HL 41: Quantum dots and wires: Preparation and characterization

Time: Tuesday 11:15–12:45 Location: H15

HL 41.1 Tue 11:15 H15

Towards III-V semiconductor nanowire field effect transistors: Atomic layer deposition of Al_2O_3 on InAs nanowires — •Torsten Jörres[1,2], Torsten Rieger[1,2], Detlev Grützmacher[1,2], and Mihail Ion Lepsa[1,2] — [1]Peter Grünberg Institut - 9, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]JARA-Fundamentals of Future Information Technology

Nanowire field effect transistors require thin gate dielectric films with a low density of interface states. Here, the use of Al_2O_3 prepared by atomic layer deposition (ALD) is promising due to a self-cleaning mechanism resulting in a reduction of the native oxides and a good thickness control. In this presentation, we demonstrate the processing of InAs nanowires covered homogeneously by amorphous Al_2O_3. The InAs nanowires are grown by a vapour-solid mechanism in a molecular beam epitaxy system. The Al_2O_3 is deposited ex-situ in the ALD machine. Trimethylaluminum and ozone are used as precursors. In advance, deposition experiments on silicon substrates were performed to optimise the Al_2O_3 layer using XRR, ellipsometry and CV measurements for characterisation. High resolution transmission electron microscopy investigations on nanowires covered with Al_2O_3 show the high uniformity of the deposition process even for high nanowire density. Further on, we demonstrate a process for contacting single nanowires with source, drain and gate contacts using only one metallization step. Preliminary DC measurement results on processed devices are presented and discussed.

HL 41.2 Tue 11:30 H15

Different Approaches for Uncovering InAs/AlAs Quantum Dots — •Evgeniya Sheremet[1], Raul D. Rodriguez[1], Torsten Jagemann[2], Wolfgang Grünewald[3], Doreen Dentel[2], Alexander Toropov[4], Alexander Milekhin[4], and Dietrich R.T. Zahn[1] — [1]Semiconductor Physics, Chemnitz University of Technology, D-09107 Chemnitz, Germany — [2]Solid Surfaces Analysis, Chemnitz University of Technology, D-09107 Chemnitz, Germany — [3]Leica Mikrosysteme GmbH, 1170 Vienna, Austria — [4]Institute of Semiconductor Physics, 630090 Novosibirsk, Russia

The versatile capability of tuning energy band-gap by changing size, and composition makes quantum dot (QD) materials of significant technological impact. In this work, towards the study of electronic, structural and vibrational properties of a single QD, we performed experimental investigations of InAs (AlAs) QD in AlAs (InAs) matrix prepared by molecular beam epitaxy on GaAs substrates. We report on the systematic investigation of different surface preparation methods including crystal cleavage, ion milling, and mechanical polishing and their effect on the QD superlattice topography. We found that the less invasive sample processing method, namely crystal cleavage, provides very good surface structure but fails for the structures with growth defects. In this case the most optimal QD surface is achieved by ion milling at low temperature and low ion energy, what is revealed by atomic force microscopy. The structural defects introduced by preparation on QD superlattices, as well as degradation over time were investigated using Raman spectroscopy.

HL 41.3 Tue 11:45 H15

MOVPE growth of InGaAs quantum dots on GaP for nanomemory cells — •Gernot Stracke, Bertram Jaeger, Tobias Nowozin, Leo Bonato, Sven Rodt, Andrei Schliwa, Andre Strittmatter, Christopher Prohl, Andrea Lenz, Holger Eisele, Udo W. Pohl, and Dieter Bimberg — Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany

InGaAs quantum dots (QDs) are realized on GaP(001) substrates by metalorganic vapor phase epitaxy. A prospective application of such QDs is the fabrication of nanomemory cells. These QD memory cells promise to combine the fast write and erase times of a DRAM with the non-volatility of a Flash memory. By replacing GaAs with GaP as matrix material, an extension of the storage time of holes in InAs QDs at room temperature from 0.5 ns to 1 s can be expected. Additionally, GaP offers the potential of integration with Si, since GaP and Si have almost the same lattice constant. The growth of coherent InGaAs QDs on GaP is found to depend critically on the deposition of a thin layer of GaAs prior to QD growth. On a bare GaP substrate the growth proceeds purely two-dimensional even for high indium concentrations of up to 83%. In contrast, Stranski-Krastanow growth of InGaAs QDs is observed already for indium concentrations as low as 25% when the surface of the GaP substrate is covered by 3 monolayers (ML) of GaAs. $In_{0.25}Ga_{0.75}As$/3 ML GaAs/GaP QDs exhibit luminescence around 1.9 eV. The storage time of holes in $In_{0.25}Ga_{0.75}As$/3 ML GaAs/GaP QDs is estimated to 3 μs at room temperature.

