MA 36: Spin transport

Time: Wednesday 15:00–18:15 Location: H53

MA 36.1 Wed 15:00 H53

Electrical control of antiferromagnetic domain walls — •Sonka Reimers[1,2], Peter Wadley[1], Richard P. Campion[1], Francesco Maccherozzi[2], Sarnjeet S. Dhesi[2], and Kevin W. Edmonds[1] — [1]University of Nottingham, United Kingdom — [2]Diamond Light Source, United Kingdom

Antiferromagnets have a number of favourable properties as active elements including ultra-fast dynamics, zero stray fields and insensitivity to external magnetic fields[1]. Tetragonal CuMnAs is a testbed system in which the antiferromagnetic order parameter can be switched reversibly at ambient conditions using electrical currents[2]. Previous experiments used orthogonal in-plane current pulses to induce 90° rotations of antiferromagnetic domains and terahertz electrical writing speeds have been demonstrated[3].

Here[4], we demonstrate that antiferromagnetic domain walls can be manipulated to realize stable and reproducible domain changes by reversing the polarity of the current only. The resulting Néel spin orbit torque acts primarily on the domain wall. The reversible domain and domain wall reconfigurations are imaged using x-ray magnetic linear dichroism microscopy, and can also be detected electrically. The switching by domain wall motion can occur at much lower current densities than those needed for coherent domain switching.

References: [1] Jungwirth, T. et al., Nat. Nanotechnol. 11 (2016). [2] Wadley, P. et al., Science 351 (2016). [3] Olejník, K. et al., Science Advances 4(3), (2018). [4] Wadley, P., Reimers, S. et al., Nat. Nanotechnol. 13(5), (2018).

MA 36.2 Wed 15:15 H53

Tetragonal CuMnAs alloy: role of defects — •Frantisek Maca[1], Josef Kudrnovsky[1], Pavel Balaz[2], Vaclav Drchal[1], Karel Carva[2], and Ilja Turek[2] — [1]Institute of Physics ASCR, Praha, Czech Republic — [2]Charles University, Faculty of Mathematics and Physics, Praha, Czech Republic

The antiferromagnetic CuMnAs alloy with tetragonal structure is a promising material for the AFM spintronics. The resistivity measurements indicate the presence of defects about whose types and concentrations is more speculated as known. We confirmed vacancies on Mn or Cu sublattices and Mn on Cu and Cu on Mn antisites as most probable defects in CuMnAs by ab-initio total energy calculations.

We have estimated resistivities of possible defect types as well as resistivities of samples for which the X-ray structural analysis is available. In the latter case we have found that samples with Cu- and Mn-vacancies with low formation energies have also resistivities which agree well with the experiment.

Finally, we have also calculated exchange interactions and estimated the Neel temperatures by using the Monte Carlo approach. A good agreement with experiment was obtained.

[1] F. Maca, J. Kudrnovsky, V. Drchal, K. Carva, P. Balaz, and I. Turek, J. Magn. Magn. Mater. 474 (2019) 467.

MA 36.3 Wed 15:30 H53

Limits of collective spin transport in easy-plane magnets — •Martin Evers and Ulrich Nowak — University of Konstanz, D-78457 Konstanz

Within certain limits, magnetism can be described by continuous field-theory, i.e. by the micromagnetic framework. The magnetic equations are rather complex since these comprise all non-linearities of the Landau-Lifshitz-Gilbert equation; but for special systems, e.g. easy-plane magnets with small out-of-plane component the equations reduce to something showing almost the same mathematical structure as the Gross-Pitaevski equation describing the time evolution of a Bose condensate—and therefore superfluidity. Because of this very resemblance, transport in such magnets is called "spin superfluidity" [1,2], although there is one mayor difference: a damping term resulting from Gilbert damping, unavoidably leading to dissipation in the spin superfluid. However, this damping can be quite small.

Our work rests on atomistic spin simulations of easy-plane ferro- and antiferromagnets, carried out within the limits of the analytical theory of the field equations and beyond. This approach allows especially to test limits of this kind of transport—e.g. with respect to a finite temperature, high driving strengths, or disorder—presented in this talk.

