MA 39: Spin-dependent Transport Phenomena I

Time: Thursday 9:30–11:30 Location: H 0112

MA 39.1 Thu 9:30 H 0112

Unified theory for charge, spin and angular momentum excitations — •Filipe Souza Mendes Guimaraes[1,2], Antonio Tavares da Costa Jr[1], Roberto Bechara Muniz[1], Manuel dos Santos Dias[2], and Samir Lounis[2] — [1]Instituto de Física, Universidade Federal Fluminense, Niterói, Brazil — [2]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

The investigation of phenomena involving the spin and charge of the electron, called spintronics, has the potential to generate and enhance tools for the development of devices with low power consumption and fast switching speeds, as well as technologies that may be mass-produced. Polarized currents and angular momentum currents may be used to transfer information more efficiently than the conventional charge currents. We have developed a fully quantum mechanical approach that allows us to study charge, spin and angular momentum excitations. This method takes into account realistic electronic structures obtained from first principles calculations. We show that spin, charge and angular momentum currents and disturbances can be expressed in terms of generalized susceptibilities. Results on static and dynamic quantities related to the Spin Hall Effect and Inverse Spin Hall Effect for ultrathin films of Pt and Co/Pt will be presented.

MA 39.2 Thu 9:45 H 0112

Enhancement of the anomalous Hall effect in ternary alloys — •Katarina Tauber[1], Albert Hönemann[1], Dmitry Fedorov[2,1], Martin Gradhand[3], and Ingrid Mertig[1,2] — [1]Martin Luther University Halle-Wittenberg — [2]Max Planck Institute of Microstructure Physics, Halle — [3]University of Bristol

We present our results for the anomalous Hall effect (AHE) in ternary alloys of the form $Cu(Mn_{1-w}T_w)$ with T as nonmagnetic Au, Bi, Ir, Lu, Sb, or Ta impurities. As was shown experimentally [1], Mn causes negligible skew scattering in copper and therefore a very weak AHE is observed in the Cu(Mn) binary alloys. In contrast, the systems Cu(T) have a strong skew scattering, but only provide a spin Hall effect (SHE) instead of an AHE, since the systems are nonmagnetic. Fert *et al.* [1] found that the AHE can be strongly enhanced in the Cu(Mn) alloys via the co-doping of 5*d*-impurities. Furthermore, they showed that it is possible to describe the SHE in the Cu(T) alloy via measurements of the AHE in the $Cu(Mn_{1-w}T_w)$ alloys. Here, a theoretical study via Matthiessen's rule is presented with focus on the connection between the AHE in the ternary alloy and the SHE in the related Cu(T) alloy. Our formalism provides the conditions for a maximal enhancement of the AHE with respect to the weighting factor w. This is underpinned by first-principles calculations using a relativistic Korringa-Kohn-Rostoker method and Boltzmann transport theory [2].

[1] A. Fert et al., JMMM **24**, 231 (1981).
[2] K. Tauber et al., Phys. Rev. B **87**, 161114(R) (2013).

MA 39.3 Thu 10:00 H 0112

Anomalous Hall Effect at Terahertz Frequencies — Tom Seifert[1], Frank Freimuth[2], Lukas Braun[1], Florin Radu[3], Ulrike Martens[4], Markus Münzenberg[4], Ilie Radu[3], Yuriy Mokrousov[2], Martin Wolf[1], and •Tobias Kampfrath[1] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin, Germany — [2]Forschungszentrum Jülich, Peter Grünberg Institut, 52425 Jülich, Germany — [3]Helmholtz-Zentrum Berlin für Materialien und Energie, BESSY II, Albert-Einstein-Straße 15, 12489 Berlin, Germany — [4]Ernst-Moritz-Arndt Universität, Institut für Physik, Felix-Hausdorff-Str. 6, 17489 Greifswald, Germany

Spin-orbit interaction (SOI) is expected to be of central importance in future spin-based electronics (spintronics) as it permits, for example, the conversion of charge into spin currents. It is highly interesting to study SOI-based effects at terahertz (THz) frequencies because (i) spintronic devices should eventually operate at THz rates and since (ii) the THz photon energy (4 meV at 1 THz) is comparable to the SOI energy in magnetically ordered solids. Here, we employ broadband THz time-domain ellipsometry [1] to measure the complex conductivity tensor of various magnetic metals from 1 to 40 THz. Supported by *ab initio* calculations [2], we discuss spectral features of the spin Hall angle in terms of SOI.

