HL 36: Materials and Devices for Quantum Technology 2

Time: Thursday 15:00–17:45 Location: H36

HL 36.1 Thu 15:00 H36

Influence of (N,H)-terminated surfaces on stability, hyperfine structure, and zero-field splitting of NV centers in diamond — Wolfgang Körner[1], •Reyhaneh Ghassemizadeh[1], Daniel Urban[1], and Christian Elsässer[1,2] — [1]Fraunhofer Institute for Mechanics of Materials IWM, Wöhlerstr. 11, 79108 Freiburg, Germany — [2]University of Freiburg, Freiburg Materials Research Center (FMF), Stefan-Meier-Straße 21, 79104 Freiburg, Germany

We present a density functional theory analysis of the negatively charged nitrogen-vacancy (NV^-) defect complex in diamond located in the vicinity of (111)- or (100)-oriented surfaces with mixed (N,H)-terminations [1]. We assess the stability and electronic properties of the NV^- center and study their dependence on the H:N ratio of the surface termination. The formation energy, the electronic density of states, the hyperfine structure and zero-field splitting parameters of an NV^- center are analyzed as function of its distance and orientation to the surface. We find stable NV^- centers with bulk-like properties at distances of at least ~ 8 Å from the surface provided that the surface termination consists of at least 25% substitutional nitrogen atoms. The studied surface terminations have a minor effect on the ground state whereas the NV orientation has major effects. Our results show that axial NV centers near a flat 100% N-terminated (111) surface are the optimal choice for NV-based quantum sensing applications as they are the least influenced by the proximity of the surface.

[1] W. Körner, R. Ghassemizadeh, D. F. Urban, and C. Elsässer, arXiv:2109.12557

HL 36.2 Thu 15:15 H36

Quantum optimal control for conveyor-mode single-electron shuttling in Si/SiGe — •Alessandro David[1], Veit Langrock[2], Julian D. Teske[3], Lars R. Schreiber[3], Hendrik Bluhm[3], Tommaso Calarco[1], and Felix Motzoi[1] — [1]Institute of Quantum Control (PGI-8), Forschungszentrum Jülich, Germany — [2]Institute of Theoretical Nanoelectronics (PGI-2), Forschungszentrum Jülich, Germany — [3]JARA-FIT Institute of Quantum Information, Forschungszentrum Jülich and RWTH Aachen, Germany

An electron shuttling device is a promising candidate for the scalability of spin-qubits quantum computers. We consider a gated Si/SiGe quantum well capable of shuttling electrons smoothly by a translating confining potential (conveyor-mode). Dephasing coupling with valley degree of freedom and geometry of the quantum well dictate a maximum shuttling speed to keep the electron state adiabatically in the ground state and avoid excitation of the valley state. In this work we use the position of the electron as a control parameter and we optimise the trajectory of the electron to show how the electron can be shuttled faster and with lower infidelity compared to the adiabatic regime.

HL 36.3 Thu 15:30 H36

Optimizing Diamonds for the Electrical Readout of Nitrogen-Vacancy Centers in Diamond — •Lina Maria Todenhagen, Hamza Ouerfelli, and Martin Stefan Brandt — Walter Schottky Institut, Technische Universität München, Garching

The nitrogen-vacancy (NV) center in diamond is one of the most attractive quantum systems used in practical applications. Owing to its exceptionally stable spin state, it can be easily initialized, manipulated and read out even at room temperature. However, the widely used optical readout (ODMR) of the NV center is not easily miniaturized, since it requires an extensive optical setup. Alternatively, we can directly read out the spins electrically by generating a spin-dependent photocurrent (EDMR). However, compared to the traditional optical readout, EDMR of NV centers has been investigated in much less detail up to now.

The present work addresses the optimization of the diamond host material for the electrical readout and compares the results to the optical analogue. The investigated substrates cover type IIa CVD diamonds as well as type Ib HPHT diamonds, both in their as-grown state and after different post-treatments, including electron irradiation and annealing. We focus on the effects of other defects such as substitutional nitrogen present in the samples on the spin-dependent photocurrent and the achievable contrast. Our results indicate that the choice of diamond material is a lot more critical for EDMR than for ODMR and may serve as a guideline for the further development of highly integrated NV sensors based on electrical readout.

