HL 23: Spin controlled transport II

Time: Tuesday 14:00–16:00 Location: H14

HL 23.1 Tue 14:00 H14

Electrical detection of donor Rabi flops — •Hans Huebl[1], Andre Stegner[1], Felix Hoehne[1], Christoph Boehme[2], Klaus Lips[3], Martin Stutzmann[1], and Martin Brandt[1] — [1]Walter Schottky Institut, Garching, Germany — [2]University of Utah, Salt Lake City, USA — [3]Hahn Meitner Institut, Berlin,Germany

Due to its potential compatibility with existing microelectronics, the proposal for a silicon based quantum computer by Kane is being pursued intensively. In this concept, the nuclear spins of single ^{31}P donors serve as qubits. Exchange coupling between donor-bound electrons, whose spins experience hyperfine interaction with their nuclei enables two and more qubit operations. An experimentally unsolved key issue is the readout of the ^{31}P quantum state. We demonstrate the measurement of the spin state of ^{31}P donor electrons in silicon and the observation of Rabi flops by purely electric means, carrying out pulsed electrically detected magnetic resonance experiments (pEDMR). Resonant microwave pulses are used to induce coherent manipulation of an ensemble of ^{31}P electron spins by electron spin resonance. The resulting change of spin-dependent charge-carrier recombination between the ^{31}P donor and paramagnetic localized states at the silicon surface is then detected by a transient photoconductivity measurement after the coherent excitation is turned off. The electron spin information is shown to be coupled through the hyperfine interaction to the phosphorus nucleus, suggesting that recombination-based readout of nuclear spins is feasible.

HL 23.2 Tue 14:15 H14

Fast polarization switching in room temperature Spin-VCSEL — •Stephan Hövel[1], Nils Gerhardt[1], Martin Hofmann[1], Fang-Yuh Lo[2], Dirk Reuter[2], and Andreas Wieck[2] — [1]Optoelectronic Devices and Materials, Ruhr-University Bochum, IC2/133, Universitätsstr. 150, 44780 Bochum, Germany — [2]Applied solid state physics, Ruhr-University Bochum, NB03/58, Universitätsstr. 150, 44780 Bochum, Germany

Spin controlled vertical-cavity surface-emitting lasers (VCSELs) are very promising devices for future spintronic applications, because of their ability to amplify electron spin information. We could show amplified polarization degrees by all optical test experiments in an InGaAs/GaAs-VCSEL at room temperature [1, 2]. Here we present time-resolved polarization measurements of the optically pumped VCSEL showing a fast switching behaviour on a ps timescale between opposite circular polarization states in a single laser pulse. The complex polarization dynamics do not depend on carrier density, spin polarization or excitation wavelength alone, but are additionally influenced by inhomogenities and strain of the sample structure. Understanding the polarization dynamics is therefore a key issue on the way to electrically pumped Spin-VCSELs. Taking the time-resolved polarization measurements into account, design considerations for a future electrically pumped Spin-VCSEL for both room temperature as well as highly modulated polarization switching will be discussed.

[1] S. Hövel et al., Electronics Letters 41, 251 [2] N. Gerhardt et al., Electronics Letters 42, 88

HL 23.3 Tue 14:30 H14

Bulk inversion and structure inversion asymmetry in (110) semiconductor quantum wells — •P. Olbrich[1], V. V. Belkov[1,2], D. Schuh[1], W. Wegscheider[1], W. Prettl[1], and S. D. Ganichev[1] — [1]Faculty of Physics, University of Regensburg, 93040, Regensburg, Germany — [2]A.F. Ioffe Physico-Technical Instituete, Russian Academy of Sciences, 194021 St. Petersburg, Russia

Quantum well structures prepared on (110)-oriented GaAs substrates are interesting for spintronics because of considerably longer spin relaxation times compared to (001)-oriented QWs. This is due to vanishing Rashba spin splitting in symmetrically grown (110)-oriented QWs. In asymmetric QWs the advantage of long spin relaxation times fades away. Here we demonstrate that the recently observed magneto-gyrotropic effect (MPGE) [1] provides a simple and direct access to symmetry properties of QWs. We show that excitation of symmetric (110)-oriented QWs with THz radiation results in the MPGE only for the magnetic field aligned parallel to growth direction while it vanishes for an in-plane magnetic field. For asymmetric QWs even the in-plane magnetic field causes an electric current whose strength increases with rising degree of asymmetry. Our measurements show that for (110)-grown QWs it is sufficient to have symmetrical doping from the both sides of QWs in order to exclude Rashba spin-splitting.

