MA 39: Micro- and Nanostructured Magnetic Materials I

Time: Thursday 9:30–13:00 Location: EB 202

MA 39.1 Thu 9:30 EB 202

Room Temperature Magnetometry of an Individual Iron Filled Carbon Nanotube Acting as Nanocantilever — •Stefan Philippi, Uhland Weissker, Thomas Mühl, Albrecht Leonhardt, and Bernd Büchner — Leibniz Institut für Festkörper- und Werkstoffforschung, Dresden, Deutschland

The influence of external magnetic fields on the bending vibration of a one-side clamped iron filled carbon nanotube (CNT) has been analyzed theoretically and experimentallywith particular consideration to the changes in the resonance frequency. The model involves the application of a modified Euler-Bernoulli-beam to analyze the zero field oscillatory behaviour as well as a magnetostatic approach to determine the influence of any external field distributions. The experiments were conducted in situ in a scanning electron microscope. The measured magnetic moment of the nanowire at room temperature was $\mu = 2.1 \cdot 10^{-14}$ Am^2. Due to the favorable geometry of the CNT oscillator, the raw signal using this approach is significantly more favourable than state of the art cantilever magnetometry. The obtained good agreement between model and experiment provides a valuable basis for the development of nanoelectromechanical systems where magnetic interactions are relevant.

MA 39.2 Thu 9:45 EB 202

X-ray microdiffraction studies on complex magnetoelectric composites with defined microstructures — •Stjepan Hrkac[1], Madjid Abes[1], Christian Koops[1], Christina Krywka[1], Martin Müller[1,2], Sören Kaps[3], Rainer Adelung[3], Olaf Magnussen[1], and Bridget Murphy[1] — [1]Institut für experimentelle und angewandte Physik, CAU Kiel, Germany — [2]Strukturforschung an Neuen Werkstoffen, Helmholtz Zentrum Geesthacht, Germany — [3]Institut für Materialwissenschaft, CAU Kiel, Germany

Magnetoelectric (ME) composites, consisting of a piezoelectric (PE) and a magnetostrictive (MS) material, are of great interest for potential applications as highly sensitive ME sensors. A large ME response is only obtained if the lattice deformation induced by an external magnetic field in the MS material can be transferred effeciently to the PE material. The understanding of this mechanical coupling and its dependence on the component's interface structure is still very rudimentary. This study aims at understanding this coupling by directly measuring the strain induced in the PE material in an external magnetic field employing X-ray diffraction methods. We present intrinsic strain maps of ZnO microrods (800 x 30 μm^2), grown by flame transportation synthesis, with a 200 nm MS $(Fe_{90}Co_{10})_{78}Si_{12}B_{10}$ (Metglas) coating, measured by the nanofocused X-ray beam provided by the Nanofocus Endstation of the MINAXS-Beamline at Petra III. The studies reveal pronounced compressive strain, which strongly varies across the sample, and a magnetic field induced strain relaxation.

MA 39.3 Thu 10:00 EB 202

Structure, microstructure and magnetic properties of electrodeposited $Fe_{70}Pd_{30}$ nanowires — •Veronika Haehnel[1,2], Christine Mickel[1], Heike Schlörb[1], Sebastian Fähler[1], and Ludwig Schultz[1,2] — [1]IFW Dresden, P.O. Box 270116, 01171 Dresden, Germany — [2]TU Dresden, Faculty of Mechanical Engineering, Institute of Material Science, 01062 Dresden, Germany

Fe-Pd alloys at about 30 at.% Pd show excellent functional properties. The scientific and technological interest is focused on these martensitic transforming alloys as they exhibit the magnetic shape memory effect (MSM). The expected strains of up to several percent make them perfect candidates for nanoactuators or sensors. Due to the reduced dimensions actuation frequencies should increase. Also a double maximum strain compared to thin films is expected for the novel "stray field induced microstructure"-actuation mode, because shape anisotropy favors only one easy axis along the nanowire axis.

In this study we use the cost and time efficient method of electrodeposition within nanoporous aluminum oxide templates to prepare Fe-Pd nanowires. A complexed electrolyte of Fe^{3+} and Pd^{2+} ions and an alternating potential regime is necessary to achieve continuous, almost defect free nanowires exhibiting a composition close to the $Fe_{70}Pd_{30}$ alloy. TEM and structural investigations reveal a bcc Fe-Pd structure and nanocrystalline grain sizes. Magnetic properties are controlled by shape anisotropy as well as magnetostatic interactions between neighboring nanowires. These results represent a promising starting point for future research toward MSM nanoactuators.

