallic oxide. Although there is experimental evidence that CrO@sub 2@ is half-metallic at low temperature, attempts to make devices based on CrO@sub 2@ have yielded very low efficiencies. One possible reason for these poor device performances is a non-stoichiometric surface region, in particular the formation of Cr@sub 2@O@sub 3@. To study the electronic properties of the surface region of CrO@sub 2@, ARUPS measurements have been performed at the 3m-TGM beamline of the CAMD synchrotron on epitaxial CrO@sub 2@ films. The CrO@sub 2@ thin films have been deposited on (100) and (110)-oriented TiO@sub 2@ substrates by chemical vapor deposition. The effects of sputtering of the CrO@sub 2@ films to remove the outer non-stoichiometric layer and of annealing the films in oxygen to heal surface defects has been studied. Sputtering results in shifts in the onset of valence emission away from the Fermi edge by as much as 0.5 eV. Annealing of the films in 10@super -6@ Torr of oxygen heals the surface and shifts the onset of emission towards the Fermi level. However, none of our spectra show evidence of a true Fermi edge. From analysis of the Cr 3p to O-2s core emission ratios for epitaxial CrO@sub 2@/TiO@sub 2@ films and Cr@sub 2@O@sub 3@(0001)/Pt(111) films grown in-situ by vapor deposition of Cr in an O@sub 2@ atmosphere and the observation of the correct symmetry in our CrO@sub 2@ LEED images, we conclude that the surface region of our epitaxial CrO@sub 2@ films is primarily CrO@sub 2@, not Cr@sub 2@O@sub 3@, even after annealing to 450 °C. These results indicate that CrO@sub 2@ is actually a narrow gap semiconductor at room temperature, not a metallic oxide as previously assumed.

4:20pm **MI-TuA8 Growth and Magnetic Properties of Ferrimagnetic Mn@sub 4@N(111) Films on GaN(0001)**, ***R. Yang,*** *E. Lu, M.B. Haider, A.R. Smith,* Ohio University; *F.Y. Yang,* Ohio State University

Heteroepitaxial growth of ferromagnet/semiconductor (FM/SC) bilayers is a topic of high importance because of the potential for spin injection systems.@footnote 1@ The FM/GaN is a system of particular interest due to the possibility to grow spin-polarized blue and ultra-violet light emitters. If we broaden this from FM@super '@s to include ferri-magnets (FiM@super '@s) having non-zero magnetization, then Mn@sub 4@N is a promising candidate since it allows to maintain a common nitrogen-bonded system for both magnetic and SC layers. Mn@sub 4@N is a FiM material with a Curie temperature of 738K and an effective moment of 1.0-1.2 uB per unit cell.@footnote 2@ Using a rf N-plasma molecular beam epitaxy

(MBE) system, we have successfully grown Mn@sub 4@N films on GaN(0001). The growth is monitored by reflection high-energy electron diffraction (RHEED). Streaky RHEED patterns indicate a smooth Mn@sub 4@N surface. RHEED and x-ray diffraction (XRD) results confirm that the epitaxial Mn@sub 4@N thin films have (111) orientation. Vibrating sample magnetometry (VSM) show that the films have magnetic hysteresis at room temperature, with the in-plane saturation magnetization M@sub s@ being larger than the out-of-plane M@sub s@ for Mn@sub 4@N(111)/GaN(0001) thin films. The authors acknowledge support from NSF and ONR. @FootnoteText@ @footnote 1@G. A. Prinz, Science 250,1092(1990).@footnote 2@W. J. Takei, R. R. Heikes and G. Shirane, Phy. Rev. 125, 1893 (1962).

4:40pm **MI-TuA9 Anisotropic X-Ray Magnetic Linear Dichroism at the Fe L@sub 2,3@ Edges in Fe@sub 3@O@sub 4@ Thin Films**, ***E. Arenholz,*** Lawrence Berkeley National Laboratory*; G. van der Laan,* Daresbury Laboratory, UK*; R.V. Chopdekar,* UC Berkeley and Cornell University*; Y. Suzuki,* UC Berkeley

X ray magnetic dichroism (XMD) spectroscopies utilizing synchrotron radiation are important tools for the study of magnetic solids. XMD is unique in its intrinsic element specificity and chemical-site sensitivity that allows the separation of the contributions of multiple magnetic species in alloys or layered systems. Most importantly, theoretically derived sum rules link, for example, x-ray magnetic circular dichroism intensities to spin and orbital magnetic moments enabling the use of polarized x rays for quantitative magnetometry. Although magnetic spectroscopy techniques have found widespread use for the study of magnetic systems, very fundamental aspects like the dependence of the XMLD signal on the relative orientation of external magnetic field, x-ray polarization, and crystalline axes have not been studied in detail to date. In this contribution, we present a systematic study of the Fe L@sub 2,3@ XMLD in ferrimagnetic Fe@sub 3@O@sub 4@(001) and (011) thin films. The Fe L@sub2,3@ XMLD is found to exhibit a strong dependence on the relative orientation of external magnetic field, x-ray polarization, and crystal lattice. These spectra can be used as a sensitive probe for the electronic and magnetic structure. We will show that all XMLD spectra can be described as a linear combination of three fundamental spectra and that the angular dependence can be derived from atomic calculations based on the crystal field symmetry.

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