O 32: Focus Session: Charge Transport at Surfaces and Nanostructures with Multi-probe Techniques I

Complex nanostructures on surfaces, e.g graphene nanoribbons, nanorods, atomic wires, or molecules in between junctions, provide a perfect platform to study both fundamental and application driven aspects. Many properties such as a targeted functionality of the nanostructure, instabilities, phase changes, etc. can be addressed and smartly probed by electron transport. 4-tip scanning probe techniques became very popular within the last years and have demonstrated their capability to address important physical and chemical aspects. Compared to conventional, i.e lithographically driven concepts, the 4-tip STM technique can directly contact delicate nanostructures with uttermost precision and variable contact spacings and geometries. Together with the STM, STS, and potentiometry capabilities, an almost complete set of information with respect to the atomic structure, electronic states, and conductivity can be gathered in-situ without the need of elaborative transfers.

Time: Tuesday 10:30–13:00 Location: WIL C307

Invited Talk O 32.1 Tue 10:30 WIL C307

Electrical detection of spin-polarized transport on topological insulator via four-probe spectroscopy — •An-Ping Li[1], Saban Hus[1], Corentin Durand[1], Xiaoguang Zhang[1,2], Giang Nguyen[1], and Yong Chen[3] — [1]Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA — [2]University of Florida, Gainesville, FL 32611, USA — [3]Purdue University, West Lafayette, IN 47907, USA

The electrical detection of spin-momentum-locking of topological surface states remains an experimental challenge. The difficulty is twofold. First, there is a lack of a convenient spin-dependent probing technique to measure the spin current. Second, it is hard to separate 2D surface conductivity from often unavoidable and more dominating 3D bulk contributions in transport experiments. Here we present a new method for detection of spin polarized currents in topological insulator, by using a spin-polarized four-probe spectroscopy on the in-situ cleaved Bi2Te2Se surfaces. The variable probe spacing measurements separate the surface 2D and bulk 3D conductions quantitatively, capable of distinguishing the vanishing Ohmic and non-dissipative spin-dependent electrochemical potentials. This method provides an alternative to the transport spectroscopy with lithographically defined contacts and enables us to access the intrinsic spin transport associated with pristine topological surface states. [1] A-P Li et al., Adv. Funct. Mater. 23 (2013), p. 2509. [2] C Durand et al., Nano Lett., 16 (2016), p. 2213. [3] S. Hus et al, to be submitted.

O 32.2 Tue 11:00 WIL C307

Multi-tip STM analysis of freestanding GaAs-NWs in dependence on surface conditioning — •Andreas Nägelein, Matthias Steidl, Peter Kleinschmidt, and Thomas Hannappel — Photovoltaics Group, Institute of Physics, Technische Universität

Nanostructures e.g. III-V nanowires (NW) are promising candidates for optoelectronic applications. The investigated NWs obtain different doping structures and were grown by MOCVD using the VLS (vapor liquid solid) growth mode. In order to investigate these freestanding nanowires electrically, a multi-tip STM (MT-STM) was used. Here, four-point probe measurements are performed non-destructively by contacting three tips at the nanowire and using the substrate as fourth contact. Besides the investigation of doping profiles, a comparison between nanowires prior to, and after, oxidation was carried out. Therefore, after transferring the NW-samples to the MT-STM in UHV, electrical characterization was performed. Subsequently, the samples were stored at ambient atmosphere and resistance profiles were recorded again. The resistance slope in the intrinsic part of the NW increased drastically with oxidation. In contrast to doped NW-parts where the charge carrier transport mainly happens in the center of a NW, a conductive channel does not exist for intrinsic NWs. Besides contamination-induced band bending, the conductivity is also affected by the surface states themselves. Hence, we consider a changed surface conductivity of the intrinsic nanowire segment as a likely explanation of its increased resistance after exposure to ambient atmosphere.

