TT 33: Nanotubes and Nanoribbons

Time: Tuesday 9:30–11:30 Location: H 0110

TT 33.1 Tue 9:30 H 0110

Excitons in MoS_2 nanoribbons: width and localization effects. — •Pino D'Amico[1], Deborah Prezzi[1], Andrea Ferretti[1], and Elisa Molinari[2,1] — [1]CNR-NANO-S3, Via Campi 213/a I-41125 Modena, Italy — [2]Physics, Computer Science and Mathematics Departement, University of Modena and Reggio Emilia, Via Campi 213/a I-41125 Modena, Italy

The formation of 1D wires of carriers at the edges of MoS_2 nanoribbons (NRs) represents a case study for spontaneous polarization effects. The spatial confinement and the charge accumulation at the edges make MoS_2-NRs a perfect candidate to investigate interaction effects at the nanoscale, also in view of possible applications in solar-energy devices [1,2]. While the electronic and optical properties of MoS_2 bulk monolayers have been the focus of an intense research, the investigation of MoS_2-NRs is at the early stages. We will present a first principle investigation of the electronic structure and optical absorption of MoS_2-NRs as a function of the NR width, as obtained within the framework of many-body perturbation theory, according to the G0W0 plus Bethe-Salpeter-Equation scheme. We will show that both width-dependent and width-independent mechanisms emerges in the formation of excitonic excitations, and we will explain the relationship between those two mechanisms and the edge-localization of the carriers. Since the investigated MoS_2-NRs are metallic, the present work deals with the fundamental issue of the presence of excitons in metals[3].

[1] M. Gibertini et al., Nat. Commun. 5, 5157(14).
[2] M.Gibertini and N. Marzari, Nano Lett. 15, 6229(15).
[3] F. Wang et al., PRL 99, 227401(07).

TT 33.2 Tue 9:45 H 0110

Doubled quasi-bound states in metallic zigzag carbon nanotubes: an *ab initio* perspective — •Kristjan Eimre[1], Gilles Buchs[2], Dario Bercioux[3,4], Carlo Pignedoli[1], and Daniele Passerone[1] — [1]Empa, Swiss Federal Laboratories for Materials Science and Technology, Switzerland — [2]Centre Suisse d'Electronique et de Microtechnique (CSEM) SA, Switzerland — [3]Donostia International Physics Center (DIPC), Spain — [4]IKERBASQUE, Basque Foundation of Science, Spain

The introduction of defects into single-walled carbon nanotubes (SWNTs) can induce electron confinement, enabling the implementation of new SWNT-based quantum devices, such as room temperature single-electron transistors [1].

By means of density funtional theory we compute the electronic structure of metallic zigzag SWNTs, 50 nm long, with defects. Scanning tunneling spectroscopy (STS) simulations are performed to obtain the local density directly comparable to STS experiments.

We show that a particular configuration of the defects produces a doubling of the quasi-bound states in the zigzag nanotube. Our predictions are supported by an experimental case where a partially suspended zigzag tube shows split quasi-bound states between defects induced by Ar^+ ions [2].

[1] Postma, H. W. C et al. *Science* 293, 76 (2001)
[2] Buchs, G. et al. *Phys. Rev. Lett.* 102, 245505 (2009)

TT 33.3 Tue 10:00 H 0110

Carbon nanotube transfer into complex devices with commercial quartz tuning forks — •Patrick Steger, Alexander Albang, Stefan Blien, and Andreas K. Hüttel — Institute for Experimental and Applied Physics, University of Regensburg, 93040, Regensburg, Germany

For experiments in the GHz regime we intend to couple suspended, clean carbon nanotubes (CNTs) to a superconducting coplanar waveguide (CPW) resonator. However, device fabrication is still challenging. Wet chemical processing as well as plasma etching can cause contamination and defects in the nanotubes while the conditions during CVD needed for nanotube growth can destroy superconducting on-chip circuitry.

To increase our fabrication yield we have developed a fork transfer method that allows us to separate the CVD process for CNT growth from the rest of the device fabrication. CNTs are grown between the tips of a commercial quartz tuning fork. In a subsequent step the tubes are transferred to the device containing dc electrodes as well as superconducting RF circuitry. Our transfer setup allows in situ precharacterization of the CNT during the transfer process. When a suitable CNT is found, the transfer process is completed by cutting the tube with current pulses at both ends.

We show first results of CNTs successfully transferred to a niobium CPW resonator device. Transport measurements at millikelvin temperatures show characteristics of a low number of high quality nanotubes and confirm the feasibility of transparent contacts.

TT 33.4 Tue 10:15 H 0110

Influence of defect-induced deformations on electron transport in carbon nanotubes — •Fabian Teichert[1,3,5], Christian Wagner[1,2], Alexander Croy[4], and Jörg Schuster[3,5] — [1]Institute of Physics, Technische Universität Chemnitz, Chemnitz, Germany — [2]Center for Microtechnologies (ZfM), Technische Universität Chemnitz, Chemnitz, Germany — [3]Dresden Center for Computational Materials Science (DCMS), Dresden, Germany — [4]Institute for Materials Science and Max Bergmann Center of Biomaterials, Technische Universität Dresden, Dresden, Germany — [5]Fraunhofer Institute for Electronic Nano Systems (ENAS), Chemnitz, Germany

We theoretically investigate the influence of defect-induced long-range deformations in carbon nanotubes on their electronic transport properties using a density-functional-based tight-binding (DFTB) model [1]. The geometry optimization leads to a strong reconstruction of the atoms close to the defect and an additional long-range deformation. The impact of both structural features on the conductance is systematically investigated for various tubes with vacancies.

