MA 2: Micro and Nanostructured Magnetic Materials I

Time: Monday 10:15–13:00 Location: EB 301

MA 2.1 Mon 10:15 EB 301

Interaction effects in Fe nanoparticle/permalloy thin-film hybrid systems — •Jens Müller[1,2], Yongqing Li[1,3], Stephan von Molnár[1], and Steffen Wirth[2] — [1]Florida State University, Tallahassee, USA — [2]MPI-CPfS Dresden — [3]MPI-FKF Stuttgart

Elongated magnetic nanoparticles attract continuing attention in view of potential technological applications in data storage or spintronics. Using gated Hall magnetometers made from GaAs/AlGaAs 2DEG heterostructures we recently demonstrated a moment sensitivity of 10^4 μ_B by measuring the switching of a single magnetic Fe particle. Particles of 5 - 15 nm in diameter and generally 80 - 250 nm in height may be grown by STM-assisted CVD, an advantageous technique for exact positioning of individual Fe particles on different substrate materials.

The investigation of such nanoparticles is not only driven by the quest for a more detailed picture of the magnetization behavior of the particles themselves but ultimately to apply these small and local magnetic flux sources to intentionally influence and investigate other materials. A first step in this direction is to study hybrid systems of magnetic particles and an underlying magnetic film. Growing arrays or individual particles onto a permalloy thin film strongly enhances interactions between adjacent particles.

Also, the particles alter the magnetic domain structure of the magnetic thin film making its transport properties sensitive to the magnetization state of the particle array grown on top. We find and discuss a distinct (negative) switching effect in the magnetoresistance that persists up to room temperature.

MA 2.2 Mon 10:30 EB 301

Micro-Hall-Magnetometry for the investigation of magnetic nanoparticles — •Bastian Büttner, Florian Lochner, Christoph Brüne, Charles Gould, Georg Schmidt, and Laurens W. Molenkamp — Physikalisches Institut (EP3), Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

Nanoscale ferromagnetic thin films and particles are of great interest for spintronic applications. The non-volatility offers capabilities for data storage and novel electronic devices. Micro-Hall-Magnetometry is known as a simple, reliable and highly sensitive measurement method which is capable of investigating the magnetization of individual nanoscale particles over a wide temperature range [1]. Here we present the fabrication and comparison of micro-Hall bars in different material systems, namely InAs, HgTe, and (Al,Ga)As. In order to achieve high sensitivity for single, isolated nanoparticles it is essential to decrease the dimensions of the Hall cross to a size where crystal defects and sidewall depletion become an important factor; we have developed various different designs to mitigate these effects. The micro-Hall bars have been characterized using lithographically defined metallic nanomagnets. As an application, we want to use the micro-Hall bars to characterize chemically synthesized randomly orientated nanoparticles. We additionally developed a process which allows for exact positioning and aligning the Hall bar without damaging the nanoparticle. We will present details of the processing and experimental results.

[1] A. K. Geim et al., Appl. Phys. Lett. 71, 2379 (1997)

MA 2.3 Mon 10:45 EB 301

CoCrPt-SiO2 films on SiO2 spherical particle arrays — •Christoph Brombacher[1], Felix Springer[2], Hartmut Rohrmann[3], Martin Kratzer[3], Magdalena Parlinska[4], Stephan Meier[4], Peter Kappenberger[4], and Manfred Albrecht[1] — [1]Chemnitz University of Technology, Institute of Physics, Germany — [2]University of Konstanz, Department of Physics, Germany — [3]OC Oerlikon Balzers AG, Data Storage, Liechtenstein — [4]Empa - Materials Science & Technology, Dübendorf, Switzerland

CoCrPt-SiO2 is a granular material consisting of small magnetically decoupled grains and is commonly used for perpendicular magnetic recording applications. In this study, the system was deposited onto SiO2 spherical particle arrays with diameters down to 10nm to form arrays of magnetic nanostructures. TEM studies reveal that the growth of CoCrPt-SiO2 particles remains columnar with the (0001) orientation of individual grains pointing perpendicular to the particle surface. By varying the growth conditions of a Ru seed-layer, the degree of intergranular exchange coupling was controlled, leading to pronounced differences in the magnetic domain structure and its magnetic reversal behavior. Multidomain magnetic caps have been obtained for magnetically decoupled grains and increasing the coupling results in the formation of single-domain magnetic caps. In this presentation, the magnetic properties depending on the particle size as well as the angular dependence of the reversal behavior will be discussed with respect to the differences in intergranular exchange coupling.

