MA 16: Magnetic Particles / Clusters II

Time: Tuesday 9:30–11:45 Location: EB 202

MA 16.1 Tue 9:30 EB 202

Switching of single-domain magnetic particles under the influence of thermal fluctuations — •Leoni Breth[1,2], Dieter Suess[2], Christoph Vogler[2], Bernhard Bergmair[2], Markus Fuger[2], Rudolf Heer[1], and Hubert Brückl[1] — [1]AIT - Austrian Institute of Technology, Health and Environment Dept.,Vienna, Austria — [2]Vienna University of Technology, Solid State Physics Dept., Vienna, Austria

The switching behavior of nanometer scale magnetic particles is of interest for various applications working at room temperature that reach from biomedicine to magnetic recording technologies. At finite temperature thermal fluctuations assist the magnetization to overcome the energy barrier separating its two stable states. The transition rate described by the Arrhenius-Néel law is exponentially decreasing with higher energy barriers. Starting from a master equation for the not-switching probability we derive a probability density function that corresponds to the switching field distribution of a single-domain particle originating solely from the presence of thermal fluctuations of the magnetization along its spatial orientation, as stated in the Néel-Brown model. Using the distribution function we are able to calculate rate-dependent coercivity and the corresponding standard deviation. Furthermore, we give mathematical arguments for the range of validity of the Néel-Brown model and we present single-spin Monte-Carlo and micromagnetic Langevin dynamics simulation data that show excellent agreement when taking into account the field-dependence of the attempt frequency in the Arrhenius-Néel law.

MA 16.2 Tue 9:45 EB 202

Time-resolved measurements of domain wall movement assisted particle transport on magnetically patterned samples — •Daniel Lengemann[1], Dennis Holzinger[1], Larysa Baraban[2], Dieter Engel[1], and Arno Ehresmann[1] — [1]Department of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel — [2]Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden (IFW), Dresden, Helmholtzstraße 20, D-01069 Dresden

IrMn/CoFe exchange biased layers were patterned into artificial parallel stripe magnetic domains with alternating magnetization directions in adjacent stripes perpendicular to the long axis of the stripes. In remanence superparamagnetic particles have been trapped in the inhomogeneous stray fields of Bloch domain walls. The different magnetization reversal mechanisms in each hysteresis loop branch cause a stepwise movement of the trapped particles [1].

Time-resolved measurements with synchronization of the video feed and the magnetic field pulses in x- and z-direction were performed to measure the particle velocity, the movement type and the magnetic field range where the movement takes place.

[1] Ehresmann, A., Lengemann, D., Weis, T., Albrecht, A., Langfahl-Klabes, J., Göllner, F. and Engel, D., Advanced Materials, doi: 10.1002/adma.201103264 (2011)

MA 16.3 Tue 10:00 EB 202

Magnetization reversal of individual Co nanoislands — •Safia Ouazi[1], Sebastian Wedekind[1], Guillemin Rodary[1,2], Hirofumi Oka[1], Dirk Sander[1], and Jürgen Kirschner[1] — [1]Max-Planck-Institut für Mikrostrukturphysik, Halle (Saale), Germany — [2]Laboratoire de Photonique et Nanostructures/CNRS, Marcoussis, France

We investigate the field induced magnetization reversal of individual Co islands on Cu(111) in the size range of 700 to 18000 atoms by spin-polarized scanning tunneling microscopy at 8 K. The switching field Hsw changes with island size in a non-monotonous manner: it increases with island size and reaches a maximum value of 2.4 T at 5500 atoms, and it decreases for larger islands. We extract the energy barrier for magnetization reversal as a function of island size. Our analysis reveals that the Co islands are magnetically inhomogeneous. The outer rim is magnetically soft, whereas the center region is magnetically hard. Thus, Co islands may be regarded as an exchange spring nanomagnet [1]. For larger islands, we propose that the magnetization reversal occurs by domain nucleation and growth. Our results elucidate a crossover of the magnetization reversal from an exchange spring behavior to domain wall formation with increasing size.

[1] H. Zeng, J. Li, J. Liu, Z. Wang, and S. Sun, Nature 420, 395 (2002).

MA 16.4 Tue 10:15 EB 202

Microfluid mixing due to domain wall movement assisted transport of superparamagnetic beads — •Dennis Holzinger, Daniel Lengemann, Dieter Engel, 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

Domain wall movement assisted transport (DOWMAT) of superparamagnetic particles[1] using a magnetic parallel-stripe patterned exchange bias layer system with head-to-head and tail-to-tail orientation of the magnetization in adjacent domains is shown to be an outstanding tool for active mixing in a microfluidic device. The controlled stepwise movement of complete particle rows increases the interface between the two fluids. The particles acting as active micro-stirrers accelerate dramatically the mixing speed as compared to thermal diffusion. Moreover, the mixing speed is precisely controllable by modification of the particle rows movement sequences.

[1] Ehresmann, A., Lengemann, D., Weis, T., Albrecht, A., Langfahl-Klabes, J., Göllner, F. and Engel, D., Advanced Materials, doi: 10.1002/adma.201103264 (2011)

MA 16.5 Tue 10:30 EB 202

GMR-effects in jelly-like structures — •Judith Meyer, Markus Schäfers, and Andreas Hütten — Bielefeld University, Universitätsstr. 25, 33615 Bielefeld, Germany

The GMR-effect was found and originally studied in magnetic multilayer systems [1,2]. In 1992, it was also independently reported within granular systems by several research groups who had embedded magnetic particles in a metallic matrix [3,4]. In contrast to previous granular layered systems prepared by the use of sputtering or metallurgical procedures, we have chosen a nonmagnetic conductive water-based gel as carrier substance for the magnetic nanoparticles. By doing so, GMR effects of up to several hundred percent have been measured for both Co- and Heusler based nanoparticles. By choosing gel matrices conductivity and hence the GMR-effect amplitude can be adjusted. Regarding future applications, the possibility of printing gel would allow the realization of a granular GMR sensor without employing photo- or e-beam lithography.

