HL 17: Materials and devices for quantum technology I

Time: Monday 15:00–17:45 Location: POT 112

HL 17.1 Mon 15:00 POT 112

3D Active Sites of Te in Hyperdoped Si by Hard X-ray Photoelectron Kikuchi Diffraction — •Moritz Hoesch[1], Mao Wang[2], Shengqiang Zhou[2], Olena Fedchenko[3], Christoph Schlüter[1], Katerina Medjanik[3], Sergej Babenkov[3], Aimo Winkelmann[4], Hans-Joachim Elmers[3], and Gerd Schönhense[3] — [1]DESY Photon Science, Hamburg, Germany — [2]Helmholt-Zentrum Dresden-Rossendorf, Germany — [3]JGU, Institut für Physik, Mainz, Germany — [4]Academic Centre for Materials and Nanotechnology, AGH University of Science and Technology, Krakow, Poland

n-type doping of Si by Te in excess of the solubility limit was recently demonstrated to lead to hyperdoped material [1]. The samples are made by ion implantation combined with pulsed laser melting. Our investigation by hard x-ray photoelectron spectroscopy (hXPS) reveals at least two different Te species. At the highest doping concentration we study the photoelectron scattering patterns using hard x-ray photoelectron diffraction (hXPD) [2]. Substitutional site occupation of both Te monomers as well as dimers is identified with increasing binding energy (main features in the XPS spectra). The sharp hXPD patterns allow the detailed analysis of the local surrounding of the dopant atoms [3]. At the highest binding energy an additional species is found and the distinct hXPD pattern at this binding energy suggests the assignment to a small fraction of Te in clusters.

[1] M. Wang et al. Phys. Rev. Appl. 11 054039 (2019) and references therein. [2] O. Fedchenko et al NJP 21, 113031 (2019); [3] O. Fedchenko et al., this conference.

HL 17.2 Mon 15:15 POT 112

UHV Lithography for STM Investigations of 3D Topological Insulators-Superconductor Hybrid Arrays — •Michael Schleenvoigt[1], Tobias W. Schmitt[2], Priyamvada Bhaskar[3], Max Vassen-Carl[1], Abdur R. Jalil[1], Benjamin Bennemann[4], Stefan Trellenkamp[4], Florian Lentz[4], Gregor Mussler[1], Markus Morgenstern[3], Peter Schüffelgen[1], and Detlev Grützmacher[1,2] — [1]Peter Grünberg Institute 9, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]JARA-FIT Institute Green IT, RWTH Aachen University, 52062 Aachen, Germany — [3]II. Institute of Physics B, RWTH University, 52056 Aachen, Germany — [4]Helmholtz Nano Facility, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany

Majorana Zero Modes (MZMs) are proposed to arise at the interface of a topological insulator (TI) and an s-wave superconductor (SC). Scanning tunneling microscopy and spectroscopy (STM/STS) enable the investigation of MZMs in such hybrid structures. To achieve high SC-TI interface qualities and protect the exposed TI surfaces, device fabrication calls for ultra-high vacuum (UHV) conditions. I will present a three-step in situ fabrication technique. First, TI arrays consisting of molecular beam epitaxy (MBE) grown (Bi,Sb)2(Te,Se)3 compounds are created via stencil lithography. In the second step, SC islands are deposited on top of the TI arrays. Finally the stencil lithography mask is removed without exposing the structures to ambient conditions to prepare the sample for STM/STS investigations in UHV. Topography and spectroscopy maps verify the viability of the process.

HL 17.3 Mon 15:30 POT 112

Fabrication of Topological Insulator Tunnel Junctions — •Dennis Heffels[1], Tobias W. Schmitt[1,2], Michael Schleenvoigt[1], Kristof Moors[1], Max Vassen-Carl[1], Florian Lentz[1], Benjamin Bennemann[1], Gregor Mussler[1], Peter Schüffelgen[1], and Detlev Grützmacher[1,2] — [1]Peter Grünberg Institute, Forschungszentrum Jülich — [2]JARA-FIT Institute Green IT, RWTH Aachen University

At the end of a one-dimensional topological superconductor Majorana zero modes are predicted to exist. As a possible platform for this exotic superconductivity, heterostructures of $(Bi_xSb_{1-x})_2Te_3$ 3D topological insulators (3D TIs) and s-wave superconductors are currently investigated. For this, tunneling spectroscopy is a powerful tool in order to characterize the superconducting proximity effect and detect signatures of Majorana zero modes as shown already on other hybrid platforms like proximitized III-V semiconductor nanowires. A major challenge in order to use this techique also for 3D TI nanoribbons is the fabrication of suitable tunnel junctions while simultaneously preventing the delicate 3D TI surface from degradation at ambient conditions. In this contribution, I will report on progress of a multi-step *in situ* fabrication technique to assemble tunnel junctions at the ends of proximitized 3D TI nanoribbons.

