HL 29: Poster Session: Spintronics; Spin-controled transport; Topological insulators; Interfaces / Surfaces; Magnetic semiconductors

Presenters are kindly asked to be near their posters at least 17:00–18:00 or to leave a note at the poster indicating a time period of availability for discussions. — Beverages will be served starting at 18:00.

Time: Monday 16:00–20:00 Location: Poster A

HL 29.1 Mon 16:00 Poster A

Spin noise spectroscopy at ultra low temperatures — •Jan Gerrit Lonnemann, Jens Hübner, and Michael Oestreich — Institute for Solid State Physics, Leibniz Universität Hannover, Appelstr. 2, D-30167 Hannover, Germany

In recent years the all optical method of semiconductor spin noise spectroscopy (SNS) has proven to be a powerful tool to investigate spin dependent processes in semiconductors [1]. Especially at low temperatures most optical methods obscure the real spin dynamics due to carrier heating and excitation. SNS on the other hand utilizes off-resonant Faraday rotation for probing the intrinsic spin fluctuations at thermal equilibrium.

Consequently SNS is ideally suited to analyze systems at ultra low temperatures due to its perturbation free nature. We present measurements performed at temperatures as low as 100 mK. At these very low temperatures we try to gain access to spin physics obscured otherwise like for example quantum phase transitions, magnetic ordering, or highly localized states. The investigated GaAs sample is doped slightly below the metal-to-insulator transition [2] and shows localization of the donor electrons especially below 1 K. We observe a strong negative shift of the electron g-factor with increasing temperature while in the same sample the opposite dependence is observed above 10 K, where the donors are delocalized. The intrinsic spin lifetime of the weakly localized electrons is measured to be well above 300 ns.

[1] G.M. Müller, *et al.*, *Physica E* **43**, 569 (2010).
[2] M. Römer, *et al.*, *Phys. Rev. B* **81**, 075216 (2010).

HL 29.2 Mon 16:00 Poster A

Spin Noise Spectroscopy at Single Photon Intensities — •Julia Wiegand[1], Ramin Dahbashi[1], Xavier Marie[2], Klaus Pierz[3], Hans Werner Schumacher[3], Jens Hübner[1], and Michael Oestreich[1] — [1]Insitute for Solid State Physics, Leibniz Universität Hannover, Appelstr. 2, D-30167 Hannover, Germany — [2]Université de Toulouse, INSA, UPS, CNRS; LPCNO, 135 avenue de Rangueil, F-31077 Toulouse, France — [3]Physikalisch Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig, Germany

Spin noise spectroscopy is capable of performing quantum non-demolition measurements of spin dynamics by off-resonant optical probing [1]. However, recent reports on heavy-hole spin dephasing in self-assembled (InGa)As quantum dots (QDs) show a non-negligible influence of the probe beam intensity on the dephasing time. This is due to residual light absorption disturbing the equilibrium [2].
A Hanbury Brown and Twiss type detection setup is implemented for single QD photoluminescence detection. This setup is further modified in order to enable Faraday fluctuation measurements by single photon counting which, in principle, provides access to the truly undisturbed spin dynamics by preventing light absorption.

[1] Müller *et al.*, Semiconductor spin noise spectroscopy: Fundamentals, accomplishments, and challenges, Physica E **43**, 569 (2011).
[2] Dahbashi *et al.*, Measurement of heavy-hole spin dephasing in (InGa)As quantum dots, Appl. Phys. Lett. **100**, 031906 (2012).

HL 29.3 Mon 16:00 Poster A

First Steps towards Spin Noise Spectroscopy in Sillicon — •André Grieger, Jan Gerrit Lonnemann, Jens Hübner, and Michael Oestreich — Insitute for Solid State Physics, Leibniz Universität Hannover, Appelstr. 2, D-30167 Hannover, Germany

Semiconductor spin noise spectroscopy (SNS) has evolved as a powerful experimental technique to explore spin dynamics in close vicinity to thermal equilibrium [1]. Not beeing masked by optical excitations SNS is a very verstile technique that uses off resonant Faraday rotation and consequently avoids carrier heating and optical excitation.

SNS has already been utilized to analyse the spin dynamics of conduction electrons in GaAs [2]. Recent measurements have been performed on highly n-doped ($10^{17} cm^{-3}$) bulk GaAs at a temperature of 20 K in dependence on the applied magnetic field (0-8T) with integration times below 5 minutes [3]. We are extending SNS to silicon which is doped well above the metal isolator transition. The theoretical calculations of the selection rules in silicon are difficult due to the indirect band gap of sillicon where transitions between valence and conduction band are phonon-assisted processes [4]. The expected long integration times require a very stable experimental setup. Thus steps taken towards such a long-term stable system will be presented.

[1] Georg M. Müller et al.; *Physica E*, **43**, 569 (2010).
[2] M. Römer et al., *Rev. Sci. Instrum.*, **78**, 103903 (2007).
[3] F. Berski et al., *arXiv*, 1207.0081 (2012).
[4] J.L. Cheng et al., *Phys. Rev. B*, **83**, 165211 (2011).

