HL 28: Poster Session: Graphen; Transport properties; Transport in high magnetic fields / Quantum Hall effect; Metal-semiconductor hybrid systems

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 28.1 Mon 16:00 Poster A

Fabrication and characterization of free-standing graphene — •Dominique Schüpfer, Katharina Huhn, Torsten Henning, and Peter J. Klar — I. Physikalisches Institut, JLU, Heinrich-Buff-Ring 16, 35392 Gießen

Up to now no simple method for characterizing graphene without the influence of its supporting material has been established. We demonstrate a simple alternative for fabricating free-standing graphene using SU-8 resist as a supporting structure. The SU-8 resist is microstructured via photolithography to prepare hollow cylinders inside the SU-8 layer. In a next step graphene can be deposited on top of this structure by mechanical exfoliation of graphite, which creates free-standing graphene on top of the hollow cylinders. Raman measurements of these graphene monolayers will be discussed aswell as the fabrication of this very suitable supporting structure.

HL 28.2 Mon 16:00 Poster A

Preparation of folded graphene layers via atomic force microscope — •Johannes C. Rode, Dmitri Smirnov, Christopher Belke, Hennrik Schmidt, and Rolf J. Haug — Institut für Festkörperphysik, Leibniz Universität Hannover, D-30167 Hannover, Germany

Naturally occurring double-layer graphene consists of two hexagonal lattices in Bernal stacking. We investigate the folding of single-layer graphene via atomic force microscope (AFM) and the properties of thusly created bilayers. The crystal lattices of these are often twisted against each other and form decoupled systems which hold interesting electronic properties like a screening effect and reduced Fermi velocities. Our samples are obtained by micromechanical cleavage of natural graphite and placed on a silicon substrate with a top layer of silicon dioxide. Graphene is located and identified using the optical microscope. Detailed height profiles can then be obtained by AFM, which also serves as a tool to mechanically manipulate the graphene by programmed tip movements. We show AFM-induced folding of graphene on a μm-scale and investigate ways to a controlled preparation of folded samples. These can be electrically contacted and characterized. To interpret the results thoroughly, the geometries must be examined with respect to twist angle and crystallographic orientation.

HL 28.3 Mon 16:00 Poster A

Nano patterning graphene by gas-assisted focused-electron-beam-induced etching — •Jens Sonntag, Benedikt Sommer, Arkadius Ganczarczyk, Martin Geller, and Axel Lorke — Faculty of Physics and CENIDE, Universität Duisburg-Essen

The transport properties of graphene devices vary dramatically with their geometric structure. E.g. confining the charge carries in lateral dimension gives rise to a band gap, which is advantageous for the current ratio between on and off state of a graphene field-effect transistor. We present a method to pattern graphene by focused-electron-beam-induced-etching (FEBIE) with water vapor as a reactive gas. While the resolution for graphene on SiO_2 is comparable to the widely used electron beam lithography (EBL) followed by reactive ion etching, no organic resist is needed for the FEBIE technique. A resolution of about 15 nm is achieved. More importantly, we are able to cut suspended graphene with an even better resolution of approximately 8 nm. In both cases, the roughness of the edges is at least better than the obtained resolution.

Transport measurements on a 1D conductive channel patterned by FEBIE indicate the expected band gap, showing that the process does not destroy the characteristic electronic properties of graphene. Therefore it is possible to fabricate devices like suspended graphene nanoribbons in a controlled top-down process.

HL 28.4 Mon 16:00 Poster A

Graphene nanostructures produced from suspended and transfered layers — •Christopher Belke, Dmitri Smirnov, Johannes C. Rode, Hennrik Schmidt, and Rolf J. Haug — Institut für Festkörperphysik, Leibniz Universität Hannover, D-30167 Hannover, Germany

Graphene consists of carbon atoms, which are arranged in a two-dimensional honeycomb lattice. It has unique electronic properties, which can be examined in high quality samples. These are often prepared by mechanical exfoliation on a silicon wafer with silicon dioxide on top. This substrate has a strong influence on the transport properties due to charge traps and surface roughness [1]. To reduce these effects, there are different possibilities, from which two were tested on flakes with different numbers of layers.

a) Etching of the SiO_2 under the flake with hydrofluoric acid is used to make the samples suspended [2]. Afterwards, the flake is cleaned by current annealing, in which a high current flows through the flake, so that contaminations are removed by the generated heat.

b) Transfer of the flakes [3]. For this, graphene is exfoliated on a thin PMMA layer, which can be detached from the silicon wafer. This layer is then placed on another flake or substrate of choice.

Using these two methods, different nanostructures were produced and characterized.

