MA 7: Micro and Nanostructured Magnetic Materials II

Time: Monday 15:15–18:30 Location: EB 301

MA 7.1 Mon 15:15 EB 301

The Effect of Step Atoms on the Switching Behavior of Superparamagnetic Nanoislands — •Gabriela Herzog[1], Stefan Krause[1], Matthias Bode[2], and Roland Wiesendanger[1] — [1]Institute of Applied Physics, University of Hamburg, Germany — [2]Center for Nanoscale Materials, Argonne National Laboratory, USA

Spin-polarized scanning tunneling microscopy (SP-STM) is a well-established tool to investigate not only static but also dynamic magnetic properties at lateral resolution down to the atomic scale [1]. Our variable temperature STM is suitable to investigate the superparamagnetic switching behavior of single nanoislands consisting of about 100 Fe atoms on W(110) over a wide temperature range between 30 K and 50 K.

From the Arrhenius-like switching behavior we can derive the anisotropy energy barrier that has to be surmounted by thermal agitation to switch the magnetization of a particular nanoisland. An analysis of the data reveals that the energy barrier is neither in agreement with a coherent switching, nor a switching by the nucleation of a domain wall.

Recently, it has been shown that the anisotropy of edge and center atoms of Co islands on Pt(111) varies by more than one order of magnitude due to different coordination [2]. Our experimental results will be presented and discussed in terms of anisotropy contributions in dependence of atom coordination number.

[1] M. Bode *et al.*, Phys. Rev. Lett. **92**, 067201 (2004)
[2] S. Rusponi *et al.*, Nature Mater. **2**, 546 (2003)

MA 7.2 Mon 15:30 EB 301

Magnetic ratchet — •Alexander Auge, Alexander Weddemann, and Andreas Hütten — Bielefeld University, Universitätsstr. 25, 33615 Bielefeld

Transport phenomena in spatially periodic magnetic systems far from thermal equillibrium are considered. The emphasis is put on directed transport of magnetic beads in a so called magnetic ratchet (Brownian motor). An asymmetric magnetic potential and Brownian motion of magnetic beads are the basic concepts for a magnetic ratchet. Two main concepts to achieve an asymmetric magnetic potential are considered. On the one hand this is achievable by a gradient in current density, on the other hand asymmetric geometries of magnetic materials can be used.

In this thesis simulations are carried out to find asymmetric magnetic potentials, which can be used for directed transport. Promising simulated geometries are experimentally realised.

MA 7.3 Mon 15:45 EB 301

Two distinct reversal modes in ordered arrays of magnetic iron oxide nanotubes prepared by atomic layer deposition — •Julien Bachmann[1,2], Jing Jing[1], Juan Escrig[1,3], Dora Altbir[3], Sven Barth[4], Sanjay Mathur[4], Ulrich Goesele[1], and Kornelius Nielsch[2] — [1]Max Planck Institute of Microstructure Physics, Halle — [2]Institute of Applied Physics, University Hamburg — [3]Departamento de Fisica, Universidad de Santiago de Chile — [4]Institute of Inorganic Chemistry, University Wuerzburg

Ordered arrays of Fe_3O_4 nanotubes have been prepared by atomic layer deposition (ALD) in a structured substrate used as template, porous anodic alumina. With these tools, the length, diameter, and wall thickness of the tubes can be tuned accurately between 1 and 5 μm, between 40 and 160 nm, and between 1 and 40 nm, respectively. This enables one to systematically study how physical properties are affected by geometry. Such arrays give rise to a ferromagnetic response that strongly depends on geometry. Variations of the tube wall thickness result in non-monotonic changes in coercive field. Theoretical modeling of the magnetization reversal between the two magnetically saturated states reproduces the experimental data. For thin tubes the reversal occurs by propagation of a "vortex"domain boundary, while in thicker ones it is driven by propagation of a "transverse"domain boundary. The optimal wall thickness thus corresponds to the crossover between the vortex and transverse modes of magnetization reversal. We envision that the method may be generalized to nanoobjects of more complex geometries.

MA 7.4 Mon 16:00 EB 301

Magnetic correlations of nanostructures created by optical interference lithography on thin films — •Artur Glavic, Stefan Mattauch, and Thomas Brückel — Institut f. Festkörperforschung-Streumethoden, Forschungszentrum Jülich GmbH, 52425 Jülich

With increasing miniaturization, coupling effects between magnetic structures used in information technology become ever more important. In order to get a better understanding of these coupling mechanisms, we prepared as model systems laterally patterned epitaxial iron films consisting of stripes with periods between 500 nm and some μm by optical interference lithography. Polarised neutron reflectometry is the method of choice to study magnetic correlations in these systems as one can separate atomic and magnetic scattering and as the lengths scales accessible by off specular scattering match quite well the periods mentioned.