HL 36.4 Thu 15:45 H36

Superconducting single-photon detectors made of NbTiN using a novel method to characterize the timing jitter — •Lucio Zugliani[1], Rasmus Flaschmann[1], Stefan Strohauer[2], Christian Schmid[1], Fabian Wietschorke[1], Stefanie Grotowski[2], Sven Ernst[2], Simone Spedicato[2], Mirco Metz[1], Björn Jonas[1], Jonathan Finley[2], and Kai Müller[1] — [1]Walter Schottky Institute and Department for Electrical and Computer Engineering, Technical University of Munich, Germany — [2]Walter Schottky Institute and Physics Department, Technical University of Munich, Germany

In recent years, superconducting single-photon detectors (SSPDs) have raised tremendous attention as a key technology for optical quantum processing and faint light detection. With their unparalleled performances to detect single photons, further investigation of these detectors is of high interest [1, 2].

Here, we present our recent progress on NbTiN SSPDs measured at 4.5K. We discuss our approaches to improve the most important figures of merit (dark count rate, dead time, timing jitter, efficiency) including an optimization of the quality of the superconducting NbTiN films and the integration of the detector in a broad-band cavity.

In particular, we focus on the impact of the substrate material on the resulting parameters such as the detected voltage pulse. We investigate the characteristic of pulse height, rise time and timing jitter, finding a relation between the timing jitter and the pulse properties.

[1]*C. Natarajan et al., Sup. Sci. and Tech. 25, 063001 (2012)
[2]*I. Zadeh, Appl. Phys. Lett. 118, 190502 (2021)

HL 36.5 Thu 16:00 H36

Focused ion beam implantation and luminescence of erbium ions in semiconductor nanostructures — •Christian Düputell[1], Patrick Lindner[2], Varvara Foteinou[3], Yujiao Li[4], Jörg Debus[2], Arne Ludwig[1], and Andreas D. Wieck[1] — [1]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum — [2]Experimentelle Physik 2, TU Dortmund — [3]RUBION, Ruhr-Universität Bochum — [4]ZGH, Ruhr-Universität Bochum

We report on focused ion beam (FIB) implantation of erbium ions in semiconductor nanostructures. Semiconductor nanostructures have attracted a lot of attention due to their unique optical, electrical and mechanical properties. Focused ion beam is an elegant method to tune these specific properties. This contribution lines out the implantation processes and the methods used to characterize the samples after implantation. Erbium is implanted in various semiconductor nanostructures in its 3+ state using an alloy liquid metal ion source. Furthermore, a sputter cathode source is used to implant erbium(III) oxide. Implantation is done at room temperature as well as at elevated temperatures to reduce radiation damage. The implanted ion distribution is simulated by SRIM and measured by atom probe tomography. After the implantation, the samples are annealed under nitrogen gas using a rapid thermal annealing technique. Photoluminescence measurements on erbium luminescence are carried out at cryogenic temperatures (10 K) as a function of the annealing and implantation parameters. The quality of the samples is then rated according to emission intensity of the important telecom-C-band wavelength of 1.54 μm.

15 min. break

HL 36.6 Thu 16:30 H36

Searching for signatures of magnetism and induced superconductivity in magnetic topological insulator-superconductor hybrid devices — •Max Vassen-Carl, Michael Schleenvoigt, Benedikt Frohn, Detlev Grützmacher, and Peter Schüffelgen — Peter Grünberg Institute 9, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany

Topological materials harbor great possibilities for the future of quantum computation. In theory, when quasi-1D topological isolators (TIs) are coupled to superconductors localized Majorana zero modes (MZM) arise at the end of the quasi-1D hybrid structure. However, quasi-1D TIs require a certain in-plane magnetic field, which depends on the cross-section area of the TI, to retrieve the topological properties lost by confinement. Deviations of said TI cross-section change the pen-

etrating flux and can lead to additional opening and closing of the topological gap, creating unwanted MZMs. One possible solution is to integrate magnetism directly into the TI, creating so-called magnetic topological insulators (MTIs), which retain their topological properties even when confined. In this work Chromium is used to magnetically dope (BixSb1-x)2Te3, by means of MBE. First, ex-situ fabricated MTI-Nb Josephson Junctions (JJ) showed no supercurrent, but instead an increase of resistance for low bias voltages. To gain further insights on the interplay between SC and MTI a new sample layout was designed which allows for Josephson and Hall bar measurements in one device. In order to obtain highest S-MTI interface quality those hybrid devices are fully fabricated under UHV conditions.

HL 36.7 Thu 16:45 H36

Coherent interactions between confined fluids of light and GHz-phonons — •Alexander Kuznetsov, Klaus Biermann, and Paulo Santos — Paul-Drude-Institut für Festkörperelektronik in Forschungsverbund Berlin, e. V., Berlin, Germany

Microcavity exciton-polaritons are at the heart of an emerging field of polaromechanics, which studies coupling between polariton and mechanical degrees of freedom and promises unit quantum cooperativity. One challenge is to reach the regime of coherent interactions, when the polariton decoherence rate is smaller than mechanical frequency.