HL 29.4 Mon 16:00 Poster A

Spin Noise Spectroscopy - towards solid-state entanglement — •Agnes Beichert[1], Fabian Berski[1], Andreas D. Wieck[2], Jens Hübner[1], and Michael Oestreich[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstr. 2, D-30167 Hannover, Germany — [2]Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstr. 150, D-44780 Bochum, Germany

In the context of quantum information processing dopants in semiconductor hosts are attractive candidates for providing a sufficient number of indistinguishable pure states on a nanoscale level [1]. Entanglement can be used to build up a non-local interaction between these states.

First, spin noise spectroscopy (SNS) is applied as a quantum non-demolition measurement to determine the temporal limit for coherent manipulation of the system state. Therefore, the spin dynamics of localised donor bound electron spins in GaAs is examined. The experiment shows spin dephasing dominated by hyperfine coupling [2].

Next, we want to expand the experiment to create entanglement between a solid state spin ensemble. Subsequently, we plan to use density matrix tomography to verify the prepared state [3].

[1] K.-M. C. Fu et al., *Millisecond spin-flip times of donor-bound electrons in GaAs*, Phys. Rev. B **74**, 121304(R) (2006).
[2] G. M. Müller et al., *Semiconductor spin noise spectroscopy: Fundamentals, accomplishments, and challenges*, Physica E **43**, 569 (2010).
[3] S. Simmons et al., *Entanglement in a solid-state spin ensemble*, Nature **470**, 69 (2011).

HL 29.5 Mon 16:00 Poster A

Anomalous spin diffusion in high-mobility (110) GaAs-based quantum wells — •Markus Schwemmer[1], Roland Voelkl[1], Tobias Korn[1], Michael Griesbeck[1], Sergey Tarasenko[2], Dieter Schuh[1], Werner Wegscheider[3], and Christian Schueller[1] — [1]Institute of Experimental and Applied Physics Faculty of Physics, University of Regensburg, Germany — [2]A. F. Ioffe Physical-Technical Institute, Russian Academy of Sciences, St. Petersburg, Russia — [3]ETH Zurich, Switzerland

We have performed spin diffusion measurements in high-mobility two-dimensional electron systems embedded in a symmetrical GaAs/AlGaAs quantum well grown in [110] direction. For mapping the diffusion of spin-polarized electrons in the sample and to determine the corresponding spin lifetimes, we use a two-beam Hanle-MOKE method. The spin diffusion was studied by moving the pump beam with respect to the probe beam using a motorized mirror. With this technique we could observe diffusion lengths as high as 50 μm for low temperatures. The diffusion length was constant over a wide temperature range (4 - 40 K). Due to a reduced influence of the photogenerated holes, a maximum of the net spin polarization is observed at a distance of a few μm away from the pump spot. Additionally, we manipulated the resident electron density by above-barrier-illumination and investigated its effect on the diffusion length. Financial support by the DFG via SFB 689 and SPP 1285 is gratefully acknowledged.

HL 29.6 Mon 16:00 Poster A

Spin dynamics in high-mobility two-dimensional electron systems embedded in GaAs/AlGaAs quantum wells — •M. Griesbeck[1], M. Glazov[2], E. Sherman[3], T. Korn[1], D. Schuh[1],

W. Wegscheider[4], and C. Schüller[1] — [1]Department of physics, Regensburg university, Germany — [2]Ioffe Physical-Technical Institute, St. Petersburg, Russia — [3]Department of Physical Chemistry, University of the Basque Country, Bilbao, Spain — [4]ETH Zürich, Switzerland

Advances in the technology of GaAs/AlGaAs based heterostructures allow for the design of high quality and well-defined two-dimensional electron systems (2DES), which are perfectly suited for the study of the underlying physics that govern the dynamics of the electron spin system. In this work, spin dynamics in high-mobility 2DES is studied by means of the all-optical time-resolved Kerr/Faraday rotation technique. In (001)-grown 2DES, an in-plane spin dephasing anisotropy is studied, resulting from the interference of comparable Rashba and Dresselhaus contributions to the spin-orbit field (SOF). The dependence of this anisotropy on the confinement length of the 2DES, the sample temperature and the carrier density is demonstrated. Moreover, coherent spin dynamics of an ensemble of ballistically moving electrons is studied within a weak magnetic field applied perpendicular to the sample plane, which forces the electrons to move on cyclotron orbits. Finally, anisotropic spin dynamics is investigated in symmetric (110)-grown 2DES, using the resonant spin amplification method. In such systems, very long out-of-plane spin dephasing times can be achieved, in consequence of the special symmetry of the Dresselhaus SOF.

