HL 63: III-V Semiconductors

Time: Friday 10:15–13:00 Location: H13

HL 63.1 Fri 10:15 H13

Theoretical Description of optical properties in III-V Semiconductor Nanostructures — •Marc Landmann, Eva Rauls, and Wolf Gero Schmidt — Universität Paderborn

We present a density functional theory (DFT) study of the electronical and optical properties of GaAs and AlAs bulk and AlAs/GaAs superlattices. Thereby, we emphasize that the DFT calculation of band offsets already yields results in quantitative agreement with the experiment. For a general description of optical properties (e.g. band structure and optical absorption) we outline the limitations of a pure independent particle (DFT) description and contrast these results with data obtained from the many body pertubation theory based independent quasiparticle approximation (GWA) and Coulomb-correlated quasiparticle approximation (BSE). [1]

[1] W. G. Schmidt et al., PRB 67, 085307 (2003)

HL 63.2 Fri 10:30 H13

Band structure and effective mass calculations for III-V compound semiconductors using hybrid functionals and optimized local potentials — •Yoon-Suk Kim, Martijn Marsman, and Georg Kresse — Faculty of Physics, University of Vienna, Austria

The band structures of III-V semiconductors (InP, InAs, InSb, GaAs, and GaSb) are calculated using the HSE06 hybrid functional, GW, and local potentials optimized for the description of band gaps. We show that the inclusion of a quarter of the exact HF exchange allows to predict accurate direct band gaps for InP, InAs, and InSb, i.e., 1.48, 0.42, 0.28 eV,[1] in good agreement with recent experiments, i.e., 1.42, 0.42, 0.24 eV,[2] respectively. The calculated effective masses and Luttinger parameters are also in reasonable agreement with experiment, although a tendency towards underestimation is observed with increasing anion mass. In order to find more efficient methods than hybrid functionals, the modified Becke-Johnson exchange potential[3] is also employed to calculate the effective masses. The agreement of the effective masses with experiment is comparable to the one obtained with the HSE06 hybrid functional. Therefore, this opens a way to model band structures of much large systems than possible using hybrid functionals.

[1] Y.-S. Kim, K. Hummer, and G. Kresse, Phys. Rev. B **80**, 35203 (2009).

[2] I. Vurgaftman, J.R. Meyer, and L.R. Ram-Mohan, J. Appl. Phys. **89**, 5815 (2001).

[3] F. Tran and P. Blaha, Phys. Rev. Lett. **102**, 226401 (2009).

HL 63.3 Fri 10:45 H13

Damping processes on coherent zero field spin oscillations in high mobility, two-dimensional electron systems — •Michael Griesbeck[1], Mikhail Glazov[2], Tobias Korn[1], Dominik Waller[1], Dieter Schuh[1], Werner Wegscheider[1], and Christian Schüller[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, D-93040 Regensburg, Germany — [2]A. F. Ioffe Physical-Technical Institute, Russian Academy of Sciences, 194021 St. Peterburg, Russia

We present time-resolved studies of two-dimensional electron systems with high mobility, where at low temperatures the weak-scattering regime of the D'yakonov-Perel spin relaxation mechanism is accessible. Using the all-optical time-resolved Faraday rotation technique, coherent oscillations of the optically-excited spin ensemble about the intrinsic spin-orbit field are observable. The lifetimes of these oscillations are limited by scattering mechanisms, which change the electrons k vector or an anisotropy of the k-dependent effective spin-orbit field. By investigating samples with different mobilities of 1.5 million cm^2/Vs and 15 million cm^2/Vs, temperature dependent measurements showed that in the lower mobility sample the momentum scattering time τ_p limits the lifetime of the zero field oscillations, whereas in the sample with the ultra high mobility the limiting processes are electron-electron scattering events. Lowering the excitation density led to a lower temperature of the electron system and due to increasing e-e-scattering times to an increasing lifetime of the observed spin beats.

HL 63.4 Fri 11:00 H13

Optically detected cyclotron-resonance in $GaAs/Al_{0.3}Ga_{0.7}As$ heterojunction — •Claudia Zens[1], G. Bartsch[1], B.M. Ashkinadze[2], D.R. Yakovlev[1], and M. Bayer[1] — [1]Experimentelle Physik II, Technische Universität Dortmund, 44227 Dortmund, Germany — [2]Solid State Institute, Technion-Israel Institute of Technology, Haifa 3200, Israel

We study the effective electron mass of a high mobility two-dimensional electron gas in a $GaAs/Al_{0.3}Ga_{0.7}As$ heterojunction. The effective mass is measured by changes in the photoluminescence, induced by far infrared radiation (FIR) under conditions of the electron cyclotron resonance. Additional illumination above the $Al_{0.3}Ga_{0.7}As$ barrier band gap allows flexible control of the carrier concentration, which was tuned in the range from 0.5 to $2{\cdot}10^{11}cm^{-2}$ in the very same sample. We have found a systematic increase of the electron effective mass with growing carrier concentration, and for higher FIR photon energies. Both trends are in qualitative agreement with the behavior expected due to conduction band nonparabolicity.

