MA 9: Magnetic Nanoparticles

Time: Monday 15:00–18:00 Location: HSZ 401

MA 9.1 Mon 15:00 HSZ 401

Spin structure of MnO and FePt@MnO nanoparticles — •Xiao Sun[1], Alice Klapper[1], Yixi Su[2], Kirill Nemkovski[2], Andrew Wildes[3], Oskar Koehler[4], Heiko Bauer[4], Anna Schilmann[4], Wolfgang Tremel[4], Oleg Petracic[1], and Thomas Brueckel[1] — [1]Jülich Centre for Neutron Science JCNS-2 und Peter Grünberg Institut PGI-4, Forschungszentrum Jülich GmbH — [2]Jülich Centre for Neutron Science JCNS Forschungszentrum Jülich GmbH, Outstation at MLZ — [3]Institut Laue-Langevin, Grenoble, France — [4]Institut für Anorganische und Analytische Chemie, Johannes Gutenberg-Universität Mainz

FePt@MnO heterodimer nanoparticles (NPs) are a novel type of multifunctional material.We have focused on the spin structure inside single MnO NPs and the influence of the exchange bias inside FePt@MnO heterodimer NPs onto the spin structure of MnO NPs. MnO NPs and FePt@MnO NPs with various sizes have been studied using SQUID magnetometry. The exchange bias effect has been observed in FePt@MnO NPs by the shift of hysteresis loops at different temperatures suggesting a magnetic coupling between FePt and MnO NPs. An exchange bias shift is also observed in single MnO NPs which is due to the coupling of the antiferromagnetic MnO core to a ferromagnetic Mn2O3 or Mn3O4 shell. The antiferromagnetic order parameter of MnO has been measured in both single MnO and FePt@MnO NPs using polarized neutron scattering. For comparison with the experimental findings, the spin structure inside single MnO NPs and FePt@MnO dimer NPs are simulated with Monte Carlo methods.

MA 9.2 Mon 15:15 HSZ 401

Magnetic Properties of FePt and FePt@MnO Heterodimer Nanoparticles and their self assemblies — •Alice Klapper[1], Sabrina Disch[2], Xiao Sun[1], Ulrich Rücker[1], Oskar Köhler[3], Heiko Bauer[3], Wolgang Tremel[3], Oleg Petracic[1], and Thomas Brückel[1] — [1]Jülich Centre for Neutron Science JCNS and Peter Grünberg Institut PGI, JARA-FIT, Forschungszentrum Jülich GmbH, 52425 Jülich, GERMANY — [2]Institut Laue-Langevin, F-38042 Grenoble Cedex 9, FRANCE — [3]Institut für Anorganische und Analytische Chemie, Johannes Gutenberg-Universität Mainz, 55099 Mainz, GERMANY

On the length scale of few nanometers, surface effects are not negligible and therefore play an important role for the magnetic behavior of nanoparticles (NP). In this work we investigate the magnetic properties of FePt NP and the change of these properties due to an exchange interaction with an attached antiferromagnetic NP, i.e. FePt@MnO heterodimer NP. The connection of the two NP lead to an increase of the blocking temperature compared to the FePt NP proven by ZFC curves obtained from SQUID measurements. Polarized SANS measurements in a magnetic field have been performed to measure the magnetic form factor of the NP. To investigate the ordering phenomenon and interaction between the NP the samples under study have been deposited on silicon substrates. The self-assembly was studied using AFM and GISAXS instruments. While the FePt NP show a long range ordered structure the heterodimer NP order in a short range structure which is dominated by the larger part of the dimer, i.e. the MnO NP.

