O 96: Focus Session: Surface Transport at the Atomic Scale

The ability to probe electronic transport on nano- and even atomic scaled structures opened a new field. Besides break junction techniques for realizing 2-terminal transport setups, recently, also multiprobe technique based on scanning tunneling microcopy (STM) allowed to go beyond and demonstrated its capability to reveal fundamental charge transport properties. This Focus Session will give an brief overview over the progress made on various topics with surface transport, ranging from functionalized semiconductor surfaces, 2D materials, topological insulators, helical molecules down to atomic wires.

Organizers: Christoph Tegenkamp (TU Chemnitz) and Bert Voigtländer (FZ Jülich).

Time: Friday 10:30–13:00 Location: H15

Invited Talk O 96.1 Fri 10:30 H15

Electrical transport in semiconductor nanocrystal assemblies and nanocrystal heterostructures — •Bruno Grandidier — IEMN-CNRS, Dept. ISEN Physics, 41 bd Vauban, 59000 Lille, France

Structures consisting of semiconductor nanocrystals are solution-processable materials that are prized for the low-cost and scalability of their fabrication method and their compatibility with flexible, thin-film electronics. Their transport properties are governed by the interfaces between the nanocrystals themselves or the nanocrystals and the supporting semiconductor substrates. Here we will investigate both types of interfaces. We will show how the direct attachment of nanocrystals via chemical bonds between atoms instead of linkage via carbon-based molecules significantly improves the conductivity of two-dimensional nanocrystal arrays. In these systems, charges are coherently delocalized along nanometer-scale segments of nanocrystals ensuring a high THz mobility, while the DC mobility is limited by the absence of long-range order in the arrays. As to solution-based nanocrystal-semiconductor heterostructures, we will show how an initial wet chemical passivation step before the epitaxial growth of the nanocrystals on semiconductor substrates is key not only to produce an atomically sharp crystalline interface, but also to form trap-free interfaces with quality comparable to that grown by molecular beam epitaxy.

O 96.2 Fri 11:00 H15

Space-charge layer effects studies by surface transport — •Frederik Edler[1,2], Ilio Miccoli[2], Herbert Pfnür[2], and Christoph Tegenkamp[1,2] — [1]Institut für Festkörperphysik, Technische Universität Chemnitz, 09126 Chemnitz — [2]Institut für Festkörperphysik, Leibniz Universität Hannover, 30167 Hannover

Electronic properties of low dimensional structures on surfaces can be comprehensively explored by surface transport experiments, e.g., giving a direct access to instability-driven metal insulator transitions. However, the surface sensitivity of this technique to atomic structures comes along with the control of bulk related electron paths and internal interfaces. We analyzed the role of Schottky-barriers and space charge layers for Si-surfaces. By means of a metal submonolayer coverage deposited on vicinal Si(111), we reliably accessed subsurface transport channels via angle- and temperature-dependent in-situ transport measurements. In particular, we show that high temperature treatments performed under even ultra high vacuum conditions lead to the formation of surface-near bulk defects, e.g. SiC interstitials. These defects act as p-type dopants and easily overcompensate pristine low dopant concentrations in Si. This effect is of high significance in low-doped Si samples.

O 96.3 Fri 11:15 H15

In-situ four-tip STM investigation of the transition from 2D to 3D charge transport in SrTiO3 — •Arthur Leis[1,2], Christian Rodenbücher[1,2], Krzysztof Szot[1,2], Vasily Cherepanov[1,2], F. Stefan Tautz[1,2], and Bert Voigtländer[1,2] — [1]Peter Grünberg Institut (PGI-3, PGI-7), Forschungszentrum Jülich, Germany — [2]Jülich Aachen Research Alliance (JARA), Fundamentals of Future Information Technology, Germany

