TT 37: Transport: Nanoelectronics II - Spintronics and Magnetotransport

Time: Thursday 9:30–13:00 Location: HSZ 105

TT 37.1 Thu 9:30 HSZ 105

Anisotropic magnetoresistance in ferromagnetic atomic-sized metal contacts — •Michael Häfner[1,2], Janne Viljas[1,3], and Juan Carlos Cuevas[2] — [1]Institut für Theoretische Festkörperphysik, Universität Karlsruhe, D-76128 Karlsruhe — [2]Departamento de Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid, E-28049 Madrid — [3]FZ Karlsruhe, Institut für Nanotechnologie, D-76021 Karlsruhe

Recent experiments in ferromagnetic atomic-sized contacts have shown that the anisotropic magnetoresistance (AMR) is greatly enhanced and has an asymmetric angular dependence as compared with that of bulk samples. The origin of these effects is still under debate. In this work [1] we present a theoretical analysis of the AMR in atomic contacts of the 3d ferromagnetic materials. Our results strongly suggest that the anomalous AMR stems from the reduced symmetry of the atomic contact geometries. We also present calculations supporting the idea that the pronounced voltage- and temperature dependence in some experiments can be attributed to impurities near the constrictions.

[1] M. Häfner et al., arXiv:0811.4491.

TT 37.2 Thu 9:45 HSZ 105

Spin-Polarized Conductance in a Single Magnetic Atom? — •Cormac Toher and Gianaurelio Cuniberti — Institute for Materials Science and Max Bergmann Center of Biomaterials, Dresden University of Technology, D-01062 Dresden, Germany.

Single atom conductance measurements can be performed by forming nanocontacts using a scanning tunnelling microscope (STM). In the case of fully spin-polarized transport, a spin resolved conductance quantum of $0.5G_0 = \frac{e^2}{h}$ is expected, in contrast to the value of $G_0 = \frac{2e^2}{h}$ expected in normal atomic nanocontacts with one full spin degenerate open channel. A spin-resolved conductance has been observed in the experiments carried out by Néel *et. al.* [1] on cobalt atoms. When the cobalt atom is placed on a copper surface and contacted by a tungsten tip, a conductance of G_0 is observed, whereas when it is placed on a cobalt island and contacted by a nickel tip, a conductance of $0.5G_0$ is observed. Here we present the results of calculations to explore the mechanism underlying this effect, investigating whether or not spin-polarized transport is actually present. These calculations were performed using the ab initio transport method SMEAGOL [2], which combines the non-equilibrium Green function formalism with the DFT implementation SIESTA [3].

[1] N. Néel, J. Kröger, and R. Berndt, Phys. Rev. Lett. (submitted).
[2] A. R. Rocha *et. al.*, Phys. Rev. B **73**, 085414 (2006).
[3] J. M. Soler *et. al.*, J. Phys. Cond. Matter **14**, 2745 (2002).

TT 37.3 Thu 10:00 HSZ 105

Transport through an interacting quantum dot tunnel coupled to a ferromagnet with time-dependent magnetisation — •Nina Winkler, Michele Governale, and Jürgen König — Theoretische Physik · Universität Duisburg-Essen

We study adiabatic pumping through a system consisting of a quantum dot coupled to a normal and a ferromagnetic lead. Adiabatic pumping is typically studied in systems in which the properties of the scattering region are changed, e.g. gate voltages to vary the tunnel couplings and the level position of the quantum dot. Here, we consider a different pumping scheme. By changing slowly in time the lead properties, e.g. the magnetisation, we can generate a pumped DC current. To this aim, we generalise a diagrammatic real-time approach for adiabatic pumping through quantum dots with ferromagnetic leads [1, 2] to account for a time-dependent magnetisation.

We consider two different pumping situations: First, we choose the amplitude of the magnetisation of the ferromagnetic lead and the level position of the dot or the tunnel coupling to the normal lead as pumping parameters. Second, we pump by periodically changing the direction of the magnetisation. We investigate the adiabatic charge and spin transport through the system by performing a systematic perturbative expansion in powers of the tunnel-coupling strengths but treating the on-site Coulomb interaction on the quantum dot exactly.

[1] J. Splettstoesser *et al.*, Phys. Rev. B **74**, 085305 (2006).
[2] J. Splettstoesser *et al.*, Phys. Rev. B **77**, 195320 (2008).