MA 9.3 Mon 15:30 HSZ 401

Magnetic Properties of Self-Assembled Fe Nanoislands on Barium Titanate (001) — Remya K. Govind[1], Vasili Hari Babu[2], Cheng-Tien Chiang[1,3], Elena Magnano[4], Federica Bondino[4], Reinhard Denecke[2], and •Karl-Michael Schindler[1] — [1]Martin-Luther-Universität Halle-Wittenberg, Halle — [2]Universität Leipzig, Leipzig — [3]Max-Planck-Institut für Mikrostrukturphysik, Halle — [4]IOM-CNR, Trieste, Italy

The coercivity and saturation magnetization of ultrathin films of Fe on a $BaTiO_3$(001) single crystal substrate have been determined using magneto-optic Kerr effect (MOKE) and X-ray magnetic circular dichroism (XMCD) as a function of annealing temperature. Films deposited at room temperature exhibit bulk-like properties, whereas with increasing annealing temperature coercivity increases and saturation magnetization decreases. Investigations with scanning electron microscopy (SEM) and low-energy electron diffraction (LEED) reveal that annealing causes a morphology transformation from a continuous flat film, which completely covers the substrate, to nanoislands via self-assembled growth. The morphology and size of the islands imply stronger pinning of domain walls or complex magnetic structures as the origin of their particular magnetic properties.

MA 9.4 Mon 15:45 HSZ 401

Temperature and size dependent investigation of the spin structure in bismuth ferrite nanoparticles — •Soma Salamon[1], Joachim Landers[1], Werner Keune[1], Marianela Escobar[2], Doru Lupascu[2], and Heiko Wende[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, Duisburg, Germany — [2]Institute for Materials Science and CENIDE, University of Duisburg-Essen, Essen, Germany

The size and temperature dependence of the cycloidal spin structure in multiferroic bismuth ferrite ($BiFeO_3$) nanoparticles was examined by Mössbauer spectroscopy. Different sized particle samples (d≥50 nm) were synthesized by a wet chemical method and analyzed at different temperatures to gain insight on the temperature dependent anharmonicity of the spin cycloid. A model has been developed to evaluate the line shape of spectra, making it possible to determine the anharmonicity from high resolution experimental spectra. We found that the anharmonicity of the long range cycloidal structure decreases at higher temperatures, starting at 150-200 K and finally reaching the harmonic state at about 400 K. Using three different sized particle samples, we were also able to show a decrease of the Néel temperature from about 652 K for 1 μm particles down to 632 K for 50 nm particles, in addition to an increasingly broader distribution of Néel temperatures for decreasing particle sizes. The spin cycloid has been shown to exist in all particle samples, despite the 50 nm particles having a mean diameter that is below the period length of the cycloid (≈62 nm). This work is supported by MERCUR (Stiftung Mercator and UAMR).

MA 9.5 Mon 16:00 HSZ 401

Magnetic Anisotropy and relaxation of 24 single 43 nm Fe/Fe_xO_y **core/shell-nanocubes** — •Alexandra Terwey[1], Sabrina Masur[1], Ralf Meckenstock[1], Christian Derricks[1], Benjamin Zingsem[1], Florian Römer[1], Miguel Comensana-Hermo[2], and Michael Farle[1] — [1]AG Farle, Experimentalphysik, Universität Duisburg Essen, Germany — [2]Centre de Recherche Paul Pascal, CNRS, Universite de Bordeaux, France

Due to their large surface contribution nano particles and small agglomerates hold unique magnetic properties distinguishing them from bulk or thin film material. Here, ferromagnetic resonance measurements of single 43nm edge length Fe/Fe_xO_y core/shell nanocubes are shown with full angle dependence. These measurements performed simultaneously on 22 of these nanocubes and on two dimers prove that the cubes show the same crystalline anisotropy field $\frac{K_4}{M} = 25mT$ which is surprisingly in the same range as that of bulk iron ($28mT$). SQUID measurements show a magnetization of $M = 2 \pm 0.5 \cdot 10^5 \frac{A}{m}$ which is roughly 10% of the value of bulk iron. Considering a ferrimagnetic Fe_xO_y shell, $d = 7nm$, the magnetization should be reduced to about 40%. This behaviour can be explained by an additional contribution such as shell anisotropy or a decrease of the magnetic moment at the internal interface. Furthermore, we find a small FMR linewidth of $4mT$ which corresponds to a damping of $\alpha = 0.045$ matching the linewidth of high quality epitaxial Fe films.

