# MA 14: General Spintronics

Time: Monday 15:00–18:15 Location: HSZ 401

MA 14.1 Mon 15:00 HSZ 401

**Tunable magnetic anisotropy energy with quantum well state in $SrRuO_3$** — •Angus Huang[1], Horng-Tay Jeng[1,2,3], and Ching-Hao Chang[4,5] — [1]Department of Physics, National Tsing Hua University, Hsinchu 30013, Taiwan — [2]Physics Division, National Center for Theoretical Sciences, Hsinchu 30013, Taiwan — [3]Institute of Physics, Academia Sinica, Taipei 11529, Taiwan — [4]Department of Physics, National Cheng Kung University, Tainan 70101, Taiwan — [5]Center for Quantum Frontiers of Research & Technology (QFort), National Cheng Kung University, Tainan 70101, Taiwan

We demonstrate theoretically the magnetic anisotropy in $SrRuO_3$ thin film can be well controlled by geometrical and electrical modulations: the easy axis (preferred magnetization direction) can be switched between perpendicular and parallel to the film either by slightly altering the film thickness or by moderately doping electrons. Such an ability is given by the spin-polarized quantum well states (QWSs) near the Fermi level. The QWSs are susceptible to the intrinsic spin orbital interaction and thus drive a large energy discrepancy when a $SrRuO_3$ thin film rotates its magnetization direction. As a result, the low-energy magnetic state can be fine controlled by varying the QWS energy positions via geometry or electricity. The significances of this phenomenon are illustrated in the thin films by the large anisotropy energy induced by the spin-polarized quantum-well resonances, and by the ideal electric control of the easy axis.

MA 14.2 Mon 15:15 HSZ 401

**Modelling phonon-driven spin-relaxation in organic semiconductors from first-principles** — •Uday Chopra[1,2], Sergei Egorov[1,3], Jairo Sinova[1], and Erik R. McNellis[1] — [1]Johannes Gutenberg University, Staudingerweg 7, Mainz, 55128 — [2]Max Planck Graduate Centre, Mainz, Germany — [3]University of Virginia, Chemistry Department, McCormick Rd, Charlottesville, VA 22901 USA

Spin-orbit coupling (SOC) is one of the major causes of spin-relaxation in organic semiconductors. As SOC itself does not conserve energy, relaxation is caused in conjunction with external factors, for example a hopping driven spin-flip mechanism [1,2]. In this work, we explore local and non-local spin-relaxation caused due to molecular vibrations. We present a model to estimate the spin-phonon couplings using finite-differences within harmonic approximation from a first-principles approach. Using these couplings we are able to derive the spin-relaxation times (T1) between the Zeeman energy levels for Raman-like processes using Fermi's Golden rule. Our model assumes a relaxation mediated via two phonons via an intermediate state. This enables us to analyse the relevant phonon-modes that dominate the relaxation in addition to evaluating the temperature dependence of T1. We present our findings using organic-semiconductors and single-molecule magnets to demonstrate transferability across different systems. [1] Chopra et al. Phys. Rev. B 100, 134410 (2019) [2] Chopra et al. J. Phys. Chem. C 123, 19112, (2019)

MA 14.3 Mon 15:30 HSZ 401

**Highly compliant planar Hall effect sensors** — •Rico Illing, Tobias Kosub, Pablo Granell, Eduardo Sergio Oliveros Mata, Jürgen Fassbender, and Denys Makarov — Helmholtz-Zentrum Dresden-Rossendorf, Institut für Ionenstrahlphysik und Materialforschung

Shapeable magnetoelectronics [1] is an integral part of prospective measurement technology for consumer electronics, medical appliances and entertainment electronics including smart textiles and electronic skins [2]. Especially for medical applications, the sensitivity of the contemporary flexible magnetic field sensors should be substantially improved to the level of 1 nT or even below. Planar Hall effect (PHE) sensors are exceptionally suited for reaching this ambitious goal. In this respect, rigid PHE sensors reveal sensitivity of 5 pT [3]. Here, we present a highly compliant magnetic field sensor based on the planar Hall effect prepared on ultrathin polymeric foils. By optimizing the sensor design and measurement methodology, we boost the sensitivity of the PHE sensors to sub-10 nT, which is more than an order of magnitude improvement compared to the state of the art devices [4]. [1] D. Makarov et al., Appl. Phys. Rev. 3, 011101 (2016). [2] J. Ge et al., Nature Communications 10, 4405 (2019). [3] N. Nhalil et al., IEEE Sensors Letters 3, 2501904 (2019). [4] P. Granell et al., npj Flexible Electronics 3, 3 (2019).

