

MA 7 Micro- and Nanostructured Magnetic Materials I

Time: Monday 15:00–18:00

Room: HSZ 03

MA 7.1 Mon 15:00 HSZ 03

Electronic and Magnetic Properties of Single Cr, Triangles and Chains on W(110) — ●TIM WEHLING, SERGEY OKATOV, and ALEXANDER LICHTENSTEIN — I. Institut für Theoretische Physik, Universität Hamburg, Jungiusstraße 9, 20355 Hamburg

We study nano-scale systems of Cr single atoms, triangles and chains on the W(110) surface in comparison to bulk and film properties of chromium within the density functional theory. Total energy, magnetic and electronic properties as well as the crystal and the band structure of the system in question have been considered. Among the results the most interesting are the following: (i) In all the systems Cr appeared to be magnetic with $\mu = 3.0 - 3.4\mu_B$; (ii) The magnetic ordering of the chains strongly depends on their orientation. The type of magnetic ordering changes from antiferromagnetic (for chains along the [111]-direction) to ferromagnetic (chains along [001]) likely according to the change in the distance between the Cr atoms.

MA 7.2 Mon 15:15 HSZ 03

Electronic structure of Co in ZnO Thin Films — ●HUIJAN ZHOU¹, CHRISTOPH KNIES¹, DETLEV M. HOFMANN¹, NIKLAS VOLBERS¹, JAN STEHR¹, SWEN GRAUBNER¹, BRUNO K. MEYER¹, PETER J. KLAR², and WOLFRAM HEIMBRODT² — ¹I. Physics Institute, Justus-Liebig-University Giessen, Heinrich-Buff-Ring 16, D-35392 Giessen, Germany — ²Material Research Center and department of semiconductor physics, Renthof 5, LB2, D-35032 Marburg/Lahn, Germany

The concern of this work is to investigate cobalt doped ZnO thin films prepared via sol-gel methods. X-ray diffraction (XRD) and Raman spectroscopy are applied to monitor the crystal quality and the segregation phase of the film. Within the concerned doping concentration (0.5%-10%) XRD shows mainly the diffraction peaks from wurtzite ZnO (0002) and (0004) planes without secondary phases. No Co-related phonon modes are observed, as proved by Raman measurements in comparison with those of a pure CoO thin films. The ZnO:Co films have a typical grain size of 20-50 nm with a thickness of 300-500 nm. Fine structures of Co²⁺ (3d7) internal d-d absorption are well resolved. All zero phonon lines (ZPL) and phonon replica related to ⁴T₁(F) → ⁴A₂ are observed, which demonstrates high crystal quality and the incorporation of Co²⁺ on Zn²⁺ lattice sites in a tetrahedral symmetry with a trigonal distortion. In the visible region transitions due to ⁴A₂ → ²T₁(G), ⁴T₁(P), ²A₁(G) processes are observed. Magnetic properties of ZnO:Co have been characterized. Electron paramagnetic resonance measurements are in agreement with the simulation of Co-doped ZnO powder. So far no evidence for ferromagnetism is obtained.

MA 7.3 Mon 15:30 HSZ 03

Control of magnetic anisotropy and magnetic patterning of perpendicular Co/Pt multilayer films by laser irradiation — ●I. GUHR¹, C. SCHUPPLER¹, A. HABENICHT¹, M. MARET², P. LEIDERER¹, J. BONEBERG¹, and M. ALBRECHT¹ — ¹University of Konstanz, Department of Physics, 78457 Konstanz, Germany — ²Laboratoire de Thermodynamique et Physico-Chimie Métallurgiques, 38402 Saint Martin d'Heres, France

We report an approach to altering the magnetic properties of (111) textured Co/Pt multilayer films grown on sapphire (0001) substrates in a controlled way using a single laser pulse ($\lambda = 532$ nm) at fixed FWHM of about 10 ns. The as-grown films reveal a strong perpendicular magnetic anisotropy induced by interfacial anisotropy. We show that laser irradiation can chemically mix the multilayer structure, leading to a reduction of the perpendicular magnetic anisotropy and coercivity and a rise in the saturation magnetization depending on the laser fluence as confirmed by XRD and SQUID magnetometry investigations.

As a result, the films can also be patterned into hard and soft magnetic regions using a regular 2D lattice of polystyrene particles acting as an array of microlenses. Regularly spaced submicrometer-sized regions of magnetically altered material have been produced over areas of a square millimeter. In this way, magnetic patterning with periods smaller than the wavelength can be achieved.

This project is funded by the DFG through SFB 513 and the Emmy-Noether program at the University of Konstanz.

[1] C. Schuppler et al., Appl. Phys. Lett. (2005) accepted for pub.

