## Magnetic Interfaces and Nanostructures
## Room 316 - Session MI+NS-TuA

### Self Assembly and Nanomagnetism
**Moderator:** S.D. Bader, Argonne National Laboratory

2:00pm **MI+NS-TuA1 Many-spin Hamiltonian for the Single-molecule Magnet Mn12-Ac**, ***K. Park***, Naval Research Laboratory and Howard University; *M.R. Pederson,* Naval Research Laboratory; *S.L. Richardson,* Howard University and Naval Research Laboratory

Nanoscale single-molecule magnets recently received great attention due to scientific and practical reasons: macroscopic quantum phenomena and possible utilization as magnetic storage devices or quantum computing. A single-molecule magnet (SMM) is a three-dimensional array of identical molecules, each of which consists of several transition metal ions surrounded by organic ligands and is independent of neighboring molecules. Among many kinds of SMMs, Mn12-Ac has been the most extensively studied for the past decade. Although the low-energy features of Mn12-Ac have been well understood by considering each molecule as an effective ground-state spin of S=10, there is still a big controversy over the energy gap between the first excited-state manifold and the ground-state manifold as well as the internal structure of the single molecule. To provide a guide to understanding the controversial many-spin features, we investigate the intramolecular exchange couplings and the projected single-ion anisotropies using density-functional theory (DFT). We use all-electron Gaussian-orbital-based Naval Research Laboratory Molecular Orbital Library (NRLMOL) within Perdew-Burke-Ernzerhof (PBE) generalized-gradient approximation (GGA). Based on the calculated exchange couplings and anisotropy parameters, we construct a model many-spin Hamiltonian which reproduces calculated single-spin results and allows for the extraction of many-spin features.

2:20pm **MI+NS-TuA2 Magnetic Interaction in Assemblies of Nanometer-sized Fe Dots on Cu (111)**, ***M.A. Torija***, *J. Pierce,* University of Tennessee, Knoxville; *J.F. Wendelken,* Oak Ridge National Laboratory; *E.W. Plummer,* University of Tennessee, Knoxville; *J. Shen,* Oak Ridge National Laboratory

Assemblies of separated iron quantum dots can be prepared on the Cu(111) surface via a buffer-layer-assisted growth process. First, an inert Xe layer is frozen onto a Cu(111) substrate that is held below 30 K. Then, Fe atoms are dosed from a typical evaporation source and form clusters on the Xe layer. Finally, the sample is warmed above 90 K, allowing the buffer layer to evaporate and the formed quantum dots to land on the surface. Scanning tunneling microscopy has shown us that we can control the average spacing and size of the dots by changing the Xe layer thickness and/or the amount of Fe deposited. Surprisingly, the dot arrays show non-zero remanent magnetization that is stable with the passage of time. To distinguish the roles of the magnetic interactions vs. the magnetic anisotropy in stabling the remanent magnetization, measured by SMOKE, we compare the ordering temperature of dot assemblies that have equal size distribution but different density. At fixed dot size distribution, varying the density of the Fe dots from 0.003 to 0.015 leads to an enhancement of ordering temperature from 153 K to 363K. This clearly indicates that magnetic interactions play an important role in stabling the remanent magnetization. Another interesting phenomena that we observed is a spin reorientation induced by the dot size. that for a fixed nominal thickness, the easy axis of magnetization is perpendicular for lower Xe thickness ( small dots), and becomes in-plane for higher Xe thickness ( big dots ). It may be explained by the interplay between surface and bulk anisotropies.

2:40pm **MI+NS-TuA3 Contribution of Orbital Magnetism to the Magnetism of Monodisperse Nanoparticles**, ***M. Farle***, Universitaet Duisburg-Essen, Germany **INVITED**

