MA 41: Micromagnetism / Computational Magnetics

Time: Wednesday 15:00–18:00 Location: HSZ 101

MA 41.1 Wed 15:00 HSZ 101

Dynamics of skyrmions in chiral ferromagnets — •Stavros Komineas[1,2] and Nikos Papanicolaou[1] — [1]University of Crete, Heraklion, Greece — [2]RWTH Aachen University, 52056, Aachen, Germany

We give a description of the dynamics of topological and non-topological solitons in ferromagnetic films. We study materials with a Dzyaloshinskii-Moriya interaction and easy-axis anisotropy. Our analysis is based on an important link between topology and dynamics which is established through the construction of unambiguous conservation laws. In particular, we study the motion of a topological skyrmion with skyrmion number Q=1 and a non-topological skyrmionium with Q=0 under the influence of an applied field gradient (which plays the role of a force). The Q=1 skyrmion undergoes Hall motion perpendicular to the direction of the field gradient with a drift velocity proportional to the gradient. In contrast, the non-topological Q=0 skyrmionium is accelerated in the direction of the field gradient, thus exhibiting ordinary Newtonian motion. When the applied field is switched off the Q=1 skyrmion is spontaneously pinned around a fixed guiding center, whereas the Q=0 skyrmionium moves with constant velocity v. We give a numerical calculation of a skyrmionium traveling with any constant velocity v that is smaller than a critical velocity vc.

MA 41.2 Wed 15:15 HSZ 101

Interdependence of the spin and lattice dynamics of CrN in the high temperature paramagnetic phase — •Irina Stockem[1,2] and Björn Alling[1,2] — [1]Department of Physics, Chemistry, and Biology (IFM), Linköping University, Sweden — [2]Max-Planck-Institut für Eisenforschung Düsseldorf, Germany

The combined magnetic and structural phase transition at the Néel temperature spurred interest to use CrN as a model system in the development of first-principles based theoretical modeling schemes of paramagnetism. While antiferromagnetic CrN exhibits an orthorhombic crystal structure at low temperatures, the crystallographic ordering becomes cubic rock salt in the paramagnetic range. It is known that the local magnetic moments of the Cr atoms do not vanish even at high temperature and their varying orientation of the magnetic moments as well as the lattice vibrations should be considered when the paramagnetic phase is simulated.

Up to now, this has been done using a combination of ab-initio molecular dynamics with rapidly changing disordered local moments electronic structure method for paramagnetism (DLM-MD). We go beyond the adiabatic approximation for the time dynamics of the magnetic degree of freedom and combine atomistic spin dynamics with ab initio molecular dynamics. A separate spin dynamics and molecular dynamics study of CrN uncovers similar time scales of the vibrations and the spin decoherence time, clearly motivating our development of the combined ASD-AIMD approach to study interdependency between spin and lattice degrees of freedom.

MA 41.3 Wed 15:30 HSZ 101

Reconfigurable nano-scale spin-wave directional coupler — •Qi Wang[1], Philipp Pirro[1], Roman Verba[2], Andrei Slavin[3], Burkard Hillebrands[1], and Andrii V. Chumak[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern 67663, Germany — [2]Institute of Magnetism, Kyiv 03680, Ukraine — [3]Department of Physics, Oakland University, Rochester, MI 48309, USA

Spin-wave wavelengths are orders of magnitude smaller than those of electromagnetic waves of the same frequency, and thus, allow for the design of nano-scaled devices for processing of analog as well as digital data. Crossing structures are a prerequisite for the realization of complex integrated two-dimensional spin-wave circuits. A simple X-type crossing does not satisfy the requirements at the nanometer scale. In this work, we study the coupling of spin waves in parallel- and anti-parallel-magnetized nano-scaled waveguides with a gap using micromagnetic simulations. A corresponding analytic theory is developed. The insulator material yttrium iron garnet (YIG) is studied due to its intrinsically low spin-wave damping. Our results show that a spin wave excited in one waveguide transfers all its energy into the second waveguide after the propagation of a certain distance. This can be utilized to cross two magnonic conduits without interaction, as a power divider, or as a frequencies separator.