[1] G. Binasch, P. Grünberg, F. Saurenbach, W. Zinn, Phys. Rev. B, 39, 4828 (1989)

[2] M. N. Baibich, J. M. Broto, A. Fert, F. Nguyen Van Dau, F. Petroff, Phys. Rev. Lett. 61, 2472 (1988)

[3] A. E. Berkowitz, J. R. Mitchell, M. J. Carey, A. P. Young, S. Zhang, F. E. Spada, F. T. Parker, A. Hütten, G. Thomas, Phys. Rev. Lett., 68, 3745 (1992)

[4] J. Q. Xiao, J. S. Jiang, C. L. Chien, Phys. Rev. Lett., 68, 3749 (1992)

MA 16.6 Tue 10:45 EB 202

Magnetic Nanorods in Ferrofluids: A Novel Template-Directed Synthesis Route — •Robert Zierold[1], Soham Banerjee[1], Martin Waleczek[1], Josep M. Montero Moreno[1], Detlef Görlitz[1], Carl E. Krill III[2], and Kornelius Nielsch[1] — [1]University of Hamburg — [2]Ulm University

In this contribution a novel synthesis route for the preparation of nickel nanorod suspensions is presented, which might allow realization of new magnetic fluids displaying novel properties. Firstly, multi-segmented magnetic nanowires with a diameter of 40 nm are synthesized by electro-deposition of alternating segments of Ni and Cu into porous alumina membranes from a single electrolyte. The length of the particular phases can be tuned individually. Secondly, the release of the multi-segmented nanowires from the alumina matrix and,thirdly, the selective etching of the copper phases finally result in a novel ferrofluidic suspension in a carrier fluid. The magnetic behavior of the short nanorods (aspect ratios 2–10) is characterized in the oxide matrix as well as in liquid suspension. Furthermore, it is proven that subjecting the nanorod ferrofluid to an external magnetic field increases its (magneto)viscosity. Moreover, we find that nanorod suspensions reveal differences in shear-thinning behavior—the decrease in the magnetovis-

cous effect as a function of shear-frequency—compared to a ferrofluid consisting of spherical nanoparticles.
The authors gratefully acknowledge the DAAD RISE program and the State of Hamburg—throuh the Excellence Cluster "Nanotechnology in Medicine"—for financial support.

MA 16.7 Tue 11:00 EB 202

Double exchange mediated ferromagnetic coupling between transition metal atoms in di-metal complexes — •Kalpataru Pradhan[1,2] and Purusottam Jena[1] — [1]Theoretical Physics III, Center for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg, D-86135 Augsburg, Germany — [2]Physics Department, Virginia Commonwealth University, Richmond, VA 23284 USA

Recent discoveries of ferromagnetic ordering in mixed-valence di-metal [1] [2] complexes show that ferromagnetic double exchange in molecular magnets can indeed be achieved via charge disproportionation between valence-variable transition metal ions. Realization of the full technological potential of molecular magnets requires a fundamental understanding of the origin of magnetic coupling in molecular systems. Using gradient corrected density functional theory and Cl as a ligand we find that the magnetic coupling between transition metal atoms in a di-metal complex can be manipulated. Our calculations show that the ferromagnetic (FM) states of Co_2Cl_6 and Co_2Cl_7 are 0.07 eV and 0.20 eV lower in energy than their respective antiferromagnetic (AFM) states but they are nearly degenerate in Co_2Cl_8. The origin of ferromagnetic coupling is explained using the double exchange model caused by charge disproportionation.

[1] B. Bechlars *et al.*, Nat. Chem. 2, 362 (2010).

[2] Lin He and Lin Guo, Appl. Phys. Lett. 97, 182509 (2010).

MA 16.8 Tue 11:15 EB 202

Mn_4 clusters covalently bonded to carbon nanotubes — •Carola Meyer[1], Robert Frielinghaus[1], Anna-Katharina Saelhoff[1], Claire Besson[1], Henrik Flötotto[1], Lothar Houben[2], Paul Kögeler[1], and Claus M. Schneider[1] — [1]Peter Grünberg Institut (PGI-6), Forschungszentrum Jülich and JARA Jülich Aachen Research Alliance, 52425 Jülich, Germany — [2]Peter Grünberg Institut (PGI-5), Forschungszentrum Jülich and Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons, Forschungszentrum Jülich, 52425 Jülich, Germany

Depending on the coordination, manganese polymetallic complexes form single molecule magnets (SMMs). The exchange coupling between the Mn atoms is mediated by the bridging ligands. Therefore, ligand exchange can be used to change the magnetic properties of such Mn SMMs. Carbon nanotubes (CNTs), on the other hand, are expected to possess large spin coherence lengths and long spin relaxation times. Thus, spin transport through CNTs could be used to probe the magnetic properties of attached magnetic molecules. Here, we present the functionalization of carbon nanotubes (CNTs), which provide a 1-dimensional template for the alignment of molecules, with Mn_4 complexes. Raman spectroscopy is used to show the successful covalent bonding using ligand exchange with the oxidized CNTs. Transmission electron microscopy including elemental analysis by EDX and EELS reveals the functionalization on a molecular level. Finally, the changes in the magnetization behavior of the Mn_4 complexes bonded to the CNTs are analyzed using data obtained in SQUID measurements.

15 min. break