HL 93: Poster Session: Metal-Semiconductor Hybrid Systems, Plasmonic Systems / Photonic Crystals / Carbon: Diamond & CNT / Quantum Information Systems

Time: Thursday 16:00–19:00 Location: Poster D

HL 93.1 Thu 16:00 Poster D

Optical properties of hybrid semiconductor-metal structures — •L.E. Kreilkamp[1], M. Pohl[1], V.I. Belotelov[2], A.K. Zvezdin[2], G. Karczewski[3], T. Wojtowicz[3], A. Rudzinski[4], M. Kahl[4], I.A. Akimov[1], D.R. Yakovlev[1], and M. Bayer[1] — [1]Experimentelle Physik 2, Technische Universität Dortmund, 44221 Dortmund, Germany — [2]A.M. Prokhorov General Physics Institute, Russian Academy of Sciences, 119992 Moscow, Russia — [3]Institute of Physics, Polish Academy of Sciences, 02668 Warsaw, Poland — [4]Raith GmbH, Konrad-Adenauer-Allee 8, 44263 Dortmund, Germany

We study the optical properties of hybrid nanostructures comprising a semiconductor CdTe quantum well (QW) separated by a thin CdMgTe cap layer of 40 nm from a patterned gold film. The CdTe/CdMgTe QW structure with a well width of 10nm was grown by molecular beam epitaxy. The one-dimensional periodic gold films on top were made using e-beam lithography and lift-off process. The investigated structures can be considered as plasmonic crystals because the metal films attached to the semiconductor are patterned with a period in the range from 475 to 600 nm, which is comparable to the surface plasmon-polariton (SPP) wavelength. Angle dependent reflection spectra at room temperature clearly show plasmonic resonances. PL spectra taken at low temperatures of about 10 K under below- and above-barrier illumination show significant modifications compared to the unstructured QW sample. The number of emission lines and their position shift change depending on the excitation energy. The role of exciton-SPP coupling and Schottky barrier at the semiconductor-metal interface are discussed.

HL 93.2 Thu 16:00 Poster D

Fabrication of plasmonic nanoantenna/nanocrystal hybrid structures — •Heiko Linnenbank[1,2], Stephan Irsen[2], and Stefan Linden[1] — [1]Physikalisches Institut Universität Bonn, 53115 Bonn, Germany — [2]Forschungszentrum caesar, 53175 Bonn , Germany

Plasmonic nanoantennas are known for their ability to focus visible and near infrared light far beyond the diffraction limit. The intensity in the nano foscus can exceed the intensity of the incident light field by orders of magnitude. Our aim is to combine this property with the second order nonlinear response of, e.g., nanocrystaline barium titanate or lithium niobate in order to achieve resonant second harmonic generation or optical parametric oscillation. A big challenge for the experimental realization of such a nanoantenna / nanoparticel hybrid structure is the controlled placement of the two components relative to each other.

To overcome this issue, we use a two step electron-beam lithography scheme, where in the first lithography step the antennas are fabricated by a standard metal lift-off technique. In the second lithography, we create holes in a PMMA resist layer with a well defined diameter at the desired positions of the nanoparticles. Afterwards, the sample is immersed in a nanoparticle solution and slowly extracted. Convective assembly leads to the exclusive deposition of the nanoparticles in the predefined holes. With this technique the precision of the placement is in the order of the diameter of the nanoparticel and we are able to produce multiple arrays of thousands of structures in a feasible time.

