MA 49: Poster: Topological insulators (with O,TT)

Time: Thursday 17:00–20:00 Location: P1

MA 49.1 Thu 17:00 P1

Theoretical description of scanning gate microscopy on quantum Hall point contacts — •Martin Treffkorn and Bernd Rosenow — Institut für theoretische Physik, Universität Leipzig, Germany

In the integer quantum Hall regime, the concept of edge states allows to describe dissipationless, one-dimensional transport along the boundary of a sample. Recent experimental progress in the application of low-temperature scan-gate microscopy has allowed to image the spatial structure of edge states with high resolution [1]. To this end, a negatively charged scanning tip approaches a quantum point contact (QPC), such that changes in the spatial edge structure can be measured in the differential resistance of the QPC. The resistance only change when the tip induced change in electron density prevents an edge channel from passing through the point contact, since electrons may only travel along the quasi one dimensional channels at the edge. From the differential change of resistance versus the tip position one obtains a picture of the edge channels that are present in the system. We use a recursive Greens function algorithm to calculate the conductance of a QPC in the presence of a scanning tip. In our calculations we consider the existence of alternating compressible and incompressible strips across the system, paying particular attention to the influence of Coulomb interactions on the edge structure.

[1] N. Pascher, C. Rössler, T. Ihn, K. Ensslin, C. Reichl, and W. Wegscheider, arXiv:1309.4918 (2013).

MA 49.2 Thu 17:00 P1

Dirac and Weyl semimetal states in Na_3Bi from first principles — •Patrick Buhl, Stefan Blügel, and Yuriy Mokrousov — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Recently, the three-dimensional Dirac semimetal state was theoretically predicted to exist [1] and experimentally observed [2] in bulk Na_3Bi. Using first principles methods in combination with the Wannier functions technique [3], we construct and analyze the topological phase diagram of Na_3Bi as a function of spin-orbit strength and external exchange field. In particular we aim at realization of the Weyl semimetal phase in this material. The topological properties are characterized in terms of what computed from ab initio Chern and spin Chern numbers of the Berry curvature flux around the points of band degeneracy. Additionally, we consider finite slabs of Na_3Bi and focus on the electronic structure of the surface states in correlation to the bulk topological phase diagram. Financial support by the HGF-YIG Programme VH-NG-513 is gratefully acknowledged.

[1] Z. Wang *et al.*, Phys. Rev. B **85**, 195320 (2012)
[2] Z.K. Liu *et al.*, arXiv:1310.0391 (2013)
[3] www.flapw.de

MA 49.3 Thu 17:00 P1

Dielectric Function of the Topological Surface States of Bi_2Se_3 — •Markus Heinemann, Christian Franz, and Christian Heiliger — I. Physikalisches Institut, Justus Liebig University, 35392 Giessen, Germany

We investigate the material system Bi_2Se_3 which recently has been discovered to belong to the new class of topological insulators (TI). In this TI, robust surface states located in the insulating band gap of the bulk are protected by time-reversal symmetry and consist of a single Dirac cone at the Γ-point [1]. We use density functional theory to investigate the electronic structure and dielectric function of Bi_2Se_3 by first principles. In our calculations we study the bulk material and the Se terminated surface of Bi_2Se_3 which we simulate by a slab model and examine the effect of the slab thickness, i.e. the number of atomic layers. The essential effect of spin-orbit-coupling for the topological state and thus on the electronic and dielectric properties is presented by comparing calculations with and without this feature.

[1] H. Zhang, C.-X. Liu, X.-L. Qi, X. Dai, Z. Fang, and S.-C. Zhang, Nature Phys. 5, 438 (2009)

MA 49.4 Thu 17:00 P1

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 inside 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. Further, a method to control the length and diameter of Bi_2Se_3 nanowires through laser-cutting was developed.

MA 49.5 Thu 17:00 P1

Strained HgTe shell on CdTe nanowires grown by Au catalyst MBE — •Maximilian Kessel, Rebekka Pfeuffer, Claus Schumacher, Hartmut Buhmann, and Laurens W. Molenkamp — Experimental Physics 3, University of Würzburg, Germany

The topological insulator properties of 2D and strained 3D HgTe layers have attracted strong attention over the past years. One interesting question that rose was how the TI state evolves in quasi-one dimensional geometry. Here, we present the first realization of a strained HgTe shell on CdTe nanowires.

