HL 77: Quantum Dots and Wires: Optical Properties II (mainly Luminescence and Electronic Structure)

Time: Thursday 9:30–11:30 Location: EW 203

HL 77.1 Thu 9:30 EW 203

Optical properties of Arsenide-based nanowire heterostructures — •Lucas Schweickert[1], Daniel Rudolph[1], Watcharapong Paosangthong[1], Dance Spirkoska[1], Max Bichler[1], Gerhard Abstreiter[1,2], Gregor Koblmüller[1], and Jonathan J. Finley[1] — [1]Walter Schottky Institut, TU München, Garching, Germany — [2]TUM Institute for Advanced Study, Garching, Germany

We report the investigation of the optical properties of single AlGaAs/GaAs core/shell nanowires using low temperature microphotoluminescence (PL) spectroscopy. The nanowires are grown using a catalyst free method using molecular beam epitaxy on lithographically patterned SiO_2-Si(111) substrates [1]. Capping the GaAs nanowires with a thin AlGaAs shell is found to result in a drastic $> 10^3$ enhancement of the PL intensity. The influence of the capping shell thickness on the PL intensity was investigated for shell thicknesses in the range 8-100nm, under conditions where free carriers are photo-generated in the entire structure and solely in the GaAs core. Time-resolved and temperature-dependent PL studies were performed to obtain a better understanding of the mechanisms that limit the internal quantum efficiency. Furthermore, we will present first results obtained on GaAs-AlGaAs axial nanowires with axial In-containing segments. It is envisaged that optically active quantum dots can be controllably incorporated into axial core-shell nanostructures.

[1] D. Rudolph *et al.*, Nano Lett. **11**, 3848 (2011)

HL 77.2 Thu 9:45 EW 203

Geometry and electric field dependence of exciton fine structure in semiconductor quantum dots — •Erik Welander and Guido Burkard — Department of Physics, University of Konstanz, D-78457 Konstanz, Germany

We investigate theoretically the exciton fine structure splitting (FSS) in semiconductor quantum dots. The exciton, the bound state of an electron and a hole, plays the important role of the intermediate step in the biexciton cascade recombination, potentially a source of entangled photons. The two relevant states of the exciton, $|X\rangle$ and $|Y\rangle$, where X and Y correspond to polarization directions, are energetically split by the FSS. For the production of entangled photons it is essential that the FSS vanishes so that the intermediate exciton states are degenerate and the which-way information separated from frequency. Hence, a rigorous understanding of the exciton FSS is important for an accurate study of the light from a biexciton cascade recombination. Experiments have also shown a non-trivial dependence of the FSS on an external electric field. We develop a model incorporating the particle-antiparticle nature of the exciton system and find that the FSS depends on the QD geometry. Further, we investigate the effects of an external in-plane electric field, focusing on the possibility to eliminate the FSS completely.

HL 77.3 Thu 10:00 EW 203

Vertical electric field tuning of exciton fine structure splitting in strain-free GaAs/AlGaAs(001) quantum dots — ranber singh and •gabriel bester — Max-Planck-Institut für Festkörperforschung, Heisenbergstrasse 1, 70569 Stuttgart, Germany

We investigate the vertical electric field tuning of exciton fine structure splitting (FSS) in strain-free GaAs/AlGaAs(001) quantum dots. We find that the bright exciton lines anticross. However, the anticrossing is very small so that the FSS in strain-free GaAs/AlGaAs quantum dots can be easily tuned to below the radiative linewidth ($\approx 1\mu$eV) by applying vertical electric field along the growth direction. The vertical electric field tuning of FSS is also advantageous because it does not reduce the oscillator strength of exciton transitions in contrast to the significant reduction in case of lateral electric field.

HL 77.4 Thu 10:15 EW 203

Excitonic lifetimes in single GaAs quantum dots fabricated by local droplet etching — •Christian Heyn[1], Christian Strelow[2], and Wolfgang Hansen[1] — [1]Institute of Applied Physics, University of Hamburg, D-20355 Hamburg, Germany — [2]Institute of Physical Chemistry, University of Hamburg, D-20146 Hamburg, Germany

We fabricate GaAs quantum dots (QDs) embedded in an AlGaAs matrix by filling of nanoholes, that are drilled in an AlAs/AlGaAs heterostructure surface utilizing self-assembled Al droplet etching. The time-dependent optical emission of the QDs is studied using single-dot photoluminescence (PL) spectroscopy with quasi resonant excitation into the QD d-shell. The analysis of the time-dependent PL data yields a lifetime of 390 ps for excitons and 426 ps for biexcitons. In comparison to most other types of self-assembled QDs, the present GaAs QD lifetimes are short, which we attribute mainly to the influence of the emission energy. We describe the time dependent PL data by a three-level rate model, that quantitatively reproduces both the experimental decay times and the influence of the excitation power on the absolute exciton and biexciton peak intensities.