HL 93.3 Thu 16:00 Poster D

Optical Investigations on Rolled-up Active Metamaterials including Plasmonic Structures — •Lena Simone Fohrmann, Stephan Schwaiger, Aune Koitmäe, Matthias Klingbeil, Andreas Rottler, Yuliya Stark, David Sonnenberg, Christian Heyn, Detlef Heitmann, and Stefan Mendach — Institut für Angewandte Physik, Universität Hamburg, Jungiusstraße 11, 20355 Hamburg

By the relaxation process of strained metal/semiconductor layers one can fabricate a rolled-up microtube whose wall consists of a metal/semiconductor superlattice representing a metamaterial. Quantum well heterostructures embedded into the semiconductor component enhance the transmission through the rolled-up metamaterial upon optical pumping [1]. A silver grating is integrated into these active metamaterials to investigate the coupling between surface plasmons on the silver grating and the quantum well. Simulations show that the integration of grating structures in rolled-up active metamaterials influences the transmission of light through the material drastically [2]. In this work I present a fiber based transmission measurement setup which is able to measure the transmission enhancement of a rolled-up metamaterial depending on the polarization of the transmitted light. Furthermore I present first results showing a polarization dependent transmission enhancement of up to 3.5%. We gratefully acknowledge support from the Deutsche Forschungsgemeinschaft (DFG) through GrK 1286. [1] S. Schwaiger et al., Phys. Rev. B 84, 155325 (2011). [2] A. Rottler et al., J. Opt. Soc. Am. B 28, 2402 (2011).

HL 93.4 Thu 16:00 Poster D

Optical Near Field Measurements on a Plasmonic Luneburg Lens — •Hoan Vu, Jens Ehlermann, Robert Blick, Detlef Heitmann, and Stefan Mendach — Institute of Applied Physics, University of Hamburg, Germany

We use a scanning near field optical microscope (SNOM) to investigate the interaction of surface plasmon polaritons (SPP) with dielectric nanostructures on gold films. For that purpose, a metal coated optical fiber with a 100 nm aperture is scanned over the samples surface in order to collect topographical and optical information simultaneously [1].

SPP properties, especially the propagation direction can be modified by varying the effective refractive index on the sample's surface. This is predominately achieved using gray scale lithographic techniques to locally modulate the height of polymeric nanostructures [2].

We present near field measurements on a plasmonic Luneburg lens [3]. Depending on the wavelength this lens focuses the SPPs to different spots on the sample.

We gratefully acknowledge support by the DFG via the Graduiertenkolleg 1286.

[1] A. Lewis et al., Ultramicroscopy 13, 227-232 (1984)
[2] P. A. Huidobro et al., Nano Letters 10(6), 1985-1990 (2010)
[3] T. Zentgraf et al., Nature Nanotechnology 6, 151-155(2011)

HL 93.5 Thu 16:00 Poster D

FDTD Simulations on three-dimensional plasmonic metamaterials containing optically active quantum wells — •Andreas Rottler, Malte Harland, Stephan Schwaiger, Aune Koitmäe, Detlef Heitmann, and Stefan Mendach — Institute of Applied Physics, University of Hamburg, Germany

Rolled-up metal/semiconductor multilayers containing optically active quantum wells opened up a new path for loss reduction in three dimensional metamaterials [1]. Recently, it was also shown that the embedding of plasmonic structures into these metamaterials can result in pumping induced transparency [2].

In this contribution we report on our recent finite-difference time-domain simulations on metamaterials consisting of alternating layers of plasmonic silver gratings and optically active semiconductor quantum wells. We investigated structure-design improvements in order to reduce the pumping power that is needed for optical net-gain.

We gratefully acknowledge support by the DFG via the Graduiertenkolleg 1286.

[1] S. Schwaiger et al., Phys. Rev. B 84, 155325 (2011).
[2] A. Rottler et al., J. Opt. Soc. Am. B 28, 2402-2407 (2011).

HL 93.6 Thu 16:00 Poster D

Transmission enhancement in three-dimensional rolled-up metamaterials including plasmonic structures — •Aune Koitmäe, Andreas Rottler, Stephan Schwaiger, Detlef Heitmann, Cornelius Bausch, Stefan Mendach, Eric Stava, and Robert Blick — Institut für Angewandte Physik, Universität Hamburg

We present numerical finite difference time domain (FDTD) simulations on three-times rolled-up semiconductor/metal microtubes (RUMMs) including an active InGaAs layer and a Ag grating [1]. The thickness of the metal layer and the grating periodicity have an influence to the wavelength of the SPP resonance and are chosen such that the resonance matches the wavelength of the quantum well emission. The simulations show a strong transmission enhancement when the RUMM is illuminated with p-polarized light. This is due to the coupling between the SPP resonance and the emission of the quantum well. Simulations using s-polarized light do not show strong transmission enhancement, and are comparable with the simulations including

planar Ag layers instead of Ag gratings. Measurements of transmission enhancement on RUMMs including planar Ag film are presented in [2].