[1] S.D. Ganichev, V.V. Bel'kov, S.A. Tarasenko, S.N. Danilov, S. Giglberger, Ch. Hoffmann, E.L. Ivchenko, D. Weiss, W. Wegscheider, Ch. Gerl, D. Schuh, J. Stahl, J. De Boeck, G. Borghs, and W. Prettl, *Nature Physics* (London) **2**, 609 (2006).

HL 23.4 Tue 14:45 H14

Pure Spin Currents and Rashba Spin-Splitting in GaN Heterojunctions — •Wolfgang Weber[1], S. Seidl[1], L.E. Golub[2], S.N. Danilov[1], V.V. Belkov[1,2], W. Prettl[1], Z.D. Kvon[3], Hyun-Ick Cho[4], Jung-Hee Lee[4], and S.D. Ganichev[1] — [1]Faculty of Physics, University of Regensburg, Germany — [2]A.F. Ioffe Physico-Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia — [3]Institut of semiconductor physics, Novosibirsk, 630090 Russia — [4]Kyungpook National University, Korea

Gallium nitride is a potentially interesting material system for spintronics since it is expected to become ferromagnetic with a Curie-temperature above room temperature if doped with manganese and long spin relaxation times are detected in this material. Recently we observed that also a substantial Rashba spin-splitting in the electron band structure due to a large piezoelectric effect is present allowing spin manipulation by an electric field [1]. Here we report on the observation of a pure spin current in AlGaN/GaN heterostructures, an effect caused by the structural inversion asymmetry. It is achieved by spin-dependent scattering of electrons due a term in the scattering matrix elements linear in wavevector k. Experiments were carried out on hexagonal (0001)-oriented GaN heterostructures applying linear or circular polarized infrared and terahertz radiation. The effect has been detected in a wide range of temperatures from technologically important room temperature to 4.2 K.

[1] W. Weber, S.D. Ganichev et.al., Appl. Phys. Lett. **87**, 262106 (2005).

HL 23.5 Tue 15:00 H14

Spin-Orbit Coupling in AlGaN/GaN 2-Dimensional Electron Gases — •Sergio Cabañas, Nicolas Thillosen, Nicoleta Kaluza, Patrick Lehnen, Vitaliy Guzenko, Hilde Hardtdegen, and Thomas Schäpers — Institute of Bio- and Nanosystemes (IBN-1) and CNI Center of Nanoelectronic Systems for Information Technology, Research Centre Jülich, 52425 Jülich, Germany

AlGaN/GaN is a very promising material system for spin electronic devices, because for GaN-based diluted magnetic semiconductors Curie temperatures above room temperature have been predicted theoretically and confirmed experimentally. We have investigated weak antilocalization in AlGaN/GaN heterostructures. By fitting the experimental curves to a theoretical model we found that the decrease of the peak height in the conductivity with temperature is solely due to the decrease of the phase coherence length. Measurements on gated samples showed that the spin-orbit scattering length is constant for all carrier concentrations. This behavior is due to the fact that the spin-orbit scattering due to crystal inversion asymmetry is the dominant contribution. Although GaN is a large band gap material, the spin-orbit scattering length has a relatively small value of approximately 300 nm, which makes this material interesting for spin electron devices relying on spin precession. If a magnetic field is applied parallel to the plane of the 2-dimensional electron gas the weak antilocalization can be suppressed. We attribute the vanishing of the weak antilocalization peak to the additional contribution of the Zeeman energy competing with the characteristic spin-orbit energy.

