Magnetic Interfaces and Nanostructures
Room: C-205 - Session MI+NS-MoA

Self-Assembly and Nanomagnetism

Moderator: D. P. Pappas, DOC/NIST/EEEL/Magnetic Technology Division

2:00pm MI+NS-MoA1 Self-assembly and Magnetism in Novel Core-shell Microspheres, *E.L. Bizdoaca*, *M. Spasova, M. Farle*, Halbleiterphysik und Optik, TU Braunschweig, Germany

We report on the fabrication and characterization of new composite core-shell particles with a defined shape, composition and multilayer shell thickness. These colloids can be produced by the layer-by-layer technique.[1] They consist of a core of a polystyrene (PS) microsphere (640 nm diameter) coated with consecutive shells of Fe_3O_4 nanoparticles (12 nm diameter) / polyelectrolytes /Au nanoparticles (15 nm). For the formation of the gold shell Au nanoparticles encapsulated in a very thin layer of silica (2 nm) were used. Composite core-shell particles were self-assembled into 1D periodic long-chain structure (up to 600 μm) by magnetophoretic deposition.[2] The length and separation of the chains were found to depend on the magnitude of the magnetic field and on the concentration of the water-based colloidal solution. The self-organization and the homogeneity of the colloidal coating were characterized by transmission electron and atomic force microscopy. Magnetic properties were determined by angular dependent ferromagnetic resonance (FMR) and SQUID-magnetometry between 5 and 300 K. FMR reveals long-range magnetic order at 300 K due to the dipolar coupling and an easy axis in plane, along the chains. We report a reduced magnetic moment in comparison with the magnetite bulk value. The remanence magnetization and the coercivity field (240 Oe) are not temperature dependent between 5 and 300 K. Supported by Deutsche Forschungsgemeinschaft. .

[1] F. Caruso et al, Chem.Mater.13 (2001) 109.
[2] E. L. Bizdoaca et al, J. Magn. Magn. Mater. 240 (2002) 44.

2:20pm MI+NS-MoA2 Magnetic Resonance and X-ray Magnetic Circular Dichroism of Monodisperse Co Nanoparticles, *U. Wiedwald*, *M. Spasova*, Technical University Braunschweig, Germany, *M. Hilgendorff*, Hahn-Meitner-Institut, Germany, *M. Ulmeanu, E.L. Bizdoaca*, Technical University Braunschweig, Germany, *M. Giersig*, Hahn-Meitner-Institut, Germany, *M. Farle*, Technical University Braunschweig, Germany

Monodisperse Co nanoparticles with an medium diameter of 12 nm ($\sigma < 5\%$) are prepared by the thermolysis of $Co_2(CO)_8$.[1] After using a size-selective separation technique they are redispersed in toluene. For structural and magnetic investigations the samples are prepared by controlled evaporation of the solvent on various substrates. Detailed TEM analysis of the structure of Co nanoparticles shows that they consist of a 8-9 nm metallic Co core and a 1-2 nm thick CoO shell, both crystallized in fcc structure.[2] Angular dependent ferromagnetic resonance (FMR) of these arrays of Co nanoparticles reveals a remanent magnetization at 300 K that is due to long-range dipolar coupling between the nanoparticles.[3,4] A preliminary g-factor analysis yields a value of $g = 2.15\pm0.02$ that is close to bulk fcc value and in good agreement with the structural analysis. X-ray absorption fine structure (XAFS) shows a multiplet structure in the Co L_3 edge that is due to a superposition of metallic Co and Co in an oxidic environment. No evidence for x-ray magnetic circular dichroism (XMCD) at the $L_{2,3}$ edges is found for as prepared ex-situ samples for temperatures between 20 K and 300 K. After slight Ar^+ ion etching a well resolved XMCD signal with a strongly enhanced orbital-to-spin-moment ratio is observed. The results of the FMR and XMCD analysis will be compared and discussed in terms of the contributions from the antiferromagnetic CoO shell. This project is supported by the European Community, contract no. HPRN-CT-1999-00150 and the Access to Research Infrastructure action of the Improving Human Potential Programme. M. H. thanks the Deutsche Forschungsgemeinschaft, Az.: II C 10 - SPP 1072 for support.