[1] P. Barthold et al. NJP **13**, 043020 (2011).
[2] K. I. Bolotin et al. Science-Direct, **146**, 351 (2008).
[3] C. R. Dean et al. Nature nanotechnology, **5**, 722 (2010).

HL 28.5 Mon 16:00 Poster A

Synthesis and characterization of graphene quantum dots based ink for printable applications — •Tessy Theres Baby[1], Suresh Garlapati[1], Falk von Seggern[1,2], Robert Kruk[1], Subho Dasgupta[1], and Horst Hahn[1,2] — [1]Institute for Nanotechnology, Karlsruhe Institute of Technology (KIT), D-76344 Eggenstein-Leopoldshafen, Germany — [2]KIT-TUD Joint Research Laboratory Nanomaterials, Institute of Materials Science, TU Darmstadt, Petersenstr. 32, 64287 Darmstadt, Germany

Graphene, the one atom thick layer of carbon, is ideally suited for numerous electronic applications on account of its high conductivity, carrier concentration (~ 1013 cm-2) and extraordinary mobility (~ 15,000 cm2/Vs). However, the absence of an electronic band gap has been an impediment in realizing graphene based devices. Therefore, the aim of this work is to synthesize graphene quantum dots with tunable electronic properties. A high temperature gasothermal (exfoliation of graphite oxide at 1050 °C in Ar atmosphere for 30 s) method is found suitable for large scale synthesis of such few nanometer diameter graphene nanodiscs. Acid functionalization has been carried out to obtain stable dispersions with tailored morphology. Finally, in the course of fabricating field-effect devices, a printable (ink-jet) grade of nanoink consisting of graphene nanodiscs has been prepared. In order to preserve the electronic properties, no surfactants or additives have been added. Electrochemically-gated field-effect transistors using composite solid polymer electrolytes have been characterized systematically.

HL 28.6 Mon 16:00 Poster A

Silicon nitride as top gate dielectric for epitaxial graphene — •Peter Wehrfritz[1], Felix Fromm[1], Stefan Malzer[2], and Thomas Seyller[1,3] — [1]FAU Erlangen-Nürnberg, Technische Physik, Erlangen, Deutschland — [2]FAU Erlangen-Nürnberg, Angewandte Physik, Erlangen, Deutschland — [3]TU Chemnitz, Institut für Physik, Chemnitz, Deutschland

Epitaxial graphene grown under atmospheric pressure offers an opportunity for large scale electronic device fabrication [1]. A suitable top gate dielectric, however, is still to be found. Al_2O_3 and HfO_2 grown by atomic layer deposition provides high quality dielectrics. Unfortunately it is not possible to grow closed layer on graphene without additional surface activation [2, 3].

We have investigated silicon nitride (SiN) grown by plasma enhanced chemical vapor deposition (PECVD) as top gate material on epitaxial graphene on 6H-SiC(0001). The NH_3 and SiH_4 flow rate ratio was optimized on the basis of x-ray photoelectron spectroscopy (XPS) measurements. The formed SiN layer is closed. Raman spectroscopy and transport measurements which were performed before and after the

SiN deposition revealed that the plasma process leads only to a minor degradation of the graphene. The SiN layer induces strong n-type doping proven by Hall measurements, transfer characteristic and XPS measurements.

[1] K. Emtsev et al., Nat. Mat. **8**, 203 - 207 (2009).
[2] S. Kim et al., Appl. Phys. Lett. **94**, 062107 (2009).
[3] B. Lee et al., Appl. Phys. Lett. **92**, 203102 (2008).

HL 28.7 Mon 16:00 Poster A

Electronic and optical properties of bilayer-array-embedded graphene — •Hengyi Xu and Thomas Heinzel — Heinrich-Heine-Universität Düsseldorf, Germany

The coexistence of monolayer and bilayer graphene is widely found in graphene samples, like large-scale monolayer/bilayer interfaces obtained from mechanical exfoliation or small-scale interfaces due to some graphite atoms sitting on graphene layers in epitaxial growth. These structures show a rich phenomenology and may provide some new possibilities for device applications.

In this work, we focus on structures with additional carbon atoms located on top of a monolayer graphene, thereby forming a regular hexagonal array of monolayer/bilayer quantum dots. The implementation of such structures seems to be rather plausible via the method of epitaxial growth. The electronic and optical transport properties of the periodic monolayer/bilayer interface are systemically studied with the Kubo formalism. The density of states as well as the electronic and optical conductivity are calculated by solving the time-dependent Schrödinger equation. It is found that the monolayer/bilayer interface array induces midgap states and suppresses the transmission in vicinity of Dirac points. Interface scattering has also a far-reaching impact on the Landau levels and Hall conductivity. In addition, the optical conductivity of such systems exhibits some extra peaks at the low frequencies due to the renormalization of density of states.

