O 5: Topological Insulators: Mostly Structure and Electronic Structure (HL jointly with MA, O, TT)

Time: Monday 9:30–12:30 Location: POT 051

O 5.1 Mon 9:30 POT 051

InAs/GaSb compound quantum wells for electrically tunable topological insulator devices — •Georg Knebl[1], Matthias Dallner[1], Robert Weih[1], Sven Höfling[1,2], and Martin Kamp[1] — [1]Universität Würzburg, Deutschland — [2]University of St Andrews, Scotland

InAs/GaSb compound quantum wells (CQW) sandwiched between two AlSb layers and a front/back gate were proposed by Liu et al. [1] to show a topological insulator phase. The advantage of this structure is the possibility to tune the phase transition from a normal to a topological insulator via the front and back gate voltage. In addition, this material combination allows the use of established III/V semiconductor technology for epitaxy and device processing.

We present results on the growth of InAs/GaSb CQWs via molecular beam epitaxy on GaSb and GaAs substrates using different buffers. Furthermore, we will discuss device fabrication on InAs/GaSb layer structures, which requires special care since oxidation or process induced damage can lead to the formation of conducting surface channels. Electrical characterization of Hall bars and the tunability of the transport properties via gates will be reported.

[1] C. Liu, et al., Phys. Rev. Lett. 100, pp. 1-4, (2008)

O 5.2 Mon 9:45 POT 051

Resolving the linear dispersion relation of topological insulator nanowires — •Johannes Gooth, Bacel Hamdou, August Dorn, Robert Zierold, and Kornelius Nielsch — Institute of Applied Physics, Universität Hamburg, Hamburg, Germany

Due to the linear dispersion relation, charge carriers in the surface states of a topological insulator (TI) behave like relativistic particles described by the Dirac equation for spin-1/2 particles leading to exotic new physics and applications. In bulk topological insulators the linear dispersion relation at the surface has been resolved by angle-resolved photoemission spectroscopy (ARPES). On nanostructures ARPES measurements have not been successful, due to the limited sample size. Instead magnetoelectrical transport measurements became the most common way to indicate the existance of surface states in nanomaterials. However, the linear dispersion relation has not been directly resolved in nanostructures to date.

Here, we show that the linear dispersion relation on the surface of a Bi_2Te_3 nanowire can directly be deduced from gate dependend magnetototransport measurements. Further carrier concentration, mobility and effective mass of the dirac fermions are determined as a function of gate voltage. It can be shown that at 2K the transport in the surface states is dominated by electron-electron interaction.

O 5.3 Mon 10:00 POT 051

Temperature-dependent surface band gap of Dirac fermions observed at the (111) surface of the crystalline topological insulator Pb-Sn-Se — •Partha S. Mandal[1], Gunther Springholz[2], Günther Bauer[2], Valentine V. Volobuev[2], Andrei Varykhalov[1], Oliver Rader[1], and Jaime Sánchez-Barriga[1] — [1]Helmholtz-Zentrum Berlin — [2]Johannes-Kepler-Universität Linz

Using angle-resolved photoemission, we studied (111)-oriented epitaxial films of Pb-Sn-Se grown by molecular beam epitaxy. The topological-to-trivial-insulator phase transition [1] is monitored probing the bulk valence band as a function of Sn concentration and temperature between 30 K and room temperature. In the topological phase, the topological surface state opens a band gap indicating a mass aquisition that is not caused by broken time reversal symmetry. We discuss this phenomenon in comparison to conventional topological insulators [2] protected by time-reversal symmetry.

[1] P. Dziawa, B. J. Kowalski, K. Dybko, R. Buczko, A. Szczerbakow, M. Szot, E. Łusakowska, T. Balasubramanian, B. M. Wojek, M. H. Berntsen, O. Tjernberg, T. Story, Nature Mat. 11, 1023 (2012).

[2] T. Sato, K. Segawa, K. Kosaka, S. Souma, K. Nakayama, K. Eto, T. Minami, Y. Ando, and T. Takahashi, Nature Phys. 7, 840 (2011).

O 5.4 Mon 10:15 POT 051

Surface-Dominated Transport on a Bulk Topological Insulator — •Lisa Kühnemund[1], Lucas Barreto[2], Frederik Edler[1], Christoph Tegenkamp[1], Jianli Mi[3], Martin Bremholm[3], Bo Brummerstedt Iversen[3], Christian Frydendahl[2], Marco Bianchi[2], and Philip Hofmann[2] — [1]Leibniz Universität Hannover, Inst. f. Festkörperphysik — [2]Aarhus University, Dep. of Physics and Astronomy, iNANO — [3]Aarhus University, Center for Materials Crystallography, iNANO

Topological insulators are guaranteed to support metallic surface states on an insulating bulk, and one should thus expect that the electronic transport in these materials is dominated by the surfaces states. Alas, due to the high remaining bulk conductivity, surface contributions to transport have so-far only been singled out indirectly via quantum oscillations, or for devices based on gated and doped topological insulator thin films, a situation in which the surface carrier mobility could be limited by defect and interface scattering. Here we present a direct measurement of surface-dominated conduction on an atomically clean surface of Bi_2Te_2Se. Using nano-scale four point setups with variable contact distance, we show that the transport at 30 K is two-dimensional rather than three-dimensional and by combining these measurements with angle-resolved photoemission results from the same crystals, we find a surface state mobility of 390(30) $cm^2V^{-1}s^{-1}$ at 30 K at a carrier concentration of $8.71(7)\times10^{12}$ cm^{-2}.

