HL 69: Quantum dots and wires III

Time: Thursday 15:00–18:00 Location: POT 151

Invited Talk HL 69.1 Thu 15:00 POT 151

Scaling networks of compound semiconductor nanowires — •Anna Fontcuberta i Morral — Ecole Polytechnique Fédérale de Lausanne, EPFL

Nanowires are filamentary crystals with a tailored diameter between few and 100 nm [1,2]. Their shape anisotropy and size confer them with advantageous properties in a variety of areas ranging from photonics to quantum computing [3-6]. In all applications, deterministic site selective growth of nanowires is absolutely necessary. In this talk we will explain how nanowires can be obtained in arrays both free standing and lying on a substrate, in a scalable manner. We will also show how the properties such as enhanced light absorption and mobility can be engineered, opening the path to advanced functionality.

[1] P. McIntyre, A. Fontcuberta i Morral, Materials Today Nano https://doi.org/10.1016/j.mtnano.2019.100058 [2] L. Güniat et al, Chemical reviews 119, 8958-8971 (2019) [3] P. Krogstrup et al, Nature Photon. 7, 306 (2013) [4] R. Frederiksen et al, ACS Photon. 4, 2235-2241 (2017) [5] M. Friedl et al, Nano Lett. 18, 2666 (2018) [6] J. Vukajlovic-Plestina, Nature Comm. 10, 869 (2019)

HL 69.2 Thu 15:30 POT 151

Ultra-doped Germanium nanowires using ion implantation and flash-lamp anneling — •Ahmad Echresh, Mao Wang, Yufang Xie, Slawomir Prucnal, Yordan M. Georgiev, and Lars Rebohle — Helmholtz Zentrum Dresden Rossendorf, Dresden, Germany

Germanium (Ge) is a promising high mobility channel material for future nanoelectronics. Materials with high carrier mobility can enable increased integrated circuit functionality or reduced power consumption. Hence, Ge based nanoelectronic devices could offer improved performance at reduced power consumption compared to Si electronics. In this work, Germanium-on-insulator (GeOI) substrates were doped with phosphorous (P) using ion beam implantation followed by flash lamp annealing (FLA). During FLA, the implanted layer recrystallized and P was electrically activated. Then, Ge nanowires were fabricated using electron beam lithography and inductively coupled plasma etching. Raman spectra showed amorphisation of the Ge structure after implantation and good recovery after FLA. Rutherford backscattering spectrometry measurements were used to verify the crystal quality of Ge layer before and after FLA. Moreover, Hall effect measurement configuration is designed for single Ge nanowires to determine the carrier mobility and carrier concentration. The results of these measurements will be shown at the conference. The goal is to fabricate a p-n junction along the Ge nanowires and use them as infrared sensors.

HL 69.3 Thu 15:45 POT 151

Electrical Characterisation of Te-doped InAs Nanowires — •Anton Faustmann[1], Pujitha Perla[1,3], Detlev Grützmacher[1,2,3], Mihail Lepsa[2,3], and Thomas Schäpers[1,3] — [1]Peter Grünberg Institute (PGI-9), Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Peter Grünberg Institute (PGI-10), Forschungszentrum Jülich, 52425 Jülich, Germany — [3]JARA-Fundamentals of Future Information Technology (JARA-FIT), Jülich-Aachen Research Alliance, Germany

InAs features high electron mobility and absence of a Schottky barrier at metal interfaces enabling ohmic contacts. In combination with large g-factor and high Rashba spin-orbit coupling this makes InAs nanowires a promising candidate for research of quantum effects.

InAs nanowires with Te doping grown by molecular beam epitaxy were investigated in terms of their electrical transport properties at both room and cryogenic temperatures. The nanowires were grown in a catalyst-free vapour-solid process without using Au droplets. In contrast to Si, which shows amphoteric behaviour, Te acts as n-type dopant. It furthermore offers the possibility of an increased overall doping level. The Te doping concentration was found to affect both the morphology of the nanowires as well as electrical properties. The shape of the nanowires depends on Te uptake. Their intrinsic as well as contact resistances decrease considerably at increased doping level. Field-effect measurements using a global back gate show great effect on the conductance, however no complete pinch-off was observable with conductance saturating at high negative gate voltages. Resistances were found to be only slightly increased at cryogenic temperatures.

