FM 63: Poster: Enabling Technologies: Quantum Materials, Quantum Dots, Quantum Wires, Point Contacts and Superconducting Systems

Time: Wednesday 16:30–18:30 Location: Tents

FM 63.1 Wed 16:30 Tents

Light-driven nuclei thermodynamics in bulk GaAs and (In,Ga)As/GaAs quantum dots — •Pavel Sokolov[1], Mikhail Petrov[2], Kirill Kavokin[2], Maria Kuznecova[2], Sergey Verbin[2], Dirk Reuter[3], Andreas D. Wieck[4], Dmitri Yakovlev[1,5], and Manfred Bayer[1,5] — [1]Experimentelle Physik 2, Technische Universität Dortmund, D-44221 Dortmund, Germany — [2]Spin Optics Laboratory, Saint Petersburg State University, 198504 St. Petersburg, Russia — [3]Department Physik Universität Paderborn, D-33098 Paderborn, Germany — [4]Angewandte Festkörperphysik Ruhr-Universität Bochum, D-44780 Bochum, Germany — [5]Ioffe Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia

We study experimentally the optical cooling dynamics of nuclei located inside the donor orbit in n-doped GaAs and (In,Ga)As/GaAs quantum dots and show that at slow modulation of excitation polarization (~ 1 s) a noticeable Overhauser field can be observed. The initial cooling rate is strongly dependent on the direction of the external magnetic field with respect to initial electron polarization direction $\pm S_0$. The lowest spin temperature in n-GaAs, $\Theta_N = 1.5$ mK was achieved in this work after cooling for $T_{\mathrm{mod}} = 1$ s. For the microstructure with (In,Ga)As/GaAs quantum dots, the achieved spin temperature is one order of magnitude lower than in n-GaAs: $\Theta_N = 0.1$ mK. Using the implemented technique allows us to verify the polarization of nuclear spins in the external magnetic field in the desired spin polarization state in two different types of semiconductor microstructures studied in this work.

FM 63.2 Wed 16:30 Tents

Phase transitions in double quantum dots coupled to superconducting leads — •Georgios Loukeris[1], Martin Žonda[1], Vladislav Pokorný[2], Tomáš Novotný[2], and Michael Thoss[1] — [1]Albert Ludwig University of Freiburg, Institute of Physics, Freiburg, Germany — [2]Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic

Various geometries of double quantum dots coupled to superconducting leads have been recently explored both theoretically and experimentally. It was shown that they can be used for the production of entangled electrons usable in computational protocols in solid state systems as well as for exploring complex quantum phase transitions. The advantage of double quantum dots is their tunability as individual gates can be used to control each dot separately. This can be utilized for setting the devices in different regimes. For example, if the dots are decoupled from each other, the gates can be used to set one dot to the so called 0-phase where its ground state is a BCS singlet and the other in π-phase with doublet ground state.

We investigate theoretically this situations by addressing a superconducting Anderson impurity model. We focus on how the properties of the junction change when we switch on the direct coupling between the dots. We show that the setup can be tuned to go trough various quantum phase transitions and crossovers. In addition the dependence of the supercurrent on the Josephson phase difference can have a complicated non-sinusoidal form.

FM 63.3 Wed 16:30 Tents

Extended nuclear spin coherence in an ensemble of (In,Ga)As/GaAs quantum dots — •Eiko Evers[1], Tomasz Kazimierczuk[1,2], Alex Greilich[1], Dmitri R. Yakovlev[1,3], Andreas D. Wieck[4], Dirk Reuter[5], and Manfred Bayer[1,3] — [1]Experimentelle Physik 2, TU Dortmund University, 44221 Dortmund, GermanyExperimentelle Physik 2, TU Dortmund Univrsity — [2]Institute of Experimental Physics, Faculty of Physics, University of Warsaw, 02-093 Warsaw, Poland — [3]Ioffe Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia — [4]Optoelectronic Materials and Devices, Paderborn University, 33098 Paderborn, Germany — [5]Angewandte Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum, Germany

Singly-charged (In,Ga)As/GaAs quantum dots (QDs) offer a playground to study the dynamics of the electron-spin (e-spin) confined within a nuclear spin bath. In a magnetic field perpendicular to the growth axis, the μs-long e-spin transverse coherence time allows preferential pumping of e-spins with a precession frequency resonant to the pumping periodicity. The periodical pumping moreover leads to a nuclear bath polarization (Overhauser field) that drives a single e-spin's precession frequency into resonance with the pumping frequency, the so called nuclei-induced frequency focusing (NIFF). While it has been reported that the nuclear spin coherence time for singly-charged QDs is in the μs range, we find that the synchroization of the nuclear-electron spin system also leads to a ms-long nuclear spin coherence time.

