HL 10: Quantum Dots and Wires: Preparation and Characterization II (mainly Arsenides)

Time: Monday 11:15–13:15 Location: EW 202

HL 10.1 Mon 11:15 EW 202

Crystal Structure Tuning of Au-catalyzed Nanowires grown by MBE — Andreas Rudolph, Marcello Soda, Dieter Schuh, Josef Zweck, Dominique Bougeard, and •Elisabeth Reiger — Institute for Experimental and Applied Physics, University of Regensburg

GaAs nanowires were grown by MBE using a thin Au layer as catalyst material. For individual nanowires we study the size and the chemical composition of the (post-growth) Au-Ga catalyst droplets as well as the crystal structure by HRTEM and EDX. We estimate the Ga-concentration of the catalyst droplets during growth and relate this value to the adopted crystal structure of the nanowires. Depending on the Ga-concentration we observe two different growth modes. For low Ga content the nanowires exhibit wurtzite crystal structure. For higher Ga concentrations (>60%) zincblende segments within a wurtzite matrix are formed. By adjusting the growth parameters of this second (pseudo-Ga) growth mode pure zincblende nanowires - as typically observed by the self-catalyzed / Ga-assisted growth technique - can be obtained

HL 10.2 Mon 11:30 EW 202

GaAs/InAs - core/shell nanowires grown by SA-MOVPE — •Fabian Haas[1,2], Kamil Sladek[1,2], Andreas Winden[1,2], Martina von der Ahe[1,2], Thomas Weirich[2,3], Hilde Hardtdegen[1,2], and Detlev Grützmacher[1,2] — [1]Peter Grünberg Institute-9, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]JARA-Fundamentals of Future Information Technology — [3]GFE, Gemeinschaftslabor für Elektronenmikroskopie, 52074 Aachen, Germany

GaAs/InAs - core/shell nanowires could show interesting low-dimensional phenomena because of the expected intrinsic conductivity in the tubular low-bandgap InAs shells. However, suitable parameters for homogeneous radial growth of InAs on GaAs nanowires are still to be developed.

In this contribution we report on the heteroepitaxial growth of GaAs/InAs - core/shell nanowires via selective-area metalorganic vapor phase epitaxy (SA-MOVPE). GaAs core nanowires were grown on hole-patterned SiO_2/GaAs($\overline{111}$)B templates, structured by thermal nanoimprint lithography, and subsequently covered with a conformal InAs shell. The influence of the growth temperature (400°C to 650°C) on shell morphology, homogeneity and crystal structure was investigated by scanning and transmission electron microscopy.

It was found that the desired homogeneous and uniform InAs overgrowth is achieved at lower growth temperatures. The InAs shell adopted the morphology and crystal structure of the underlying GaAs core and dislocations at the GaAs/InAs interface were observed. At higher temperatures, the shell formed additional sidewall facets.

HL 10.3 Mon 11:45 EW 202

Growth of an InAs shell around GaAs nanowires — •Torsten Rieger[1,2], Mihail Ion Lepsa[1,2], Thomas Schäpers[1,2], and Detlev Grützmacher[1,2] — [1]Peter Grünberg Institute - 9, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]JARA-Fundamentals of Future Information Technology

Due to the small dimensions, nanowires are promising candidates for the combination of highly lattice mismatched materials such as GaAs and InAs. We present the growth of GaAs/InAs core/shell nanowires (NWs) by molecular beam epitaxy. The GaAs NW core is grown using the self-cataylzed growth method and has an almost pure zinc blende crystal structure. The growth of the InAs shell is analyzed using scanning and transmission electron microscopy. The As_4 beam flux is found to be crucial for the growth of a continuous shell. The growth of InAs starts with islands along the NW, which merge and form a continuous layer after around 5 nm thickness. The strain due to the lattice mismatch of 7% is accommodated by the formation of misfit dislocations. Relaxation along the growth direction ([111]B) saturates at about 80%. Depending on the core diameter, the core/shell NWs bend during the growth. Special emphasis is given to different defects in the InAs shell. Apart from the pure core/shell NWs, we discuss briefly about some correlated structures: free-standing InAs nanotubes and GaAs NWs which are covered only on one side by InAs.

HL 10.4 Mon 12:00 EW 202

Fabrication of ultra-low density GaAs quantum dots by filling of self-organized nanoholes — •David Sonnenberg, Andreas Graf, Vera Paulava, Achim Küster, Christian Heyn, and Wolfgang Hansen — Institut für Angewandte Physik, Universität Hamburg, 20355 Hamburg, Germany

We use the local droplet etching (LDE) technique to drill self-organized nanoholes into AlGaAs surfaces using molecular beam epitaxy. We fabricate quantum dots (QDs) by subsequent filling of these nanoholes. Here, we report on the control of the nanohole density to fabricate ultra-low densitiy QDs down to $6 \cdot 10^6$ cm^{-2}. Using Al droplets for etching, non-optimized process parameters yield a broad hole depth distribution with shallow (depth of some nanometers) and deep (deeper than 10 nm) holes. By optimizing the arsenic background flux, the generation of shallow holes can be suppressed and only deep holes (>20 nm) remain with a strongly reduced density. Ultra-low density GaAs QDs generated by filling of the nanoholes demonstrate intensive optical emission and clear excitonic features.