[1] S. Takei et al., Phys. Rev. Lett. **112**, 227201 (2014)
[2] B. Flebus et al., Phys. Rev. Lett. **116**, 117201 (2016)

MA 36.4 Wed 15:45 H53

First principles studies of XAS/XMCD experiments in 2D heterostructures under steady-state non-equilibrium conditions — •Alberto Marmodoro, Masako Ogura, Sebastian Wimmer, and Hubert Ebert — Ludwig-Maximilians-Universität, München, Germany

We report on progress in the field of ab initio theoretical spectroscopy for out-of-equilibrium scenarios. This regime can be approached through either pump-probe experiments, or the application of a steady-state, time independent but finite external perturbation.

We consider here the case of XAS/XMCD investigations in multilayer compounds subjected to a finite electric field [1]. These techniques allow for high selectivity in the chemical element and even local environment being targeted. In combination with various kinds of theoretical sum rules, this can lead to fundamental insight on basic electronic structure features of a material.

Our computational framework is based on a fully relativistic multiple scattering / KKR Green function solution scheme for the basic SCF-DFT problem, and the simulation of various kind of spectroscopy and transport experiments. We put to the test a combination of recent developments for the non-equilibrium extension of this basic formalism [2] with established procedures for the study of x-ray absorption in bulks or 2D heterostructures.

[1] R. Kukreja et al., PRL 115, 096601 (2015); G. van der Laan, Physics 8, 83 (2015). [2] S. Achilles et al., PRB 88, 125411 (2013); M. Ogura, H. Akai, JPSJ 85, 104715 (2016)

MA 36.5 Wed 16:00 H53

Non-local magnetotransport in ferromagnetic insulator/Pt heterostructures — •Richard Schlitz[1,2], Toni Helm[3,4], Michaela Lammel[5], Kornelius Nielsch[5,6], Artur Erbe[4], and Sebastian T.B. Goennenwein[1,2] — [1]Institut für Festkörper- und Materialphysik, Technische Universität Dresden, Germany — [2]Center for Transport and Devices of Emergent Materials, Technische Universität Dresden, Germany — [3]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [4]Helmholtz-Zentrum Dresden-Rossendorf e.V., Germany — [5]Leibniz Institute for Solid State and Materials Research Dresden (IFW Dresden), Institute for Metallic Materials, Dresden, Germany — [6]Technische Universität Dresden, Institute of Materials Science, Germany

Non-local long range spin transport phenomena in yttrium iron garnet/Pt heterostructures recently attracted a lot of interest. The experiments are commonly interpreted in terms of magnon diffusion in combination with spin Hall physics[1]. In this study, we first reproduce the fingerprint of the non-local magnetoresistance reported in literature by rotations of the magnetic field in three mutually orthogonal planes and current dependent experiments. After characterization we use a focused ion beam (FIB) to alter the shape of the yttrium iron garnet film in between the Pt contacts and study the ensuing changes in the non-local transport properties. Our results corroborate that magnon transport indeed is the main mechanism for the non-local transport.

[1] L. J. Cornelissen *et al.*, Nature Physics **11**, 1022-1026 (2015)

MA 36.6 Wed 16:15 H53

Atomic Layer Deposition of spin Hall active platinum thin films — •Michaela Lammel[2], Richard Schlitz[1], Akinwumi A. Amusan[2], Stefanie Schlicht[3], Tommi Tynell[2], Julien Bachmann[3], Georg Woltersdorf[4], Kornelius Nielsch[3], Sebastian T.B. Goennenwein[1], and Andy Thomas[3] — [1]Institut für Festkörper- und Materialphysik, Technische Universität Dresden — [2]Leibniz Institute for Solid State and Materials Research Dresden (IFW Dresden), Institute for Metallic Materials — [3]Friedrich-Alexander University Erlangen-Nürnberg, Inorganic Chemistry — [4]Institute of Physics, Martin Luther University Halle-Wittenberg

Due to its strong spin orbit coupling, platinum (Pt) is often used as a spin injector/detector in spintronics. We used atomic layer deposition (ALD) to fabricate Pt thin films in various thicknesses on $Y_3Fe_5O_{12}$(YIG)/$Gd_3Ga_5O_{12}$ substrates. Magnetotransport experiments were performed on the YIG/Pt heterostructures in three mutually orthogonal rotation planes, revealing the fingerprint of spin Hall magnetoresistance (SMR). Hereby the SMR ratio in our YIG/Pt bilayers is smaller by approximatley a factor of 20 in comparison to results reported for high-quality sputtered Pt. Clearly, further experiments will be required to optimize the interface quality in such ALD-based heterostructures. Nevertheless, our results show that spin Hall active Pt thin films can be fabricated by ALD. Our results pave the way for establishing conformal coating of non-planar surface geometries with spin Hall active metals via ALD [1].

