TT 24: Quantum Dots: Transport (joint session HL/TT)

Time: Tuesday 9:30–12:15 Location: POT 151

TT 24.1 Tue 9:30 POT 151

Contact formation analysis of nickel to SiGeOI to form Nickel-Germano-silicide using Flash lamp annealing — •Muhammad Moazzam Khan[1], Slawomir Prucnal[1], and Yordan M. Georgiev[1,2] — [1]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, D-01328 Dresden, Germany — [2]Institute of Electronics at the Bulgarian Academy of Sciences, 72, Tzarigradsko chaussee blvd, 1784-Sofia, Bulgaria

In CMOS technology, parasitic source/drain (S/D) resistance becomes more crucial in determining the overall device performance as the device dimensions get smaller. The contact resistance dominates this parasitic S/D resistance to a great extent, which limits the drive current. In order to have minimal impact on electrical performance, the contact should have linear Current-Voltage characteristics and negligible resistance in comparison to the device resistance. When replacing silicon with silicon-germanium as a channel material in future devices, it is necessary to investigate the contact formation mechanism in order to develop suitable contacts for energy-efficient devices. In this work, we are investigating metal semiconductor contact formation on SiGeOI using flash lamp annealing and studying their properties using structural and electrical characterization.

TT 24.2 Tue 9:45 POT 151

Predicting charge density maps in 2D nanostructures with machine learning techniques — •Amanda Teodora Preda[1,2,3], Calin Andrei Pantis-Simut[1,2,3], Nicolae Filipoiu[2,3], Lucian Ion[2], Andrei Manolescu[4], and George Alexandru Nemnes[1,2,3] — [1]Research Institute of the University of Bucharest (ICUB), Sos. Panduri 90, Bucharest, Romania — [2]University of Bucharest, Faculty of Physics, 077125 Magurele-Ilfov, Romania — [3]Horia Hulubei National Institute for Physics and Nuclear Engineering, 077126 Magurele-Ilfov, Romania — [4]Department of Engineering, Reykjavik University, Menntavegur 1, IS-102 Reykjavik, Iceland

Machine learning (ML) models have the potential to significantly improve and assist the design process of nanodevices that require precise control of the quantum states.

For 2D nanoelectronic structures, charge and spin densities are relevant observables and are also suited for ML techniques which employ image processing. The model systems that we considered are two dimensional quantum dots with multiple electrons and random confinement potentials. With convolutional neural networks, we built a ML model to predict whether a configuration displays singlet-triplet transitions in the ground state. For image translation problems, we used models based on conditional generative adversarial networks in order to predict the charge density distribution for arbitrary interacting systems taking as input either the non-interacting cases or just the shape of the confining potential.

TT 24.3 Tue 10:00 POT 151

Mesoscopic transport properties of individually prepared GaN-nanowire field-effect transistors — •Hannes Hergert[1,2], Matthias T. Elm[1,2,3], and Peter J. Klar[1] — [1]Institute of Experimental Physics I, Giessen, Germany — [2]Center for Materials Research, Giessen, Germany — [3]Institute of Physical Chemistry, Giessen, Germany

In order to keep the optimization of transistors within Moore's law new material systems as well as new transistor concepts such as GaN-nanowire field effect transistors (NW-FET) are needed. In this work we characterize the electrical transport properties of single NW-FET. Furthermore, we are able to obtain a deeper understanding of the mesoscopic transport processes. Unintentionally doped GaN-nanowires were fabricated using molecular-beam-epitaxy and device fabrication was performed by a combination of different lithographic methods and atomic layer deposition. After an annealing process the nanowire's resistance shows an ohmic behaviour. Electrical transport measurements were performed between 2 and 280 K. The investigated NW-FET exhibits a transfer characteristic identical to those of classical field-effect transistors. We show that the electrical transport is dominated by two transport processes: a transport within a metal-like impurity band at low temperatures and a hopping process at higher temperatures. Furthermore we were able to identify universal conductance fluctuations at temperatures below 140 K, which arise from the shift of the Fermi level when applying a topgate voltage.

TT 24.4 Tue 10:15 POT 151

Multi-Channel Kondo Effect in Few-Electron Quantum Dots — •Olfa Dani[1], Johannes C. Bayer[1], Timo Wagner[1], Gertrud Zwicknagl[2], and Rolf J. Haug[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, Germany — [2]Institut für Mathematische Physik, Technische Universität Braunschweig, Germany

The Kondo effect is a many particle entangled system, that involves the interaction between a localized spin in the quantum dot and free electrons in the electron reservoirs. This entanglement can be calculated using simplifying assumptions concerning the electronic structure of the quantum dot.