[1] M. Hilgendorff et al., Aust. J. Chem. 54 (2001)
[2] M. Spasova et al., Proc. Spring MRS Meeting, San Francisco (2002), submitted
[3] U. Wiedwald et al., J. Vac. Sci. Technol. A 19 (2001)
[4] M. Spasova et al., J. Magn. Magn. Mat. 240 (2002)

2:40pm MI+NS-MoA3 Surfactant-mediated Shape Control, Magnetism and Self-assembly of Cobalt Nanocrystals, *K.M. Krishnan*, *Y.P. Bao, M. Beerman*, University of Washington **INVITED**

Magnetic nanocrystals, monodisperse in size, shape and surface structure are now routinely synthesized by the rapid injection of an organometallic precursor into a hot coordinating solvent containing appropriate surfactants.

The success of this method depends on temporally separating the nucleation and growth of the nanocrystals in solution and to control the precursor concentration to achieve size distribution focusing. In addition, careful choice of surfactant pairs that preferentially bond to different crystallographic planes of the growing nanocrystal can also be used to control the shape of the nanocrystals, including the preparation of high-aspect ratio particles or nanorods. For practical applications these nanocrystals must be organized into ordered arrays with well-defined inter-particle distances. In such nanocrystals, with a weak (van der Waals) attractive interaction between the metallic cores and a weak steric repulsion arising from the surfactant chains, entropy-driven self-assembly processes dominate. If particles of two different sizes are allowed to self-assemble, entropy driven wetting arising from depletion forces can be used to control the final organization. Use of solvent-nonsolvent pairs can be used to gently precipitate the nanocrystals into large scale ordered arrays. Details of the growth of Co nanocrystals with controlled size and shape, their subsequent self-assembly into ordered arrays, their characterization by a range of electron microscopy measurements and their isolated and collective magnetic behavior will be discussed.

3:20pm MI+NS-MoA5 Structure and Magnetism of Colloidal Composite AgCo Nanoparticles, *M. Spasova*, Technishe Universität Braunschweig, Germany, *T. Radetic*, Lawrence Berkeley Laboratory, *N.S. Sobal*, Hahn-Meitner-Institut Berlin, Germany, *C. Raeder*, Technishe Universität Braunschweig, Germany, *M. Hilgendorff*, Hahn-Meitner-Institut Berlin, Germany, *U. Dahmen*, Lawrence Berkeley Laboratory, *M. Giersig*, Hahn-Meitner-Institut Berlin, Germany, *M. Farle*, Technishe Universität Braunschweig, Germany

Monodisperse, air-stable $Ag_{100-x}Co_x$ composite nanoparticles with a mean diameter of 12 nm have been synthesized by methods of colloidal chemistry.[1] The composition x was varied between 20 and 73 at.% Co. High resolution Transmission Electron Microscopy (TEM) and selected area electron diffraction have showed that the nanoparticles consist of precipitates of fcc Co and fcc Ag grains. No evidence for alloy formation was observed. Element-specific TEM images obtained by electron energy-loss spectroscopy and X-ray microanalysis indicate that Co is predominantly found in the surface region of the particles and the particles have an $Ag_{core}Co_{shell}$ structure. No Co oxide formation was observed in spite of Co being located at the particle surface. Magnetic properties of arrays of the nanoparticles on Si substrates were investigated by angular dependent ferromagnetic resonance and SQUID magnetometry between 5 and 300 K. The blocking temperature is found to depend on the particle composition. It increases with increasing Co content. At room temperature the nanoparticles containing 73 at.% Co are below and the $Ag_{55}Co_{45}$ nanoparticles are above their respective blocking temperatures. At lower temperatures contributions from additional magnetic phases are observed. The magnetization curves were analyzed as a function of temperature taking into account both paramagnetic and ferromagnetic contributions. The results are discussed in context to contributions from the Co/Ag interfacial and surface magnetism. The work has been supported through EC contract no. HPRN-CT-1999-00150.

[1] N.S. Sobal at el., Nano Letters, in press.

3:40pm MI+NS-MoA6 Study of the Magnetic Cluster/Superconductiviting Matrix Interface: the Co/Nb System, *V. Dupuis*, *L. Favre, M. Jamet, J. Tuaillon-Combes, P. Melinon, A. Perez*, DPM Lyon - France