Semiconductor tubes can be used for biological applications [3].

[1] A. Rottler et al., J. Opt. Soc. Am. B 28, 2402 (2011).
[2] S. Schwaiger et al., Phys. Rev. B 84, 155325 (2011).
[3] M. Yu et al., American Chemical Society (2011).

HL 93.7 Thu 16:00 Poster D

Transformation optics with radial metamaterials — •Daniel Diedrich, Andreas Rottler, Detlef Heitmann, and Stefan Mendach — Institute of Applied Physics, University of Hamburg, Germany

Metamaterials are artificially structured materials which obtain their optical properties from the structure of the unit cell rather than from the constituent materials.

In this poster we discuss the possible realizations of transformation-optics devices with radial metamaterials, e.g. for cylindrical cloaking [1]. To obtain the required anisotropic permittivity values, we utilized finite-integration technique simulations and investigated the properties of a composite material made of silver spheres embedded into a PMMA host. By varying the distances and hence the interaction strength between the silver spheres, one can control the change in the permittivity.

With this method, a design of a cylindrical cloaking device operating in the visible regime was achieved. Furthermore we introduce designs for devices with an isotropic permittivity distribution, like the optical black hole or the Luneburg lens.

We gratefully acknowledge support by the DFG via the Graduiertenkolleg 1286.

[1] W. Cai, U.K. Chettiar, A.V. Kildishev, V.M. Shalaev, Nature Photonics 1, 224-227 (2007).

HL 93.8 Thu 16:00 Poster D

Gold diffusion into silicon during thermal annealing — •Anne-Dorothea Müller[1], Falk Müller[1], Stephanie Wengel[1], Christine Baumgart[2], Ilona Skorupa[2], Helfried Reuther[2], Arndt Mücklich[2], and Heidemarie Schmidt[2] — [1]Anfatec Instruments AG, Melanchthonstr. 28, 08606 Oelsnitz, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany

Gold was found to diffuse into silicon by a complex mechanism involving a vacancy-controlled interstitial-substitutional equilibrium. We investigated the Au diffusion into silicon using differently thick Au layers on n-Si and thermal annealing in a tube furnace at 800°C for 20 h in an argon atmosphere. After thermal treatment the lateral inhomogeneity in the Au distribution has been probed by Auger electron spectroscopy (AES) scans, Scanning electron microscopy, High resolution transmission electron microscopy (HRTEM), and by Kelvin probe force microscopy (KPFM) measurements [1]. The Au diffusion led to very complex diffusion concentration profiles which deviate from the ideal ones for Au diffusion into dislocation-free silicon. The resulting depth distribution of Au in Si has been determined by AES measurements. The KPFM contrast is independent of the surface topography and reveals different long-range chemical and local electrostatic interaction between the conducting KPFM tip and sample surface. HRTEM on cross-sections prepared from the sample with a nominal 10 and 20 nm thick Au layer reveal different phases of silicide formation. [1] C. Baumgart, A.-D. Müller, F. Müller, H. Schmidt, phys. stat. sol. (a), 2011, 208, 777-789.

HL 93.9 Thu 16:00 Poster D

Photon statistics of the quantum emission of a metallic nanoparticle and quantum dot hybrid system — •Thorsten Sverre Theuerholz, Oliver Esser, Andreas Knorr, and Alexander Carmele — Institut für Theoretische Physik EW 7-1, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin

Electrons in a metallic nanoparticle (MNP) exhibit collective oscillations with frequencies in the range of visible light. In our contribution, we derive the second order photon correlation function of a hybrid system made of a MNP and a semiconductor quantum dot (QD) driven coherently [1]. For this purpose, we treat the hierarchy problem by expressing the dynamical quantities in number states [2]. Within our theoretical framework, we discuss bunching and antibunching effects for the plasmons, depending on the frequency and intensity of the driving field.

