TT 24: Focus Session: Functional Semiconductor Nanowires II (organized by HL)

This is the continuation of the morning session "Functional semiconductor nanowires I".

Organization: Carsten Ronning (FSU Jena), Martin Eickhoff (JLU Giessen), Tobias Voss (TU Braunschweig)

Time: Monday 15:00–18:45 Location: EW 201

Invited Talk TT 24.1 Mon 15:00 EW 201

Light-matter interaction in wire cavities - from Purcell effect to Bose-Einstein condensates — •Rüdiger Schmidt-Grund — Universität Leipzig, Inst. für Exp. Physik II, Leipzig, Germany

I will discuss effects emerging in different regimes of light-matter interaction in, basically, ZnO-based nano- and micro-wire cavities of various type. The superior crystal quality along with very smooth surfaces of that self-organized structures allows for the observation of bosonic quantum effects like parametric mixing and multi-mode bosonic final state stimulation respective Bose-Einstein condensation (BEC), which in particular benefit from the rich mode structure of such cavities.

Depending on the photonic confinement strength lasing arises gained by electron-hole plasmas [1], from coherent photonic states fed by stimulated exciton-phonon scattering [2], and from BECs of exciton-polaritons [3]. Further, lateral conformal coating with concentric distributed Bragg reflector (DBR) shells prevents lateral losses and causes Purcell enhancement of the states lifetime in typical micropillar cavities [4]. The involved photonic modes are of one-dimensional Fabry-Perot and Whispering-Gallery type. In bare wires, usually modes of only one of these types can be observed. In DBR coated nano-wire cavities, both can coexist being at the same time in the strong and weak coupling regime with the electronic system.

[1] C. Czekalla *et al*, phys. stat. sol. b **247**, 1282 (2010). [2] T. Michalsky *et al*, Appl. Phys. Lett. **105**, 211106 (2014). [3] C.P. Dietrich *et al*, Phys. Rev. B: Rapid Comm. (2015). [4] T. Jakubczy *et al*, ACS Nano **8**, 9970 (2014).

TT 24.2 Mon 15:30 EW 201

GaAs/AlGaAs core shell nanowire lasers and their integration on Si — •Sabrina Sterzl[1], Benedikt Mayer[1], Lisa Janker[1], Bernhard Loitsch[1], Gerhard Abstreiter[1,2], Christopher Gies[3], Gregor Koblmüller[1], and Jonathan Finley[1] — [1]Walter Schottky Institut and Physik Department, TU München, Garching, Germany — [2]Institute of Advanced Studies, TU München, Garching, Germany — [3]Institute for Theoretical Physics, University of Bremen, Bremen, Germany

We present lasing from individual GaAs/AlGaAs core shell nanowires (NWs) under pulsed and continuous wave (CW) optical excitation. The tailored composition profile of the NW lasers studied by photolumines- cence measurements reveals highly efficient fundamental mode lasing with emission coupling efficiencies (β) up to 0.1, ultrafast pulse emission down to 5ps as well as CW operation. Monolithic integration of the NW lasers is achieved by a universally applicable porous dielectric SiO2 reflection layer on top of the Silicon growth substrate. The SiO2 layer maintains direct contact of the NW core to the substrate and provides sufficient reflectivities for lasing operation directly on Si. The fast pulse emission found in our experiments are in good agreement with theoretical calculations predicting possible repetition rates up to 33GHz. The findings demonstrate the versatility and high functionality of the coherent on-chip NW light sources.

TT 24.3 Mon 15:45 EW 201

Time-resolved optical spectroscopy of InGaN/GaN 3D-LEDs — •Linus Krieg[1], Johannes Dühn[1], Kathrin Sebald[1], Jürgen Gutowski[1], Christian Tessarek[2], Martin Heilmann[2], Silke Christiansen[2], and Tobias Voss[3] — [1]Institute of Solid State Physics, University of Bremen — [2]Max-Planck-Institute for the Science of Light, Erlangen — [3]Institute of Semiconductor Technology, TU Braunschweig

GaN is an efficient and widely established material for optoelectronic devices, especially light-emitting diodes (LEDs). Core-shell InGaN/GaN nano- and microrod structures are supposed to further improve the efficiency and spectral range of conventional GaN-based structures leading to LEDs in the green-to-ultraviolet spectral region. Using optical spectroscopy, we perform a characterisation of self-assembled GaN micro- and nanorods with an embedded threefold InGaN quantum well (QW). The GaN rod structures were grown in a vapour-liquid-solid (VLS) growth mode. Afterwards, InGaN QWs were deposited around the rods. After using time-integrated photoluminescence measurements to analyse the concentration and homogeneity of the indium, we focus on time-resolved optical spectroscopy and determine the temperature dependent decay times. The tip of the micro- and nanorods is partly covered with a GaN pyramid. By using micro-PL measurements, we can determine the InGaN distribution on the tip as well as the impact of the GaN pyramid. Our results show a clear decrease of decay time with rising temperature and a spectral shift of the luminescence originating from the tip.

