HL 24: Poster Session: Ge/Si/SiC / III - V Semiconductors

Time: Monday 16:00–19:00 Location: Poster D

HL 24.1 Mon 16:00 Poster D

Spin Noise Spectroscopy — •Fabian Berski, Carsten Schulte, Katharina-Sophie Isleif, Jens Hübner, and Michael Oestreich — Institute for Solid State Physics, Leibniz Universität Hannover, Appelstr. 2, D-30167 Hannover, Germany

We study the spin dynamics of localized non interacting donor electrons in Gallium Arsenide at low temperatures by means of all optical spin noise spectroscopy (SNS) [1]. SNS avoids the generation of free carries by tuning the cw–probe laser light to the transparent regime of the semiconductor and is therefore a promising tool to reveal hyperfine interaction dominated dephasing processes, as they are expected in low doped semiconductor systems in thermal equilibrium. The experiment is carried out on a specially prepared, MBE–grown GaAs sample. The detected signal contains the longitudinal and transversal dephasing with respect to the effective stochastic magnetic field caused by nuclear spins. The fast transversal timescale is 4.5±3 ns, which is in good agreement with previous reported measurement [1]. The second dephasing time is about 127ns, which states a lower limit on the longitudinal spin dephasing time.

[1] G. M. Müller, M. Oestreich, M. Römer, and J. Hübner, Semiconductor spin noise spectroscopy: Fundamentals, accomplishments, and challenges, Physica E 43, 569 (2010).

HL 24.2 Mon 16:00 Poster D

Detection of high frequency spin dynamics via ultrafast spin noise spectroscopy — •Jan Gerrit Lonnemann, Fabian Berski, Hendrik Kuhn, Petrissa Zell, Georg Müller, Jens Hübner, and Michael Oestreich — Institute for Solid State Physics, Leibniz Universität Hannover, Appelstr. 2, D-30167 Hannover, Germany

Semiconductor spin noise spectroscopy has proven to be a powerful experimental technique to explore spin dynamics in semiconductors [1], however, the bandwidth of the photoreceivers has been a limiting factor if trying to detect high frequency spin noise. In pioniering Experiments Müller et al. showed that this obstacle can be overcome by utilising pulsed lasers [2]. However this implementation is in general restricted to spin dephasing rates that are smaller than the laser repetition rate. We present the experimental relalization of a complementary technique [3] that is sensitive to spin dephasing rates that exceed the repetition rate of the laser system. Due to this spin lifetimes as short as 1 ns and lamor precession frequency above 40 GHz have been observed.

[1] Georg M. Müller, Michael Oestreich, Michael Römer, and Jens Hübner; Semiconductor spin noise spectroscopy: Fundamentals, accomplishments, and challenges; *Physica E*, 43; 569 - 587 (2010).

[2] Georg M. Müller, Michael Römer, Jens Hübner, and Michael Oestreich; Gigahertz spin noise spectroscopy in n -doped bulk GaAs; *Phys. Rev. B*, 81; 121202 (2010).

[3] Sebastian Starosielec and Daniel Hägele; Ultrafast spin noise spectroscopy; *Applied Physics Letters*, 93; 051116 (2008).

HL 24.3 Mon 16:00 Poster D

Hole spin dynamics in 2D GaAs/AlGaAs systems at low temperatures — •Michael Kugler[1], Kamil Korzekwa[2], Pawel Machnikowski[2], Christian Gradl[1], Stephan Furthmeier[1], Michael Griesbeck[1], Marika Hirmer[1], Dieter Schuh[1], Werner Wegscheider[3], Tillmann Kuhn[4], Christian Schüller[1] und Tobias Korn[1] — [1]Universität Regensburg, D-93040 Regensburg, Germany — [2]Wroclaw University of Technology, 50-370 Wroclaw, Poland — [3]ETH Zurich, 8093 Zurich, Switzerland — [4]Westfälische Wilhelms-Universität, D-48149 Münster, Germany

We performed time-resolved Kerr rotation measurements (TRKR) on p-doped GaAs/AlGaAs single wells to resolve the spin dynamics of hole ensembles, confined in so-called natural quantum dots. For long spin lifetimes, we employ the resonant spin amplification (RSA) technique. Hole spins in such systems may be a viable alternative to electron spins for solid-state quantum-bit systems. A key requirement for this is the generation of a resident hole spin polarization (RHSP).