Self-organized magnetic nanoparticles with diameters of less than 10 nm are interesting for technological applications and for the investigation of interface properties due to their high surface-to-volume atom ratio. One of the most important magnetic properties, the magnetic anisotropy energy (MAE) is strongly influenced by the local structure and size of the particles, since on the atomic level MAE is related to the anisotropy of the orbital magnetic moment. Well-known techniques to measure the orbital contribution to the total magnetic moment are ferro-/paramagnetic resonance (FMR/EPR) and x-ray magnetic circular dichroism. Two examples will be discussed: a)disordered 3 nm FePt with different Fe contents, b)11.4 nm CoO@Co (a 2nm CoO shell surrounding a 8 nm Co core). For the FePt particles with different Fe concentration we find a linear increase of the g-factor measured by FMR/EPR , i.e. of the ratio of orbital-to-spin magnetic moment for larger Pt contents. This indicates that the presence of Pt induces an enhanced orbital magnetic moment in the nanoparticle. In the case of CoO@Co we find by FMR a bulk- like g factor g = 2.15 of fcc Co, while XMCD yields a 300 % enhanced ratio of orbital-to-spin moment. A quantitative comparison taking the different sampling depths of both techniques into account reveals the presence of uncompensated large magnetic Co moments at the interface of the antiferromagnetic CoO shell to the ferromagnetic Co core . Supported by EC contract no. HPRN-CT-1999-00150 and Deutsche Forschungsgemeinschaft.

3:20pm **MI+NS-TuA5 Self-assembly of FePt Nanoparticles on Si(100) Surface**, ***N. Shukla***, *J. Ahner, D. Weller,* Seagate Research

Chemically synthesized monodispersed FePt nanoparticles are of great interest due their high magnetic anisotropy. The self-assembly and uniform coating of these nanoparticles on substrates is crucial for enabling high-density magnetic recording media. We have studied various parameters, potentially influencing the uniformity of FePt nanoparticle coatings. In particular, we report on the effects of excess surfactant concentration, type of surfactant, solvents and substrates. Films are fabricated using dip-coating and spin-coating methods. A narrow range of surfactant concentration is identified that leads to long range (~ 1x 1 mm@super2@) uniformity. Outside this concentration range the nanoparticle coatings form clusters with local self-assembly. In addition, the type of solvent and type of surfactant has a profound impact on the self-assembly of FePt. Decreasing the size of surfactant chain length changes the self-assembly from uniform to ring structures. Polarity and viscosity of the solvents also impact the self-assembly. Polar solvents give poor uniformity. Low viscous solvents have a similar impact.

3:40pm **MI+NS-TuA6 Submicron Cobalt Particle Fabrication by Ion Beam Induced Chemical Vapor Deposition (IBICVD)**, ***Y. Kageyama***, *T. Suzuki,* Toyota Technological Institute, Japan

Nanometer-sized patterned structures for high density data storage have recently become of great interest. It has been demonstrated that the ion-beam induced chemical vapor deposition (IBICVD) technique has a potential benefit for fabrication of nano-dots.@footnote 1,2@ Characterization of IBICVD-synthesized Co particles was performed, and the result is presented in this paper. The submicron Co particles were deposited on Si@sub 3@N@sub 4@ substrates by a focused Ga@super +@ ion beam (FIB) system equipped with a source reservoir filled with precursor of octacarbonyl dicobalt [Co@sub 2@(CO)@sub 8@] powders. Vapor of the precursor was introduced though a feeding nozzle (0.5mm diameter) above the substrate separated by 0.5 mm. The base pressure of the deposition chamber was about 10@super -5@ Pa. The ion current and the pressure during deposition were 14 pA and 0.7 - 1.4 x 10@super -4@ Pa, respectively. The in-situ image of Co particles was taken by SEM of the FIB system. Under the condition of irradiation of ion beams, the particle formation process is rather complicated due to concurrence of competitive processes (etching and deposition), therefore the morphology of Co particles strongly depends on the ion beam dwell time (5 to 120 µms) and the partial pressure of Co@sub 2@(CO)@sub 8@ precursor, as revealed by AFM analysis. The smallest size of Co particle obtained is about 150 nm so far. They exhibit ferromagnetic behaviors. Further studies on modification of properties by heating substrates, and on formation of alloys by introducing a second deposition source, are in progress. @FootnoteText@@footnote 1@ A. Lapicki, E. Ahmad, and T. Suzuki, J. Magn. Magn. Mat. 240 (2002) 47@footnote 2@ A. Lapicki, K. Kang, and T. Suzuki, IEEE Trans. Magns. 38 (2002) 2589.