[1] A. Ridolfo, O. Di Stefano, N. Fina, R. Saija and S. Savaste, Phys. Rev. Lett. 105 (26), 263601-263605 (2010)
[2] M. Richter, A. Carmele, A. Sitek and A. Knorr, Phys. Rev. Lett. 103 (8), 0874707-0874711 (2009)

HL 93.10 Thu 16:00 Poster D

Photonic Crystal Cavities for Temperature and Refractive Index Measurement — •Niko Nikolay[1], Carlo Barth[1], Andreas W. Schell[1], Jürgen Probst[2], Max Schoengen[2], Bernd Löchel[2], Janik Wolters[1], and Oliver Benson[1] — [1]Nano-Optics, Institute of Physics, Humboldt-Universität zu Berlin, Newtonstraße 15, D-12489 Berlin, Germany — [2]Department for Micro- and Nanostructured Optical Systems, Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Albert-Einstein-Straße 15, D-12489 Berlin, Germany

Nano-photonic devices based on quantum optical effects at the single-emitter and single-photon level are promising for integrated quantum technology [1]. In particular, photonic crystal cavities attracted intense research effort, as the electromagnetic field is strongly localized and the interaction with incorporated emitters is strongly enhanced. However, the transition frequency of solid-state quantum emitters typically exhibits a strong temperature dependence. Thus, a precise thermometer to monitor and control the local temperature close to the emitter is needed. We demonstrate how higher order modes in photonic crystal cavities can be used to tackle this problem. As a side-effect the method can be used to measure the refractive index of semiconductors in a wide temperature and wavelength range.

[1] J.L. O'Brien, A. Furusawa, J. Vučković, *Photonic quantum technologies*, Nature photonics **3**:687, 2009.

HL 93.11 Thu 16:00 Poster D

Design and Optimization of Photonic Crystal Waveguides and Grating Couplers for Single Photon Applications — •Carlo Barth, Niko Nikolay, Andreas W. Schell, Janik Wolters, and Oliver Benson — Nano-Optics, Institute of Physics, Humboldt-Universität zu Berlin, Newtonstraße 15, D-12489 Berlin, Germany

Photonic crystals are a promising platform for integrated quantum optical networks. Recently, the controlled coupling of single emitters to photonic crystal cavities has been strikingly demonstrated in several experiments [1]. However, for future integrated single photon devices efficient waveguides and out-coupling structures will be needed. The latter ones are particularly important, as they form the interface between photonic chips and the macroscopic measurement equipment. We present our latest results on the design and optimization of high efficient couplers with large directivity and their integration into photonic networks.

[1] J. Wolters, A.W. Schell, G. Kewes, N. Nüsse, M. Schoengen, H. Döscher, T. Hannappel, B. Löchel, M. Barth, O. Benson. *Enhancement of the zero phonon line emission from a single nitrogen vacancy center in a nanodiamond via coupling to a photonic crystal cavity.* Applied Physics Letters **97**(14):141108, 2010.

HL 93.12 Thu 16:00 Poster D

Enhanced spontaneous emission from quantum dots in short photonic crystal waveguides — •Johannes Beetz[1], Thang Hoang[2], Leonardo Midolo[2], Matthias Skacel[2], Matthias Lermer[1], Sven Höfling[1], Laurent Balet[2,3], Nicolas Chauvin[2], Andrea Fiore[2], and Martin Kamp[1] — [1]Universität Würzburg, Technische Physik, Am Hubland, 97074 Würzburg, Germany — [2]COBRA Research Institute, Eindhoven University of Technology, P.O. Box 513, NL-5600MB Eindhoven, The Netherlands — [3]École Polytechnique Fédérale de Lausanne, CH-1015 Lausanne, Switzerland

Single photon emitters are key building blocks for the implementation of many quantum information processing schemes. Photonic crystal waveguides (WGs) which contain semiconductor quantum dots (QDs) are perfectly suited for this purpose because they can be easily integrated into on-chip photonic circuits. We fabricated WGs with short lengths (10-25 μm) to avoid localization of light and probed the photoluminescence from the top of the WG and from the cleaved facet. In agreement with simulations, we observe Fabry-Pérot modes formed by the two WG end facets in the slow-light regime of the dispersion curve.