FM 63.4 Wed 16:30 Tents

Hybrid Devices of Spin-photon Interfaces for Singlet-triplet Quantum Dots — •Zheng Zeng[1], David Fricker[1], Arne Ludwig[2], Marcel Schmidt[2], Chao Zhao[1], Hendrik Bluhm[3], and Beata Kardynał[1] — [1]Peter Grünberg Institute 9, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Lehrstuhl für Angewandte Festkörperphysik, Ruhr- Universität Bochum, 44780 Bochum, Germany — [3]JARA-Institute for Quantum Information, RWTH Aachen University, 52074 Aachen, Germany

Connecting quantum processors over long distances using photon qubits would enable more complex quantum computing architectures and quantum networks. Recently a protocol to transfer a quantum state from a photonic qubit to a singlet-triplet spin qubit in GaAs/AlGaAs heterostructure has been theoretically demonstrated. In practice, the coherent transfer is facilitated by a hybrid device where a GaAs/AlGaAs gate-defined double quantum dot (GDQD) is tunnel coupled to a self-assemble quantum dot (SAQD), in which a conversion between a photon state and a spin state takes place. In this contribution we discuss fabrication techniques to achieve the precise alignment of both types of QDs both in energy as well as in space, which is essential for the device operation. We fabricate front- and back-gates to enable tuning the energy levels of the quantum dots. We discuss the method to align the gates of the GDQD to a SAQD. Further we explore methods of QDs growth to minimize the impact on the GDQDs. In particular we compare the performance of strain-free droplet QDs with high quality Stransky-Krastanov QDs in the hybrid devices.

FM 63.5 Wed 16:30 Tents

Hybrid assembly of the quantum optical elements — •Andreas Schell — Leibniz University Hannover, Germany — PTB, Braunschweig, Germany — CEITEC BUT, Brno, Czechia

Bringing quantum technology from the laboratory to real world applications is a complex, but very rewarding, task. It will enable society to exploit the new opportunities the laws of quantum mechanics offer compared to purely classical physics. However, before the new quantum technology can be deployed, platforms to implement such a technology need to be discovered and developed. Here, we will show our ongoing efforts to implement such a platform using the so called hybrid approach for the assembly of quantum photonic elements. This approach is highly flexible and can be adapted to many different material systems and structures. In particular, we will introduce techniques based on scanning probe microscopy and three-dimensional laser writing. The hybrid quantum photonic elements assembled with these approached include emitter coupled to on-chip resonators and waveguides, different kinds of fiber integrated cavities and incorporate a variety of emitter such as NV centers, quantum dots, and defects in two-dimensional materials, such as hexagonal boron nitride. From these examples it can be seen that photonics elements assembled using hybrid techniques might help to facilitate the transition of quantum photonic networks out of lab to real-world applications.

FM 63.6 Wed 16:30 Tents

Exciton spin and recombination dynamics in CdSe nanocrystals in glass matrix — •Gang Qiang[1], Elena V. Shornikova[1,2], Dmitri R. Yakovlev[1,3], Aleksandr A. Golovatenko[3], Anna V. Rodina[3], Evgeniy A. Zhukov[1], Alexey A. Onushchenko[4], and Manfred Bayer[1,3] — [1]Experimentelle Physik 2, Technische Universität Dortmund, 44221 Dortmund, Germany. — [2]Rzhanov Institute of Semiconductor Physics, Siberian Branch of Russian Academy of Sciences, 630090 Novosibirsk, Russia. — [3]Ioffe Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia. — [4]ITMO University, 199053, St.-Petersburg, Russia

Semiconductor quantum dot spin as one of the carrier candidates for quantum bit or Qubit has attracted much attention during the last few decades. With time going by, the technics to prepare samples also become more and more powerful, such as molecular beam epitaxy, wet-chemical method, solid state reaction and so on. Former experiments have suggested that surface states of nanocrystals (NCs) play an important role in determining their thermodynamic, transport and optical properties. Comparing with colloidal NCs synthesized using wet chemical method, those grown in glass matrix are quite different, especially their surface state. NCs in glass matrix are completely free from passivation and the surface is dominated by dangling bond orbitals which sharply modify their magneto-optical properties. In this work, we studied the spin and recombination dynamics of exciton confined in CdSe nanocrystals grown in glass matrix with diameter range from 2.8 to 6.2 nm.

