# MA 26: Thin films – coupling effects

Time: Wednesday 9:30–12:15 Location: EB 301

MA 26.1 Wed 9:30 EB 301

**Influence of oxygen content on magnetic properties in La2/3Sr1/3MnO3-$\delta$ thin films** — •Lei Cao[1], Oleg Petracic[1], Alexander Weber[1,2], Paul Zakalek[1], and Thomas Brückel[1,2] — [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 at Heinz Maier-Leibnitz Zentrum MLZ, Forschungszentrum Jülich GmbH, Garching

Complex oxides display a multitude of unique phenomena, such as various forms of magnetism, superconductivity, colossal magnetoresistance, and couplings between these states. The role of oxygen content after sample preparation onto the physical properties is mostly unknown. The ability to control the oxygen composition after the preparation may provide the possibility to dynamically tune the physical properties and establish a comprehensive understanding of the structure-property relationship. We report on the fabrication of La0.7Sr0.3MnO3-$\delta$ thin films on SrTiO3 substrates by high oxygen pressure sputtering. Using an in-situ x-ray diffraction setup we investigate the crystallographic properties while annealing the samples in vacuum and at various temperatures. While annealing induces a desorption of oxygen, absorption of oxygen is realized in a controlled oxygen plasma of a sputtering setup. By employing magnetometry and electrical resistivity measurements, we study the magnetic and transport properties of the as-prepared, annealed and plasma treated systems. We then relate the influence of oxygen absorption/desorption to the physical properties of the films.

MA 26.2 Wed 9:45 EB 301

**Influence of deposition and field cooling parameters on sputter-deposited polycrystalline exchange bias layer systems** — •Maximilian Merkel[1], Jonas Zehner[2], Karin Leistner[2], Dennis Holzinger[1], and Arno Ehresmann[1] — [1]Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel — [2]Leibniz Institute for Solid State and Materials Research Dresden, IFW Dresden, Helmholtzstr. 20, D-01069 Dresden

Magnetic properties of sputter-deposited polycrystalline exchange bias thin films evolve from a complex interplay of different individual magnetic anisotropies which are directly connected to the grain size distribution, crystallite texture and interface structure of the layer system. These structural characteristics can be controlled via deposition parameters or manipulated during a thermal activation procedure in an external magnetic field. Angle-resolved hysteresis measurements using Kerr magnetometry in comparison to an extended Stoner-Wolfarth model [1], X-ray diffraction experiments and interface roughness characterization allowed for the quantification of material properties in dependence of deposition and field cooling parameters supporting common structure zone models.

[1] Müglich, N. D., Gaul, A., Meyl M., Ehresmann, A. , Götz, G., Reiss, G., Kuschel T., Time-dependent rotatable magnetic anisotropy in polycrystalline exchange-bias systems: Dependence on grain-size distribution, Physical Review B **94**, 184407 (2016)

MA 26.3 Wed 10:00 EB 301

**Cooling field and sample orientation dependent magnetization reversal processes in exchange biased Co/CoO on MgO(100)** — •Andrea Ehrmann[1] and Tomasz Blachowicz[2] — [1]Bielefeld University of Applied Sciences, Faculty of Engineering and Mathematics, 33619 Bielefeld, Germany — [2]Silesian University of Technology, Institute of Physics - Center for Science and Education, 44-100 Gliwice, Poland

Co/CoO is a typical exchange bias (EB) system which was investigated for long time, either as core/shell particles, as thin film systems or in other shapes. While other systems seem to be of higher interest in basic and applied research, a surprising effect could be found in Co/CoO thin film systems epitaxially grown on MgO(100) substrates: Such samples show a strong influence of the orientation of the average uncompensated antiferromagnetic magnetization with respect to the cooling field direction, resulting in unexpected asymmetric behavior during sample rotations. The horizontal loop shift as well as the sign of the transverse magnetization peaks in magneto-optical Kerr effect (MOKE) experiments change their values depending on the rotational direction. Here we will give a broad overview of the impact of cooling field and sample orientation on the magnetization reversal processes in this system.

[1] A. Ehrmann, T. Blachowicz: Angle and rotational direction dependent horizontal loop shift in epitaxial Co/CoO bilayers on MgO(100), AIP Advances 7, 115223 (2017)

MA 26.4 Wed 10:15 EB 301

**Enhanced exchange bias in MnN/CoFe bilayers after high-temperature annealing** — •Mareike Dunz, Jan Schmalhorst, and Markus Meinert — Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany

The exchange bias effect is crucial for pinning ferromagnetic electrodes in GMR or TMR devices. Recently, we found that optimized polycrystalline MnN/CoFe bilayer systems with $t_{\mathrm{MnN}} = 30\,\mathrm{nm}$ show exchange bias of up to 1800 Oe at room temperature [1]. This makes antiferromagnetic $\Theta-$MnN a promising alternative for expensive materials like MnIr.