[1] A. Rubano, L. Braun, M. Wolf, and T. Kampfrath, Appl. Phys. Lett. **101**, 081103 (2012).
[2] F. Freimuth, S. Blügel, and Y. Mokrousov, Phys. Rev. Lett. **105**, 246602 (2010).

MA 39.4 Thu 10:15 H 0112

Separation of different contributions to the spin Hall effect in dilute alloys based on the Kubo-Středa approach — •Kristina Chadova[1], Dmitry Fedorov[2,3], Christian Herschbach[2], Martin Gradhand[4], Ingrid Mertig[2,3], Diemo Ködderitzsch[1], and Hubert Ebert[1] — [1]Department of Chemistry, Physical Chemistry, Ludwig-Maximilians University Munich, Germany — [2]Institute of Physics, Martin-Luther University Halle-Weinberg, 06099 Halle, Germany — [3]Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle, Germany — [4]H.H. Wills Physics Laboratory, University of Bristol, Bristol BS8 1TL, United Kingdom

In recent years several first-principles approaches have been established to describe transverse electron transport phenomena as e.g. the anomalous Hall and spin Hall effects. Starting from an earlier decomposition scheme [1] we extract the coherent part of the SHC as well as the extrinsic vertex-correction (vc) based skew-scattering and the side jump (sj) contributions. Further using insight from Boltzmann transport theory we separate the sj into a sum of a term being exclusively caused by the vc and a term that does not depend on the vc. The proposed procedure was applied within first-principles fully relativistic KKR transport framework (Kubo-Středa) to dilute alloys based on Cu, Au and Pt hosts [2].

[1] S Lowitzer, D Ködderitzsch, H Ebert, PRL **105**, 266604 (2010)
[2] K Chadova, D Fedorov, C Herschbach, M Gradhand, I Mertig, D Ködderitzsch, H Ebert (to be published)

MA 39.5 Thu 10:30 H 0112

Higher dimensional Wannier functions for a description of multi-parameter ab initio Hamiltonians — •Jan-Philipp Hanke, Frank Freimuth, Stefan Blügel, and Yuriy Mokrousov — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Maximally localized Wannier functions (MLWFs) have become a widely applied tool in understanding the electronic structure [1]. Here, we present higher dimensional Wannier functions (HDWFs), which provide a minimal and accurate description of multi-parameter Hamiltonians $H^{(\mathbf{k},\boldsymbol{\lambda})}$ carrying a dependence on the crystal momentum $\mathbf{k}$ and an additional periodic parameter $\boldsymbol{\lambda}$. We derive a generalized interpolation scheme and emphasize the essential conceptual and computational simplifications in using the formalism for instance in the evaluation of linear response coefficients. The necessary machinery to construct HDWFs from *ab initio* is implemented within the full-potential linearized augmented plane-wave method (FLAPW) as realized in the `FLEUR` code [2]. We further apply our implementation to accurately interpolate the Hamiltonian of a one-dimensional magnetic chain of Mn atoms with spin-spiral texture in a composite space of Bloch and spin-spiral vectors, and thereby extract efficiently Heisenberg exchange constants.

Financial support by the HGF-YIG programme VH-NG-513 and SPP 1538 of DFG is gratefully acknowledged.

[1] N. Marzari and D. Vanderbilt, Phys. Rev. B **65**, 12847 (1997).
[2] See http://www.flapw.de

MA 39.6 Thu 10:45 H 0112

Description of electron transport in multilayer systems using Boltzmann approach — •Ondřej Stejskal[1], André Thiaville[2], Shunsuke Fukami[3], Hideo Ohno[3], and Jaroslav Hamrle[1] — [1]IF, VSB-Technical University of Ostrava, Czech Republic — [2]LPS, Univ. Paris-Sud, Orsay, France — [3]CSIS/RIEC/WPI-AIMR, Tohoku University, Sendai, Japan

Recent discoveries of spin current, spin Hall effect and Rashba effect have attracted a new interest in transport phenomena in multilayer systems. The Fuchs-Sondheimer theory that is based on the Boltzmann transport equation covers the transport phenomena in thin films. Though the paper was released in 1952, the theory is still being used with great success and is in a great agreement with experiments. We use this theory for the description of an in-plane current density in a multilayer system Ta/Pt/[Co/Ni]/Pt/Ta. The resistance of the multilayer is measured as the function of the thicknesses of individual layers. Using the Fuchs-Sondheimer model, we obtain the material and interface parameters of the layers and the current distribution in the sample. This is of a great importance for multilayers, as the spin phenomena, like spin Hall effect and spin-transfer torque, are proportional to current densities in the vicinity of the interface with ferromagnetic material. This work is partly supported by R&D Project for ICT Key Technology to Realize Future Society of MEXT.