This research has been supported by ERC Starting Grant 678309 MagnonCircuit.

MA 41.4 Wed 15:45 HSZ 101

Control of magnetization reversal in ferromagnetic coaxial nanorods: micromagnetic simulations — •Irene Iglesias[1], Thomas Feggeler[1], Benjamin Zingsem[1], and Michael Farle[1,2] — [1]Faculty of Physics and Center for Nanointegration (CENIDE), University Duisburg-Essen, Lotharstr. 1, 47057 Duisburg — [2]Center of Functionalized Magnetic Materials, Immanuel Kant Baltic Federal University, 236041 Kaliningrad, Russian Federation

We present the results of micromagnetic simulations on the magnetization reversal in ferromagnetic coaxial nanorods consisting of different ferromagnetic materials in the inner wire and outer dia- and ferromagnetic tubular shells. To make our simulations compatible with real nanorods (typical length 200 nm and diameter 50 nm) that can be obtained by means of colloidal chemistry three main morphologies of coaxial nanorods have been selected: coaxial cylinders, coaxial ellipsoids and coaxial nanobones. Parameters were chosen such that two state magnetic switching was obtained and the arrangement of magnetic moments during the magnetization reversal was analyzed. The magnetic field was applied along the nanorods axis for all simulations. It is shown that the magnetization dynamics of ferromagnetic coaxial nanorods can be controlled by tuning their thickness, length and composition. The results of our studies may allow the enhanced control of magnetization reversal in coaxial structures, increasing their potential for biological applications and as information carriers in storage devices.

MA 41.5 Wed 16:00 HSZ 101

Calculating GMR in granular Systems using 3D resistor networks — •Daniel Kappe[1,2], Christian Schröder[2], and Andreas Hütten[1] — [1]Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany — [2]Bielefeld Institute for Applied Materials Research, University of Applied Sciences Bielefeld, Germany

To investigate the impact of particle arrangement on the Giant Magnetoresistance (GMR) effect in granular systems, a resistor network model has been devised to calculate GMR in these systems. Analytical solutions to this problem usually neglect the specific arrangement of particles and instead implement their properties as mean values. This is sufficient for studying large clusters of particles, but might fall short as soon as smaller, organized arrangements are of interest.

Our model uses the geometric arrangement of particles and their micromagnetic state to calculate the system's resistivity. The input is modelled as a three dimensional network of resistors, which is then converted into a set of linear equations. Its solution can be determined inverting the system's matrix.

Combining this approach with micromagnetic simulations, it is possible to calculate the resistivity for arbitrary external magnetic fields, particle arrangements and particle shapes.

15 min. break.

MA 41.6 Wed 16:30 HSZ 101

Shell-ferromagnetism of nano-precipitate in a Ni-Mn-In off-stoichiometric Heusler alloy by ferromagnetic resonance — •Franziska Scheibel[1], Detlef Spoddig[1], Ralf Meckenstock[1], Asli Çakir[2], Michael Farle[1], and Mehmet Acet[1] — [1]Faculty of Physics and CENIDE, University Duisburg-Essen, 47057 Duisburg, Germany — [2]Department of Metallurgical and Materials Engineering, Muğla Sitki Koçman University, 48000 Mugla, Turkey

Previous studies have shown that the off-stoichiometric Ni-Mn-based Heusler alloys decompose into a ferromagnetic (FM) $Ni_{50}Mn_{25}X_{25}$ Heusler alloy and the antiferromagnetic $Ni_{50}Mn_{50}$ alloy during temper-annealing [1]. Annealing of $Ni_{50}Mn_{45.1}In_{4.9}$ in a field of 5 T leads to an alignment of the magnetic moments at the interface of the nano-precipitates along the field direction, leading to a vertical shift of the magnetic hysteresis which is stable up to 9 T and 500 K. The hard magnetic shell can only be reversed in a field of 12 T, which makes

this material interesting for permanent magnetic memory application. We studied the coupling mechanism and interface exchange energy by ferromagnetic resonance (FMR). Bidirectional FMR measurements in the range $-1.1 \le \mu_0 H \le 1.1$ T at 400 K show a corresponding signal to the decomposed FM phase, indicating a shape anisotropy. FMR studies up to 12 T shows that the FMR of the hard magnetic shell appears at the same resonance field as the FMR of the soft magnetic core but is only present after saturation at 12 T. Work supported by the Deutsche Forschungsgemeinschaft (SPP 1599).
[1] A. Çakir et al., Sci. Rep. 6 , 28931 (2016)