Here, we report on even higher exchange bias that is observed in similar bilayers after annealing them at high temperatures around 500°C. For systems with $t_{\mathrm{MnN}} = 48\,\mathrm{nm}$, exchange bias of more than 2700 Oe is achieved. However, this is only observable for bilayers with thicknesses of MnN higher than 40 nm. To identify the origin of this behavior, X-ray diffraction and Auger depth profiling measurements were performed. They reveal a strong diffusion of nitrogen from the MnN into the Ta buffer layer of the samples. As thicker MnN layers have a better thermal stability due to their large nitrogen reservoir, they can tolerate the high annealing temperatures that induce the increase of exchange bias. Reversed field cooling experiments show that high-temperature annealing also yields an increased median blocking temperature of the MnN/CoFe system.

[1] M. Meinert et al., Phys. Rev. B 92(14), 144408 (2015)

MA 26.5 Wed 10:30 EB 301

**Manipulation of Perpendicular AF-Coupled Thin Film Systems by Ion Beam Irradiation** — •Leopold Koch[1,2], Miriam Lenz[1], Fabian Samad[2], Phani Arekapudi[2], Lorenzo Fallarino[1], and Olav Hellwig[1,2] — [1]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstrasse 400, 01328 Dresden, Germany — [2]Institute of Physics, Chemnitz University of Technology, 09126 Chemnitz, Germany

The tuning of the magnetic properties of antiferromagnetically (AF) coupled multilayer films by ion beam irradiation has been investigated. Stacks of Co/Pt multilayers, AF-coupled by Ru interlayers, have been a model system for studying the energy contributions of interlayer exchange, perpendicular anisotropy and demagnetization [1]. The system shows a complex mixture of magnetic phases that can be tuned by the number of repeats of the Co/Pt-bilayers (X) and the number of Ru interlayers. A lateral homogeneous AF remanent magnetic structure occurs for small X due to the dominance of the AF-coupling. For large X the demagnetization energy prevails and ferromagnetic stripe domains evolve. Ion beam irradiation causes atomic intermixing at the Co/Pt and Co/Ru interfaces and successively changes the balance of the energy contributions. By irradiating locally, lateral heterogeneous structures of magnetic phases can be realized. Initial irradiation studies will be presented and discussed.

[1] O. Hellwig, J. B. Kortright, A. Berger and E. E. Fullerton, *J. Magn. Magn. Mater.*, 2007, 319, 13.

MA 26.6 Wed 10:45 EB 301

**Interfacial Magnetic Exchange Coupling in a L10-MnGa/FeCo Bilayer** — •Elvis Shoko and Udo Schwingenschloegl — King Abdullah University of Science and Technology, Physical Science and Engineering Division (PSE), Thuwal 23955-6900, Saudi Arabia

Epitaxial bilayers of L10-MnGa/Fe1-xCox are of interest in perpendicular magnetic tunnel junctions, with interfacial magnetic exchange coupling playing an important role in the functionality of such devices.[1] This exchange coupling is reported to undergo an abrupt transition from ferromagnetic (FM) to antiferromagnetic (AF) as x increases to 0.25. [2] The origin of this abrupt transition is not well understood. Using LDA+U density functional theory, we have studied the magnetic properties of these bilayers for compositions in the vicinity of x = 0.25. I will discuss the features of the exchange coupling that we obtain and some insight they provide in relation to the experimental result of Ref. 2.

[1] K. Z. Suzuki et al., Sci. Rep. 6, 30249 (2016). [2] Q. L. Ma et al., Phys. Rev. Lett. 112, 157202 (2014).

**15 minutes break**

MA 26.7 Wed 11:15 EB 301

**TbCoFe/[Co/Ni/Pt] Exchange Coupled Heterostructure** — •Michael Heigl, Ralph Wendler, Birgit Hebler, and Manfred Albrecht — Lehrstuhl für Experimentalphysik IV, Institut für Physik, Universität Augsburg, Germany

Heat-assisted magnetic recording (HAMR) is envisioned to increase the achievable storage density in future magnetic hard disk drives (HDD). We present a candidate composite structure consisting of two exchange-coupled materials with different Curie temperatures. The heterostructure consists of an amorphous ferrimagnetic TbCoFe thin film as a storage layer coupled to a softer [Co/Ni/Pt] multilayer, acting as a write and read-out layer. TbCoFe is in comparison to classic HAMR materials like $L1_0$FePt [1] highly tunable by its composition, exhibits a smaller Curie temperature $T_c$, larger damping, and perpendicular magnetic anisotropy (PMA). Due to its small magnetization, the switching and read-out layer [Co/Ni/Pt] is required. [Co/Ni/Pt] multilayers were chosen because of their PMA, high $T_c$ and large saturation magnetization.

