Magnetic Interfaces and Nanostructures
Room 2006 - Session MI-TuM

Magnetic Nanostructures, Nanoparticles and Interfaces

Moderator: J. Shen, Oak Ridge National Laboratory

8:00am **MI-TuM1 Overview of Magnetic Recording Technologies**, ***D. Weller,*** Seagate Technology **INVITED**

The recording industry is currently undergoing a transition from longitudinal to perpendicular magnetic recording (PMR). Areal densities (AD) have reached more than 130 Gbit per sq.in. in products and 250 Gbit per sq.in. in laboratory demostrations. The key technology enablers are head, media and head-disk interface, which all face significant scaling challenges and limitations. Fundamental limitation include thermal stability of media grains and write fringe field of the recording heads, which will likely limit PMR recording to 500-1000 Gbit per sq.in.. At an AD growth rate of 40% per year it should take between 4-8 years to reach those limitations. Technologies beyond PMR include Heat-Assisted Magnetic Recording (HAMR), which eliminates the field constraint of the recording head and self-organized magnetic arrays (SOMA), which eliminate microstructural constraints of sputtered media. The current perspective is that both technologies will eventually be needed to push beyond Terabit per sq. in. recording and to continue to grow this industry.@footnote 1@ This talk is intended to lay out a future technology roadmap and to provide a perspective of "what's next". @FootnoteText@ @Footnote 1@Dieter Weller and Terry McDaniel, chapter 11, Media for Extremely High Density Recording in Advanced Magnetic Nanostructures, eds. David Sellmyer and Ralph Skomski, Springer 2006.

8:40am **MI-TuM3 Orbital Magnetism of Fe and Pt in Monodisperse FePt Nanoparticles**, ***M. Farle,*** *C. Antoniak,* Universitaet Duisburg-Essen, Germany*; K. Fauth,* MPI Stuttgart, Germany*; M. Spasova,* Universitaet Duisburg-Essen, Germany*; F. Wilhelm, A. Rogalev,* ESRF, France **INVITED**

X-ray absorption (XAS)and x-ray magnetic dichroic spectra (XMCD) were measured at both the Fe and Pt L@sub3,2@ edges on wet-chemically synthesized monodisperse Fe@sub50@Pt@sub50@ particles with a mean diameter of 6.3 nm before and after complete removal of the organic ligands and the oxide shell covering the particles by soft hydrogen plasma resulting in a pure metallic state. After thermal treatment of the metallic particles, the coercive field increased by a factor of 6, the orbital magnetic moment at the Fe site increased by 330% and decreased at the Pt site by 30%, while the effective spin moments did not change. A decrease of the frequency of oscillations in the extended x-ray absorption fine structure (EXAFS) at the Pt L@sub3,2@ edges provides evidence for crystallographic changes towards the L1@sub0@ phase. These results are discussed in context to recent results revealing a layerwise structural relaxation of the surface layers in FePt nanoparticles.

9:20am **MI-TuM5 Probing the Exchange Interactions Between Stable Photogenerated Carriers in Colloidal Magnetic Semiconductor Quantum Dots**, ***W.K. Liu***[1], University of Washington