HL 63.5 Fri 11:15 H13

Engineering ultralong spin coherence in 2D hole systems at sub-Kelvin temperatures — •Kugler Michael, Korn Tobias, Griesbeck Michael, Schulz Robert, Hirmer Marika, Schuh Dieter, Wegscheider Werner, and Schüller Christian — Institut für Experimentelle und Angewandte Physik, Universität Regensburg

For the realisation of scalable solid-state quantum-bit systems, spins in semiconductor quantum dots are promising candidates. A key requirement is a sufficiently long coherence time of the spin system. Recently, hole spins in III-V-based quantum dots were discussed as alternatives to electron spins, since the hole spin is not affected by contact hyperfine interaction with the nuclear spins.

Here, we report a breakthrough in the spin coherence times of hole ensembles, confined in so called natural quantum dots, in narrow GaAs/AlGaAs quantum wells at sub-Kelvin temperatures. Consistently, time-resolved Faraday rotation and resonant spin amplification techniques deliver hole-spin coherence times, which approach in the low magnetic field limit values above 70 ns. The optical initialisation of the hole spin polarisation, as well as the interconnected electron and hole spin dynamics in our samples are well reproduced using a rate equation model [1].

Furthermore, electric control of the hole g factor could be achieved via application of a gate voltage, resulting in a shift of more than 50 % in the value of the g factor [2].

[1] Korn et al., cond-mat0909.3711v2, submitted.

[2] M. Kugler et al., Phys. Rev. B 80, 035325 (2009).

15 Min. Coffee Break

HL 63.6 Fri 11:45 H13

Carbon doped GaAs/AlGaAs heterostructures with high mobility two dimensional hole gas — •Marika Hirmer[1], Dieter Schuh[1], and Werner Wegscheider[1,2] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, D 93040 Regensburg, Germany — [2]present address Laboratorium für Festkörperphysik, ETH Zürich, Schafmattstr. 16, 8093 Zürich, Switzerland

Two dimensional hole gases (2DHG) with high carrier mobilities are required for both fundamental research and possible future ultrafast devices.

Here, two different types of GaAs/AlGaAs heterostructures hosting a 2DHG were investigated. The first structure is a GaAs QW embedded in AlGaAs barrier grown by molecular beam epitaxy with carbon-doping only at one side of the QW (single side doped, ssd), while the second structure is similar but with symmetrically arranged doping layers on both sides of the QW (double side doped, dsd).

The ssd-structure shows mobilities up to $1.2 * 10^6 cm^2/Vs$ which are achieved only after illumination, while the dsd-structure hosts a 2DHG with mobility up to $1.6 * 10^6 cm^2/Vs$. In addition, mobility and density is not affected by illuminating this sample. Both samples showed distinct Shubnikov-de-Haas oscillations in magnetotransport experiments done at 350mK, indicating the high quality of the material. Further, the influence of different temperature profiles during growth and the influence of the Al content of the barrier $Al_xGa_{1-x}As$ on carrier concentration and mobility were investigated.

HL 63.7 Fri 12:00 H13

Ferromagnetic and transport properties of very thin (Ga,Mn)As layers — •Lars Ebel, Stefan Mark, Michael Freitag, Tsvetelina Naydenova, Charles Gould, Karl Brunner, and Laurens W. Molenkamp — Physikalisches Institut (EP III), Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

We have fabricated by low-temperature molecular beam epitaxy series of typically 4nm thin (Ga,Mn)As layers with homogeneous or parabolically graded Manganese content on un-GaAs(001). The average Mn content was varied between 2 and 10%. The samples have been studied by RHEED, SQUID, room- and low-temperature magneto-transport measurements. The results as well as self consistent model calculations by "nextnano" show a strong influence of hole compensation and band bending caused by LT-GaAs and surface defects. Thin layers with graded Mn content reveal better conductivity and higher Curie temperatures (up to about Tc=71K, as-grown) compared to homogeneous layers. Thus, such layer with moderate hole density but well-controlled transport and ferromagnetic behavior may be used for novel spintronic devices with large tunability by a gate voltage.