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MA 2.4 Mon 11:00 EB 301

Co-Pt films and nanostructures by electrodeposition into diblock copolymer templates — •Manvendra Singh Khatri[1], Heike Schlörb[1], Sebastian Fähler[1], Ludwig Schultz[1], Bhanu Nandan[2], Marcus Böhme[2], Radim Krenek[2], and Manfred Stamm[2] — [1]IFW Dresden, P.O. Box 27 00 16, 01171 Dresden, Germany — [2]IPF Dresden, Postfach 120 411, 01005 Dresden, Germany

Co-Pt and Fe-Pt alloys are favored materials for future magnetic data storage due to good hard magnetic properties like high coercivity and anisotropy. The Co-rich $Co_{80}Pt_{20}$ was chosen for this study because it does not require post annealing in contrast to the ordered $L1_0$ CoPt or FePt. The Co-Pt films have been deposited from an aqueous bath containing Pt-p-salt and Co sulphamate at different current densities. The influence of deposition current density on film properties was investigated. As an alternative to the porous alumina templates, diblock copolymer templates have been proposed that allow smaller feature sizes and thus yield to higher pore densities. Templates have been fabricated by dip-coating a conducting substrate into a solution of polystyrene-block-poly(4-vinylpyridine) (PS-b-P4VP) and 2-(4-hydroxybenzeneazo) benzoic acid (HABA). Depending on the polymer composition lamellar or cylindrical structures can be achieved. By dissolving the HABA the pores are opened and afterwards electrodeposition of Co-Pt was carried out. Due to the inhomogeneous filling shape anisotropy parallel to the substrate surface is observed, whereas shape anisotropy along the wire axis (perpendicular to the surface) is expected for ideally filled Co-Pt nanowires.

MA 2.5 Mon 11:15 EB 301

CoPt alloy films on SiO_2 nanoparticle arrays — •Denys Makarov[1], Esteban Bermudez[2], Christoph Brombacher[3], Fabiola Liscio[4], Mireille Maret[4], Oliver G. Schmidt[2], Günter Schatz[1], and Manfred Albrecht[3] — [1]University of Konstanz, Department of Physics, 78457 Konstanz, Germany — [2]IFW Dresden, 01069 Dresden, Germany — [3]Chemnitz University of Technology, Institute of Physics, D-09107 Chemnitz, Germany — [4]ENSEEG, Saint Martin d'Heres, France

Combining self-assembled SiO_2 nanoparticle arrays with magnetic film deposited onto the particles, enables an elegant possibility to create magnetic nanostructure arrays with defined magnetic properties. In this regard, materials such as CoPt alloy are of particular interest due to their large magnetic anisitropy required for thermal stability in the high density magnetic recording applications. In order to induce high perpendicular magnetic anisotropy in CoPt alloys, the $L1_0$ phase with (001) texturing is required. For this purpose, a 10nm thick MgO(001) seed layer was introduced. Results on planar amorphous SiO_2 substrates reveal an uniaxial out-of-plane magnetic anisotropy and saturation magnetization for the CoPt alloy grown at 450°C of about $5x10^5 J/m^3$ and 800kA/m. These properties were transfered to CoPt alloy deposited onto arrays of SiO_2 particles with diameters down to 50nm. The formed CoPt nanocaps are in a magnetic single domain state with a large out-of-plane coercivity, which increases with decreasing particle size. In this presentation, the structural and magnetic properties will be discussed and compared to the planar film.

MA 2.6 Mon 11:30 EB 301

The first ternary intermetallic Heusler nanoparticles: Co_2FeGa. — •Lubna Basit[1], Aswani Yella[1], Sergej A. Nepijko[2], Vadim Ksenofontov[1], Gerhard H. Fecher[1], and Claudia Felser[1] — [1]Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg - University, 55099 Mainz — [2]Institute of Physics, Johannes Gutenberg - University, 55099 Mainz

Synthesis of materials with controlled particle size on the nanometer scale is an active area in the field of materials research. With the control over particle size, the electronic and magnetic properties of materials can be easily tuned. To study the effect of nanometer dimensions on the properties of Heusler alloys, a first example of Heusler nanoparticles is presented. Co_2FeGa Heusler *nanoparticles* were produced by reducing a methanol impregnated mixture of $CoCl_2.6H_2O$, $Fe(NO_3)_3.9H_2O$, and $Ga(NO_3)_3.xH_2O$ after loading on fumed silica. The dried samples were heated under pure H_2 gas at 900°C. The synthesized Co_2FeGa Heusler nanoparticles were characterized by HRTEM, XRD and Mößbauer spectroscopy. All peaks of the XRD pattern can be attributed to a $L2_1$ Heusler structure with a lattice constant of $a = 4.37$ Å. The size of the particles, as determined by transmission electron microscopy, is between 16 nm and 20 nm. The ferromagnetic behaviour of the particles as determined by the SQUID measurements is presented and compared with the bulk Co_2FeGa Heusler alloy.

