MA 38: Magnetic Nanoparticles

Time: Thursday 9:30–12:45 Location: H 0110

MA 38.1 Thu 9:30 H 0110

Tuning the magnetic properties of granular FePt media by seed layer conditioning — •S. Wicht[1,2], V. Neu[1], L. Schultz[1,2], O. Mosendz[3], V. Mehta[3], S. Jain[3], J. Reiner[3], O. Hellwig[3], D. Weller[3], and B. Rellinghaus[1] — [1]IFW Dresden, Hemholtzstr. 20, D-01069 Dresden, Germany — [2]TU Dresden, IFWW, D-0162 Dresden, Germany — [3]HGST, 3403 Yerba Buena Rd, San Jose, CA-95135, USA.

In the course of the steadily increasing amount of digitized information reliable data storage at ultimate storage densities is mandatory. Accordingly, areal densities in future storage media will soon cross the 1TB/in^2 border. For such media, $L1_0$ ordered, granular FePt-X films, grown on highly textured MgO, are promising materials candidates. The present work aims at a better understanding of the influence of the MgO seed layer roughness on the structure and the magnetic performance of the granular media. Therefore, the MgO was subjected to Ar^+ ion irradiation prior to the deposition of the magnetic material. Aberration-corrected high-resolution transmission electron microscopy (HRTEM) and vibrating sample magnetometry (VSM) are used to correlate the structure with the magnetic properties. We find that decreasing the surface roughness of the oxide seed layer results in a change of the morphology of the grains from spherical over cylindrical to island-type shapes. This modification is accompanied by an enhanced fraction of small second layer particles and an increasing degree of coalescences of the primarily deposited grains. Concerning the magnetic properties, this results in a reduction of the coercivity from 5 to 2.6 T.

MA 38.2 Thu 9:45 H 0110

Experimental investigation and modeling of the spin structure in MnO nanoparticles — •Xiao Sun[1], Alice Klapper[1], Yixi Su[2], Kirill Nemkovski[2], Oskar Köhler[3], Heiko Bauer[3], Anna Schilmann[3], Wolfgang 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, Jülich — [2]Jülich Centre for Neutron Science JCNS, Forschungszentrum Jülich GmbH, Outstation at MLZ, Garching — [3]Institut für Anorganische und Analytische Chemie, Johannes Gutenberg-Universität Mainz, Mainz

The spin structure of antiferromagnetic (AF) MnO nanoparticles (NPs) has been investigated for various NP diameters (5-20nm) using both magnetometry and polarized neutron scattering. Magnetization curves show a peculiar peak at low temperatures (ca. 25K) instead at the Néel temperature of 120K. However, the AF order parameter of MnO shows the expected behavior from polarized neutron scattering studies. In MnO powder, features at both the low temperature (ca. 25K) and the Néel temperature can be found. To understand the observed behavior further magnetometry studies using hysteresis curves, memory effect and susceptibility measurements were employed. We conclude that the magnetic behavior of MnO NPs can be explained by a superposition of superparamagnetic-like thermal fluctuations of the AF Néel vector inside an AF core and a strong magnetic coupling to a FM shell. Moreover, we employed Monte-Carlo simulations of the spin structure to model the observed behavior.

MA 38.3 Thu 10:00 H 0110

Magnetic Properties of FePt and FePt@MnO Heterodimer Nanoparticles — •Alice Klapper[1], Sabrina Disch[2], Xiao Sun[1], Oskar Köhler[3], Heiko Bauer[3], Wolfgang 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]Department Chemie, Universität zu Köln, 50939 Köln, GERMANY — [3]Institut für Anorganische und Analytische Chemie, Johannes Gutenberg-Universität Mainz, 55099 Mainz, GERMANY

For particles with characteristic length scales of a few nanometers, surface and interface effects compared to bulk systems play an important role and can drastically alter 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 epitaxial intergrowth of the two NP leads to an increase of the blocking temperature compared to the FePt NP proven by ZFC curves obtained from SQUID measurements. Polarized small angle neutron scattering (SANS) measurements in a magnetic field have been performed to measure the magnetic form factor of the NP.