MA 39.4 Thu 10:15 EB 202

Magnetic coupling and magnetic anisotropy of iron doped platinum wires — •Lucila Juarez and Gustavo Pastor — Institut für Theoretische Physik, Universität Kassel, Germany

We report a first principles study of the magnetic coupling and magnetic anisotropy in monoatomic freestanding $FePt_n$ wires ($n = 1-4$) focusing mainly on the case where iron dopands are equally spaced along the chain. The magnetic coupling between iron dopands was found to change from antiferromagnetic to ferromagnetic depending on the position that impurities occupy with respect to each other. The results can be understood analysing the magnetic polarization of platinum atoms in chains doped with iron at very low concentations. Large anisotropies are present in spin and orbital moments of platinum atoms leading to magnetic anisotropy energies in the order of 10meV /at for some concentrations. The orbital moment of iron atoms couples antiferromagnetically to its spin moment for in chain axis magnetization. However, this does not lead to the destabilization of the easy axis.

MA 39.5 Thu 10:30 EB 202

Directed self-assembly of (sub-)phthalocyanine submonolayers by magnetic stray field landscapes — •Florian Ahrend[1], Ulrich Glebe[1], Tobias Weidner[2], Ulrich Siemeling[1], and Arno Ehresmann[1] — [1]Department of Physics and Chemistry, CINSaT, University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel — [2]Department of Bioengineering, University of Washington, Seattle

Magnetic stray field landscapes are produced by ion bombardment induced magnetic patterning (IBMP) of exchange-biased magnetic bilayers (A. Ehresmann, Recent Res. Devel. Applied Phys., 7 (2004)) into artificial parallel-stripe magnetic domains. The μm-sized magnetic stripe patterns with antiparallel magnetizations in adjacent domains (head-to-head/tail-to-tail) lead to strong magnetic stray fields above the domain walls. It will be shown that these stray fields influence the self-assembly of submonolayers of chemically modified (sub-)phthalocyanines. Diamagnetic derivatives of these molecules are shown to assemble preferentially in areas offering low magnetic stray field gradients. Characterization of the samples has been performed by X-ray photoelectron emission microscopy (X-PEEM), time-of-flight secondary ion mass spectroscopy (ToF-SIMS) and near-edge x-ray absorption fine structure imaging (NEXAFS-imaging) measurements.

MA 39.6 Thu 10:45 EB 202

Defect-induced ferromagnetism in SiC — •Yutian Wang[1], Lin Li[1], Slawomir Prucnal[1], Kay Potzger[1], Shengqiang Zhou[1], Zhaorong Yang[2], Wolfgang Anwand[3], and Andreas Wagner[3] — [1]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, POB 51 01 19, 01314 Dresden, Germany — [2]Key Laboratory of Materials Physics, Institute of Solid State Physics, Chinese Academy of Sciences, Hefei 230031, People's Republic of China — [3]Institute of Radiation Physics, Helmholtz-Zentrum Dresden-Rossendorf, POB 51 01 19, 01314 Dresden, Germany

A controllable method to create defects in SiC is the key requirement for understanding the mechanism of the defect-induced ferromagnetism. Using Ne-ion irradiation, defect-induced ferromagnetism in SiC can be established. Electron-spin resonance and positron annihilation spectroscopy [1] are adopted to determine the location of unpaired electrons and the type of defects. The dependence of magnetic properties on the concentrations of VSi-VC divacancies has been studied. We found that by increasing the irradiation fluence the saturation magnetization has increased initially, then dropped to almost zero since a large irradiation fluence induced too much disorder [2]. Temperature dependent magnetization indicates two ferromagnetic components. One reveals a Curie temperature around 70 K while another one has a Curie temperature above room temperature. Employing electron-spin resonance and SQUID magnetometry leads to the observation of large magnetic anisotropy. Reference: 1.Brauer, G., et al., Phys. Rev. B, 54, 3084 (1996). 2.Li, L. et al., Appl. Phys. Lett., 98, 222508 (2011).

MA 39.7 Thu 11:00 EB 202

Formation of spin-spiral states in Fe zig-zag chains and ladders: A first principles study — •Muhammad Tanveer, Pedro Ruiz-Díaz, and Gustavo Pastor — Institut für Theoretische Physik, Universität Kassel, Heinrich Plett Straße 40, 34132 Kassel, Germany.

A first-principles study of the stability of spiral spin-density wave (SDW) states in free standing Fe wires having linear, zig-zag and ladder geometries is presented. The calculations are based on density-functional theory in the generalised gradient approximation. The spin-spiral magnetic arrangement is described by the wave vector $\mathbf{q} = (0, 0, q)2\pi/a$ along the chains axis. The stability of the spiral structure is quantified in terms of the total energy difference as a function of **q** and for different nearest-neighbor (NN) distances. We observed that the zigzag chains have a ferromagnetic (FM) stable ground state whilst the ladders chains tend to favour the formation of a spiral SDW with wave vector $\mathbf{q} \cong (0, 0, 0.2)2\pi/a$. The dependence of the local magnetic moments as a function of **q** reflects the itinerant character of magnetism in the Fe chains. The magnetic order and its stability as a function of the NN distances are interpreted in terms of the effective exchange-interaction parameters J_{ij}, which are derived in the framework of a phenomenological classical Heisenberg model.