MA 7.4 Mon 15:45 HSZ 03

Magnetic patterning of interlayer exchange coupled Fe/Cr/Fe-trilayers induced by ion irradiation — ●S. BLOMEIER¹, B. HILLEBRANDS¹, V. E. DEMIDOV², S. O. DEMOKRITOV², B. REUSCHER³, A. BRODYANSKI³, and M. KOPNARSKI³ — ¹Fachbereich Physik, TU Kaiserslautern, 67663 Kaiserslautern, Germany — ²Institut für Angewandte Physik, Westfälische Wilhelms-Universität Münster, 48149 Münster, Germany — ³Institut für Oberflächen- und Schichtanalytik, TU Kaiserslautern, 67663 Kaiserslautern, Germany

We demonstrate the fabrication of small ferromagnetic elements embedded in a continuous, antiferromagnetically coupled epitaxial Fe/Cr/Fe-trilayer with a zero net-magnetic moment in remanence. The trilayer is locally irradiated with 30 keV Ga⁺ ions within a fluence range of $1.25 - 6 \cdot 10^{16}$ ions/cm², using a focused ion beam source. According to a previously established model [1], the irradiation leads to interfacial intermixing and to a change of the interlayer thickness. As a result, a local transition from antiferromagnetic to ferromagnetic coupling due to direct exchange through ferromagnetic pinholes is achieved. Micron-sized areas with different geometries are irradiated in this way and analyzed with atomic force microscopy and magnetic force microscopy. It is shown that small ferromagnetic elements embedded into a smooth, antiferromagnetically coupled film can be created with this technique.

This work was supported by the EC-RTN NEXBIAS and by the Alexander von Humboldt Foundation.

[1] Demokritov et al., Phys. Rev. Lett. 90, 097201 (2003).

MA 7.5 Mon 16:00 HSZ 03

Magnetic reversal of microstructured patterns — ●ANDREAS WESTPHALEN, ARNDT REMHOF, KATHARINA THEIS-BRÖHL, and HARTMUT ZABEL — Institut für Experimentalphysik/Festkörperphysik,

We have investigated the magnetization reversal of regular arrays of magnetic continuous and discontinuous open triangles using the magneto-optical Kerr effect in Vector-MOKE and Bragg-MOKE configuration. With Vector-MOKE both components of the magnetization vector, m_x and m_y , yield the vector sum of the average magnetization vector. We performed Vector-MOKE not only at the specular reflection, but also at diffraction spots where we obtain information about the Fourier components of the magnetization distribution. For the analysis we have combined MOKE measurements with micromagnetic simulations. A satisfactory agreement between the experiments and the predictions from the micromagnetic model allows the interpretation of the experimental data. By interrupting the triangular structure with one or more notches the remagnetization breaks down into individual reversals in different parts of the structure. The continuous triangles are characterized by a narrow switching field distribution; the formation of domains is more favored in the discontinuous triangles than in the continuous ones.

We acknowledge financial support through SFB 491.

MA 7.6 Mon 16:15 HSZ 03

Real space observation of dipolar interaction in arrays of iron and permalloy elements — ●GUIDO MEIER¹, MARKUS BOLTE¹, RENE EISELT¹, ULRICH MERKT¹, DONG-HYUN KIM², and PETER FISCHER² — ¹University of Hamburg, Institute of Applied Physics and Microstructure Advanced Research Center Hamburg, Jungiusstr. 11, 20355 Hamburg — ²Center for X-Ray Optics, Lawrence Berkeley National Lab, 1 Cyclotron Road, Mail Stop 2R0400, Berkeley, CA 94720, USA

Square lattice arrays of thin micro- and nanoelements of iron and permalloy are investigated by magnetic transmission x-ray microscopy. The influence of dipole interaction is analyzed by varying the inter-element distance, the angle of the applied magnetic field, and the lattice configuration. For the iron squares the magnetostatic field caused by inter-element interaction leads to a substantial stabilization of the center elements of the array [1] comparable to the magnetization process previously found by numerical solution of the Landau-Lifshitz equation for magnetic dot arrays. Micromagnetic simulations show, that for high field strengths the dipolar interaction is collinear with the external field, while in the low-field-regime the strayfields have significant perpendicular components leading to a complex reversal mechanism.