MA 38.4 Thu 10:15 H 0110

A unique multiple-twinned, chemically ordered FePt nanocrystal observed by transmission electron microscopy — •Zi-An Li[1], Marina Spasova[1], Quentin Ramasse[2], Markus Gruner[1], Christian Kisielowski[3], and Michael Farle[1] — [1]Faculty of Physics and Center for Nanointegration Duisburg-Essen (CeNIDE), University Duisburg-Essen, Germany — [2]SuperSTEM Laboratory, STFC Daresbury Campus, United Kingdom — [3]National Center for Electron Microscopy, Lawrence Berkeley National Laboratory, University of California, USA

Using a combination of high-resolution transmission electron microscopy (HRTEM) and high angle annular dark field (HAADF) imaging in scanning transmission electron microscopy (STEM), we characterize the crystal structure of multiple-twinned FePt nanocrystals produced by gas-phase condensation. These FePt nanocrystals are found to be chemically ordered, decahedral or icosahedral shaped, and Pt enriched at the surfaces. [1,2] The experimentally determined crystallographic lattice constants and distribution of Fe and Pt atoms are compared with first-principles calculations of FePt nanocrystals to confirm the discovery of a unique multiple-twinned structure with Fe/Pt ordering and Pt surface segregation. References: 1. Zi-An Li, et al. Phys. Rev. B 89, 161406(R) (2014). 2. Financial support by ERC-Grant *IMAGINE* is acknowledged.

MA 38.5 Thu 10:30 H 0110

The effect of segregation on the magnetic properties of RE-TM nanoparticles — •Frank Schmidt[1,2], Darius Pohl[1], Ludwig Schultz[1], and Bernd Rellinghaus[1] — [1]IFW Dresden, Helmholtzstraße 20, D-01069 Dresden, Germany. — [2]TU Dresden, IFWW, D-01062 Dresden, Germany.

Rare earth transition metal compounds like $Nd_2Fe_{14}B$ or $SmCo_5$ are among the magnets with the highest energy product and coercive field. Nonetheless, there is still demand further to improve the magnetic properties of these alloys. The present study reveals the investigation on the formation and phase stability of RE-TM nanoparticles from the gas phase which could serve as a model system for their bulk counterparts. Particular attention is paid to the question, if the intermetallic $Nd_2Fe_{14}B$ and $SmCo_5$ phase form in particles with only a few nanometers in size, which grow without contact to any solid or liquid matrix in a low pressure Ar atmosphere. It also addresses the possibility of segregation that goes along with the phase formation and how this possibly affect the magnetic properties. Aberration-corrected transmission electron microscopy was used in combination with spectroscopic methods to determine the local atomic structure and the chemical composition, and it was found that in both cases, the RE element segregates to the particle surface. The magnetic properties of Nd-Fe-B and Sm-Co nanoparticles ensembles as determined from VSM measurements are correlated with the resulting core-shell structure of these RE-TM particles.

MA 38.6 Thu 10:45 H 0110

Interface strain mediated magnetoelectric coupling in BaTiO3 /Iron oxide nanoparticle composites — •Li-Ming Wang, Oleg Petracic, Emmanuel Kentzinger, and Thomas Brückel — Jülich Centre for Neutron Science JCNS and Peter Grünberg Institut PGI, JARA-FIT, Forschungszentrum Jülich GmbH, Jülich

We demonstrate strain mediated magnetoelectric coupling in a composite consisting of ferrimagnetic iron oxide nanoparticles coupled to a BaTiO3 (BTO) ferroelectric single crystal substrate. We performed measurements of the magnetization as function of the magnetic and electric field and measurements of the magneto-electric AC susceptibility (MEACS) as function of temperature and field. We find jumps in the magnetization at the BTO phase transition temperatures and corresponding peaks in the MEACS signal. An interface strain coupling model is proposed to understand the observed effects. Up to 8%magnetization change is achieved upon the BTO phase transition between orthorhombic and rhombohedral phase. Moreover, an electric

field controlled magnetic "hardening effect" is observed from magnetization hysteresis loops. The self-assembly of the nanoparticles on top of the BTO substrate is investigated using grazing incidence small angle X-ray scattering (GISAXS).