The spontaneous emission of the QDs within the WGs is enhanced by a factor of 1.7. Furthermore, the coupling efficiency of the QD emission into the slow-light mode is estimated to be around 50%. The broad spectral range of the slow-light mode and the large WG mode volume allow for large photon collection efficiencies even in the case of limited spectral and spatial matching.

HL 93.13 Thu 16:00 Poster D

Semiconductor Colloidal Nanocrystals in PMMA Microresonators — •Felix Büchle, Daniel Rülke, Tobias Grossmann, Michael Hetterich, and Heinz Kalt — Institut für Angewandte Physik and Center for Functional Nanostructures (CFN), Karlsruhe Institute of Technology (KIT), Wolfgang-Gaede-Straße 1, 76131 Karlsruhe, Germany

Our work is based on the incorporation of colloidal CdSe/ZnS core-shell quantum dots (QDs) into the light-confining environment of high-Q (up to 10^6) optical PMMA microresonators fabricated by standard e-beam lithography and a subsequent etching process. QDs have been embedded into the PMMA matrix, mainly by direct mixing into the resist or via layer-by-layer deposition of QD films sandwiched between the resonator-forming PMMA layers, respectively. We focus on the investigation of the interaction between the nanocrystal emitter and the surrounding modal structure of the high-Q conical microresonators in the context of cavity-quantum-electrodynamics as well as on a possible realisation of low-threshold lasing from densely packed QD layers inside the resonator.

HL 93.14 Thu 16:00 Poster D

High-Q Polymer Goblet Resonators for Biosensing Applications — •Torsten Beck[1], Saskia Becker[1], Tobias Grossmann[1,2], Patrik Rath[1], Assegid Flatae[1], and Heinz Kalt[1] — [1]Institut für Angewandte Physik, KarlsruherInstitut für Technologie (KIT), Karlsruhe, Germany — [2]Institut für Mikrostukturtechnik, KarlsruherInstitut für Technologie (KIT), Karlsruhe, Germany

Biosensors for label-free molecule detection with high sensitivity are of great interest for many applications in life sciences. We developed a new type of whispering gallery mode (WGM) resonator made of out of low-loss polymer poly (methyl methacrylate) (PMMA). These optical cavities are fabricated using standard semiconductor processing methods in combination with a specific thermal reflow process. A significantly reduced surface roughness results in low surface scattering losses of the WGMs, as lithographic blemishes vanish. The Q-factor of these goblet resonators is above two million in the 1310 nm wavelength range. The high optical quality and the fabrication method suitable to mass production make these resonators promising candidates for low-cost bio-sensing devices with low limit of detection. Various surface functionalization methods for selective binding of specific molecules were investigated. The influence on the optical properties of the resonators was determined. In order to demonstrate the applicability of the goblet resonators for bio-sensing, Bovine Serum Albumin was detected by monitoring the spectral shift of resonator modes due to protein adsorption.

HL 93.15 Thu 16:00 Poster D

Wave packet dynamics of coherent states in waveguiding structures with quantum emitters — •Julia F. M. Werra[1], Paolo Longo[1], and Kurt Busch[2] — [1]Institut für Theoretische Festkörperphysik, Karlsruher Institut für Technologie, 76128 Karlsruhe, Germany — [2]Humboldt-Universität zu Berlin, Institut für Physik, AG Theoretische Optik, Newtonstr. 15, 12489 Berlin, and Max-Born-Institut, Max–Born–Str. 2A, 12489 Berlin, Germany

We present our recent results on the wave packet dynamics of coherent states in waveguiding structures coupled to artificial atoms. Physical realizations of such systems include coupled-resonator optical waveguides, defect structures in tailored nanophotonic media and microwave photonics in superconducting circuits.