[1] Markus Bolte, Rene Eiselt, Guido Meier, Dong-Hyun Kim, and Peter Fischer, J. Appl. Phys., accepted

MA 7.7 Mon 16:30 HSZ 03

Intergrain interactions in nanocomposite Fe-Pt alloys — ●JULIA LYUBINA, KIRILL KHLOPKOV, OLIVER GUTFLEISCH, KARL-HARTMUT MÜLLER, and LUDWIG SCHULTZ — IFW Dresden, Institute for Metallic Materials, P.O. Box 270016, D-01171 Dresden, Germany

The structure and magnetic properties of nanocomposite $\text{Fe}_{100-x}\text{Pt}_x$ ($x=40-60$) powders prepared by mechanical alloying followed by annealing are investigated. Different microstructures were obtained depending on the Pt concentration: a combination of the hard magnetic L1_0 FePt and paramagnetic L1_2 FePt_3 phases, essentially single phase L1_0 FePt and a mixture of L1_0 FePt and soft magnetic L1_2 Fe_3Pt phases. For ferromagnetic phases, a domain structure comprised of elongated interaction domains was observed by magnetic force microscopy (MFM). MFM data and remanence curves were used to provide insight into the nature of intergrain interactions in such powders. The analysis points to strong intergrain coupling in the $\text{Fe}_{100-x}\text{Pt}_x$ powders. An additional small magnetostatic contribution can be observed for the Pt-rich powders.

MA 7.8 Mon 16:45 HSZ 03

Neutron scattering and modeling of dipole-field-induced spin disorder in Nanoperm — ●ANDREAS MICHELS¹, C. VECCHINI², O. MOZE², K. SUZUKI³, P.K. PRANZAS⁴, J. M. CADOGAN⁵, and J. WEISSMÜLLER⁶ — ¹Technische Physik, Universität des Saarlandes, Saarbrücken, Germany — ²Physics Department, University of Modena and Reggio Emilia, Italy — ³Department of Materials Engineering, Monash University, Melbourne, Australia — ⁴GKSS Research Center, Geesthacht, Germany — ⁵School of Physics, University of New South Wales, Sydney, Australia — ⁶Institut für Nanotechnologie, Forschungszentrum Karlsruhe, Karlsruhe, Germany

We present temperature and magnetic-field-dependent small-angle neutron scattering data for the ferromagnetic nanocomposite Nanoperm ($\text{Fe}_{89}\text{Zr}_7\text{B}_3\text{Cu}_1$). The spin-misalignment scattering in the approach-to-saturation regime unexpectedly reveals pronounced lobes of high intensity at angles $\pm 30 - 40^\circ$ relative to the magnetic-field axis. Based on numerical calculations, the four-fold angular symmetry of the scattering pattern can be explained in terms of local spin misalignment, which originates from dipolar stray fields due to the mismatch of the saturation-magnetization values between the bcc Fe particles and the amorphous magnetic matrix.

[1] A. Michels *et al.*, Europhys. Lett. **72**, 249 (2005).

[2] C. Vecchini *et al.*, Appl. Phys. Lett., in press (2005).

MA 7.9 Mon 17:00 HSZ 03

Preparation of single-crystalline Fe nanopillars for Spin-Transfer Switching — ●HENNING DASSOW, R. LEHNDORFF, D. E. BÜGLER, M. BUCHMEIER, P. GRÜNBERG, and C. M. SCHNEIDER — Institut für Festkörperforschung, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany

We report on the preparation of single-crystalline Fe nanopillars and on the first measurements of spin-transfer effects in this system. By using molecular beam epitaxy, we first deposit a layered magnetic system containing three Fe layers on top of a thick Ag buffer layer: $\text{Ag}(150)/\text{Fe}(14)/\text{Cr}(0.9)/\text{Fe}(10)/\text{Ag}(6)/\text{Fe}(2)$ [thicknesses in nm]. The measurement of the Magneto Optical Kerr Effect (MOKE) yields the magnetic properties of the samples. In various cleanroom steps we fabricate nanopillars of a diameter of 150 nm by a combined optical / e-beam lithography technique in which the pillars are defined by Ion Beam Etching (IBE). Redeposition of etched material is observed with Atomic Force Microscopy (AFM) and can significantly broaden the structure. After planarization we open the isolation and contact the top of the nanopillar with lift-off of Au. The effect of dipolar stray fields can be estimated by comparison of the Giant Magneto Resistance (CPP-GMR) and MOKE hysteresis loops. The stray fields also have direct influence on the spin-transfer switching of the nanopillars which is observed at current densities of $j \sim 2 \cdot 10^7$ A/cm² and can increase the critical current density by a factor of 10.