FM 63.7 Wed 16:30 Tents

In Situ Probing of Conductive Superlattices Formation of Cu1.1S Nanodisks at the Liquid/Air Interface — •Sonam Maiti[1,2], Santanu Maiti[1], Marcus Scheele[2], and Frank Schreiber[1] — [1]Institute of Applied Physics, University of Tuebingen, Tübingen, Germany — [2]Institute of Physical and Theoretical Chemistry, University of Tübingen, Tübingen, Germany

Assembling of colloidal NCs with anisotropic shape into ordered superstructures is one of the existing challenges in nano-fabrication [1,2]. We report the formation of conductive superlattices of Cu1.1S nanodisks through directional cross-linking with CoTAPc molecule at the liquid/air interface monitored by real-time GISAXS. We investigate the structure, symmetry and lattice parameters of the superlattices, formed during solvent evaporation and ligand exchange with elapsed time. Cu1.1S nanodisks self-assemble into 2D hexagonal superlattice with minor in-plane contraction and continuous contraction during ligand exchange reaction. This attributes to the continuous replacement of the native oleylamine surface ligands with smaller CoTAPc molecules. The NDs has a preferential atomic orientation in the superlattices with respect to the substrates. The subsequent superlattices show high electrical conductivity, which corresponds to the successful cross-linking of the nanodisks. Our work thus provides a correlation between the structure and transport of the coupled superstructures of organic and inorganic NCs with anisotropic shape. [1] Saunders et al, Nano Lett. 2006, 6, 12. [2] Maiti et al, JPCL 2018, 9, 4.

FM 63.8 Wed 16:30 Tents

Quantum thermodynamics in driven nanosystems: A hierarchical quantum master equation approach — •Jakob Bätge[1], Wenjie Dou[2], Amikam Levy[2], and Michael Thoss[1] — [1]Institute of Physics, University of Freiburg, Freiburg, Germany — [2]Department of Chemistry, University of California, Berkeley, USA

For the development and optimization of macroscopic engines thermodynamics is fundamental. In view of the tremendous recent progress in experimental techniques to study charge and heat transport in nanostructures based on single atoms or molecules [1], theoretical research on the impact of quantum fluctuations on thermodynamic laws at the nanoscale is of significant interest [2,3].

In this context, we investigate nanosystems with electronic and vibrational degrees of freedom, which are exposed to an environment in nonequilibrium. In particular, we are interested in thermodynamic quantities of driven nanosystems. For this purpose, we use the hierarchical quantum master equation method [4], which generalizes perturbative master equation methods by including higher-order contributions as well as non-Markovian memory and allows for the systematic convergence of the results. This approach allows for treating fermionic and bosonic environments on equal footing.

[1] L. Cui *et al.*, Science **355**, 1192 (2017). [2] R. S. Whitney *et al.*, Phys. Rev. B **98**, 085415 (2018). [3] W. Dou *et al.*, Phys. Rev. B **98**, 134306 (2018). [4] C. Schinabeck *et al.*, Phys. Rev. B **94**, 201407(R) (2016).

FM 63.9 Wed 16:30 Tents

Quantum transport through molecular nanojunctions with conical intersections — •Christoph Kaspar and Michael Thoss — Albert-Ludwigs-Universität, Freiburg, Germany

A conical intersection corresponds to a crossing of two potential energy surfaces in the configuration space of a polyatomic molecule. In the vicinity of the crossing, the coupling between the electronic states diverges resulting in the breakdown of the Born-Oppenheimer approximation [1]. As a consequence, the dynamics of electrons and nuclei is strongly correlated, which can have impact on electron transport through the molecule [2]. In this contribution, we theoretically investigate the characteristics of quantum transport through a molecule exhibiting a conical intersection. To this end, we consider a model for a molecular junction and employ the hierarchical quantum master equation approach, which generalizes perturbative master equation methods by including higher-order contributions as well as non-Markovian memory [3,4]. We show that the transport characteristics is strongly influenced by the interaction with the vibrational modes. In particular, the scenario of two degenerate electronic states coupled to two degenerate vibrational modes leads to interesting new phenomena [2].