HL 41.4 Tue 12:00 H15

High density (Ga,In)As/GaP self-assembled quantum dots — •Matthias Heidemann, Sven Höfling, and Martin Kamp — Technische Physik and Wilhelm-Conrad-Röntgen-Research Center for Complex Material Systems, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

The large lattice mismatch between usual III/V materials and Si is one of the most important issues considering defect-free nucleation of layer structures for monolithic integration with Si CMOS technology. Among the III/V materials, GaP offers the lowest lattice mismatch to Si with only 0.37% at 300K and the incorporation of 2% nitrogen results in a perfect lattice match to Si. Since GaP has an indirect bandgap, a direct bandgap III/V material epitaxially grown on GaP is required and various materials and nanostructures have been proposed. Dilute Nitride Materials are used to enhance the direct bandgap character in GaAsPN/GaP and GaInPN/GaP quantum wells. By using quantum dots (QDs) the growth of larger lattice-mismatched nanostructures is possible, resulting in a direct bandgap without the incorporation of nitrogen.

In this work self-assembled InGaAs QDs embedded in GaP have been grown using molecular beam epitaxy. Based on these QDs, light emitting diodes and laser structures were fabricated and characterized. The latest results show QDs with a high density of $8.2 * 10^{10} cm^{-2}$ and photo-/electroluminescence signal up to room temperature.

HL 41.5 Tue 12:15 H15

Whispering gallery modes in zinc-blende AlN microdisks embedded with cubic GaN quantum dots — •Matthias Bürger, Marcel Ruth, Stefan Declair, Cedrik Meier, Jens Förstner, and Donat Josef As — Universität Paderborn, 33098 Paderborn, Deutschland

Optical microcavities, like semiconductor microdisks offer applications in quantum information technology as well as low threshold lasing devices. Microdisks support strong confined whispering gallery modes (WGM). In the case of group III-nitrides only microdisks of wurtzite AlN/InN/GaN have been fabricated up to now. However, piezoelectric and spontaneous polarization fields in the polar (0001) c-direction of hexagonal GaN induce a Quantum Confined Stark Effect. These built-in electric fields influence the behavior of optoelectronic devices containing quantum dots (QDs). The recombination probability of electrons and holes is reduced due to a spatial separation of electron and hole wave functions and limits the performance of photonic devices. Therefore, the fabrication of real non-polar metastable cubic GaN (c-GaN) and AlN (c-AlN) in (001) growth direction is very interesting for future applications. To improve the light extraction efficiency QDs can be integrated into microdisks. This work reports on the growth of c-AlN layers and c-GaN QDs on 3C-SiC substrate by means of molecular beam epitaxy. The freestanding microdisk located on a 3C-SiC pedestal were fabricated by reactive ion etching. Morphological investigations were realized by scanning electron microscopy. WGMs were observed in low temperature micro-photoluminescence measurements.

HL 41.6 Tue 12:30 H15

Confinement enhancement in InGaN quantum dots by AlGaN barriers — •Carsten Laurus, Timo Aschenbrenner, Stephan Figge, Marco Schowalter, Andreas Rosenauer, and Detlef Hommel — Institute of Solid State Physics, University of Bremen, Otto-Hahn-Allee, 28359 Bremen, Germany

InGaN quantum dots (QDs) are of great interest to realize single photon emitters for quantumcryptography. Single photon emission (SPE) up to 50 K was achieved utilizing spinodal phase decomposition for QD formation [S.Kremling, APL **100**, 061115 (2012)]. One approach reaching SPE at 300 K is the implementation of a barrier which improves the confinement of charge carriers and thus the temperature stability. Using InGaN as active layer, AlGaN is a promising barrier material because of its higher bandgap. Several sample series were grown by MOVPE with respect to diverse growth parameters e.g. growth temperature of the AlGaN barrier, barrier thickness and aluminum concentration of the barrier. For structural analysis by SEM samples without a GaN capping layer were used, whereby μ-PL investigations were made with capped samples. Based on SEM data the surface structures of the uncapped samples are divided in two phases with different indium concentration. The indium-rich phase consists mostly of islands and the indium-low is a meander-like structure which are QDs. On the basis of TEM data the quality of the AlGaN barrier in dependence of the aluminum concentration will be evaluated. Furthermore the capping of InGaN QDs with GaN or AlGaN and its problems will be discussed.