TT 24.4 Mon 16:00 EW 201

Surface functionalization and its influence on excitonic emission of ZnO nanowires — •Lisa Schade[1], Sebastian Resch[2], Sascha Creutzburg[1], Robert Röder[1], Davide Cammi[1], Siegfried R. Waldvogel[2], and Carsten Ronning[1] — [1]Institut für Festkörperphysik, FSU Jena, Max-Wien-Platz 1, 07743 Jena — [2]Institut für Organische Chemie, JGU Mainz, Duesbergweg 10-14, 55128 Mainz

Semiconductor nanowires (NW) are expected to serve as a basis for next-generation high performance devices as they serve as functional and the electrical or optical connection unit for new devices with enhanced properties. This implementation has already succeeded for NW field effect transistors as well as photonic devices like LEDs, waveguides and lasers. The combination of inorganic semiconductors and organic molecules promises hybrid systems with superior functionality. Electrical and optical properties of semiconductor NWs are very sensitive to the treatment of the surface due to the high surface-to-volume ratio, thus especially the surface bound exciton becomes a dominant feature in low temperature photoluminescence spectra, indicating information about the surface properties. For that reason ZnO NWs were coated with organic molecules and photoluminescence measurements were taken before and after the functionalization. There are some anchor-groups, which are suited for functionalization: e.g. -COO-Bu_4N^+ and -Si$(C_2H_5O)_3$ allowing the link of different chains like e.g. C_6F_{12}-C_2H_4- and C_8- . Further functionality increase will be achieved by linking organic dyes for photonic devices.

TT 24.5 Mon 16:15 EW 201

Carrier dynamics in GaN-nanowire based AlN/GaN heterostructures doped with Germanium — •Nils Rosemann[1], Pascal Hille[2], Jan Müssener[2], Pascal Becker[2], María de la Mata[3], César Magén[4], Jordi Arbiol[3,5], Jörg Teubert[2], Jörg Schörmann[2], Martin Eickhoff[2], and Sangam Chatterjee[1] — [1]Faculty of Physics and Materials Sciences Center, Philipps-Universität Marburg, Renthof 5, D-35032 Marburg, Germany — [2]I. Physikalisches Institut, Justus-Liebig-Universität Gießen, Heinrich-Buff-Ring 16, D-35392 Gießen, Germany — [3]Institut de Ciencia de Materials de Barcelona, ICMAB-CSIC, Campus de la UAB, ES-08193 Bellaterra, CAT, Spain — [4]Laboratorio de Microscopas Avanzadas, Instituto de Nanociencia de Aragon-RAID, Universidad de Zaragoza, ES-50018 Zaragoza Spain — [5]Institucio Catalana de Recerca I Estudis Avantas (ICREA), ES-08010 Barcelona, CAT, Spain

Wide gap materials based on AlN/GaN are promising candidates for opto electronic devices in the UV-range. Here, nanowires (NWs) are of particular interest as they exhibit a significantly reduced potential for structural defects compared to bulk due to efficient strain-relaxation during the self-assembled growth. We investigate the influence of Ge doping which has a much larger covalent radius than Si or Mg on a series of AlN/GaN structures based on GaN NWs using a streak-camera setup with high spatial resolution.

TT 24.6 Mon 16:30 EW 201

Luminescence dynamics of hybrid ZnO nanowire/CdSe quantum dot structures — •Stephanie Bley[1], Friederike Albrecht[1], Michael Diez[1], Alejandra Castro-Carranza[1], Jürgen Gutowski[1], and Tobias Voss[2] — [1]Institute of Solid State Physics, Semiconductor Optics, University of Bremen, 28359 Bremen,

Germany — [2]Institute of Semiconductor Technology , Braunschweig University of Technology, 38106 Braunschweig, Germany

The development of cheap and efficient hybrid solar cells, which show high absorption, and a fast and efficient conversion of the incident photon energy into electrical energy is of paramount interest for regenerative energy applications. To achieve that, colloidal CdSe quantum dots with different organic linker molecules were attached to ZnO nanowires to study the luminescence dynamics and the electron transfer inside these hybrid nanostructures via time-resolved photoluminescence and photoconductivity experiments. Photo-induced electron tunneling from an excited state of the QD into the nanowire becomes visible by a particular decrease of the QD decay time. This will be discussed by introducing an appropriate rate equation model. The electron tunneling is further clearly verified by a strong enhancement of the photocurrent which can be controlled by different linker molecule lengths. Further, the influence of surface oxidation on the luminescence dynamics and electron transfer will be discussed by studying polymethylmethacrylate- and polystyrene-passivated hybrid structures.