Here, we report on a novel mechanism that leads to a RHSP after optical excitation. It is driven by quick relaxation of the hole spins in the first few ps after excitation. The recombination of electrons and holes with matching spin polarization leads then to a RHSP pointing in the opposite direction than the optically generated spins. It is greatly enhanced by increased temperature, excitation density and excess carrier energy provided by detuning the laser from resonant excitation. The interconnected e/h spin dynamics leading to this behavior are well reproduced theoretically for TRKR as well as for RSA setups.

HL 24.4 Mon 16:00 Poster D

Site-controlled In droplets on GaAs substrates by in situ focused ion beam implantation and droplet epitaxy — •Yu-Ying Hu, Dirk Reuter, and Andreas D. Wieck — Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany

We use a focused ion beam (FIB) to modify (100) GaAs surfaces so that subsequent molecular beam epitaxy (MBE) overgrowth forms In droplets at pre-selected sites. The droplets are then crystallized into InAs by supplying As. During the process of crystallization, In droplets can be transformed into InAs quantum dots or quantum rings by tuning substrate temperature and As flux. In this study, site-controlled single and paired In droplets have been fabricated with the sizes from 80 nm to 150 nm, depending on the focus and the ion fluence. The In amount is also an important parameter for the site-selected droplet formation. The distance between the paired droplets is so far closed to 150 nm by utilizing the ability of FIB patterning.

HL 24.5 Mon 16:00 Poster D

Influence of dilute amounts of Nitrogen in GaAs - A comparison of simulated and experimental STEM HAADF-Z-Contrast measurements — •Nikolai Knaub[1], Andreas Beyer[1], Vivien Vossebürger[1], Rafael Fritz[1], Kakhaber Jandieri[1], Markus Heidelmann[2], and Kerstin Volz[1] — [1]Faculty of Physics and Material Science Centre, Philipps Universität Marburg, D-35032 Marburg — [2]IFF and ER-C, Research Centre Jülich, D-52425 Jülich

The integration of small concentrations of nitrogen into III-V semiconductors such as GaAs and GaP has a big influence on their band gaps and electronic properties. Therefore dilute nitrides are very interesting for electronic and optoelectronic applications. A high crystal quality is necessary to ensure a high efficiency of these devices.

We used a high-angle annular dark field (HAADF) detector in a probe-corrected scanning transmission electron microscope (STEM) to investigate the influence of nitrogen on the structure of these materials. The small covalent radius of nitrogen compared with gallium or arsenic induces static atomic displacements (SADs), whose influence on the crystal-structure also can be measured by quantitative evaluation of HAADF images. An absorptive potential approximation and crystal input structures with and without SADs have been used for the simulation.

It will be shown, that for the low sample thicknesses used for high-resolution Z-contrast imaging, the absorptive potential approximation is valid and that simulation and experiment are in a good agreement, when we take SADs into account.

HL 24.6 Mon 16:00 Poster D

Evolution & optical characteristics of self assembled III-nitride nanowires formed by reactive ion etching — •Anna Haab[1,2], Martin Mikulics[1,2], Toma Stoica[1,2], Jürgen Moers[1,2], Eli Sutter[3], Beata Kardynal[1,2], Sally Riess[1,2], Andreas Winden[1,2], Hilde Hardtdegen[1,2], and Detlev Grützmacher[1,2] — [1]Peter Grünberg Institute-9, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]JARA-Fundamentals of Future Information Technology — [3]Center for Functional Nanomaterials, Brookhaven National Laboratory, Upton, NY 11973, USA

In the past group III-nitrides have received increasing interest for photovoltaic applications (PV) due to their large band gap span in the visible range from 0.7 eV to 3.4 eV. An enhancement of photovoltaic cell performance could be achieved by using nanostructured material which has the possibility to absorb incoming photons more effectively. In this work we studied a simple method for nanostructure fabrication: reactive ion etching (RIE) without any lithographic procedure. The RIE process was optimized to achieve a dense array of nanowires with high aspect ratios. Metal-organic vapor phase epitaxy (MOVPE) was employed to deposit group III-N layers on c-plane sapphire. Subsequent maskless RIE yields a self assembled array of nanowires. Finally the structural and optical characteristics of the nanostructures were

investigated. They exhibit intense bandgap emission in accordance with transmission electron microscopy investigations, which indicate that the nanostructures are without dislocations. RIE on unmasked GaN templates may be a viable route to obtain materials for PV.