The preparation of the samples by Molecular Beam Epitaxy MBE and interference lithography will be presented. The advantages of interference lithography for this application and the setup we build for this purpose will be shown. The methods of x-ray and polarised neutron reflectometry will be introduced, as well as the setup of the used neutron reflectometer, TREFF at the FRM II research reactor in Munich. Off-specular scattering allows us to deduce the magnetic domain structure as function of the external field. The results will be discussed in comparison to the magnetic behaviour on lager scales measured with MOKE, and compared with earlier works.

MA 7.5 Mon 16:15 EB 301

Nucleation and propagation of transverse and vortex domain walls in nanowires with a thickness gradient — •Oleg Petracic[1,3], Hartmut Zabel[1], Detlef Görlitz[2], Kornelius Nielsch[2], Dan Read[3], and Russell P. Cowburn[3] — [1]Institut für Experimentalphysik, Ruhr-Universität Bochum, D-44780 Bochum — [2]Institute of Applied Physics and Microstructure Research Center, University of Hamburg, D-20355 Hamburg — [3]Physics Department, Imperial College London, London SW7 2AZ, UK

Permalloy nanowires with a thickness gradient along the nanowire axis have been prepared by electron beam lithography and studied using a magneto-optic Kerr effect setup. The nucleation and propagation of either transverse or vortex domain walls is strongly modified by a slope in the thickness. For relatively narrow and thin wires, i.e., width w = 150nm and thickness t=8nm, wires with a slope have a strongly decreased coercive field compared to wires without a slope. However, wider and thicker wires, i.e., w=500...2000nm and t=18nm show a much smaller effect of the slope. We assume that in the sloped region a transverse domain wall nucleates for all wire geometries. For narrow and thin wires the transverse wall is the energetically preferred configuration, while wider and thicker wires show a vortex wall. The initial transverse wall either can propagate through the entire wire or has to transform to a vortex wall, respectively. Micromagnetic simulations confirm our experimental investigations.

MA 7.6 Mon 16:30 EB 301

Thermische und magnetsiche Charakterisierung von Fe + Co Streifenstrukturen mittels Rastersondenmikroskopie basierter Detektion der ferromagnetischen Resonanz — •Sven Stienen, Ralf Meckenstock, Jürgen Lindner, Igor Barsukov und Michael Farle — Fachbereich Physik und Center for Nanointegration (CeNIDE), Universität Duisburg-Essen, 47048 Duisburg

Es wurden Fe und Co Streifenstrukturen mit einer Länge von 100 μm und einer Breite von 0.5 - 2 μm mittels ortsaufgelöster ferromagnetischer Resonanz (FMR) untersucht. Die Schichtdicke betrug 15 - 25 nm. Für diese Streifenstrukturen erwartet man formanisotropiebedingte, nicht homogene magnetische Mikrowellenanregungen.

Zur ortsaufgelösten Detektion dieser FMR-Anregungen wurde ein Rasterkraftmikroskop verwendet, welches mit einer thermischen Spitze ausgerüstet ist, die den thermischen Nahfeldeffekt ausnutzt (SThM-FMR)[1]. Dabei wird eine örtliche Auflösung von 30nm und eine thermische Auflösung von 1mK erreicht. Die Spitze befindet sich in Kontakt zu der magnetischen Struktur. Im Falle der ferromagnetischen Resonanz erwärmt sich die Struktur durch die Absorption von Mikrowellenleistung.

Mittels der SThM-FMR konnten sowohl die homogene FMR-Resonanz einer einzelnen Nano-Struktur als auch über die Nano-

Struktur lateral verteilte Randresonanzen und Spinwellen detektiert werden. Mit diesem Verfahren ist man sensitiv auf ca. 10^6 Spins. Dieser Beitrag wurde von der DFG SFB491 gefördert.