A major obstacle in developing practical spin-based electronic devices is producing ferromagnetic semiconductors that exhibit a Curie temperature (Tc) higher than room temperature. Diluted magnetic semiconductors (DMSs), where a fraction of the host lattice cations are substitutionally replaced by 3d transition metal ions (TM@super 2+@), are promising candidates due to observation of high-Tc ferromagnetism in oxide DMSs. Recently, we have demonstrated a close link between the electronic structures and polarity-dependent high-Tc ferromagnetism of TM@super 2+@:ZnO DMSs.@footnote 1@ Our investigation, using complementary optical spectroscopic and photoelectrochemical probes, have identified light-induced donor- or acceptor-type ionizations states of the transition metal dopants immediately below the ZnO band edge in Co@super 2+@:ZnO and Mn@super 2+@:ZnO. These charge transfer electronic states clearly relate the observed high-Tc ferromagnetism in these materials to mediation by shallow donors or acceptors, as well as to the polarity of the mediating charge carrier. To further examine the interplay between the charge carriers and magnetic dopant ions we have successfully generated stable carriers in colloidal Co@super 2+@:ZnO and Mn@super 2+@:ZnO DMS quantum dots using photochemical methods.@footnote 2@ The carriers were identified as conduction band electrons and the resulting electron-magnetic dopant ion interactions were studied by electron paramagnetic resonance spectroscopy. This new motif of colloidal charged magnetic semiconductor nanocrystals provides new opportunities for examining spin effects in DMS nanostructures relevant to proposed spintronics technologies. @FootnoteText@ @footnote 1@K.R. Kittilstved, W.K. Liu, D.R. Gamelin, Nat. Mat. 5 (2006) 291.@footnote 2@W.K. Liu, K.R. Kittilstved, K.M. Whitaker, D.R. Gamelin, J. Am. Chem. Soc. 128 (2006) 3910.

9:40am **MI-TuM6 Single Domain and Vortex State Phase Fractions in Arrays of sub-100nm Fe Nanodots***, ***R.K. Dumas***[2], University of California - Davis*; C.-P. Li, I.V. Roshchin, I.K. Schuller,* University of California - San Diego*; K. Liu,* University of California - Davis

Deep sub-100 nm magnets have been the focus of intense research interest due to their fascinating fundamental properties and potential technological applications. Here we report the investigation of magnetization reversal in arrays of Fe nanodots prepared by a nanoporous alumina shadow mask technique.@footnote 1@ In particular we have examined the single domain to vortex state transition in 52, 58, and 67 nm nanodots, using a first order reversal curve (FORC) method.@footnote 2-5@ Striking differences in the FORC diagrams have been observed, despite only subtle differences in their major hysteresis loops. The 52 nm nanodots exhibit single domain behavior. The extracted coercivity distribution agrees well with a simple theoretical calculation. The 67 nm dots have more complex FORC characteristics which clearly indicate reversal via a vortex state. These experimental FORC features have been confirmed by OOMMF micromagnetic simulations. The 58 nm dots show characteristics common to both the 52 and 67 nm samples. By selectively integrating the normalized FORC distribution corresponding to the single domain phase, we have determined that 43% and 10% of the nanodots in the 58 and 67 nm sample, respectively, are in the single domain state. Additionally, we have studied the single domain phase fraction as a function of temperature in the 67 nm dots. With decreasing temperature, it is more difficult to nucleate vortices within the dots and the single domain phase fraction increases. @FootnoteText@ *Supported by NSF, ACS-PRF, AFOSR, UC-CLE, and the Alfred P. Sloan Foundation. @footnote 1@K. Liu, et al, Appl. Phys. Lett. 81, 4434 (2002). @footnote 2@C. P. Pike, et al, J. Appl. Phys. 85, 6660 (1999). @footnote 3@H. G. Katzgraber, et al. Phys. Rev. Lett. 89, 257202 (2002). @footnote 4@J. E. Davies, et al, Phys. Rev. B 70, 224434 (2004). @footnote 5@J. E. Davies, et al, Appl. Phys. Lett. 86, 262503 (2005).

10:40am **MI-TuM9 Nanostructured Ultrathin Films and Nanowires: A Playground for Manipulating the Magnetic Anisotropy**, ***F. Bisio,*** CNR-INFM Unita' di Genova, Italy*; R. Moroni,* CNISM Unita' di Genova, Italy*; F. Buatier de Mongeot, M. Canepa, U. Valbusa, L. Mattera,* University of Genova, Italy

We report the investigation of the magnetic anisotropy of nanorippled ultrathin magnetic films and magnetic nanowires fabricated by means of the ion sculpting technique. The nanoscale rippled morphology that develops under grazing incidence ion irradiation unbalances the number of surface atomic steps oriented parallel and perpendicular to the ripple direction, thus inducing a clearly observable in-plane uniaxial anisotropy. We have isolated the atomic-step-contribution to the magnetic anisotropy of the nanostructures and experimentally measured the uniaxial anisotropy energy of Co and Fe monoatomic steps located at the surface of Co/Cu(001) and Fe/Ag(001) films. We show that the simmetry and intensity of the magnetic anisotropy of these systems can be manipulated by varying the irradiation conditions and by functionalization of the nanostructures surface by magnetic or nonmagnetic overlayers.