HL 28.8 Mon 16:00 Poster A

Ultrafast photocurrents of monolayer graphene on sapphire — •Martin Schwarz, Andreas Brenneis, Max Seifert, Jose Garrido, and Alexander Holleitner — Walter Schottky Institut and Physik-Department, TU München, 85748 Garching, Germany

We present picosecond-time resolved optoelectronic measurements of monolayer graphene, grown by chemical vapor deposition (CVD), on sapphire substrates. Our optoelectronic on-chip scheme samples the photocurrents within the graphene with a picosecond time resolution [1]. We verify an ultrafast displacement current at the metal-graphene interfaces and the dynamics of hot charge carriers within the graphene. In particular, we compare our results to the ones of freely suspended bilayer graphene with special emphasis on the thermal coupling of the graphene to its environment. Financial support by the ERC-grant NanoREAL is acknowledged.

[1] L. Prechtel, L. Song, D. Schuh, P. Ajayan, W. Wegscheider, A.W. Holleitner, Nature Comm. 3, 646 (2012).

HL 28.9 Mon 16:00 Poster A

Photocurrent in epitaxial graphene — •Stefan Link[1], Peter Wehrfritz[1], Felix Fromm[1], Stefan Malzer[2], and Thomas Seyller[1,3] — [1]FAU Erlangen-Nürnberg, Lehrstuhl für Technische Physik — [2]FAU Erlangen-Nürnberg, Lehrstuhl für Angewandte Physik — [3]TU Chemnitz, Institut für Physik

Graphene, the two-dimensional sheet of carbon promises a lot for electronic applications. For example, Mueller et al. [1] have demonstrated the potential of graphene for high-speed optical communications. In particular, they investigated the behavior of graphene-based photodetectors. Epitaxial graphene on SiC, which can be grown on a wafer scale [2], is the ideal platform for the development of such devices. We have investigated the photocurrent generation in graphene-metal junctions using different types of epitaxial graphene grown on SiC(0001). The photoresponse was shown to be due to a photovoltaic effect and improved by optimization of device design and by the use of quasi-freestanding graphene [3].

[1] T. Mueller et al., Nat. Photon. **4** (2010) 297. [2] K. V. Emtsev et al., Nat. Mater. **8** (2009) 203. [3] C. Riedl et al., Phys. Rev. Lett. **103** (2010) 246804.

HL 28.10 Mon 16:00 Poster A

Phototransmission and Photoconductivity in the THz Spectral Range of Graphene Samples — •Markus Göthlich[1], Fathi Gouider[1], Miriam Grothe[2], and Georg Nachtwei[1] — [1]Institut für Angewandte Physik, Technische Universität Braunschweig, Mendelssohnstraße 2, D-38106 Braunschweig — [2]Physikalisch Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig

Graphene has first been isolated in 2004. Since then this material has become a major field of interest in research, not least due to it's remarkable Landau quantization $E_n = \mathrm{sgn}(n)\sqrt{2\hbar e v_F^2 |n| B}$ with n being the Landau level (LL) index. Thus, an intraband transition between LLs with an enery of 10meV (corresponding to electromagnetic radiation with a frecquency of about 2.4THz) can theoretically be achieved with a magnetic field as low as 0.2T. In the case of cyclotron resonance the phototransmission drops and the conductivity of the sample changes due to a change of the carrier density at the Fermi energy. In this contribution, we present the magnetoconductivity and the terahertz (THz) photo-conductivity of devices with graphene. For the photoconductivity measurements, a THz laser system (p-Ge-Laser) is applied. This laser uses transitions between Landau levels of light holes and emits laser impulses in the wavelength range $120\mu\mathrm{m} \leq \lambda \leq 180\mu\mathrm{m}$. The THz laser radiation is used in order to excite charge carriers over the Landau gap. To characterize the examined graphene samples, the Shubnikov-de Haas-effect measurements at a temperature of $T = 4\mathrm{K}$ and in the region of the magnetic fields of $0 \leq B \leq 10\mathrm{T}$ were performed.

HL 28.11 Mon 16:00 Poster A

Terahertz-sensitive devices based on epitaxial graphene — •Christian Sorger, Alexander Glas, Stefan Hertel, Sascha Preu, and Heiko B. Weber — Lehrstuhl für Angewandte Physik, Universität Erlangen-Nürnberg, 91058 Erlangen, Germany

Epitaxially grown graphene is a hybrid system comprising graphene as a metal and silicon carbide as a semiconductor. Through patterning the graphene layer by means of local intercalation (i.e. without metallic gates), electronic functionality can be achieved [1].

