HL 25: Group IV (other than C): Si/Ge/SiC

Time: Wednesday 9:30–12:00 Location: H33

HL 25.1 Wed 9:30 H33

Room-temperature coherent electrical readout of silicon vacancy defect spins in silicon carbide — •Matthias Niethammer[1], Matthias Widmann[1], Torsten Rendler[1], Naoya Morioka[1], Yu-Chen Chen[1], Rainer Stöhr[1], Jawad Ul Hassan[3], Sang-Yun Lee[2], Amlan Mukherjee[1], Junichi Isoya[4], Nguyen Tien-Son[3], and Jörg Wrachtrup[1,5] — [1]3rd Institute of Physics, IQST and SCOPE, University of Stuttgart — [2]Korea Institute of Science and Technology — [3]Linköping University — [4]University of Tsukuba — [5]Max Planck Institute for Solid State Research

4H-Silicon Carbide (SiC) is a matured semiconductor with advanced manufacturing technology and is widely used in the power electronics industry. Recently, it has gained lot of attention as a host material for point defects which can be exploited to build quantum sensors. Optical readout of single spin defects with long-lived coherence has already been demonstrated at room temperature. Here we combine the quantum properties of the spin defects in SiC with electrical readout. We demonstrate, electrical readout of the spin state of an silicon vacancy (V_{Si}^-) ensemble in SiC at room temperature using two-photon absorption and photo-current detection technique in a metal-semiconductor-metal device. We show coherent control of the spin states indicating spin preserving nature of the electrical readout technique. Such a technique apart from being scalable, is also compatible with advanced control techniques, which can be directly adapted from the optical domain for an increased sensitivity or other sensing purposes.

HL 25.2 Wed 9:45 H33

Investigation of the Temperature Dependence of the Critical Points E_0 and $E_0+\Delta_0$ of Bulk Ge — •Carola Emminger, Nuwanjula Samarasingha, Farzin Abadizaman, and Stefan Zollner — New Mexico State University, Las Cruces, USA

Knowledge of the behavior of critical points (CPs) of Ge and other semiconductors is valuable for the further development of electronic and optoelectronic devices. The authors investigate the dielectric function of Ge between 0.5 eV and 1.3 eV using spectroscopic ellipsometry at various temperatures between 10 K and 740 K. The interband CPs E_0 and $E_0+\Delta_0$, where E_0 is the direct band gap of Ge and Δ_0 is the spin-orbit splitting occurring at the center of the Brillouin zone, lie in this energy range and are subject of our investigations. Applying an analysis in reciprocal space by performing a discrete Fourier transform of the data points and fitting the resulting Fourier coefficients, the parameters describing the line shape of E_0 are found as a function of temperature. Like for the CPs at higher energies, the authors find a red shift of the E_0 and $E_0+\Delta_0$ energies which can be described by a Bose-Einstein factor accounting for electron-phonon interactions. The results of the reciprocal-space analysis are compared to the parameters determined by a parametric semiconductor fit.

HL 25.3 Wed 10:00 H33

Application of Flash Lamp Annealing for Controlled Nickel Silicidation of Silicon Nanowires — •Muhammad Bilal Khan, Dipjyoti Deb, Slawomir Prucnal, Artur Erbe, and Yordan M. Georgiev — Institute Of Ion Beam Physics And Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany

Silicon (Si) nanowires (NWs) have potential applications in various areas including electronics, opto-electronics and biochemical sensing. These wires are used to fabricate electronic devices with new architectures to complement the scaling down of electronic circuits. Our work focuses on one such architecture called Reconfigurable field effect transistors (RFET). An RFET is a Nickel(Ni)Si_2-Si-$NiSi_2$ Schottky junctions based device, which has an intrinsic Si channel. To fabricate an RFET, SiNWs are silicided at both ends to form Schottky junctions with the Si channel. Typically, it has two gates placed on each of the two Schottky junctions. It can be tuned to p- or n- polarity by applying appropriate electrostatic potential at one of the gates. Therefore, functional complexity and performance of electronic circuits can be enhanced using such FETs. Formation of $NiSi_2$ is a pre-requisite for proper operation of these devices because metal work function of $NiSi_2$ aligns itself near the mid-bandgap of Si. This enables band bending by application of an appropriate electrostatic potential for the operation of devices either as p- or as n- FET. We report our results on Ni silicidation using flash lamp annealing. By optimizing the silicidation process, control over the diffusion of Ni into the nanowire and proper silicide phase formation is achieved.

