Q 30: Color Centers I

Time: Wednesday 11:00–13:00 Location: HS 3118

Q 30.1 Wed 11:00 HS 3118

Spectral stability of V2-centres in sub-micron 4H-SiC membranes — •Jonah Heiler[1,2], Jonathan Körber[2], Erik Hesselmeier[2], Pierre Kuna[2], Rainer Stöhr[2], Philipp Fuchs[3], Misagh Ghezellou[4], Jawad Ul-Hassan[4], Wolfgang Knolle[5], Christoph Becher[3], Florian Kaiser[1,2], and Jörg Wrachtrup[2] — [1]MRT Department, Luxembourg Institute of Science and Technology & Department of Physics and Materials Science, University of Luxembourg, Belvaux, Luxembourg — [2]3rd Institute of Physics, University of Stuttgart, Germany — [3]Universität des Saarlandes, Fachrichtung Physik, Saarbrücken, Germany — [4]Department of Physics, Chemistry and Biology, Linköping University, Sweden — [5]Leibniz-Institute of Surface Engineering (IOM), Leipzig, Germany

Colour centres in solids emerge as a promising quantum technology platform, since they inherently provide a spin-photon interface. Overcoming its low photon extraction efficiency requires nanophotonic structuring, which can reduce the colour centres' spectral stability. Here, we focus on silicon vacancy colour centres in the industry's leading third-generation semiconductor silicon carbide and show a systematic large-scale study of their optical properties in sub-μm membranes. We develop a highly reproducible recipe to produce those membranes using chemical mechanical polishing together with reactive ion etching. Further, we observe close-to lifetime limited optical linewidths with almost no signs of spectral wandering in 0.7 μm membranes. Our findings open the avenue for the integration of silicon vacancies into a variety of nanophotonic structures that improve the photon extraction.

Q 30.2 Wed 11:15 HS 3118

Photon-collection enhancement of V2-centers integrated in a cavity-based 4H-SiC antenna. — •Jonathan Körber[1], Jonah Heiler[1,2], Erik Hesselmeier[1], Pierre Kuna[1], Rainer Stöhr[1], Philipp Flad[3], Philipp Fuchs[4], Misagh Ghezellou[5], Jawad Ul-Hassan[5], Wolfgang Knolle[6], Christoph Becher[4], Florian Kaiser[1,2], and Jörg Wrachtrup[1] — [1]3rd Institute of Physics, University of Stuttgart, Germany — [2]MRT Department, Luxembourg Institute of Science and Technology & Department of Physics and Materials Science, University of Luxembourg, Belvaux, Luxembourg — [3]4th Physics Institute, University of Stuttgart, Germany — [4]Universität des Saarlandes, Fachrichtung Physik, Saarbrücken, Germany — [5]Department of Physics, Chemistry and Biology, Linköping University, Sweden — [6]Leibniz-Institute of Surface Engineering (IOM), Leipzig, Germany

Color centers in semiconductors promise various applications for quantum technologies. However, due to the typically large refractive indices of the host materials, photons are extracted inefficiently from such color centers, while high photon count rates are a key requirement for many applications. Here, we present the fabrication of a planar, cavity-based antenna based on silver-coated, sub-micron-thin silicon carbide membranes to increase the photon extraction from integrated silicon-vacancy color centers. Further, we report a count rate enhancement of up to one order of magnitude for single, cavity-integrated color centers compared to bulk and find stable, resonant absorption lines at cryogenic temperatures.