15 min. break

MA 9.6 Mon 16:30 HSZ 401

Magnetic proximity effects in nanoparticle-composite systems — •Genevieve Wilbs[1], Oleg Petracic[1], Emmanuel Kentzinger[1], Joachim Gräfe[2], Eberhard Goering[2], and Thomas Brückel[1] — [1]Jülich Centre for Neutron Science JCNS and Peter Grünberg Institute PGI, JARA-FIT, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany — [2]Max-Planck-Institute for Intelligent Systems, 70569 Stuttgart, Germany

In recent years, nanoparticle assemblies have shifted into the focus of scientific interest because they behave neither like bulk material nor correspond to isolated particles. Hence, they offer the possibility to fabricate 'artificial materials' with novel emerging physical properties for a broad range of applications. We report about the magnetic properties of self-assembled iron oxide nanoparticle superlattices. The

particles have a diameter of 20 nm and are covered with an organic surfactant shell. By applying them onto a silicon substrate via spin-coating, they form self-organized sub-monolayers. The lateral order is demonstrated by GISAXS (Grazing Incidence Small Angle X-ray Scattering) and SEM (Scanning Electron Microscope) studies. Using SQUID (Superconducting Quantum Interference Device) magnetometry, it is shown that the particles exhibit superspin glass behavior due to dipolar inter-particle interactions. If the organic matrix is exchanged by a polarizable metal like platinum, the superspin glass behavior is partially suppressed and the inter-particle interactions become dominated by the polarization of Pt.

MA 9.7 Mon 16:45 HSZ 401

Transport of superparamagnetic particles on magnetically structured exchange bias bilayer systems for enhanced mixing in microfluidic devices — •Iris Koch, Dennis Holzinger, Daniel Lengemann, and Arno Ehresmann — Department of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel

The active mixing of two aqueous fluids in a microfluidic device obtained via controlled movement of superparamagnetic particle rows above micromagnetic stripe-patterned exchange bias bilayer systems with head-to-head and tail-to-tail orientation of the magnetization in adjacent domains parallel to the short stripe axis,[1] fabricated via ion bombardment induced magnetic patterning (IBMP), was experimentally optimized by investigating the mixing efficiency as a function of the mixing parameters, i.e. the concentration of magnetic particles, the movement scheme of the particles while mixing and both the frequency and pulse shape of the external magnetic field responsible for the particle transport. It is shown that the mixing efficiency is doubled as a result of the optimization procedure as compared to prior investigations. Hence, the active mixing due to the particle movement is five times faster compared to passive mixing via thermal diffusion.

[1] D. Holzinger, D. Lengemann, F. Göllner, D. Engel and A. Ehresmann, Appl. Phys. Lett. 100, 153504 (2012)

MA 9.8 Mon 17:00 HSZ 401

Microfluidic device using anchored one-dimensional, chain-like superstructures of superparamagnetic beads for controllable particle filtering — •Patrick Stohmann, Bernhard Eickenberg, and Andreas Hütten — Department of Physics, Thin Film and Physics of Nanostructures, University of Bielefeld, D-33615 Bielefeld, Germany

Superparamagnetic beads are of interest for microfluidic applications. They can be manipulated via external homogeneous magnetic fields and their functionalized surface allows for the immobilization of various bio-molecules. The presence of an external magnetic field results in an alignment of the particles to chain-like superstructures. When the magnetic field is rotated, the chains follow the movement of the field. Inside a microfluidic channel, the ends of the chains can be anchored on the bottom of the channel. Based on this method, a microfluidic particle filter device was developed that allows for controlling its filter activity by changing the direction of the external field. A regular pattern of anchorbeads was created on the channel bottom by standard lithography. This pattern serves as a substructure for the field-induced agglomeration of magnetic chains. A magnetic field perpendicular to the channel bottom causes the chains to protrude into the liquid flow. Switching the field direction by 90° yields a rapid decrease of the chain-liquid-interaction. The microfluidic particle filter device may enhance the functionality of lab-on-a-chip systems. Chemical interactions of specific dissolved particles with the surface functionalization of the beads may realize on-demand filtering of molecules or cells.