HL 25.4 Wed 10:15 H33

Engineering the light emission properties of hexagonal Ge by structural modifications — •Jens Renè Suckert, Claudia Rödl, Jürgen Furthmüller, Friedhelm Bechstedt, and Silvana Botti — Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany

The design of CMOS integrable laser sources allows for intra- and interchip optical communications at an attojoule/bit energy consumption. To this end, a pure silicon laser would be the ideal solution, but unfortunately Si has an indirect gap and, therefore, it is not suitable for laser applications.

Hexagonal Ge, on the other hand, may represent a viable alternative: It features excellent CMOS compatibility and, even though its direct gap of 0.3 eV is only weakly dipole allowed, the strongly dipole-active optical transition to the second conduction band is only about 0.3 eV higher in energy. This opens the way to band-structure engineering by structural modifications, such as nanostructuring, alloying, or straining.

Here, we use *ab initio* density-functional theory to investigate the impact of various lattice strains (hydrostatic pressure, biaxial strain, uniaxial strain, etc.) on the electronic structure of hexagonal Ge. We demonstrate that the order of the two lowest conduction bands can be inverted with less than 5 % of tensile uniaxial strain which strongly improves the light-emission properties of hexagonal Ge.

HL 25.5 Wed 10:30 H33

Atomic Effective Pseudopotentials for Large Scale Defect Calculations — •Walter Pfäffle and Gabriel Bester — University of Hamburg, Hamburg, Germany

We present a method to derive atomic effective potentials for defects in semiconductors (AEPs) based on the total screened potentials calculated using density functional theory that involves no free parameters and features a robust procedure for achieving a dense G-space sampling. We take advantage of the fundamentally short-ranged nature of impurity-induced potential changes and demonstrate that impurity potentials obtained using the self-consistently calculated potentials for small supercells can be accurately applied in non-self-consistent calculations for different geometries and substantially larger systems. This approach allows an accurate treatment of impurity problems free from the significant restrictions usually associated with finite supercell size. Impurity potentials for substitutional Mn and group-IV acceptors in GaAs are presented.

15 min. break

HL 25.6 Wed 11:00 H33

Group IV Nanowires: Fabrication and Particular Applications — •Yordan M. Georgiev[1], Muhammad Bilal Khan[1], Dipjyoti Deb[1], Ahmad Echresh[1], Shima J. Ghamsari[1], Slawomir Prucnal[1], Lars Rebohle[1], Artur Erbe[1], Manfred Helm[1], Anushka S. Gangnaik[2], Alexander D. Game[2], Subhajit Biswas[2], Nikolay Petkov[2], and Justin D. Holmes[2] — [1]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]School of Chemistry and Tyndall National Institute, University College Cork, Cork, Ireland

Group IV semiconductor nanowires (NWs) are very attractive because of the variety of possible applications as well as of the good silicon (Si) compatibility, which is important for their integration into the existing semiconductor technology. We will give an overview of our activities on fabrication and application of group IV NWs. These include top-down fabrication (based on electron beam lithography and reactive ion etching) of Si and germanium (Ge) NWs having widths down to 6-7 nm as well as bottom-up (vapour-liquid-solid) growth of alloyed germanium-tin (Ge1-xSnx) NWs with x = 0.07-0.1 and diameters of 50-70 nm. We will discuss the innovative nanoelectronic devices that we are working on: junctionless nanowire transistors (JNTs) and reconfigurable field effect transistors (RFETs). We will present results on Si JNTs for sensing application as well as on Ge and GeSn JNTs for digital logic. We will also show results on Si RFETs as well as preliminary data on SiGe and GeSn RFETs, which are expected to outperform the Si RFETs.