MA 2.7 Mon 11:45 EB 301

Size dependence of the magnetization switching field of nano-island — •Guillemin Rodary, Sebastian Wedekind, Dirk Sander, and Jürgen Kirschner — Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle (Saale), Deutschland

We have explored the magnetization switching field of Co nano-islands grown on Cu(111). We apply spin-polarized scanning tunneling microscopy (SP-STM) at 7 K to measure the magnetocurrent hysteresis loop of a magnetic tunnel junction composed of a single nanostructure and the magnetic tip of the STM. We measure directly the magnetic response by spin-dependent scanning tunneling spectroscopy of an individual Co nano-island as a function of magnetic field of up to 4 T, oriented perpendicular to the sample surface [1].

We observe a transition from superparamagnetic to ferromagnetic behavior with increasing island size. In the ferromagnetic state, the switching of the magnetization of the island is identified by a sharp drop of the differential conductance as a function of magnetic field. Switching fields of the order of 1 T are observed [2], and we discuss our result in view of the Stoner-Wohlfarth model of magnetization rotation and also with regard to magnetic domain formation. Our work opens the way for studies of magnetic anisotropy of single nano-objects.

[1] G. Rodary, S. Wedekind, D. Sander and J. Kirschner, unpublished.

[2] O. Pietzsch, A. Kubetzka, M. Bode and R. Wiesendanger, Phys. Rev. Lett. 92, 057202 (2004).

MA 2.8 Mon 12:00 EB 301

Magnetic ordering in 2 dimensional arrays of polarized particles with higher order multipole moments — •Matthias Schult, Nikolai Mikuszeit, Elena Vedmedenko, and Roland Wiesendanger — Institute of Applied Physics, University of Hamburg, Jungiusstrasse 11, 20355 Hamburg, Germany

In arrays of polarized nanoparticles the stray field couples each particle to all others as stray field interaction is of long range nature. For non-spherical or multidomain polarized particles the stray field deviates from that of a point dipole and in dense arrays higher order moments must be taken into account [1].

Finite arrays of polarized single and two domain particles with spheroidal shape are investigated by means of Monte-Carlo simulation. Typical magnetic self-energy is neglected as the system is regarded as a model for spinor Bose-Einstein condensates. The simulation uses analytical solutions for the higher order moments [2]. For systems with a strong quadrupolar contribution a new ground state, different from the well known dipolar ground state, is found. Lattices of different symmetry are investigated. Lattice-symmetry-induced as well as particle-geometry-induced phase transitions are observed.

[1] E. Y. Vedmedenko, N. Mikuszeit, H. P. Oepen, and R. Wiesendanger, 2005, Phys. Rev. Lett. **95**, 207202

[2] M. Schult, N. Mikuszeit, E. Y. Vedmedenko, and R. Wiesendanger, 2007, J. Phys. A, *accepted*

MA 2.9 Mon 12:15 EB 301

Magnetische Neutronenkleinwinkelstreuung an edelgaskondensierten Ferromagneten — •MIHDI ELMAS[1], FRANK DÖBRICH[1], STEFAN MONZ[1], MELISSA SHARP[2], HELMUT ECKERLEBE[2], RAINER BIRRINGER[1] und ANDREAS MICHELS[1] — [1]Technische Physik, Universität des Saarlandes, Saarbrücken, Germany — [2]GKSS Forschungszentrum, Geesthacht, Germany