MA 14.4 Mon 15:45 HSZ 401

**Spin transport phenomena in vertical spin valves with spacer layers consisting of layered tetragonal $FeGe_2$** — •Dietmar Czubak, Samuel Gaucher, Jens Herfort, Holger Grahn, and Manfred Ramsteiner — Paul-Drude-Institut für Festkörperelektronik, Berlin, Germany

The formation of $FeGe_2$ in a layered tetragonal structure has been recently achieved by solid-phase epitaxy of Ge on $Fe_3Si$. This thin polymorphic film of $FeGe_2$ does not exist in bulk form and appears to be a promising material for spintronic applications. We investigate vertical spin valve structures, in which $FeGe_2$ serves as a spacer layer between the two ferromagnetic Heusler alloy films $Fe_3Si$ and $Co_2FeSi$. The spin valves exhibit magnetoresistances up to 0.3%, originating from the switching between parallel and antiparallel magnetization orientations of the ferromagnetic electrodes. This spin valve effect becomes larger with increasing thickness of the spacer layer, which can be explained by a non-dissipative tunneling process dominating the transport through the $FeGe_2$ spacer layer. Additionally, we observe inverted spin valve-like signals by rotating the in-plane direction of the external magnetic field, which are attributed to a tunneling anisotropic magnetoresistance (TAMR). With decreasing temperature, both, the spin valve and the TAMR signals, become smaller and exhibit a correlation with a ferromagnetic phase transition in the $FeGe_2$ layer. These results constitute a crucial step towards the understanding of the fundamental properties of layered $FeGe_2$ films.

MA 14.5 Mon 16:00 HSZ 401

**Noise-driven magnetic spin dynamics for an insulating Heisenberg magnet coupled to a metallic lead** — •Benjamin F. McKeever[1], Karin Everschor-Sitte[1], and Kei Yamamoto[2] — [1]Institute of Physics, Johannes Gutenberg-Universität, 55128 Mainz, Germany — [2]Advanced Science Research Center, Japan Atomic Energy Agency, Tokai 319-1195, Japan

Near interfaces between a magnet and a non-magnetic metal, Gilbert damping in magnetic spin dynamics is enhanced due to spin-dependent scattering of conduction electrons. The enhancement corresponds to a transfer of spin angular momentum into the normal metal from the magnet (spin pumping), with strength determined by the spin mixing conductance. Similarly, the reciprocal effect, where spin-angular momentum is transferred into the ferromagnet from the normal metal, is pertinent when applying an electric current (Slonczewski spin-transfer torque). To go beyond the paradigm of magneto-electric circuit theory which defines the mixing conductance, and to tie together the different relevant effects, we investigate the role of interface-induced noise fluctuations in the spin dynamics; this is done by modelling the coupling between the normal metal conduction electron spin density and magnetic insulator spins with sd exchange interaction for any kind of magnetic spin system. Ferromagnetic and antiferromagnetic spin chains are presented as example applications of the resulting stochastic LLG equation, which is accurate up to second order in the sd exchange. The formalism presents a way to address interface-driven nonequilibrium noise effects in heterostructures with thin magnetic layers.

MA 14.6 Mon 16:15 HSZ 401

**Evidence for Magnetic Polarons in the Ferromagnetic Semiconductor $HgCr_2Se_4$? – A Fluctuation Spectroscopy Study** — •Merlin Mitschek[1], Shuai Yang[2], Yongqing Li[2], and Jens Müller[1] — [1]Institute of Physics, Goethe-University, Frankfurt (Main), Germany — [2]Institute of Physics, Chinese Academy of Sciences, Beijing, China

Semiconducting $HgCr_2Se_4$ is a member of the spinel family of compounds where one can observe a colossal magnetoresistance (CMR) effect, a field of research that expanded the knowledge of electronic correlations, phase transitions and magnetism. The complexity of the physics underlying the CMR makes it desirable to study a preferably simple system, where the relevant degrees of freedom, including spin, charge, orbital and lattice, along with disorder and strong electron correlations are less intertwined. A typical model system is $EuB_6$ [1] and also $HgCr_2Se_4$, where the phase transition from the paramagnetic to the ferromagnetic phase coincides with an insulator-to-metal transi-

tion at $T_C \approx 105$ K. The CMR effect [2] is found to strongly depend on the degree of disorder in the samples. In our noise measurements, we find $1/f^\alpha$-type fluctuation spectra from room temperature down to low temperatures. The normalized resistance noise power spectral density (PSD) increases by nearly two orders of magnitude upon approaching $T_C$. For $100\,\mathrm{K} < T < 150\,\mathrm{K}$, we observe superimposed Lorentzian spectra originating in single two-level processes. We discuss our findings in terms of a model of percolating magnetic polarons.
[1] PRB **86**, 184425, [2] PRB **94**, 224404.

