HL 21 Transport properties I

Time: Tuesday 16:30–19:30 Room: BEY 118

HL 21.1 Tue 16:30 BEY 118

DENSITY-OF-STATES IN MICROCRYSTALLINE SILICON FROM THERMALLY-STIMULATED CONDUCTIVITY — •Nacera Souffi, Rudolf Brüggemann, and Gottfried H. Bauer — Institut für Physik, Carl von Ossietzky Universität Oldenburg, D-26111 Oldenburg

The technique of thermally stimulated currents has been applied to extract the density-of-states profile in microcrystalline silicon. Exploiting the experimental parameter space a consistent density-of-states profile emerges with an exponential conduction band tail and a broader deeper distribution. Calibrating the absolute density of states profile from other techniques like modulated photoconductivity, steady-state photocarrier grating technique and intensity-dependent photoconductivity allows a determination of the capture coefficient of the probed localised states.

HL 21.2 Tue 16:45 BEY 118

Characterization of Ti / TiO_2 / Pt - Schottky diodes — •Philipp Zabel[1], Sven Bönisch[1], Germà García-Belmonte[2], Juan Bisquert[2], and Thomas Dittrich[1] — [1]Hahn-Meitner-Institut, Glienicker Str. 100, 14109 Berlin, Germany — [2]Departament de Ciències Experimentals, Universitat Jaume I, E-12080 Castelló, Spain

UV photodiodes (sglux tw30sx, TiO_2 made by sol-gel processing) were used as a model system to study Ti / TiO_2 / Pt - Schottky diodes by temperature dependent current-voltage, impedance spectroscopy and transient photocurrent measurements. The equivalent circuit has been taken into account for the analysis. The Schottky barrier is about 1.3 eV which is equal to the work function difference between Ti and Pt. At lower potentials, the current is limited by the barrier while at higher potentials, control by space charge limited currents sets on. The temperature dependent dielectric constant of the TiO_2 layer was obtained. Photocurrent transients were excited with short UV laser pulses. The current at 1 μs and the integral of the photocurrent transients depend linearly on the laser intensity until an electron density of about 10^{12} cm^{-2} is reached in the TiO_2 layer (thickness 160 nm). At higher intensities, the photocurrent goes to saturation due to recombination. The electron drift mobility depends only weakly on the illumination intensity and temperature.

HL 21.3 Tue 17:00 BEY 118

Surface photovoltage for characterization of porous semiconductors — •Thomas Dittrich[1], Iván Mora-Seró[2], Germà García-Belmonte[2], and Juan Bisquert[2] — [1]Hahn-Meitner-Institut, Glienicker Str. 100, 14109 Berlin, Germany — [2]Departament de Ciències Experimentals, Universitat Jaume I, E-12080 Castelló, Spain

The surface photovoltage method is a locally sensitive technique with respect to even extremely short charge separation lengths. In conventional semiconductors, the charge separation length is given mainly by the thickness of the space charge region. The situation may change for porous semiconductors. In such systems, a time dependent development of the charge separation length from an initial value, given also by the duration time of the laser pulse, up to a screening length (Debye screening length in homogeneous media) has been observed and described by a diffusion model. The processes of diffusion and screening will be discussed on the example of porous TiO_2 layers sensitized with dye molecules.

HL 21.4 Tue 17:15 BEY 118

Quantitative modelling of the temperature and magnetic-field dependence of the resistivity of paramagnetic $Ga_{1-x}Mn_xAs$ with x up 7% — •C. Michel[1], S. Ye[1], V. Rajevac[1], P.J. Klar[1], S.D. Baranovskii[1], P. Thomas[1], W. Heimbrodt[1], and B. Goldlücke[2] — [1]Dept. Physics and WZMW, Philipps-University of Marburg, Germany — [2]MPI for Computer Science, Saarbrücken, Germany

We measured and modelled quantitatively the magneto-resistance behaviour above the Curie-temperature of several different p-type $Ga_{1-x}Mn_xAs$ samples with x up to 7%. A network model [1] accounting for alloy disorder and tuning of the band structure due to the strong s,p-d exchange interaction between the spins of the extended band states and the localized Mn 3d spins was employed. The band structure description is based on parabolic hole bands and an acceptor level with a Gaussian broadening. The calculated temperature dependence of the resistance in zero-field as well as the magnitude of the magneto-resistance effects are very sensitive to the choice of model parameters, e.g. the valence band exchange-integral $N_0\beta$, the width of the Gaussian broadening of the acceptor level, the degree of zero-field disorder etc., allowing one to determine these parameters by fitting the experimental data. The magnitude of the extracted parameters and the trends with x will be discussed and compared with literature values.

[1] Phys. Rev. B **69**, 165211 (2004).

