HL 42: Quantum dots and wires: Preparation and characterization

Time: Thursday 15:00–17:15 Location: H34

HL 42.1 Thu 15:00 H34

Monolithic co-integration of III-V-based structures on silicon using multiple step relaxation technique — •Ramasubramanian Balasubramanian[1], Vitalii Sichkovskyi[1], Gadi Eisenstein[2], and Johann Peter Reithmaier[1] — [1]Institute of Nanostructure Technologies and Analytics (INA), Technische Physik, CINSaT, University of Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany — [2]Andrew and Erna Viterbi Faculty of Electrical Engineering, Technion, Haifa 32000, Israel

Monolithic co-integration of group III-V materials on silicon (Si) aims at integrating advantages of both in a single chip. Si possesses excellent electronic, thermal and mechanical properties, whereas group III-V materials exhibit excellent photonic properties due to their direct band gap. Development of defects due to the difference in thermal expansion coefficient and lattice constants between III-V materials and Si could be overcome by the use of strain relaxation technique. Here we report on GaAs buffer layer followed by InGaAs/GaAs strained layer super lattices (SLS) directly grown on 5° off-cut Si wafers by MBE. The quality of grown structures is examined by transmission electron microscopy (TEM), atomic force microscopy and photo luminescence (PL). TEM studies have shown an efficient dislocation filtering by SLS layers. Optically active InGaAs quantum dots grown on top of such structures showed PL properties comparable to InGaAs quantum dots grown directly on GaAs substrates.

HL 42.2 Thu 15:15 H34

GaAs based quantum dot structures for VECSEL and MIXSEL applications — •Tanja Finke[1], Vitalii Sichkovskyi[1], Cesare Alfieri[2], Léonard Krüger[2], Jacob Nürnberg[2], Matthias Golling[2], Ursula Keller Keller[2], and Johann Peter Reithmaier[1] — [1]Institute of Nanostructure Technologies and Analytics (INA), Technische Physik, CINSaT, University of Kassel, Germany — [2]Institute for Quantum Electronics, Ultrafast Laser Physics Laboratory, ETH Zürich, Switzerland

By integration of a semiconductor saturable absorber mirror (SESAM) into a vertical external cavity surface emitting lasers (VECSEL), one can form a so-called mode-locked integrated external-cavity surface emitting laser (MIXSEL). With this approach, a very compact ultrashort high-power fs laser source for frequency comb generation can be realized. By using quantum dots (QDs) for the gain and absorber regions, the material properties can be tailored by geometrical parameters of the QDs. The QDs gain material was optimized by MBE towards high dot density and narrow photo luminescence (PL) emission. The influence of the growth parameters like growth temperature and In content on the optical and morphological properties of QDs was studied by PL and AFM, respectively. For SESAM structures QDs test samples with different designs were grown on DBR mirrors and characterized by reflectivity and pump-probe experiments. Fast recovery time of only 10 ps and good saturation parameters close to QW based SESAMs were achieved. Finally, all the sections, including high quality DBR mirrors were integrated into a single VECSEL structure.

HL 42.3 Thu 15:30 H34

Tuning the emission energy of self-assembled low density In(Ga)As quantum dots — •Timo Langer, Nandlal Sharma, and Dirk Reuter — Universität Paderborn, Department Physik, Warburger Str. 100, 33098 Paderborn

Self-assembled InAs and $In_xGa_{1-x}As$ quantum dots (QDs) were grown on GaAs(100) substrates by molecular beam epitaxy (MBE). The density can be controlled by modifying the growth conditions. Furthermore, the transition energies can be tuned by using the In-flush-technique or by ex-situ annealing.

Experiments using a gradient approach resulted in densities from 10^8 to $10^{10}\,cm^{-2}$. An alternative approach is the deposition of a subcritical amount of InAs with subsequent annealing. Using this approach, we were able to achieve a low density of $10^8\,cm^{-2}$ homogeneously over the whole wafer. The ground state transition energy at 4.2 K can be increased from 1.0 to 1.3 eV by using the In-flush-technique. Also, by growing $In_xGa_{1-x}As$ QDs we were able to increase the emission energy to 1.3 eV.

The QDs grown by different approaches have been investigated by photoluminescence spectroscopy and atomic force microscopy. The results are discussed in comparison.

HL 42.4 Thu 15:45 H34

Temperature controlled phase transition in single Ag2Se nanowires — •Maximilian Schwarz, August Dorn, and Alf Mews — Institute of Physical Chemistry, University of Hamburg, Germany

One-dimensional nanostructures grown via the solution-liquid-solid method (SLS) offer great application in electronic devices given the variety of materials and a well-established and low-cost synthetic route. Fine-tuning the characteristics of individual nanowires makes them suitable for numerous fields of interest. At this, silver selenide (Ag2Se) has gained the interest of many researchers for its temperature dependent change of conductivity, driven by a phase transition of the crystal lattice.

Here we show the fabrication of single nanowire transistor devices by growing cadmium selenide (CdSe) nanowires directly on substrates [1]. These act as a template to obtain silver selenide nanowires through a simple cation exchange reaction, leading to conductivities in the order of 10E5 S/m. The n-type character of the semiconductor is confirmed by field-effect transport measurements. Heating the device to 100 °C leads to a transformation of the crystal structure from monoclinic to body-centered cubic, resulting in a conductivity enhancement of 50 %. Adjusting the degree of cation exchange and the operating temperature allows for precise control of the electronic properties of single nanowire devices. Hereby, the system can be adapted to the desired application.