HL 23.6 Tue 15:15 H14

Spin-orbit coupling in InGaSb-based two-dimensional electron gas — •Vitaliy Guzenko[1], Masashi Akabori[2], Thomas Schäpers[1], Sergio Cabañas[1], Taku Sato[2], Toshi-kazu Suzuki[2], and Syoji Yamada[2] — [1]Institute of Bio- and Nanosystems (IBN 1), Reserach Centre Jülich, 52425 Jülich, Germany — [2]Center for Nano-Materials and Technology (CNMT), Japan Advanced Institute of Science and Technology (JAIST), 1-1 Asahidai, Nomi, Ishikawa 923-1292, Japan

Two-dimensional electron gases (2DEG) formed in high-mobility

InGaSb-based heterostructures with high indium content are promising candidates for spintronic applications because of their strong spin-orbit coupling and large g-factor. To investigate these properties magnetoconductance measurements around zero magnetic field (localization measurements) as well as in strong magnetic fields (coincidence method) were performed. A pronounced enhancement of magnetoconductance at $B = 0$ T due to the weak antilocalization effect was observed, which is an unambiguous indication of the spin-orbit coupling in these samples. Experimental curves measured as a function of temperature could be fitted by a theoretical model [1], and a quantitative estimation of the characteristic scattering times was done. By the coincidence method g-factor as large as 31 could be determined. By applying an additional constant magnetic field in the plane of 2DEG a strong suppression of the weak antilocalization peak was achieved. This is a qualitative confirmation of the result of the coincidence measurements. [1] M.M.Glazov and L.E.Golub, Semicond. **40** (2006) 1209.

HL 23.7 Tue 15:30 H14

Digital magneto resistance in ferromagnetic resonant tunneling diodes — •Christian Ertler and Jaroslav Fabian — Institute of Theoretical Physics, University of Regensburg, Universitätsstrasse 31, D-93040 Regensburg, Germany

The development of ferromagnetic dilute magnetic semiconductors has paved the way for novel all semiconductor spintronic device concepts. For example, spin dependent resonant tunneling in magnetic double barrier heterostructures with either a ferromagnetic or a paramagnetic quantum well have already been investigated both experimentally and theoretically.

In this talk a novel spintronic device, which consists of two serial connected resonant tunneling diodes, is proposed. One diode is nonmagnetic whereas the other comprises a ferromagnetic emitter and quantum well. Using a selfconsistent coherent transport model we show that the current-voltage characteristic of the ferromagnetic diode can be strongly modulated by changing the relative orientation of the magnetizations in the emitter and quantum well, respectively. By a continuous change of the relative magnetization angle the total resistance exhibits a discrete jump realizing digital magneto resistance. The interplay between the emitter's Fermi energy level and the relative magnetization orientations allows to tailor the current voltage characteristics of the ferromagnetic diode from ohmic to negative differential resistance regime at low voltages. The proposed spintronic device might be useful for a very fast detection of magnetically stored information or magnetic random access memory applications.

HL 23.8 Tue 15:45 H14

Giant anisotropic magnetoresistance in ultrathin (Ga,Mn)As films — •R.R. Gareev, M. Döppe, M. Schlapps, J. Sadowski, M. Sperl, G. Bayreuther, W. Wegscheider, and D. Weiss — 1Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Universitätsstraße 31 D-93040 Regensburg

We report on the giant anisotropic magnetoresistance (GAMR) effect, which we observed in ultrathin (Ga,Mn)As films close to the metal-insulator transition (MIT). We prepared 5nm-thick $Ga_{0.95}Mn_{0.05}As$ films ontop (Al,Ga)As buffer layer followed by subsequent annealing. Finally, for films with optimized carrier-mediated ferromagnetism and a well-defined MIT we obtained the Curie temperature $Tc \approx 90K$ and hole concentration $p \approx 4 * 10^{20} cm^{-3}$. We studied magneto-transport properties using Hall bars for different orientations of magnetic field H and both longitudinal Rxx and transverse Rxy components of resistance. We found that below MIT ($T < 20K$) both Rxx and Rxy components become comparable. Moreover, both components show enhanced magnetization-regulated magnetoresistance, which we relate to delocalization of carriers dependent on orientations of magnetization and current. In the planar geometry of H both Rxx and Rxy demonstrate reproducible multi-step switching patterns, which are symmetric to the direction of H. In the planar geometry of H the AMR is enhanced and exceeds 100