HL 29.7 Mon 16:00 Poster A

Magnetometry on spin-orbit effects in InGaAs/InP quantum wells — •Ayman Ibrahim[1], Florian Herzog[1], Benedikt Rupprecht[1], Marc Wilde[1], Thomas Schäpers[2], Hilde Hartdegen[2], Sebastian Heedt[2], Christian Heyn[3], and Dirk Grundler[1] — [1]Physik.-Dep. E10, TU München, D-85748 Garching — [2]Peter Grünberg Institute (PGI-9), FZ Jülich, D-52425 Jülich — [3]Institute of Applied Physics, University of Hamburg, D-20355 Hamburg

Spin-orbit coupling provokes beating patterns in both magnetic field dependent resistance (MR) and magnetization (MAG) measurements performed on a two-dimensional electron system (2DES) at low temperature. Recently, we have found an unexpected frequency shift and phase anomaly in the quantum oscillations when comparing separately conducted MR and MAG experiments. To understand the anomaly in detail, we aim at performing both experiments simultaneously on one-and-the-same 2DES. For this, we prepare a micromechanical torque magnetometer with integrated electrical contacts and mount the 2DES using a conductive bonding technique. We report our latest results. Financial support by the DFG via GR1640/3 in SPP 1285 "Semiconductor Spintronics" and NIM is gratefully acknowledged.

HL 29.8 Mon 16:00 Poster A

Full cancellation of the Spin-Orbit field in (110) GaAs/AlGaAs Quantum Wells via the application of strain — •Arthur Varkentin[1], David English[1], Richard Harley[2], 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

We present measurements of the spin relaxation rate Γ^s in (110) GaAs/AlGaAs quantum wells (QW). QW grown parallel to the (110) axis offer the unique opportunity to completely suppress the usually dominant Dyakonov-Perel (DP) spin relaxation mechanism via the application of strain [1]. The DP mechanism occurs because the electrons sense a momentum dependent spin-orbit field that is randomised due to the thermal motion of the electrons [2]. The bulk contribution to the spin orbit field for (110) QW is aligned along the growth axis z. This results in the suppression of DP for electron spin populations initially aligned parallel to z [3]. The exciting property of (110) QW is that the strain contribution to the spin-orbit field is also aligned parallel to z [1]. The application of strain can potentially cancel all spin-orbit fields and thus completely suppress DP spin relaxation for all orientations of electron spins.

[1] S.-W. Chang & S.-L. Chuang, Phys. Rev. B, **72** (2005).
[2] M. I. Dyakonov & V. I. Perel, Sov. Phys. Sol. St., **13**, 3023 (1972).
[3] Y. Ohno *et al.* & H. Ohno, Phys. Rev. Lett., **83**, 4196 (1999).

HL 29.9 Mon 16:00 Poster A

Charge and spin dynamics in quantum wells under surface acoustic waves — •Johannes Wanner, Cosimo Gorini, Peter Schwab, and Ulrich Eckern — Institute of Physics, University of Augsburg, 86135 Augsburg, Germany

Various recent experiments have shown the flexibility of surface acoustic waves as a mean for transporting charge and spin in quantum wells [1]. In particular, they have proven highly effective for the coherent transport of spin-polarized wave packets, suggesting their potential in spintronics applications. Motivated by these experimental observations we have theoretically studied the spin and charge dynamics in a quantum well under surface acoustic waves. Based on previous work by some of us [2], we show that the dynamics acquires a simple and transparent form in a reference frame co-moving with the surface acoustic wave. A number of experimentally observed features can thus be explained.

[1] J. A. H. Stotz et al., Nat. Mat. **4**, 585 (2005); H. Sanada et al., Phys. Rev. Lett. **106**, 216602 (2011)
[2] P. Schwab et al., Phys. Rev. B **74**, 155316 (2006)

HL 29.10 Mon 16:00 Poster A

Magnetic-Field Contol of Photon Echo from the Electron-Trion System in a CdTe Quantum Well: Shuffling Coherence between Optically Accessible and Inaccessible States — •Lukas Langer[1], Sergey V. Poltavtsev[1,2], Irina A. Yugova[1,2], Dmitri R. Yakovlev[1,3], Grzegorz Karczewski[4], Tomasz Wojtowicz[4], Jacek Kossut[4], Ilya A. Akimov[1,3], and Manfred Bayer[1] — [1]Experimentelle Physik 2, Technische Universität Dortmund, 44221 Dortmund, Germany — [2]Spin Optics Laboratory, St. Petersburg State University, 198504 St. Petersburg, Russia — [3]A.F. Ioffe Physical-Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia — [4]Institute of Physics, Polish Academy of Sciences, PL-02668 Warsaw, Poland

We report on magnetic field-induced oscillations of the photon echo signal from negatively charged excitons in a CdTe/(Cd,Mg)Te semiconductor quantum well. The oscillatory signal is due to Larmor precession of the electron spin about a transverse magnetic field and depends sensitively on the polarization configuration of the exciting and refocusing pulses. The echo amplitude can be fully tuned from the maximum down to zero depending on the time delay between the two pulses and the strength of the magnetic field. The results are explained in terms of the optical Bloch equations accounting for the spin level structure of electrons and trions.