TT 37.4 Thu 10:15 HSZ 105

Spin-Electric Coupling in Molecular Magnets — •Mircea Trif[1], Filippo Troiani[2], Dimitrije Stepanenko[1], and Daniel Loss[1] — [1]Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland — [2]CNR-INFM National Research Center S3 c/o Dipartimento di Fisica via G. Campi 213/A, 41100, Modena, Italy

We study the triangular antiferromagnet Cu3 in external electric fields, using symmetry group arguments and a Hubbard model approach. We identify a spin-electric coupling caused by an interplay between spin exchange, spin-orbit interaction, and the chirality of the underlying spin texture of the molecular magnet. This coupling allows for the electric control of the spin (qubit) states, e.g., by using an STM tip or a microwave cavity. We propose an experimental test for identifying molecular magnets exhibiting spin-electric effects.

TT 37.5 Thu 10:30 HSZ 105

Magnetic and transport properties of ferromagnet / semiconductor Heterostructures (Ga,Mn)As/GaAs — •S R Dunsiger[1], T Goko[2,3], J P Carlo[2], G Nieuwenhuys[4], T Prokscha[4], E Morenzoni[4], D Chiba[5], T Tanikawa[5], F Matsukura[5], H Ohno[5], R H Heffner[6], and Y J Uemura[2] — [1]Physik Dept E21, TU München, Garching, Germany — [2]Dept of Physics, Columbia University, New York, USA — [3]TRIUMF, Vancouver, Canada — [4]PSI, Villigen, Switzerland — [5]Laboratory for Nanoelectronics and Spintronics, RIEC, Tohoku University, Sendai, Japan — [6]LANL, Los Alamos, USA

Ferromagnet-Semiconductor heterostructures show immense promise for device applications, in particular in the injection of polarised spins into a semiconducting substrate. More fundamentally, the III-V semiconducting materials (Ga,Mn)As exhibit unusual long range indirect exchange interactions between Mn ions, where the Mn atoms simultaneously act as a magnetic species and charge donors. An intriguing link between the magnetic and transport properties is hence implied.

Low-energy μSR, in addition to magnetization and transport measurements on specimens with Mn concentrations between 1.0 and 3.4 % are reported. Ferromagnetism with a sharp onset temperature and nearly 100 % volume fraction is observed, at odds with debate over the rather inhomogeneous nature of the phase transitions. In addition, the semiconductor-to-metal transition and paramagnetic-to-ferromagnetic transitions occur at different Mn concentrations, while unusually, even a semiconducting film shows static ferromagnetism developing.

TT 37.6 Thu 10:45 HSZ 105

Anomalous Hall effect in granular ferromagnetic metals and effects of weak localization — •Hendrik Meier, Maxim Kharitonov, and Konstantin Efetov — Institut für Theoretische Physik III, Ruhr-Universität Bochum, D-44780 Bochum

We theoretically investigate the anomalous Hall effect in a system of dense-packed ferromagnetic grains in the metallic regime. Using the formalism recently developed for the conventional Hall effect in granular metals, we calculate the residual anomalous Hall conductivity σ_{xy} and resistivity ρ_{xy} and weak localization corrections to them for both skew-scattering and side-jump mechanisms. We find that, unlike for homogeneously disordered metals, the scaling relation between ρ_{xy} and the longitudinal resistivity ρ_{xx} does not hold. The weak localization corrections, however, are found to be in agreement with those for homogeneous metals.

TT 37.7 Thu 11:00 HSZ 105

Anisotropy of the intrinsic anomalous Hall effect in FePt, FePd and FeNi ordered alloys — •Yuriy Mokrousov[1,2], Eric Roman[1], and Ivo Souza[1] — [1]University of California at Berkeley, USA — [2]Institut für Festkörperforschung, Forschungszentrum Jülich, 52425 Jülich, Germany

We calculate from first principles the intrinsic anomalous Hall conductivity (AHC) of the layered $L1_0$ alloys FePt, FePd and FeNi. We find large intrinsic contributions (comparable to those of bulk Fe, Co, and Ni), in apparent disagreement with a recent experimental work (K.M. Seemann *et al.*, arXiv:0811.1258) which attributed the anomalous Hall effect in FePd and FePt entirely to skew-scattering from impurities. We propose that a clear signature of the intrinsic effect in these materials is its strong dependence on the orientation of the magnetization with respect to the uniaxial direction, while skew-scattering is expected to be largely isotropic. The calculated anisotropy has opposite signs for FePt (where the AHC is reduced by almost a factor of two as the magnetization direction is changed from the [001] to the [110] direction) and for FePd and FeNi, where instead it increases, but by a smaller amount. By selectively turning off the spin-orbit interaction on the Fe and X atoms (X=Pt,Pd,Ni), we investigate their individual contributions to the AHC.

15 min. break.

