HL 115: Symposium SYOM: One-dimensional metals - Reality or fiction?

Time: Friday 9:30–12:30 Location: HSZ 02

Invited Talk HL 115.1 Fri 9:30 HSZ 02

Atomic-scale dopant wires for quantum computer architectures — •Michelle Y Simmons — Centre of Excellence for Quantum Computation and Communication Technology, University of New South Wales, Sydney, NSW 2052, Australia

Down-scaling has been the leading paradigm of the semiconductor industry since the invention of the first transistor in 1947. As silicon electronics approaches the atomic scale, interconnects and circuitry become comparable in size to the active device components. Maintaining low electrical resistivity at this scale is challenging because of the presence of confining surfaces and interfaces. We report on the fabrication of wires in silicon-only one atom tall and four atoms wide-with exceptionally low resistivity ˜ 0.3 milliohm-centimeters. By embedding phosphorus atoms within a silicon crystal with an average spacing of less than 1 nanometer we achieved a diameter-independent resistivity [1]. Atomistic tight-binding calculations confirm the low resistivity of these atomic-scale wires [2], which pave the way for single-atom device architectures for both classical and quantum information processing. I will demonstrate how we have incorporated these wires into single atom transistors [3] and performed single-shot spin read-out of precisely-positioned P donor electron spins as potential qubits in Si [4].

[1] B. Weber et al., Science 335, 6064 (2012). [2] H. Ryu et al., Nanoscale 5, 8666 (2013). [3] M. Fuechsle et al., Nature Nanotechnology 7, 242 (2012). [4] H. Buch et al., Nature Communications 4, 2017 (2011).

Invited Talk HL 115.2 Fri 10:10 HSZ 02

$1 + \delta$: Tuning the Dimensionality of Organic Conductors — •Martin Dressel — 1. Physikalisches Institut, Universität Stuttgart

Organic charge-transfer salts are prime candidates for tuning the dimension by applying pressure. Strictly one-dimensional systems, such as the Fabre salts $(TMTTF)_2X$, are Mott insulators that undergo a deconfinement transition towards a Luttinger liquid and eventually a two-dimensional Fermi liquid if the interchain interaction increases with pressure. The deconfinement transition can be identified when the transverse hopping integral $2t_\perp = \Delta_\rho$, the Mott gap. Ab-initio density functional theory allows us to study the influence of temperature and pressure on the electronic band structure.

Quasi-one-dimensional organic conductors, like the Bechgaard salts $(TMTSF)_2X$, exhibit a cross-over from a Luttinger liquid to a Fermi liquid behavior upon cooling and application of external pressure. Frequency and temperature dependent transport measurement yield a change in power-laws and Luttinger exponent.

Often the metallic phase is not stable in reduced dimensions: at low temperatures the electronic charges and spins tend to arrange themselves in an orderly fashion due to relatively strong correlations. There are a growing number of molecular materials where electronic degrees of freedom and electronic interactions are directly responsible for electric polarization and ferroelectric transition, termed electronic ferroelectricity. Recently, it was discovered that charge order not only produces ferroelectricity but also breaks the symmetry of the magnetic degree of freedom in organic quantum spin chains.

Coffee break (20 min)

Invited Talk HL 115.3 Fri 11:10 HSZ 02

Spectral and transport properties of one-dimensional correlated electrons — •Volker Meden — Institut für Theorie der Statistischen Physik, RWTH Aachen University

Two-particle interactions strongly alter the low-energy physics of electrons confined to one spatial dimension. Excitations cannot be described by fermionic quasi-particles. Metallic systems of this type fall into the Luttinger liquid universality class and are characterized by power-law decay of correlation functions. I will give an overview over the one-particle spectral and transport properties of such systems including a discussion of the model dependent low-energy scale beyond which Luttinger liquid power laws are observable. Leaving the framework of equilibrium physics I will report on recent progress in understanding the non-equilibrium steady state as well as relaxation dynamics of isolated and contacted quantum wires.

Invited Talk HL 115.4 Fri 11:50 HSZ 02

Atomic nanowires on surfaces: Spectroscopic reality versus theoretical fiction — •Ralph Claessen — Physikalisches Institut and Röntgen Center for Complex Material Systems (RCCM), Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

Solids with electrons confined to only one spatial dimension are predicted to behave quite different from conventional metals. Many-body theory finds that electronic interactions may lead to Peierls-type instabilities or even a breakdown of Landau's quasiparticle picture, which works so well in higher dimensions. Atomic nanowires formed by self-organized growth of metal atoms on suitable semiconductor surfaces can be viewed as closest approach to perfect 1D electron confinement, and therefore serve well as model systems for experimental tests of the expected 1D physics. In my presentation I will discuss current experiments on atomic nanowires, using photoelectron spectroscopy and scanning tunneling microscopy as experimental probes, and compare the results to corresponding theoretical predictions. Examples include the observation of Tomonaga-Luttinger behavior as well as the possible detection of (quasi-)1D antiferromagnetic order.