O 5.5 Mon 10:30 POT 051

Room temperature high frequency transport of Dirac fermions in MBE grown Sb_2Te_3 based topological insulators — •T. Herrmann[1], P. Olbrich[1], S.N. Danilov[1], Ch. Weyrich[3], J. Kampmeier[3], G. Mussler[3], D. Grützmacher[3], L. Plucinski[3], C.M. Schneider[3], M. Eschbach[3], L.E. Golub[2], V.V. Bel'kov[2], and S.D. Ganichev[1] — [1]University of Regensburg, Regensburg, Germany — [2]Ioffe Institute, St. Petersburg, Russia — [3]Peter Grünberg Institute (PGI) & Jülich Aachen Research Alliance (JARA-FIT), Research Center Jülich, Jülich, Germany

We report on the observation of terahertz (THz) laser radiation induced currents in epitaxially grown Sb_2Te_3 based topological insulators (TI) [1]. We demonstrate that the excitation of the sample with linearly polarized THz radiation results in a photoresponse solely stemming from the surface states of the 3D TI. Our analysis shows that the photocurrent is caused by the photogalvanic effect [2], which emerges in the surface states but is forbidden in the centrosymmetric bulk material. As an important result our measurements demonstrate that the high frequency transport can be obtained in the Dirac fermion system even at room temperature.

[1] Plucinski et al.; J. Appl. Phys. **113**, 053706 (2013)

[2] Weber et al.; Phys. Rev. B **77**, 245304 (2008)

O 5.6 Mon 10:45 POT 051

Topological Insulator Nanowires by Chemical Vapour Deposition — •Piet Schönherr and Thorsten Hesjedal — Department of Physics, Clarendon Laboratory, University of Oxford, Oxford OX1 3PU, United Kingdom

Topological insulators (TIs) are a new state of quantum matter which insulates in the bulk and conducts on the surface. The study of bulk TIs has been hindered by high conductivity in the bulk, arising from crystalline defects. Such problems can be tackled through compositional engineering or the synthesis of TI nanomaterials. We combined both approaches in a systematic study of various growth parameters to achieve uniform, high purity nanowires with high substrate coverage.

The highlight of this study is the development of a new growth route for nanowires, based on a TiO_2 catalyst rather than the conventional Au. Comparative studies demonstrate that Au significantly contaminates the nanowires, whereas TiO_2 stays well separated. Details of the Au and TiO_2-catalysed growth mechanism were investigated. For Au it was found that the growth mechanism is vapour-liquid-solid. For TiO_2 nanoparticles, in contrast, the growth mechanism can be described in the vapour-solid scheme.

Nanowires of the doped compound $(Bi_{0.78}Sb_{0.22})_2Se_3$ were studied using synchrotron radiation. It was discovered that the material mainly adopts an orthorhombic phase known from Sb_2Se_3. The Raman spectrum is reported and matched with the structural information for the first time. Furthermore, a method to control the length and diameter of Bi_2Se_3 nanowires through laser-cutting was developed.

Coffee break (15 min.)

O 5.7 Mon 11:15 POT 051

Optoelectronic flow trajectories in topological insulators — •Paul Seifert[1], Christoph Kastl[1], Tong Guan[2], Kehui Wu[2], X. Y. He[2], Yongqing Li[2], and Alexander W. Holleitner[1] — [1]Walter Schottky Institut and Physik-Department, Technische Universität München — [2]Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China

We report on the optoelectronic properties of thin films of the topological insulator $(Bi_xSb_{1-x})_2Te_3$ grown by molecular beam epitaxy. In spatially resolved experiments, we observe photocurrent patterns with positive and negative amplitude [1]. We interpret the patterns to originate from a local photocurrent generation due to potential fluctuations [1]. Exploiting the local photocurrent generation in combination with a sub 100-nm lithography, we visualize the current flow in nanoscale circuits based on topological insulators [2].

[1] C. Kastl, T. Guan, X. Y. He, K. H. Wu, Y. Q. Li, and A. W. Holleitner, Appl. Phys. Lett. 101, 251110 (2012). [2] C. Kastl et al., (2014).

We gratefully acknowledge financial support from the DFG-project HO3324/8 within the SPP 1666 on topological insulators.