11:00am **MI-TuM10 Fingerprinting Magnetization Reversal in Magnetic Nanostructures**, ***K. Liu,*** *J.E. Davies, R.K. Dumas, G.T. Zimanyi,* UC Davis*; O. Hellwig, E.E. Fullerton,* Hitachi Global Storage Tech.*; J.S. Jiang, S.D. Bader,* Argonne National Lab*; G. Denbeaux,* Univ. at Albany*; J.B. Kortright,* Lawrence Berkeley National Lab*; C.-P. Li, I.V. Roshchin, I.K. Schuller,* UC San Diego **INVITED**

Magnetization reversal is often complex, yet critical for the understanding and applications of magnetic nanostructures. Here we present recent studies using a first order reversal curve (FORC) method@footnote 1-4@ on a few technologically important systems. In Co/Pt multilayers,@footnote 2@ we have found three distinct stages for reversal domain nucleation, propagation, and annihilation. Interestingly, significant irreversible switching persists for applied fields well beyond the apparent saturation field due to residual bubble domains. In exchange spring magnets,@footnote 3@ we have investigated the effect of the hard layer crystallinity on irreversible switching. In Fe/epitaxial-SmCo films, the

[1] **Falicov Student Award Finalist**

[2] **Falicov Student Award Finalist**

reversal proceeds by a reversible rotation of the Fe soft layer, followed by an irreversible switching of the SmCo hard layer. In FeNi/polycrystalline-FePt films, the FeNi and FePt layers reverse in a continuous process via a vertical spiral. The successive vs. continuous rotation of the soft/hard layer system is primarily due to the different hard layer anisotropy. In arrays of Fe nanodots,@footnote 5@, we have studied a vortex state to single-domain transition as the dot size decreases. Striking differences in the FORC diagrams have been observed. The 52nm dots exhibit single domain behavior, whereas the 58 and 67nm dots exhibit vortex states. The FORC method gives quantitative measures of the magnetic phase fractions and vortex nucleation and annihilation fields. These results demonstrate that FORC is a powerful method for magnetization reversal studies, due to its capability of capturing distributions of magnetic properties, sensitivity to irreversible switching, and the quantitative phase information it can extract. @FootnoteText@ *Supported by NSF, ACS-PRF, DOE, UC-CLE, and Sloan Foundation. @footnote 1@Pike, et al, JAP, 85, 6660 (1999). @footnote 2@Davies, et al, PRB 70, 224434 (2004). @footnote 3@Davies, et al, APL 86, 262503 (2005). @footnote 4@Davies, et al, PRB 72, 134419 (2005). @footnote 5@Liu, et al, APL 81, 4434 (2002).

11:40am **MI-TuM12 Ultrathin Film Magnetism by Surface Manipulation**, ***X.F. Jin,*** Fudan University, China **INVITED**

The lattice-constant of a solid-state material is a key parameter in determining its physical and chemical properties. By varying the lattice constant one can tune the electronic band structure as well as the density of states at the Fermi level, therefore change correspondingly all the physical and chemical properties. In this work, by using the "composition wedge" and "lattice-constant wedge" techniques with molecular beam epitaxy, we show that one can manipulate independently the surface chemistry and lattice constant of a single crystal substrate. Applying them to ultrathin Fe and Ni on Cu(001), two of the most important yet still controversial nanomagnetic systems, we show how to manipulate their magnetic properties including magnetic ordering and anisotropy in a well controlled way which is helpful to clarify some longstanding critical issues of the systems.

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