HL 36 Optical properties

Time: Wednesday 16:15–19:15 Room: POT 151

HL 36.1 Wed 16:15 POT 151

Temperature- and size-dependence of light absorption on silicon nanoparticles — •Andreas Gondorf[1], Stephan Lüttjohann[1], Cedrik Meier[1], Axel Lorke[1], and Hartmut Wiggers[2] — [1]Laboratorium für Festkörperphysik, Universität Duisburg-Essen, 47048 Duisburg — [2]Institut für Verbrennung und Gasdynamik, Universität Duisburg-Essen, 47048 Duisburg

Silicon nanoparticles with diameters d< 8 nm show photoluminescence in the IR-red region of the spectrum. In temperature dependent studies it is found that the PL intensity exhibits a maximum around T=80K. It has been proposed that an energy splitting of the exciton state is responsible for this. However, as silicon is an indirect semiconductor one might argue that phonon emission or absorption processes play a decisive role in the temperature behaviour of the PL. Therefore, we have studied absorption spectra of silicon nanoparticles in the temperature range between T=30K and 300K in order to clarify the phonon contribution.

HL 36.2 Wed 16:30 POT 151

Type I type II transition in optical spectra - experiments and microscopic theory — •Christoph Schlichenmaier[1], Angela Thränhardt[1], Torsten Meier[1], Jörg Hader[2], Jerome V. Moloney[2], Stephan W. Koch[1], Kristian Hantke[1], Wolfgang Rühle[1], Heiko Grüning[1], Peter J. Klar[1], and Wolfgang Heimbrodt[1] — [1]Fachbereich Physik, Philipps-Universität Marburg, Renthof 5, 35032 Marburg — [2]Arizona Center for Mathematical Sciences, The University of Arizona, Tucson, AZ 85721, USA

The band alignment of GaNAs in heterostructures is determined by investigating the energetically lowest optical band-to-band transition of $In_{0.23}Ga_{0.77}As/GaN_yAs_{1-y}$ samples with varying y. In a type II alignment this transition is between states located in different layers. Photoreflectance, photoluminescence, and the radiative decay of excited carrier densities are both measured and microscopically modeled. The bandstructure for every sample is computed. Based on this bandstructure all optical properties and the radiative decay are computed using the semiconductor Bloch [1] and luminescence [2] equations including electron-electron and electron-phonon interaction on scattering level. Thus the modeling is consistent and without free parameters. Overall good agreement between theory and experiment is achieved and used to explain all experimental features and to determine the band alignment [3,4].

[1] J. Hader et al., Sol. State El. **47**, 513 (2003)
[2] M. Kira et al., Prog. Quantum Electron., **23**, 189 (1999)
[3] C. Schlichenmaier et al., Appl. Phys. Lett., **86**, 081903, (2005)
[4] K. Hantke et al., Phys. Rev. B, **71**, 165320 (2005)

HL 36.3 Wed 16:45 POT 151

Theory of bosonic signatures in semiconductor luminescence — •Stefan Pfalz, Daniel Hägele, and Michael Oestreich — Universität Hannover, Institut für Festkörperphysik, Abteilung Nanostrukturen, Appelstr. 2, D-30167 Hannover

Much experimental and theoretical effort has been devoted to the goal of observing Bose-Einstein Condensation (BEC) of excitons in semiconductors. While this ultimate goal is still to be reached, recent experiments showed that stimulated bosonic scattering of excitons leaves a characteristic signature in the photoluminescence of direct quantum wells [1]. Luminescence at the biexciton energy is usually unpolarized due to the opposite spin orientation within the bound exciton pair. In the presence of spin polarized excitons, however, the photoluminescence exhibits a finite degree of polarization due to stimulated scattering. This signature appears already at temperatures far above the critical value for BEC. The level of theory required to explain this effect exceeds available microscopic photoluminescence theories as inclusion of exciton correlations beyond the biexcitonic level is required. Using a one-dimensional model and exact diagonalization, we calculate photoluminescence spectra for the case of high exciton densities and find good qualitative agreement with experiments. Bosonic signatures are also found in cases where the Bose-commutation relations are not perfectly fulfilled.