MA 14.7 Mon 16:30 HSZ 401

**Magnon transport in three-terminal magnetically ordered insulator/platinum nanostructures** — •Janine Gückelhorn[1,2], Tobias Wimmer[1,2], Sudhir Regmi[3], Arunava Gupta[3], Stephan Geprägs[1], Hans Huebl[1,2,4], Rudolf Gross[1,2,4], and Matthias Althammer[1,2] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, Technische Universität München, Garching, Germany — [3]University of Alabama, Center for Materials for Information Technology MINT and Department of Chemistry, Tuscaloosa, AL, USA — [4]Munich Center for Quantum Science and Technology (MCQST), München, Germany

The transport of information via spin waves (magnons) in magnetically ordered insulators provides novel routes for information processing. We present our results of the transport of magnons in the ferrimagnetic insulators (FMI) nickel ferrite (NFO), and yttrium iron garnet (YIG). In our experiments, we deposit three electrically isolated platinum (Pt) strips on top of our FMI thin films. The outer Pt strips act as spin current injector and detector. The center strip is utilized to modulate the magnon transport via a charge current. In the injector and modulator strip the charge current flow controls the magnon density in the FMI via the spin Hall effect and thermal Joule heating. We systematically study the magnon transport in NFO and YIG as a function of applied magnetic field and temperature. Moreover, we compare these results to simultaneous spin Hall magnetoresistance measurements.

Financial support by the DFG (AL2110/2-1) is acknowledged.

**15 min. break.**

MA 14.8 Mon 17:00 HSZ 401

**Resistivity of bulk tetragonal CuMnAs at finite temperatures from the first principles** — •David Wagenknecht[1,2], Karel Výborný[3], Karel Carva[1], and Ilja Turek[1,2] — [1]Department of Condensed Matter Physics, Faculty of Mathematics and Physics, Charles University, Prague, Czechia — [2]Institute of Physics of Materials, The Czech Academy of Sciences, Brno, Czechia — [3]Institute of Physics, The Czech Academy of Sciences, Prague, Czechia

From the first principles, we investigate antiferromagnetic CuMnAs and its finite-temperature electrical transport [1]. It is primary motivated by spintronic applications, such as electrical switching of its magnetic moments, and by testing of novel ab initio codes. Tetragonal bulk CuMnAs was prepared recently [2], which opened a possibility to measure the out-of-plane resistivity. Explaining temperature-dependent electrical transport is a challenging task for ab initio calculation. For this purpose, we employ our implementation of the alloy analogy model based on the coherent potential approximation, previously used, e.g., to study half-Heusler NiMnSb [3]. Because of antiferromagnetic character of CuMnAs, there are many specifics in the description of both magnons and phonons; above that, we will discuss a role of chemical impurities. Three models of magnetic disorder and a combined effect with other scattering phenomena will be shown [1]. Last but not least, our approach is reliable and it reproduces the experimental data.

[1] D. Wagenknecht et al. Submitted to JMMM (October 2019) [2] K. Uhlířová et al. J. Alloys Compd. 771 680-685 (2019) [3] D. Wagenknecht et al. PRB 99 174433 (2019)

MA 14.9 Mon 17:15 HSZ 401

**Modeling of current induced switching in Mn2Au** — •Severin Selzer[1], Leandro Salemi[2], András Deák[3], Eszter Simon[3], Karel Carva[4], László Szunyogh[3], Peter M. Oppeneer[2], and Ulrich Nowak[1] — [1]Fachbereich Physik, Universität Konstanz, DE-78457 Konstanz, Germany — [2]Department of Physics and Astronomy, Uppsala University, Box 516, SE-75120 Uppsala, Sweden — [3]Department of Theoretical Physics, Budapest University of Technology and Economics, H-1111 Budapest, Hungary — [4]Department of Condensed Matter Physics, Charles University, Ke Karlovu 5, CZ 121 16 Prague, Czech Republic

Mn2Au is a promising candidate as material for future antiferromagnetic spintronic devices, since its order parameter can be switched by 90 degree via electric currents [1]. The switching mechanism relies on the Edelstein effect that gives rise to induced magnetic moments, which in Mn2Au are staggered due to the broken inversion symmetry.

