HL 6: Ge/Si I

Time: Monday 9:30–11:30 Location: EW 203

HL 6.1 Mon 9:30 EW 203

Heterostructure growth study for GaP collector integration in SiGe HBT technology — •Oliver Skibitzki[1], Fariba Hatami[2], Yuji Yamamoto[1], Peter Zaumseil[1], M. Andreas Schubert[1], Bernd Tillack[1,3], W. Ted Masselink[2], and Thomas Schroeder[1] — [1]IHP, Im Technologiepark 25, 15236 Frankfurt (Oder), Germany — [2]Humboldt Universität zu Berlin, MNF1, Newtonstrasse 15, 12489 Berlin, Germany — [3]Technische Universität Berlin, HFT4, Einsteinufer 25, 10587 Berlin, Germany

A heterostructure growth study of GaP on pseudomorphic 4° off-oriented $Si_{0.8}Ge_{0.2}$/Si(001) substrates was performed to develop a III/V wide band gap collector concept for future SiGe heterobipolar transistor performance increase. Before pseudomorphic GaP/$Si_{0.8}Ge_{0.2}$/Si(001)) heterostructure growth, critical thickness of GaP on Si and maximum thermal budget for GaP deposition were evaluated by preliminary investigations. Using XRD, AFM and TEM for structure and defect characterization, we were able to report single crystalline 170 nm GaP growth on 20 nm $Si_{0.8}Ge_{0.2}$/Si(001) substrates. Results show that 20 nm $Si_{0.8}Ge_{0.2}$/Si(001) can be overgrown by 170 nm GaP without affecting the pseudomorphism of the $Si_{0.8}Ge_{0.2}$/Si(001) layer. However, due to defect nucleation at the GaP/ $Si_{0.8}Ge_{0.2}$ interface during initial island coalescence, the GaP layer grows partially relaxed. The achievement of 2D GaP growth conditions on $Si_{0.8}Ge_{0.2}$/Si(001) systems is thus a crucial step for achieving fully pseudomorphic heterostructures. APD-free GaP growth is observed for film thicknesses beyond 70 nm.

HL 6.2 Mon 9:45 EW 203

Picosecond hole scattering and cooling dynamics in Ge/SiGe quantum wells. — •Kolja Kolata[1], Sebastian Imhof[2], Niko Köster[1], Giovanni Isella[3], Daniel Chrastina[3], John E. Sipe[4], Angela Thränhardt[2], and Sangam Chatterjee[1] — [1]Fachbereich Physik, Philipps Universität Marburg, Germany — [2]Technische Universität Chemnitz, Fakultät für Naturwissenschaften, Germany — [3]Dip. di Fisica del Politecnico di Milano, L-NESS, Polo di Como, Italy — [4]Department of Physics, University of Toronto, Canada

We investigated the hole scattering and cooling dynamics in Ge/SiGe quantum wells on a picosecond time scale. Time-resolved pump-probe experiments show an efficient scattering process between the electron and hole systems in the L- and Γ-valley, respectively. The Ge quantum wells are excited 10 meV above the band edge and probed with a white-light supercontinuum. After optical excitation, the electrons scatter from the Γ-valley into the lower lying L-valleys within a few hundreds of fs. At later times, only the hole system is investigated as photons can only access vanishing momenta. We observe a hot hole system with a temperature far beyond what is expected from the excess energy of the excitation. The additional heating is due to efficient energy transfer from the electron system in the L-valley which heats the hole-system in the Γ-valley mediated by Coulomb-interaction. The dependence on excitation energy as well as carrier density support this explanation. Our findings are corroborated by semiconductor Bloch equations calculations of the absorption spectra for various hole-system carrier-densities and temperatures.