15 min. break

MA 38.7 Thu 11:15 H 0110

Magnetic trapping of a superparamagnetic particle by a single micro-ring conductor — •Benjamin Riedmüller, Meng Li, and Ulrich Herr — Institut für Mikro- und Nanomaterialien, Ulm, Deutschland

In this work we present a magnetic trap for superparamagnetic particles, consisting of a single ring-shaped current conductor, which allows to transport and trap magnetic particles to a defined position with an accuracy of ≈ 1 um. The functionality of the device can be understood on the magnetic force caused by the superposition of a magnetic field gradient (generated by a static current through the conductor ring) and a superimposed, homogeneous magnetic field perpendicular to the plane of the substrate. The tracking of a single trapped Dynabead M-280 particle allows to determine the viscosity of the surrounding medium (here water was used) with an accuracy of < 10 %. By applying the fluctuation-dissipation-theorem the stiffness constant of the trap, which is a measure for the remaining particle fluctuation around the energy minimum caused by Brownian motion, can be extracted. The stiffness constant is then systematically changed by applying different static currents and by changing the externally applied field. We find a good correlation between the experimentally extracted stiffness constants to the values which are predicted from numerically modeling the energy landscape near the energy minimum with a simple spring model.

MA 38.8 Thu 11:30 H 0110

On the statistical nature of intermetallic nanoparticle assemblies — •Markus Gellesch[1], Franziska Hammerath[1,2], Silke Hampel[1], Sabine Wurmehl[1,2], and Bernd Büchner[1,2] — [1]Institut für Festkörperforschung, IFW Dresden — [2]Institut für Festkörperphysik, TU Dresden

It is well known, that the synthesis of nanoparticles usually results in the formation of particles with a certain distribution of geometries (e.g. diameter, shape). Since, especially at the nanoscale, shape and size govern the physical properties including the occurence of magnetic phenomena, one of the challenges in magnetic nanoparticle synthesis is to create monodisperse particle assemblies.

Here, we raise the issue of an additional challenge since we report about distributed chemical compositions in intermetallic nanoparticle assemblies with ternary precursor conditions. Our results were obtained by an extensive TEM-EDX study of a larger number of individual particles. In order to crosscheck and to validate our results obtained with TEM we successfully applied the solid state NMR technique where the local environments of all particles in the sample are observed.

We are confident, that our results guide the way to establish NMR as a powerfull tool to characterize complex multi-element magnetic nanoparticle assemblies.

MA 38.9 Thu 11:45 H 0110

Phase formation in colloidal systems with tunable interaction — •Hauke Carstensen, Vassilios Kapaklis, and Max Wolff — Dept of Physics & Astronomy, Box 516, SE-751 20 Uppsala, Sweden

Self assembly is one of the most fascinating phenomena in nature and one key component in the formation of hierarchic structures forming the basis for living organisms. The formation of structure depends critically on the interaction between the different constituents. We have realized a two dimensional system of colloidal particles with tunable magnetic dipole forces. Particles with a diameter in the micrometer range are embedded in a magnetic medium, which is composed of nanometer sized magnetic particles dispersed in water. The result is an effective magnetic susceptibility of the embedded particles which can be altered by the concentration of nanoparticles. The phase formation and diagram of the micrometer particles are studied by transmission optical microscopy. For in-plane magnetic fields we report a phase transition from hexagonal to cubic, when tuning the magnetic interaction between the individual particles from antiferromagnetic to ferrimagnetic. Quantitatively information is extracted from the pair correlation function and explained by the dipolar particle interaction. For out-of plane fields the phase diagram is more rich and is mapped for different particle ratios and concentrations.