[1] D. Hägele, S. Pfalz, and M. Oestreich, Solid State Commun. **134**(3), 171 (2005).

HL 36.4 Wed 17:00 POT 151

1.55 μm luminescence from $InAs/In_xGa_{1-x}As_{1-y}N_y$ quantum dots grown on GaAs substrates — •Mirja Richter[1,2], Benjamin Damilano[1], Jean Massies[1], Jean-Yves Duboz[1], Dirk Reuter[2], and Andreas D. Wieck[2] — [1]Centre de Recherche sur l'Hétéro-Epitaxie et ses Applications, CNRS, Sophia-Antipolis, F-06560 Valbonne, France — [2]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany

Self-assembled InAs quantum dots (QDs) encapsulated with an $In_xGa_{1-x}As_{1-y}N_y$ (GINA) layer were grown by molecular beam epitaxy on GaAs substrates. The objective is to get efficient 1.55 μm emission from these nanostructures. The interest of adding nitrogen to the classical system $InAs/In_xGa_{1-x}As$ is that it decreases the bandgap of $In_xGa_{1-x}As$ with an enormous band bowing but also compensates parts of the strain. However, adding nitrogen introduces a high density of point defects which results in degraded photoluminescence (PL) properties. Fortunately, the density of these defects can be decreased by rapid thermal annealing (RTA). The growth process was optimized including a change in growth temperature and rate for the QDs and the GINA layer. RTA was carried out at optimized temperatures. Thereby we achieve high intensity PL emission in the 1.55 μm range with a small full width at half maximum from these InAs/GINA QDs. Finally, studies of the growth on focussed ion beam structured doping regions will be presented.

HL 36.5 Wed 17:15 POT 151

Extracting the Random Potential of Disordered Semiconductors via Directional Interference of Photoluminescence — •Peter Bozsoki[1], Walter Hoyer[1], Mackillo Kira[1], Klaus Maschke[2], Torsten Meier[1], Peter Thomas[1], and Stephan W. Koch[1] — [1]Department of Physics and Material Sciences Center, Philipps-Universität Marburg, Germany — [2]Institut de Théorie des Phénomènes Physiques, Ecole Polytechnique Fédérale, CH-1015 Lausanne, Switzerland

We suggest a new method to gain information about the influence of disorder on the emitting electronic states in semiconductors. It uses the interference contrast of the spontaneously emitted light into different directions [1]. A microscopic expression is presented for the interference contrast in a model which includes both random disorder and Coulomb interaction. This relation gives a direct access to detailed information about the effect of disorder on the electronic states.

[1] W. Hoyer et.al. PRL 93, 067401 (2004)

HL 36.6 Wed 17:30 POT 151

Semiconductor microtubes acting as optical ring resonators — •T. Kipp, H. Welsch, Ch. Strelow, Ch. Heyn, and D. Heitmann — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg

We demonstrate optical modes in InGaAs/GaAs microtubes acting as an optical ring resonator. Self-supporting microtubes with a diameter of about 5 μm and a wall thickness of about 200 nm were fabricated by optical lithography and wet-etching processes utilizing the self-rolling mechanism of strained bilayers. The optical modes were probed by the photoluminescence of InAs quantum dots embedded in the tube's wall. In this novel microtube ring resonator we find a spectrum of sharp modes. They are in very good agreement with the theoretical results for a closed thin dielectric waveguide. Financial support is acknowledged by the Deutsche Forschungsgemeinschaft via the SFB 508.

HL 36.7 Wed 17:45 POT 151

Optical activation and electrical stabilization of the ultra violet electroluminescence from SiO2:Gd gate oxide layers by fluorine and potassium co-implantations — •Slawomir Prucnal, J.M. Sun, H. Reuther, and W. Skorupa — Institute of Ion Beam Physics and Materials Research,Forschungszentrum Rossendorf,POB 510119, D-01314 Dresden, Germany.