The differences of the transport properties between a coherent state and a single-photon Fock state ([1]-[4]) in terms of various parameters such as the atom-photon coupling strength and the intensity of the light field is investigated numerically. Furthermore, quantum effects such as the atom-photon bound-state, which is a spatially localized, mixed excitation of light and matter, and nonlinear effects such as self-induced transparency that does not occur in the single-photon case are compared to the known results on single-photon excitations ([2]-[4]).

[1] J. T. Shen and S. Fan, Phys. Rev. Lett. 98, 153003 (2007)
[2] P. Longo e al., J. Opt. A: Pure Appl. Opt. 11, 114009 (2009)
[3] P. Longo et al., Phys. Rev. Lett. 104, 023602 (2010)
[4] P. Longo et al., Physical Review A 83, 063828 (2011)

HL 93.16 Thu 16:00 Poster D

Deterministic aperiodic photonic structures based on woodpiles — •Michael Renner and Georg von Freymann — Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Erwin-Schrödinger-Str. 56, 67663 Kaiserslautern, Germany

Unlike most random photonic structures deterministic aperiodic structures (DAS) offer the possibility to reproducibly create specific potential landscapes whose Fourier components are determined by the underlying aperiodic sequence. In accordance with Lebesgue's spectral theorem the Fibonacci, Thue-Morse and Rudin-Shapiro sequences are examples of the three basic spectral measures, namely pure-point, singularly-continuous and absolutely-continuous, respectively.

We choose the woodpile structure as a starting point which can be routinely produced with a very small degree of structural imperfections. Minimizing these is crucial since intrinsic and extrinsic sample properties are often inseparable. Two layers of a fcc woodpile are grouped (bi-layer) and their rods are modulated in size by varying the laser power according to a binary deterministic aperiodic sequence. Rods which represent element 1 are written with raised laser power compared to the periodic case, rods representing element -1 were consequently lowered in power. Along the stacking direction the original bi-layer and its inverse are also arranged following the sequence in order to introduce aperiodicity in three dimensions. Structures derived from the above mentioned sequences are fabricated with increasing modulation depth and thickness. The transition from order to disorder is investigated in their optical transmission and reflection spectra.

HL 93.17 Thu 16:00 Poster D

Distribution of NV optical centers in nitrogen-implanted diamond: Effects of radiation-induced defects and the surface potential — •Torsten Rendler[1], Andrej Denisenko[1], Jan Meijer[2], and Joerg Wrachtrup[1] — [1]3rd Physics Instiute and Research Center SCoPE, University of Stuttgart, Germany — [2]RUBION, Ruhr-Unveristaet Bochum, Germany

In this contribution we present the results on vertical distribution of nitrogen-vacancy (NV) centers in diamond, evaluated using step-etching in Ar/O2 plasma and confocal microscopy analysis. A nitrogen-free single crystal diamond was co-implanted by 15N and 12C atoms and subjected to thermal annealing in high vacuum to activate the NV defects.It was revealed that the optical centers are distributed in depth with different conversion rates of nitrogen atoms to NV defects (yield): about 10% within the stopping range of the implanted atoms and below 0.1% within the channeling tail at the implantation at 0° tilt. The concentration of electrically active defects (traps) within the implanted region was estimated by changing the surface potential of the initially O-terminated diamond in a microwave hydrogen-plasma. It was concluded that the thickness of the sub-surface region depleted with NV- was limited by charged defects in the bandgap of diamond. Subsequent wet-chemical oxidation of the H-terminated surface increased the contribution of NV- centers within the evaluated profile, consistent with the model of surface band bending and charged defects in the implanted region.