We report on the magnetic properties of the separate layers as well as the coupled system for different compositions, thicknesses, and temperatures. Additionally, the structural stability of the amorphous TbCoFe films and the multilayers were investigated as function of annealing temperature.

References: [1] D. Weller et al., Phys. Status Solidi A210 (2013) 1245.

MA 26.8 Wed 11:30 EB 301

**Preparation and Characterization of Granular Magnetic Exchange Coupled Nano-Composites** — •Runbang Shao[1], Benjamin Riedmüller[1], Balati Kuerbanjiang[1], Ulrich Herr[1], Adrian Schillik[2], and Berndt Koslowski[2] — [1]Institut für Mikro- und Nanomaterialien, Universität Ulm, Ulm, Deutschland — [2]Institut für Festkörperphysik, Universität Ulm, Ulm, Deutschland

Granular magnetic exchange coupled nano-composites have potentials in further increasing the storage density of hard disk drives, and producing permanent magnets with high energy product $(BH)_{max}$. These nano-composites of nano-particles (NPs) embedded in or covered by thin films were produced, using a combination of inert gas condensation (IGC) and sputter deposition, in which variable material combinations could be selected. The sizes and volume filling factor (VFF) of the NPs could be controlled independently. SEM, especially in transmission mode (T-SEM) was used to measure the NP sizes. In case of superparamagnetic NPs, we compared these results to the magnetic particle sizes obtained by fitting the $m$-$H$ curve to a superposition of Langevin functions. For blocked NPs embedded in antiferromagnetic films, a dependence of exchange bias ($H_{ex}$) and coercivity ($H_c$) on the ferromagnetic NP VFF was observed. We also studied the magnetisation of individual NPs by the means of MFM.

MA 26.9 Wed 11:45 EB 301

**Transport in graphene and possible Cooper pair formation** — •Klaus Morawetz — Münster University of Applied Sciences,Stegerwaldstrasse 39, 48565 Steinfurt, Germany — International Institute of Physics- UFRN,Campus Universitário Lagoa nova,59078-970 Natal, Brazil — Max-Planck-Institute for the Physics of Complex Systems, 01187 Dresden, Germany

Based on the quantum kinetic equations for systems with SU(2) structure, regularization-free density and pseudospin currents are calculated in graphene realized as the infinite mass-limit of electrons with quadratic dispersion and a proper spin-orbit coupling. The currents possess no quasiparticle part but only anomalous parts. The intraband and interband conductivities are discussed with respect to magnetic fields and magnetic domain puddles. For large Zeeman fields the dynamical conductivities become independent of the density and are universal. The optical conductivity agrees well with the experimental values using screened impurity scattering and an effective Zeeman field. The universal value of Hall conductivity is shown to be modified due to the Zeeman field. The pseudospin current reveals an anomaly since a quasiparticle part appears though it vanishes for particle currents. The density and pseudospin response functions to an external electric field are calculated. A frequency and wave-vector range is identified where the dielectric function changes sign and the repulsive Coulomb potential becomes effectively attractive allowing Cooper pairing. Phys. Rev. B 94 (2016) 165415, Phys. Rev. B 92 (2015) 245425 errata: Phys. Rev. B93 (2016) 239904(E), Phys. Rev. B 92 (2015) 245426

MA 26.10 Wed 12:00 EB 301

**Resonant states in graphene: Interplay with magnetic field and spin orbit coupling** — •Jeongsu Lee, Denis Kochan, and Jaroslav Fabian — Institute for Theoretical Physics, University of Regensburg, 93040 Regensburg, Germany

A vacancy or an adatom in graphene induces $\pi$-magnetism and resonant scattering. Even without the magnetism in consideration, the resonant phenomenon can exhibit interesting physics when combined with an external magnetic field. A strong magnetic field in graphene induces Landau levels overlapping with the resonance peak near the Dirac point. As a result, the resonant state splits into two bound states with effective magnetic momenta of opposite sign. Employing realistic tight-binding parameters, we theoretically investigate the interplay between resonance scattering and the magnetic field in the presence of the magnetic moment and local spin-orbit coupling. This work is supported by SFB 1277.