Thin films consisting on pure Co nanoparticles embedded in a Nb superconducting matrix have been prepared from clusters preformed in the gas phase using the Low Energy Cluster Beam Deposition (LECBD) technique.[1] Such films are subsequently e-beam lithographied in view to prepare ultrahigh sensitivity Micro-SQUID magnetometer devices and to study the magnetization reversal mechanism of an individual nanocluster.[2] X-ray characterization experiments and Transmission Electron Microscopy performed on an assembly of cobalt clusters embedded in a niobium matrix have shown that such nanogranular films consist on crystallized fcc Co-grains in the form of 3 nm-diameter truncated octahedron (~ 1000 Co-atoms) randomly distributed in the polycrystalline niobium matrix. Sites of Co-atoms in the cluster core and at the cluster-matrix interface have been evidenced showing an alloyed Co-Nb interface concerned by almost one monolayer. On another hand, VSM magnetization measurements performed in the superparamagnetic regime evidenced a magnetic size of the Co-clusters lower than the one as deduced from TEM observations. So, in-situ complementary measurements under synchrotron radiation performed on Co/Nb bilayers grown in UHV confirm the presence of an alloyed Co_6Nb_7 interface which acts as a magnetically dead layer. Finally, from micro-SQUID measurements performed at 35 mK on one individual Co-cluster,

we obtained a 3D-astroid shape corresponding to second order bi-axial anisotropy terms which can be attributed to surface anisotropy contributions ("Néel" model) underlying the main interfacial contribution in such nano-object.

[1] A. Perez et al. Materials Transactions, Special Issue on Nano-Metals 1, 42,1460 (2001).
[2] M. Jamet et al. Phys. Rev. Lett., 86, 4676 (2001).

4:00pm MI+NS-MoA7 Magnetic Nanowires for Media and Devices Fabricated Using Copolymer Templates, *M.T. Tuominen*, *M. Bal, A. Ursache, Q. Xiao, J.T. Goldbach, T.P. Russell*, University of Massachusetts
INVITED

Arrays of magnetic nanowires and nanowire devices were fabricated using nanoporous templates derived from self-assembling diblock copolymer films. Poly(styrene-methacrylate) (PS-PMMA) diblock copolymers as porous templates that were used to fabricate hexagonal arrays of vertical nanowires with densities of exceeding 1×10^{12} per square inch. Electrodeposition within the template produces 10nm-scale magnetic cobalt nanowire arrays that exhibit large perpendicular coercivity and remanance making them potential candidates for ultrahigh-density perpendicular magnetic storage media. The internal crystal morphology of the nanowires, and consequently magnetic properties, can be manipulated and tuned by electrodeposition process parameters. The copolymer templates have been patterned laterally using conventional lithographic exposure to fabricate novel 3D magnetic nanowire devices. This includes current-in-plane magnetoresitive devices and current-through-wire switching field devices. Anisotropic magnetoresistance measurements show a sharp and complete magnetization reversal, indicating single-domain nanowire switching behavior. Such properties offer promising potential for new magnetic nanodevices built upon on single-domain elements. This work is supported by US National Science Foundation Nanoscale Interdisciplinary Research Team grant DMI-0103024 and Materials Research Science and Engineering Center grant DMR-9809365.

4:40pm MI+NS-MoA9 Evolution of Fe Nanocluster Magnetism Grown on Pt(111), *P. Bencok*, *S.S. Dhesi*, European Synchrotron Radiation Facility, France*, P. Ohresser,* Laboratoire pour l'Utilisation du Rayonnement Electromagnétique, France*, N. Brookes*, European Synchrotron Radiation Facility, France

The magnetic structure of nanoparticles is a fascinating research area with many new and unexpected results. For the preparation of nanostructures one may use a well chosen system with appropriate growth modes. Room temperature deposition of submonolayer Fe ultrathin films on Pt(111) results in the formation of single layer clusters whose size increases with the amount of Fe. The structure of the stable pseudomorphic fcc clusters was studied using scanning tunnelling microscopy. The clusters were grown and measured in-situ by x-ray magnetic circular dichroism of Fe $L_{2,3}$ edge at beamline ID8 of the European Synchrotron Radiation Facility in Grenoble. Sum rule analysis was used to extract the magnetic spin and orbital moments with changing cluster size. The clusters show superparamagnetic behaviour with blocking temperature in the range 10-250 K increasing with cluster size. The easy axis of magnetization is perpendicular to the surface for all the range of cluster sizes studied. The orbital moment of the clusters as well as its angular anisotropy (related to the magnetic anisotropy energy) is enhanced in comparison with the bulk value and increases with decreasing cluster size. This enhancement is given by the increase in the number of perimeter atoms as the cluster radius diminishes. The perimeter atoms have reduced atomic coordination leading to the higher orbital moment. The magnetic spin moment per atom is lower than for bulk Fe. This behaviour can be explained by changes in the local atomic structure that is very sensitive to the atomic volume.

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