HL 25.7 Wed 11:15 H33

Laser-induced nonthermal diffusion of impurities and vacancies — •Christelle Inès Kana Mebou, Tobias Zier, and Martin E. Garcia — Theoretische Physik, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany

Laser-induced disordering processes like nonthermal-melting have been studied intensively during the last three decades. In this work, we present first investigations of laser induced ordering processes. With the help of ab-initio molecular dynamics (MD) using our code CHIVES (Code for Highly Excited Valence Electron Systems) we have studied the motion of sulfur impurities and vacancies in silicon. The aims is to study the impact of laser excitation on the mechanisms of defects (vacancies and impurity atoms) migrations in Silicon (Si). Starting from initially randomly distributed defects, we simulated the ultrashort time dynamics of the system after laser heating. Preliminary results show a tendency of the vacancies to become more ordered. Electronic structure of Si doped with sulfur are analysed in the scope of these results.

HL 25.8 Wed 11:30 H33

Ordered Si nanopillar arrays with alternating diameters by metal-assisted chemical etching — •Michael Kismann, Thomas Riedl, Xia Wu, Bertram Schwind, Thorsten Wagner, and Jörg K.N. Lindner — Paderborn University, 33098 Paderborn, Germany

Ordered Si nanopillar arrays have a great potential for e.g. photonic, sensing and electronic devices. In the present contribution, we employ nanosphere lithography combined with metal-assisted chemical etching (MACE), which permits the fabrication of well ordered Si nanopillar arrays on large areas. Compared with conventional fabrication techniques such as optical lithography combined with deep RIE or CVD our approach is more cost-effective and enables realization of high aspect ratio structures. Moreover, as a new feature of MACE we demonstrate the formation of Si nanopillars with alternating diameters by variation of the etch solution composition, which is accomplished by varying the HF/H_2O_2 ratio. In this way single and multiple necks can be formed in each nanopillar. By controlled oxidation in water vapour we obtain nanoscale Si inclusions surrounded by an amorphous SiO_2 shell. The morphology and structure of these pillar arrays are analyzed by SEM and TEM, complemented by optical measurements and band structure calculations. The obtained necked Si pillar morphologies are attractive for vertical nanopillar FETs and vertical tunneling FETs. In addition, they are of interest for thermoelectric generators because of the strongly reduced thermal conductivity in the nanostructures and the possibility of resonant tunneling through the SiO_2 necks.

HL 25.9 Wed 11:45 H33

Time-resolved spectroscopic ellipsometry on Ge and Si — •Steffen Richter[1], Shirly Espinoza[1], Oliver Herrfurth[2], Mateusz Rebarz[1], Rüdiger Schmidt-Grund[2], Jakob Andreasson[1,3], and Stefan Zollner[4] — [1]ELI Beamlines, Za Radnicí 835, Dolní Břežany, Czech Republic — [2]Universität Leipzig, Felix-Bloch-Instiut für Festkörperphysik, Linnéstr. 5, 04103 Leipzig, Germany — [3]Chalmers tekniska högskola, Institutionen för fysik, Kemigården 1, 41296 Göteborg, Sweden — [4]New Mexico State University, Department of Physics, PO Box 30001, Las Cruces, NM, 88003-8001, USA

Highly excited semiconductors feature a large number of concurrent processes of carrier scattering, relaxation, ambipolar diffusion and recombination. Discriminating them and understanding their dynamics is crucial for potential applications. To this aim, the distinction between amplitude and phase information of the optical response is essential. This cannot be provided by conventional transient spectroscopy. Here, we report on recent progress in developing pump-probe broadband ellipsometry with sub-picosecond resolution. We present measurements carried out on Ge, Si and InP single crystals. The obtained pseudo dielectric-functions hint on band gap renormalization of higher conduction bands and band filling by electrons at the minima of the conduction band. Their dynamics allow to understand scattering mechanisms for the hot charge carriers, and also indicate phonon coupling.