Q 30.3 Wed 11:30 HS 3118

Towards Quantum Computing with Divacancies in Silicon Carbide — •Flavie Marquis, Jonah Heiler, and Florian Kaiser — MRT Department, Luxembourg Institute of Science and Technology & Department of Physics and Materials Science, University of Luxembourg, Belvaux, Luxembourg

Colour-centres provide an excellent platform for quantum technology. They enable a pairing of spin-photon interfaces with robust qubits and memories. The nitrogen-vacancy (NV) centre in diamond has lead most of the developments. However, new promising systems are being investigated [1]. Here, we consider stacking-fault divacancies (sf-VVs) in silicon carbide (SiC). The sf-VV centre resembles the diamond-NV in terms of spin level structure, spin-control fidelities, high ODMR contrast at room temperature, nuclear spin control capabilities and adequately high photon count rates [2]. Since sf-VV centres are integrated into a semiconductor host, they benefit from industry technology, such as integration into p-i-n diodes for wavelength tuning [3], as well as mature nanofabrication for improving optical efficiencies [4]. Here, we present our first results on fabrication and control of sf-VVs in SiC at room temperature, including spin coherence times and control fidelities. An outlook towards high-level nuclear spin control within the di-atomic lattice is discussed.

[1] Nat. Photonics 12, 516 (2018)
[2] Nat. Sci. Rev. 9, nwab122 (2022)
[3] Science 366, 1225 (2019)
[4] Nat. Mater. 21, 67 (2022)

Q 30.4 Wed 11:45 HS 3118

Waveguide-coupled single photon source in silicon carbide — •Marcel Krumrein[1], Raphael Nold[1], Flavie Davidson-Marquis[2], Arthur Bourama[1], Erik Hesselmeier[1], Ruoming Peng[1], Lukas Niechziol[1], Di Liu[1], Rainer Stöhr[1], Patrick Berwian[3], Jawad Ul-Hassan[4], Florian Kaiser[2], and Jörg Wrachtrup[1] — [1]3rd Institute of Physics, University of Stuttgart, Germany — [2]MRT Department, Luxembourg Institute of Science and Technology, Luxembourg — [3]Fraunhofer Institute for Integrated Systems and Device Technology IISB, Germany — [4]Department of Physics, Chemistry and Biology, Linköping Unversity, Sweden

Spin defects in silicon carbide are promising quantum emitters for quantum information applications. The silicon vacancies V1 and V2 in 4H-SiC possess very promising spin-optical properties, as lifetime-limited emission and a rich nuclear spin bath. However, the collection efficiency of bulk emitters is very poor, leading to low photon count rates, and thus, long measurement times. To address this, we integrate V2 defects into single mode nanobeams [1] and collect the emitted photons by tapered fibers [2]. Here, we present the characterization of the waveguide-fiber interface experimentally and theoretically with coupling efficiencies exceeding 93%. Using this interface, the emission of waveguide-integrated, single V2 centers was proven with saturated photon count rates of 181 kcps. Finally, we perform Rabi and Hahn-Echo sequences to show the accessibility of the defect's spin.

[1] C. Babin et al., Nat. Mater. 21, 67 (2022). [2] M. J. Burek et al., Phys. Rev. Applied 8, 024026 (2017).

Q 30.5 Wed 12:00 HS 3118

Single-photon emission from silicon-vacancy color centers in polycrystalline diamond membranes — •Assegid Flatae[1,2], Florian Sledz[1,2], Haritha Kambalathmana[1,2], Stefano Lagomarsino[3,4], Silvio Sciortino[3,4,5], and Mario Agio[1,2,5] — [1]Laboratory of Nano-Optics, University of Siegen, 57072 Siegen, Germany — [2]Cμ-Research Center of Micro- and Nanochemistry and (Bio)Technology, University of Siegen, 57068 Siegen, Germany — [3]Istituto Nazionale di Fisica Nucleare, Sezione di Firenze, 50019 Sesto Fiorentino, Italy — [4]National Institute of Optics (INO), National Research Council (CNR), 50125 Florence, Ital — [5]National Institute of Optics (INO), National Research Council (CNR), 50125 Florence, Italy

Single-color centers in thin polycrystalline diamond membranes are of interest in integrated quantum photonics and hybrid quantum systems. However, their practical application was so far limited by crystallographic defects, impurities and graphitic grain boundaries. We report on a single-photon source based on silicon-vacancy color centers in a polycrystalline diamond membrane, we discuss the spectroscopic approach and the photophysics, reaching g2(0)= 0.04.