First, we focus on the transmission of Terahertz radiation through a grid-like, p-n-patterned graphene layer. The physics is predominantly governed by the excitation of plasmons and we currently explore the potential influence of Klein-Tunneling. Secondly, we form Schottky-Diodes following the strategy of reference [1]. When equipped with a metallic antenna, we examine their suitability as Terahertz detectors.

[1] S. Hertel *et al.*, Nature Communications **3**, 957 (2012)

HL 28.12 Mon 16:00 Poster A

Hot Carrier Photoluminescence in Graphene — •Andreas Neff, Reiner Bormann, Sascha Schäfer, and Claus Ropers — Materials Physics Institute and Courant Research Centre, University of Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

The photoluminescence of hot carriers in graphene yields insight into the ultrafast carrier and phonon dynamics after optical excitation [1,2], providing complementary information to transient spectroscopy [3]. In this contribution, we study the blue-shifted spectral component of hot-carrier photoluminescence of graphene on sapphire substrates, excited by sub-10-fs near-infrared laser pulses. We characterise the nonlinear spectral dependence of the emission as a function of laser fluence and pulse duration. The experimental findings are analysed using a microscopic model of carrier dynamics based on Boltzmann rate equations, including carrier-carrier and carrier-phonon scattering processes. Specifically, the role of Auger recombination and impact ionization on the photoluminescence properties is discussed.

[1] C.H. Lui, *et al.*, Phys. Rev. Lett. **105**, 127404 (2010)
[2] W. Liu, *et al.*, Phys. Rev. B. **82**, 081408 (2010)
[3] M. Breusing, *et al.*, Phys. Rev. B. **83**, 153410 (2011)

HL 28.13 Mon 16:00 Poster A

Acoustic charge transport in epitaxial graphene on SiC — •Paulo V. Santos, Timo Schumann, Myriano H. Oliveira Jr., Joao Marcelo J. Lopes, and Henning Riechert — Paul-Drude-Institut für Festkörperelektronik, Berlin, Germany

Graphene is emerging as an important material for electronic applications due to its high carrier mobility. Here, we investigate carrier control in epitaxial graphene on SiC (epiG) using dynamic strain field produced by a surface acoustic wave (SAW). The strain field periodically modulates the epiG band structure[1]. Electron beam collimators based on this effect have been proposed [2]. We report on the piezoelectric excitation and on acoustic charge transport by SAWs in epiG. SAWs with GHz frequencies were generated by interdigital transducers

(IDTs) fabricated on a piezoelectric ZnO island on semi-insulating SiC. These SAW frequencies are substantially higher than those reported for acoustic transport in graphene flakes[3]. Acoustic transport studies in a Hall bar geometry show that SAWs transport carriers in epiG, with the transport direction being determined by the direction of the acoustic beam. The mechanisms for the carrier transport, including the effects of the strain field and the weak piezoelectric field in SiC will be discussed.

[1] C.-H. Park *et al.*, *Phys. Rev. Lett.*, **101**, 126804 (2008).
[2] C.-H. Park*et al.*, *Nano Lett.*, **8** 2920 (2008).
[3] V. Miseikis *et al.*, *Appl. Phys. Lett.*, **100**, 133105 (2012).

HL 28.14 Mon 16:00 Poster A

Proximity induced superconductivity in bilayer graphene — •Julien Bordaz[1], Michael Wolf[1,2], Fan Wu[1], Hilbert von Löhneysen[1,2,3,4], Detlef Beckmann[1,2], Kenji Watanabe[5], Takashi Taniguchi[5], and Romain Danneau[1,3] — [1]Institute of Nanotechnology, Karlsruhe Institute of Technology, Germany — [2]DFG Center for Functional Nanostructures, Karlsruhe Institute of Technology, Germany — [3]Institute of Physics, Karlsruhe Institute of Technology, Germany — [4]Institute for Solid-State Physics, Karlsruhe Institute of Technology, Germany — [5]Advanced Materials Laboratory, National Institute for Materials Science, Tsukuba, Japan

Proximity induced superconductivity effect occurs when graphene is connected with close enough superconducting electrodes. Observations of Andreev reflection and induced supercurrents flowing through graphene sheets have already been reported in graphene. However, these effects have not been explored in bilayer graphene so far. By applying a perpendicular electric field, it is possible to open a gap in a bilayer graphene. This can be achieved in practice by designing a top gate in addition to the usual back gate. Our devices are produced on top of sapphire wafers by using transfer techniques and standard electron-beam lithography. The bilayers are sandwiched between two atomically flat hexagonal boron nitride multilayers which are both used as gate dielectric. By inducing a band gap into a bilayer graphene connected by two superconducting leads, the supercurrent could be switched off inducing a superconductor-insulator transition.