O 32.3 Tue 11:15 WIL C307

Electrical resistance of individual defects at a topological insulator surface — •Felix Lüpke, Markus Eschbach, Tristan Heider, Martin Lanius, Peter Schüffelgen, Daniel Rosenbach, Nils von den Driesch, Vasily Cherepanov, Gregor Mussler, Lukasz Plucinski, Detlev Grützmacher, Claus M. Schneider, and Bert Voigtländer — Peter Grünberg Institute and JARA-FIT, Forschungszentrum Jülich GmbH, D-52425 Jülich, Germany

We determine the resistance of different kinds of defects at the surface of a $(Bi_{0.53}Sb_{0.47})_2Te_3$ topological insulator thin film by scanning tunneling potentiometry. The largest localized voltage drop we find to be located at domain boundaries in the topological insulator film, with a resistivity about four times higher than that of a step edge. Furthermore, we resolve resistivity dipoles located around voids in the sample surface. The influence of such defects with a typical diameter of 5 nm on the resistance of the topological insulator is analyzed by means of a resistor network model. Here, we show that local changes in the conductivity, e.g. due to the voids in the surface, give rise to a persistent voltage drop across the sample far away from the actual position of the defect.

O 32.4 Tue 11:30 WIL C307

In-situ electro-migration studies on silver(Ag) contacts for nanogap fabrication — •Atasi Chatterjee[1], Ejvind Olsen[1], Frederik Edler[1], Torsten Heidenblut[2], Christoph Tegenkamp[1], and Herbert Pfnür[1] — [1]Leibniz Universität Hannover,Institut für Festkörperphysik, 30167, Hannover, Germany — [2]Leibniz Universität Hannover, Institut für Werkstoffkunde, 30823, Hannover,Germany

With the aim to create nanometer-spaced silver(Ag) electrodes as testbeds for molecular electronic studies, the process of electro-migration is adopted amongst the different methods available for fabricating atomic contacts. With the help of a 4-tip SEM/STM setup, the lithographically patterned silver (Ag) structures are probed efficiently with an in-situ monitoring of the electro-migration process using the SEM and STM. The step-by-step morphological changes are observed close to the atomic scale, which is an important pre-requisite for the understanding of the phenomena at nanoscale. Temperature dependent and geometry dependent measurements are performed to separate thermal diffusion from electro-migration. All measurements are done using a feedback controlled lab-view program. The well-defined conductance plateaus obtained as a function of time are the characteristic to atomic scale gaps. Tunneling characteristics were analyzed using I-V curves in Fowler-Nordheim representation. In order to better locate these gaps, a focused ion beam (FIB) is used to reduce the cross-section of these wires. With the reduced cross-section, we characterize the gaps of nearly atomic size with an STM and SEM.

Invited Talk O 32.5 Tue 11:45 WIL C307

Probing electron transport with atomic scale precision — •Christian A. Bobisch — Faculty of Physics, Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, 47057 Duisburg, Germany

To track down the elementary contributions to macroscopic properties such as the electric resistance, nanoscale electron transport measurements are essential. I will discuss that this can be achieved by combining scanning tunneling microscopy (STM) with transport measurements. We use a four probe STM to perform scanning tunneling potentiometry (STP)[1] which gives direct access to the topography and the lateral variations of the electrochemical surface potential μ_{ec} under realistic conditions, i.e. while a lateral current flows along the surface. Thereby, we analyze the spatial variations of μ_{ec} with nm lateral resolution. In particular, we study the interaction of conduction electrons with defect sites, e.g., atomic step edges or grain boundaries.

The two dimensional electron gas system of Si(111)-$\sqrt{3}\times\sqrt{3}$:Ag is a model 2D system, where scattering at step edges and grain boundaries is identified as major contribution to the resistance [2]. Also at the surface of the topological insulator Bi_2Se_3 [3] we find step-like variations of μ_{ec} in the vicinity of defects which is a fingerprint of electron scattering [4]. Here, we evaluate the electric resistivities of individual step edges and grain boundaries.

[1] Appl. Phys. Lett. 48, 514 (1986). [2] Nano Letters 9, 1588 (2009). [3] Rev. Mod. Phys. 82, 3045 (2010). [4] Nature Comm. 7, 11381 (2016).