[1] R.Meckenstock et.al., Appl.Phys.Let. 91, 142507, 2007

MA 7.7 Mon 16:45 EB 301

Temperature-dependent investigation of domain wall depinning in nanowires by ballistic Hall micromagnetometry — •Peter Lendecke, René Eiselt, Ulrich Merkt, and Guido Meier — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstraße 11, 20355 Hamburg, Germany

We use ballistic Hall micromagnetometry [1] to determine depinning fields of domain walls in permalloy nanowires in the temperature range between 1.6 and 50 K. The walls are pinned in lithographically defined triangularly shaped constrictions. Pinning and depinning of single domain walls is detected via the stray field of the walls. The high sensitivity of our Hall magnetometer to the local micromagnetic structure allows the detection of single domain walls and a distinction of different wall types. A strong decrease of depinning fields at raised temperature is observed. For temperatures above 20 K additional domain wall types occur that can be distinguished by different stray field strengths as well as by different depinning field values [2]. We fit the depinning field decrease to a model describing the depinning process by hopping over a single energy barrier [3].

[1] A. K. Geim et al., Appl. Phys. Lett. **71**, 2379 (1997)
[2] P. Lendecke, R. Eiselt, U. Merkt, and G. Meier, submitted.
[3] J. Kurkijärvi, Phys. Rev. B. **6**, 832 (1972).

MA 7.8 Mon 17:00 EB 301

On the aspect ratio and packing factor dependence of magnetostatic interactions in densely-packed Co nanowire arrays — •Giray Kartopu[1], Orhan Yalçın[2], Ali Cemil Başaran[3], Morten Madsen[4], Horst-Günter Rubahn[4], and Mohammed Es-Souni[1] — [1]Institute for Materials and Surface Technology, University of Applied Science of Kiel, Grenzstrasse 3, 24149, Kiel, Germany — [2]Department of Physics, Bozok University, 66500 Yozgat, Turkey — [3]Department of Physics, Gebze Institute of Technology, 41400 Gebze, Kocaeli, Turkey — [4]Mads Clausen Institute, NanoSYD, University of Southern Denmark, Alsion 2, DK-6400, Sønderborg, Denmark

Densely-packed and ordered cobalt nanowire (NW) arrays with aspect ratio (wire legth/diameter) varying between 5-250 have been fabricated via electrodeposition into porous alumina templates (<60 nm channel diameter). For a fixed diameter the NW length was controlled by monitoring the total deposited charge, and for high-aspect ratio NWs with variable diameters the template pores were adjusted by a post-anodization wet etching. Room temperature magnetization measurements (M-H loops) show that the magnetic behaviour of Co NW arrays is governed largely by aspect ratio- or packing factor-dependent magnetostatic wire-wire interactions.

MA 7.9 Mon 17:15 EB 301

Dipolar interactions on lateral structured square lattices — •Alexandra Schumann[1], Arndt Remhof[3], Andreas Westphalen[1], Hartmut Zabel[1], Torsten Last[2], Ulrich Kunze[2], Elena Vedmedenko[4], and Nikolai Mikuszeit[4] — [1]Institut für Experimentalphysik, Ruhr-Universität Bochum, 44780 Bochum, Germany — [2]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum, 44780 Bochum, Germany — [3]EMPA, Hydrogen & Energy, Überlandstrasse 129, 8600 Dübendorf, Switzerland — [4]Institut für Angewandte Physik, Universität Hamburg, Jungiusstr. 11a, 20355 Hamburg, Germany

We investigated the remanent states of laterally structured permalloy dipole arrays. A single permalloy island has a length of L = 3 μm and a width of w = 0.3 μm. Due to the arrangement on a square lattice the magnetic dipoles are inherently frustrated and show different ground states depending on their separation. We implemented separations in the range of a = 0.42 μm to 3.4 μm. Theory predicts that for this geometry either an onion, a horseshoe or a vortex state may be realized in the remanent magnetic state. To achieve a vortex state a high energy barrier is required to overcome, therefore it is more likely to observe the onion or the horseshoe state. We could confirm these predictions of theory in our experiments by MFM images. Our experiments show that the remanent configuration of the dipoles depends on the direction of the initial magnetization as well as on the distance between the single elements.

This work was supported by the SFB 491 and the SFB 668.