HL 63.8 Fri 12:15 H13

Quantitative analysis of III-V on Si(100) anti-phase domains — •Henning Döscher[1], Benjamin Borkenhagen[2], Peter Kleinschmidt[1], Sebastian Brückner[1], Anja Dobrich[1], Oliver Supplie[1], Gerhard Lilienkamp[2], Ulrike Bloeck[1], Winfried Daum[2], and Thomas Hannappel[1] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie, Hahn-Meitner-Platz 1, 14109 Berlin — [2]IEPT, TU Clausthal, Leibnizstr. 4, 38678 Clausthal-Zellerfeld

GaP growth on Si(100) is considered as an important model system for polar on non-polar epitaxy required for the combination of opto- and microelectronic devices. Anti-phase disorder according to the step structure of the substrate surface prior to III-V deposition has been identified as a major challenge. Destructive techniques such as anisotropic etching or adequate post growth annealing can highlight anti-phase boundaries (APBs) as height contrast. Transmission electron microscopy (TEM) is able to visualize APBs in high resolution images and even anti-phase domains (APDs) directly, if proper dark field imaging conditions are applied.

The influence of anti-phase disorder on surface reconstructions enables alternative concepts for direct APD investigation with non-destructive surface sensitive instruments: Reflectance anisotropy spectroscopy (RAS) integrates over large surface areas (cm scale) and provides a quantitative in situ access to the APD content of a sample. Low-energy electron microscopy (LEEM) allows the lateral resolution of APDs in GaP/Si(100) samples via dark field imaging with related higher order diffraction spots from the surface.

HL 63.9 Fri 12:30 H13

Identification of the character of ferromagnetic Mn in Epitaxial Fe/GaMnAs heterostructures by XMCD and XRMS measurements — •Marcello Soda[1], Francesco Maccherozzi[2], Matthias Sperl[1], Dieter Schuh[1], Günther Bayreuther[1], Werner Wegscheider[1,4], Giancarlo Panaccione[3], and Christian Back[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg, Deutschland — [2]Soleil Synchrotron, L'Orme des Merisiers Saint-Aubin, BP 48, F- 91192 Gif-sur-Yvette , France — [3]Laboratorio Nazionale TASC, INFM-CNR, in Area Science Park, S.S. 14, Km 163.5, I-34012, Trieste, Italy — [4]Laboratorium für Festkörperphysik, Schafmattstr. 16, 8093 Zürich, Switzerland

We demonstrate that the growth of Fe/(Ga,Mn)As heterointerfaces can be efficiently controlled by epitaxy, and that robust ferromagnetism of the interfacial Mn atoms is induced at room temperature by the proximity effect. X-ray magnetic circular dichroism and X-ray resonant reflectivity data, supported by theoretical calculations, were used to monitor both the temperature and the magnetic field dependence of the Mn magnetic moment in the semiconducting host. We identify distinct Mn populations, each of them with specific magnetic character.

HL 63.10 Fri 12:45 H13

GHz Spin Noise Spectroscopy in n-Doped Bulk GaAs — •Georg Müller, Michael Römer, Jens Hübner, and Michael Oestreich — Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover, Germany

We advance spin noise spectroscopy (SNS) to GHz frequencies in order to resolve high frequency spin dynamics in n-doped bulk GaAs [1]. SNS relies on the statistical imbalance of electron spins in thermodynamical equilibrium, which is detected by below band gap Faraday rotation. Hence, SNS is an ideal experimental tool to deliver intrinsic spin lifetimes. In the past, these advantages could not be exploited to full extend since the bandwidth of the detection system ($\lesssim 1$ GHz) has capped SNS to slow spin dynamics at relatively low frequencies. In the advanced experimental method of GHz SNS, ps laser pulses are utilized as probe light. The spin dynamics in the sample at the Larmor frequency is sampled by the repetition rate of the laser such that spin noise at frequencies above 10 GHz can be detected without any loss of sensitivity. With this new measurement technique at hand, we study the magnetic field dependence up to 3 T of the electron Landé-g-factor g^* and the spin dephasing time T_2^* of two n-doped bulk GaAs samples at and above the metal-to-insulator transition (MIT). Our findings reveal in conjecture with high aperture SNS, which allows depth resolved SNS measurements, that the observed inhomogeneous broadening of the spin dephasing rate at the MIT originates from a local g-factor variation in the sample due to surface electron depletion.

[1] G. M. Müller *et al.*, arXiv:0909.3406 (2009).