The electrical properties of SrTiO3(100) single crystals were investigated in-situ at different stages of thermal reduction by means of a 4-tip STM. Using the tips of the STM as electrical probes, distance-dependent four-point measurements were performed at the surface of the crystal at room temperature after reduction by thermal treatment. For annealing temperatures T $<$ 700°C, charge transport is confined to a surface region $<$ 3mm below the surface. For reduction at T $>$ 900°C a transition from a conducting 2D sheet with insulating bulk to a system with dominant 3D bulk conductivity is found. At an intermediate reduction temperature of T = 800°C, a regime with mixed 2D/3D contributions is observed in the distance-dependent resistance measurements. Describing the depth dependent conductivity with an analytical N-layer model, this regime of mixed 2D/3D conductivity is evaluated quantitatively under the assumption of an exponentially decaying conductivity profile, correlated with the previously observed depth dependent dislocation density in the sample. A non-monotonous temperature dependence of the 3D conductivity in the respective conducting layer is found and the underlying mechanism is discussed.

O 96.4 Fri 11:30 H15

Length dependent electrical transport trough single polyalanine molecules — •Diana Slawig[1], Nguyen Thi Ngoc Ha[2], Herbert Pfnür[1], and Christoph Tegenkamp[1,2] — [1]Leibniz Universität Hannover — [2]TU Chemnitz

A new promising and effective approach for spintronics has emerged using spin selectivity in electron transport through chiral molecules, named Chiral Induced Spin Selectivity (CISS)[1]. Recently, by utilizing this effect a proof of concept for a new type of chiral-based Si-compatible universal magnetic memory device was demonstrated[2]. Nevertheless, the electrical transport through helical peptides itself is not completely understood yet. Our study focuses on transport through single polyalanine (PA) molecules by means of mechanically controlled break junctions.

Transport measurements for PA molecules consisting of 16- and 36 monomers revealed two characteristic conductions values accompanied by satellite peaks. The length dependence of the conductance revealed an exponential decay pointing towards tunneling. Moreover, this lengths distribution see in transport correlates nicely with STM investigations showing also PA molecules of various lengths. The conductance through these molecules is comparably high and indicates that superexchange tunnelling may play a role.

[1]R. Naaman et.al., ,J. Phys. Chem. Lett., 3 (2012)
[2]O. Ben Dor et.al.Nat. Commun. 4:2256 (2013)

Invited Talk O 96.5 Fri 11:45 H15

Multiprobe STM measurements of electron transport at the atomic level — •Marek Kolmer, Wonhee Ko, and An-Ping Li — Center for Nanophase Materials Sciences, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA

Techniques based on multiprobe scanning tunneling microscopy (MP-STM) allow determination of electronic and spin transport in variety of systems supported on surfaces of solid materials. These MP-STM methods are currently considered as universal tools for in-situ characterization of mesoscopic transport phenomena in scales down to hundreds of nanometers. Alternatively, application of scanning tunneling potentiometry visualizes potential change during such mesoscopic charge current transport with a nominal nm resolution.

Here, we would like to discuss our efforts towards changing of this mesoscopic experimental paradigm by downscaling MP-STM experiments to the atomic level. In this case charge or spin current supplying probes are positioned in atomically defined locations with respect to the characterized nanosystem. Our experiments rely on fully STM-based tip positioning protocol with probe-to-probe separation distances reaching tens of nm. This is combined with about 5 pm vertical sensitivity in probe-to-system contact definitions. Those two factors enable realization of multiprobe scanning tunneling spectroscopy experiments, where transport properties could be characterized by macroscopic probes kept in well-defined tunneling conditions.

This research was conducted at the Center for Nanophase Materials Sciences, which is a DOE Office of Science User Facility.