HL 93.18 Thu 16:00 Poster D

Ab initio simulations of CNTs for sensor application — •Christian Wagner[1], Jörg Schuster[1,2], and Thomas Gessner[1,2] — [1]Center for Microtechnologies, Chemnitz University of Technology, 09107 Chemnitz — [2]Fraunhofer Institute for electrical nanosystems ENAS, Technologie-Campus 3, 09126 Chemnitz

Carbon nanotubes (CNTs) are of great interest e.g. for sensor application because of their unique properties. Small-gap single-wall CNTs (sgSWCNTs) show a change of resistivity over several orders of magnitude while being strained only by a few percent. This is due to strain-induced band gap opening of sgSWCNTs. They are mechanically stable as well and show high fracture strain. Thus, they are favorable candidates for the application in nano-scaled, mechanical sensors.

Within the group of sgSWCNTs only a few are of practical relevance due to chemical selection methods. Thus we present DFT-calculations of the piezoresistive effect of such application-relevant CNTs. We investigated the band gap by means of DFT and compare our results with analytical tight-binding models, accessible in literature [1, 2], and published DFT-results.

Until now, only ideal CNTs have been considered for ab-initio, piezoresistance calculations. As real CNTs contain defects, we present first results of defective CNTs.

[1] Yang, L. and Han, J., Electronic Structure of Deformed Carbon Nanotubes, *Phys. Rev. Lett. 85*, 154-157, **2000**

[2] Kleiner, A. and Eggert, S., Band gaps of primary metallic carbon nanotubes, *Phys. Rev. B 63*, 073408, **2001**

HL 93.19 Thu 16:00 Poster D

Growth of carbon nanotubes for transistor applications — •Michael Trefz, Kerstin Schneider, Ronny Löffler, Monika Fleischer, and Dieter Kern — Institute for Applied Physics, University of Tübingen, Auf der Morgenstelle 10, 72076 Tübingen, Germany

Carbon nanotube field effect transistors (CNTFETs), that utilize a single carbon nanotube (CNT) as the channel material instead of bulk silicon in the traditional metal-insulator-semiconductor field effect transistor (MOSFET) structure could play a decisive role in the continuing path of miniaturization of electronic devices. In particular the possible narrow channels and the high electrical conductivity of the CNTs are attractive features. However, besides low resistance contacting issues the targeted and reliable preparation of individual transistors still presents problems. Control over the position of a nanotube has been achieved via positioning of catalyst material by lithographic means, followed by chemical vapour deposition (CVD) growth from this catalyst island. The orientation of the growing CNTs may be controlled by an electric field generated by a voltage applied between micro electrodes underneath the catalyst island. Strong van der Waals interaction with the surface impedes this orientation. We present a method to increase the yield of the oriented CNTs by applying an additional electric field so that a contact of the CNTs with the substrate during the growth is avoided. Results from growth experiments and electrical characterization of completed CNTFETs will be presented.

HL 93.20 Thu 16:00 Poster D

Functionalization of carbon nanotubes with Mn_4-clusters — •Anna-Katharina Saelhoff[1], Robert Frielinghaus[1], Claire Besson[1], Henrik Flötotto[1], Lothar Houben[1,2], Paul Kögeler[1], Claus M. Schneider[1], and Carola Meier[1] — [1]Peter Grünberg Institut, Forschungszentrum Jülich and JARA Jülich Aachen Research Alliance, 52425 Jülich, Germany — [2]Ernst Ruska-Center for Microscopy and Spectroscopy with Electrons, Forschungszentrum Jülich, 52425 Jülich, Germany

Due to their exceptional mechanical and transport properties, carbon nanotubes (CNTs) are a promising material for various applications in nanoelectronics. Their properties can be modified by different chemical functionalizations.

Here, we present covalent functionalization of CNTs with magnetic Mn_4-clusters. The route for this functionalization is very general, based on ligand exchange and can be applied for different types of molecules. The yield of the functionalization depends on the number of carboxylic groups on the CNTs created by oxidation. This process is monitored using Raman spectroscopy. However, the specific atomic structure can only be investigated by transmission electron microscopy (TEM).

Thus, for comprehensive characterization, CNTs are grown on patterned Si_3N_4 membranes by chemical vapor deposition. These suspended CNTs are contacted using e-beam lithography. The transport behaviour of such a device is then correlated to the information obtained by TEM and Raman spectroscopy.

