HL 42: Quantum dots: Growth

Time: Thursday 15:00–17:15 Location: POT 151

HL 42.1 Thu 15:00 POT 151

Cone-shell quantum structures with tunable wave functions — •Christian Heyn, Ahmed Alshaikh, Kristian Deneke, and Robert Blick — Center for Hybrid Nanostructures (CHyN), University of Hamburg

We discuss the tailoring of the wave functions (WF) in strain-free GaAs quantum structures (QS) fabricated using self-assembled local droplet etching (LDE) during molecular beam epitaxy (MBE). Here, Al droplets are deposited on an AlGaAs surface and drill nanoholes with tunable shape and size. Subsequently, the holes are filled with GaAs to form strain-free QS. Dependent on the process parameters, the QS have the shape of a cone or of a cone-shell. In particular the low-density (about 1x10^7 cm^{-2}) cone-shell QS (CSQS) demonstrate sharp exitonic lines with linewidth down to 25 μeV, a precise control of the emission wavelength from 680...810 nm by the nanohole filling level, a neutral exiton fine-structure splitting below 5 μeV, and nearly perfect single photon emission. To tune the WF in CSQS, a vertical electric field is applied which causes a strong charge-carrier separation. The resulting Stark shift is measured using micro-photoluminescence (PL). In combination with simulation results the optical data allow the determination of the QS size and shape. In addition, simulations indicate the transformation of either the electron or the hole WF into a quantum ring. As a further consequence of the field-induced charge-carrier separation, simulations of the exciton-recombination lifetimes predict a variability from nanoseconds up to milliseconds. This suggests CSQS for applications in the field of light storage

HL 42.2 Thu 15:15 POT 151

DNA Origami for low-dimensional electronics — •Borja Rodriguez-Barea[1], Shima Jazavandi-Ghamsari[1], Madhuri Chennur[1], Archa Jain[1], Turkan Bayrak[1], Jingjing Ye[2], Ralf Seidel[2], and Artur Erbe[1] — [1]Institute of Ion Beam Physics und Material Science, Helmholtz-Zentrum Dresden-Rossendorf, Germany — [2]Peter Debye Institute for Soft Matter Physics, Universität Leipzig, Germany

The increasing demand for energy-efficient products gave rise to electronic fabs looking for new green manufacturing processes. Bottom-up techniques have the potential to reduce economic and environmental costs due to implementing low-dimensional materials with unique properties.

We demonstrated the formation of low-dimensional metallic nanostructures based on the DNA origami technique, which can be considered as molds to guide the placement and growth of the metallic 1D nanowires. This solution-based and high-resolution nanofabrication technique complements other nanolithography techniques such as electron-beam lithography and thermal scanning probe lithography. Thus, the shape of the nanostructures can be controlled and measured.

Electronic transport on these assemblies is non-ohmic and deteriorates at low temperatures. Temperature-dependent charge transport measurements reveal the dominating mechanisms along these wires.

HL 42.3 Thu 15:30 POT 151

1D Nanowires on DNA mold-based template — •Madhuri Chennur[1], Borja Rodriguez-Barea[1], Jazavandi-Ghamsari Shima[1], Archa Jain[1], Türkan Bayrak[1], Ulrich Kemper[2], Jingjing Ye[2], Christoph Hadlich[2], Ralf Seidel[2], and Artur Erbe[1] — [1]Institute of Ion Beam PhysicsundMaterial Science, HZDR — [2]Peter Debye Institute for Soft MatterPhysics, Universität Leipzig, Germany

Sensors have a fundamental role in improving the world around us. For increasing sensitivity and faster response, new bottom-up approaches are required. DNA nanotechnology allows the creation of nanostructure arrays that can serve the purpose.

We study the controlled growth of 1D metallic nanostructures using DNA origami templates. The DNA nanomolds are folded via staples to obtain the desired conformation. The functionalized template provides the active site for a localized seed nanoparticle attachment, thus allowing metallization by electroless plating. We report continuous Pd and Au 1D nanowires based on this method.

The conductance of the assembled nanostructures through two-probe measurements was investigated. Different origami templates lead to diverse metal morphologies, which influence electronic properties. Temperature-dependent measurements determined the transport mechanism of these nanowires, proving the first step toward an electronic nanosensor.

HL 42.4 Thu 15:45 POT 151

Maximizing Homogeneity of GaAs LDE-QDs on Full Wafer Scale — •Hans-Georg Babin, Timo Kruck, Andreas D. Wieck, and Arne Ludwig — Lehrstuhl für angewandte Festkörperphysik, Ruhr-Universität Bochum, Deutschland

Local droplet etched GaAs quantum dots (LDE-QDs) are a promising candidate for excellent single and entangled photon sources. [1] Taking further steps towards application, this requires structures of increasing complexity, engineering the electronic and photonic environments of the QDs. [2] In previous studies, we showed how properties of GaAs LDE-QDs can be modulate, containing both 737 nm and 795 nm QDs on a single wafer. [3]

However, in device mass production, for example for creating larger quantum networks, it can also be intriguing to maximize the useable area of the produced wafer. This means for the QDs, that the ensemble should be of high homogeneity locally, but also on global wafer scale. Due to the short deposition times of material during LDE this can be challenging due to intrinsic inhomogeneities. We overcome these problems by matching the substrate rotation time with the material deposition time. With this method we receive light emitting QDs on over 96 % of the wafer, with 86 % of the wafer emitting between 792 nm and 802 nm (peak-center). The mean ensemble FWHM of the QD emission is as low as (11.3+-0.4) meV.