[1] Schlitz *et al.*, Appl. Phys. Lett. **112**, 242403 (2018)

MA 36.7 Wed 16:30 H53

Spin Fano factor for spin pumping, spin Seebeck effect and spin transfer torque — •Yuichi Ohnuma — Kavli Institute for Theoretical Sciences, University of Chinese Academy of Sciences, Beijing, China

Noise measurements on nonequilibrium electric currents are known as effective probes of the electron transport in mesoscopic systems. While the equilibrium noise is related to the linear response conductance through the fluctuation-dissipation theorem, nonequilibrium shot noise contains unique information on the effective charge and statistics of a quasiparticle, which cannot be obtained from the resistance measurement.

Recently, it has been proposed that the fluctuation of spin current provide the effective spin of spin transport. In this talk, we show the effective spin carried by magnons in the spin pumping (SP), spin Seebeck effect (SSE) and spin transfer torque (STT) at the interface of a bilayer of a paramagnetic metal and a ferromagnetic insulator. Using the method of non-equilibrium Green's function, we have derived the expressions of the spin current and spin current noise. Combing these two results, we find the conditions for the spin shot noise and obtain the spin Fano factor which describes the effective spin for SP, SSE, and STT.

MA 36.8 Wed 16:45 H53

Topological magnetotransport in antiferromagnetic spintronics — •Libor Šmejkal[1,2], Rafael González-Hernández[1], Tomáš Jungwirth[2], and Jairo Sinova[1,2] — [1]INSPIRE group, Uni Mainz, Germany — [2]Institute of Physics, Czech Academy of Sciences, Prague, Czech Rep.

Merging topological quasiparticles with magnetism became a new direction in the field of topological quantum materials and topological spintronics [1]. Based on ab initio theory, we have predicted a large anisotropic magnetoresistance reaching 6% in Mn_2Au antiferromagnet which was recently observed in current-induced torques experiments [2]. Here, we will catalogue antiferromagnetic systems based on their symmetry and topology [3]. We will show how the presence and breaking of time-reversal symmetry in our antiferromagnetic models open the avenues for relativistic metal-insulator transition and giant anisotropic magnetoresistance [4], and topological anomalous Hall effect in complex magnetic systems [5]. Finally, we will identify a broad list of real material candidates by our first-principle calculations and band-structure engineering.

[1] L. Šmejkal, Y. Mokrousov, B. Yan, and A. H. MacDonald, Nat. Phys. (2018) [2] S. Yu. Bodnar, L. Šmejkal, et al. Nat. Comm. (2018) [3] L. Šmejkal, and T. Jungwirth, book chapter in Topology in Magnetism, Springer (2018) [4] L. Šmejkal, J. Železný, J. Sinova, and T. Jungwirth, Phys. Rev. Lett. (2017) [5] L. Šmejkal, R. González-Hernandez, T. Jungwirth, and J. Sinova, arXiv (2018)

15 min. break

MA 36.9 Wed 17:15 H53

Organic spin valves based on spin-coated P(VDF-TrFE) films on $La_{0.7}Sr_{0.3}MnO_3$ — •Camillo Ballani[1] and Georg Schmidt[1,2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Von-Danckelmann-Platz 3, 06120 Halle(Saale) — [2]Interdisziplinäres Zentrum für Materialwissenschaften, Martin-Luther-Universität Halle-Wittenberg, Nanotechnikum Weinberg, 06120 Halle(Saale)

Organic spin valves (OSV) are well known for the occurrence of magnetoresistive effects and resistive switching and, therefore, have a huge potential for applications. However, the exact mechanism of transport through the organic interlayer often remains unclear [1]. Furthermore it has been demonstrated that the ferroelectric copolymer P(VDF-TrFE) in combination with a ferromagnetic $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) bottom layer exhibits large resistive switching (RS) effects [2]. The functionality of OSV devices for studying TAMR and RS requires smooth and continuous ultra-thin organic interlayers with clean interfaces. An easy way to deposit such films is spin-coating of dissolved organic polymer powder and subsequent thermal annealing. This study reports on properties like morphology and thickness dependence of spin-coated P(VDF-TrFE) copolymer thin films on the deposition parameters. The films are deposited on epitaxial ferromagnetic LSMO layers grown by pulsed laser deposition on $SrTiO_3$ (001) substrates. Furthermore, we present a patterning process for OSV based on P(VDF-TrFE) and LSMO, and a characterization of their magnetotransport properties.