O 5.8 Mon 11:30 POT 051

Polarization-controlled picosecond spin currents in topological insulators — •Christoph Kastl[1], Christoph Karnetzky[1], Helmut Karl[2], and Alexander W. Holleitner[1] — [1]Walter Schottky Institut and Physik-Department, Technische Universität München, 85748 Garching, Germany — [2]Institute of Physics, University of Augsburg, 86135 Augsburg, Germany

Controlling spin currents in topological insulators may lead to applications in future spintronic devices [1]. Here, we show that surface currents in Bi2Se3 can be controlled by circularly polarized light on a time-scale of a picosecond with a fidelity near unity even at room temperature. We reveal the temporal interplay of such ultrafast spin currents with photo-induced thermoelectric and drift currents in optoelectronic circuits [2].

[1] C. Kastl, T. Guan, X. Y. He, K. H. Wu, Y. Q. Li, and A. W. Holleitner, Appl. Phys. Lett. 101, 251110 (2012).

[2] C. Kastl et al., (2014).

We gratefully acknowledge financial support from the DFG-project HO3324/8 within the SPP 1666 on topological insulators.

O 5.9 Mon 11:45 POT 051

Scanning Tunneling Microscopy of Ultrathin Topological Insulator Sb_2Te_3 Films on Si(111) grown by Molecular Beam Epitaxy — •Martin Lanius, Jörn Kampmeier, Gregor Mussler, and Detlev Grützmacher — Peter Grünberg Institut, Forschungszentrum Jülich, Germany

Topological insulators (TIs) are a class of materials in the field of condensed matter physics. In addition to the fascinating electronic properties, the Van der Waals growth mode of TIs, i.e. the TI epilayer is only weakly bonded to the substrate, which allows the use of substrates with high lattice mismatch, is of high interest. In this case we have studied the nucleation and growth process of the TI Sb_2Te_3 on Si(111) substrates by STM (Scanning Tunneling Microscopy) and AFM (Atomic Force Microscopy). The thin films from several nanometers thickness down to one quintuple layer thickness have been grown by molecular beam epitaxy. To determine the thickness and composition of the films we used x-ray reflectivity and x-ray diffraction. Further investigations of $Ge_2Sb_2Te_3$, which is a phase-changing material and a topological insulator, and the comparison to the growth mode of Sb_2Te_3 will be presented.

O 5.10 Mon 12:00 POT 051

Transport of Dirac fermions in the presence of spin-orbit impurities — •Pierre Adroguer[1], Dimitri Culcer[2], and Ewelina Hankiewicz[1] — [1]Institute for Theoretical Physics and Astronomy, Würzburg University, Würzburg, Germany — [2]School of Physics, University of New South Wales, Sidney, Australia

The recent exprimental realizations of three dimensional topological insulators (3DTI) have provided a new tool to investigate Dirac physics.

Indeed, these materials exhibit an insulating bulk and a single metallic surface state described by Dirac fermion physics.

In the regime of weak scalar disorder, Dirac fermions do not backscatter because of time-reversal symmetry. Further, this absence of backscattering leads to a weak antilocalization correction (an increase in conductivity in the absence of magnetic field, due to quantum interference of conjugated paths) [1,2].

In this presentation, we will review these phenomena, and show how these features are modified when there are spin-orbit impurities in the Dirac fermion systems.

We acknowledge financial support via grant HA 5893/4-1 within SPP 1666.

[1] G. Tkachov and E. M. Hankiewicz, Phys. Rev. B 84, 035444 (2011)

[2] P. Adroguer, D. Carpentier, J. Cayssol, and E. Orignac, New Journal of Physics 14, 103027 (2012)

O 5.11 Mon 12:15 POT 051

Oscillatory surface dichroism of the insulating topological insulator Bi_2Te_2Se — •Susmita Basak[1], Madhab Neupane[2], Hsin Lin[1], N. Alidoust[2], S.-Y. Xu[2], Chang Liu[2], I. Belopolski[2], G. Bian[2], J. Xiong[2], H. Ji[3], S. Jia[3], S.-K. Mo[4], M. Bissen[5], M. Severson[5], N. P. Ong[2], T. Durakiewicz[6], R. J. Cava[3], A. Bansil[1], and M. Z. Hasan[2] — [1]Department of Physics, Northeastern University, Boston, Massachusetts, USA — [2]Joseph Henry Laboratory and Department of Physics, Princeton University, Princeton, New Jersey, USA — [3]Department of Chemistry, Princeton University, Princeton, New Jersey, USA — [4]Advanced Light Source, Lawrence Berkeley National Laboratory, Berkeley, California, USA — [5]Synchrotron Radiation Center, Stoughton, Wisconsin, USA — [6]Condensed Matter and Magnet Science Group, Los Alamos National Laboratory, Los Alamos, New Mexico, USA

We present a study of the effect of angular momentum transfer between polarized photons and topological surface states of the insulating topological insulator Bi_2Te_2Se using circular dichroism-angle resolved photoemission spectroscopy. The photoelectron dichroism demonstrate a dramatic sign flip with the change of photon frequency and we show that this is a consequence of a strong coupling between the photon field and the spin-orbit nature of the initial Dirac states on the surface. Our studies reveal the intrinsic dichroic behavior of topological surface states and point toward the potential utility of bulk insulating topological insulators in opto-spintronics device applications.