HL 77.5 Thu 10:30 EW 203

Size dependent excitonic states in self-assembled GaAs quantum dots: theory and experiment — •Andreas Graf[1], David Sonnenberg[1], Vera Paulava[1], Andrei Schliwa[2], Christian Heyn[1], and Wolfgang Hansen[1] — [1]Institut für Angewandte Physik, Universität Hamburg, 20355 Hamburg, Germany — [2]Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin, Germany

Local droplet etching (LDE) allows for a molecular beam epitaxy compatible self-assembled patterning of semiconductor surfaces. Using LDE with aluminium droplets, nanoholes with 12 nm depth are drilled in AlAs capped AlGaAs layers. Partial filling of these nanoholes with GaAs provides quantum dots (QD) with a precisely defined size. We present photoluminescence measurements of single GaAs QDs. The QD size dependent exciton and biexciton recombinations and in particular the splitting of exciton and biexciton peaks are studied. Calculations based on $\boldsymbol{k}\cdot\boldsymbol{p}$ theory and configuration interaction scheme were performed, in order to investigate the general behavior of the excitonic states in GaAs QDs as well as the influence of QD size. The comparison between measured and calculated recombination energies and intensities demonstrates good agreement.

HL 77.6 Thu 10:45 EW 203

Fundamentale Photolumineszenzuntersuchungen von Tieftemperatureigenschaften der Silizium-Nanokristall-Bandlücke — •Andreas Markus Hartel, Sebastian Gutsch, Daniel Hiller und Margit Zacharias — IMTEK, Faculty of Engineering, Albert-Ludwigs-University Freiburg, Georges-Köhler-Allee 103, 79110 Freiburg, Germany

Im Allgemeinen werden zur Beschreibung der Temperaturabhängigkeit der Bandlückenenergie von Halbleitern die empirischen Formeln nach Varshni oder Cardona angewendet. Seit der Entdeckung von Photolumineszenz von Silizium-Nanokristallen (SiNC) in oxidischer Matrix, wurde erfolglos versucht diese Beziehungen auch darauf anzuwenden. Wenngleich sich der Verlauf der Bandlücke von SiNCs sehr gut für Temperaturen bis ca. 50K anpassen lässt, gibt es aufgrund starker Blauverschiebung der PL für Temperaturen zwischen 50K und 4K starke Abweichung von den "konventionellen" Modellen. Diese Diskrepanz ist bis heute Bestandteil kontroverser Diskussionen in der Literatur und deren Herkunft bislang nicht vollständig geklärt. Anhand von größenkontrollierten SiNCs (1.5 bis 4.5nm) ist es uns gelungen die Gültigkeit der "konventionellen" Modelle auch für nanostrukturierte Materialien zu belegen. Unsere Analysen zeigen, dass sich die Abweichungen ausschließlich auf zu hohe Anregungsleistungsdichten zurückführen lassen. Weiterhin konnte ein theoretisches Modell entwickelt werden, welches es gestattet den Temperaturverlauf der PL-Intensität von SiNCs in Abhängigkeit der Anregungsleistung zu simulieren. Dieses Modell wird unter Zuhilfenahme unserer experimentellen Ergebnisse diskutiert.

HL 77.7 Thu 11:00 EW 203

Ultrasmall silicon nanoclusters, an *ab-initio* study of the photoluminescence lineshapes — •Davoud Pouladsaz — Department of Biological Physics, Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

In recent years the observations in the Red Rectangle nebula, which is famous for its extended red emission, show a blue luminescence centered at 375 nm. Although it was first supposed to be associated with

small neutral PAHs, small silicon nanocrystals with diameters of 1 nm are thought to be very good candidates for the carrier of this phenomenon. In this work, the optical properties of tetrahedral silicon nanocrystals Si_{17} and Si_{29} with hydrogen- and oxygen-passivation of surface dangling bounds are determined by the energetics of frontier orbitals and their dependence on the deformation in the relaxed excited state, using DFT, TD-DFT, and post Hartree-Fock methods. The results show a quantitative agreement between the calculated photoluminescence (PL) energy and the observed spectra better than 0.2 eV. Besides, the calculated PL linewidth agrees with experimental values within a factor of 1.2.

HL 77.8 Thu 11:15 EW 203

Computational characterisation of optical properties of CdSe nanostructures — •Farzana Aslam[1] and Christian von Ferber[1,2] — [1]Applied Mathematics Research Centre, Coventry University, UK — [2]Physikalisches Institut, University Freiburg

Quantum dots have numerous potential applications1 because their optical and electronic properties can be readily tuned by varying their size, shape, structure and composition. Rational engineering of optoelectronic devices is enabled by high quality, highly monodisperse and trap-free nanoparticles. The main focus of experimental and theoretical research on nanoparticles so far has been on the properties resulting from the quantum confinement effect and still there are many unanswered questions about the fundamental properties of nanoparticles and their surfaces.

We report the systematic investigations of the optical, electrostatic and structural trends of nanostructures using empirical potentials, dynamical simulations, time *dependent density functional theory and non-linear regime. The stability and properties of the structure of the nanostructure are studied as a function of the size, shape, structure and surface of the nanostructures. Furthermore the optical properties of different nanostructures as a result of laser matter interaction are also investigated.

[1] F. Aslam , D.J.Binks , M.D.Rahn, D.P.West, P.O*Brien , N.Pickett and S.Daniels , J.Chem. Phys,122 , 184713 (2005) [2] F. Aslam and C.von Ferber ; Shape dependent properties of CdSe nanostructures, Chemical Physics