HL 17.4 Mon 15:45 POT 112

Optical Spectroscopy of the ^{28}Si:P donor bound exciton transition — Eduard Sauter[1], M. Beck[1], N. V. Abrosimov[2], J. Huebner[1], and •M. Oestreich[1] — [1]Leibniz Universität Hannover - Abt. Nanostrukturen — [2]Leibniz Institut für Kristallzüchtung Berlin

The donor bound exciton states of ^{28}Si:P show remarkable ensemble transition linewidths[1]. For a ^{29}Si concentration of less than 50ppm, made possible by the avogadro project[2], the D^0X T_2^* coherence times are unprecedented in a semiconductor[3] and the T_1 spin relaxation can be prolonged to the order of minutes[4]. These material qualities may be exploited for spin qubit manipulation and quantum information storage. Spectroscopy of the ≈ 100Mhz FWHM zero phonon line does provide means to verify existing theory of silicon and semiconductors in general to a high degree of accuracy[5]. This contribution explores some of the existing experiments and the possibilities which the donor bound exciton transition might provide for future experiments.

[1] Karaiskaj, D., et al., Physical review letters 86.26 (2001): 6010.
[2] Becker, P., et al. "Enrichment of silicon for a better kilogram." physica status solidi (a) 207.1 (2010): 49-66.
[3] Tyryshkin, Alexei M., et al., Nature materials 11.2 (2012): 143.
[4] Saeedi, Kamyar, et al. Science 342.6160 (2013): 830-833.
[5] Cardona, Manuel, T. A. Meyer, and M. L. W. Thewalt. "Temperature dependence of the energy gap of semiconductors in the low-temperature limit." Physical review letters 92.19 (2004): 196403.

HL 17.5 Mon 16:00 POT 112

Laser-assisted local metalorganic vapor phase epitaxy of (Al,Ga)As layers — •Max Trippel, Jürgen Bläsing, Matthias Wieneke, Armin Dadgar, and Andrè Strittmatter — Institut für Physik, Otto-von-Guericke Universität Magdeburg, Universitätsplatz 2, 39106 Magdeburg, Germany

Up to now, an unsolved problem of integration between Si and III/V semiconductor materials is the misfit between optimum III/V growth conditions and Si electronics. We propose laser-assisted local III/V epitaxy based on metalorganic vapor phase epitaxy (MOVPE) to resolve the growth-temperature related incompatibility of both worlds. (Al,Ga)As/GaAs(001) and (Al,Ga)As/Si(111) have been investigated first study to mark the differences to full-wafer growth on planar substrates. Our custom made epitaxy system comprises a conventional gas mixing cabinet, a stainless-steel vertical growth reactor, a xyz-movable substrate holder and a temperature-controlled laser-heater. Pyrometric temperature measurement is done in the center of the laser spot being as small as 150 μm in diameter. Initial experiments were devoted to find conditions for epitaxial growth with planar top surfaces. With a 200 μm diameter Gaussian-like laser intensity profile on the substrate surface, circular growth areas of 50-150 μm are obtained for a focal plane position of the substrate. A narrow temperature window exists in which planar growth fronts evolve in the center of the mesa. Below this temperature window, only convex growth fronts appear while above a more complex cross-section of the growth front is observed. Epitaxial growth of AlAs mesas on GaAs substrates is demonstrated.

30 min. break.

HL 17.6 Mon 16:45 POT 112

Developing a stand-alone fiber-coupled single-photon source emitting in the telecom O-band — •Jan Grosse[1], Anna Musiał[2], Nicole Srocka[1], Pawel Mrowinski[1,2], Kinga Żołnacz[2], Oleh Kravets[2], Philipp-Immanuel Schneider[3], Jacek Olszewski[2], Krzysztof Poturaj[4], Grzegorz Wójcik[4], Paweł Mergo[4], Kamil Dybka[5], Mariusz Dyrkacz[5], Michał Dłubek[5], Sven Rodt[1], Sven Burger[3], Lin Zschiedrich[3], Wacław Urbańczyk[2], Grzegorz Sek[2], and Stephan Reitzenstein[1] — [1]Institute of Solid State Physics, Technical University of Berlin, Berlin, Germany — [2]Wrocław University of Science and Technology, Wrocław, Poland — [3]JCMwave GmbH, Berlin, Germany —

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We report on the development of an advanced SPS demonstrator providing fiber coupled single photons in the telecom O-band around 1300 nm. The quantum emitter consists of redshifted low-density InGaAs QDs grown by MOCVD on top of an AlGaAs/GaAs DBR. The outcoupling of photons is enhanced by micromesas patterned deterministically on pre-selected QDs via in-situ EBL resulting in high single-photon purity with $g^{(2)}(0)$ as low as 3%, and temperature stability of emission up to about 60 K. The on-chip fiber coupling of micromesas uses an optical alignment process based on the interferometric mapping using a special high numerical aperture (NA=0.42) single mode fiber which results in an alignment accuracy of about 50 nm. The chip is cooled to 40 K by a compact Stirling cryocooler.

