TT 39: Transport: Nanoelectronics II - Spintronics and Magnetotransport

Time: Friday 10:15–13:00 Location: EB 202

Invited Talk TT 39.1 Fri 10:15 EB 202

EuO_{1-x} Epitaxially Integrated with Silicon — •Andreas Schmehl[1,2], Stefan Thiel[2], Christoph Richter[2], Ross Ulbricht[1], Tassilo Heeg[1], Marco Liberati[3], Martin Röckerath[4], Sebastian Mühlbauer[6], Peter Böni[6], Yuri Barash[5], Jürgen Schubert[4], Yves Idzerda[3], Jochen Mannhart[2], and Darrell G. Schlom[1] — [1]Pennsylvania State University, University Park, PA, USA — [2]Universität Augsburg, Augsburg — [3]Montana State University, Bozeman, MT, USA — [4]Forschungszentrum Jülich, Jülich — [5]Russian Academy of Sciences, Chernogolovka, Russia — [6]Technische Universität München, Garching

The ferromagnetic semiconductor EuO is well known for its outstanding magneto-transport and magneto-optical properties, but for decades its instability in air has prevented the thorough exploration of this exciting material. Exploiting oxide MBE and advanced capping techniques, we are now able to epitaxially integrate EuO with a multitude of substrates including silicon and GaN and pattern it using photolithography. Using Andreev reflection spectroscopy, we demonstrate that these films have spin-polarizations exceeding 90%, rendering EuO a very promising candidate to establish spin-selective ohmic contacts to silicon. A novel patterning process, combining *insitu* ion etching and sputtering, allows for the patterning of the films, paving the way to exploit EuO in semiconductor-based spintronic devices as well as in devices making use of its exceptional magneto-transport and magneto-optical properties.

TT 39.2 Fri 10:45 EB 202

Simultaneous ferromagnetic semiconductor-metal transition in Gd-doped EuO — •Michael Arnold and Johann Kroha — Physikalisches Institut, Universität Bonn

At room temperature, europium oxide, EuO, is a paramagnetic semiconductor with a large band gap of 1.2 eV which undergoes a ferromagnetic ordering transition at a Curie temperature of $T_C = 69$ K. Upon minute electron doping, this transition turns into a simultaneous ferromagnetic semiconductor-metal transition, with nearly 100 % of the conduction electrons polarized and a huge magnetoresistance effect. This has made EuO a prototypical material for possible spintronics applications.

Here we present a general framework for describing this phase transition in Gd-doped EuO. This system is described by a Heisenberg lattice of the Eu 4f moments S=7/2, a conduction band (which in the high-temperature phase is empty), and singly occupied impurity levels in the gap, provided by the Gd 5d orbitals. The theory correctly describes detailed experimental features of the conductivity and of the magnetization, in particular the enhancement of T_C by a minute Gd doping concentration. The existence of correlation-induced local moments on the impurity sites is essential for this description. We also predict that the ferromagnetic semiconductor-metal transition can be switched by applying a gate voltage to EuO films.

TT 39.3 Fri 11:00 EB 202

Effect of spin-orbit coupling on transport through ferromagnetic atomic-sized contacts — •Michael Häfner[1,2,3], Janne Viljas[1,2], and Juan Carlos Cuevas[3,1,2] — [1]Institut für Theoretische Festkörperphysik, Universität Karlsruhe, D-76128 Karlsruhe — [2]Institut für Nanotechnologie, FZ Karlsruhe, D-76021 Karlsruhe — [3]Departamento de Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid, E-28049 Madrid

Based on a tight-binding model we analyze the effect of spin-orbit coupling on the transport through ferromagnetic atomic-sized contacts. Our calculation shows a strong dependence of the conductance on the direction of magnetization. The results suggest that the anisotropic magnetoresistance found in recent experiments on transport through ferromagnetic atomic-sized contacts [1] stems from the spin-orbit coupling.

[1] K. Bolotin et al., Phys. Rev. Lett. **97**, 127202 (2006)

TT 39.4 Fri 11:15 EB 202

Spin transport across double quantum dots and carbon nanotubes — •S. Koller, R. P. Hornberger, G. Begemann, A. Donarini, and M. Grifoni — Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg

Spin polarized transport through nanostructures is a topic attracting increasing interest. Utilizing not only the charge, but also the electron's spin degree of freedom opens various potential applications in spintronics as well as in quantum computing. Among the promising candidates for future electronic devices are e.g. carbon nanotubes as well as semiconducting quantum dots. By employing the reduced density matrix technique, we have developed a quite general model for spin dependent transport across nanostructures weakly coupled to ferromagnetic electrodes with both collinear or non-collinear magnetization directions. The model can be applied e.g. to single or double quantum dots [1] as well as to carbon nanotubes. For the two latter systems, the low bias conductance as a function of gate voltage exhibits a characteristic repeating pattern of four peaks distinct in height, possessing certain mirror symmetries representing electron-hole-symmetries. For devices like spin valve transistors, the tunnelling magnetoresistance (TMR) is a decisive parameter. It is found that the TMR is heavily influenced by a Zeeman splitting of energy levels, which in fact is not only crucial for the occurence of negative TMR, but also found to break the electron hole-symmetries. Overmore, in the nonlinear bias regime, negative differential conductance arises for non-collinear polarizations.

[1] R. P. Hornberger et al., in preparation.