[1] Domcke *et al.*, *Conical Intersections* (World Scientific, 2011)
[2] Schultz *et al.*, Phys. Rev. B **77**, 0753223 (2008)
[3] Härtle *et al.*, Phys. Rev. B **98**, 081404 (2018)
[4] Schinabeck *et al.*, Phys. Rev. B **94**, 201407R (2016)

FM 63.10 Wed 16:30 Tents

Tunneling between isolated quasiparticle levels via Cooper pair splitting in an atomic contact — •Haonan Huang[1], Jacob Senkpiel[1], Robert Drost[1], Ciprian Padurariu[2], Simon Dambach[2], Björn Kubala[2], Juan Carlos Cuevas[3], Alfredo Levy Yeyati[3], Joachim Ankerhold[2], Christian R. Ast[1], and Klaus Kern[1,4] — [1]MPI für Festkörperforschung, Germany — [2]Institut für komplexe Quantensysteme, Universität Ulm, Germany — [3]Departamento de Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid, Spain — [4]EPFL, Switzerland

Tunneling processes between discrete levels have been extensively studied in double quantum dots typically with the size of hundreds of nanometers. Scaling down these devices to the atomic scale remains, however, challenging. One alternative approach is to use scanning tunneling microscopy to build atomic sized tunnel junctions, and use the Yu-Shiba-Rusinov (YSR) states, quasiparticle levels generated by magnetic atoms on a superconductor, as discrete levels. With a scanning tunneling microscope at 15mK, we study the tunneling processes between a YSR state on the tip and a YSR state on the sample, which we call Shiba-Shiba tunneling. While Shiba-Shiba tunneling inherits features of tunneling between discrete levels, the physics is much richer because of the Cooper pair splitting processes involved. Depending on the energy of the Shiba state, four regimes with distinctly different behavior of Shiba-Shiba tunneling exist. This results in different interactions with the environment, which may shed light on the coherence and entanglement of the quasiparticles during tunneling processes.

FM 63.11 Wed 16:30 Tents

Josephson junctions and SQUIDs created by focused helium-ion-beam irradiation of $YBa_2Cu_3O_7$ — •Max Karrer[1], Benedikt Müller[1], Fabienne Limberger[1], Theodor Luibrand[1], Zeynep Kaczmarek[1], Maximilian Becker[1,2], Birgit Schröppel[2], Claus Burkhardt[2], Reinhold Kleiner[1], Edward Goldobin[1], and Dieter Koelle[1] — [1]Physikalisches Institut and Center for Quantum Science (CQ) in LISA$^+$, Universität Tübingen, Germany — [2]NMI Natural and Medical Sciences Institute at the University of Tübingen, Reutlingen, Germany

For epitaxially grown thin films of the high-T_c cuprate superconductor $YBa_2Cu_3O_7$ (YBCO), He focused ion beam (He-FIB) irradiation can be used to directly write Josephson junction (JJ) barriers into the material by driving locally the material into the insulating state [1]. In addition, He-FIB irradiation can also be used to pattern YBCO films on the nanoscale, without removing material [2]; this provides an alternative way to define insulating areas, e.g. for nanoSQUID fabrication. Here, we present our recent progress in the fabrication of He-FIB-induced YBCO JJs and SQUIDs as well as the analysis of their electric transport and noise properties, in particular with respect to the possible control of the critical current density of the JJs by variation of the He-FIB dose [3]. This approach may be also applied to the realization of YBCO-based quantum devices.

[1] S. Cybart *et al.*, Nature Nanotechnol. **10**, 598–602 (2015).
[2] E. Y. Cho *et al.*, Appl. Phys. Lett. **113**, 022604 (2018).
[3] B. Müller *et al.*, Phys. Rev. Applied **11**, 044082 (2019).