Coffee break

Invited Talk TT 24.7 Mon 17:00 EW 201

Quantum Transport in Core/Shell Semiconductor Nanowires — •Thomas Schäpers, Fabian Haas, Patrick Zellekens, Torsten Rieger, Tobias Wenz, Yusuf Günel, Önder Gül, Natalia Demarina, Mihail Lepsa, Hans Lüth, and Detlev Grützmacher — Peter Grünberg Institute (PGI- 9) and JARA-Fundamentals of Future Information Technology, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany

The transport properties of GaAs/InAs core/shell nanowires is investigated, where the highly conductive InAs shell is wrapped around an insulating GaAs core nanowire. At low temperatures pronounced flux periodic (h/e) magnetoconductance oscillations are observed, when the magnetic field is oriented along the nanowire axis. These very regular oscillations are explained by the formation of closed-loop quantum states in the tube-like InAs shell comprising a flux periodic energy spectrum. The magnetoconductance oscillations are even observed at temperatures as high as 50K. When the GaAs/InAs core/shell nanowire is contacted by two superconducting Nb electrodes the carrier transport is governed by phase-coherent Andreev reflection processes. Here, the observed oscillation period in the magneto-transport corresponds to half a flux quantum (h/2e).

TT 24.8 Mon 17:30 EW 201

Influence of growth parameters on electrical transport characteristics in InAs Nanowires — •Jonathan Becker[1], Stefanie Morkötter[1], Phillip Geselbracht[1], Julian Treu[1], Simon Hertenberger[1], Max Bichler[1], Gerhard Abstreiter[1,2], Jonathan J. Finley[1], and Gregor Koblmüller[1] — [1]Walter Schottky Institut und Physik Department, TU München, Garching, Germany — [2]Walter Schottky Institut and Physik Department, TU München, Garching, Germany

In this work we present recent results on the electrical transport of nominally undoped MBE grown InAs nanowires (NWs). In particular we explore the influence of growth parameters, microstructure, aspect ratio and contact metal on the electrical properties of the NWs. Four-terminal measurements on planar, back-gated NW field effect transistor (NWFET) devices revealed room-temperature mobilities ranging from 500 to 2000 cm^2/Vs and on-off ratios of $>10^3$ at 4.2K. The obtained electron densities are in the order of $10^{17}cm^{-3}$. A strong effect of the diameter and the microstructure, altered by growth parameters, on the mobility was observed. The latter was investigated by HRTEM, simulations and temperature-dependent measurements in high detail. Here, the impact of band discontinuieties induced by stacking faults and WZ/ZB crystal phase boundaries on electron scattering is evaluated.

TT 24.9 Mon 17:45 EW 201

Giant Magnetoconductance Oscillations in Hybrid Superconductor - Semiconductor Core/Shell Nanowire Devices — •Fabian Haas[1,2], Önder Gül[1,2], Haci Yusuf Günel[1,2], Hans Lüth[1,2], Torsten Rieger[1,2], Tobias Wenz[1,2], Patrick Zellekens[1,2], Mihail Lepsa[1,2], Gregory Panaitov[1,2], Detlev Grützmacher[1,2], and Thomas Schäpers[1,2] — [1]Peter Grünberg Institute (PGI-9 and PGI-8), Forschungszentrum Jülich GmbH, 52425 Jülich, Germany — [2]JARA - Fundamentals of Future Information Technology

In GaAs/InAs core/shell nanowires the electrons are confined in the cylindrical conductive InAs shell. In recent publications we have shown that this InAs nanotube allows the observation of h/e flux periodic oscillations in the nanowires magnetoconductance, when a magnetic field is aligned in parallel with the nanowire axis.

In this contribution, we present novel magnetotransport measurements of GaAs/InAs core/shell nanowires, this time contacted with two superconducting Nb electrodes. We observe regular $h/2e$ half-flux periodic oscillations with amplitudes in the order of e^2/h, which is larger by two orders of magnitude than observed for the h/e oscillations in a reference sample contacted with Ti/Au leads.

Phase-coherent resonant Andreev reflections at the Nb-nanowire interface, where interfering electron-hole trajectories enclose the penetrating magnetic flux, can explain these strongly enhanced oscillations as well as the $h/2e$ flux periodicity.