HL 24.7 Mon 16:00 Poster D

Epitaxial GaN around ZnO nanopillars — •Mohamed Fikry[1], Manfred Madel[2], Ingo Tischer[2], Ren Zhe[1], Klaus Thonke[2], and Ferdinand Scholz[1] — [1]Institut für Optoelektronik, Universität Ulm, Albert-Einstein-Allee 45, 89081 Ulm — [2]Institut für Quantenmaterie, Gruppe Halbleiterphysik, Universität Ulm, Albert-Einstein-Allee 45, 89081 Ulm

We report on the investigation of the epitaxial quality of GaN layers forming non-polar m-plane facets grown coaxially around ordered ZnO nanopillars. The GaN layers were grown using Metal Organic Vapor Phase Epitaxy (MOVPE). For developing a scalable process, in a first step successful position control of single ZnO nanopillars grown on top of ordered GaN pyramids is achieved. At growth temperatures above 800°C and using hydrogen as a carrier gas, the ZnO nanopillars start to dissolve during the GaN growth, leaving hollow GaN nanotubes. A strong and broad luminescence at 2.8 eV indicates the presence of heavily Zinc doped GaN layers. Characterization involves photoluminescence, scanning electron microscopy, transmission electron microscopy and cathodoluminescence.

HL 24.8 Mon 16:00 Poster D

Band alignment between III-V polytypes — •abderrezak belabbes, Christian Panse, Jürgen Furthmüller, and Friedhelm Bechstedt — Friedrich-Schiller-Universität Jena Max-Wien-Platz 1 D-07743 Jena

Growth of III-V nanorods leads to several stackings and hence besides of 2H also to the formation of other polytypes (4H and 6H). The hexagonal polytypes 2H, 4H, and 6H give rise to a drastic changes of the bonding topology along the cubic [111] or hexagonal [0001] axis but also to significant changes of the electronic structure, e.g. the fundamental energy gap, with respect that of the cubic 3C polytype. Heterocrystalline but homomaterial junctions appear. The trials toward their understanding by means of almost first-principles calculations were basically restricted to the junction 3C-2H and the density functional theory (DFT) which however significantly underestimates the fundamental gaps. In this study, the electronic structure for a variety of polytypes of the Ga-V and In-V compounds (V = P, As, Sb) is computed using a recently developed approximate calculation scheme, the LDA-1/2 method, and taking into account the spin-orbit interaction. Clear trends for the resulting band gaps and band orderings are observed. The aligned electronic structures are used to explain properties of junctions between two polytypes. The gaps and offsets allow to discuss spectroscopic results found recently for such III-V nanowires.

HL 24.9 Mon 16:00 Poster D

Confinement effects and band gap tuning of III-Nitride nanowires — •Klaara Viisanen, Laura Oikkonen, Katri Laaksonen, Maria Ganchenkova, and Risto Nieminen — Aalto University School of Science, Espoo, Finland

Nanowires of semiconductor materials are expected to play an important role in future nanoscale technologies such as third generation photovoltaics and light emitting diodes. It is very important that the electronic properties of a wire can be modified by changing its size. This opens possibilities for band gap engineering without alloying, for which we need a clear understanding of the effect of confinement on the electronic properties of the nanostructures. One of the key choices for nanowire materials are group III-V compound semiconductors. The aim of this work is to computationally examine how the size of the structure affects the width of the band gap for three different materials: AlN, GaN and InN. In addition to the confinement, the band structures of nanowires are also affected by the treatment of their highly reactive surfaces. This has been taken into account by considering two types of surfaces: clean and hydrogen-passivated. The calculations are performed by using three different approaches: density-functional theory within the semilocal approximation (PBE), a range-separated hybrid functional (HSE06) and the GW approximation.

HL 24.10 Mon 16:00 Poster D

Growth mechanisms of thin GaN on AlN — •Konrad Bellmann, Abdul Kadir, Markus Pristovsek, and Michael Kneissl — TU Berlin, Berlin, Deutschland

GaN based QD devices are very promising to reach single photon emission at room temperature, because of their feasibility of higher electron confinement. The lattice mismatch of GaN and AlN is about 2.5%. However, overgrowth of AlN by GaN results in 2D growth at normal growth conditions. In order to achieve QDs in Stranski-Krastanov mode, a small parameter window at low V/III ratio with additional annealing step is needed.