HL 93.21 Thu 16:00 Poster D

Er-ion implantation in Si-based materials — •Nadezhda Kukharchyk[1], Stepan Shvarkov[1], Pavel Bushev[2], Alexey Ustinov[2], and Andreas D. Wieck[1] — [1]Angewandte Festkoerperphysik, Ruhr-Universitaet Bochum, Deutschland — [2]Physikalisches Institut, Karlsruhe Institut fuer Technologie, Deutschland

Erbium, embedded in a solid state matrix, is one of the most promising elements for future quantum information processing. The crystal structure as well as its magnetic impurities plays a quite important role for the magnetic properties of Er-ions. As silicon-based materials proved to be the base of the modern electronics world, they are also of high interest for future implementation in quantum data processing. In the following work, the behaviour of implanted Er species in Si-containing materials is discussed. Czochralski Si, float-zone Si, SiO2 and Y2SiO5 are taken as possible matrix (substrate materials). The electron parametric resonance study of implanted Er3+ ions is presented and discussed.

HL 93.22 Thu 16:00 Poster D

Broad-band electrically detected magnetic resonance experiments and electroelastic hyperfine tuning of phosphorus donors in silicon — •Florian M. Hrubesch[1], Lukas Dreher[1], Timon A. Hilker[1], Andreas Brandlmaier[2], Sebastian T.B. Goennenwein[2], Hans Huebl[2], Martin Stutzmann[1], and Martin S. Brandt[1] — [1]Walter Schottky Institut, Technische Universität München, Am Coulombwall 4, 85748 Garching — [2]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Walther-Meißner-Strasse 8, 85748 Garching

We performed broad-band electrically-detected magnetic resonance (EDMR) experiments of ^{31}P in Si using short-circuited coplanar strip lines (CPS) for on-chip microwave magnetic field generation. With this approach, EDMR measurements with frequencies from 1-20 GHz are possible, demonstrating a cost effective way of performing multi-frequency experiments. Using the CPS technique, we demonstrate the electroelastical control of the hyperfine interaction between phosphorus nuclear and electronic spins opening an effective way to address spin-based qubits [1]. The hyperfine interaction is measured employing a hybrid structure consisting of a Si:P layer, a SiGe virtual substrate, and a piezoelectric actuator. By applying a voltage to the actuator, the hyperfine interaction is changed by up to 0.9 MHz, demonstrating the feasibility of electroelastic hyperfine tuning.

[1] L. Dreher, *et al.* Phys. Rev. Lett. **106**, 037601 (2011)

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HL 93.23 Thu 16:00 Poster D

Coherent Photon-spin Transfer with NV Center in Diamond — •Seyed Ali Momenzadeh[1], Sen Yang[1], Petr Siyushev[1], Naofumi Abe[2], Hideo Kosaka[2], Helmut Fedder[1], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Universität Stuttgart — [2]Research Institute of Electrical Communication, Tohoku University, Japan

Nitrogen vacancy (NV) center in diamond is a solid state single photon source which has been under renewed research interest since decade. Possessing several remarkable advantages like photostability, relatively long coherence time, high ability for readout and manipulation of the spin state [1][2], etc, give it unique highlighting applications such as coherent multi-qubit registers. The NV center can be considered as an artificial atom inside diamond being served as a qubit for quantum information processing. In this scence, the interaction (markedly entanglement) between two NVs (as stationary qubits) or between an NV and photons (as flying qubits) is of great importance to study. In this work, I present the development of a cryogenic setup based on a commercial cold-finger cryostat equipped with a home-made confocal setup, ESR, and NMR instrumentations. Furthermore, I show our results studying the coherent spin-photon interactions. The better coherence conditions and other unique features observable at low temperatures [3] offer NV center as a promising system candidate for future applications in quantum information field like quantum repeaters.

[1] Science,329,542,(2010) [2] Nature,466,730,(2010) [3] NJP,11,113029,(2009)