HL 29.11 Mon 16:00 Poster A

Spin Dynamics of Heavy-Holes in (InGa)As Quantum Dots — •Ramin Dahbashi[1], Julia Wiegand[1], Xavier Marie[2], Klaus Pierz[3], Hans Werner Schumacher[3], Jens Hübner[1], and Michael Oestreich[1] — [1]Insitute for Solid State Physics, Leibniz Universität Hannover, Appelstr. 2, D-30167 Hannover, Germany — [2]Université de Toulouse, INSA, UPS, CNRS; LPCNO, 135 avenue de Rangueil, F-31077 Toulouse, France — [3]Physikalisch Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig, Germany

The spin dynamics of heavy-holes confined in (InGa)As quantum dots (QDs) are of particular interest for future applications in solid state quantum information processing. We employ spin noise spectroscopy as a quantum non-demolition experiment to get access to the intrinsic spin dynamics [1]. The spin noise method is transferred from ensembles of QDs [2] to single dot heavy-hole measurements. Numerical simulations show an extremely long spin dephasing time if light absorption is negligible [2]. The investigated QDs are characterized by polarization resolved photoluminescence measurements and via a Hanbury Brown-Twiss setup. The discharging of the QDs via Auger recombination due to residual light absorption is deactivated by copumping the dots with low intensity light.

[1] Müller *et al.*, Semiconductor spin noise spectroscopy: Fundamentals, accomplishments, and challenges, Physica E **43**, 569 (2011).
[2] Dahbashi *et al.*, Measurement of heavy-hole spin dephasing in (InGa)As quantum dots, Appl. Phys. Lett. **100**, 031906 (2012).

HL 29.12 Mon 16:00 Poster A

Optical spin polarization of donor electrons through donor bound exciton states in ZnO — Sebastian Kuhlen[1], •Ralph Ledesch[1], Christoph Schwark[1], Vera Klinke[1], Christian Weier[1], Gernot Güntherodt[1], Matthias Althammer[2], Sebastian T. B. Gönnenwein[2], Matthias Opel[2], Rudolf Gross[2], Thomas Wassner[3], Martin S. Brandt[3], and Bernd Beschoten[1] — [1]II. Physikalisches Institut A, RWTH Aachen University, Aachen — [2]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching — [3]Walther Schottky Institut, Technische Universität

München, Garching

ZnO exhibits a large variety of natural dopants, which present a promising playground for coherent spintronics as each donor type presents an individual spin state with different spin lifetimes and Landé factors. Furthermore, long spin dephasing times as high as 20 ns have been observed. We demonstrate that the electrons can be polarized by optical pumping and detected using the Faraday effect in a standard pump-probe experiment. We furthermore observe that the polarization mechanism is most effective when the pump photon energy matches one of various donor bound exciton state energies, while the spin dephasing time exceeds the exciton lifetime by several orders of magnitude. Hence we conclude that electron spins are polarized by optical selection rules during the transition to the exciton state, but are eventually transferred to the donor electron of the impurity to which the exciton has been bound.
Work supported by DFG through SPP 1285.

HL 29.13 Mon 16:00 Poster A

Spin manipulation in spin light-emitting diodes: electron spin resonance in the ZnMnSe spin aligner — •Franziska Reiter, Andreas Merz, Robert Schittny, Benjamin Wolter, Daniel Rülke, Heinz Kalt, and Michael Hetterich — KIT, Karlsruhe, Germany

We investigate the possibility to perform electron spin resonance experiments within a spin-injection light-emitting diode. The latter contains a ZnMnSe spin aligner for spin injection into single optically active InGaAs quantum dots with a spin polarization degree of up to 100% [1]. For the manipulation experiments, a specially prepared spin light-emitting diode is placed in a microwave cavity and is exposed to microwave pulses with different powers and frequencies. At 53 GHz we observe the resonance of the manganese ions in the ZnMnSe spin aligner at 2 T via optically detected magnetic resonance in the photo luminescence signal. Furthermore, this influence is optimized towards coherent manipulation of spin states and spin injection into single quantum dots. This method could pave the way towards future spin manipulation experiments in such semiconductor structures.

[1] W. Löffler et al., Appl. Phys. Lett. 90, 232105 (2007).

HL 29.14 Mon 16:00 Poster A

A novel metastable spin triplet in diamond — •Matthias Widmann[1], Sang-Yun Lee[1], Helmut Fedder[1], Torsten Rendler[1], Moritz Eyer[1], Sen Yang[1], Petr Siyushev[1], Marcus Doherty[2], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, University Stuttgart, Germany — [2]Laser Physics Center, National University, Canberra, Australia

The poster introduces a newly found, photo stable single spin center in a HTHP diamond nano-pillar. This new defect poses many properties, similar to those of the well-known NV-center in diamond. However, optically detected magnetic resonance showed positive contrast at room temperature in contrast to NV-centers. The photo physics and spin physics of this new defect have been studied to understand the enhancement of photon emission (contrast up to 45 %) at three different electron spin resonance frequencies. It will be shown that the defect contains a singlet ground-, and excited state, and a metastable spin 1 triplet state which act as a shelving state. The strong enhancement of photon emission by ESR can be attributed to the huge difference in the deshelving rates of each triplet states. It will be also shown that the coherent spin manipulation of the metastable triplet state is possible at room temperature. Even though the electron spin coherence time is limited by the life time of the triplet state (up to 2.5 μs), these findings suggest that the electron spin in this spin system can be used to read-out the coupled nuclear spin state because the nuclear spin can be protected during the initialization and storage processes thanks to the spin-less electron ground state.