HL 28.15 Mon 16:00 Poster A

Generalized Boltzmann equation approach to rectification at a potential step — •Stephan Rojek, Alfred Hucht, and Jürgen König — Theoretische Physik, Universität Duisburg-Essen and CENIDE, 47048 Duisburg, Germany

In a recent experiment[1, 2] a density modulated two-dimensional electron gas has been shown to work as a tunable rectifier. Tow top-gates define two regions of different carrier density separated by a potential step. A bias voltage parallel to the potential step leads to a transverse voltage proportional to the square of the applied bias voltage. The experiment could be well explained within a diffusion thermopower model in terms of a Boltzmann equation approach.[2] The latter is based on a local equilibrium distribution function with a spatially dependent effective chemical potential and temperature.

In our current theoretical investigation, we go beyond this diffusion thermopower model and derive a general theory, which, in principal, allows for a systematic calculation of all contributions to a non-equilibrium distribution function.

[1] A. Ganczarczyk, C. Notthoff, M. Geller, A. Lorke, D. Reuter, and A. D. Wieck, AIP Conf. Proc. **1199**, 143 (2009).
[2] A. Ganczarczyk, S. Rojek, A. Quindeau, M. Geller, A. Hucht, C. Notthoff, J. König, A. Lorke, D. Reuter, and A. D. Wieck, Phys. Rev. B **86**, 085309 (2012).

HL 28.16 Mon 16:00 Poster A

Quasi-ballistic electron transport through bipolar localized magnetic fields — Tudor Chirila, Bernd Schüler, •Mihai Cerchez, and Thomas Heinzel — Heinrich Heine University Düsseldorf, Condensed Matter Laboratory, Universitätsstr. 1, 40225 Düsseldorf

We investigated the electron transport in hybrid ferromagnet/semiconductor devices produced by a series of two magnetic barriers of opposite polarity, placed on top of a Hall bar etched into a GaAs/AlGaAs heterostructure. The size of the Hall bar is comparable to the size of the magnetic structure and smaller than the mean free path of the electrons which places the structure in the quasi-ballistic regime [1]. The strength of the magnetic field profile is tuned by an external applied magnetic field, and the electron density is tuned by a metallic top gate. The magnetoresistance of the device shows non-ohmic behavior with characteristic transmission and reflection resonances. The measurements are in agreement with semi-classical simulations using the Landauer-Büttiker formalism with scattering [2, 3], and reveal the origin of the resonances residing in the quasi-ballistic transport of electrons confined by the edges of the Hall bar and the magnetic field profile.

[1] M. Cerchez and T. Heinzel, Appl. Phys. Lett., 98, 232111, 2011 [2] S. Hugger, M. Cerchez, H. Xu, and T. Heinzel, Phys. Rev B, 76, 195308, 2007 [3] M. Cerchez, S. Hugger, and T. Heinzel, Phys. Rev B, 75:035341, 2007

HL 28.17 Mon 16:00 Poster A

Mobility Studies on High Electron Mobility Structures — •Christian Schulte-Braucks, Arne Ludwig, and Andreas D. Wieck — Angewandte Festkörperphysik, Ruhr-Universität Bochum

Two Dimensional Electron Gases in modulation doped High-Electron-Mobility-Transistor-Structures (HEMT) have huge potential in current and prospect research and application. Therefore, a good understanding of properties and scattering processes depending on the sample structure is essential to design samples with desired characteristics such as high electron mobility. A systematic study of Hall-mobility (μ) depending on 2D charge carrier concentration (n) of Molecular-Epitaxy-grown δ-doped $GaAs-AlGaAs$-HEMTs is in progress. There are two aspects which are focussed on intensively. First varying structural aspects such as spacer thickness, material composition and doping. Second, changing measurement parameters such as sample current and illumination intensity. n has been tuned by succsessive illumination, exploiting persistent photo effect in DX-centres and measurements are planned to be compared by tuning n by Gate bias. Moreover, Shubnikov-de-Haas-Oscillations are projected to get access to the occupation of subbands, the existence of parallel conductance and scattering mechanisms. A power function law $\mu \propto n^{\alpha}$ where α depends on the spacer thickness has been observed, which can be assigned to remote impurity scattering. In congruence with [1] α is approximately 0.6 but contradictory to [2] increases with increasing spacer thickness.