HL 69.4 Thu 16:00 POT 151

Polar optical phonons' splitting in nanowires — •Norma Rivano[1], Thibault Sohier[1,2], and Nicola Marzari[1] — [1]Theory and Simulation of Materials (THEOS) and National Centre for Computational Design and Discovery of Novel Materials (MARVEL), École Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland — [2]nanomat/QMAT/CESAM and European Theoretical Spectroscopy Facility, Université de Liège, Belgium

The need for an accurate description of the vibrational properties of 1D materials is strongly motivated by the growing interest in low-dimensionality in general and semiconductor nanowires in particular. Dimensionality has been shown to have an important impact on materials' properties, thus being crucial for both fundamental understanding and technological applications. At small momenta, longitudinal and transverse polar-optical modes are known to undergo a frequency splitting which depends upon the phonon wave-vector, the effective charges, the dielectric properties and the dimensionality of the system. Indeed, in the long-wavelength limit, the amount of electrostatic energy built up by the longitudinal polar-optical phonons is finite in 3D, but it vanishes in 2D. Here, we show that it also vanishes in 1D, but with a different asymptotic behavior. We also discuss the role of the nanowire's radius, which is particularly relevant for characterization through Raman spectroscopy. To this aim, we develop an analytical model and compare it with ab-initio simulations. We provide insights into the vibrational physics of nanowires as well as a ready-to-use tool for the experimental community to encourage further studies.

30 min. break.

HL 69.5 Thu 16:45 POT 151

Fluorescence spectral diffusion of single type-II semiconductor ZnSe/CdS dot-in-rod nanostructures at room and cryogenic temperatures — •Hans Werners, Sven-Hendrik Lohmann, Christian Strelow, Alf Mews, and Tobias Kipp — Institut für Physikalische Chemie, Universität Hamburg, Grindelallee 117, 20146 Hamburg, Germany

In this work, we investigate type-II dot-in-rods, where the intrinsic band offset leads to a spatial separation of the electron and hole wavefunctions. Fluorescence measurements at room temperatures of our ZnSe/CdS DRs show a monoexponential decay and an emission energy that can be assigned to an interface recombination between an electron in the shell and a hole in the core. The ensemble fluorescence lifetimes exceeds 100 ns at room temperature. We use confocal fluorescence spectroscopy at cryogenic temperatures and observe abrupt spectral shiftings of the emission line over time, superimposed on smoother spectral diffusion processes. The spectral diffusion covers a larger range in energy than for type-I CdSe/CdS DRs [1], indicating the larger susceptibility of type-II structures to external stimuli, like surface charges. At cryogenic temperatures, we measure shorter fluorescence lifetimes compared to room temperature measurements. We observe a biexponential decay and the fluorescence lifetime-intensity distribution (FLID) suggest stable trion emission at low temperatures. To further analyze the temperature dependency of the charge carrier dynamics, we use time resolved transient absorption measurements.

[1] Lohmann et al., ACS Nano 11, 12185-12192 (2017)

HL 69.6 Thu 17:00 POT 151

Monolithic co-integration of III-V compound semiconductors on silicon using a multiple step relaxation technique — •Ramasubramanian Balasbramanian[1], Vitalii Sichkovskyi[1], Johann Peter Reithmaier[1], Larisa Popilevsky[2], Gadi Eisenstein[2], Galit Atiya[3], and Yaron Kauffmann[3] — [1]University of Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germnany — [2]Russel Berrie nanotechnology Institute, Technion, Haifa 32000, Israel — [3]Material Science and Engineering Dep., Technion, Haifa 32000, Israel

Monolithic co-integration of III-V compound semiconductors on Si intends to combine advantages of both materials in a single chip. Si possesses excellent electronic, thermal and mechanical properties, whereas III-V materials exhibit excellent photonic properties due to their direct band gap. Development of defects, due to the differences in thermal expansion coefficient and lattice constants between III-V materials and

Si, are filtered using Dislocation Filtering Layers (DFLs) which are either strained layer super lattices or highly strained QDs. Here, we report on the integration of InP and GaAs on 5° off-cut Si wafers by MBE using DFLs. The grown structures are characterized using high resolution transmission electron microscopy (HRTEM), atomic force microscopy and photo luminescence (PL) spectroscopy. HRTEM studies showed an efficient dislocation reduction by DFLs. The InP based laser structure grown on top of such DFL buffer showed PL properties comparable to the reference one grown directly on InP . RWG lasers are being processed and results will be discussed during the conference.