MA 41.7 Wed 16:45 HSZ 101

High throughput screening for magnetic antiperovskites M_3XY (M = Cr, Mn, Fe, Co, and Ni, and Y = C or N) — Zeying Zhang, •Harish K. Singh, and Hongbin Zhang — Institute of Materials Science, TU Darmstadt, Jovanka-Bontschits-Str. 2, 64287 Darmstadt, Germany

Like perovskite materials, compounds with antiperovskite structure show many intriguing physical properties like superconductivity, barocaloric effect, negative thermal expansion etc. In the present work, we investigate the stability of antiperovskite M_3XY (M = Cr, Mn, Fe, Co, and Ni, and Y = C or N) compounds based on extensive first-principles calculations. Assuming crystal structures with Pm$\bar{3}$m space group, the thermodynamic, mechanical, and dynamical stabilities have been examined by evaluating the formation energy, elastic constants, and phonon spectra. The distance from the convex hull has been evaluated by considering *all* possible decompositions into binary compounds available in the Materials Project database. In order to benchmark our calculations, the stability criteria have been validated on existing antiperovskite materials. Based on the calculations, we predict more than 20 new antiperovskite compounds which satisfy all the above mentioned stability criteria. We hope our work will stimulate more experimental efforts to synthesize and characterize the predicted novel antiperovskite materials.

MA 41.8 Wed 17:00 HSZ 101

Size-induced changes of structural and ferromagnetic properties in $La_{1-x}Sr_{Sr}MnO_3$ nanoparticles — •Cornelia Hintze[1], Dirk Fuchs[1], Michael Merz[1,2], Houari Amari[3], Christian Kübel[2,3], Meng-Jie Huang[1], Annie Powell[3,4], and Hilbert von Löhneysen[1] — [1]Karlsruhe Institut für Technologie, Institut für Festkörperphysik, 76021 Karlsruhe — [2]Karlsruhe Institut für Technologie, Karlsruhe Nano Micro Facility, 76021 Karlsruhe — [3]Karlsruhe Institut für Technologie, Institut für Nanotechnologie, 76021 Karlsruhe — [4]Karlsruhe Institut für Technologie, Institut für Anorganische Chemie, 76021 Karlsruhe

$La_{1-x}Sr_xMnO_3$ nanoparticles (NP) were grown by microemulsion, with Sr concentrations from $x = 0.35$ to 0.50 and diameters between 20 and 40 nm. This technique allows the controlled growth of structurally well-defined NP in a range of sizes using the same preparation conditions. With decreasing particle size, the unit cell volume and the Mn-O bond length increase, while the Mn-O-Mn bond angle decreases. The size-dependent change of structural properties is possibly related to surface effects or disorder. With the decrease of NP size the ferromagnetic ordering temperature T_C decreases by up to 20%. The reduction of T_C can be understood with respect to structural changes: the increase of Mn-O bond length and decrease of Mn-O-Mn bond angle weaken the double-exchange coupling and hence reduce T_C. In addition the intrinsic finite-size effect reduces T_C. The observed size-induced change of magnetic properties may allow for a controlled manipulation of magnetism in $La_{1-x}Sr_xMnO_3$ NP by varying NP size.

