HL 5: Spintronics: mainly interfaces and heterostructures

Time: Monday 9:30–11:45 Location: H16

HL 5.1 Mon 9:30 H16

Spin Transport and Spin Dephasing in ZnO — Matthias Althammer[1,2], Eva-Maria Karrer-Müller[1], Sebastian T. B. Goennenwein[1], •Matthias Opel[1], and Rudolf Gross[1,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]University of Alabama, Center for Materials for Information Technology MINT, Tuscaloosa, AL 35487 USA — [3]Physik-Department, TU München, 85748 Garching, Germany

The wide bandgap semiconductor ZnO is interesting for spintronic applications because of its small spin-orbit coupling implying a large spin coherence length. Utilizing vertical spin valve devices with ferromagnetic electrodes (TiN/Co/ZnO/Ni/Au), we create and detect a spin-polarized ensemble of electrons and demonstrate the transport of this spin information across several nanometers in ZnO [1]. The measured magnetoresistance of up to 8.4% at 2 K agrees well with the prediction of a two spin channel model with spin-dependent interface resistance [2]. Fitting the data yields spin diffusion lengths of 10.8 nm (2 K), 10.7 nm (10 K), and 6.2 nm (200 K) in ZnO, corresponding to spin lifetimes of 2.6 ns (2 K), 2.0 ns (10 K), and 31 ps (200 K) [1]. The evolution of the measured spin relaxation rates with temperature is consistent with the D'yakonov-Perel' mechanism above 30 K. For future semiconductor spintronic devices, such all-electrical experiments will be mandatory to extract the relevant spin transport parameters.

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[1] M. Althammer *et al.*, Appl. Phys. Lett. **101**, 082404 (2012).
[2] A. Fert and H. Jaffrès, Phys. Rev. B **64**, 184420 (2001).

HL 5.2 Mon 9:45 H16

Anisotropy at the Fe/GaAs(001) interface - resistance and AMR-effect — •Thomas Hupfauer[1], Alex Matos-Abiague[2], Bernhard Endres[1], Matthias Sperl[1], Georg Woltersdorf[1], Martin Utz[1], Dieter Schuh[1], Dominique Bougeard[1], Christian Back[1], Jaroslav Fabian[2], and Dieter Weiss[1] — [1]Institute of Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany — [2]Institute of Theoretical Physics, University of Regensburg, 93040 Regensburg, Germany

We investigate transport anisotropies at Fe/GaAs interfaces. These experiments were motivated by theoretical calculations derived from a spin-orbit-field model for the TAMR-effect [1,2] which was applied to the case of lateral transport. Samples with an epitaxially grown Fe-layer consisting of six monolayers were investigated. The measurements show an anisotropy of the conductance dependent on the crystallographic axes of the GaAs, featuring a maximum along the [110]-direction and a minimum in [1$\bar{1}$0]. Additionally the strength of the AMR-effect is also dependent on the crystallographic axes, showing maxima in both [110]- and [1$\bar{1}$0]-directions, with the maximum in [110] being somewhat larger. This behavior could be reproduced by the theoretical model. Financial support by DFG via SFB 689 is gratefully acknowledged.

[1] M. Wimmer, *et al.*, Phys. Rev. B **80**, 121301(R) (2009)
[2] J. Moser, *et al.*, Phys. Rev. Lett. **99**, 056601 (2007)

HL 5.3 Mon 10:00 H16

Anisotropic Thermal Transport Through Magnetic Tunnel Junctions — •Carlos López-Monís, Alex Matos-Abiague, and Jaroslav Fabian — Institute für Theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany

Tunneling anisotropic magnetoresistance (TAMR) has been observed in Fe/GaAs/Au tunneling heterostructures [1]. Theoretically, the two-fold symmetry observed in the TAMR was shown to be originated by the C_{2v} symmetry of the tunneling probability, resulting from the interference between Bychkov-Rashba and Dresselhaus spin-orbit interactions [2]. In this talk I shall discuss further extensions to this model in order to account for thermal spin transport phenomena in magnetic tunnel junctions in the presence of spin-orbit interaction. We acknowledge financial support from the DFG via No. SPP 1538.