HL 6.3 Mon 10:00 EW 203

Ultra-fast intersubband-relaxation and the evidence of non-thermal carrier distribution in Ge/SiGe quantum wells — •Alexej Chernikov[1], Verena Bornwasser[1], Martin Koch[1], Niko Köster[1], Ronja Woscholski[1], Sangam Chatterjee[1], Eleonora Gatti[2], Emanuele Grilli[2], Mario Guzzi[2], Danny Chrastina[3], and Giovanni Isella[3] — [1]Faculty of Physics and Material Sciences Center, Philipps-Universität Marburg, Renthof 5, D-35032 Marburg, Germany — [2]L-NESS and Dipartimento di Scienza dei Materiali, Università di Milano-Bicocca, via Cozzi 53, I - 20125 Milano, Italy — [3]L-NESS and Dipartimento di Fisica, Politecnico di Milano, Polo Territoriale di Como, via Anzani 42, I - 22100 Como, Italy

In the last decade, optical properties of Ge/SiGe-heterostructures have received much attention in the scientific community being a possible candidate for the realization of a semiconductor laser on Si-substrates. In addition, the optical properties of the material system are of fundamental interest due to the combination of a direct transition only slightly higher in energy than the indirect band-gap. Further advantages are the enhancement of the light-matter coupling as well as the tunability of the band strucure, both inherent for the low-dimensional systems. Here, we present a systematic study of carrier relaxation in Ge/SiGe quantum wells applying photoluminescence and pump-probe spectroscopy. Ultra-fast intersubband-relaxation on a 100 fs time-scale and the presence of a non-thermal carrier distribution are found to strongly influence the optical response of the material.

HL 6.4 Mon 10:15 EW 203

On the strain partitioning phenomenon in Ge clusters on free-standing Si(001) nanopillars — •Grzegorz Kozlowski[1], Peter Zaumseil[1], Andreas Schubert[1], Yuji Yamamoto[1], Joachim Bauer[1], Tobias Schulli[2], Bernd Tillack[1,3], and Thomas Schroeder[1,4] — [1]IHP, Im Technologiepark 25, 15236 Frankfurt (Oder), Germany — [2]European Synchrotron Radiation Facility, BP 220, F-38043 Grenoble Cedex, France — [3]Technische Universität Berlin, HFT4, Einsteinufer 25, Berlin 10587, Germany — [4]Brandenburgische Technische Universität, Konrad-Wachsmann-Allee 1, 03046 Cottbus, Germany

Ge is attracting increasing interest to integrate photonic modules within Si chip baseline technology. The major stumble block is given by the 4.2% lattice mismatch. The theory of nanoheteroepitaxy (NHE) offers the vision to shift the critical thickness for defect nucleation in Ge to infinity by the so-called strain partitioning phenomenon. We report on the structural characterization of Ge clusters selectively grown by chemical vapor deposition on free-standing Si(001) nanopillars of 50 nm width. Synchrotron based x-ray diffraction studies and transmission electron microscopy were performed to experimentally verify NHE theory as a technique to grow high quality Ge on Si(001). Although the structure dimensions are comparable to the theoretical values required for the strain partitioning phenomenon, the compliant character of Si is not unambiguously proven. In consequence, the strain is relieved by nucleation of misfit dislocations at the Ge/Si interface. By gliding out of threading arms, high quality Ge nanostructures are achieved.

HL 6.5 Mon 10:30 EW 203

Kelvin probe force microscopy imaging on horizontal locally doped silicon nanowires — •Christine Baumgart[1], Stefan Habicht[2], Sebastian Feste[2], Manfred Helm[1], Siegfried Mantl[2], and Heidemarie Schmidt[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Institut für Ionenstrahlphysik und Materialforschung, P.O. Box 510119, 01314 Dresden, Germany — [2]Peter Grünberg Institute 9 (PGI 9-IT), and JARA-Fundamentals of Future Information Technology, Forschungszentrum Jülich, 52425 Jülich, Germany

Kelvin probe force microscopy (KPFM) [1] has been used for the electrical characterization of silicon nanowires (NWs). Arrays of horizontal Si NWs [2] with widths down to 10 nm have been prepared from a silicon-on-insulator (SOI) starting material. After transferring the NW structures into the Si top layer by conventional top-down approach, the samples have been locally implanted with B and As. Quantitative dopant profiling by means of KPFM is successfully employed to locate the junctions along the B-doped and As-doped Si NWs. In addition, the influence of local intrinsic electric fields [3] is discussed for the investigated SOI structures.