O 96.6 Fri 12:15 H15

Parallel conduction channels in topological insulator thin films: Role of the interface layer and the band bending in the film — •Sven Just[2,3], Felix Lüpke[4], Stefan Korte[1], Vasily Cherepanov[1], Frank Stefan Tautz[1], and Bert Voigtländer[1] — [1]Peter Grünberg Institute (PGI-3) and JARA-FIT, Forschungszentrum Jülich, Germany — [2]II. Physikalisches Institut B, RWTH Aachen, Germany — [3]Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden, Germany — [4]Departement of Physics, Carnegie Mellon University, Pittsburgh, PA 15213, USA

Topological insulator (TI) thin films can exhibit multiple parallel channels for current transport: beside the topological surface states (TSS), e.g. the interior of the TI film, the interface layer and the substrate. A crucial task is to minimize the influence of the parasitic channels for taking advantage of the TSS properties. We present a method for determining the conductivity of the interface between substrate and TI film by distance-dependent surface-sensitive four-probe measurements with a multi-tip STM. Moreover, as the conductivity of the interior of the TI thin film (bulk) is difficult to access by measurements, we propose here an approach for calculating the near-surface band bending and the mobile charge carrier density inside the TI thin film based on data from surface-sensitive measurements, e.g. (gate-dependent) four-point resistance measurements and ARPES. It turns out that in the thin-film limit the band-bending is largely independent on the dopant concentration of the film, which allows to estimate the total mobile charge carrier density and the conductivity of the TI thin film.

O 96.7 Fri 12:30 H15

In-situ disentangling surface state transport channels of a topological insulator thin film by gating — •Bert Voigtländer, Felix Lüpke, Sven Just, Vasily Cherepanov, and F. Stefan Tautz — Peter Grünberg Institut (PGI-3) and JARA-FIT, Forschungszentrum Jülich, 52425 Jülich, Germany

In the thin film limit, the surface state of a three-dimensional topological insulator gives rise to two parallel conduction channels at the top and bottom surface of the film, which are difficult to disentangle in transport experiments. Here, we present gate-dependent multi-tip scanning tunneling microscope transport measurements combined with photoemission experiments all performed in-situ on pristine BiSbTe3 thin films. To analyze the data, we develop a generic transport model including quantum capacitance effects. This approach allows us to quantify the gate-dependent conductivities, charge carrier concentrations, and mobilities for all relevant transport channels of three-dimensional topological insulator thin films (i.e., the two topological surface state channels, as well as the interior of the film). For the present sample, we find that the conductivity in the bottom surface state channel is minimized below a gate voltage of V = *34 V and the top surface state channel dominates the transport through the film.

O 96.8 Fri 12:45 H15

Exploring the unjamming of electrons with a multi-probe STM — •Yaroslav Gerasimenko[1,2], Michele Diego[2], Jan Ravnik[2], and Dragan Mihailovic[1,2] — [1]CENN Nanocenter, Jamova 39, 1000, Ljubljana, Slovenia — [2]Department of Complex Matter, Jozef Stefan Institute, Jamova 39, 1000, Ljubljana, Slovenia

The combination of a multi-probe STM and an in situ ultrafast excitation allows us to explore novel states of matter that can emerge from many-body interactions under highly non-equilibrium conditions. Here we show that a single femtosecond-scale optical pulse, applied to the prototypical transition metal dichalcogenide 1T-TaS_2, can convert a perfect hexagonal charge order into an exotic metastable amorphous jammed state of strongly correlated electrons [1].

Tunnelling spectra and four-probe surface transport measurements reveal a remarkable duality of localized and itinerant charges in this state. While the latter are predominantly responsible for hopping conductivity, the potential landscape is provided by the former ones. As the jammed state starts to relax at higher temperatures, consecutive STM images reveal the onset of the diffusion of the previously localised charges. By matching it with the multi-probe resistivity measurements, we identify a highly unusual dynamical regime in the surface transport.

[1] Ya. A. Gerasimenko, I. Vaskivskyi, J. Ravnik, J. Vodeb, V. Kabanov, D. Mihailovic, Quantum jamming transition to a correlated electron glass in 1T-TaS_2, arXiv:1803.00255 (2018)