[1] J. Moser, A. Matos-Abiague, D. Schuh, W. Wegscheider, J. Fabian and D. Weiss, Phys. Rev. Lett. **99**, 056601 (2007).
[2] A. Matos-Abiague and J. Fabian, Phys. Rev. B **79**, 155303 (2009).

HL 5.4 Mon 10:15 H16

Spin storage and readout in charge-tunable structures with InGaAs quantum dots — •Andreas Merz, Helge Wurst, Franziska Reiter, Arne Ludwig, Andreas Wieck, Michael Hetterich, and Heinz Kalt — KIT, Karlsruhe, Germany

To enable electron spin manipulation in semiconductor quantum dots (QDs), the control over the lifetime of the created excitonic species in the QD is indispensable. For Schottky diode-like structures this can be obtained with charge tuning via top and back contact. The applied voltage controls electron and hole tunneling rates, enabling carrier separation and subsequent storage of spin-polarized carriers in the microsecond regime [1]. This is a promising scenario for coherent microwave spin manipulation with optically detected magnetic resonance experiments to enable spin manipulation in QDs. Since the optical injection and readout of the spin states in these devices is well-controlled, this would enable the last but most important step towards an application of single QDs as spin memory devices. [1] Carrier storage and capture dynamics on quantum-dot heterostructures. J.M. Smith, P. A. Dalgarno, R.J. Warburton et al., Appl. Phys. Lett. 82, 21 (2003).

HL 5.5 Mon 10:30 H16

Hole spin coherence in coupled GaAs/AlAs quantum wells — •Christian Gradl, Michael Kugler, Dieter Schuh, Dominique Bougeard, Christian Schüller, and Tobias Korn — Universität Regensburg, D-93040 Regensburg, Germany

We perform time-resolved Kerr rotation, as well as resonant spin amplification measurements, on an undoped, [100]-grown GaAs/AlAs double quantum well (QW) structure to resolve the spin dynamics of hole ensembles at low temperatures. The gated system consists of two QWs with different well widths, which we use for the spatial separation of the optically excited electron-hole pairs.

Thus we are able to build up a hole spin polarization with a spin lifetime of several nanoseconds in the narrower QW. On the other hand, we observe a tunable behaviour in the broader QW, where the spin dynamics are dominated either by holes or by electrons, depending on the gate voltage.

A system like this might expand the recent, very successful investigations on hole spins in [100]-grown, p-doped GaAs/AlGaAs QWs to different growth directions or other materials like InGaAs, where the difficulty of proper p-type doping has limited detailed observations, so far.

HL 5.6 Mon 10:45 H16

Electric suppression of spin dephasing in GaAs (111) quantum wells — •Alberto Hernandez-Minguez, Klaus Biermann, Rudolph Hey, and Paulo V. Santos — Paul-Drude-Institut für Festkörperelektronik

Diakonov-Perel spin dephasing is a major mechanism limiting the electron spin lifetime in III-V zincblende quantum wells: electrons with different wavevector experience different effective magnetic fields associated to spin-orbit interaction (SOI). Their spins will then precess at different frequencies, thus leading to a reduction of the initial spin polarization of an electron ensemble. In this contribution, we demonstrate that this dephasing can be effectively suppressed in GaAs (111) quantum wells by applying an electric field. The suppression has been attributed to the compensation, for all electron wavevectors simultaneously, of the intrinsic SOI associated to the bulk inversion asymmetry (BIA) of the GaAs lattice by a structural induced asymmetry (SIA) SOI term induced by the electric field [1]. We provide direct experimental evidence for this mechanism by demonstrating the transition between the BIA-dominated to a SIA-dominated regime via photoluminescence measurements carried out over a wide range of applied fields in quantum wells embedded in a n-i-p structure. Spin lifetimes exceeding 100 ns are obtained near the compensating electric field [2], thus making GaAs (111) quantum wells excellent candidates for spin-based quantum information processing.

[1] X. Cartoixà *et al.*, Phys. Rev. B **71**, 045313 (2005).
[2] A. Hernández-Mínguez *et al.*, Phys. Rev. Lett., accepted.