An additional challenge for QD growth is smooth AlN surfaces. Therefore, we have varied the V/III ratio during AlN growth. Due to the high binding energy of AlN, aluminum has a low diffusibility on the surface. With lower ammonia partial pressure higher aluminum ad atom mobility was achieved, resulting in smoother surfaces. High V/III ratio results in spiral growth.

HL 24.11 Mon 16:00 Poster D

Morphology and atomic structure of InGaN surfaces — •Sabine Alamé[1], Christian Friedrich[1], Daria Skuridina[1], Duc Dinh[1], Norbert Esser[2], Michael Kneissl[1], and Patrick Vogt[1] — [1]TU Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Leibniz-Institut für Analytische Wissenschaften-ISAS-e.V., Albert-Einstein-Str. 9, 12489 Berlin, Germany

Although $In_xGa_{1-x}N$ alloys have received much interest over the last years, there is still only limited knowledge about their atomic surface structure. We present a study on the morphology and electronic properties of group-III and group-V polar $In_xGa_{1-x}N$ surfaces with varying indium content ($0 \leq x \leq 100$), grown by metalorganic vapour phase epitaxy on sapphire substrate. In order to obtain clean surfaces, the samples were prepared by thermal annealing between 400°C and 800°C under ultra-high vacuum conditions and in nitrogen plasma. The surface morphology was measured by atomic force microscopy in tapping mode, surface symmetries were investigated by low energy electron diffraction. X-ray photoelectron spectroscopy (XPS) was used to study the binding configurations and electronic properties of the surface. We obtained contamination free $In_{0.15}Ga_{0.85}N$ (0001) surfaces within a temperature range of 600°C - 760°C, showing stable (1x1), (1+1/6), ($\sqrt{3}$x$\sqrt{3}$)R30°, and (2x2) reconstructions, respectively. The results show that the amount of surface indium plays a crucial role for the formation of the surface reconstructions. For further investigation we compared indium-rich $In_xGa_{1-x}N$ (000-1) layers ($0.3 \leq x \leq 0.8$) by means of numerically analyzed XPS core-level spectra.

HL 24.12 Mon 16:00 Poster D

Das Temperaturverhalten von Cd dotiertem $Al_xGa_{(x-1)}N$ — •Patrick Kessler[1], Sahar Hamidi[1], Sérgio Miranda[2], Katharina Lorenz[2] und Reiner Vianden[1] — [1]Helmholtz-Intstitut für Strahlen- und Kernphysik, Universität Bonn, Bonn, Deutschland — [2]Instituto Tecnológico e Nuclear, Sacavém, Portugal

Für verschiedene Anteile von Al wurde das Temperaturverhalten von Cd dotiertem AlGaN untersucht.

Mit der Methode der gestörten Winkelkorrelation wird der elektrische Feldgradient (EFG) in der Umgebung von Sondenatomen untersucht. Dazu werden radioaktive ^{111m}Cd und ^{117}Cd Isotope in dünne AlGaN Schichten auf Saphir Substrat mit einer Energie von 30 keV implantiert. Die dadurch verursachten Kristallschäden werden unter Stickstoffffluss bei einer Temperatur von 1220 K ausgeheilt.

Im Gegensatz zu ^{111}In, das zu ^{111}Cd zerfällt und zwei Sondenumgebungen in AlGaN zeigt, ist bei den Sonden ^{111m}Cd und ^{117}Cd nur eine definierte Umgebung beobachtbar. Mit steigender Temperatur und Al Anteil nimmt der dazugehörige EFG zu. Zusätzlich wird beobachtet. dass die Kristallqualität mit dem Al Anteil zunimmt.