HL 10.5 Mon 12:15 EW 202

Einfluss eines vergrabenen Stressors auf das Wachstum von InGaAs mit MOCVD — •David Quandt, Jan-Hindrik Schulze, Tim David Germann, André Strittmatter, Udo Pohl und Dieter Bimberg — Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstraße 36, D-10623 Berlin

Das Wachstum von InGaAs ist abhängig vom Verspannungsfeld der Wachstumsoberfläche. Durch Einsatz einer vergrabenen Oxidapertur kann die Oberflächenverspannung lateral moduliert werden. Hierzu werden Mesen oder Steifen mit einer AlGaAs-Schicht und einer GaAs-Deckschicht hergestellt. Durch selektive Oxidation erfährt das AlGaAs eine Volumenreduktion, wodurch die GaAs-Deckschicht verspannt wird. Wird auf eine solche Oberfläche InGaAs abgeschieden kommt es zu lateral unterschiedlichen Wachstumsraten für GaAs und InAs. Wird die Oberflächenverspannung relativ zur Gitterkonstante von GaAs betrachtet, so ist das InAs-Wachstum an Stellen mit tensiler Verspannung begünstigt und das GaAs-Wachstum an unverspannten Stellen. Durch diese lokale Variation der Wachstumsraten weißt die InGaAs-Schicht sowohl eine Dicken- wie auch Kompositionsvariation auf.

Die Wirkung dieser Wachstumsmodulation wird sowohl zum selektiven Wachstum von Quantenpunkten als auch zur lateralen Modulation von InGaAs-Quantenfilmen verwendet. Die Anwendung dieser Methode in optoelektronischen Bauelementen wird diskutiert.

HL 10.6 Mon 12:30 EW 202

MOVPE grown InAs quantum dots on InGaAs strain reducing layers — •Matthias Paul, Jan Kettler, Elisabeth Koroknay, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, University Stuttgart, Allmandring 3, 70569 Stuttgart, Germany

Self-assembled semiconductor quantum dots (QDs) have been studied extensively due to their potential application in the field of quantum information processing. Therefore, optically addressable single quantum dots are needed on a mass production scale using metal-organic vapor-phase epitaxy (MOVPE). By burying InAs QDs in InGaAs strain-reducing layers (SRL) their emission wavelength can be shifted to the infrared region. Of special interest are the telecom wavelength bands around 1.3 μm and 1.55 μm of optical fibers where losses are reduced to a minimum. In contrast to high densities for laser applications, low densities of QDs will allow for single-photon sources, one key device in quantum information networks. The approach pursued to reach emission wavelengths of 1.3 μm is depositing InAs QDs between two InGaAs SRLs grown on GaAs substrates. Reduced strain and increased QD size cause a red-shift of the emission wavelength. Photoluminescence (PL) experiments and scanning electron microcopy (SEM) are used to characterize the InGaAs layers. Furthermore, PL and μ-PL measurements are performed to investigate optical properties of the InAs QDs, as well as, atomic force microscopy (AFM) to determine structural properties, e.g. density and size.

HL 10.7 Mon 12:45 EW 202

Prepatterning of GaAs substrates using microsphere photolithography for the site-controlled growth of InP quan-

tum dots — •Ulrich Rengstl, Elisabeth Koroknay, Moritz Bommer, Michael Jetter, and Peter Michler — Universität Stuttgart, Institut für Halbleiteroptik und Funktionelle Grenzflächen, Allmandring 3, D-70569 Stuttgart and Research Center SCoPE

To use quantum dots (QDs) in single photon applications, we are working on separate addressable, site-controlled QDs. For this, we generate surface potential modulations by patterning a GaAs buffer before the overgrowth in a metal-organic vapor-phase epitaxy system (MOVPE). Instead of using expensive conventional patterning techniques, such as electron beam lithography, we use microsphere photolithography for the fast and periodic patterning of large areas [1]. A hexagonal closepacked microsphere monolayer is used as an array of microlenses to focus UV light on a UV-sensitive photoresist. We obtain structures with controllable diameters of 300 to 700 nm in the photoresist, which can be used as an etching mask for isotropic wet chemical etching to generate holes in the GaAs buffer. Due to the later overgrowth of the patterned samples, it is crucial to sustain a clean surface with low roughness. This is traced by atomic force microscopy, which shows atomic steps between the holes in the (100) on-axis surface. After overgrowth we observe face-selective growth of GaAs and a preferred InP deposition inside the holes, which leads to the formation of site-controlled InP islands. This can be observed in a spatial photoluminescence mapping.

[1] W. Wu et al., Nanotechnology 18, 485302 (2007)

HL 10.8 Mon 13:00 EW 202

Relaxation of excited charge carriers in silicon nanocrystals embedded in silicon dioxide — •Andrey Moskalenko[1], Jamal Berakdar[1], Alexander Poddubny[2], Alexei Prokofiev[2], Irina Yassievich[2], and Serguei Goupalov[2,3] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Germany — [2]Ioffe Physical-Technical Institute of RAS, St. Petersburg, Russia — [3]Department of Physics, Jackson State University, USA

We study different mechanisms of the charge carrier relaxation in silicon nanocrystals embedded in silicon dioxide. In our work we assume the spherical shape of the nanocrystals and use the single carrier states obtained in the framework of the multiband effective mass approximation [1]. We find that the relaxation is dominated by the phonon-induced transitions. For small nanocrystals, generally, several phonons needed to be emitted due to the relatively large interlevel energy spacings for both electrons and holes. The corresponding transition rates of the multiphonon transitions are calculated in dependence on the nanocrystal size and temperature. Typically, these rates vary in a broad range from nanoseconds to picoseconds for an ensemble of nanocrystals with a certain size distribution, leading to the multiexponential decay of the carrier populations that should be observed.

[1] A. S. Moskalenko, J. Berakdar, A. A. Prokofiev, and I. N. Yassievich, Phys. Rev. B **76**, 085427 (2007).