[1] Shayegan, M et al., Appl.Phys.Lett., **52**(13), (1988)
[2] Schmult, et al., J.Cryst.Growth., **331**(7), (2009)

HL 28.18 Mon 16:00 Poster A

Determination of trap and band states in printable thin film transistors by scanning Kelvin probe microscopy — •Sebastian Hietzschold[1,2,3], Florian Mathies[1,2,4], Rebecca Saive[1,2,3], Norman Mechau[2,4], and Wolfgang Kowalsky[1,2,3] — [1]Kirchhoff-Institut für Physik, Universität Heidelberg, Germany — [2]InnovationLab, Heidelberg, Germany — [3]Institut für Hochfrequenztechnik, Technische Universität Braunschweig, Germany — [4]Lichttechnisches Institut, Karlsruhe Institut für Technologie, Germany

The development of printed thin film transistors (TFTs) is of utmost importance enabling large-area electronics by low cost fabrication. Former work, e.g. M. Koehler *et al.*, has shown that a fundamental understanding of charge carrier transport in the active material and at interfaces is essential improving device performance [1]. Therefore we investigate TFTs with scanning Kelvin probe microscopy (SKPM) in an ultra-high vacuum environment. We apply different gate bias leading to a filling and emptying of electronic states and measure in-situ the shift in the surface potential respectively. Hereby we indirectly gain the density of trap as well as band states (DOS). The DOS energy distribution provides information on many electronic properties in semiconductor films and is therefore crucial for a performance improving of printed thin film transistors.

[1] M. Koehler and I. Baggio, Phys. Rev. B 68, 075205 (2003)

HL 28.19 Mon 16:00 Poster A

Weak antilocalization and disorder-enhanced electron interactions in crystalline $Ge_1Sb_2Te_4$ — Nicholas Breznay[1], •Hanno Volker[2], Alexander Palevski[3], Riccardo Mazzarello[4], Aharon Kapitulnik[1], and Matthias Wuttig[2,5] — [1]Department of Applied Physics, Stanford University, Stanford, CA 94305, USA — [2]I. Physikalisches Institut (IA), RWTH Aachen University, 52056 Aachen, Germany — [3]School of Physics and Astronomy, Raymond and Beverly Sackler Faculty of Exact Science, Tel-Aviv University, 69978 Tel-Aviv, Israel — [4]Institut für theoretische Festkörperphysik, RWTH Aachen University, 52056 Aachen, Germany — [5]JARA FIT, RWTH Aachen

Phase-change materials (PCMs) are characterized by their high optical and electrical contrast between an amorphous and a crystalline phase, the long-term stability of both phases at room temperature and their fast crystallization kinetics[1]. Recently, it has been demonstrated that many PCMs undergo a disorder-induced metal-insulator transition[2].

In the present study[3], we focus on the metallic state, in which disorder-enhanced electron-electron interaction and weak antilocalization caused by strong spin-orbit scattering are observed at low temperatures. Employing well-established theories[4], we are able to consistently fit experimental data and extract the relevant scattering rates.

[1] M. Wuttig and N. Yamada, Nat. Mater. 6, 824 (2007)
[2] T. Siegrist et al., Nat. Mater. 10, 202 (2011)
[3] N.P. Breznay et al., Phys. Rev. B 86, 205302 (2012)
[4] P.A. Lee and V. Ramakrishnan, Rev. Mod. Phys. 57, 287 (1985)

HL 28.20 Mon 16:00 Poster A

Charge Transport and Passivation of ZnO-TFTs Deposited by Spray Pyrolysis — •Yulia Trostyanskaya, Marlis Ortel, Nataliya Kalinovish, Gerd Roeschenthaler, and Veit Wagner — Research Center for Functional Materials and Nanomolecular Science, Jacobs University Bremen, Campus Ring 1, 28759 Bremen, Germany

ZnO serves as a suitable semiconductor for thin film transistors (TFTs) due to its high mobility, wide band gap and simple and cheap way of deposition e. g. via spray pyrolysis. However the electronic properties of the material have a disadvantage of being highly sensitive to the surrounding environment due to the formation of surface states. In this work flour terminated diketones e.g. 4,4,4-trifluoro-1-(3-fluorophenyl)1-3-butanedione were bound on the zinc oxide surface to reduce the impact of the environment. The effect on the charge transport processes in the semiconductor was analyzed by bias stress measurements and temperature dependent electrical measurements which were correlated to optical and morphological investigations. The passivation of the TFTs induced an increase of the linear mobility from 4cm2/Vs to 7.3cm2/Vs and improved the bias stress stability remarkably which is in good agreement with a shift of the optical band gap. Furthermore, significant difference in the conduction processes with and without passivation was found. While similar activation energies are found above 100K clear difference is observed below, reflecting the passivated states.