FM 63.12 Wed 16:30 Tents

Crossed Andreev reflection in 3d TI-superconductor nanowire hybrid systems — •Michael Barth, Jacob Fuchs, Cosimo Gorini, and Klaus Richter — Institut für Theoretische Physik, Universität Regensburg, Germany

3d topological insulator (TI) nanowires are materials with helical surface states which are protected by time-reversal symmetry [1]. By bringing a normal s-wave superconductor into close proximity to such a wire one can create a topologically non-trivial superconducting state. Furthermore, in such hybrid systems of normal and superconducting materials the process of crossed Andreev reflection (CAR) [2] can occur. This is the effect we are interested in and therefore we are studying quantum transport in a 3d T-junction of normal TIs and a topological superconductor with additional external magnetic fields. Even though in 2d TI systems this phenomenon can be fully suppressed [3], our full 3d numerical simulations show clear signatures of CAR. Moreover in our setup the CAR can in principle be tuned by the external magnetic fields.

[1] J. Ziegler et al., Phys. Rev. B 97, 035157 (2018)
[2] G. Falci, D. Feinberg, and F. W. J. Hekking, EPL 54, 255 (2001)
[3] P. Adroguer et al., Phys. Rev. B 82, 081303 (2010)

FM 63.13 Wed 16:30 Tents

Physical implementation of quantum walks in effective Dirac systems — •Vanessa Junk, Philipp Reck, Cosimo Gorini, and Klaus Richter — Institut für Theoretische Physik, Universität Regensburg, Germany

Scientific interest in quantum walks (QW) [1] originally arose in the field of quantum computation since QWs can replace classical random walks and thus pose a powerful tool to speed up classical algorithms. In the last years however, QWs have become particularly promising to simulate different topological phases [2].

We will present how to physically implement such a QW in an effective Dirac system like graphene. Our proposal is based on the extension of the concept of the Quantum Time Mirror [3]. In the latter, a pulse coupling both branches of the Dirac cone is used to split an initial wave-packet into two parts moving in opposed directions. The amplitudes of the two parts can be adjusted via the pulse length. Hence, the pulse represents the 'coin toss' [4] in general QWs with the advantage of offering additional degrees of freedom. By periodically repeating the pulse, the initial wave-packet performs a QW. Since the walk is realized in a spatially continuous Dirac system instead of on a fixed graph, we can arbitrarily time the pulses and create a further variety in the resulting probability distribution of the wave-packet in space.

[1] Y. Aharonov, et al., Phys. Rev. A **48**, 1687-1690 (1993)
[2] T. Kitagawa, Quantum Inf Process **11**, 1107 (2012)
[3] P. Reck, et al., Phys. Rev. B **95**, 165421 (2017)
[4] J. Kempe, Contemporary Physics **44**, 307-327 (2003)

FM 63.14 Wed 16:30 Tents

Electronic transport in the spinless Falicov-Kimball model with inhomogeneous charge orderings — •Rudolf Smorka, Martin Zonda, and Michael Thoss — Albert-Ludwigs-Universität Freiburg, Institute of Physics

The ordered phases of the spinless Falicov-Kimball model (FKM) outside the particle-hole symmetric point display a variety of stable inhomogeneous charge orderings. These include exotic charge stripes and charge segregation orderings which are also observed experimentally in various strongly correlated materials. In our work, we investigate theoretically how different ordered phases, both homogeneous and inhomogeneous, influence the non-equilibrium charge transport through a correlated material. We focus on a heterostructure, where a two-dimensional correlated system modelled by FKM on a square lattice is sandwiched between two non-interacting semi-infinite leads. First, we determine the ground state configurations of the central system as a function of chemical potential by employing a canonical Monte-Carlo based simulated annealing procedure. Then we couple the system to the leads with mutually shifted chemical potentials used to introduce a non-equilibrium steady state. The transmission function and the current-voltage characteristics are approached with a non-equilibrium Green's function technique for various stable phases. We show, that different orderings lead to qualitatively different transport characteristics showing metallic, insulating or even multi-gap properties. The study of the most interesting cases is further extended to finite temperatures.