4:00pm **MI+NS-TuA7 Magnetic Nanostructures Made by Self-assembled Block Copolymer Lithography**, ***C.A. Ross***, *J.Y. Cheng, H.I. Smith, E.L. Thomas,* Massachusetts Institute of Technology; *G. Vancso,* University of Twente, The Netherlands **INVITED**

The fabrication and magnetic properties of thin-film particles with diameters of 35 nm and periodicity of 50 nm made using block copolymer nanolithography will be described. Such particle arrays may be used in magnetoelectronic and magnetic storage devices, where it is important to control the magnetization state, switching field, and uniformity of the particles and to understand their size-dependent magnetic behavior. Arrays of single-layer Co and NiFe particles with thicknesses of 5, 10, 15 and 20 nm, and Co/Cu/NiFe multilayer particles have been made. The Co and NiFe particles show an increase in coercivity and a decrease in switching field distribution with thickness. The particles exhibit thermally-assisted reversal, with switching volumes larger than the physical particle volume due to strong magnetostatic coupling between the particles. The multilayer

particles show hysteresis behavior consistent with interlayer magnetostatic coupling, and measurable giant magnetoresistance despite the small dimensions of the particles. These arrays have short-range close-packing, but no long-range order. To impose long-range order the substrates have been patterned with shallow grooves, which induce alignment of the rows of polymer features parallel to the steps creating an ordered array. The polymer domain spacing conforms to the dimensions of the templating features leading to a quantized number of rows of domains within each groove. It is also possible to confine the polymer to certain regions of the substrate using soft printing methods, which also leads to a limited degree of ordering. Results from these templated self-assembly processes will be discussed. This work was supported by NSF. Refs: Cheng et al, Adv. Mater. 13 1174 (2001); Appl. Phys. Letts. 81 3657 (2002); IEEE Trans. Magn. 38 2541 (2002).

4:40pm **MI+NS-TuA9 Magnetic Properties of Low-dimensional Nanostructures on an Insulator**, ***Z. Gai***, *J.R. Thompson, J. Pierce, J. Shen,* Oak Ridge National Laboratory

Magnetic nanostructured materials are attracting much attention because of the dramatic changes in their magnetic, electronic and transport properties compared with conventional bulk materials. In previous work, iron zero-dimensional dots, one-dimensional nanowires and two-dimensional films have been successfully prepared on top of a commonly used insulating NaCl (001) single crystal surface. In-situ atomic force microscopy images show that the sizes of the dots and the widths of the wires are very uniform; the films are atomically flat and are formed due to a high nucleation density. In the present work, the magnetic properties of the dots, wires and films are measured by Superconducting Quantum Interference Device (SQUID) magnetometer X-ray magnetic circular dichroism (XMCD). The wires have an out-of-plane easy magnetization axis, and surprisingly show ferromagnetic stability even at room temperature. The magnetic behaviors of the dots and films are very different from the wires. The detailed comparison will be discussed in the talk. Oak Ridge National Laboratory, managed by UT-Battelle, LLC, for the U.S. Dept. of Energy under contract DE-AC05-00OR22725.

5:00pm **MI+NS-TuA10 Magnetic Reversal of Co/Pd Multilayer Films and Sub-100nm Islands**, ***G. Hu***, *T. Thomson, M.E. Best, B.D. Terris,* Hitachi San Jose Research Center*; C.T. Rettner, S. Raoux, G.M. McClelland, M.W. Hart,* IBM Almaden Research Center

Patterned arrays of Co/Pd multilayer islands with perpendicular anisotropy are one approach to increasing magnetic recording density towards 1Tbit/in@super 2@. To realize this technology arrays consisting of single domain islands with sufficient anisotropy for thermal stability and a narrow switching field distribution will be required. In order to understand the reversal properties of islands we have compared the reversal mechanism and anisotropy of patterned arrays to nominally identical unpatterned, continuous films. The island arrays were fabricated by creating an etch mask using electron beam lithography and nano-imprinting followed by etching of a SiO@sub 2@ substrate. Multilayer films of Co/Pd were then sputter deposited onto the topographically patterned substrates. We found that for the continuous films, the magnetic anisotropy is only sensitive to the Co and Pd layer thicknesses while coercivity and magnetization reversal mechanism can be easily tuned by varying the deposition conditions. However, for small, single domain islands, the coercivity is much less sensitive to deposition conditions and more sensitive to composition than for the continuous films. The coercivity of these islands is generally significantly greater than that of the continuous films. Moreover, the switching behavior of the islands does not exhibit any correlation with the film reversal mechanism, but rather follows the film magnetic anisotropy closely. Systematic studies have been carried out to adjust the magnetic anisotropy of the multilayer films by varying the cobalt and palladium layer thicknesses. Unlike the continuous films, the measured coercivity of the islands agrees well with the reversal field calculated based on the measured anisotropy of the film and the Sharrock equation.

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