HL 48: Quantum dots and wires: preparation and characterization II

Time: Thursday 16:15–18:00 Location: H13

HL 48.1 Thu 16:15 H13

Evidence for Reduction of the Critical Nucleus in InAs/GaAs Quantum Dot Stacks — •Thomas Hammerschmidt[1,3], Peter Kratzer[2,3], and Matthias Scheffler[3] — [1]Department of Materials, University of Oxford, Oxford, UK — [2]Fachbereich Physik, Universität Duisburg-Essen, Duisburg, Germany — [3]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany

Growth of quantum dot (QD) stacks is a possible route to influence the lateral arrangement of self-assembled semiconductor QDs. In stacks of InAs QDs in GaAs, the QDs in a new layer form preferably right above those in the previous layer. Is is surprising, how the weak interactions of surface atoms with the buried QD trigger this 'correlated' growth. In this work we offer a quantitative explanation based on the influence of elastic interactions on the critical nucleus for QD formation.

In particular, we apply a recently developed Abell-Tersoff potential to realistic QD nanostructures. For the formation of a new layer of QDs on a capping layer above a layer of buried QDs, we study systematically the formation energy as a function of lateral distance of buried and free-standing QD. We find it to be minimal if the free-standing QD is placed exactly vertically above the buried QD, in line with the growth correlation observed in most experiments of stacked QD growth. The elastic interactions observed in our calculations lower the energy barrier for QD nucleation by up to 2 eV per QD as compared to nucleation in a single QD layer. The size of the critical nucleus thereby reduces from approximately 70 to not more than 25 InAs units.

HL 48.2 Thu 16:30 H13

InP-quantum dots: Towards high temperature emission — •Wolfgang-Michael Schulz, Robert Rossbach, Michael Jetter, Matthias Reischle, Gareth Beirne, and Peter Michler — Institut für Strahlenphysik, Allmandring 3, 70569 Stuttgart, Germany

To increase the carrier confinement and luminescence at elevated temperatures for InP-quantum dots, we embedded them in $Al_{0.50}Ga_{0.50}InP$. Atomic force microscope measurements are showing a bimodal size distribution of uncapped samples, which can also be seen in the photoluminescence measurements. From time-resolved, power- and temperature-dependent PL measurements, we could deduce a confinement energy of 274 meV for small A-type dots and 572 meV for bigger B-type dots. Therefore, the temperature where the thermal reemission of the carriers out of the dots dominates, could be estimated to 160 K for A-type, respectively 250 K for B-type dots. The sample also shows a thermally induced, wetting layer assisted carrier transfer between these bimodal dots, increasing the luminescence intensity of the A-type dots at elevated temperatures. A further increase of the luminescence at elevated temperatures was achieved by placing the QD layer on top of a DBR structure. On account, luminescence up to 460 K was observable. The zero-dimensional behavior was verified with high resolution μ-PL and autocorrelation measurements, showing single photon emission at 4 K.

HL 48.3 Thu 16:45 H13

Growth condition dependence of MOVPE InGaN quantum dots — •Christian Tessarek, Tomohiro Yamaguchi, Jens Dennemarck, Stephan Figge, and Detlef Hommel — Universität Bremen, Otto-Hahn-Allee 1, 28359 Bremen

InGaN is a very interesting material for optical application due to the blue-green emission. The implementation of InGaN quantum dots into the active region promises an improvement in optical behavior as well as in device performance. The conventional growth method to a strain driven formation of quantum dots is the Stranski-Krastanov growth mode. The problem is the capping process, which causes a dissolution of the dots. We develop a novel two-step growth method. A first In(x)Ga(1-x)N nucleation layer is stabilized by a second In(y)Ga(1-y)N formation layer with different indium compositions (y<x) in the two-step growth method. The existence of quantum dots is confirmed by micro-PL-measurements for this structure [1]. The influence of nucleation layer growth parameters like temperature, (TM)In-flux and thickness is further investigated with PL-measurements. XRD-results will show strain relaxation due to increasing number of stacking layer. First EL-results will be also presented for the implementation of quantum dots into LED device structure. [1] K. Sebald, H. Lohmeyer, J. Gutowski, T. Yamaguchi and D. Hommel, phys. stat. sol. (c) 243, 1661-1664 (2006)

HL 48.4 Thu 17:00 H13

Stability and structure of free-standing III-V nanorods: An ab initio investigation — •Roman Leitsmann and Friedhelm Bechstedt — Friedrich-Schiller Universit\"at Jena, Institut f\"ur Festkörpertheorie und -optik, Max-Wien Platz 1, 07743 Jena

The interest in anisotropic needlelike crystals, especially in the ultimately thin varieties, has been recently stimulated by the potential need as building blocks for nanoscale electronic and photonic devices. Due to their considerable potential for optoelectronics or high-speed electronics nanorods consisting of III-V semiconductors are of special interest. In the most cases the growth direction of III-V semiconductor nanorods is parallel to the [111] axis of the bulk zinc-blende (zb) structure. However, the crystal structure of the nanowires may change noticable, depending on growth conditions and growth method. In particular, changes of the crystal symmetry from the cubic to the hexagonal (wurtzite - w) stacking of the cation-anion bilayers have been observed in many cases.