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[2] S. F. Feste, J. Knoch, S. Habicht, D. Buca, Q.-T. Zhao, S. Mantl, Solid-State Electronics 53, 1257 (2009).

[3] C. Baumgart, A.-D. Müller, F. Müller, and H. Schmidt, Phys. Stat. Sol. A 208, 777 (2011).

HL 6.6 Mon 10:45 EW 203

Raman scattering study of hydrogen-induced defects in ion-implanted Si — •Sebastian Socher, Edward V. Lavrov, and Jörg Weber — Technische Universität Dresden, 01069 Dresden

A Raman scattering study of single crystalline silicon implanted with ^{28}Si and subsequently treated in a rf hydrogen plasma at 200 °C is presented. Such a treatment results in a broad band at 3830 cm^{-1} (60 K) previously assigned to the vibrational $Q(J)$ transitions of hydrogen molecules trapped in Si multivacancies [Ishioka *et al.*, Phys. Rev. B **60**, 10852-10854 (1999)]. Here, J is the rotational quantum

number. The 3830 cm^{-1} band reveals a substructure, which is assigned to at least two different types of the molecules. The H_2 signals are shown to correlate with the Si–H vibrational modes at 1888, 1930, and 1964 cm^{-1}. A quantitative analysis of the 3830 cm^{-1} band revealed the splitting of the $Q(1)$ modes of H_2 by the trapping potential. Ortho to para conversion rates of the hydrogen molecules at 77 K and room temperature were found to be 62 ± 15 and 8 ± 2 hours, respectively.

HL 6.7 Mon 11:00 EW 203

Cobalt-related defects in silicon: A deep level transient spectroscopy study — •Leopold Scheffler, Vladimir Kolkovsky, and Jörg Weber — Technische Universität Dresden, 01069 Dresden, Deutschland

In the present work cobalt-doped p- and n-type silicon samples were studied by means of deep level transient spectroscopy (DLTS) and Laplace-DLTS (LDLTS). We demonstrate that two dominant DLTS peaks previously assigned to an interstitial Co defect show different annealing behaviour and seem to belong to different defects. After wet chemical etching three other peaks (E90, E140 and H170) were observed in the samples. The intensity of the peaks becomes larger in the H-plasma treated samples. This together with depth profiling demonstrate that the peaks are hydrogen-related defects. The origin of the peaks will be discussed.

HL 6.8 Mon 11:15 EW 203

Observation of the oxygen precipitation in CZ-silicon by X-ray diffraction — •Christoph Bergmann, Johannes Will, Groeschel Alexander, and Magerl Andreas — Chair for Crystallography and Structural Physics, FAU Erlangen-Nuremberg, Erlangen-Germany

We investigated the formation, kinetics and final dissolution of oxygen precipitates in single crystalline silicon as a function of the temperature applied (up to 1200°C). The knowledge about and the control of such processes is one of the major challenges during the fabrication of integrated circuits. With the means of x-ray diffraction we examined the integrated intensity of a Bragg peak which is a direct function of the stress inventory introduced by the growing oxygen particles.

Samples cut in such a way that we were able to examine the whole radius of a 12" single CZ-Si crystal at once were illuminated with highly energetic X-radiation. Both in-situ and ex-situ measurements enabled us to follow the precipitation what gave strong indications for thermal donor formation, different point defect regimes along the radius ("V/G-model") and their influence on the precipitation regarding size, morphology and density of the precipitates grown.

A fit of the time-dependent evolution of the integrated intensity with a growth function given by the model of diffusion limited precipitation gave values for the precipitate density which excellently reproduce the values obtained by defect etching.