We find that the long-range deformation additionally affects the transmission spectrum and the conductance compared to the short-range reconstruction. The conductance of larger CNTs is overall less affected implying that the influence of the long-range deformation decreases with increasing tube diameter. Our results indicate that the long-range deformation must be included in order to reliably describe the electronic structure of defective, small-diameter CNTs.

[1] F. Teichert et al., arXiv:1705.01753 [cond-mat.mes-hall]

TT 33.5 Tue 10:30 H 0110

Renormalization group study of competing low-temperature phases in single-wall carbon nanotubes — Wen-Min Huang[1], •Junichi Okamoto[2,3], and Ludwig Mathey[2,3] — [1]Department of Physics, National Chung-Hsing University, Taichung 40227, Taiwan — [2]Zentrum für Optische Quantentechnologien and Institut für Laserphysik, Universität Hamburg, 22761 Hamburg, Germany — [3]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany

Carbon nanotubes (CNs) are intriguing one-dimensional systems where various electronic states emerge from their microscopic details. Examples are superconducting states in CNs embedded in a zeolite matrix [1], Mott insulating states in ultraclean CNs [2], and Wigner crystals in semiconducting CNs [3]. Here, we theoretically investigate the low-temperature phase diagrams of single-wall CNs by a renormalization group method. Important ingredients are: (i) electron-phonon interactions that may induce superconductivity or Peierls distortion and (ii) electronic correlations that may cause Mott insulating states. We discuss some preliminary consequences of the competition among these phases.

[1] Z. K. Tang et al., Science 292, 2462 (2001)
[2] V. V. Deshpande et al., Science 323, 106 (2009)
[3] V. V. Deshpande and M. Bockrath, Nat. Phys. 4, 314 (2008)

TT 33.6 Tue 10:45 H 0110

Dark states in a carbon nanotube quantum dot - theory — Michael Niklas[1], Michael Schafberger[2], •Andrea Donarini[1], Nicola Paradiso[2], Christoph Strunk[2], and Milena Grifoni[1] — [1]Institute of Theoretical Physics, University of Regensburg, 93053 Regensburg, Germany — [2]Institute of Experimental and Applied Physics, University of Regensburg, 93053 Regensburg, Germany

The dark states are the key to interpret the transport characteristics of a class of single electron transistors based on carbon nanotubes (CNT) quantum dots. The emergence of the dark states relies on the (quasi) valley degeneracy of the CNT and on the particular coupling to the metallic leads. The difference between the tunneling phases to the two electrodes is the most relevant parameter of the theory. Besides characterizing the dark states, this phase difference determines also the precession dynamics of the pseudospin associated to the orbital degeneracy. This theory predicts current suppression with a specific gate and bias dependence which accurately matches the experimental results.

TT 33.7 Tue 11:00 H 0110

Dark states in a carbon nanotube quantum dot - experiment — Michael Niklas[1], Michael Schafberger[2], Andrea Donarini[1], •Nicola Paradiso[2], Christoph Strunk[2], and Milena Grifoni[1] — [1]Institute of Theoretical Physics, University of Regensburg, 93053 Regensburg, Germany — [2]Institute of Experimental and Applied Physics, University of Regensburg, 93053 Regensburg, Germany

Illumination of three level atoms (λ-systems) by detuned lasers can pump electrons into a coherent superposition of hyperfine-split levels which can no longer absorb light. Because fluorescent light emission is then suppressed, the coherent superposition is known as a *dark state*. We report an all-electric analogue of this destructive interference effect in a carbon nanotube quantum dot. A dark state is in this case a coherent superposition of states with opposite angular momentum which is fully decoupled from either the drain or the source leads. The emergence of dark states impacts the current-voltage characteristics, where missing current steps are observed depending on the sign of the applied source-drain bias. Our results demonstrate for the first time coherent-population trapping by all-electric means in an artificial atom.

TT 33.8 Tue 11:15 H 0110

Coupling a terahertz cavity to a carbon nanotube quantum dot — •F. Valmorra[1,2], K. Yoshida[3], L. Contamin[1], T. Cubaynes[1], M. Dartiailh[1], M. Desjardins[1], S. Massabeau[1], K. Hirakawa[3], J. Mangeney[1], A. Cottet[1], and T. Kontos[1] — [1]Laboratoire Pierre Aigrain, CNRS UMR 8551, ENS, 24 rue Lhomond, 75005 Paris, France — [2]Early-Postdoc Fellow of the Swiss National Science Foundation — [3]Institute of Industrial Science, University of Tokyo, 4-6-1 Komaba, Meguro-ku, Tokyo 153-8505, Japan

One of the most interesting aspects of science is the fundamental, coherent interaction of light and matter, down to the quantum level of countable photons and single electronic transitions. Such kind of investigations gave birth to the field of cavity-Quantum ElectroDynamics and later to circuit-QED. Mesoscopic QED uses quantum dots as the matter part, aiming at the realisation of spin-qubits and at the investigation of fundamental physical phenomena. While these investigations have focussed on the microwave range, it comes natural to extend them to the THz, where the energies of the quantum dots realised in a carbon nanotube lie. We thus couple the QD to a THz-split-ring resonator: the transport characterisation of the device shows a region of suppressed conductance, close to zero bias, as large as the photon energy. This gap is reminiscent of the Franck-Condon blockade effect transposed to photons. Such system paves the way towards more complex condensed matter studies and the demonstration of strong coupling pushing forward optoelectronics and quantum optics in the THz frequency range.