HL 21.5 Tue 17:30 BEY 118

Transistor characteristics of three leaky contacts defined in a two dimensional electron gas — •Daniela Spanheimer, Lukas Worschech, Christian R. Müller, and Alfred Forchel — Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

The capacitance of leaky nanojunctions has recently attracted considerable attention. It has been stated that in mesoscopic system the capacitance not only depends on the geometry, but also on electrochemical entities and the transmission probability between the reservoirs [1]. We have studied the capacitive couplings between three leaky contacts by studying the gain properties of a transistor like junction. For that purpose we have realized two rows of etched holes in a modulation doped GaAs/AlGaAs heterostructure. The two rows define three electron reservoirs, which are leaky coupled to each other. We have determined the current voltage characteristics for several possible variations of the three terminals for different separations between the rows and different hole diameters. For row separations in the order of 1 μm transistor characteristics have been observed even at room temperature, which we discuss in terms of a leaky capacitor model.

[1] T. Christen and M. Büttiker, Phys. Rev. Lett. 77, 143 (1996).

HL 21.6 Tue 17:45 BEY 118

Full non-equilibrium quantum transport theory of high-scattering semiconductor devices — •Tillmann Kubis, Alexandros Trellakis, and Peter Vogl — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching

We present fully self-consistent non-equilibrium Green's function (NEGF) calculations for semiconductor heterostructures in a regime where multiple scattering and quantum effects such as interference, carrier confinement and carrier capture must be treated on an equal footing. We have implemented non-local energy- and momentum-dependent scattering self-energies in the self-consistent Born approximation for charged impurities, as well as acoustic and polar optical phonons. Electron-electron interaction is included via the self-consistent Hartree potential. This ab-initio implementation of quantum transport theory allows us to predict carrier dynamics in any kind of semiconductor nanodevice, ranging from simple n-i-n resistors to complex multi-quantum well structures. We present the I-V characteristics, the charge density and potential profile of a 12nm InGaAs quantum well that illustrates carrier capture into multiple bound states/resonances and compare the results with ballistic and quantum drift diffusion models.

HL 21.7 Tue 18:00 BEY 118

Source switching in an electron Y-branch switch — •Stefan Lang, David Hartmann, Lukas Worschech, and Alfred Forchel — Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

We have observed gate controlled source switching in an electron Y-branch switch. The Y-branched nanojunctions were realized on the basis of a modulation doped $GaAs/AlGaAs$ heterostructure and are controlled by four side-gates. Gate voltage up-sweeps at one side-gate firstly open the first source channel. Then the second source-branch becomes conductive and above a critical gate voltage the first source is pinched-off. This leads to a peak in the current-voltage characteristic of the first source-branch. We have modeled the source switching taking into account gating as well as selfgating of the Y-branch nanojunction.

HL 21.8 Tue 18:15 BEY 118

Mobility Enhancement of Shallow Modulation Doped GaAs/AlGaAs Heterostructures by Presence of Metal at the Surface — •Holger Welsch, Christian Heyn, and Wolfgang Hansen — Universität Hamburg, Institut für Angewandte Physik, Jungiusstrasse 9-11, 20355 Hamburg

We perform magneto-transport measurements on shallow modulation doped GaAs/AlGaAs heterostructures. Compared to standard structures, where the two-dimensional electron gas (2-DES) is unaffected of surface states, shallow structures need higher doping in order to prevent depletion of the 2-DES. High doping concentrations as well as small spacer layers, both applied at shallow structures, are normally accompanied by reduced mobility due to scattering of the 2-DES electrons at ionised donators in the doping layer. On account of this, the minimum distance between 2-DES and surface is limited by vanishing carrier density and reduced mobility. Here we compare shallow heterostructures with open and metal coated surfaces. We find that surface metal coating on samples with a 2-DES 23 nm beneath the surface feature an up to three times higher mobility compared to the uncoated ones.

HL 21.9 Tue 18:30 BEY 118

Photoexcited electron and hole transport in thin film tunnel systems — •Peter Thissen[1], Domokos Kovacs[2], Jörg Winter[2], Eckart Hasselbrink[1], and Detlef Diesing[1] — [1]Institut für Physikalische Chemie, Universität Duisburg Essen — [2]Institut für Experimentalphysik 2, Ruhr Universität Bochum

The photoeffect in semiconductor based devices is often discussed as transport of the majority carriers across the metal–semiconductor interface. The photoexcited charge carriers propagate over the Schottky barrier ($E_{barrier} \approx 0.7\ eV$ for silicon–metal interfaces). In tunnel barrier systems (metal$_1$–metal$_1$oxide–metal$_2$) with thin oxide layers ($\approx$ 3 nm) and metal films (10 - 70 nm) other transport channels may also contribute to the measured photocurrent: 1. tunneling of electrons through the conduction band barrier. 2. tunneling of holes through the valence band barrier. 3. excitation of charge carriers both in the top and in the ground metal film of the tunnel device. By applying a bias voltage between the metals, the band structure of the tunnel device can be changed allowing a discrimination between the different transport channels. Photoinduced tunnel currents ($h \cdot \nu = 1.53, 1.37, 1.27\ eV < E_{barrier} = 1.8\ eV$) were investigated as well as photoinduced UV-electronic excitations ($h \cdot \nu = 11eV >> E_{barrier}$) with different bandstructures in the the tunnel devices. The investigations show a clear contribution of hot hole induced tunnel currents to the measured photo current even in the low energy range. Transport effects of excited charge carriers in the metal films are discussed refering to experiments with variable metal film thicknesses.