We report ab initio investigations of hexagon-shaped III-V semiconductor nanowires with varying crystal structure, varying surface passivation, and varying diameter [1]. Their stability is dominated by the free surface energies of the corresponding facets. We observe a phase transition between local zb and w geometry of the rods versus the preparation conditions of the surfaces. The influence of the actual III-V compound InAs, GaAs, and InP remains small.

[1] R. Leitsmann, F. Bechstedt, cond-mat/0611521, Phys. Rev. B, submitted (2006)

HL 48.5 Thu 17:15 H13

Influence of the electron injection energy on ballistic transport in nanoscale GaAs/AlGaAs cross junctions — •Matthias Wiemann[1], Ayhan Cetinkaya[1], Ulrich Wieser[1], Ulrich Kunze[1], Dirk Reuter[2], and Andreas Wieck[2] — [1]Werkstoffe und Nanoelektronik - Ruhr-Universität Bochum, D-44780 Bochum, Germany — [2]Angewandte Festkörperphysik - Ruhr-Universität Bochum, D-44780 Bochum, Germany

Ballistic electron transport is studied in a modified nanoscale cross junction prepared from a high-mobility GaAs/AlGaAs heterostructure. The device is defined by combining electron-beam lithography with standard photo lithography and is transferred by wet-chemical etching. The lateral geometry is given by a central orthogonal cross junction and two additional branches which orthogonally merge in the vertical bar on each side of the central junction. A potential barrier is formed by a nanoscale Schottky top-gate finger, which crosses the vertical bar near the central cross junction. The barrier enables to vary the kinetic energy of injected electrons. If an input bias is applied between the vertical bar embedding the barrier and an orthogonal lead of the central cross junction, negative bend resistance is found in the nonlocal I-V transfer characteristics. In this configuration V describes the potential difference between the voltage probes opposite to the current leads. If the transfer voltage is detected between the barrier free part of the vertical bar and its neighboring branch, gate-voltage dependent nonlinearities are observed.

HL 48.6 Thu 17:30 H13

Advances in Quantum Dot Fabrication by Cleaved Edge Overgrowth — •Jörg Ehehalt, Christoph Kamseder, Christian Neugirg, Christian Gerl, Dieter Schuh, and Werner Wegscheider — Universität Regensburg, Germany

Single and coupled quantum dot systems with precisely controlled sizes and positions can be fabricated using the Cleaved Edge Overgrowth (CEO) method. They result from quantum mechanical bound states at the intersection of three perpendicular GaAs quantum wells.

Due to the high degree of growth control, these quantum dots are promising candidates for research in areas like quantum computing or photon correlation. However, most applications have been prevented so far by the relatively low confinement energies in these quantum dots of up to 10 meV. This value needs to be significantly increased in order to study excited states, apply external fields without loosing confinement and increase storage times of charge carriers.

Using techniques formerly applied to CEO-grown quantum wires, such as asymmetrical structures and strained layers, the confinement energies can be substantially improved. The properties of these structures are studied by photoluminescence and photoluminescence excitation spectroscopy and compared to theoretical simulations.

These structures are now to be used to generate and detect spin-polarized charges in the quantum dots and study the properties of quantum dot molecules made by arrays of quantum dots. The results can also be applied to fabricate novel quantum wire lasers working at higher temperatures and lower threshold currents.

HL 48.7 Thu 17:45 H13

Spin resonance investigations of P-doped Si nanocrystals: Charge compensation and interface states — •Andre R. Stegner[1], Rui N. Pereira[1], Robert Lechner[1], Roland Dietmüller[1], Martin S. Brandt[1], Hartmut Wiggers[2], and Martin Stutzmann[1] — [1]Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany — [2]Universität Duisburg-Essen, Institute for Combustion and Gas Dynamics, Lotharstrasse 1, 47048 Duisburg, Germany

Silicon nanocrystals (Si-ncs) are attracting interest as a possible base material for low cost electronics and solar cells. To explore the full potential of these materials, a detailed understanding and control of doping is crucial. Si-ncs with diameters in the range 4-50 nm were grown in a low pressure microwave plasma reactor using silane and phosphine as precursor gases. In this type of isolated Si-ncs, the surface termination plays an even more significant role than for Si-ncs embedded in amorphous SiO_2 host matrices. Electron paramagnetic resonance (EPR) spectra of highly doped samples exhibit resonances originating from donor-impurity bands and dangling bond defects at the interface between the Si-ncs and their native oxide shell. Additionally, for the particles with low doping level, the characteristic EPR hyperfine signature of the P donor electrons in Si is also observed, providing proof for substitutional incorporation of dispersed P donor atoms in the Si-ncs. The influence of interface states and charge compensation effects are discussed on the basis of hydrogen thermal desorption spectroscopy and Fourier transform infrared absorption spectroscopy data.