HL 29.15 Mon 16:00 Poster A

Inverse spin Hall effect in p-GaAs nanostructures — •Markus Ehlert[1], Thomas Hupfauer[1], Cheng Song[1,2], Martin Utz[1], Dominique Bougeard[1], and Dieter Weiss[1] — [1]Institute of Experimental and Applied Physics, University of Regensburg, D-93040 Regensburg, Germany — [2]Laboratory of Advanced Materials, Department of Material Science & Engineering, Tsinghua University, Beijing 100084, China

We performed experiments with “H-geometry” structures in lightly doped *p*-GaAs (4×10^{16} cm^{-3}), which allow for inverse spin Hall effect (ISHE) measurements without using ferromagnetic contacts [1]. A current is driven in the first branch of the “H” to create a spin current via direct spin Hall effect, which then leads to a charge accumulation in the adjacent branch of the “H” due to ISHE. External magnetic field, either *in-plane* or *out-of-plane*, is applied to induce spin precession and modulate the resulting signal. From analysis we mainly identify classical transport mechanisms being responsible for detected large ISHE-like signal, as previously reported [2]. A small underlying contribution is presumably related to thermally induced effects, due to the small width of our conduction channels (300 nm), and cannot be unambiguously attributed to ISHE. This work was supported by DFG SPP1285.

[1] E. M. Hankiewicz *et al.*, Phys. Rev. B **70**, 241301(R) (2004).
[2] G. Mihajlović *et al.*, Phys. Rev. Lett. **103**, 166601 (2009).

HL 29.16 Mon 16:00 Poster A

Modification of spin dynamics in ion-implanted wurtzite semiconductors — •Jago Döntgen[1], Jan Heye Buss[1], Jörg Rudolph[1], Stepan Shvarkov[2], Andreas D. Wieck[2], and Daniel Hägele[1] — [1]AG Spektroskopie der kondensierten Materie, Ruhr-Universität Bochum, Germany — [2]Angewandte Festkörperphysik, Ruhr-Universität Bochum, Germany

The wide-gap wurtzite semiconductors GaN and ZnO possess high potential for opto-electronics as well as high-frequency and high-power electronics. Their spin-related properties are in the focus of intense research originally motivated by theoretical predictions of ferromagnetism above room-temperature in rare-earth- or transition-metal-doped material [1]. We use time-resolved Kerr-Rotation spectroscopy to investigate electron spin oscillations in a magnetic field after implantation of GaN with Gadolinium and coimplantation with Si. We find strongly increased spin lifetimes for moderate Gd-implantation doses and a transition to isotropic spin relaxation from the anisotropic case known from unimplanted GaN [2]. The increased spin lifetimes in combination with the disappearance of anisotropy is a fingerprint of localized defect-states caused by implantation with Gd. An enhanced alignment of electron spins along the magnetic field by Gd could not be observed.

[1] T. Dietl *et al.*, Science **287**, 1019 (2000)
[2] J. H. Buss *et al.*, Appl. Phys. Lett. **95**, 192107 (2009)

HL 29.17 Mon 16:00 Poster A

The topological insulator HgTe - grown on GaAs substrates — •Philipp Leubner, Christopher Ames, Maximilian Kessel, Hartmut Buhmann, and Laurens Molenkamp — Phys. Inst. (EP III), Univ. Würzburg, D-97074 Würzburg, Germany

In the past few years MBE-grown HgCdTe/HgTe heterostructures have revealed to be suitable systems to study the magnetotransport properties of both two-dimensional topological insulators [1] with spin polarized edge channels [2] and just recently of three-dimensional topological insulators [3].

In this work we present the successful change of substrate material. So far, growth has been carried out on either CdTe or CdZnTe, with both systems being limited with respect to wafer size and pricing. By growing a ZnTe/CdTe heterostructure on GaAs substrates, we were able to prepare a high-quality <001> CdTe surface, as revealed by RHEED, AFM and HRXRD measurements. The subsequently grown HgCdTe/HgTe quantum-well systems showed carrier mobilities comparable to such grown on commercial CdTe substrates.

The new material system allows not only a much higher yield in working wafer size per growth run, but offers also new possibilities with respect to backgating, doping and lattice-matching and avoids the problematic wet-etching needed to prepare CdTe and CdZnTe prior to growth.

[1] König et. al., Science 318 766 (2007)
[2] Brüne et. al., Nature Phys. 8 485 (2012)
[3] Brüne et. al., Phys .Rev. Lett. 106 126803 (2011)

HL 29.18 Mon 16:00 Poster A

MBE - growth of capped, strained HgTe, a 3D topological insulator — •Christopher Ames, Philipp Leubner, Christoph Brüne, Hartmut Buhmann, and Laurens Molenkamp — Universität Würzburg, D-97074 Würzburg, Germany

The discovery of two (2D) [1] and three dimensional (3D) [2] topological insulator (TI) behavior in HgTe - systems opens a large field for studying magneto transport properties of both.