O 32.6 Tue 12:15 WIL C307

Oxygen adsorption induced tuning of transport in atomic gold chains on vicinal silicion — •Frederik Edler[1], Ilio Miccoli[1], Jan P. Stöckmann[1], Herbert Pfnür[1], Christian Braun[2], Simone Sanna[2], Wolf G. Schmidt[2], and Christoph Tegenkamp[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, 30167 Hannover — [2]Lehrstuhl für Theoretische Physik, Universität Paderborn, 33098 Paderborn

Adsorption of Au submonolayer on Si(hhk) surfaces results in growth of long-range ordered quasi one dimensional 1D metallic quantum wires. We present a systematic study on the transport properties of these self-assembled chains of gold atoms on vicinal Si(553) and Si(557) surfaces via a multi-tip STM/SEM system in combination with SPALEED. The transport characteristics of these Au/Si(hhk) systems, i.e. conductivity values along and perpendicular to the chains were carefully analyzed during in-situ adsorption of molecular oxygen. In combination with recent DFT calculations, we discuss the transport in terms of the different structural building blocks (Au chains, Si-adatom chain, Si edge) found for the Au/Si(hhk) systems. It will be shown, that the origin for the metallic surface bands along the wires are of different origin. Therefore, while the Si(553)-Au surface turns out to be rather immune against oxidation, the Si(557)-Au surface reveals a strong decrease of the conductance due to complete destruction of the Si-adatom ordering along the chains.

O 32.7 Tue 12:30 WIL C307

Interface Conductivity of Tellurium on Si(111) Investigated by in situ Charge Transport Measurements with a Multi-Tip STM — Felix Lüpke[1], •Sven Just[1], Martin Lanius[1], Gustav Bihlmayer[1], Jiri Dolezal[2], Martina Luysberg[1], Elmar Neumann[1], Vasily Cherepanov[1], Ivan Ostadal[2], Gregor Mussler[1], Detlev Grützmacher[1], and Bert Voigtländer[1] — [1]Peter Grünberg Institut (PGI) and JARA-FIT, Forschungszentrum Jülich — [2]Departement of Surface and Plasma Science, Faculty of Mathematics and Physics, Charles University Prague, Czech Republic

A combined experimental and theoretical analysis of the structural and electrical transport properties of a Tellurium layer on Si(111) is presented. The Te forms a Te/Si(111)-(1×1) reconstruction saturating the substrate bonds and forming the template for van der Waals epitaxy, e.g. for the topological insulator Bi_2Te_3 based thin fim growth on Si(111). As DFT calculations propose a high carrier concentration in the Te layer, the interface layer might be highly conductive limiting the applicability of the on-top grown film. For determining the conductivity of the Te interface layer on differently reconstructed Si surfaces directly, in situ distance-dependent four-probe resistance measurements with a multi-tip STM are carried out. In a second part, further four-probe measurements on different material systems are presented, e.g. on semiconductors combined with an N-layer model for describing multiple interface layers arising from an approximation of the space-charge region, and on the weak topological insulator $Bi_{14}Rh_3I_9$ proposed to have one-dimensional edge-channels on the surface.

O 32.8 Tue 12:45 WIL C307

Separating 2D and 3D resistivities using a modified 4-probe method — Snorre Kjeldby, Simon Cooil, and •Justin Wells — Norwegian University of Science and Technology (NTNU), Trondheim, Norway.

4-probe electrical measurements have been in existence for many decades. One of most useful aspects of the 4-probe method is that it is not only possible to find the resistivity of a sample (independently of the contact resistances), but that it is also possible to probe the dimensionality of the sample. In theory, this is straightforward to achieve; by measuring the 4-probe resistance as a function of probe separation. In practice, it is challenging to move all four probes reliable and with sufficient precision over the necessary range. The available instrumentation (usually based on 4 independently driven STM tips) is complex, expensive and often unreliable.

Here, we present an alternative approach. Combining analytical and numerical modelling with scaled experiments, we demonstrate that the dimensionality of the sample resistivity can be directly probed using a modified 4-probe method in which 3 of the probes are kept stationary, and the position of only one probe is changed. This allows 2D and 3D contributions the to resistivity to be easily deconvolved. The required experimental instrumentation is vastly simplified relative to traditional variable spacing 4-probe instruments.