HL 28.21 Mon 16:00 Poster A

Effects of p-doping on charge carrier concentration and charge carrier transport in organic-inorganic composite thin layers — •Carsten Leinweber[1,2], Diana Nanova[1,2], Daniela Donhauser[1,4], Eric Mankel[2,3], Wolfgang Kowalsky[1,2,4], Uli Lemmer[5], and Norman Mechau[2,5] — [1]Kirchhoff-Institut für Physik, Universität Heidelberg, Germany — [2]InnovationLab, Heidelberg, Germany — [3]Institut für Materialwissenschaft, Technische Universität Darmstadt, Germany — [4]Institut für Hochfrequenztechnik, Technische Universität Braunschweig, Germany — [5]Lichttechnisches Institut, Karlsruhe Institute of Technology, Germany

Understanding the influence of doping on conductivity, mobility and charge carrier concentration is one of the main challenges towards high-efficiency organic devices. It has been shown that p-type doping of 4,4*-Bis(N-carbazolyl)-1,1*-biphenyl (CBP) with transition metal oxides like MoO3 increases the bulk conductivity of the organic layer. However, a very low doping efficiency for various mixing ratios has been observed. Therefore, we investigated the electronic properties of thermally co-evaporated layers with different doping concentrations using charge extraction by linearly increasing voltage (CELIV). In the CELIV technique charge carriers are extracted by a linearly increasing voltage pulse in reverse bias over a non-injecting contact. From the resulting current transient charge mobilities and charge carrier densities were determined. Furthermore, we correlated our investigations to morphology studies on the dopant distribution to understand the fundamentals of the underlying doping mechanism and its low efficiency.

HL 28.22 Mon 16:00 Poster A

Optical conductivity of the Anderson model calculation using Kernel Polynomial Method — •Paul Wenk[1], John Schliemann[1], and Georges Bouzerar[2] — [1]Institut I - Theoretische Physik, Universität Regensburg, D-93040 Regensburg, Germany — [2]Institut Néel, 25 avenue des Martyrs, B.P. 166, 38042 Grenoble Cedex 09, France

We investigate the optical conductivity of a three-dimensional system with non-interacting electrons in a random potential (Anderson model) in linear response.[1] The application of the Chebyshev expansion method[2,3] allows for the analysis of large systems at finite temperatures. However, an improper choice of expansion cutoff and Fermi-Energy can lead to unphysical results - not only concerning negative Drude weights. By applying the f-sum rule[4] and a precise analysis of the spectrum degeneracies we resolve the conductivity-artifacts and calculate the suppression of the Drude weight as a function of impurity strength, the Drude weight being the order-parameter for the Metal-Insulator transition.

[1] P. Wenk *et al.* in prep. (2013)
[2] A. Weiße *et al.* Rev. Mod. Phys. **78**, 275 (2006)
[3] A. Weiße Eur. Phys. J. B **40**, 125 (2004)
[4] G. Bouzerar *et al.* Phys. Rev. B **49**, 12 (1994)

HL 28.23 Mon 16:00 Poster A

Metal complexes and organic radicals as electronic components — •Karin Goss, Simon Seyfferle, Martin Dressel, and Lapo Bogani — 1. Physikalisches Institut, Universität Stuttgart

Using molecules as building blocks for electronic devices offers ample possibilities for new device functionalities due to a chemical tunability much higher than that of standard inorganic materials, and, at the same time, offers a decrease in the size of the electronic component down to the single-molecule level. Metal clusters with an organic shell are a very versatile playground since both the metallic ions as well as the organic ligands can be chemically tuned to fulfill a particular functionality. For example, metallic ions can induce magnetism in the system on a single-molecular basis and ligands can be tailored to increase the affinity for binding to metallic electrodes or other organic material. But also purely organic molecules containing no metallic centers can serve as an electronic component. We present our results on electronic devices based on magnetic materials of different kind and functionality. We show the conducting behaviour of several sample layouts, all of which contain a molecular material as the functional element, and we provide a correlation between the electronic behaviour and the pre-designed chemical functionality. In particular, organic radical molecules can be reversibly switched between two oxidation states by applying a bias voltage across a thin layer of molecular material. Some members of this family of molecules also offer spintronic applications, which can be probed by injecting and detecting spin-polarized electrons with ferromagnetic leads.

