HL 72: Focus Session: Functionalization of Semiconductors I

Kerstin Volz, Sangam Chatterjee (Universität Marburg), Michael Dürr (Universität Giessen)

Time: Thursday 9:30–12:45 Location: H16

Invited Talk HL 72.1 Thu 9:30 H16

Group IV alloys: New tricks with Silicon — •Detlev Grützmacher — Peter Grünberg Institute - 9 and JARA-FIT, Forschungszentrum Jülich, 52425 Jülich, Germany

Group IV alloys, namely semiconductor alloys composed from C, Si, Ge and Sn offer new routes for band engineering on Si. In particular GeSn alloys have been predicted to have a fundamental direct band gap more than 30 years ago. Using reactive gas source epitaxy (RGSE) finally the limitations due to Sn precipitation and low solubility of Sn in Ge have been overcome and prestine crystal quality is achieved. Optically pumped lasers using various geometries have been fabricated from GeSn alloys with Sn concentrations up to 14.5%. Light emitting diodes (LED)working at room temperature have been realised using p- and n-type doped GeSn layers. Additionally, hetero- and multiple quantum well structures including SiGeSn, GeSn and strained Ge layers have been deposited and employed for LEDs. Moreover, the low effective mass of electron and holes in GeSn alloys and accordingly their predicted high mobility and carrier injection velocity makes these alloys interesting candidates for ultra low power devices. The potential of group IV alloys as a platform for electronic-photonic integrated circuitry is discussed.

HL 72.2 Thu 10:00 H16

MOVPE growth studies of Ga(PBi) on GaP and on GaP/Si — •Lukas Nattermann, Nikolai Knaub, Andreas Beyer, Wolfgang Stolz, and Kerstin Volz — Materials Sciences Center and Faculty of Physics, Philipps-Universität Marburg, Germany

Dilute bismide containing materials can play an important role in addressing the issue of finding new highly efficient lasers. In the last few years a growing body of literature has emerged, especially on the growth and characterization of Ga(AsBi) on GaAs. The growth on GaP makes achieving a direct band gap on Si possible by alloying Bi and N. In this work we will present the first Ga(PBi) structures grown with metal organic vapour phase epitaxy on GaP and on GaP on Si. By careful characterization with high resolution X-ray diffraction, atomic force microscopy, secondary ion mass spectrometry, photoluminescence spectroscopy and scanning transmission electron microscopy, we will show that we have achieved high quality Ga(PBi) with Bi fractions up to 8%. Carbon incorporation due to low temperature growth as well as results from optical measurements will be discussed.

Acknowledgements: We gratefully acknowledge support from German Science Foundation (DFG) in the framework of the RTG1782 "Functionalization of Semiconductors".

HL 72.3 Thu 10:15 H16

X-ray Fluorescence of individual GaAs/InGaAs/GaAs core-shell nanowires grown by molecular beam epitaxy on silicon (111) — •Ali Al Hassan[1], Hanno Küpers[2], Ryan B. Lewis[2], Danial Bahrami[1], Abbes Tahraoui[2], Lutz Geelhaar[2], and Ullrich Pietsch[1] — [1]Naturwissenschaftlich-Technische Fakultät der Universität Siegen, 57068 Siegen, Germany — [2]Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5-7, 10117 Berlin, Germany

The growth of GaAs/In(x)Ga(1-x)As/GaAs core-shell nanowires (NWs) on silicon is a challenging route to combine optoelectronics with the silicon technology. Due to the different lattice parameters, growth of the InGaAs shell onto the NW core side plane is affected by epitaxial strain. X-ray diffraction (XRD) measurements taken on NW ensembles with momentum transfer perpendicular to the NW axis show separated Bragg peaks for core and shell materials. We probed the spatial homogeneity of the Indium distribution in the shell layers of individual core-shell NWs by means of X-ray fluorescence (XRF) analysis using a 50nm x 50nm sized white x-ray beam. For low indium contents within the InGaAs layer (nominal values of 15% and 25%), the Indium distribution within the six side facets is almost homogeneous. On the other hand, NWs with 60% of indium show randomly distributed indium-rich aggregates at the core circumference. The result are compared with XRD and SEM measurements.

Invited Talk HL 72.4 Thu 10:30 H16

SiGe heterostructures for photonics interconnects — •Giovanni Isella[1], Jacopo Frigerio[1], Andrea Ballabio[1], Daniel Chrastina[1], Vladyslav Vakarin[2], Papichaya Chaisakul[2], Laurent Vivien[2], and Delphine Marris-Morini[2] — [1]L-NESS, Dipartimento di Fisica, Politecnico di Milano, Polo di Como, Via Anzani 42, I 22100 Como, Italy — [2]IEF, Univ. Paris-Sud, CNRS, Univ. Paris-Saclay, UMR 8622, Bât. 220, 91405 Orsay Cedex, France

Over the last years Ge/SiGe multiple quantum wells (MQW) have received a great attention in the context of silicon photonics for the realization of efficient electro-absorption modulators based on the quantum confined Stark effect. At present day, one of the main challenges toward the integration of Ge/SiGe MQW modulators is their coupling with Si-compatible passive optical components such as waveguides. In particular, the integration with silicon waveguides is very difficult due to the presence of a thick SiGe layer which act as a virtual substrate (VS) for the MQW stack. We demonstrate that the VS can be used as a low loss optical waveguide by choosing a suitable compositional mismatch with respect to the MQW stack. A photonic interconnection made by a Ge/SiGe MQW modulator connected to a Ge/SiGe MQW photodetector through a SiGe waveguide has been fabricated and tested in order to demonstrate the great potential of this approach. More complex SiGe heterostructures, such as coupled QWs can be employed to attain efficient phase modulation. Moreover the building blokcs required for the fabrication of passive waveguide devices such as ring-resonators and optical filters can also be implemented in a SiGe material platform.