HL 24.13 Mon 16:00 Poster D

Lifetime measurements on III-V solar cell relevant materials — •Anja Dobrich[1], Klaus Schwarzburg[1], Elias Martinez[1], Marinus Kunst[1], and Thomas Hannappel[1,2,3] — [1]Helmholtz-Zentrum Berlin, Institut Solare Brennstoffe und Energiespeichermaterialien, D-14109 Berlin — [2]TU Ilmenau, Institut für Physik, Fachgebiet Photovoltaik, D-98693 Ilmenau — [3]CiS Forschungsinstitut für Mikrosensorik und Photovoltaik, D-99099 Erfurt

The lifetime of minority charge carriers in III-V relevant solar cell absorber materials is essential for the performance of solar cells. Suitable nondestructive methods to get informations about the electronic quality of the grown layers are the time resolved photoluminescence (TRPL) and transient microwave photoconductivity (TRMC). The lifetime of minority charge carriers generated by a laser pulse is measured and gives direct results about the material quality. Both methods should lead to the same results under similar excess charge carrier

density conditions and deliver informations about the bulk material quality and the interface quality as well. However, if electric fields are generated caused by growth conditions in the structures to be examined (i.e. on interfaces) or p-n junctions in solar cell structures are investigated, the assumption of a homogeneous charge carrier distribution is no more valid and leads to the false interpretation of the measured results. With the help of some examples the influences of these effects should be demonstrated for the measured minority charge carrier lifetimes of MOVPE grown InP/InGaAs /InP test structures and solar relevant absorbers and structures in generally.

HL 24.14 Mon 16:00 Poster D

Coherent phonon excitation in SiC — Toru Shimada[1], •Wiktor Pronobis[1], Martin Scheuch[1], Kamaraju Natarajan[1], Christian Frischkorn[2], Martin Wolf[1], and Tobias Kampfrath[1] — [1]Fritz-Haber-Institut der MPG, Faradayweg 4-6, 14195 Berlin — [2]Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin

Silicon carbide (SiC) is a prominent material for high-temperature, high-power, high-frequency and radiation-resistant devices. In view of these important applications, it is of great interest to characterize the basic solid-state properties of this material. Here, we consider coherent vibrations of the crystal lattice (coherent phonons) which we trigger by impulsive excitation with a femtosecond laser pulse (pump pulse). A second time-delayed laser pulse (probe pulse) is used to monitor the lattice vibration in the time domain by measuring the pump-induced birefringence of the sample as a function of the delay between pump and probe pulses. Based on the temperature dependence of their decay, we discuss the anharmonic coupling of the LO (29.3 THz) and the folded TO (23.8 THz) phonon mode in the 3C (cubic) and 6H (hexagonal) polytypes of SiC, respectively.

HL 24.15 Mon 16:00 Poster D

Sol-Gel-assembly of micro-crystalline silicon carbide and EPR-measurements — •Tim Baumgarten, Andre Konopka, Eva Rauls, Wolf-Gero Schmidt, Uwe Gerstmann, and Siegmund Greulich-Weber — Physics, University of Paderborn, Paderborn, Germany

Micro-crystalline semiconductor materials offer a huge amount of optical and electrical applications due to their vast surface to volume ratio. Silicon carbide (SiC) has become a material of interest in this field, because of its wide band gap and chemical stability, offering potential applications as semiconductor substrate and high power applications material, as well as chemical catalytic structure. In order to benefit from these abilities, it is most important to get a deep understanding of the crystalline structure and the electro-optical characteristics resulting from the large surface. In our sol-gel process we produce SiC microcrystals with various sizes and dopings. We performed Electron Paramagnetic Resonance measurements (EPR), to obtain information on the electronic structure of our samples, Debye-Scherrer X-Ray diffraction to analysis the crystalline parameters and optical spectroscopy to analysis the electro-optical characteristics. In order to get a deeper understanding of our experimental results, we performed calculations via density functional theory (DFT). In this contribution we present our results on the analysis of different surfaces of micro-crystaline SiC.

HL 24.16 Mon 16:00 Poster D

Light-induced electron spin resonance (LESR) studies of silicon vacancy centers in 6H-SiC — •Daniel Riedel[1], Andreas Sperlich[1], Hannes Kraus[1], Franziska Fuchs[1], Alexandra Soltamova[2], Pavel Baranov[2], Georgy Astakhov[1], and Vladimir Dyakonov[1,3] — [1]Experimental Physics VI, Julius Maximilian University of Würzburg, D-97074 Würzburg — [2]Ioffe Physical-Technical Institute, St. Petersburg, RU-194021 Russia — [3]ZAE Bayern, D-97074 Würzburg

The silicon vacancy V_{Si} centers in hexagonal polytypes of SiC, in particular 6H-SiC, have C_{3v} symmetry allowing for zero field splitting between spin sublevels in the ground state. Below-band-gap illumination of 6H-SiC samples results in nonequilibrium spin population, which is directly detected in our X-band (9.4 GHz) ESR setup. We investigated LESR as a function of temperature, illumination wavelength and intensity in order to find the most efficient conditions for initialization, manipulation and readout of the V_{Si} spin. The observed saturation of the LESR signal at relatively low illumination intensities and microwave powers indicates efficient optical spin pumping mechanism and long spin relaxation time, much longer than radiative lifetime in the excited states. Our observations suggest that V_{Si} centers are promising candidates for qubits.