[1] E. Sondheimer, Advances in Physics 1, 1 (1952)

[2] P. M. Haney, H.-W. Lee, K.-J. Lee, A. Manchon, M. D. Stiles, Physical Review B., 87, 174411 (2013)

MA 39.7 Thu 11:00 H 0112

Higher order contributions to Anisotropic Interface Magnetoresistance (AIMR) in Ni/Pt thin films — •Afsaneh Farhadi, André Kobs, Gerrit Winkler, Carsten Thönnissen, and Hans Peter Oepen — Institut für Nanostruktur- und Festkörperphysik, Universität Hamburg, Jungiusstr. 11a, 20355 Hamburg, Germany

The influence of interfaces on the magnetotransport in systems with one ferromagnetic layer has attracted much attention. In Pt/Co/Pt the resistivity behaves as $\rho(\varphi,\theta) = \rho_t + \Delta\rho_{ip}\cos^2\varphi\sin^2\theta + \Delta\rho_{op}\cos^2\theta$ where φ/θ is the angle between magnetization and current direction/film normal [1]. While $\Delta\rho_{ip}$ is caused by the conventional AMR (bulk effect) a $\Delta\rho_{op} \propto 1/t$ behavior was found for Pt(5nm)/Co(t)/Pt(3nm) sandwiches revealing that $\Delta\rho_{op}$ originates at the Co/Pt interfaces (anisotropic interface magnetoresistance (AIMR)). So far the AIMR was observed also for Py/Pt and Co/Pd [2,3]. In order to answer the question if interfacial MR contributions also exist when stacking isoelectronic materials we investigated Ni/Pt systems. We prepared Pt(5nm)/Ni(t)/Pt(3nm) sandwiches with Ni thicknesses of $1 - 50$ nm by dc magnetron sputtering on Si_3N_4 substrate. As a result, in contrast to previous findings, the $\rho(\theta)$ behavior can only be satisfactorily described when considering higher orders in the expansion of the MR up to $n = 3$: $\rho(\theta) = \rho_t + \sum_n \Delta\rho_{op,2n}\cos^{2n}\theta$. The thickness dependence of the amplitudes $\Delta\rho_{op,2n}$ behaves according to $1/t$ revealing that also the higher orders have their origin at the Ni/Pt interfaces.

[1] A. Kobs et al., PRB **90**, 016401 (2014), [2] Y.M. Lu et al., PRB **87**, 220409 (2013), [3] J.-C. Lee et al., JAP **113**, 17C714 (2013).

MA 39.8 Thu 11:15 H 0112

Lattice strain accompanying the colossal magnetoresistance effect in EuB_6 — •Rudra Sekhar Manna[1,2], Pintu Das[1], Mariano de Souza[1], Frank Schnelle[1], Michael Lang[1], Stephan von Molnár[3], Zachary Fisk[4], and Jens Müller[1] — [1]Phys. Inst., Goethe-University Frankfurt, 60438 Frankfurt (Main), SFB/TR49, Germany — [2]EP VI, EKM, Augsburg University, 86159 Augsburg, Germany — [3]Phys. Dept., FSU, Tallahassee, Florida 32306, USA — [4]Phys. Dept., UC Irvine, California 92697, USA

Semimetallic EuB_6 shows a complex ferromagnetic order and a colossal magnetoresistance effect due to the interplay of magnetic, electronic and lattice degrees of freedom. EuB_6 may be viewed as a model system, where pure magnetism-tuned transport and the response of the crystal lattice can be studied in a comparatively simple environment, i.e., not influenced by strong crystal-electric field effects and Jahn-Teller distortions. We performed thermal expansion and magnetostriction measurements and find a large lattice response when the system enters the ferromagnetic region. Our analysis reveals that a significant part of these lattice effects - quantified by the large magnetic Grüneisen parameter and spontaneous strain when entering the ferromagnetic region - originates in the magnetically driven delocalization of charge carriers, consistent with the scenario of percolating magnetic polarons. A strong effect of the formation and dynamics of local magnetic clusters on the lattice parameters is suggested to be a general feature of colossal magnetoresistance materials [1].

[1] R. S. Manna *et al.*, PRL **113**, 067202 (2014)