FM 63.15 Wed 16:30 Tents

Complex magnetic and dielectric properties of pyrochlore compounds with application potential for quantum technology — •Thomas Herrmannsdörfer and Sumanta Chattopadhyay — Hochfeld-Magnetlabor Dresden (HLD-EMFL), Helmholtz-Zentrum Dresden - Rossendorf (HZDR), Dresden, Germany

We report the magnetic and dielectric properties of selected pyrochlore compounds such as $Ho_2Ti_2O_7$, $Pr_2Hf_2O_7$ and $Nd_2Hf_2O_7$. In this material class, the particular balance of magnetic interactions between rare-earth Ising spins which are located on a network of corner sharing tetrahedra leads to a wide spectrum of frustrated magnetic ground states, such as spin ice and quantum spin ice behavior as well as all-in-all-out antiferromagnetism. We highlight these properties in the context of their potential use for future quantum technological applications.

FM 63.16 Wed 16:30 Tents

Spectroscopic investigation of the neutral charge state of the tin-vacancy centre in diamond — •Johannes Görlitz[1], Dennis Herrmann[1], Morgane Gandil[1], Philipp Fuchs[1], Gergö Thiering[2], Takayuki Iwasaki[3], Takashi Taniguchi[4], Mutsuko Hatano[3], Adam Gali[2], and Christoph Becher[1] — [1]Fachrichtung 7.2, (Experimentalphysik), Universität des Saarlandes, Campus E2.6, 66123 Saarbrücken, Germany — [2]Wigner Research Centre for Physics, Institute for Solid State Physics and Optics, Hungarian Academy of Sciences, Hungary — [3]Department of Electrical and Electronic Engineering, Tokyo Institute of Technology, Meguro, Tokyo 152-8552, Japan — [4]Advanced Materials Laboratory, National Institute for Material Science, 1-1 Namiki, Tsukuba, 305-0044, Japan

Colour centres in diamond, in particular the well studied nitrogen vacancy centre (NV), are highly suitable to tackle many of the challenges occuring in quantum information processing and furthermore constitute sensitive electrical and magnetic field sensors. Nevertheless there are major limitations to the usefulness of the NV centre like the severe spectral diffusion and low photon emission rates into the zero phonon line. A promising candidate in order to outperform the NV in this areas and still maintain its excellent spin coherence is the neutral tin vacancy centre (SnV(0)). Spectral diffusion should be minimized due to its inversion symmetry and theoretical ab initio calculations predict a high Debye-Waller factor and long spin coherence. We here provide experimental evidence of the SnV(0) including emission spectra and the charge transition from the negative to the neutral charge state.

FM 63.17 Wed 16:30 Tents

Spectroscopy of the negatively charged tin-vacancy centre in diamond — •Dennis Herrmann[1], Johannes Görlitz[1], Morgane Gandil[1], Philipp Fuchs[1], Takayuki Iwasaki[2], Takashi Taniguchi[3], Mutsuko Hatano[2], and Christoph Becher[1] — [1]Fachrichtung 7.2, (Experimentalphysik), Universität des Saarlandes, Campus E2.6, 66123 Saarbrücken, Germany — [2]Department of Electrical and Electronic Engineering, Tokyo Institute of Technology, Meguro, Tokyo 152-8552, Japan — [3]Advanced Materials Laboratory, National Institute for Material Science, 1-1 Namiki, Tsukuba, 305-0044, Japan

Colour centres in diamond have proven their suitability for applications in quantum information processing. While the nitrogen-vacancy centre (NV) offers milliseconds spin-coherence times at room temperature, the silicon-vacancy (SiV) centre shows superior optical properties such as negligible spectral diffusion and high photon emission rates into its zero phonon line. Phonon mediated effects that have been identified as the source of decoherence in the SiV centre can be supressed for the negatively charged tin-vacancy (SnV(-)) centre due to its larger ground state splitting rendering it a promising candidate for reaching long spin-coherence times already at liquid helium temperatures. We present the SnV(-) centre's optical properties such as lifetime, polarization as well as the temperature dependence of linewidth, line shift and Debye-Waller factor. Furthermore we show lifetime-limited transition linewidths and investigations on the charge state stability under resonant excitation and spectral diffusion of single centres.