Q 30.6 Wed 12:15 HS 3118

Creation of a single SiV center in nanodiamond by ion implantation — •Tim Buskasper[1,2] and Carsten Schuck[1,2] — [1]Center for Soft Nanoscience, Münster, Germany — [2]Center for Nanotechnology, Münster, Germany

Single photon emitters are a crucial component in the further development of quantum technologies such as quantum computers or quantum key distribution. For this purpose, especially group IV defects in diamond are promising candidates due to their robustness, short lifetime, and large Debye-Waller factor. However, the production of a single color center in (nano)diamonds remains a persistent challenge.

Here, we report on the successful generation of SiV centers in nanodiamonds through ion implantation using a focus ion beam technique, followed by thermal post-treatment. Notably, we present the creation of both: ensembles and a single SiV center in a nanodiamond. The single SiV center exhibits a lifetime of $t_1 = (2.40 \pm 0.17)$ ns and

$g(\tau = 0) = 0.08$.

Our fabrication process is enhanced by an automatic mark detection system in our FIB system and in combination with our precise nanoparticle placement technique, the creation approach becomes scalable and semi-automatable. Furthermore, integration of the single nanodiamond into nanophotonic circuits is feasible, paving the way for fully integrated nanophotonic devices.

Q 30.7 Wed 12:30 HS 3118

Spin Control of Silicon-Vacancy Centers in Nanodiamonds — •Marco Klotz[1], Andreas Tangemann[1], Viacheslav Agafonov[2], and Alexander Kubanek[1] — [1]Institute for Quantum Optics, University Ulm, Germany — [2]GREMAN, UMR 7347 CNRS, INSA-CVL, Tours University, 37200 Tours, France

For the realization of quantum networks, qubits that can be interfaced with scalable photonic technologies are of major interest. Due to their good optical and spin properties [1], group IV defects in diamond are promising candidates for these applications. We are using negatively-charged silicon-vacancy-centers hosted in nanodiamonds that can be integrated into photonic structures. Compared to bulk diamond, SiVs hosted in a nanodiamond experience less dephasing due to a combination of locally modified phonon density of states and increased ground-state splitting [2]. Hence, they are a candidate for operation above mK temperature, decreasing the technological overhead. Here, we present our progress in characterizing and controlling the electron-spin qubit of a SiV- in a nanodiamond at liquid Helium temperature for future application in quantum networks.

[1] R. Waltrich et al., Two-photon interference from silicon-vacancy centers in remote nanodiamonds, 10.1515/nanoph-2023-0379

[2] M. Klotz et al., Prolonged Orbital Relaxation by Locally Modified Phonon Density of States for the SiV- Center in Nanodiamonds, 10.1103/PhysRevLett.128.153602

Q 30.8 Wed 12:45 HS 3118

Thin-film 4H-silicon carbide-on-Insulator for spin-mechanical applications — •Yan Tung Kong — 3. Physikalisches Institut, Universität Stuttgart, Stuttgart, Germany

High-quality, wafer-scale, thin-film silicon carbide (SiC) holds significant potential in the realms of modern microelectromechanical systems (MEMS), integrated nonlinear photonic circuits, and quantum photonics. Nevertheless, the properties of thin-film SiC often suffer a significant degradation comparing to bulk crystals, primarily due to surface damage incurred during bonding and thinning processes. In this study, we present a successful demonstration of the complete process flow for thin-film 4H-silicon carbide-on-Insulator (4H-SiCOI). Our approach integrated plasma activation bonding, Chemical Mechanical Polishing (CMP), and Inductively Coupled Plasma Etching (ICP-RIE) techniques, effectively mitigating surface damage and ensuring the production of high-quality thin-film SiC with preserved properties. Furthermore, we fabricated nano-mechanical and photonic SiC devices featuring implanted Si vacancies within our SiC thin films (<1 um). This provides a unique platform for exploring spin-phonon-photon dynamics in nanoscale opto-mechanical devices.