In this work we investigate a quantum dot device formed electrostatically in a two-dimensional electron gas using top-gates. A quantum point contact is used as a sensitive charge detector to detect single-electrons tunneling through the system. This enables us to know the exact number of electrons in the quantum dot (Ne). By changing the applied gate voltage, we are able to control Ne.

A Zero-bias anomaly is observed for a strong coupling to the leads and possible symmetrical tunnel barriers. This Kondo resonance appears for successive Ne showing a deviation from the conjectured odd-even behavior. The Kondo resonance is strongest for Ne=9 and displays a particle-hole symmetry for Ne =7,..,11. It is absent for Ne =6 and Ne = 12. These observations indicate the influence of the shell structure [1] of the electronic states in the quantum dot where orbital degeneracy is present.

[1] L. P. Kouwenhoven, et. al., Rep. Prog. Phys. 64, 701-736 (2001).

TT 24.5 Tue 10:30 POT 151

Highly Conductive Silicon Nanowires by Modulation-Doping via Aluminum-Induced Acceptor States in an SiO2-shell — •Daniel Hiller[1], Ingmar Ratschinski[1], Soundarya Nagarajan[2], Jens Trommer[2], Thomas Mikolajick[2,3], and Dirk König[4] — [1]Institute of Applied Physics, TU Bergakademie Freiberg, Germany — [2]Nanoelectronic Materials Laboratory gGmbH, Dresden, Germany — [3]Institute of Semiconductors and Microsystems, TU Dresden, Germany — [4]Integrated Materials Design Lab, ANU, Canberra, Australia

Silicon nanowires (Si NWs) enable maximum gate control over the source-drain current when configured in a gate-all-around FET-architecture. However, Si NWs with few nm in diameter suffer from severe difficulties with efficient impurity doping due to a multitude of physical and technological problems (diffusion, dielectric and quantum confinement, statistics of small numbers, etc.). Here, we present a novel doping concept for Si NWs comparable to the modulation doping approach of III-V semiconductors. Based on results from density functional theory (DFT) calculations, we use Al-doped SiO_2 shells around the Si NWs, which contain unoccupied Al-induced acceptor states that are energetically located below the Si valence band edge. These states can capture electrons from the Si, creating free holes as majority charge carriers [1-5]. In this presentation, recent results from the experimental realization of this concept on Si NWs are shown. We demonstrate that modulation doping using SiO_2:Al-shells allows for several orders of magnitude lower resistances when compared to undoped SiO_2-shells.
[1] D. König et al., Sci. Rep. 7, 46703 (2017)

30 min. break

TT 24.6 Tue 11:15 POT 151

Carrier dynamics in quantum-dot tunnel- injection structures: microscopic theory and experiment — •Michael Lorke[1], Igor Khanonkin[2], Stephan Michael[1], Johann Peter Reithmaier[3], Gadi Eisenstein[2], and Frank Jahnke[1] — [1]Institute for Theoretical Physics, University of Bremen, Otto-Hahn-Allee 1, Bremen, 28359, Germany — [2]Electrical Engineering Department and Russel Berrie Nanotechnology Institute, Technion, Haifa, 32000, Israel — [3]Technische Physik, Institute of Nanostructure Technologies and Analytics, Center of Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Kassel, 34132, Germany

Among the challenges for the next generation of semiconductor lasers is the enhancement of their modulation speed to satisfy the need for higher data transfer rates. For this purpose, tunnel injection lasers are an appealing concept, as they promise improved modulation rates and better temperature stability. Moreover, they eliminate a major detri- mental effect of quantum dot lasers, which is the gain nonlinearity caused by hot carriers. It is shown in this work how the aforementioned improvements depend on the design of tunnel-injection devices. We perform a theory-experiment comparison on scattering times in tunnel injection devices to highlight the importance of alignment between the injector well and the quantum dot ensemble. It is shown how differences in the coupling to the injector quantum well caused by the alignment lead to scattering times into the quantum dot ensemble that vary by an order of magnitude.