Die magnetische Neutronenkleinwinkelstreuung ist eine weit verbreitete Methode zur Untersuchung der magnetischen Mikrostruktur nanokristalliner Materialien. Insbesondere eignet sie sich zum Studium der Volumeneigenschaften dieser Materialien. Streuuntersuchungen an zweiphasigen Nanokompositen weisen eine ungewöhnliche "kleeblattförmige" Anisotropie im Streubild auf. Zur tiefer gehenden Analyse dieser Beobachtung wurden edelgaskondensierte magnetische Materialien verwendet. Neben einer Korngrösse von 10-20 nm zeichnen sich diese Materialien durch einen signifikanten Anteil an Porosität aus. Hierbei manifestieren sich die Poren als nichtmagnetische Gebiete in einer magnetischen Matrix. Dahingehend stellt ein edelgaskondensierter magnetischer Festkörper ein zweiphasiges System dar, beidem einerseits die zufällige Orientierung der kristallographischen Achsen zwischen benachbarten Kristalliten, andererseits der Sprung in der Sättigungsmagnetisierung an der Phasengrenzfläche zu einem starken magnetischen Streusignal führen. Gegenstand dieses Beitrags ist die Untersuchung nanoporöser edelgaskondensierter Ferromagnete mittels magnetischer Neutronenkleinwinkelstreuung.

MA 2.10 Mon 12:30 EB 301

Ion irradiation induced local creation of ferromagnetism in $Fe_{60}Al_{40}$ alloys — •T. Strache[1], M. O. Liedke[1], J. Fassbender[1], W. Möller[1], E. Menendez[2], J. Sort[2,3], T. Gemming[4], A. Weber[5], L. J. Heyderman[5], K. V. Rao[6], S. C. Deevi[7], and J. Nogues[3,8] — [1]Forschungszentrum Dresden-Rossendorf, Germany — [2]Universitat Autonoma de Barcelona, Spain — [3]ICREA Barcelona, Spain — [4]IFW Dresden, Germany — [5]PSI Villigen, Switzerland — [6]Royal Institute of Technology, Stockholm, Sweden — [7]Research Center Philip Morris, Richmond, USA — [8]Institut Catala de Nanotecnologia, Spain

Ion irradiation of $Fe_{60}Al_{40}$ alloys results in the phase transformation from the paramagnetic, chemically ordered B2-phase to the ferromagnetic, chemically disordered A2-phase. The magnetic phase transformation is related to the number of displacements per atom (dpa) during the irradiation. For heavy ions (Ar^+, Kr^+, Xe^+) a universal curve is observed with a steep increase in the fraction of ferromagnetic phase reaching saturation, i. e., a complete phase transformation, at about 0.5 dpa. This proves the purely ballistic nature of the disordering process. If light ions are used (He^+, Ne^+) a pronounced deviation from the universal curve is observed. This is attributed to bulk vacancy diffusion from dilute collision cascades, which leads to a partial recovery of the thermodynamically favored B2-phase. Comparing different noble gas ion irradiation experiments allows to asses the corresponding counteracting contributions. In addition, the potential to create local ferromagnetic areas embedded in a paramagnetic matrix is demonstrated.

MA 2.11 Mon 12:45 EB 301

Entwicklung eines magnetischen Lab-on-a-Chip für die Point-of-Care Diagnostik — •Astrit Shoshi, Joerg Schotter und Hubert Brueckl — Austrian Research Centers GmbH - ARC, Nano-Systemtechnologien, Wien, Oesterreich

Der Begriff Lab-on-a-Chip (LOC) bezeichnet mikrofluidische Systeme, welche in der Lage sind, eine Vielzahl der bislang händisch durchgeführten Schritte der molekularen Diagnostik automatisiert anhand von kaum vorpräparierten Proben schnell und sensitiv durchzuführen.

Eine sehr viel versprechende Variante solcher LOC's sind magnetische Biochips, bei welchen magnetische Partikel zur Aufreinigung und Detektion der Zielmoleküle verwendet werden. Da alle benötigten Komponenten leicht in ein Desktop-Gerät integriert werden können, sind magnetische Biochips sehr gut für den Einsatz im Bereich der Point-of-Care Diagnostik geeignet.

In diesem Vortrag stellen wir das von uns verfolgte Konzept eines magnetischen LOC vor. Hierbei werden die Zielmoleküle in einer Probenkammer spezifisch an funktionalisierte magnetische Partikel (Marker) angebunden, welche zur Beschleunigung des Bindungsprozesses mit Hilfe von magnetischen Gradientenfeldern durchmischt werden. Anschließend werden die Marker magnetisch auf bis zu 8 unterschiedlich funktionalisierte GMR-Sensoren gezogen, welche die Oberflächenbelegung mit magnetischen Markern nachweisen. Es können sowohl anziehende als auch abstoßende magnetische Kräfte auf die Marker ausgeübt werden, wodurch unspezifische Bindungen stark reduziert werden.