HL 68: Heterostructures and interfaces

Time: Wednesday 15:00–17:00 Location: POT 051

HL 68.1 Wed 15:00 POT 051

Electronic properties of the ideal Fe/GaAs(110) interface — •Tim Ifflände, Steffen Rolf-Pissarczyk, Lars Winking, Rainer G. Ulbrich, and Martin Wenderoth — IV. Physikalisches Institut, Georg-August-Universität Göttingen, Germany

In this study we present the investigation of the ideal Fe/GaAs(110) interface by scanning tunneling microscopy (STM) and spectroscopy (STS) in cross-sectional geometry. The Fe/GaAs(110) interface was grown at low temperature and subsequently annealed to room temperature yielding an epitaxial and atomically flat interface without any sign of compound formation [1]. Atomically resolved STS measurements across the Schottky contact reveal a continuum of states in the band gap of the semiconductor in the first few atomic layers at the interface. Furthermore, we report STS measurements of the electronic landscape of the space charge region (SCR) of the Schottky contact. The bending of the valence and conduction band along the SCR for differently n- and p-type doped Fe/GaAs(110) interfaces is demonstrated. To properly interpret the STS data the tip induced band bending has to be taken into consideration. This is addressed by means of a 3-dimensional finite element method calculation. A comparison of the measured and calculated data yields the Schottky barrier (SB) height of the interface and enables us to discuss our findings in the context of theoretical works on SB formation. This work was supported by the DFG SPP 1285.

[1] Winking et al. Appl. Phys. Lett. 92, 193102 (2008)

HL 68.2 Wed 15:15 POT 051

Early stages of nucleation in Cu/a-Si system — •Mohammed Ibrahim[1], Zoltán Balogh[1], Dietmar Baither[1], Patrick Stender[1], and Guido Schmitz[2] — [1]Institut für Materialphysik, University of Münster — [2]Institut für Materialwissenschaft, Universität Stuttgart

Laser-assisted atom probe shows a unique potential in the analysis of embedded Si/metal interfaces, owing to its ability to deliver 3D chemical mapping with near atomic resolution. It is therefore a complementary part to the 2D electron microscopic methods [1]. Recently, we observed that the reaction between Cu and a-Si to form silicide phases is strongly influenced by the deposition sequence. From that, if Cu deposited on a-Si, an instantaneous reaction happens at low temperature and a reacted layer increases linearly with increasing annealing time [2]. For the reverse case, high temperatures or long annealing time are required for the appearance of silicide at the interface [3]. In this work, we focus on the phase nucleation with higher nucleation barrier in case of a-Si deposited upon Cu. We observed an increase of roughness at the interface, the appearance of Cu rich particles in the a-Si bulk as well as spikes of high Cu contents protruding from the metallic Cu. As opposed to previous reports [4], these findings indicate that a significant nucleation barrier exists for nucleating the silicide at the interface. Nucleation happens at the a-Si side probably even inside the Si bulk.

[1] R. Schlesiger et al., Rev. Sci. Instrum., 81 (2010) 043703. [2] B. Parditka et al., Acta Mater., 61 (2013) 7173. [3] M. Ibrahim, et. al, Phys. Stat. Sol. C, DOI: 10.1002/pssc.201300370. [4] F. Hodaj , and. A. Gusak, Acta Mater., 52 (2004) 4305.

HL 68.3 Wed 15:30 POT 051

An XPS study on $Al_xGa_{1-x}N$/metal oxide hetero interfaces with ZnO and CuO_x, respectively — •Benedikt Kramm, André Portz, Philipp Hering, Achim Kronenberger, Angelika Polity, and Bruno K. Meyer — 1. Physikalisches Institut, Justus Liebig Universität, Heinrich-Buff-Ring 16, 35392 Gießen, Germany

For semi-conductor devices the energy band alignment of hetero junctions is one of the crucial factors which deliver a judgment for a successful operating electronic device. For our research on the nitride-oxide hetero interface we fabricated various hetero junctions based on n-type aluminum gallium nitride alloys (with 7%, 11% and 15% aluminum content) plus pure n-type and p-type gallium nitride. Copper oxide and zinc oxide were on top, respectively. The nitrides were epitaxial grown on sapphire substrates whereas the oxide top layers were deposited by RF-magnetron sputtering as 50 nm thick poly crystalline thin films. To get knowledge of the energetic behavior, like the band offsets of the valence and conduction band, charging effects as well as diffusion and the shape of the oxy-nitrogen mixed interface we performed X-ray photoelectron spectroscopy. A special focus was on the naturally build oxygen overlayer on gallium nitride which is typically a few angstroms thick and how it affects the hetero interface. Furthermore we evaluated the shifting of the photoelectron signals due to the preferential sputtering effect during depth-profiling with argon-ion bombardment.