Invited Talk TT 37.8 Thu 11:30 HSZ 105

Quantum dissipative spin ratchets — •Milena Grifoni — University of Regensburg, Regensburg, Germany

Rather than fighting it, so-called quantum Brownian motors take advantage of thermal noise and quantum tunneling to move efficiently microscopic entities, as e.g. electrons, along predetermined directions. Here we focus on a particular class of quantum Brownian motors, i.e., quantum ratchets which, due to broken spatial symmetry, produce movement in one direction from a force that may be acting at random. We shall discuss, in particular, how the ratchet effect can be used to produce pure spin currents, i.e., a finite spin current and the absence of charge transport. To this extent we consider electrons moving in a quasi-one-dimensional asymmetric periodic structure with Rashba spin-orbit interaction, strong dissipation and subject to ac-driving. We show that under a finite coupling strength between the orbital degrees of freedom the electron dynamics at low temperatures exhibits a pure spin ratchet behaviour with in-plane polarization. Moreover, the equilibrium spin currents are not destroyed by the presence of strong dissipation.

TT 37.9 Thu 12:00 HSZ 105

Spin-orbit ratchet mechanism: correlation between dissipation and magnetic field effects — •Sergey Smirnov[1], Dario Bercioux[2], Milena Grifoni[1], and Klaus Richter[1] — [1]Institut für Theoretische Physik, Universität Regensburg, D-93040 Regensburg, Germany — [2]Physikalisches Institut and Freiburg Institute for Advanced Studies, Universität Freiburg, D-79104 Freiburg, Germany

We investigate ratchet-like behavior of electron spin transport in a periodic quasi-one-dimensional system with Rashba spin-orbit interaction [1]. The orbital longitudinal electron degree of freedom is coupled to orbital degrees of freedom of an external environment which is the source of dissipation. The spin ratchet effect appears when the periodic potential is asymmetric and the electron orbital degrees of freedom are coupled [2]. We additionally apply an in-plane magnetic field which is transverse to the transport direction. The magnetic field does not break the existence conditions of the spin ratchet effect. However, it has an impact on the spin current when the effect is present. Theoretically it is interesting that the magnetic field is correlated only with the friction part of the dissipation and not with the noise part [3]. What is important for applications is that in particular the magnetic field can both reduce and enhance the spin current, produce the spin current reversals and affect the dependence on the electric field driving.

[1] S. Smirnov, et al., EPL 80, 27003 (2007).
[2] S. Smirnov, et al., Phys. Rev. Lett. 100, 230601 (2008).
[3] S. Smirnov, et al., arXiv:0809.1296v1 (accepted in Physical Review B).

TT 37.10 Thu 12:15 HSZ 105

Universal Spin and Charge Fluctuations in Quantum Dots with Rashba Spin-Orbit Interaction — •Juan-Diego Urbina[1], Diego Espitia[1,2], Dominik Bauernfeind[1,3], and Klaus Richter[1] — [1]Universitaet Regensburg — [2]Universidad Pedagogica y Tecnologica de Colombia — [3]Harvard University

We present a novel approach to study spin and charge fluctuations in quantum dots subject to Rashba spin-orbit interaction. From the numerical side we present a spinorial implementation of the Plane Wave Decomposition Method (widely used in non-spin billiards) which allows us to efficiently construct eigenstates and energies of Rashba billiards. The method can be applied to dots with arbitrary shape and with spin-orbit interaction of any strength. With this technique we calculate exact spatial correlations for a dot with irregular shape. The results are then used to test the universal prediction given by a spinorial version of the celebrated Berry's ansatz presented here for the first time.

Our results fully support the claim that the spin-spin, charge-charge and spin-charge correlations in typical quantum dots with Rashba interaction are described by a spinorial Gaussian Random Field universally characterized by its two-point correlation matrix, which is presented in closed analytical form.

TT 37.11 Thu 12:30 HSZ 105

Effective spin-orbit coupling in a benzene interference SET — •Andrea Donarini, Georg Begemann, Dana Darau, and Milena Grifoni — University of Regensburg, Germany

Electronic transport through a benzene single electron transistor is dominated by the interplay between Coulomb interaction and interference between degenerate molecular states. The presence of spin polarized leads induces a novel spin accumulation effect explained in terms of an effective coupling between the orbital and spin degrees of freedom of the molecule.

TT 37.12 Thu 12:45 HSZ 105

Single electron transport in exchange-coupled spin systems — •Gerold Kiesslich, Clive Emary, and Tobias Brandes — Institut für Theoretische Physik, Technische Universität Berlin

We study a single electron transistor setup where the localized electron spin is exchange-coupled to another spin. We utilize a quantum master equation approach with the exact dynamics for the spin system in nonequilibrium and the coupling to the electronic reservoirs in Born-Markov-Secular approximation. We discuss the spin-resolved magnetotunneling properties (e..g electron counting statistics) and present a novel spin blockade effect.