[1] Huber, Daniel et al., Nat. Commun. 8 (1), S. 15506 (2017).
[2] Zhai, Liang et al. Nat. Commun. 11 (1), S. 4745 (2020).
[3] Babin et al.; J. Cryst. Growth 591, S. 126713 (2022)

30 min. break

HL 42.5 Thu 16:30 POT 151

Wafer-Scale Epitaxial Modulation of Quantum Dot Densitiy — •Nikolai Bart[1,2], Christian Dangel[2], Peter Zajac[1], Nikolai Spitzer[1], Marcel Schmidt[1], Kai Mueller[2,3], Andreas D. Wieck[1], Jonathan Finley[2], and Arne Ludwig[1] — [1]Ruhr-Universitaet Bochum, Lehrstuhl fuer Angewandte Festkoerperphysik, Universitaetsstraße 150, 44801 Bochum, Germany — [2]Walter Schottky Institut and Physik Department, Technische Universitaet Muenchen, Am Coulombwall 4, 85748 Garching, Germany — [3]Walter Schottky Institut and Department of Electrical and Computer Engineering, Technische Universitaet Muenchen, Am Coulombwall 4, 85748 Garching, Germany

The effect of nanoscale surface roughness on the nucleation of self-assembled InAs quantum dots (QD) is investigated with photoluminescence spectroscopy and atomic force microscopy. We show in-situ control of the roughness modulation by common epitaxial layer-by-layer growth, leaving alternating atomically smooth (rough) surfaces for integer (fractional) completion of a monolayer. We report significant differences in both PL intensity and QD surface density at the critical threshold of nucleation. By varying the underlying GaAs thickness gradients, we create and control 1- and 2-dimensional density modulation patterns on entire 3-inch wafers with modulation periods between a few mm and down to hundreds of μm and densities between 1 and 10 QDs/μm^2.

Bart, N., Dangel, C. et al. Wafer-scale epitaxial modulation of quantum dot density. *Nat Commun* **13**, 1633 (2022).

HL 42.6 Thu 16:45 POT 151

Statistical Analysis of the Spatial Distribution of MBE Grown InAs Quantum Dots on GaAs(100) — •Normen Auler, Akshay Kumar Verma, Ziyang Zhang, and Dirk Reuter — Universität Paderborn, Warburger Str. 100, 33098 Paderborn

Self-assembled InAs quantum dots (QDs) have been intensively studied as model systems for strong three-dimensional confinement over decades and gained considerable interest for applications in quantum technology. The growth by molecular beam epitaxy has been widely studied. In this contribution, we discuss the spatial distribution of InAs QDs grown by solid source molecular beam epitaxy on a

GaAs(100) surface for different QD densities. Therefore, we determine the distribution of nearest-neighbor distances from atomic force microscope (AFM) images and compare them to simulated random distributions. We find good agreement under the assumption of a "denuded" zone of ca. 40 nm around each quantum dot center. This means that the QDs are basically randomly distributed as one would expect from the statistical nature of the nucleation process. The diameter of the denuded zone can either be interpreted as the average geometrical diameter of the QDs or the geometrical diameter plus a small distance due to a repelling interaction between QDs mediated by the strain field. We cannot decide this from our experimental data because AFM overestimates the geometrical diameter. For very low quantum dot densities as often required for single dot experiments, it is very difficult to obtain experimental data with statistical significance, whereas simulations can give insight into the spatial distribution.

HL 42.7 Thu 17:00 POT 151

Controlled MOF Growth on Functionalized Carbon Nanotubes — •Marvin J. Dzinnik[1], Necmettin E. Akmaz[1], Adrian Hannebauer[2], Peter Behrens[2], and Rolf J. Haug[1] — [1]Leibniz Universität Hannover, Institut für Festkörperphysik, Appelstraße 2, 30167 Hannover, Germany — [2]Leibniz Universität Hannover, Institut für Anorganische Chemie, Callinstraße 9, 30167 Hannover, Germany

The class of metal organic frameworks (MOFs) is continuously growing. These materials consist of inorganic building blocks, held together by organic linker molecules. Schulze *et al.* [1] showed that adding functionalized multi-walled carbon nanotubes (MWCNTs) to a UiO-66 synthesis drastically decreased the nucleation time. The MOFs preferably grow on the MWCNT until they fully encapsulate it. We demonstrate a mechanism to spatially control the UiO-66 MOF growth on individual carbon nanotubes and deplete the encapsulation. The MWCNTs are drop-casted on a silicon dioxide surface and then locally modified. The samples are then submerged in the synthesis solution. This process leads to a growth of MOF crystals on the MWCNT surface leaving the modified areas depleted. With this method we are able to define lines free of MOF on the length of a single MWCNT down to several hundred nanometres for example to electrically contact the tubes ends.

[1] Schulze, H. A., et al. Electrically Conducting Nanocomposites of Carbon Nanotubes and Metal-Organic Frameworks with Strong Interactions between the two Components. ChemNanoMat, 5(9), (2019), 1159-1169.