HL 21.10 Tue 18:45 BEY 118

Thermoelectric cooling: a new approach — •G.N. Logvinov[1], J. E. Velazquez[2], and Yu. G. Gurevich[2,3] — [1]SEPI-ESIME Culhuacan, I.P.N., Santa Ana 1000, Culhuacan, C.P. 04430, D.F., Mexico — [2]Depto. de Física Aplicada, Universidad de Salamanca, Pza. de la Merceds/n, E-37008 Salamanca, Spain — [3]On leave at the University of Salamanca. Permanent address: Depto. de Física, CINVESTAV-IPN, D.F., Mexico

A new approach is suggested to explain the Peltier effect. It assumes that the Peltier effect is not an isothermal effect. The approach is based on the occurrences of induced thermal fluxes in a structure which consists of two conducting media, through which a dc electric current flows [1]. These induced thermal diffusion fluxes arise to compensate for the change in the thermal flux caused by the electric current (the drift thermal flux) flowing through the junction, in accordance with the general Le Châtelier*Braun principle. The occurrence of these thermal diffusion fluxes leads to temperature heterogeneity in the structure and, as a result, to a cooling or heating of the junction. Within the framework of this concept, the thermoelectric cooling is analysed. It is shown that in the general case the Peltier effect always occurs together with another thermoelectric effect [1]. This thermoelectric effect is predicted for the first time. Both these effects essentially depend on the junction surface thermal resistance [2].

[1] Yu. G. Gurevich and G.N. Logvinov 2005 Semicon. Sci. Technol. vol. 20 R57 [2] Gurevich Yu G and Logvinov G N 1992 Sov. Phys. Semicond. vol. 26 1091

HL 21.11 Tue 19:00 BEY 118

Admittance of open quantum systems — •Paul Racec[1,2], Roxana Racec[3,4], and Ulrich Wulf[3,1] — [1]IHP/BTU Joint Lab, Postfach 101344, 03013 Cottbus, Germany — [2]National Institute of Materials Physics, PO Box MG-7, 077125 Bucharest Magurele, Romania — [3]Technische Universität Cottbus, Fakultät 1, Postfach 101344, 03013 Cottbus, Germany — [4]University of Bucharest, Faculty of Physics, PO Box MG-11, 077125 Bucharest Magurele, Romania

We present a formalism for the treatment of mesoscopic systems under a small time dependent bias superimposed to a static external bias which defines the working point. The scheme is based on linear response theory, where the unperturbed system is considered the system under the static external bias. For the unperturbed system, Hartree calculations are performed in the Landauer-Buettiker formalism. In order to describe the time dependent quantities, the corresponding response functions (charge-charge or current-charge correlations functions) are computed in the random phase approximation. Applications for blocking structures (like metal-insulator-semiconductor) and current carrying structures (like double barrier resonant tunneling diode) are presented. Based on quantum mechanical expressions for their admittance, equivalent small signal circuits are proposed.

HL 21.12 Tue 19:15 BEY 118

Non-linear I-V characteristics of nano-transistors in the Landauer-Büttiker formalism — •Ulrich Wulf[1,2], Paul Racec[2,3], and Alexandru Nemnes[4,5] — [1]Technische Universität Cottbus, Fakultät 1, Postfach 101344, 03013 Cottbus, Germany — [2]IHP/BTU Joint Lab, Postfach 101344, 03013 Cottbus, Germany — [3]National Institute of Materials Physics, PO Box MG-7, 077125 Bucharest Magurele, Romania — [4]Institut für Physik, Technische Universität Chemnitz, — [5]University of Bucharest, Faculty of Physics, PO Box MG-11, 077125 Bucharest Magurele, Romania

We present the non-linear I-V characteristics of a nanoscale metal-oxide-semiconductor field-effect-transistor in the Landauer-Büttiker formalism. In our three-dimensional ballistic model the gate, source and drain contact are treated on an equal footing. As in the drift-diffusion regime for ballistic transport a saturation of the drain current results. We demonstrate the quantum mechanism for the ballistic drain current saturation. As a specific signature of ballistic transport we find a specific threshold characteristic with a close-to-linear dependence of the drain current on the drain voltage. This threshold characteristic separates the ON-state regime from a quasi OFF-state regime in which the device works as a tunneling transistor. Long- and short-channel effects are analyzed in both regimes and compared qualitatively with existing experimental data by INTEL [B. Doyle et al., Intel Technol. J. 6, 42, (2002)].