HL 22: Heterostructures, Interfaces and Surfaces

Time: Wednesday 15:00–18:00 Location: H33

HL 22.1 Wed 15:00 H33

Band-gap and strain engineering in GeSn alloys using post-growth pulsed laser melting — •O. Steuer[1], D. Schwarz[2], M. Oehme[2], J. Schulze[3], H. Maczko[4], R. Kudrawiec[4], I. Fischer[5], R. Heller[1], R. Hübner[1], M. Khan[1], Y. Georgiev[1], S. Zhou[1], M. Helm[1], and S. Prucnal[1] — [1]Helmholtz-Zentrum HZDR, GER — [2]University of Stuttgart, GER — [3]Fraunhofer IIS, GER — [4]Wroclaw University, POL — [5]TU Cottbus-Senftenberg, GER

Alloying Ge with Sn enables effective band-gap engineering and improves significantly the charge carrier mobility. The pseudomorphic growth of Ge1-xSnx on Ge causes in-plane compressive strain, which degrades the superior properties of the Ge1-xSnx alloys. Therefore, efficient strain engineering is required. In this talk, we will present strain and band-gap engineering in GeSn alloys grown on a Ge virtual substrate using post-growth nanosecond pulsed laser melting (PLM). Micro-Raman spectroscopy and X-ray diffraction show that the initial in-plane compressive strain is removed. Moreover, for PLM energy densities higher than 0.5 J cm-2, the Ge0.89Sn0.11 layer becomes tensile strained. Simultaneously, as revealed by Rutherford Backscattering spectrometry, cross-sectional transmission electron microscopy investigations and X-ray diffraction, the crystalline quality and Sn-distribution in PLM-treated Ge0.89Sn0.11 layers are only slightly affected. Additionally, the change of the band structure after PLM is confirmed by low-temperature photoreflectance measurements. The presented results prove that post-growth ns-range PLM is an effective way for band-gap and strain engineering in highly-mismatched alloys.

HL 22.2 Wed 15:15 H33

Reconfigurable Complementary and Combinational Logic based on Monolithic and Single-Crystalline Al-Si Heterostructures — •Raphael Böckle[1], Masiar Sistani[1], Martina Bažíková[1], Lukas Wind[1], Zahra Sadre-Momtaz[2], Martien I. den Hertog[2], Corban G.E. Murphey[3], James F. Cahoon[3], and Walter M. Weber[1] — [1]Institute of Solide State Electronics, TU Wien, Vienna, Austria — [2]Institut Néel, CNRS, Grenoble, France — [3]Department of Chemistry, University of North Carolina, Chapel Hill, North Carolina, United States

Overcoming the difficulty in reproducibility and deterministically defining the metal phase of metal-Si heterostructures is among the key prerequisites to enable next-generation nanoelectronic devices. Here, the formation of monolithic Al-Si-Al heterostructures obtained from Si nanowires and Al contacts is presented. Transmission electron microscopy and energy-dispersive X-ray spectroscopy confirmed both the composition and crystalline nature of the presented Al-Si-Al heterostructures, with no intermetallic phases formed during the exchange process in contrast to state-of-the-art metal silicides. In this context, reconfigurable field-effect transistors (RFET), capable of dynamically altering the operation mode between n- or p-type are realized. Having devised symmetric on-currents as well as threshold voltages for n- and p-type operation as a necessary requirement to exploit complementary reconfigurable circuits, selected implementations of logic gates such as inverters and combinational wired-AND gates are built from single elementary RFETs.

HL 22.3 Wed 15:30 H33

Investigations on graphene-oxide-silicon structures for field emission — •Alexander Mai[1], Florian Herdl[2], Simon Edler[1], Andreas Schels[2], Michael Bachmann[1], Felix Düsberg[1], Andreas Pahlke[1], and Georg Duesberg[2] — [1]Ketek GmbH, Hofer Str. 3, 81737 Munich, Germany — [2]University of the Bundeswehr Munich, Institute of Physics, Werner-Heisenberg-Weg 39, 85577 Neubiberg, Germany

In field emission (FE) electrons can tunnel through a potential barrier by applying a large electric field ($>$ 1 V/nm), which is required to obtain a reasonable current. Therefore, often high voltages ($>$ 300 V) and sharp tip geometries are used. However, a high sensitivity to poor vacuum makes these emitters unsuitable for many applications. Planar devices like graphene-oxide-semiconductor (GOS) structures are promising candidates as they are independent on the ambient pressure level. The necessary electric fields are achieved by applying a low operation voltage ($<$ 20 V) on a thin oxide barrier (5 - 20 nm). The maximum emission to tunnel current ratio (efficiency) achieved in a GOS structure to this date is 48.5%. In this presentation, results of recent measurements and simulations on GOS structures are shown. The measured structures show efficiencies between 0.1 and 23%, mainly depending on the thickness of the gate electrode, while an emission current of at least about 1 nA was achieved in most samples. Simulations show a voltage drop near the contact pad resulting from the sheet resistance of the gate electrode, which limits the maximum tunnel current in the GOS structure.