[1] A. Dorn et al., Advanced Materials, 2009, 21 (34), pp 3479-3482

15 min. break

HL 42.5 Thu 16:15 H34

Heterointegration of III-V materials on silicon substrates using quantum dot strain relaxation layers — •Cedric Corley, Vitalii Sichkovskyi, and Johann Peter Reithmaier — Institute of Nanostructure Technologies and Analytics (INA), Technische Physik, CINSaT, University of Kassel, Germany

The heterointegration of III-V materials and Silicon is of significant interest, e.g. for telecommunication technology, but faces challenges due to threading defect generation at the GaAs/Si interface. Photoluminsecent emission (PL) from optically active Quantum Dots (QDs) embedded in a GaAs buffer layer grown on a Silicon substrate by Molecular Beam Epitaxy (MBE) is deteriorated by these dislocations. Peach-Koehler forces exerted from highly strained QDs grown in between the interface and the optically active layers can redirect the dislocations and thus compensate their impact on the optical properties. In the past, defect filtering by structures encompassing multiple (five or more) highly strained QD layers seperated by GaAs spacer layers has been shown. This contribution compares defect filtering in structures grown by MBE incorporating a various number of InAs QD layers. An efficient defect filtering can already be achieved by as few as two layers. The material quality is monitored by the optical emission properties of an $In_{0.5}Ga_{0.5}As$ QD layer grown on top of the relaxation layer structure. The results are compared with a similar QD layer grown directly on a GaAs substrate showing similar PL properties in intensity and linewidth.

HL 42.6 Thu 16:30 H34

Multi-probe electrical characterization of axial pn-junction in GaAs nanowires — •Andreas Nägelein, Juliane Koch, Cornelia Timm, Matthias Steidl, Peter Kleinschmidt, and Thomas Hannappel — Institute of Physics, TU Ilmenau, 98693 Ilmenau, Germany

Charge separating contacts in nanowires (NWs) are crucial for all future optoelectronic devices. To receive high efficiencies, suitable doping profiles as well as abrupt junctions are required. In this work, multi-probe electrical characterizations were conducted on GaAs-NWs with axial pn-junction. By the utilization of a multi-tip scanning tunneling microscope (MT-STM), which is equipped with a scanning electron microscope (SEM), four tips can be controlled via nanopositioners at the nanoscale. With this setup it is possible to perform four-point probe measurement on single freestanding NWs.

Besides the non-linear IV-characteristic, we detected a threshold voltage, which correlates to the forward bias of the GaAs-pn-junction. Local ideality factors of the diode can be extracted from the IV-curves, which enable a classification of the quality of the diode. By performing four-point probe measurements axial resistance profiles were recorded, which are proportional to the axial doping profile of single NWs. The doping concentration of the p- and n-doped region was determined, as well as the position and width of the charge separating contact. The latter was also made visible with electron beam induced current (EBIC) images.

HL 42.7 Thu 16:45 H34

Short wavelength InGaAs quantum dots grown via droplet epitaxy — •David Fricker[1,3], Paola Atkinson[4], Mihail Lepsa[2,3], Detlev Grützmacher[1,2,3], and Beata Kardynal[1,3] — [1]Peter Grünberg Institute (PGI-9), Forschungszentrum Jülich, Germany — [2]Peter Grünberg Institute (PGI-10), Forschungszentrum Jülich, Germany — [3]JARA - Fundamentals of Future Information Technology, RWTH Aachen University, Germany — [4]Institut des NanoSciences de Paris, CNRS UMR 7588, Sorbonne Université, France

Epitaxial In(Ga)As quantum dots in GaAs, typically grown by the Stranski-Krastanov growth mode, have been used in solid state quantum optics experiments for over a decade, as the basic building block of single and entangled photon sources and as hosts for spin qubits. Here we investigate an alternative method of growing these dots based on low temperature droplet epitaxy, which may allow a higher degree of control over dot density and dot wavelength as well as allowing dots without an underlying wetting layer to be grown. The grown quantum dots are characterized structurally, mainly using atomic force microscopy and optically, using low temperature micro-photoluminescence. We show the effect of substrate temperature and deposition amount of Ga and In on the droplet size and dot emission wavelength. The impact of the capping layer growth parameters on the dot emission intensity and linewidth is presented as well. Finally, we discuss the influence of these parameters on the physical presence of the wetting layer and the corresponding intensity of photoluminescence.

HL 42.8 Thu 17:00 H34

Quantum dot-microlenses and -mesas for single-photon sources operating at telecom wavelength — •Nicole Srocka[1], Jan Grosse[1], Pawel Mrowinski[1,2], Anna Musial[2], David Quandt[1], André Strittmatter[1,3], Grzegorz Sek[2], Sven Rodt[1], and Stephan Reitzenstein[1] — [1]Institut für Festkörperphysik, Technische Universitӓt Berlin, D-10623 Berlin, Germany — [2]Laboratory for Optical Spectroscopy of Nanostructures, Wroclaw University of Science and Technology, 50-370 Wroclaw, Poland — [3]Present address: Institute of Experimental Physics, Otto von Guericke University Magdeburg, D-39106 Magdeburg, Germany

Advanced quantum communication applications require single photon sources featuring i) high photon-extraction efficiency, ii) high flux rate, iii) high suppression of multi-photon emission and iv) high degree of photon indistinguishability. The concept of monolithic microlenses and -mesas aligned to self-assembled semiconductor-quantum-dots has been proven to be an efficient approach to satisfy all of these four requirements in a single device operating at $900 - 950\,\mathrm{nm}$ [1]. We report on applying this approach to In(Ga)As/GaAs quantum dots emitting in the telecom O-band. We will sketch a full circuit from theory based design optimization to fabrication utilizing in situ three-dimensional electron-beam lithography and results of a final spectroscopic evaluation [2].

[1] M. Gschrey, A.Thoma *et al*, Nat. Commun., 6, 7662 (2015). [2] N. Srocka, *et al*, AIP Adv., 8, 085205 (2018).