15 min. break

MA 39.8 Thu 11:30 EB 202

Highly coercive and textured SmCo5 nanoflakes prepared by surfactant assisted high energy ball milling — •Santosh Kumar Pal[1], Juliane Thielsch[1], Ludwig Schultz[1], and Oliver Gutfleisch[1,2] — [1]IFW Dresden, Helmholtzstraße 20, 01069 Dresden, Germany — [2]Technische Universität Darmstadt, Institut für Materialwissenschaft, Petersenstr. 23, 64287 Darmstadt, Germany

Exchange-coupled nanocomposite magnets consisting of a highly coercive and textured hard magnetic phase and a soft magnetic phase with high magnetization have potential to be the next generation of permanent magnets with very high energy products. In this study, we discuss the effects of the type and amount of surfactants on the structural, morphological and magnetic properties of SmCo5 nanoflakes prepared by high energy ball milling. Increase in surfactants concentration result in the decrease of degree of amorphization and reduction in crystallite size with milling time. The coercivity of flakes first increase with milling time up to maximum values of 1.78, 1.96 and 2.07 tesla for 5, 10 and 30 wt.% of PVP respectively, further milling results in decrease of the coercivity and the rate of decrease is lower for higher surfactant concentration. A maximum coercivity of 2.29 tesla was obtained after a milling time of 1.0 and 2.0 h for 10 and 50 wt.% of OA respectively. Degree of texture (DOT) increases with increase in surfactants concentration and decreases monotonically with milling time, 73% of DOT was obtained for 50 wt.% OA after 0.5 h of milling. The pronounced anisotropy and high coercivity of the nanoflakes should prove advantageous for the preparation of exchange spring magnets.

MA 39.9 Thu 11:45 EB 202

Magneto-static interaction of single NiFe nanostructures — •Philipp Staeck, Mahmoud Reza Rahbar Azad, André Kobs, Daniel Stickler, Björn Beyersdorff, Hendrik Spahr, Robert Frömter, and Hans Peter Oepen — Inst. für Angewandte Physik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg, Germany

The magneto-static interaction of submicron Ni80Fe20 rectangles (aspect ratio 2:1) has been investigated by means of magnetotransport measurements using anisotropic magneto resistance (AMR). The structures were carved into a Cr(10nm)/Ni80Fe20(20nm)/Pt(2,5nm) trilayer utilizing a focused ion beam (FIB). The material around the rectangles has been rendered via ion milling. Microcircuits are milled by FIB that allow to contact electrically an individual element via a micromanipulator [1]. For this work structure sizes down to 300 nm x 600 nm have been investigated. This one-step structuring approach in combination with a magneto-resistive measuring setup (sensitivity of $\Delta R/R=10^{-6}$) was utilized to measure the magnetic energy of micro-magnetic states of single, isolated rectangle obtaining flux closure structures, like Landau state [2]. Recently, it has been shown that rectangles with flux closure structure can magneto statically interact [3]. We have varied the distance between rectangles in an array and measured the energy change of a single element. The strength of the magneto-static interaction between rectangles revealing flux closure domain pattern has been quantified. [1] Daniel Stickler et al., Rev. Sci. Instr. 79, 103901 (2008), [2] André Kobs et al., Phy. Rev. B 80, 134415 (2009), [3] Sebastian Hankemeier et al., PRL 103, 147204 (2009)

MA 39.10 Thu 12:00 EB 202

Temperature dependent switching of single superparamagnetic nanodots — •Alexander Neumann[1], Carsten Thönnissen[1], Simon Hesse[1], Andreas Meyer[2], and Hans Peter Oepen[1] — [1]Institut für Angewandte Physik, Universität Hamburg, Germany — [2]Institut für Physikalische Chemie, Universität Hamburg, Germany

We have investigated the temperature dependence of the coercive field and the time dependent switching behavior of single Co/Pt nanodots (<30nm) in the range of 80K to 300K. We used Sharrocks formula to determine from the coercivities the anisotropy constant K and the saturation magnetization M_S [1]. Additionally, the anisotropy constant is determined from the temperature dependent switching behavior [2]. The magnetic volume V of the nanodots is determined directly from images taken by scanning electron microscopy. Both fittings give results that are identical within the error margin and slightly smaller than the film value. The time constant τ_0 is considerably smaller than expected for a macro-spin behavior. The dots were fabricated out of thin Co/Pt film via Ar^+ ion milling at 150eV utilizing SiO_2 particles as a shadow mask. The Co/Pt film is tuned to give perpendicular anisotropy which is preserved in the nanodots [3]. Via a hall cross the state of magnitization is obtained by the anomalous Hall-Effect.