MA 7.10 Mon 17:30 EB 301

Magnetoresistance in epitaxial Fe wires on GaAs(110) — •Christoph Hassel, Florian M. Römer, Jürgen Lindner, and Günter Dumpich — Fachbereich Physik and Center for Nanointegration (CeNIDE), Universität Duisburg-Essen, Lotharstrasse 1, 47048 Duisburg, Germany

From epitaxial Fe films grown on GaAs (110) wires of different widths are prepared using electron beam lithography and Ar sputtering. Before processing, the structural properties of the substrate and the Fe films are determined by AES, LEED and IV-LEED. For further processing, the films are capped with Ag and Pt to prevent oxidation of the Fe films under ambient conditions. The anisotropy constants of the capped films are quantified using ferromagnetic resonance. After preparing the wires, their magnetic properties are studied in a magnetic force microscope. These measurements confirm the epitaxial structure of the Fe wires. To investigate the magnetoresistance of the Fe nanowires, the wires are contacted by gold leads in a second EBL process. These measurements also clearly show the epitaxial structure of the wires. The magnetoresistance behaviour allows to determine anisotropy fields of the wires.

This work is financially supported within the SFB 491.

MA 7.11 Mon 17:45 EB 301

Spin structure of nanocrystalline Gadolinium studied by magnetic small-angle neutron scattering — •Frank Döbrich[1], Mihdi Elmas[1], Adrian Ferdinand[1], Jürgen Markmann[1], Melissa Sharp[2], Helmut Eckerlebe[2], Rainer Birringer[1], and Andreas Michels[1] — [1]Technische Physik, Universität des Saarlandes, Saarbrücken, Germany — [2]GKSS Forschungszentrum, Geesthacht, Germany

We report on magnetic-field-dependent small-angle neutron scattering (SANS) experiments on nanocrystalline inert-gas condensed bulk Gd, which was synthesized using the low-capturing isotope ^{160}Gd. The angular dependency of the scattering cross section is in very good agreement with recent theoretical predictions. Rather unexpected for this type of material, we observe a "clover-leaf" anisotropy in the SANS signal, the origin of which is attributed to the existence of longitudinal magnetization fluctuations associated with a disordered grain-boundary component.

MA 7.12 Mon 18:00 EB 301

Exchange coupled $L1_0$-FePt/Fe thin films and nanopatterns — •Achim Breitling and Dagmar Goll — Max-Planck-Institut für Metallforschung, Heisenbergstr. 3, 70569 Stuttgart, Germany

Bilayered $L1_0$-FePt/Fe composite nanopatterns are a very promising possibility to push data storage density up to 1 Tbit/inch^2 and beyond. The hard magnetic $L1_0$-FePt layer with its high uniaxial anisotropy constant of $K_1 = 6.6 \cdot 10^6$ J/m^3 guarantees long-term stability even at small particle sizes whereas the addition of a Fe layer creates moderate switching fields achievable by conventional write heads. Therefore in a first step the magnetic properties of $L1_0$-FePt/Fe films were investigated as a function of the Fe film thickness. It is found that the coercive field $\mu_0 H_c$ can be tailored between 0.29 T and 2.75 T by the appropriate choice of the thickness of the Fe film. In a second step $L1_0$-FePt and $L1_0$-FePt/Fe nanopatterns respectively were produced using various electron lithography techniques. The magnetic properties of the nanopatterns are compared with those of the continuous films.

MA 7.13 Mon 18:15 EB 301

Magnetische Eigenschaften und kritisches Verhalten von nanokristallinem Terbium — •Stefan Philippi, Rainer Birringer und Andreas Michels — Technische Physik, Universität des Saarlandes, Saarbrücken, Germany

Die Mikrostruktur eines ferromagnetischen Materials hat starken Einfluss auf dessen magnetische Eigenschaften. In nanostrukturierten Materialien wirken sich insbesondere die konkurrierenden Längenskalen der charakteristischen magnetischen Austauschlänge und der durch die Geometrie eingeschränkten strukturellen Längen aus.

An nanokristallinem Terbium manifestiert sich dieses Wechselspiel u.a. durch die Unterdrückung der antiferromagnetischen Helixphase bei mittleren Korngrößen von etwa 20 nm: Die im grobkristallinen Material charakteristischen Peaks in der temperaturabhängigen Anfangssuszeptibilität um 221 K und 229 K, die der Curie- bzw. Neél-Temperatur zugeordnet sind, verschwinden zugunsten eines einzelnen

Maximums bei 224 K.

Die Charakterisierung dieses veränderten Phasenüberganges erfolgte anhand von Magnetisierungs- und Suszeptibilitätsmessungen an edelgaskondensiertem Terbium für verschiedene mittlere Korngrößen im betreffenden Temperaturbereich. Der Phasenübergang wurde hinsichtlich der Übergangstemperatur und der kritischen Exponenten analysiert.