HL 5.7 Mon 11:00 H16

Spin injection into semiconductor 2D systems — •Martin Oltscher, Mariusz Ciorga, Josef Loher, Dieter Schuh, Dominique Bougeard, and Dieter Weiss — Institute for Experimental and Applied Physics, University of Regensburg, Regensburg, Germany

Electrical generation and control of electron spins in semiconductor material is the central theme in semiconductor spintronics and of a big importance for device prospects. In particular spin injection into two-dimensional (2D) electron systems would allow for many new functionalities in future devices, with a Datta-Das Spin Field Effect Transistor [1] being a primary example. Building on successful realization of spin injection into bulk GaAs employing the diluted magnetic semiconductor (Ga,Mn)As as a ferromagnetic material [2] we extended our work into heterostructures containing 2D electron gases. We investigate two types of systems: an electron gas confined in an inverted AlGaAs/GaAs heterojunction and an InGaAs quantum well structure. We observe clear nonlocal spin-valve signals in both systems, however the origin of the high signal amplitude and its strong bias dependence for the high mobility AlGaAs/GaAs structure is still an open issue.

[1] S. Datta and B. Das, Appl. Phys. Lett. 56, 665 (1990)
[2] M . Ciorga et al., Phys. Rev. B 79, 165321 (2009)

HL 5.8 Mon 11:15 H16

Spin injection and spin relaxation: Magnetic field effects — •Henning Höpfner[1], Carola Fritsche[1], Arne Ludwig[2], Astrid Ludwig[2], Frank Stromberg[3], Heiko Wende[3], Werner Keune[3], Dirk Reuter[2], Andreas D. Wieck[2], Nils C. Gerhardt[1], and Martin R. Hofmann[1] — [1]Photonik und Terahertztechnologie, Ruhr-Universität Bochum, D-44780 Bochum — [2]Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum — [3]Fakultät für Physik und CENIDE, Universität Duisburg-Essen, D-47048 Duisburg

In the last two decades, intensive research in the field of spintronics has led to remarkable progress of spintronic devices. Particularly electrical spin injection into semiconductors has provided a challenge to researchers around the world.

In magnetic remanence spin polarization of up to 3% could be achieved in spin-LEDs, while using external fields values up to 32% have been reached. We show experimentally that external magnetic fields strongly suppress spin relaxation during transport from the injector to the active region (APL 101, 112402 (2012)). Consequently, results obtained for spin injection with and without magnetic fields can hardly be compared and the efficiency of spin-induced effects will be overestimated as long as magnetic fields are applied. Since strong magnetic fields are not acceptable in application settings, this leads to wrong conclusions and potentially impairs proper device development.

Nevertheless, our results show that spin injection in magnetic remanence is possible and may provide a viable path to overcome the challenges at hand.

HL 5.9 Mon 11:30 H16

Low Temperature Spin Relaxation Rate Anisotropy in (001) GaAs/AlGaAs Quantum Wells — •David English[1], Peter Eldridge[1], Richard Harley[2], Roland Winkler[3], Jens Hübner[1], and Michael Oestreich[1] — [1]Institute for Solid State Physics, Leibniz University Hannover, Appelstr. 2, 30167 Hannover, Germany — [2]School of Physics and Astronomy, University of Southampton, Southampton, SO17 1BJ, UK — [3]Department of Physics, Northern Illinois University, DeKalb, IL 60115, USA

We present measurements of the appearance of an unexpected spin relaxation rate anisotropy below a temperature of 80K in (001) GaAs/AlGaAs quantum wells with asymmetric barriers. We develop a theoretical model that reveals the origin of this anisotropy.

In general, in-plane anisotropy of the spin relaxation rate is produced by interference of the bulk inversion asymmetry (BIA) term in the spin-orbit field with the structural inversion asymmetry (SIA) term [1]. Quantum wells with asymmetric barrier growth lack an SIA term due to the isomorphous nature of the bands [2]. The new theoretical model accounts for the temperature dependent filling of k-space by the conduction electrons away from k = 0. By considering higher order k states we demonstrate that the relaxation rate can be anisotropic at low temperatures, requiring only a BIA term and an asymmetric conduction electron wavefunction.

[1] N. Averkiev and L. Golub, Physical Review B 60, 15582 (1999).
[2] P. Eldridge, et al. Physical Review B 82, 045317 (2010).