HL 22.4 Wed 15:45 H33

Topological photonics for optoelectronic sensing — •Jakob Lindenthal[1,2], Johannes Benduhn[1], and Karl Leo[1,2] — [1]Institute of Applied Physics, Technische Universität Dresden — [2]ct.qmat - Würzburg-Dresden Cluster of Excellence

Topological properties of photonic systems are a quickly emerging research field. The physical realisation of topological invariants allows the creation of photonic states with strong protection of the state's existence against perturbation. The energy levels of topological states can be made highly sensitive to external influences, enabling the design of novel optoelectronic sensing devices. Theoretical concepts of different topological photonic systems are discussed, and experimental systems are showcased. The presentation reports about an optoelectronic pressure sensor developed at the Institute of Applied Physics at TU Dresden and other devices fabricated by partnering organisations. Key concepts and technological advantages of topological systems are summarised, highlighting the prospects for incorporating topology in optoelectronic sensing devices.

HL 22.5 Wed 16:00 H33

Interplay of anomalous strain relaxation and minimization of polarization changes at nitride semiconductor heterointerfaces — Yuhan Wang[1,2], •Michael Schnedler[1,2], Qianqian Lan[1,2], Fengshan Zheng[1,2], Lars Freter[1,2], Yan Lu[1,2], Uwe Breuer[3], Holger Eisele[4], Jean-François Carlin[5], Raphaël Butté[5], Nicolas Grandjean[5], Rafal E. Dunin-Borkowski[1,2], and Philipp Ebert[1,2] — [1]Peter Grünberg Institut, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany — [2]Ernst Ruska Centrum, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany — [3]Zentralinstitut für Engineering, Elektronik und Analytik (ZEA-3), Forschungszentrum Jülich GmbH, 52425 Jülich, Germany — [4]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany — [5]Institute of Physics, Ecole Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland

Polarization and electron affinity changes at $Al_{0.06}Ga_{0.94}N$/GaN and $In_{0.05}Ga_{0.95}N/Al_{0.06}Ga_{0.94}N$ interfaces are quantified by combining off-axis electron holography in transmission electron microscopy, scanning tunneling microscopy, and simulations of the electrostatic potential and electron phase maps. The $In_{0.05}Ga_{0.95}N/Al_{0.06}Ga_{0.94}N$ interface reveals, as expected, biaxial relaxation as well as polarization and electron affinity changes. However, at the $Al_{0.06}Ga_{0.94}N$/GaN interface anomalous lattice relaxations and vanishing polarization and electron affinity changes occur, whose underlying physical origin is anticipated to be total energy minimization by the minimization of Coulomb interactions between the polarization-induced interface charges.

30 min. break

HL 22.6 Wed 16:45 H33

Determination of relaxation in thin InGaAs-films by Raman spectroscopy — •Johann Friedemann Schulz[1], Tobias Henksmeier[2], Martin Feneberg[1], Elias Kluth[1], Dirk Reuter[2], and Rüdiger Goldhahn[1] — [1]Otto von Guericke University, Institute of Physics, Universitätsplatz 2, 39106 Magdeburg, Germany — [2]Paderborn University, Department of Physics, Warburger Str. 100, 33089 Paderborn, Germany

Semiconductor heterostructures suffer inherently from differences in their lattice parameters. This causes strain and, in the worst case, crystal defects in the material, rendering it potentially unusable for electronic or optical devices. The relaxation of thin mismatched films is therefore important for assessing the crystal quality. One possibility to experimentally access the degree of relaxation is to accuracteley determine the phonon frequencies of the strained material, as

Phonon frequencies depend on composition and lattice parameters. Such measurements can be carried out quickly and easily using Raman spectroscopy. Here, we present results on $In_xGa_{1-x}As$ grown on GaAs-substrates by molecular beam epitaxy. We investigate different strained films with varied composition and several different film thicknesses. We find Raman spectroscopy a viable tool to determine the degree of relaxation even in films which are too thin for usual reciprocal space map experiments.

HL 22.7 Wed 17:00 H33

Time-resolved measurement of propagating exciton-polariton condensates in confined systems using a streak camera — •Christian Mayer, Simon Betzold, Philipp Gagel, Tristan H. Harder, Monika Emmerling, Adriana Wolf, Fauzia Jabeen, Sven Höfling, and Sebastian Klembt — Technische Physik, RCCM and Würzburg-Dresden Cluster of Excellence ct.qmat, University of Würzburg, Germany

Strong coupling between photons and excitons in an optical microcavity leads to the formation of hybrid light-matter quasiparticles called exciton-polaritons. In the low-density regime, these particles follow bosonic statistics and can therefore undergo dynamical condensation above a critical particle density by stimulated relaxation to the ground state. The low effective mass of polaritons compared to excitons, which results from the photonic fraction, leads to comparatively long diffusion lengths. The excitonic fraction, on the other hand, is responsible for relevant polariton-polariton interaction, which leads to a repulsive behavior. Exciting non-resonantly with a pulsed laser results in an additional repulsive force at finite wavevector due to the exciton reservoir. These factors can lead to a significant propagation of the polariton condensate, with relevant effects already taking place on the time scale of a few picoseconds.