MA 38.10 Thu 12:00 H 0110

Superparamagnetische Partikel als Bausteine für komplexe Mikrostrukturen? — •Claus Fütterer — Translational Centre of Regenerative Medicine, Leipzig & Biophysical Tools GmbH, Leipzig

Superparamagnetische Partikel zeigen auch auf makroskopischer Skala ungewöhnliche Strukturbildung und unterscheiden sich wesentlich von elektrostatisch selbstorganisierenden Partikel (z.B. Moleküle). Der Grund ist die Form des Potentials sowie die starke Abhängigkeit der Wechselwirkung von der relativen Partikel-Orientierung in Konkurrenz zur Diffusion und weiteren Kräften. Diese Kräfte, die zeitliche Dynamik und die Möglichkeit 2D- oder sogar 3D-Strukturen gezielt zu erzeugen allein basierend auf Selbstorganisation werden diskutiert und durch Simulationen gestützt. Vereinfachte Ausdrücke erlauben die Interpretation der ebenfalls gezeigten Experimente. Die möglichen Anwendungen sind vor allem wichtig für die Biotechnologie, aber möglicherweise auch für Metamaterialien.

MA 38.11 Thu 12:15 H 0110

X-ray magnetic circular dichroism of free iron and cobalt dimer cations — •Vicente Zamudio-Bayer[1,2], Konstantin Hirsch[2], Arkadiusz Ławicki[2], Andreas Langeberg[2], Akira Terasaki[3,4], Bernd von Issendorff[1], and Tobias Lau[2] — [1]Physikalisches Institut, Universität Freiburg, Stefan-Meier-Straße 21, 79104 Freiburg, Germany — [2]Institut für Methoden und Instrumentierung der Forschung mit Synchrotronstrahlung, Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Albert-Einstein-Straße 15, 12489 Berlin, Germany — [3]Cluster Research Laboratory, Toyota Technological Institute, 717-86 Futamata, Ichikawa, Chiba 272-0001, Japan — [4]Department of Chemistry, Kyushu University, 6-10-1 Hakozaki, Higashi-ku, Fukuoka 812-8581, Japan

Only recently was it possible for the first time to measure the x-ray magnetic circular dichroism (XMCD) of small, free, size selected clusters. This achievement opens up new possibilities to better understand how spin coupling and orbital magnetic moment in $3d$ transition metals develop from the isolated atom to the bulk material. With this in mind, we have now measured the XMCD of free iron and cobalt dimer cations. The high complexity of the electronic structure of these smallest molecules is evidenced by the numerous attempts in the literature to theoretically describe their electronic ground states. By applying the XMCD sum rules it is possible to resolve spin and orbital contributions to the total magnetic moment in these molecules and to therefore determine their electronic ground state. Experimental results and possible trends in trimers and larger clusters will be discussed.

MA 38.12 Thu 12:30 H 0110

Magnetism of free Rh clusters via ab-initio calculations: which intuitive concepts can or cannot be used — •Ondřej Šipr[1], Hubert Ebert[2], Sergey Mankovsky[2], and Ján Minár[2,3] — [1]Institute of Physics ASCR, Praha, Czech Republic — [2]Universität München, München, Germany — [3]University of West Bohemia, Plzeň, Czech Republic

A fully relativistic ab-initio study on free Rh clusters of 13-135 atoms is performed to identify general trends concerning their magnetism and to check whether concepts which proved to be useful in interpreting magnetism of $3d$ metals are applicable to magnetism of $4d$ systems. Some important intuitive concepts which proved to be useful in interpreting magnetism of $3d$ metals are not applicable to magnetism of $4d$ systems (such as Rh clusters). In particular, there is no systematic relation between local magnetic moments and coordination numbers. On the other hand, the Stoner model appears to be well-suited as a criterion for the onset of magnetism of Rh clusters and, on the top of that, it can serve as a guide for the dependence of local magnetic moments on the local density of states at the Fermi level.

Fully-relativistic calculations indicate that in some cases there can be large orbital magnetic moments antiparallel to the spin magnetic moments. The intra-atomic magnetic dipole T_z term can be quite large at certain sites, however, as a whole it is unlikely to affect the interpretation of x-ray magnetic circular dichroism (XMCD) experiments based on the sum rules.