HL 24.17 Mon 16:00 Poster D

Spatially-resolved photoluminescence of silicon vacancy centers in 6H-SiC — •Franziska Fuchs[1,2], Georgy Astakhov[1], Alexandra Soltamova[3], Pavel Baranov[3], and Vladimir Dyakonov[1,2] — [1]Experimental Physics VI, Julius Maximilian University of Würzburg, D-97074 Würzburg — [2]ZAE Bayern, D-97074 Würzburg — [3]Ioffe Physical-Technical Institute, St. Petersburg, RU-194021 Russia

Defects in silicon carbide (SiC) are considered as promising candidates for qubits operating at ambient conditions (i.e., room temperature and zero magnetic field). As a rule, defects in SiC are created by electron or neutron irradiation, which is extensive and therefore causes damage of the crystal lattice.

In this study we demonstrate that 6H-SiC monocrystals grown by high temperature Lely technique contain silicon vacany (V_{Si}) defects, even without irradiation. We performed systematic studies of the V_{Si} photoluminescence (PL) as a function of temperature. Strong PL signal observed at room temperature confirms high crystalline quality of our SiC monocrystals. Moreover, using confocal arrangement we performed spatially resolved PL measurements and demonstrated homogeneous distribution of V_{Si} in all three dimensions throughout the samples.

Summarizing, the high temperature Lely growth technique seems to be an appropriate method for the fabrication of high quality SiC samples for quantum information processing.

HL 24.18 Mon 16:00 Poster D

Organic Functionalization of 3C-SiC Surfaces — •Matthias Sachsenhauser[1], Sebastian Schoell[1], Alexandra Oliveros[2], John Howgate[1], Martin Stutzmann[1], Stephen Saddow[2], and Ian Sharp[1] — [1]Walter Schottky Institut, Technische Universitaet Muenchen, Garching, Germany — [2]Electrical Engineering Department, University of South Florida, Tampa, FL, USA

3C-SiC is a promising substrate material for electronic and mechanical biosensing applications due to its exceptional stability, strength, and biocompatibility. Although the quality of epitaxially grown 3C-SiC on Si has significantly improved in recent years, only limited work has been devoted to establishing methods of bio-organic functionalization of its surfaces. Here, we utilize wet chemical processing techniques for the formation of self-assembled aminopropyldiethoxymethylsilane (APDEMS) and octadecyltrimethoxysilane (ODTMS) monolayers on n-type (100) and (111) 3C-SiC. Chemical activation of the surfaces is achieved by HF treatment in a first step, followed by reaction with ODTMS and APDEMS molecules. The structural and chemical properties of the surfaces are characterized using static water contact angle, atomic force microscopy, and X-ray photoelectron spectroscopy. These techniques verify the formation of covalently bound monolayers. Contact potential difference and surface photovoltage measurements are used to examine the near-surface band-bending and changes of interfacial dipoles due to chemical binding. Finally, ODTMS layers are micropatterned by means of lithographically-defined oxidation and the resulting changes of local wettability are illustrated.

HL 24.19 Mon 16:00 Poster D

Isotopically modulated silicon and its thermoelectric properties — •Soizic Eon[1], Nadine Wehmeier[1], Hartmut Bracht[1], Georg Bastian[2], Arne Vogelsang[2], Saeed M. Ullah[2], Anton Plech[3], Christian Heiliger[4], and Dietrich Wolf[5] — [1]WWU Münster — [2]U Rhine-Waal — [3]KIT Karlsruhe — [4]U Giessen — [5]U Duisburg-Essen