If amorphous SiO2 is bombarded with energetic ions, various types of defects are created as a consequence of ion-solid interaction and annealing processes (oxygen deficiency centres ODC, non-bridging oxygen hole centres NBOHC, E*-centres, etc.) leading to charge trapping effects during electrical excitation. Metal-Oxide-Silicon-based light emitting diodes

(MOSLEDs) with Gd implanted SiO2 layers exhibit strong ultra violet electroluminescence (EL) at 316 nm from Gd3+ ions and an enhancement of the luminescence from the aforementioned defects. Elimination or neutralisation of such defects is very important from the viewpoint of electrical stability of MOSLEDs. It will be demonstrated that (i) an additional fluorine implant into a SiO2:Gd layer leads to decrease of E*-centres and ODCs improving the efficiency of the MOSLED; and (ii), an additional potassium implant produces positive ions leading to a compensation effect for the negatively charged electron traps and, hence, to an reduced quenching of the EL efficiency and increased MOSLED lifetime .

HL 36.8 Wed 18:00 POT 151

Theory of Photoluminescence for Semiconductor Quantum Dots — •Christopher Gies, Jan Wiersig, Norman Baer, and Frank Jahnke — Institute for Theoretical Physics, Universität Bremen, Postfach 330 440, 28334 Bremen, Germany

Semiconductor quantum dots have unique properties suited for the development of new light emitting devices. Their emission properties can be controlled to a great extent by embedding in a microcavity. Enhanced spontaneous emission and ultra-low-threshold lasers are among possible applications. Direct insight into the light-matter interaction in these systems can be gained from time-resolved photoluminescence measurements.

For an analysis of these measurements we use a theory beyond the widely established two-level atom model. In a semiconductor system, electrons and holes are in general not fully correlated, and thus, the influence of correlations should be explicitly calculated.

We present results from a microscopic quantum kinetic theory. The influence of many-body effects on the photoluminescence spectrum and decay for systems in a cavity and in free space is studied. From our results we draw conclusions upon the validity of the two-level atom approach.

HL 36.9 Wed 18:15 POT 151

Optical properties and energy transfer studies of AlN doped with rare earths at high concentrations — •Gregor Öhl[1], Ulrich Vetter[1,2], and Hans Hofsäss[1] — [1]Georg-August-Universität, II. Physikalisches Institut, Göttingen — [2]Philipps-Universität, AG Oberflächenphysik, Marburg

Rare earths (RE) in AlN, e.g. AlN:Gd [1,2] or AlN:Eu [3], have increasingly been attracting interest during recent years due to their promising features, e.g. as electroluminescent light emitters.

For increasing RE concentrations, one expects energy transfer reactions between different RE ions, leading to possible changes in luminescence intensity and lifetime.

In our studies, we investigated the systems (Pm,Sm):AlN, Gd:AlN and Eu:AlN. The REs were implanted at a fluence of about $10^{13}cm^{-2}$ in the first case, in the latter cases at different energies giving a square implantation profile, with RE concentrations of the order of atomic percent. Monitoring the effect of the post-implantation annealing procedure (up to about 1600 K), the critical implantation fluence for lattice recovery was determined to be in the order of some $10^{16}cm^{-2}$.

Optical properties were investigated by temperature dependent time-resolved cathodoluminescence studies, energy transfer studies were performed on selected $intra - 4f$ transitions of the implanted lanthanide ions showing concentration-related effects.