Here, we utilize electron beam lithography and etching techniques to form potential landscapes such as coupled resonator lattices and waveguides. We use a streak camera to resolve and visualize the propagation of polaritons in these systems.

HL 22.8 Wed 17:15 H33

Towards predictive modeling of optical properties of quantum dots under externally applied stress — •Petr Klenovsky[1,2], Xueyong Yuan[3], Saimon Filipe Covre da Silva[3], and Armando Rastelli[3] — [1]Department of Condensed Matter Physics, Faculty of Science, Masaryk University, Brno, Czech Republic — [2]Czech Metrology Institute, Brno, Czech Republic — [3]Institute of Semiconductor and Solid State Physics, Johannes Kepler University Linz, Austria

GaAs quantum dots (QDs) have been found in the past to be an exceptionally good platform for construction of the light emitters. They have also advantageous properties for spin physics because of the absence of strain and strain inhomogeneity. Still, strain is important to achieve quadrupolar splitting, e.g., to build up a quantum register with nuclear spins. Understanding and quantitative prediction of strain-induced effects will be important to guide future optimization, since a trial and error procedure is not acceptable in view of the huge parameter space available for GaAs QDs (e.g. WL thickness tunable at will). Former attempts have qualitatively reproduced results but failed to achieve the quantitative agreement, e.g., bright-dark exciton splitting or used unphysical assumptions. That was further exacerbated by the lack of knowledge of the exact applied strain configuration.

Here we go beyond by combining precisely determined strain and QD properties with dedicated calculations using $\mathbf{k} \cdot \mathbf{p}$ and correlated configuration interaction (CI) methods. We show for the first time quantitative agreement between experiment and theory for strained GaAs QDs.

HL 22.9 Wed 17:30 H33

Growth of epitaxial GaN by reactive magnetron sputtering — •Ralf Borgmann, Florian Hörich, Jürgen Bläsing, Armin Dadgar, André Strittmatter, Anja Dempewolf, Frank Bertram, Jürgen Christen, and Gordon Schmidt — Otto-von-Guericke-Universität Magdeburg, Universitätsplatz 2, 39106 Magdeburg, Germany

For high power transistors GaN is an excellent base material semiconductor with a high bandgap and a high breakdown field which is often realized on Si substrates. A specific buffer arrangement is needed for MOVPE grown structures, to achieve these properties. Especially doping with Fe or C is essential for insulating sheets. In comparison with reactive magnetron sputtering uses pure metal targets and does not necessarily require Fe or C doping to achieve highly insulating GaN. We investigated growth parameters like growth temperature and reactive gas flow on various templates. An important parameter determining the material quality is the reactive gas. Ga droplets occur on the wafer surface, when using nitrogen. Investigations on growth temperature reveal a narrow growth window. An optimum growth temperature was by around 715 °C. With low ammonia gas flow the AFM measurement shows a grainy surface. By using a higher ammonia gas flow, the growth rate decreases and a closed meandering surface structure appears. Full sputtered undoped layers show a vertical breakdown field strength of > 2.5 MV/cm for 200 nm AlN 2x 200 nm transition layer AlGaN and 820 nm GaN.

HL 22.10 Wed 17:45 H33

Ultrafast transient spectroscopy of $Cu(In,Ga)Se_2$ coupled to different buffer layers. — •Pirmin Schweizer, Ricardo Rojas-Aedo, Alice Debot, Philip Dale, and Daniele Brida — Department of Physics and Materials Science, University of Luxembourg, 162a avenue de la Faïencerie, L-1511 Luxembourg, Luxembourg

The dynamic parameters of photo-induced electron-hole pairs, such as recombination time and charge conductivity, play a major role in the efficiency of photovoltaic devices. Among thin film materials for photovoltaics, one of the most interesting is the p-type $Cu(In,Ga)Se_2$ alloy (CIGS) on which an n-type buffer layer is deposited, forming the initial part of the device p-n junction. The inter-material transport dynamics strongly depend on how the band structure is affected by the buffer layer, and also on the quality of the CIGS / buffer layer interface which may contain defects. In our experiments we have compared the ultrafast transient reflectivity on CIGS epitaxially grown on a GaAs substrate. New Cd free buffer layers In_2S_3 and band offset tunable Zn(O,S), are compared to the most commonly used buffer layer, CdS. The transient reflection measurements allows for the extraction of the electronic transport dynamics at the interface with the buffer. This study allows us to draw conclusions about the pair formation capacity mediated by the transport properties between the CIGS and the buffer layer. The results can guide the development of Cd free buffer layers thus reducing the environmental impact caused by CdS in traditional CIGS solar cells.