In order to use silicon (Si) for thermoelectric applications, it is necessary to increase the figure of merit ZT for example by decreasing the thermal conductivity. A promising approach is the use of isotopically modulated Si structures. Isotopically enriched Si multilayers were grown on natural Si substrates by means of molecular beam epitaxy. Homogeneously p- and n-type samples were fabricated and assembled to a thermoelectric module. Information about the thermal stability was gained by depth profiling before and after thermal treatments. The electrical conductivity was determined by Van de Pauw and current-voltage measurements after ohmic contact formation. Various methods were applied to determine the thermal conductivity of the multilayer structures. This includes measurements with time-domain thermoreflectance, time-resolved X-Ray scattering and the 3-ω-method. Our investigations reveal a reduced conductance due to phonon scattering at the isotopes interface while the electrical conductivity remains

unchanged. Molecular dynamics and ab-initio calculations confirm a reduced thermal conductivity between Si layers of different isotopic composition. Further reduction is expected by optimizing the arrangement of the isotope layers and by an additional lateral confinement.

HL 24.20 Mon 16:00 Poster D

DLTS study on deep levels after aluminum gettering in FZ silicon — •Sarina Grevsmühl, Patricia Krenckel, Doaa Abdelbarey, and Michael Seibt — IV. Physikalisches Institut, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany

In silicon device fabrication gettering is an important process for reducing metal contamination. In particular, iron is known to have detrimental effects on the electrical performance of these devices due to its deep levels in the silicon band gap which reduce minority carrier lifetime [1]. Recently it was reported that illumination after performing an aluminum gettering step on iron contaminated p-type FZ silicon introduces a deep level ("FeD") that has tentatively been attributed to an iron vacancy complex [2].

In this work aluminum gettering was performed after iron indiffusion into boron-doped FZ silicon. Additionally, the samples were exposed to white light. The material was characterized using deep level transient spectroscopy (DLTS) on Schottky contacts. Along with the signal corresponding to the FeD defect and the iron interstitial level, a level probably due to divacancies was observed with a concentration of $5 \cdot 10^{12}$ cm^{-3} in illuminated samples. Results on the effects of thermal annealing, illumination and Schottky contact preparation on these deep levels will be reported on this contribution.

This work was financially supported by the BMU.

[1] A. A. Istratov at al., Appl. Phys. A 70, 489-534 (2000)
[2] D. Abdelbarey et al., J. Appl. Phys. 108, 043519 (2010)

HL 24.21 Mon 16:00 Poster D

Measurement of the dependency of the defect density on the band gap in a-SiGe:H thin films — •Burkhard Gilles[1], Ulrich Heinzmann[1], Helmut Stiebig[2], Andreas Gondorf[2], Pavel Prunici[2], and Florian Maier[2] — [1]Molecular and Surface Physics, Bielefeld University, 33615 Bielefeld, Germany — [2]Malibu GmbH Co. KG, 33609 Bielefeld, Germany

Increasing the quality of the amorphous silicon [aSi] and Silicon-Germanium alloys [aSiGe] is a necessary task for solar energy conversion efficiency of thin film solar cells. The defect states of a-Si:H based materials - represented by the dangling bond density and the Urbach tail - depend on the applied deposition conditions and the composition of the layer. A deeper understanding of the defect state distribtion is a crucial requirement to further enhance the efficiency and the long term stability of thin film silicon based solar cells. The dependency of the defect density on the Fermi energy was already subject of many investigations. In this work, the dependency of the defect density on the band gap will be investigated. In order to determine the defect distribution a constant photocurrent measurement (CPM) setup was installed. CPM spectra from a-SiGe:H layers will be presented. The quality of the material and the dependency of the defect density on the band gap will be discussed.

HL 24.22 Mon 16:00 Poster D

Photoluminescence spectra of SiGe quantum islands grown on prepatterned Si substrates: evidence of carrier interaction and biexcitonic transitions — •Petr Klenovský[1,2], Moritz Brehm[3], Vlastimil Křápek[1,4], Elisabeth Lausecker[3], Florian Hackl[3], Thomas Fromherz[3], Günther Bauer[3], and Josef Humlíček[3] — [1]Department of Condensed Matter Physics, Faculty of Science, Masaryk University, Kotlářská 2, 61137 Brno, Czech Republic — [2]CEITEC - Central European Institute of Technology, Masaryk University, Kamenice 753/5, 62500 Brno, Czech Republic — [3]Institute of Semiconductor and Solid State Physics, Johannes Kepler University Linz, 4040 Linz, Austria — [4]Institute of Physics, Academy of Sciences of the Czech republic, Cukrovarnická 10, Praha 6, 162 53, Czech Republic