MA 41.9 Wed 17:15 HSZ 101

Magnetic characterization of cobalt ferrite nanoparticles in PEG-solution studied by Mössbauer spectroscopy and magnetic AC-susceptometry — •Samira Webers[1], Joachim Landers[1], Soma Salamon[1], Melissa Hermes[2], Annette M. Schmidt[2], and Heiko Wende[1] — [1]Faculty of Physics, Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen — [2]Institute for Physical Chemistry, University of Cologne

Spherical, monodisperse cobalt ferrite nanoparticles dispersed in an aqueous solution display fast Brownian motion. By adding polyethylene glycol (PEG) the viscosity of the mixture increases and the particle motion is slowed by the PEG chains. We investigate the influence of different PEG chain lengths and various concentrations resulting in similar macroscopic properties by magnetic characterization of the particle motion via Mössbauer spectroscopy and AC-susceptometry (ACS). The main aspect is to study the particle-matrix interaction in macroscopic similar mixtures which differ in their microscopic composition. Since the particles are in the size of the structural units of the matrix, the relative length scale of the magnetic particles compared to the size of the structural units of the polymer gets relevant and is expected to influence the particle mobility. Further structural characterization of the particles regarding to the particle size and spinel structure are performed by low temperature in-field Mössbauer spectroscopy. To crosscheck the Mössbauer results, the Brownian rotation frequency of the particles is studied by ACS. This work is supported by the DFG-Priority Programme SPP1681.

MA 41.10 Wed 17:30 HSZ 101

Inverse magnetostrictive stress sensors based on CoFeB/MgO/CoFeB tunnel junctions — •Niklas Dohmeier[1], Günter Reiss[1], Karsten Rott[1], Ali Tavassolizadeh[2], and Dirk Meyners[2] — [1]Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany — [2]Institute for Materials Science, Christian-Albrechts-Universität zu Kiel

We investigate double-pinned CoFeB/MgO/CoFeB tunnel junctions as sensors for mechanical stress.
Applying stress on a magnetic material induces an anisotropy. Depending on the material and direction of the stress, the anisotropy can be parallel or perpendicular to the stress direction. This effect can be utilized in TMR stacks to detect mechanical stress via changes in the tunnel resistance.
A standard TMR stack with a pinned and a free magnetic layer needs a magnetic bias field to set the optimum working condition. We are aiming for a replacement of the external bias field.
TMR stacks have been realized with MnIr-based pinning of both electrodes. By choosing different MnIr thicknesses, different blocking temperatures were accomplished. Through a series of field cooling processes with increasing temperatures the optimum temperature was found for crossed ground state magnetizations of the electrodes.
On these systems TMR measurements and bending experiments have been performed in order to show the performance of non-collinear pinned TMR stacks as stress sensors with the possibility of differentiating tensile and compressive stress.

MA 41.11 Wed 17:45 HSZ 101

Magnetoelastic modeling of ΔE-effect magnetic field sensors for sub nT — •Benjamin Spetzler[1], Sebastian Zabel[1], Christine Kirchhof[2], Eckhard Quandt[2], and Franz Faupel[1] — [1]Institute for Materials Science, Chair for Multicomponent Materials, Faculty of Engineering, Christian-Albrechts-University at Kiel, Kaiserstraße 2, D-24143 Kiel, Germany — [2]Institute for Materials Science Chair for Inorganic Functional Materials, Faculty of Engineering, Christian-Albrechts-University at Kiel, Kaiserstraße 2, D-24143 Kiel, Germany

Stimulated by our new approach of a fully integrable ΔE-effect magnetic field sensor [Gojdka et al., APL 99 (2011) 223502, Nature 480 (2011) 155], we present a comprehensive description of the ΔE-effect in magnetostrictive thin films and their application for magnetic field sensors. The ΔE-effect describes the nonlinearity of stress-strain behavior in magnetic materials. It originates from magnetoelastic coupling and results in a change of elastic modulus upon application of a magnetic field. This is modeled using an extended Stoner-Wohlfarth approach including anisotropy distributions and thin film geometry. The model is then expanded to correctly describe the properties of a MEMS cantilever resonance shift with magnetic field and stress. Such high Q cantilevers have been studied intensely for the application as magnetic field sensors. To operate the sensor, it is externally excited using an additional piezoelectric layer of AlN. The impedance change of this magnetically detuned electromechanical resonator is used for high sensitivity sensors able to detect magnetic fields well below 1 nT.