HL 28.24 Mon 16:00 Poster A

Wigner solid phases near fractional and integer Landau level filling — •Guenther Meissner and Uwe Schmitt — Department of Physics, Saarland University, P.B.O. 151150, D-66041 Saarbruecken, Germany

Electrons in a high magnetic field are quasi two-dimensional (2D) due to the perpendicular cyclotron motion. If the cyclotron radius becomes less than half of the mean distance of the electrons, Wigner solid formation may minimize their Coulomb repulsion. Since the Cartesian components of the guiding center positions of the cyclotron motion turn out to be non-commuting (because of the magnetic vector potential), their density fluctuations are non-commuting, too. Correlation functions of these two quantities have thus been used for studying quantitatively the nature of Coulomb-interacting 2D electrons at high magnetic fields [1]. Here, it will be shown how recent observations of Wigner solid pinning modes [2] near the fractional filling factor 1/3 and the integer filling factor 1 of the Landau levels exhibiting the fractional respectively integer quantum Hall effect could be explained in our many-body approach via Chern-Simons magnetic fields. [1] G. Meissner, Physica B 184,66 (1993).[2] H. Zhu, Y.P. Jiang, L.W. Engel, D.C. Tsui, L.N. Pfeiffer, and K.W. West, Phys Rev. 105, 12608 (2010) and references therein.

HL 28.25 Mon 16:00 Poster A

Application of $CuInS_2$ nanocrystals in hybrid and Schottky-type solar cells — •Katja Frevert, Florian Witt, Nikolay Radychev, Dorothea Scheunemann, Marta Kruszynska, Rany Miranti, Joanna Kolny-Olesiak, Holger Borchert, and Jürgen Parisi — University of Oldenburg, Department of Physics, Energy and Semiconductor Research Laboratory (EHF), 26111 Oldenburg, Germany

So called hybrid solar cells built from blends of conductive polymers and inorganic nanoparticles are a possible candidate to improve the performance of solution processed thin film photovoltaics. In most studies on this topic toxic nanoparticle compounds like CdSe or PbS are used. Here we demonstrate results with less toxic $CuInS_2$(CIS)

nanocrystals. CIS offers advantages such as high absorption coefficients in the visible range, size-dependent spectral bandwidth, and suitable charge transport properties. We will show the influence of stabilizing ligands on the morphology of the active layer and the electrical characteristics of hybrid solar cells based on elongated and pyramidal CIS nanocrystals blended with poly(3-hexylthiophene) (P3HT). Another approach for solution processed photovoltaic devices involves all inorganic nanoparticle Schottky-type solar cells. Here thin films of CIS nanoparticles are deposited layer-by-layer and finished by a suitable top electrode like aluminum. We will show first results from an early stage of this development.

HL 28.26 Mon 16:00 Poster A

Influence of Förster interaction on the light emission statistics of hybrid systems — •T. Sverre Theuerholz, Alexander Carmele, Marten Richter, and Andreas Knorr — Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Germany

Hybrid systems consisting of semiconductor quantum dots (SQD) and metallic nanoparticles (MNP) are in the focus of current experimental and theoretical [1] research, since they may combine the advantages of both constituents.

In our contribution, we theoretically investigate a hybrid system of two SQDs and a MNP driven by coherent light. Within our theoretical framework, we focus on the second-order correlation plasmon-plasmon function $g^{(2)}$ and its dependency on the external field and on the internal interactions between the constituents. We find, that even relatively weak internal interactions, like the Förster coupling [2] between the SQDs, can have a significant impact on the second-order correlation function. Since the strength of this coupling depends on the size, shape and distance between the SQDs, it can be engineered to tune the $g^{(2)}$-function. We also investigate how MNPs in the vicinity of SQDs influence the Förster interaction between the dots.

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HL 28.27 Mon 16:00 Poster A

Purcell effect in rolled-up active hyperbolic metamaterials — •Marvin Schulz, Hoan Vu, Stephan Schwaiger, David Sonnenberg, Christian Heyn, and Stefan Mendach — Institute of Applied Physics, University of Hamburg, Jungiusstraße 11, 20355 Hamburg, Germany

Using the relaxation process of strained semiconductor layers [1] we fabricate microtubes whose walls represent three-dimensional hyperbolic metamaterials consisting of alternating semiconductor ((Al)(In)GaAs) and metal (Ag) layers [2]. Here, we investigate the Purcell effect for a GaAs quantum well embedded in the semiconductor compound of the metamaterials [3]. We varied the Ag/GaAs thickness ratio $\eta = \mathrm{d\_(Ag)/d\_(GaAs)}$ to tune the anisotropic effective permittivity tensor of the metamaterial at the quantum well emission energy (1.63 eV). Time-resolved photoluminescence measurements reveal a sharp decrease of the embedded quantum well's lifetime τ from $\tau = 430$ ps for metamaterials with $\eta < 0.53$ to $\tau = 250$ ps for metamaterials with $\eta > 0.53$. This well corresponds to an increase of the photon density of states as expected at the transition to the hyperbolic dispersion regime [4, 5]. The authors acknowledge financial support by the Deutsche Forschungsgemeinschaft via Graduiertenkolleg 1286.

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