We grow HgTe as a 3D topological insulator by molecular beam epitaxy. Unstrained bulk HgTe is a semimetal but opens a gap of roughly 22 meV when grown fully strained on <001> CdTe substrate due to 0.3 % lattice mismatch and shows magnetotransport properties of a 3D TI. Hall measurements show electron mobilities of around 50.000 cm^2(V s)^-1. To increase electron mobilities, various growth optimizations have been carried out. Firstly we grew an HgCdTe buffer layer between the substrate and bulk HgTe. Different buffer thicknesses were analyzed ex-situ by HRXRD, AFM and standard Hall measurements. Secondly, we added a cap-layer of HgCdTe on top of the bulk HgTe. Doing so, we were able to raise the electron mobility of the bulk HgTe up to one order of magnitude. Time-dependent XPS measurements allowed us to hold the suppressed oxidization of the surface responsible for this effect.

Through the advanced material quality we have now more prospects for better understanding of the transport properties in strained HgTe.

[1] König et. al., Science 318 766 (2007)
[2] C. Brüne et. al., Phys. Rev. Lett. 106 126803 (2011)

HL 29.19 Mon 16:00 Poster A

Growth of High-Mobility Bi_2Te_2Se Nanoplatelets on hBN Sheets by van der Waals Epitaxy — •Pascal Gehring[1], Bo Gao[1], Marko Burghard[1], and Klaus Kern[1,2] — [1]Max Planck Institute for Solid State Research, Heisenbergstrasse 1, D-70569 Stuttgart, Germany — [2]Institute de Physique de la Matière Condensée, Ecole Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland

The electrical detection of the surface states of topological insulators is strongly impeded by the interference of bulk conduction, which commonly arises due to pronounced doping associated with the formation of lattice defects. As exemplified by the topological insulator Bi_2Te_2Se, we show that via van der Waals epitaxial growth on thin hBN substrates the structural quality of such nanoplatelets can be substantially improved. The surface state carrier mobility of nanoplatelets on hBN is increased by a factor of about 3 compared to platelets on conventional Si/SiO_x substrates, which enables the observation of well-developed Shubnikov-de Haas oscillations. We furthermore demonstrate the possibility to effectively tune the Fermi level position in the films with the aid of a back gate.

HL 29.20 Mon 16:00 Poster A

Synthesis of topological insulators at the nanoscale — •Christian Nowka[1], Silke Hampel[1], Udo Steiner[2], Lars Giebeler[1], Jochen Geck[1], Jorge E. Hamann Borrero[1], Sandeep M. Gorantla[1], Andreas Teichgräber[1], Romain Giraud[1], Joseph Dufouleur[1], and Bernd Büchner[1] — [1]Institute of Solid State Research - IFW Leibniz institute, Helmholtzstr. 20, D-01069 Dresden — [2]Hochschule für Technik und Wirtschaft Dresden, Friedrich-List-Platz 1, D-01069 Dresden

In this work we investigated the growth of Bi_2Se_3 topological insulator by gasphase transports. The obtained crystals have been characterized by SEM, TEM, AFM, EDX and XRD. To understand the growth mechanisms we performed thermodynamic modelling with the program Tragmin. The experimental growth of Bi_2Se_3 has been simply done by decomposition sublimation. By synthesis of Bi_2Se_3-layers thin ($\approx$ 10 nm), singlecrystalline crystals was deposited on the Si/SiO_2–substrate. For instance nanoribbons with a crystal size in a, b–direction between 3–40 μm and up to 70 μm for nanowires. The manganese-doped Bi_2Se_3 crystals were grown by chemical transport reaction. For this purpose powder of Mn/Bi/Se with different Mn content and Iodine as a transport agent was used. Several experiments showed the possibility of a gasphase transport of Mn/Bi/Se-powder with a high Mn content in a gradient $\triangle T < 100\ K$. In this case, crystals of $MnBi_2Se_4$ was deposited on the Si/SiO_2–substrate.

HL 29.21 Mon 16:00 Poster A

Group theoretical and topological analysis of the band structure of silicene — •Florian Geissler[1], Jan Carl Budich[2], and Björn Trauzettel[1] — [1]Institute for Theoretical Physics and Astrophysics, University of Würzburg, 97074 Würzburg, Germany — [2]Department of Physics, Stockholm University, Se-106 91 Stockholm, Sweden

Silicene is a monolayer of silicon atoms in a buckled honeycomb structure. It was recently shown, that a perpendicular electric field is able to couple to the sublattice pseudospin, allowing to electrically tune and close the band gap. Increasing electric fields may therefore generate a topological phase transition from a topological insulator to a normal insulator or semimetal. We perform a group theoretical analysis to systematically construct the Hamiltonian at the K-points of silicene by symmetries only. We discuss, that when further lowest-order terms are respected, the parameter space exhibiting a topological insulator phase is reduced. This is analyzed by an explicit calculation of the topological invariant of the underlying bandstructure.