HL 68.4 Wed 15:45 POT 051

Heteroepitaxial growth of GaP on Si(111) — •Agnieszka Paszuk[1,2], Weihong Zhao[1,2], Matthias Steidl[1,2], Sebastian Brückner[1,2], Anja Dobrich[1], Oliver Supplie[1], Peter Kleinschmidt[1,3], and Thomas Hannappel[1,2,3] — [1]Technische Universität Ilmenau, Institute for Physics, Ilmenau, Germany — [2]Helmholtz-Zentrum Berlin, Institute for Solar Fuels, Berlin, Germany — [3]CiS Forschungsinstitut für Mikrosensorik und Photovoltaik, Erfurt, Germany

III-V nanowires exhibit properties for new concepts of high efficiency solar cells. The use of Si instead of III-Vs as substrate benefits from large cost reduction. We prepare thin GaP films on Si as transition buffer layer for subsequent NW growth, since GaP is almost lattice matched to Si. GaP(111) exhibits two polarities, GaP(111)A and B type, which differ by an inversion of the crystal lattice. However, vertical growth of NWs requires GaP(111) layers with B-type polarity. Further, rotational domains might occur in GaP layers during heteroepitaxy, decreasing the crystal quality. Here, we show that surface preparation of Si(111) substrates strongly influences the subsequently grown GaP film polarity during heteroepitaxy by metalorganic vapor phase epitaxy (MOVPE). Low energy electron diffraction (LEED) can be applied to distinguish between the two GaP polarities, which exhibit two different surface reconstructions. X-ray diffraction (XRD) enabled analysis of rotational domains in the GaP buffer layer. Our MOVPE prepared GaP(111)B/Si(111) quasisubstrates enabled vertical growth of III-V NWs.

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***In situ* RAS and *ab initio* DFT study of GaP/Si(100) interface structures** — •Oliver Supplie[1,2], Sebastian Brückner[1,2], Oleksandr Romanyuk[3], Peter Kleinschmidt[1,2], Henning Döscher[1,2,5], Frank Grosse[4], and Thomas Hannappel[1,2] — [1]Helmholtz-Zentrum Berlin, Institute Solar Fuels — [2]TU Ilmenau, Institut für Physik, FG Photovoltaik — [3]Institute of Physics, Academy of Sciences of the Czech Republic, Prague — [4]NREL, Golden, CO, USA — [5]Paul-Drude Institut für Festkörperelektronik, Berlin

GaP/Si(100) is considered as quasi-substrate for lattice-matched GaPN/Si photoelectrochemical tandem diodes [1]. The formation of the crucial polar-on-nonpolar heterointerface in vapor phase epitaxy ambient is studied here by *in situ* reflection anisotropy spectroscopy (RAS) in combination with *ab initio* density functional theory (DFT). We can choose between energetically and kinetically [2] driven Si(100) step formation, which results in either A-type or B-type majority domains of Si dimers. The sublattice orientation of the subsequently grown GaP film depends on the type of Si surface. In an abrupt interface model [3], Si–P bonds are found to be favored. *Ab initio* DFT calculations [4] show that Si–P bonds are energetically favored over Si–Ga bonds at abrupt interfaces. Charge can be compensated in an in-plane (2x1) interface unit cell with a Si to P (Ga) atomic mixing ratio of 0.5:0.5 which is favorable in thermodynamic equilibrium.

[1] Döscher et al., *ChemPhysChem* **13** (2012) 2899. [2] Brückner et al., *PRB* **86** (2012) 195310. [3] Beyer et al., *JAP* **111** (2012) 083534. [4] Romanyuk et al., *PRB* **88** (2013) 115312.