The pumping intensity (I) dependence of the photoluminescence (PL) spectra of SiGe quantum dots grown on prepatterned Si(001) substrates was studied. Their analysis revealed up to seven spectral bands attributed to phonon-assisted recombinations, no-phonon recombinations of the ground and excited states of excitons, all showing linear dependencies of the peak intensity on I. At large values of I, additional lines with a quadratic dependence on I appear in he PL spectra that are assigned to biexciton transitions. The experimentally obtained energies of the no-phonon transitions are in good agreement with the exciton and biexciton energies calculated within the framework of a $\vec{k} \cdot \vec{p}$ theory. To the best of our knowledge this is the first clear evidence of the carrier interaction and biexcitonic transitions in SiGe/Si QDs.

HL 24.23 Mon 16:00 Poster D

Impact of p-type doping on Germanium self-diffusion — •Tobias Südkamp[1], Hartmut Bracht[1], Giorgia Scapellato[2], Elena Bruno[2], and Dominique Bougeard[3] — [1]Institut für Materialphysik, WWU-Münster, Germany — [2]Center MATIS CNR-IMM, University of Catania, Italy — [3]Institur für Experimentelle und Angewandte Physik, Universität Regensburg, Germany

Self-diffusion in germanium (Ge) under n-type doping has been recently investigated by means of Ge isotope multilayer structures. The n-type dopants of interest such as phosphorus, arsenic and antimony were diffused from the surface into the isotope structure. The gradual change of the self-atom profile along the dopant profile reveals the dominance of doubly negatively charged vacancies. Similar experiments on the impact of p-type dopants on Ge self-diffusion are hampered by the slow diffusivity of acceptor dopants such as boron (B), aluminium and gallium. In order to study the self-diffusion of Ge under p-type doping we utilize a Ge isotope multilayer structure doped with B by implantation. Implantation of B was performed in an amorphous $\left({}^{\mathrm{nat}}\mathrm{Ge}/{}^{73}\mathrm{Ge}\right)_{10}$-multilayer structure grown by molecular beam epitaxy on a preamorphized Ge wafer. The amorphous, B-implanted samples were recrystallized by annealing and subsequently used for diffusion anneals. First results of this approach to study self-diffusion in Ge under p-type doping are presented.

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Glancing Angle Deposition: Structural Aspects and Growth Modelling — Christoph Grüner, •Jens Bauer, and Bernd Rauschenbach — Leibniz-Institut für Oberflächenmodifizierung, Permoserstrasse 15, D-04318 Leipzig, Germany

Recently, considerable progress in understanding ballistic deposition has been achieved. Over a long time the topic was inscrutable, since it was not possible to simulate the structure evolution properly. New results in kinetic Monte Carlo studies showed that the large variety of contradicting results originates from the so-called grid-effect in on lattice-simulations. To avoid this problem Tanto et al. [1] proposed the usage of cluster particles for ballistic deposition modelling. We applied this novel conception to generate a fast and easy experiment-adaptable Monte Carlo simulation code. The nanostructure evolution in glancing angle deposition and the influence of the deposition parameters on the structural properties were studied in comparison between experiment and simulation. Substrates with nanoscopic pre-patterns were successfully applied to form arranged fields of nanostructures. The temporal evolution of ordered and disordered nanocolumns was investigated in simulation and experiment. Regarding the nanostructured film porosity two contributions have to be considered: an interstructure contribution because of the spatial nanostructure separation and an innerstructure contribution originating from distinct density changes within the nanostructures. The results are applied to describe macroscopic film properties as the film density and the effective refractive index.

[1] B. Tanto, C. F. Doiron, T.-M. Lu: Phys. Rev. E 83 (2011) 016703

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High throughput investigation of the thermoelectric properties of Si based compounds — •Ingo Opahle, Georg K. H. Madsen, and Ralf Drautz — ICAMS, Ruhr-Universität Bochum, Bochum, Germany

We have investigated the structural stability and electronic structure of a series of known and hypothetical Si based compounds. Calculations are performed in the framework of density functional theory using a recently developed High Throughput Environment (HTE). The HTE calculations are used for an efficient screening of candidate structures for enhanced thermoelectric properties. We discuss trends in the structural stability as well as the electronic and transport properties. Furthermore, details of the HTE implementation like an efficient prescreening of trial structures will be discussed.