HL 17.7 Mon 17:00 POT 112

Coherent 2D fluorescence spectroscopy on a single molecule indicates electron transfer related to the optical Gunn effect — •Matthias Nuss, Simon Büttner, Donghai Li, Friedrich Schöppler, Tobias Hertel, and Tobias Brixner — Institut für Physikalische und Theoretische Chemie, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

The Gunn effect [1] has changed daily lives through the use of "transferred-electron devices". Further developments would benefit from reduced dimensionalities (single-molecule transistors) with tunable quantized nonlinear electro-optical response. Special challenges are to overcome the "THz gap" and to access quantum effects at room temperature that are limited by ensemble averaging or lifetime. In this regard an optical Gunn behaviour was shown in Si nanowires and GaAs and proposed in single-walled carbon nanotubes (SWCNTs) [2]. We carried out ultrafast two-dimensional (2D) fluorescence spectroscopy [3] on an individual SWCNT. We provide insight into the spatio-temporal evolution of electron phonon-mediated intervalley and annihilation dynamics during ultrafast polaron decay in the phonon sideband of an individual SWCNT. We compare the temperature and power dependence, as well as the fourth-order 2D signal of the fluorescence with simulations, to identify the mechanism for electron transfer and discuss this in the light of the Gunn effect [1].

[1] J. B. Gunn, *Solid State Commun.* **1**, 88-91 (1963).
[2] G. Pennington et al.,*Phys. Rev. B* **68**, 045426 (2003)
[3] S. Goetz et al., *Optics Express* **26**, Nr. 4: 3915-25 (2018).

HL 17.8 Mon 17:15 POT 112

Data storage with irradiation-induced defects in SiC — •M. Hollenbach[1,2], C. Kasper[3], D. Poprygin[3], H. Kraus[4], G. Hlawacek[1], Y. Berencén[1], W. Kada[5], T. Ohshima[6], V. Dyakonov[3], and G.V. Astakhov[1,3] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Institute of Ion Beam and Materials Research,Dresden — [2]Technische Universität Dresden,Dresden — [3]Julius-Maximilians-Universität Würzburg, Experimental Physics VI,Würzburg — [4]Jet Propulsion Laboratory, California Institute of Technology,Pasadena — [5]Gunma University,Kiryu — [6]National Institutes for Quantum and Radiological Science andTechnology,Takasaki

The demand for reducing cost and increasing capacities of storing data has led to a continuous improvement of current technologies such as hard disk drives. One of the disadvantages of the present digital media is the limited life span up to 100 years. However, SiC, as a host material for atomic-scale spin centers, especially the Si vacancy, is a promising approach to overcome this limitation. Due to their intrinsic stability, these centers hold promises for next generation long-term data storing. Here, we show the controlled generation of defects by using either focused H^+ or He^+ irradiation. The depth of the defect-rich layer and the number of created luminescent sites are controlled by the energy and the fluence of the ion beam. We demonstrate three dimensional- and multi-bit coding in SiC by using He ions for the writing process. To read out the written defects, a confocal microscope is used. Annealing experiments allowed us to estimate the defect stability to be far above 100 years.

HL 17.9 Mon 17:30 POT 112

Optical characterization of deterministically fabricated quantum-dot microlenses on (111)B GaAs substrate — •Martin von Helversen[1], Alexey Haisler[2], Sarah Fischbach[1], Dimitry Dimitriev[2], Sven Rodt[1], Vladimir Haisler[2], Ilya Derebezov[2], and Stephan Reitzenstein[1] — [1]Institute of Solid State Physics, Technische Universität Berlin, 10623 Berlin, Germany — [2]Institute of Semiconductor Physics, Siberian Branch of Russian Academy of Sciences, 630090 Novosibirsk, Russia

Entangled photon-pairs are excellent candidates for the implementation of secure quantum key distribution schemes [1]. Among suitable single-photon emitters semiconductor quantum dots (QDs) are promising due to their ability to emit polarization entangled photon-pairs on demand via the radiative biexciton-exciton cascade [2]. This, however, requires QDs with a vanishing fine-structure-splitting (FSS) of the excitonic state. We report on QDs grown via molecular beam epitaxy on (111)B GaAs substrate, where the piezoelectric field is directed along the growth direction and allows for a more symmetric growth compared to QDs on (100)-substrate. We find a reduced FSS of $13 \pm 2\,\mu$eV compared to (100) QDs with reported values of around $30\,\mu$eV [3]. By further integation of these emitters into deterministic microlenses [4], their outcoupling efficiency can be optimized to values of above 40%.

[1] Ekert, A. K., Phys. Rev. Lett. 67(6), 661 (1991).
[2] Benson, O. et al., Phys. Rev. Lett. 84(11), 2513 (2000).
[3] Gammon, D. et al., Phys. Rev. Lett. 76(16), 3005 (1996).
[4] Gschrey, M. et al., Nat. Commun. 6, 7662 (2015).