HL 68.6 Wed 16:15 POT 051

Effect of growth conditions on electrical properties of epitaxial GaP/Si (100) — •Emad H. Hussein[1,2], Fariba Hatami[1], and W. Ted Masselink[1] — [1]Institut für Physik, Mathematisch-Naturwissenschaftliche Fakultät I, Humboldt Universtät zu Berlin, Newtonstrasse D-15, 12489 Berlin, Germany — [2]On leave from department of Physics, college of Science, Al-Mustansiriyah University, Baghdad, Iraq

Gallium phosphide layers were grown using gas-source molecular beam epitaxy on p-type silicon substrates of orientation (100). The growth

temperature was varied between 250 and 550 °C. Samples grown at 250 and 400 °C were thermally annealed at 500 and 480 °C for 10 and 90 min, respectively. (Subsequent contact alloying was carried out at much lower temperature.) Current-voltage (I-V) and capacitance-voltage (C-V) measurements were carried out in the dark at room temperature. The structures were also characterized using x-ray diffraction. From I-V measurements, it was found that the GaP/Si heterostructures grown at 400 °C and annealed at 480 °C for 90 minutes exhibited rectifying characteristics. The C-V data show the increased dopant diffusion during the annealing process. Furthermore, the C-V allows us to characterize the location of the junction and the electrically active defects. We conclude that the electrical properties of the GaP/Si can be improved after long-time annealing due to reduction of the defects in the structure which is in agreement with the x-ray analysis.

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THz Transmission Spectroscopy of Charge Carriers in Semiconductor Heterostructures with epitaxial, complementary doped gate — •Shovon Pal[1,2], Hanond Nong[2], Sascha Valentin[1], Arne Ludwig[1], Nathan Jukam[2], and Andreas D. Wieck[1] — [1]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum — [2]Arbeitsgruppe Terahertz-Spektroskopie und Technologie, Ruhr-Universität Bochum

Intersubband transitions take place between quasi-two-dimensional (2D) electronic states called subbands, which are formed due to confinement of electrons in the growth direction. Confined electrons in the ground subband absorb incident infrared radiation and are excited to higher subbands, resulting in transmission minima at intersubband resonance (ISR) frequencies. These frequencies lie in the THz domain and hence THz-transmission spectroscopy of these 2D charge carriers serves as an effective tool to investigate ISR. In the present work, an epitaxial, complementarly doped gate is used to control the 2D electron density in a modulation doped GaAs-AlxGa(1-x)As heterojunction to observe the ISR. Hall measurements of the sample show that the 2D electron density is n=1.76e11 cm-2. Density chopping measurements between the threshold voltage (n=0) and a certain gate voltage (n) were performed with the sample tilted at 30°, normalizing the transmission spectra T(n) via division by T(0). With a magnetic field in beam direction and the sample tilted at the same angle as before, half-field coupling of the cyclotron resonance with the ISR was observed. All measurements were performed at 4.2 K.

HL 68.8 Wed 16:45 POT 051

Investigation of interband dynamics in single InAs/GaAs quantum dots — •Daniel Stephan[1,2], Jayeeta Bhattacharyya[1], Manfred Helm[1,2], Yongheng Huo[3], Oliver Schmidt[3], Armando Rastelli[4], and Harald Schneider[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Germany — [2]Technische Universität Dresden, Germany — [3]Leibniz Institute for Solid State Materials Research Dresden, Germany — [4]Johannes Kepler Universität, Austria

We investigate the dynamics of inter-sublevel transitions in single InAs/GaAs self-assembled quantum dots (QDs). By using a micro-photoluminescence (PL) setup and low-density QD samples, we measure the PL emission from single QDs. The QDs is manipulated by a free-electron laser pulse tuned to the inter-sublevel transition energy, which excites carriers to a higher energy level, from which they decay non-radiatively back to the ground state. The PL is measured spectrally resolved, as well as time-resolved, employing time-correlated single photon counting. In time resolved measurements, the inter-sublevel dynamics causes quenching in the exponential PL decay. In contrast to previous studies on QD ensembles[1,2], the use of single dots eliminates effects such as inhomogeneous broadening and inter-dot transfer, providing a better understanding of inter-sublevel carrier dynamics.

[1] J. Bhattacharyya, et al., Applied Physics Letters 97, 031101 (2010).

[2] J. Bhattacharyya, et al., Applied Physics Letters 100, 152101 (2012).