[1] M. Grünewald *et al.*, Phys.Rev. B, **84**, 125208 (2011)
[2] S. Majumdar *et al.*, Adv.Funct.Mater. **28**, 1703273 (2018)

MA 36.10 Wed 17:30 H53

Lateral spin transport in chemically doped organic semiconductors — •Janis Siebrecht[1,2], Shu-Jen Wang[1], Deepak Venkateshvaran[1], and Henning Sirringhaus[1] — [1]Cavendish Laboratory, University of Cambridge, J. J. Thomson Avenue, Cambridge CB3 0HE, United Kingdom — [2]present address: Max Planck Institute for Solid State Research, Heisenbergstrasse 1, 70569 Stuttgart, Germany

A central goal in the field of spintronics is the development of materials with high spin diffusion lengths. Their low cost and long spin lifetimes make organic semiconductors a potential candidate for technological applications. Here, we test the spin transport in the conjugated polymers IDTBT, N2200, P3HT and CDT-BTZ at different levels of chemical doping. Our devices generate a pure spin current using ferromagnetic resonance (FMR) and exploit the inverse spin Hall effect (ISHE) to convert the spin current into a voltage. By varying the channel width of the organic between source and detector, we find a spin diffusion length of several hundred nanometers for P3HT doped with F4TCNQ. We use the dependence of the ISHE signal on thermal de-doping to test a theoretical model [1] that describes spin diffusion based on hopping and exchange coupling.

1. Yu. Z.G., Nanoelectron. Spintron. 1:1-18 (2015)

MA 36.11 Wed 17:45 H53

Accurate and generalized formalism for spin-admixture parameter calculations — •Uday Chopra[1,2], Shambhawi Shambhawi[3], Sergei Egorov[1,4], Jairo Sinova[1], and Erik R. McNellis[1] — [1]Johannes Gutenberg University, Staudingerweg 7, Mainz, 55128 — [2]Graduate School Material Science in Mainz, Staudingerweg 9, Mainz, 55128 Germany — [3]Dept. of Chemical Engineering and Biotechnology, University of Cambridge, Philippa Fawcett Dr, Cambridge CB30AS — [4]University of Virginia, Chemistry Department, McCormick Rd, Charlottesville, VA 22901 USA

The spin-admixture parameter, γ [1,2], is key to understanding spin-dynamics in molecules. It characterizes the influence of spin-orbit coupling (SOC) on spin-dynamics in virtually all models for molecular materials with the spin- up/down mixing in a SOC perturbed wave-function. The parameter governs the probability of spin-flip as the charge hops in a network of sites in an organic semiconductor. However, the quality of its current first-principles electronic structure theory formulation is severely limited by multiple approximations. We generalize this formulation to remove all of these flaws and demonstrate its accurate predicability of spin-relaxation in organic semiconductors. The resulting γ is straightforwardly computed, valid for vastly greater variations in target molecules and chemical composition, and more sensitive to aspects of geometric and electronic structure. We discuss this by highlighting trends in spin-admixture influenced by molecular design. [1] Z. G. Yu, Phys. Rev. B, 85, 115201 (2012). [2] Z. G. Yu, Phys. Rev. Lett, 106, 106602 (2011).

MA 36.12 Wed 18:00 H53

Proximity induced anisotropic magnetoresistance in graphene with broken sublattice symmetry — •Jeongsu Lee and Jaroslav Fabian — Universität Regensburg, 93047 Regensburg, Germany

Proximity induced anisotropic magnetoresistance (PAMR) is present when spin-orbit coupling and proximity-induced exchange fields coexist and the PAMR response could also provide means to observe ferromagnetic order in the tunnel barrier. Recent, experimentally demonstrated 2D ferromagnets made a breakthrough in ferromagnetic van der Waals heterostructures. Employing realistic parameters extracted from the first principles calculations, we theoretically investigate the proximity-induced anisotropic magnetoresistance in spin-orbit coupled systems with exchange field in consideration of broken sublattice symmetry.

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