30 min. Coffee Break

HL 72.5 Thu 11:30 H16

III/V on Si by selective area growth for optoelectronics — •Bernardette Kunert, Weiming Guo, Yves Mols, Robert Langer, and Kathy Barla — Imec, Kapeldreef 75, B-3001 Leuven, Belgium

III/V compound materials and hetero-structures are well established in conventional optoelectronic applications due to their direct band gap structure. However, in the field of Silicon Photonics the successful integration of a laser diode with sufficient life time is still unsolved. The monolithic growth of high quality III/V materials on Si substrate would open up a huge field of applications, combining the mature functionalities of Si microelectronics with the excellent optoelectronic properties of III/V hetero-structures. But the lattice mismatch between most interesting III/V candidates and Si initiates the formation of misfit and threading dislocation defects. The selective area growth of III/V materials on patterned Si wafer is a novel integration approach to achieve a low defect density in the active III/V layers. A high aspect ratio in patterned trenches leads to an efficient trapping of defects in the bottom of the trench whereas the top region has a high crystal quality (aspect ratio trapping (ART)). This presentation is an introduction to selective growth of III/V materials on patterned 300mm Si wafers by metal organic vapour phase epitaxy (MOVPE). A new approach to realize a III/V laser diode on patterned Si substrates will be discussed based on first achieved results.

HL 72.6 Thu 12:00 H16

Quantitative investigation of high resolution HAADF STEM images of Ga(NAsP) laser structures — •Lennart Duschek, Tatjana Wegele, Andreas Beyer, Wolfgang Stolz, and Kerstin Volz — Material Sciences Center and Faculty of Physics, Philipps-Universität Marburg, Germany

Growing suitable III/V laser structures for optical data transmission on silicon substrate is a highly focused goal to achieve the integration of optics on electronic devices. The quaternary material system Ga(NAsP) is a promising candidate because it can be grown lattice-matched on silicon substrate and is a direct bandgap semiconductor. Due to its metastability, Ga(NAsP) has to be grown at rather low temperatures, i.e. 575°C. Post- growth thermal annealing allows the reduction of certain types of structural defects and thus improves the optical properties. Annealing at high temperatures e.g. 975°C can cause changes in the structure of the material [1]. This contribution will show high resolution scanning transmission electron microscopy images (STEM) of Ga(NAsP) with different Nitrogen and Phosphorous concentration, recorded at varied detector regions, collecting electrons scattered in different angles. Furthermore simulation results of these given structures will be shown and discussed in comparison to the experimental images. Acknowledgements: We gratefully acknowledge support from German Science Foundation (DFG) in the framework of the RTG1782 "Functionalization of Semiconductors".

[1]*S. Gies et al., J. Cryst. Growth, vol. 402, pp. 169*174, Sep. 2014.

HL 72.7 Thu 12:15 H16

Identification of anti-phase boundaries on a GaP/Si(001) cross-sectional surface — Christopher Prohl[1], Henning Döscher[2], Peter Kleinschmidt[2], Thomas Hannappel[2], and •Andrea Lenz[1] — [1]Technische Universität Berlin, Institut für Festkörperphysik, 10623 Berlin, Germany — [2]Helmholtz Center Berlin for Materials and Energy, 14109 Berlin, Germany

GaP-based materials are of high interest for realization of epitaxial integration of III-V layers for optoelectronics on Si(001) substrates due to the small lattice mismatch of GaP compared to Si. However, the growth of polar GaP on non-polar Si substrates leads to anti-phase domains accompanied with anti-phase boundaries (APBs), which are charged structural defects, reducing the device performance. Here, we present a cross-sectional scanning tunneling microscopy (XSTM) investigation of APBs at an epitaxially grown GaP/Si(001) interface. The APB can be identified by a brighter contrast and by surface step edges starting/ending at the position of an APB. The specific image contrast mechanisms of APBs oriented along different directions are discussed in detail. On the atomic scale the change of the atomic position of P and Ga atoms along growth direction is directly observed, in agreement with the structure model of APBs in the GaP lattice. This work was supported by the DFG, project LE 3317/1-1.

HL 72.8 Thu 12:30 H16

Gain Spectroscopy on Ga(N,As,P)/(B,Ga)(As,P) Heterostructures — •Florian Dobener[1], Peter Ludewig[2], Kerstin Volz[1], Wolfgang Stolz[1,2], and Sangam Chatterjee[1] — [1]Faculty of Physics and Materials Science Center, Philipps-Universität Marburg, D-35032 Marburg, Germany — [2]$NAsP_{III/V}$ GmbH, Am Knechtsacker 19, D-35041 Marburg, Germany

The realization of monolithically integrated on-chip laser sources for optical data transmission remains one of the major goals of optoelectronic integration nowadays. The quaternary III-V material system Ga(N,As,P) promises to fulfil this task as composition variations allow both, bandgap engineering and tuning of the lattice constant through the control of nitrogen and phosphorous incorporation, potentially covering the near-infrared regime as well as the datacom wavelength.

Here, we investigate two series of Ga(N,As,P) multiple quantum well samples grown by metal-organic vapour-phase epitaxy. Either the substrate temperature or the chemical composition was systematically varied. Room temperature optical gain measurements by the variable stripe-length method show a maximum modal gain of about 100 cm^{-1} for the best samples, helping to identify the optimum growth conditions according to the amplification performance.