FM 63.18 Wed 16:30 Tents

Characterization of in-house grown CVD diamond with NV centers — •Tingpeng Luo[1], Lukas Götz[1], Brett Johnson[2], David Simpson[2], Liam Hall[2], Di Wang[2], Julia Langer[1], Volker Cimalla[1], and Jan Jeske[1] — [1]Fraunhofer IAF, Freiburg, Germany — [2]The University of Melbourne, Melbourne, Australia

Nitrogen-vacancy (NV) centers in diamond with its special optical and spin properties have become a promising instrument for quantum sensing. For sensitive sensing with high NV density, we aim to combine chemical vapour deposition (CVD) growth and consecutive characterization to optimize material parameters, which often are contrary in demand: High NV density concentration, yet long coherence time, low absorption or low birefringence. We design a systematic procedure to investigate the quality of in-house grown NV ensemble CVD diamonds, comparing our CVD diamond with type 1b high-pressure-high-temperature (HPHT) diamond. Multiple methods such as EPR, FTIR, photoluminescence maps, ODMR, UV-Vis spectroscopy and birefringence measurements are applied in the characterization work, to investigate the NV center formation in the synthesis procedure, the absorption, and the birefringence. Moreover, we take ODMR and coherence time measurements to investigate the spin properties. These methods give preliminary results of our first grown CVD diamond series, which assist to establish a further growth plan.

FM 63.19 Wed 16:30 Tents

Nanostructuring diamond with self-organized metal droplets as etching mask — •Patricia Quellmalz, Christian Giese, Peter Knittel, and Christoph Nebel — Fraunhofer Institute for Applied Solid State Physics, 79108 Freiburg, Germany

Diamond has many applications due to its outstanding properties, notably the mechanical hardness, wide optical window or chemical inertness. Nitrogen vacancy centers bring diamond further into focus, especially for quantum technology. Electron beam lithography is state-of-the-art to pattern nanometer-sized features. This technique offers high resolution but is laborious and expensive. A viable alternative is patterning via dewetted metals. By yielding high-aspect diamond nanostructures with enormous surface enlargement, it is of great interest for electrochemical or quantum applications (e.g. supercapacitors or room-temperature hyperpolarisators). We present this fast and low-cost way to nanostructure wafer-scale, polycrystalline diamond (PCD). The PCD is patterned top-down by inductively coupled plasma reactive ion etching (ICP-RIE) employing randomly distributed metal droplets as mask. These nanometer-sized droplets form after dewetting a thin evaporated metal film via rapid-thermal annealing. Various metals and layer thicknesses for mask formation on in-house grown layers of intrinsic and heavily boron doped PCD are investigated in addition to different plasma etching parameters. The material shows a dark black color, which points to strong light absorbance in the visible due to the nanostructuring. We achieve an increase in surface area with micrometer deep coral-like structures of some ten-nanometer size.

FM 63.20 Wed 16:30 Tents

VLS-Growth and characterization of bulk-insulating topological insulator nanowires — •Felix Münning[1], Oliver Breunig[1], Zhiwei Wang[1], Mengmeng Bai[1], Stefan Roitsch[2], Klaus Meerholz[2], Thomas Fischer[3], Sanjay Mathur[3], and Yoichi Ando[1] — [1]Physics Institute II, University of Cologne — [2]Institute of Physical Chemistry, University of Cologne — [3]Institute of Inorganic Chemistry, University of Cologne, Germany

We report on the growth of $Bi_xSb_{2-x}Te_3$ and $Bi_2Te_xSe_{3-x}$ nanowires and their characterizations in terms of morphology, material composition and electronic transport at low temperatures. Growth is performed using the vapour-liquid-solid (VLS) method on Si/SiO_2 substrates decorated with 20-nm Au nanoparticles and devices featuring ohmic contacts to the nanowires are fabricated using electron-beam lithography.

$Bi_xSb_{2-x}Te_3$ nanowires were successfully grown in a bulk-insulating composition, with the chemical potential tunable through the Dirac point by electrostatic gating. While in $Bi_2Te_xSe_{3-x}$ the charge-neutrality point could not be reached, the transport appears to be cleaner, featuring AB-like oscillations over a wide range of the chemical potential within the band-gap.

The observed signatures of the topological surface states are modeled on the basis of their size-quantized sub-bands within the insulating band-gap.