[1] U. Vetter et al., Appl. Phys. Lett. 83, 11 (2003)
[2] J.B. Gruber, U. Vetter et al., Phys. Rev. B 69 (2004)
[3] W.M. Jadwisienczak, H.L. Lozykowski et al., JAP 89 (2001)

HL 36.10 Wed 18:30 POT 151

Interband Thermoluminescence of Semiconductors and Semiconductor Nanocrystals in the Near-Infrared — •Stefan Hanna and Alois Seilmeier — Physikalisches Institut, Universität Bayreuth, D-95440 Bayreuth, Germany

Generally semiconductor luminescence is measured following electronic or optical sample excitation. In this contribution experiments are presented in which the luminescence of undoped semiconductors and of semiconductor nanocrystals near the band gap is solely thermally excited and explored by a simple and unconventional technique. Luminescence spectra are obtained at ambient conditions after slightly heating the samples to approximately 100°C *without using any additional electronic or optical means of excitation.* In our investigations, bulk GaAs, bulk InP and semiconductor doped glasses are studied. We show that absorption properties and band gap positions obtained directly from emission spectra not only correspond well to those obtained from transmission measurements, but also yield additional information about the role of defects giving rise to emission from within the band gap. This technique may be of considerable interest for online monitoring of material growth, which is generally performed at elevated temperatures, without any interference with the growth process.

HL 36.11 Wed 18:45 POT 151

Radiative Lifetime of Excitons in Multi Quantum-Well Systems — •Martin Schäfer, Marco Werchner, Walter Hoyer, Mackillo Kira, and Stephan W. Koch — Department of Physics and Material Sciences Center, Philipps University, Marburg, Germany

Effects like superradiance occurring in multi-quantum-well systems suggest that the radiative coupling between the quantum-wells can change the exciton lifetime with respect to a single quantum well. Therefore, a fully quantum-mechanical theory [1,2] is applied to analyze the exciton lifetime in a planar array of multiple radiatively coupled quantum wells. In the incoherent limit, the exciton lifetime of optically active excitons is independent of the homogeneous dephasing and therefore determined by the radiative lifetime.

In this talk, it is shown that the exciton lifetime in a multi-quantum-well system is enhanced compared to that in a single quantum-well. The lifetime is determined by the specific coupling between the quantum-wells and thus influenced by their spacing as well as by the background refractive-index profile of the structure. In this connection, a step-function-like refractive-index profile is investigated where the distance of the first quantum-well to the step is shown to have strong influence on the exciton lifetime. Furthermore, it is shown that an exciton population in one quantum well is able to create exciton populations in neighboring quantum wells due to the radiative coupling.

[1] M. Kira, F. Jahnke, W. Hoyer and S.W. Koch, Prog. in Quantum Electron. **23**, 189 (1999)
[2] M. Kira and S.W. Koch, E. Phys. J. D **36**, 143 (2005)

HL 36.12 Wed 19:00 POT 151

Recombination kinetics of excitons in AlN — •Barbara Bastek[1], T. Riemann[1], J. Christen[1], K. Balakrishnan[2], N. Fujimoto[2], T. Kitano[2], M. Iwaya[2], S. Kamiyama[2], I. Akasaki[2], and H. Amano[2] — [1]Otto-von-Guericke-University Magdeburg, Germany — [2]Meijo University, Nagoya, Japan

The luminescence of AlN layers is analyzed by spatially, spectrally and ps-time resolved cathodoluminescence microscopy (CL) at variable temperature. AlN was grown directly on 6H-SiC substrate by MOVPE above 1350°C. CL spectra at T=6K show bright near band edge emission (NBE) around 5.98eV and two broad defect related luminescence bands at 4.2eV and 3.2eV, respectively. The NBE peak position evidences tensile stress in the AlN layers and perfectly maps the stress relaxation at micro-cracks. The dominant NBE emission at 6K is assigned to an impurity bound exciton. At about 60K we observe the thermal activation of a high energy peak, identified as the free A-exciton X_A (Ry=59meV; E_{loc}=19meV). Periodic excitation of the AlN was performed in ps-CL by rectangular e-beam pulses. The NBE decay follows two different time scales ($\tau_1 \approx$100ps, $\tau_2 \approx$2.5ns). The slow component is preferentially found at the spectral position of X_A and vanishes at temperatures above T=15K. For the 3.2eV band a strongly non-exponential decay is found with time constants in the ms-range. The NBE recombination kinetics of different AlN layers is correlated with appearance and strength of the defect bands.