We reached this milestone by coupling polariton fluids of light (macroscopic quantum state) to GHz phonons. High-resolution optical spectroscopy revealed ns-long coherence time reaching $\tau = 2ns$. Monochromatic $\Omega_M = 7GHz$ phonons were injected into a trap using acoustic transducers. Since $1/\tau < \Omega_M$, the interaction resulted in the appearance of well-resolved phonon sidebands in the emission – an optical frequency comb. We demonstrated tuning of the sidebands by the phonon amplitude, which was controlled by the radio-frequency power applied to the transducer.

The demonstrated coherent polaromechanical device is a building block for a bi-directional interface between microwave and optical domains, atomic clocks, and is useful to study rich physics of sideband cooling and amplification.

HL 36.8 Thu 17:00 H36

A solid-state source of single and entangled photons at diamond SiV-center transitions operating at 80 K — •Eddy P. Rugeramigabo[1], Xin Cao[1], Jingzhong Yang[1], Tom Fandrich[1], Yiteng Zhang[1], Benedikt Brechtken[1], Rolf J. Haug[1,2], Michael Zopf[1], and Fei Ding[1,2] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, Germany — [2]Laboratorium für Nano- und Quantenengineering, Leibniz Universität Hannover, Germany

Epitaxially grown quantum dots (QDs) hold great potential for the generation of 'flying' qubits. Coupling these emitters to quantum memories with long coherence times enables the development of hybrid nanophotonic devices incorporating the advantages of both systems. GaAs/AlGaAs QDs based on droplet etching and nanohole infilling exhibit tunable, well-defined optical properties, with emission typically reported at around 780nm. Silicon-vacancy (SiV) centers in diamond show long coherence times and strong interactions with single photons via their zero phonon line (ZPL) at around 737 nm. Here we report the first quantum dot containing material emitting nonclassical light that matches the SiV ZPL. Careful adjustments of the GaAs thickness in the QDs lead to a narrow wavelength distribution (736.2 ± 1.7 nm) and small exciton fine structures (7.0 ± 4.6 eV). Polarization entangled photons are generated via the biexciton-exciton cascade decay with a fidelity of 0.727 ± 0.092. High single photon purity is maintained from 4 K ($g^{(2)}(0) = 0.07 \pm 0.02$) up to 80 K ($g^{(2)}(0) = 0.11 \pm 0.01$), therefore, paving the way towards cost-efficient applications in quantum repeaters and quantum memories.

HL 36.9 Thu 17:15 H36

Electric field-induced exciton darkening and fine structure vanishing in GaAs/AlGaAs coneshell quantum structures — •Geoffrey Pirard[1] and Gabriel Bester[1,2] — [1]Physical Chemistry and Physics Departments, University of Hamburg, Luruper Chaussee 149, D-22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, University of Hamburg, Luruper Chaussee, 149, D-22761 Hamburg, Germany

Electronic and optical properties of coneshell quantum structures (CSQS) are investigated via a combination of the empirical pseudopotential and the configuration interaction methods. It is found that the application of a vertical electric field onto CSQS can provoke a darkening of the exciton bright doublet accompanied by the suppression ot its fine structure. The existence of such a four-fold degenerate exciton state finds its origins in the carriers' localization: one type of carrier is strongly confined at the bottom of the nanostructure whereas its counterpart is pulled apart in such a way that its probability density acquires a delocalized ring-like nature. The separation between carriers' wave functions leads to a vanishing exchange interaction and reduces the values of the direct Coulomb integrals, giving rise to a tunable long-lived degenerate dark exciton. These properties make the CSQS promising candidates to construct the building blocks of quantum memories.

HL 36.10 Thu 17:30 H36

Bright InAs quantum dot based single-photon sources at telecom wavelengths — •Monica Pengerla[1], Alkaales Mohanad[2], Ranbir Kaur[2], Jan Donges[1], Lucas Bremer[1], Johannes Schall[1], Sven Rodt[1], Mohamed Benyoucef[2], and Stephan Reitzenstein[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, D-10623 — [2]Institute of Nanostructure Technologies and Analytics (INA), Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany

Quantum dot (QD) based single-photon sources are key elements of photonic quantum networks. Most interesting are sources emitting at telecom wavelengths to enable long distance quantum communication. Here, we report on deterministically fabricated single-photon sources based on InAs QDs grown on InP substrate. Numerical simulations of such QD heterostructures with backside distributed Bragg reflector and reveal photon extraction efficiency exceeding 50% when integration the QD into mesa or circular Bragg grating structures. The numerical designs are implemented by deterministic device processing using machine learning enhanced in-situ electron beam lithography. Microphotoluminescence studies reveal the excellent optical and quantum optical properties of the fabricated quantum devices.