FM 63.21 Wed 16:30 Tents

Recovering the homogeneous absorption of SiV^--ensemble — •Anna Breunig[1], Ohr Lahad[2], Johannes Görlitz[1], Eilon Poem[2], Ofer Firstenberg[2], and Christoph Becher[1] — [1]Universität des Saarlandes, Saarbrücken 66123, Germany — [2]Weizmann Institute of Science, Rehovot 76100, Israel

The negatively-charged silicon-vacancy centre in diamond is a promising system for quantum information processing due to its optically accessible spin states and all-optical coherent spin control, its long spin coherence time (albeit at very low temperatures) and its exceptional homogeneity of optical transitions. The latter recently enabled the demonstration of strong light-matter interactions in an ensemble of SiV^- centres [1] putting within reach applications such as quantum memories or single-photon nonlinearities. However, inhomogeneous broadening due to the local crystal strain remains a limiting factor. To circumvent this limitation, we investigate recovery of the homogeneous absorption line based on light shifts introduced by auxiliary fields. We here present calculations according to the scheme in [2] for a SiV^--ensemble and discuss possible applications.

[1] C.Weinzetl et al., Phy. Rev. Lett. 122, 063601 (2019).
[2] arXiv:1904.06233v2 [quant-ph]

FM 63.22 Wed 16:30 Tents

Anomalous and topological Hall effect in magnetically doped topological insulator thin films — •Gertjan Lippertz[1,2], Andrea Bliesener[1], Alexey Taskin[1], Lino Pereira[2], and Yoichi Ando[1] — [1]Institute of Physics II, University of Cologne, Germany — [2]Instituut voor Kern- en Stralingsfysica, KU Leuven, Belgium

Breaking TRS in a topological insulator (TI) by magnetic doping opens an energy gap at the Dirac point on the top and bottom surface. Thin films of this kind of gapped topological insulator exhibit new quantum phenomena, including the quantum anomalous Hall effect (QAHE), where spontaneous magnetization leads to a dissipationless spin-polarised edge channel and a quantized Hall resistance of h/e^2 [1]. Furthermore, an additional topological Hall component has recently been observed in such samples, possibly originating from the formation of Skyrmions [2].

Here we report on our observation of the anomalous and topological Hall effect in V- and Cr-doped $(Bi_xSb_{1-x})_2Te_3$ films grown by MBE. We will show how a gradient in the Bi/Sb ratio along the growth direction leads to a broken inversion symmetry and the appearance of an additional topological Hall component at the coercive field. Uniform samples on the other hand show the usual anomalous Hall effect close to the quantized Hall resistance of h/e^2.

References:

[1] C.-Z. Chang et al., Nature Materials 14, 473-477 (2015)
[2] K. Yasuda et al., Nature Physics 12, 555-559 (2016)

FM 63.23 Wed 16:30 Tents

Selective area growth of topological insulator nanowires by molecular beam epitaxy — •Andrea Bliesener[1], Gertjan Lippertz[1,2], Oliver Breunig[1], Alexey Taskin[1], and Yoichi Ando[1] — [1]Institute of Physics II, University of Cologne, Germany — [2]Instituut voor Kern- en Stralingsfysica, KU Leuven, Belgium

Inducing superconductivity into a topological insulator nanowire by proximitizing it with an s-wave superconductor is predicted to give rise to Majorana bound states. [1] This strategy promises a more robust alternative to the conventional semiconductor approach.

To realize this platform, we grow Si_3N_4 on a sapphire substrate and pattern it by electron-beam lithography into nanowire devices. We use this pre-patterned substrate to selectively grow topological insulator nanowires by molecular beam epitaxy. Control of the chemical potential is achieved by a side-gate, alleviating the need for additional fabrication steps after growth. The nanowires are characterized using magneto-transport measurements.

Here we show our first results towards growing bulk insulating $(Bi_{1-x}Sb_x)_2Te_3$ (BST) nanowires which have widths below 100nm. Optimizing the composition between n-type Bi_2Te_3 and p-type Sb_2Te_3 can give almost perfect compensation of charge carriers in BST.

[1] L. Fu and C.L. Kane, Phys. Rev. Lett. 100, 096407 (2008)