[1]M. P. Sharrock, IEEE Trans. Magn. **26**, p193-197, (1990)
[2]Bean and Livingston, J. Appl. Phys. **30**, 120S, (1959)
[3]H. Stillrich *et al.* Adv. Funct. Mat. **18**, p76-81, (2008).

MA 39.11 Thu 12:15 EB 202

Mesoscopic magnetic structure and competing anisotropies in laterally structured Fe / Cr-layer systems — •Markus Schmitz, Alexander Weber, Emmanuel Kentzinger, Elisabeth Josten, Ulrich Rücker, and Thomas Brückel — JCNS-2, PGI-4: Streumethoden Forschungszentrum Jülich GmbH

Patterned magnetic structures are the basic elements of spintronic devices. The ongoing miniaturization makes the influence of neighboring structures more and more important. Fe/Cr multilayers have been grown epitaxially on GaAs (100) single crystals by Molecular Beam Epitaxy. The Cr interlayers induce an antiferromagnetic coupling between adjacent Fe layers. Thus, the magnetic dipole moment is reduced and a magnetic superstructure is created, which is, due to the contrast of Cr to Fe, easily observable by polarized neutron reflectometry. The lateral structuring was performed by UV-nanoimprint lithography and Reactive Ion Etching. The structural characterization was carried out by Scanning Electron Microscopy, Atomic Force Microscopy and X-ray scattering under grazing incidence. The macroscopic magnetic properties were determined by MOKE and SQUID magnetometry. Polarized neutron reflectometry and off-specular scattering was used to determine the magnetic domain formation within the individual layers. Furthermore, simulations of the neutron data were generated and compared with the measurement in order to improve the simulation model. The work presented gives insight into the interplay of shape and crystalanisotropy within the individual layers and patterns.

MA 39.12 Thu 12:30 EB 202

Magnetic reversal in a laterally structured spin valve system with one tunable magnetic layer — •Frank Brüssing, Melanie Ewerlin, Radu Abrudan, and Hartmut Zabel — Department of Physics, Ruhr-University Bochum, 44780 Bochum, Germany

We investigated the magnetization reversal of interacting Co islands and how their behavior is altered after switching on the interlayer exchange interaction to a second magnetic island with different magnetic domain structure and different coercivity values. We prepared an epitaxial magnetic heterostructure comprising two ferromagnetic layers, one with a high Curie temperature (T_C) (Co) and one with a T_C below room temperature (RT) ($Fe_{1-x}Cr_x$), and a mediating Cr layer in between. After lateral patterning via e-beam lithography and ion beam etching into islands, we investigated elements selectively the magnetization reversal of Co at RT and of the combined system at low temperature, using x-ray resonant magnetic scattering (XRMS). As reference we also investigated the same heterostructure before patterning. The lateral periodic pattern gives raise to new in-plane Bragg reflections, revealing the structural and magnetic intra- and inter-island correlation. For the measurments we have used a CCD camera for investigating the magnetic Bragg peaks and magnetic diffuse scattering as a function of temperature above and below the T_C of $Fe_{1-x}Cr_x$.

MA 39.13 Thu 12:45 EB 202

Fabrication and characterization of patterned exchange-coupled trilayers — •M. Langer[1], J. Osten[1], A. Neudert[1], M. Körner[1], A. Banholzer[1], I. Mönch[2], R. Mattheis[3], J. Fassbender[1], and J. McCord[4] — [1]HZDR, Inst. of Ion Beam Physics and Materials Research, 01314 Dresden — [2]IFW Dresden, Inst. for Integrative Nanosciences, 01069 Dresden — [3]IPHT Jena, Inst. of Photonic Technology, 07702 Jena — [4]Christian-Albrechts-University Kiel, Inst. for Materials Science, 24143 Kiel

Magnetic patterning by means of ion-implantation is an advanced technique to fabricate ferromagnetic micro-/nanostructures. In this case antiferromagnetically exchange coupled trilayers, consisting of two $Co_{90}Fe_{10}$ layers with a Ru interlayer, were used. The ion induced intermixing of the interlayer with its surrounding magnetic layers alters the coupling to a ferromagnetic one. Therefore Co ions with energies of 40-80 keV and a fluence of $5{\cdot}10^{15}$ cm^{-2} were used. Hence, applying masks, ferromagnetically coupled micro-/nanometer sized elements (stripes, squares, circles etc.), embedded in a so-called artificial antiferromagnetic environment, have been fabricated. These structures were characterized by the use of Kerr-microscopy and MOKE-magnetometry to determine the mutual influence of the ferromagnetic elements with the antiferromagnetically coupled environment. Also their magnetic switching behavior was compared to etched single ferromagnetic structures. Domain pinning at the element boundaries was observed.

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