We model the current-induced switching within the framework of atomistic spin dynamics simulations based on a multiscale approach were the parameters for the spin model as well as for the Edelstein effect were calculated from first principles [2]. Within this model, we explore the mechanism and the time scales involved in the switching process.

[1] J. Železný, P. Wadley, K. Olejník, A. Hoffmann, and H. Ohno, Nature Physics 14, 220 (2018).

[2] L. Salemi, M. Berritta, A. K. Nandy, and P. M. Oppeneer, Nat Commun 10, 1 (2019).

MA 14.10 Mon 17:30 HSZ 401

**Transport characterization of individual hemispherical shells by zero-offset Hall magnetometry** — •Eduardo Sergio Oliveros Mata[1], Tobias Kosub[1], Oleksii M. Volkov[1], Oleksandr Pylypovskyi[1,2], Jürgen Fassbender[1], and Denys Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf e.V., Institute of Ion Beam Physics and Materials Research, 01328 Dresden, Germany — [2]Taras Shevchenko National University of Kyiv, 01601 Kyiv, Ukraine

Magnetic thin films exhibit novel anisotropic and chiral effects driven by local curvatures. In this context, various curvilinear effects have been studied in theoretical and experimental works [1]. Typically, magnetic properties are assessed based on integral measurements or relying on advanced microscopy characterization. Spintronic studies of individual curvilinear magnetic nanoobjects are missing, primarily due to the low adaptability of standard lithographic processes to integrate with 3D submicron objects. Here, we apply zero-offset Hall magnetometry [2] to carry out electron transport measurements of curvilinear nanostructures. We test the viability of the technique by comparing the transport characteristics between flat nanodisks and individual hemispherical nanoshells in magnetic vortex and hedgehog states. This approach is relevant to perform both fundamental characterization of curved magnetic architectures and direct integration of these structures in magnetic sensorics.

[1] R. Streubel, et al., J. Phys. D: Appl. Phys. 49, 363001 (2016) [2] T. Kosub, et al., PRL 115, 097201 (2015)

MA 14.11 Mon 17:45 HSZ 401

**Ab-initio calculations of transport properties of doped permalloy: exploring the effect of the host disorder** — •Ondrej Sipr[1,2], Sebastian Wimmer[3], Sergey Mankovsky[3], and Hubert Ebert[3] — [1]Institute of Physics, Czech Academy of Sciences, Praha — [2]NTC, University of West Bohemia, Pilsen, Czech Republic — [3]Ludwig-Maximilians-Universität München, Germany

The transport properties of permalloy $Fe_{0.19}Ni_{0.81}$ (Py) doped with V, Co, Pt, and Au have been explored by evaluating the Kubo-Bastin formula within the ab-initio KKR Green function framework, both for zero and for finite temperatures. It is demonstrated that the fact that the Py host is not crystalline but randomly disordered has profound consequences. Transverse conductivities characterizing the anomalous Hall effect (AHE) and the spin Hall effect (SHE) are found to be not proportional to the longitudinal conductivity for low dopant concentrations; consequently, the dependence of the AHE and SHE on the dopant concentration cannot be unambigously ascribed to skew scattering, side-jump scattering, or intrinsic contributions in the same way as it can be done for a crystalline host.

Several relationships between quantities are considered. The longitudinal charge conductivity decreases with increasing dopant concentration and the rate of this decrease depends on the dopant type, following the sequence Co-Au-Pt-V, in accordance with the scattering properties of each atom type. The dependence of the AHE and SHE conductivities on the dopant concentration is found to be nonmonotonic and strongly dependent on the temperature.

MA 14.12 Mon 18:00 HSZ 401

**High-throughput screening for ferromagnetic intermetallics with giant anomalous Hall/Nernst conductivities** — •Ilias Samathrakis, Teng Long, Harish Kumar Singh, and Hongbin Zhang — Theory of Magnetic Materials, TU Darmstadt, Darmstadt, Germany

Topological transport properties in magnetic materials, such as the anomalous Hall conductivity (AHC) and anomalous Nernst conductivity (ANC), are promising for future spintronic applications, as they are dissipationless. In this work, we performed first-principles calculations to evaluate the AHC and ANC in 1827 ferromagnetic compounds. This is achieved by using an in-house developed high-throughput scheme to construct the Wannier functions automatically. Our results signify AHC values larger than 2000 S/cm in several ferromagnetic compounds and giant ANC which can be further tuned to realize heat rectification. Detailed analysis on the symmetry and the electronic structure is performed in order to understand the origin of such abnormal AHC and ANC.