MA 9.9 Mon 17:15 HSZ 401

ON THE NONLINEAR RESPONSE OF NON-INTERACTING ELECTRIC DIPOLES AND SINGLE DOMAIN FERROFLUID PARTICLES SUBJECTED TO STRONG ALTERNATING AND DC BIAS FIELDS — Y.P. Kalmykov[1], •William T. Coffey[2], and N. Wei[3] — [1]University of Perpignan, Perpignan, France — [2]Department of Electronic and Electrical Engineering, Trinity College, Dublin — [3]Department of Electronic and Electrical Engineering, Trinity College, Dublin

The perturbation theory approach to the nonlinear dielectric relaxation of noninteracting permanent electric dipoles (W.T.Coffey and B.V.Paranjape, Dielectric and Kerr Effect Relaxation in Alternating Electric Fields, Proc. R.Ir. Acad. Section A, 78, 17 (1978)) and the analogous magnetic relaxation of ferrofluids is revisited for the particular case of a strong D.C. bias field superimposed on a strong A.C. field. Unlike weak A.C. and strong bias D.C. fields, a frequency dependent D.C. term now appears in the response as well as additional nonlinear terms at the fundamental and second harmonic frequencies. These may be experimentally observable particularly in the ferrofluid application, the corresponding result for the D.C. term for anomalous relaxation is also given.

MA 9.10 Mon 17:30 HSZ 401

Magnetische Eigenschaften von Co80Ni20-Nanostäbchen — •Juliane Perl, Sara Liébana Viñas, Benjamin Zingsem, Anna Elsukova, Marina Spasova und Michael Farle — Experimentalphysik AG Farle, Universität Duisburg-Essen

Magnetische Co80Ni20-Nanostäbchen werden durch Reduktion von Metallacetaten in flüssigem Polyol nass-chemisch synthetisiert. Die Partikel besitzen eine mittlere Länge von 52 nm und Durchmesser von 6,5 nm sowie ein Aspektverhältnis von 8-9. Die HR-TEM Aufnahmen zeigen, dass die Nanostäbchen in hexagonaler Struktur kristallisieren, wobei die <0001>-Richtung parallel zur Wachstumsrichtung der Stäbchen liegt. Die Partikel sind natürlich oxidiert mit einer Oxidschichtdicke von 1,5-2 nm. Die magnetischen Eigenschaften werden mit dem SQUID-Magnetometer im Zero-Field-Cooled- und Field-Cooled-Modus gemessen. Die Magnetisierungskurven (ZFC) der in einer Matrix ausgerichteten Nanostäbchen zeigen im Vergleich zu einer Pulverprobe (0,1 T) bei Raumtemperatur eine hohe Koerzitivfeldstärke (0,24 T), die durch die Form- und magnetokristalline Anisotropie verursacht wird. Die FC-Messungen zeigen bei tiefen Temperaturen eine vertikale und horizontale Verschiebung (Exchange-Bias) sowie eine Verbreiterung der Magnetisierungskurven die durch die Exchange-Anisotropie hervorgerufen werden. Die magnetischen Eigenschaften der hoch anisotropen Co80Ni20-Nanopartikel lassen sich variieren und sind geeignet für permanentmagnetische Anwendungen.

MA 9.11 Mon 17:45 HSZ 401

Structural and magnetic properties of SBA-15 assisted Heusler nanowires and nanoparticles — •Changhai Wang, Jinfeng Qian, Paul Simon, Gerhard Fecher, and Claudia Felser — Max-Planck-Institut für Chemische Physik fester Stoffe

We report the first preparation of Heusler nanowires and nanoparticles with examples of Co2FeGa and Co2NiGa using SBA-15 silica as the templates. Structural probes using XRD and XAFS confirm the formation of L21 Co2FeGa Heusler phase. Magnetic dipole stray fields are observed for isolated Co2FeGa nanowires indicating multiple magnetic domains. The magnetic inductions of selected Co2FeGa nanowires are evaluated by the magnetic phase shift giving rise to intrinsic magnetic induction magnitude lying in the range 1.1 T. The particle size of Co2NiGa Heusler nanoparticles significantly affect their phase transition and magnetic properties. The scientific and technical implications of Heusler nanowires and nanoparticles in application fields such as spintronics and magnetic shape memory alloys are also discussed.