TT 24.7 Tue 11:30 POT 151

Electron transport through a quantum dot in controlled heat bath environment — •Hatef Ghannadi maragheh, Johannes C. Bayer, and Rolf J. Haug — Institute for Solid State Physics, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany

For optimizing any device, amongst them semiconductor-based qubit, one has to understand the effects of the environment on them. In this sort of devices, not just quantum states of the channel but also the state of the particles is affected [1-3]. The device consists of split-gate quantum dot in a GaAs/AlGaAs heterostructure. The temperature of the measurement ranged from 49.9 mK to 800 mK.

There have been several works on explaining how electron transport through the quantum dot system would behave for different temperatures [4-5]. As the temperature changes, the Fermi distribution of the lead*s changes. This influenced the conductivity of the dot since in the presence of the bias voltage the transport window gets altered. Besides, depending on the presence of energy levels in the transfer window, the conductivity is manipulated by changing the temperature. For low temperatures, due to the local density of states and coupling of the barrier gates to the leads, fluctuations start to emerge.

[1]*K. C. Nowack et al, Science 318, 1430-1433 (2007)
[2]*Pioro-Ladrière, et al, Nature Physics 4, 776*779 (2008)
[3]*Jan K Kühne, et al, physica status solidi (b) 256(6) (2019)
[4]*E. B. Foxman, et al, Phys. Rev. B 47, 10020(R) (1993)
[5]*O. Dani, et al, Communications Physics 5 (1), 1-7 (2022)

TT 24.8 Tue 11:45 POT 151

Manipulation of temporal correlations in single-electron tunneling — •Johannes C. Bayer, Adrian Schmidt, Timo Wagner, and Rolf J. Haug — Institut für Festkörperphysik, Leibniz Universität Hannover

Precisely timed single-particle operations are of critical importance for quantum technologies operating at fixed clock cycles. A detailed understanding of the interplay between an external drive and the response of the single-particle source is essential for achieving and improving the accuracy in the time domain. We here demonstrate a high level of control over the time domain of a driven single electron transistor (SET). Using a gate defined quantum dot connected to a highly sensitive charge detector [1] allows detecting electrons tunneling into and out of the SET in real-time [2, 3]. The tunneling rates of such devices are controllable by gate voltages. We drive the SET by modulating gate voltages periodically in time and use time-dependent tunneling rates [2] and waiting time distributions [4] to analyze the impact of the driving parameters on temporal correlations in the tunneling times.

[1] J. C. Bayer, T. Wagner, E. P. Rugeramigabo and R. J. Haug, Ann. Phys. 531, 1800393 (2019)
[2] T. Wagner, P. Talkner, J. C. Bayer, E. P. Rugeramigabo, P. Hänggi and R. J. Haug, Nat. Phys. 15, 330-334 (2019)
[3] R. Hussein, S. Kohler, J. C. Bayer, T. Wagner and R. J. Haug, Phys. Rev. Lett. 125, 206801 (2020)
[4] F. Brange, A. Schmidt, J. C. Bayer, T.Wagner, C. Flindt and R. J. Haug, Sci. Adv. 7, eabe0793 (2021)

TT 24.9 Tue 12:00 POT 151

Scalable integrated readout electronics for semiconductor quantum dots — •Jonas Bühler[1], Arun Ashok[1], Lammert Duipmans[1], Patrick Vliex[1], Christian Grewing[1], André Zambanini[1], and Stefan Van Waasen[1,2] — [1]Central Institute of Engineering, Electronics and Analytics, Electronics Systems (ZEA-2) Forschungszentrum Jülich GmbH, 52428 Jülich, Germany — [2]Faculty of Engineering, Communication Systems, University Duisburg-Essen, 47057 Duisburg, Germany

Quantum computing is one of the promising candidates to overcome the limitations of *classical* computing, e.g. von Neumann architecture. Nowadays much progress has been made on the implementation of scalable qubits. This work focuses on semiconductor qubits, which need operating temperatures near 0 K. Room temperature electronics for control and readout, which are limiting the bandwidth and the scalability due to parasitic elements and heat conduction, are still widely used. Some progress has been made to integrate the qubit control and readout in the direct vicinity of the qubit at cryogenic temperatures. Especially readout electronics still have a limited scalability because of circuit size and power consumption. This work tries to overcome those limitations by comparing different readout architectures and implement a multiplexed and integrated readout circuit with lower area and power consumption. This integrated circuit in a 22nm FD-SOI technology will be placed on top of scalable quantum computing architectures and therefore might be a crucial step on the way to a multi-million qubit quantum computer.