TT 24.10 Mon 18:00 EW 201

Heterogenous Assembly of Silicon Nanowires for Battery Applications — •Andreas Krause[1,2], Matthias Grube[1], Jan Brückner[3], Susanne Dörfler[3], Ulrike Langklotz[4], Tony Jaumann[5], Florian M. Wisser[6], Thomas Mikolajick[1,2,7], and Walter M. Weber[1,2] — [1]Namlab gGmbh, 01187 Dresden — [2]Center for Advancing Electronics Dresden (CfAED), TU Dresden — [3]Fraunhofer Institute for Material and Beam Technology (IWS), 01277 Dresden — [4]Fraunhofer Institute for Ceramic Technologies and Systems (IKTS), 01277 Dresden — [5]Chemistry of Functional Materials (IKM), Leibniz Institute for Solid State and Materials Research (IFW), Dresden — [6]Department for Inorganic Chemistry I, Dresden University of Technology, Germany — [7]Chair of Nanoelectronic Materials, Institute of Semiconductor and Microsystems Technology, TU Dresden

Silicon is a promising anode material for Lithium storage due to its high theoretical specific capacity surpassing 4200 Ah/kg, but with a large volume expansion of 400 per cent. We show innovative anode assemblies composed of a forest of free standing Si nanowires conformally integrated on a carbon fiber network. The morphology of Si nanowires allows a volume expansion and compression lowering strain incorporation. TEM micrographs of samples before and after cycling in a battery stack show the morphology change of the incorporated nanowires. A detailed electrochemical analysis is done on various samples and shows an increased stability of Si with a remaining effective capacitance above 2000 Ah/kg(Si) after 225 full charge/discharge cycles.

TT 24.11 Mon 18:15 EW 201

Monitoring cation exchange from CdSe to Ag_2Se in individual nanowires. — •Cornelius Fendler[1], August Dorn[1], Hauke Heller[2], Andreas Kornowski[2], Robert Schön[2], and Robert Blick[1] — [1]Center for Hybrid Nanostructures, Institutes of Nanostructure and Solid State Physics, University of Hamburg, Jungiusstrasse 11c, 20355 Hamburg, Germany — [2]2Institut for physical chemistry, Grindelallee 117, 20146 Hamburg

Cation exchange is a relatively simple tool to broaden the range of material compositions available in nanostructures.[1] With sufficient monitoring tools, partial cation exchange can be used to tune the material properties to desired values.[2]

In this study we investigated the correlation between the electrical conductivity and the degree of the exchange from CdSe to Ag_2Se on individuelal nanowires. We used the solution-liquid-solid (SLS) process to directly grow CdSe nanowires off bismuth thin films on Si/SiO_2-substrates. Single CdSe wires with diameters of 30 nm to 100 nm and lengths exceeding 10 μm were contacted with titanium electrodes by confocal laser lithography. The conductivity of the individual nanowires was monitored in situ during the cation exchange reaction from CdSe to Ag_2Se. At different stages of the cation exchange reaction the samples were removed from solution, the voltage-current-characteristics were measured and the material composition was determined by wavelength-dispersive X-ray spectroscopy (WDS).

[1] J.B. Rivest et al., Chem. Soc. Rev.,2013, 42, 89.

[2] A. Dorn et al., Nano Lett. 2010, 10, 3948-3951.

TT 24.12 Mon 18:30 EW 201

Charge transport along GaAs nanowires: Surface conductivity and band bending — •Stefan Korte[1], Matthias Steidl[2], Weihong Zhao[2], Werner Prost[3], Felix Lüpke[1], Vasily

Cherepanov[1], Bert Voigtländer[1], Peter Kleinschmidt[2], and Thomas Hannappel[2] — [1]Peter Grünberg Institut (PGI-3), Forschungszentrum Jülich, 52425 Jülich, Germany, and JARA-Fundamentals of Future Information Technology — [2]Photovoltaics Group, Institute for Physics, Technische Universität Ilmenau, 98684 Ilmenau, Germany — [3]CeNIDE and Center for Semiconductor Technology and Optoelectronics, University of Duisburg-Essen, 47057 Duisburg, Germany

Using a multi-tip STM as nanoprober to explore the electrical transport properties of freestanding *p*-doped GaAs nanowires, we revealed a highly increased resistivity in the nanowire base, which caused bad contact to the substrate. This high resistance can be explained by a charge carrier depletion through the whole nanowire cross section due to Fermi level pinning at surface states. To explore this, Zn-doped GaAs nanowires were grown by Au-assisted metal-organic vapor-phase epitaxy (MOVPE) in the vapor-liquid-solid growth mode with different growth procedures. We measured and analyzed I/V characteristics and resistance profiles to understand the conduction mechanisms and band bending along these nanowires.