HL 29.22 Mon 16:00 Poster A

Surface modification of ZnO bulk single crystals in vacuum — •Lennart Fricke[1], Tammo Böntgen[1], Jan Lorbeer[2], Jörg Lenzner[1], Rüdiger Schmidt-Grund[1], and Marius Grundmann[1] — [1]Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig — [2]Leibniz-Institut für Oberflächenmodifizierung e.V., Permoserstr. 15, 04318 Leipzig

We discuss the modification of the surface of ZnO bulk single crystals under different environmental conditions. For that purpose, in-situ and ex-situ spectroscopic ellipsometry (SE) have been applied to get access to thin surface layers and the bulk as well as the surface near dielectric function. Ambient Atomic force microscopy (AFM) and scanning electron microscopy (SEM) have been used ex-situ to characterize the surface morphology and the electrical properties of the surface.

Commercial ZnO single crystals where pre-treated to exhibit atomically flat terraces with unit cell step heights. During exposition to low pressure conditions between 1 mbar and 10^{-2} mbar for 2 hours, a considerable change in the SE data was observed, revealing a irreversible change in the optical thickness of the surface near region of the samples. Applying lower pressure ($< 10^{-3}$ mbar) or nitrogen atmosphere, no change in the optical response was detected. In all cases, no distinct change in the surface morphology or AFM phase contrast have been observed. The change of SE data can be explained by adsorption or a structural rearrangement, that is hindered by the presence of adsorbates or surface water in atmospheric air, both leading to a change in the electronic configuration of the surface.

HL 29.23 Mon 16:00 Poster A

In situ observation of monolayer removal on Si(100) in H_2 ambient — •Sebastian Brückner[1,2], Peter Kleinschmidt[3], Oliver Supplie[2], Henning Döscher[1,2], and Thomas Hannappel[2,3] — [1]Helmholtz-Zentrum Berlin, Institut für Solare Brennstoffe — [2]TU Ilmenau, Institut für Physik, Fachgebiet Photovoltaik — [3]CiS Forschungsinstitut für Mikrosensorik und Photovoltaik, Erfurt

Step formation is crucial for subsequent heteroepitaxial growth of III-V semiconductors on Si(100). Single-layer steps on Si(100) are associated with the presence of two domains with different dimer orientations on the reconstructed surface, leading to the initiation of anti-phase domains (APDs) in the epitaxial III-V layer. Therefore, double-layer steps are required to prevent APD formation.

Here, we used reflection anisotropy spectroscopy (RAS) to study the preparation of Si(100) surfaces during chemical vapor deposition (CVD) processing. Interaction between H_2 process gas and Si(100) surface strongly influences the surface structure. Oscillations in the RAS signal during annealing in H_2 ambient indicate alternating formation of preferential A- and B-type domains on Si(100) due to Si removal. Based on scanning tunneling microscopy measurements we conclude that formation and anisotropic expansion of vacancies on the terraces induces a layer-by-layer removal mechanism. In situ RAS enables precise control of Si removal and domain formation on Si(100) surfaces.

HL 29.24 Mon 16:00 Poster A

Electronic Properties of Si/ZnO Interfaces by ab initio Quasiparticle Calculations — •Benjamin Höffling and Friedhelm Bechstedt — Institut für Festkörpertheorie und -optik and European Theoretical Spectroscopy Facility (ETSF), Friedrich-Schiller-Universität, Max-Wien-Platz 1, 07743 Jena, Germany

Transparent Conducting Oxides like ZnO are routinely used in Si-based photovoltaics. However, key electronic properties are still controversially discussed in the literature. Modern ab-initio simulations can help to address this problem.

The applicability of these methods rests on the construction of realistic atomic models for such systems. Modeling interfaces between materials with different crystal structures, bonding mechanisms and chemical character within the repeated-slab supercell method is a particularly difficult challenge.

We develop a method for the construction of atomic models of heterostructural interfaces based on coincidence lattices, maximum bond saturation, and total energy minimization, which enables us to construct model geometries for the interface between diamond structure

Si and wurtzite-ZnO. In particular we investigate the Si(001)/ZnO(20-23) by means of density functional theory (DFT). We predict electronic properties of the interfaces using both DFT and modern quasiparticle theory based on semilocal exchange-correlation functionals. We examine band discontinuities and interface states. The influence of dangling bond passivation, strain, and charge transfer is studied by their respective influence on the electronic density of states.

HL 29.25 Mon 16:00 Poster A

Milli-Kelvin transport experiments on GaAs/(Ga,Mn)As core-shell nanowires — •Christian Butschkow[1], Elisabeth Reiger[1], Andreas Rudolph[1], Stefan Geissler[1], Dieter Schuh[1], Werner Wegscheider[2], and Dieter Weiss[1] — [1]Institute for Experimental and Applied Physics, University of Regensburg, D-93040 Regensburg, Germany — [2]ETH Zürich, 8093 Zürich, Switzerland

We performed transport measurements on ferromagnetic GaAs/-(Ga,Mn)As core-shell nanowires at temperatures T<1K. These nanowires were grown in a bottom-up process using molecular beam epitaxy and the Vapor-Liquid-Solid technique. The nanowires show a length of up to 4.5μm at a diameter of ∼100nm and a shell thickness of ∼30nm. For T<200mK we observe a pronounced localization of charge carriers resulting in an increase of the resistance by two orders of magnitude. This localization can be suppressed by applying a finite bias voltage or an external magnetic field. Additionally we observe conductance oscillations as a function of the magnetic field. The oscillations are observable for T<900mK, with increasing amplitude at lower temperatures. Considering previous investigations on (Ga,Mn)As nanostructures, fabricated lithographically from bulk material, it is likely that our observations can be ascribed to phase coherent transport effects. It was shown on lithographically defined nanowires of similar dimensions as the core-shell nanowires, that weak antilocalization like features as well as universal conductance fluctuations are observable [1].