15 min. break

TT 39.5 Fri 11:45 EB 202

Adiabatic pumping through a quantum-dot spin valve — •Janine Splettstoesser[1], Michele Governale[2], and Jürgen König[2] — [1]Département de Physique Théorique, Université de Genève, Switzerland — [2]Institut für Theoretische Physik III, Ruhr-Universität Bochum, Germany

We investigate the adiabatically pumped current through a quantum-dot spin-valve setup, consisting of a quantum dot coupled to two differently polarized ferromagnetic leads (F-dot-F). We therefore resort to a real-time diagrammatic technique in the adiabatic limit, taking into account the Coulomb interaction on the dot exactly. On one hand we investigate the influence of the lead polarizations and of the on-site Coulomb interaction on the pumped charge. On the other hand we are interested in the influence of the pump mechanism on the average dot polarization during a pumping cycle. In the case where only one lead is ferromagnetic and the other one is a normal metal (F-dot-N), we extend our analysis to spin pumping, where we are in particular interested in the ratio between pumped spin and pumped charge.

TT 39.6 Fri 12:00 EB 202

Electrically driven spin dynamics in disordered electron systems — •Mathias Duckheim and Daniel Loss — Department of physics, University of Basel, CH-4056 Basel, Switzerland

A key principle of many spintronics applications is the coherent control of spins at the nanometer scale using electric fields. However, with no direct electrical coupling to the spin available, indirect mechanisms are necessary to achieve this task.

In this talk we discuss the possibility of coherent spin control using electric-dipole-induced spin resonance[1-4](EDSR) and the magneto-electrocal effect[5]. We investigate the spin polarization and the associated spin-Hall current due to EDSR and study the disorder-induced broadening of the resonance due to the D'yakonov-Perel mechanism, which limits the efficiency of EDSR[3] drastically. We show[4] that these limitations can be partially circumvented by exploiting the interference of different spin-orbit interaction mechanisms and give a phenomenological description of the spin dynamics that recovers the diagrammatic linear response calculation for a weak electric field but extends to the non-equilibrium situation of strong driving.

[1] R. L. Bell, Phys. Rev. Lett. **9**, 52 (1962).
[2]Y. K. Kato and R. C. Myers and A. C. Gossard and D. D. Awschalom, Nature **427**, 50 (2004).
[3] M. Duckheim and D. Loss, Nature Phys. **2**, 195 (2006).
[4] M. Duckheim and D. Loss, Phys. Rev. B **75**, 201305(R) (2007).
[5] V. M. Edelstein, Solid State Comm. **73**, 233 (1990).

TT 39.7 Fri 12:15 EB 202

Photon-assisted spin transport in a two-dimensional electron

gas: spin-polarized current and spin valve effect — •Mikhail Fistul[1] and Konstantin Efetov[1,2] — [1]Theoretische Physik III, Ruhr-Universität Bochum, Germany — [2]L. D. Landau Institute for Theoretical Physics, Moscow, Russia

We study spin-dependent transport in a two-dimensional electron gas subject to an external step-like potential $V(x)$ and irradiated by an electromagnetic field (EF). In the absence of EF the electronic spectrum splits into spin sub-bands originating from the "Rashba"spin-orbit coupling. We show that the resonant interaction of propagating electrons with the component EF parallel to the barrier induces a *non-equilibrium dynamic gap* $(2\Delta_R)$ between the spin sub-bands. Existence of this gap results in coherent spin-flip processes that lead to a spin-polarized current and a large magnetoresistance, i.e the spin valve effect. These effects may be used for controlling spin transport in semiconducting nanostructures, e.g. spin transistors, spin-blockade devices etc. , by variation of the intensity S and frequency ω of the external radiation.

TT 39.8 Fri 12:30 EB 202

Transport through Inhomogeneous Magnetization Textures - Domain-Wall Resistance — •Christian Wickles and Wolfgang Belzig — Universität Konstanz, Fachbereich Physik, 78457 Konstanz, Germany

We microscopically derive a transport equation for the conduction electrons in ferromagnetic materials with inhomogeneous magnetisation profiles featuring spin-flip scattering at magnetic impurities. In the diffusive limit, we calculate the conductance through a domain-wall and find that the domain-wall resistance can be positive or negative. In the limit of long walls we find analytical expressions which differ from previous works, which used less general models or different theoretical frameworks.

TT 39.9 Fri 12:45 EB 202

Extracting current-induced spins: spin boundary conditions at narrow Hall contacts — •Matthias Scheid[1], Inanc Adagideli[1], Michael Wimmer[1], Gerrit E. W. Bauer[2], and Klaus Richter[1] — [1]Universität Regensburg, Institut für theoretische Physik, 93040 Regensburg, Germany — [2]Kavli Institute of Nanoscience, TU Delft, Lorentzweg 1, 2628 Delft, The Netherlands

We consider the possibility to extract spins that are generated by an electric current in a disordered two-dimensional electron gas with Rashba/Dresselhaus spin orbit interaction (R2DEG) in the Hall geometry. In that respect we discuss boundary conditions for the spin accumulations between a spin orbit (SO) coupled region and a contact without SO coupling, i.e. a normal two-dimensional electron gas (2DEG). We demonstrate that in contrast to contacts that extend along the whole sample, a spin accumulation can diffuse into the normal region through finite contacts and be detected by e.g. ferromagnets. For an impedance-matched narrow contact the spin accumulation in the 2DEG is equal to the current induced spin accumulation in the bulk of R2DEG up to a geometry-dependent numerical factor.

[1] I. Adagideli, M. Scheid, M. Wimmer, G.E.W. Bauer, and K. Richter, New J. Phys. **9**, 382