MA 7.10 Mon 17:15 HSZ 03

In flight optical heating of FePt nanoparticles — ●ELIAS MOHN, FRANZISKA SCHÄFFEL, CHRISTINE MICKEL, BERND RELLINGHAUS, and LUDWIG SCHULTZ — IFW Dresden, P.O. Box 270116, D-01171 Dresden

Monodisperse fractions of FePt nanoparticles are prepared by DC magnetron sputtering in an inert gas atmosphere at elevated gas pressures. Subsequent ejection into high vacuum results in an increase of the mean

free path of the particles and thereby allows to substantially suppress inter-particle coalescence and sintering. In order to benefit from the high magnetic anisotropy of L1_0 ordered FePt without sacrificing monodispersity, the particles are to be subjected to in-flight thermal annealing prior to their deposition to establish the chemically ordered tetragonal phase. Since convective in-flight heating [1] is no longer efficient in high vacuum, optical heating is applied. We have therefore developed a UHV compatible light furnace, in which the light of 3 halogen lamps (with a power of up to 1.2 kW each) is focussed on the particles' flight path at a length of 150 mm. The crystal structure of the particles is characterized by means of TEM. The status quo of these experiments is reported. First investigations reveal the occurrence of recrystallization twins in the particles upon switching on the light furnace. This indicates an effective heat transfer from the electromagnetic field to the particles. The experimental results are corroborated by model calculations of the energy transfer based on classical electrodynamics. The dependence of the heating rate on the particle size is discussed.

[1] S. Stappert *et al.*, J. Cryst. Growth **252** (2003) 440-450.

MA 7.11 Mon 17:30 HSZ 03

Arrays of magnetic nano particles using self-organised semiconductor surfaces — ●NIKOLAI MIKUSZEIT¹, MIGUEL ANGEL NIÑO¹, JULIO CAMARERO¹, JUAN JOSÉ DE MIGUEL¹, RODOLFO MIRANDA¹, CHRISTIAN HOFER², CHRISTIAN TEICHERT², THOMAS BOBEK³, and STEPAN KYRSTA⁴ — ¹Dpto. Física de la Materia Condensada, Universidad Autónoma de Madrid, E-28049 Madrid, Spain — ²Institut für Physik, Montanuniversität, A-8700 Leoben, Austria — ³Institut für Halbleitertechnik, RWTH-IHT, D-52056 Aachen, Germany — ⁴Lehrstuhl für Werkstoffchemie, RWTH-MCh, D-52056 Aachen, Germany

The self-organisation of semiconductor surfaces has been used to create arrays of magnetic nano particles [1]. The surface structure and magnetic properties are amongst others investigated by AFM and MOKE. In a first approach we use strain induced self-assembled SiGe surfaces as growth templates. Shadow deposition onto these surfaces results in elongated magnetic dots [2]. In a second approach the formation of self-organised hexagonal dots of GaSb surfaces, due to Ar⁺ sputtering, are used [3]. Deep trenches between the dots cut an embedded magnetic layer into discs. Both systems show dipolar coupling between the dots. To overcome the dipolar coupling a high magnetic anisotropy energy is required. In order to enhance the magnetic anisotropy, CoPt-multilayers with perpendicular anisotropy and Co/CoO in-plane systems are studied. The dot magnetic behaviour is compared to micromagnetic simulations.

[1] C. Teichert Appl. Phys. A **76**, 653 (2003)

[2] A. M. Mulders *et al.* Phys. Rev. B, **71**, 214422 (2005)

[3] S. Facsko *et al.* Science **285**, 1551 (1999)

MA 7.12 Mon 17:45 HSZ 03

Magnetic nanostructures produced by micelle masks — ●S. PÜTTER¹, H. STILLRICH¹, A. FRÖMSDORF², C. MENK¹, R. FRÖMTER¹, S. FÖRSTER², and H. P. OEPEN¹ — ¹Institut für Angewandte Physik, Jungiusstr. 11, 20355 Hamburg — ²Institut für Physikalische Chemie, Grindelallee 117, 20146 Hamburg

The production of magnetic nanostructure arrays on the length scale of centimeters is a challenge of today's research. Usually, lithography is used though it is very time consuming. We follow an alternative way by utilizing self organized micelle patterns as masks. The micelles consist of diblock copolymers and can be produced in the diameter range from 20 nm to 100 nm. By dip coating single layers of micelles are deposited onto the substrates. The micelles form an almost hexagonal array with height modulation smaller than the micelle diameter.

Various ways to produce nanostructures are possible and applied. The growth of magnetic films on top of the micelles preserves the morphology. By sputtering the sample at grazing incidence the caps of the micelles are taken off and an antidot array is produced. An alternative way is to use filled micelles (e.g. with SiO₂). These micelles are deposited onto magnetic films. Sputtering at normal incidence produces a dot array due to different sputtering yields.

We have investigated the morphology and topography of the nanostructure arrays by SEM and AFM. We correlate the results of the aforementioned studies with the magnetic behaviour obtained via magneto optical Kerr effect as well as scanning electron microscopy with polarization analysis.