HL 69.7 Thu 17:15 POT 151

Fabrication and Characterization of Reconfigurable Field Effect Transistors — •Muhammad Bilal Khan, Sayantan Ghosh, Slawomir Prucnal, René Hübner, Artur Erbe, and Yordan M. Georgiev — Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany

To complement scaling down of CMOS, new device concepts have been introduced. These concepts include undoped silicon nanowire (SiNW) based reconfigurable field effect transistors (RFETs). In an RFET, SiNWs are nickel silicided at both ends. This results in silicide-Si-silicide Schottky junctions. Two distinct gate electrodes are placed on these junctions. By controlling the electrostatic potential on the gate electrodes, the RFET is programmed to p- or n-polarity. We report on fabrication and electrical characterization of top-down fabricated SiNW based RFETs. Flash lamp annealing is used for silicidation instead of rapid thermal annealing for better control over the silicidation process. Different gate dielectrics are used to improve the device performance.

HL 69.8 Thu 17:30 POT 151

Influence of UiO-66 Metal-Organic Framework Synthesis on contacted Carbon Nanotubes — •Marvin J. Dzinnik[1], Benedikt B. Brechtken[1], Hendrik A. Schulze[2], Peter Behrens[2], and Rolf J. Haug[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany — [2]Institut für Anorganische Chemie, Leibniz Universität Hannover, Callinstrasse 9, 30167 Hannover, Germany

Carbon Nanotubes (CNT) and metal-organic framework (MOF) hybrid materials are candidates for novel sensors [1]. While in previous experiments MOFs were synthesized on carbon nanotube networks [1] we are presenting measurements on individual multi-walled CNTs with UiO-66 MOFs.

We show the electronic properties of CNT samples before and after the MOF synthesis. DC-transport measurements were used in order to investigate the change in conductivity due to the MOF synthesis. The measured conductance decreased by a factor of 30. The electrical properties of the CNTs after the synthesis show Tomonaga-Luttinger liquid behavior indicating that the carbon nanotube still behaves as a one-dimensional system. In a further experiment a MOF between a contact and the CNT was used as a dielectric medium in a transistor setup. A positive gate voltage leads to a lower conductance of the CNT showing the gate action.

[1] H. A. Schulze et al., ChemNanoMat, 5, 1159-1169, (2019).

HL 69.9 Thu 17:45 POT 151

Shell-filling and spin-valley coupling in gate-defined BLG quantum dots — Luca Banszerus[1,2], •Samuel Möller[1], Eike Icking[1], Christian Volk[1], Kenji Watanabe[3], Takashi Taniguchi[3], and Christoph Stampfer[1,2] — [1]2.Physikalisches Institut A, RWTH Aachen University, Germany — [2]Peter Grünberg Institute (PGI-9), Forschungszentrum Jülich, Germany — [3]National Institute for Materials Science,1-1 Namiki, Tsukuba, 305-0044, Japan

We present a gate-defined single quantum dot in electrostatically gapped bilayer graphene with full occupational control up to the first electron. Quantum dot states are examined by applying perpendicular and in-plane magnetic fields to the sample at low and high bias, allowing to extract addition energies and g-factors. We obtain the electron g-factor of 2 and valley g-factors in the order of 30, depending on the orbital state. Each orbital state (shell) is occupied four times due to the spin and valley degrees of freedom in graphene. Single particle states are found sufficient to describe the ground state (excited states) of the quantum dot up to occupations of 12(8) electrons. The order of states in which electrons enter the quantum dot is extracted and found to be constant across shells. Remarkably, we find the fourfold degeneracy at zero magnetic field is lifted. Instead, two pairs each with two states of opposite spin and valley form. We denote this phenomenon to an effective spin-valley coupling of 0.5 meV.