[1] D. Neumaier et al. New Journal of Physics 10, 055016 (2008).

HL 29.26 Mon 16:00 Poster A

Anisotropic Magnetotransport in Mn doped, p-type InAs quantum wires — •Sabine Weishäupl[1], Ursula Wurstbauer[2], Werner Wegscheider[3], and Dieter Weiss[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, D-93040 Regensburg — [2]Department of Physics, Columbia University, New York, USA — [3]Solid State Physics Laboratory, ETH Zurich, Zurich, Switzerland

The ratio of Rashba and Dresselhaus spin-orbit interaction strengths, α and β, can be deduced by measuring the conductance of narrow wires, where the weak antilocalization correction to the conductance is switched off. The in-plane magnetic field direction where the conductance displays a minimum is related directly to the ratio α/β [1].

Motivated by this proposal we have measured the conductance of quantum wires (widths w=150 nm, w=200 nm) in Mn doped, p-type InAs quantum wells as a function of magnetic field, topgate voltage and manganese concentration.

In the out-of-plane configuration, a strong localization in the low field regime is present. At higher fields the localization is lifted and Shubnikov-de-Haas oscillations start to appear. In the in-plane magnetic field, the wires feature an anisotropy which can be tuned by gate voltage, magnetic field strength and temperature.

We compare these samples with similar ones that have lower manganese concentration. With these, weak antilocalization is observed.

[1] M. Scheid et al., Phys. Rev. Lett. 101, 266401 (2008)

HL 29.27 Mon 16:00 Poster A

Anomalous Hall effect under the influcence of a metal-insulator transition in Mn doped InAs quantum wells — •Dieter Vogel, Christina Wensauer, Ursula Wurstbauer, Dieter Schuh, Werner Wegscheider, and Dieter Weiss — Institute for Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany

We report on magnetotransport studies in InAs:Mn quantum wells (QW), containing a two dimensional hole gas, which reveal a considerable anomalous Hall effect (AHE) in coexistence with a magnetic field driven insulator-to-metal transition. Earlier experimental and theoretical studies made clear that there are at least three different regimes for the behavior of AHE as a function of σ_{xx}[1]:(i) high conductivity regime (ii) good-metal regime (iii) bad-metal hoping regime. In our case a transition from $\sigma_{xy}^{(AH)} \propto \sigma_{xx}^{1.6}$ for the insulating regime to a good-metal regime, in which $\sigma_{xy}^{(AH)}$ is roughly independent of σ_{xx}, is observed. The scaling relation in the low-conductivity region is consistent with a recently developed theory of the anomalous Hall effect in the insulation regime [2]. Finally, we discuss the possibility to separate the intrinsic and the extrinsic scattering contribution in the good-metal regime following recent work by [3].

[1] N.Nagaosa et. al., Rev. Mod Phys. 82, 1539 (2010)
[2] X. Liu et. al., Phys. Rev. B 84, 165304 (2011)
[3] A. Shitade and N. Nagaosa, ArXiv ID 1109.5463 (2012)

HL 29.28 Mon 16:00 Poster A

Optical third-harmonic spectroscopy of the magnetic semiconductors EuSe and EuTe — •Marco Lafrentz[1], David Brunne[1], Benjamin Kaminski[1], Victor V. Pavlov[2], Andre B. Henriques[3], Roman V. Pisarev[2], Dmitri R. Yakovlev[1], and Manfred Bayer[1] — [1]Technische Universität Dortmund — [2]A. F. Ioffe Physical-Technical Institute — [3]Instituto de Física, Universidade de São Paulo

EuX (X=O, S, Se, and Te) are magnetic semiconductors possessing the centrosymmetric crystal structure $m3m$ of rock-salt type in which the second-harmonic generation is forbidden in the electric dipole approximation but the third-harmonic generation (THG) is allowed. We studied the THG spectra of EuSe and EuTe near the band gap at $2.1-2.6$ eV and at higher energies up to 4 eV. The observed signals are attributed to four-photon THG processes involving specific combinations of electronic transitions between the $4f^7$ ground state at the top of the valence band and the excited $4f^6 5d^1$ states of the Eu^{2+}-ions forming the lowest conduction bands. Strong modifications of the THG intensity were observed in applied magnetic fields up to 10 T revealing the magnetic phases to play the leading role. Temperature, magnetic field, and rotational anisotropy measurements allow us to unambiguously separate the crystallographic and magnetic-field-induced contributions. In addition, we developed a microscopic quantum-mechanical model that is in good agreement with the experimental results.[1,2]

[1] M. Lafrentz, *et al.*, Phys. Rev. B **82**, 235206 (2010).
[2] M. Lafrentz, *et al.*, Phys. Rev. B **85**, 035206 (2012).