Doped GaAs wafers are used as substrates for the nanowire growth in a multi-chamber ultra-high vacuum system. The CdTe growth is seeded by liquid Au/Ga eutectic droplets. For straight, uniform and smooth shaped CdTe wires, a special growth start is performed and the substrate temperature is hold within narrow limits. The wires have a diameter of 30 to 100 nm and grow along the [111]B direction up to a length of 3 μm. The ensemble of CdTe wires is used as substrate for HgTe molecular beam epitaxy. Shell and core of the nanowires are characterized by electron and X-ray diffraction. The radial heterostructures show strained crystalline structure. Transport characterization measurements on separated radial HgTe/CdTe heterostructures are done at low temperature.

MA 49.6 Thu 17:00 P1

Weak anti-localization in HgTe quantum wire arrays — •Johannes Ziegler[1], Sabine Weishäupl[1], Christopher Ames[2], Christoph Brüne[2], Harmut Buhmann[2], Laurens W. Molenkamp[2], and Dieter Weiss[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Germany — [2]Physikalisches Institut (EP III), Universität Würzburg, Germany

We present our progress in fabricating quasi-1D quantum wire arrays in inverted HgTe quantum wells, being a 2D topological insulator. These quasi-1D quantum wire arrays were fabricated with widths between 120 nm and 250 nm. Our experiments focus on phase-coherent effects, like weak anti-localization and weak-localization, in both wire arrays and 15 and 40 μm wide Hall-bars. From these measurements we extract the phase-coherence length l_ϕ and the spin-relaxation length l_{SO}.

Our work is motivated by a proposal for all-electrical detection of the relative spin-orbit interaction strength α / β [1,2], where α is the Rashba and β the Dresselhaus spin-orbit parameter. A key requirement for this method is the transition from weak anti-localization (WAL) to weak localization (WL) through 1D confinement. The analysis of these characteristic lengths allows us to check when the suppression of WAL occurs.

[1] M. Scheid *et al.*, Phys. Rev. L **101**, 266401 (2008).
[1] M. Scheid *et al.*, Semicond. Sci. Technol. **24**, 064005 (2009).

MA 49.7 Thu 17:00 P1

Magnetotransport and ac conductivity in 2D and 3D topological insulators — •Christian Michel and Ewelina M. Hankiewicz — Institute for Theoretical Physics and Astrophysics, University of Würzburg, D-97074 Würzburg, Germany

We study theoretically Landau level structure and optical selection rules in 2D and 3D TIs. Our focus is to find the features which are specific to the Dirac physics. We show that the optical selection rules are different for the particle-hole symmetric Dirac model in comparison with the particle-hole asymmetric models. We explain the influence of dimensionality on the characteristic features of optical selection rules.

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

MA 49.8 Thu 17:00 P1

Ferromagnetic contacts on topological insulators: Lithographic realization on strained 3-dimensional HgTe — •Kalle Bendias, Erwann Bocquillon, Simon Hartinger, Christoph Brüne, Hartmut Buhmann, and Laurens Molenkamp — EP3, Physikalisches Institut, Universität Würzburg, Am Hubland, D-97074 Würzburg

Topological insulators are a new class of material with insulating bulk and conducting Dirac-like surface states. These states are associated with spin-momentum locking, which is supposed to lead to numerous applications in spintronics [1].

Here we report on lithographic ways to realize the concept of spin injection and detection into the Dirac-like surface states of the 3-dimensional topological insulator HgTe. We discuss fabrication challenges such as unstrained deposition of ferromagnetic material and the realization of a diffusion barrier on the high temperature-sensitive HgTe material system.

[1]C. Brüne, et. al, Phys. Rev. Lett. 106, 126803 (2011)

MA 49.9 Thu 17:00 P1

Transport properties of the high mobility topological insulator HgTe — •Jonas Wiedenmann[1], Cornelius Thienel[1], Christopher Ames[1], Christopher Brüne[1], Steffen Wiedmann[2], Hartmut Buhmann[1], and Laurens Molenkamp[1] — [1]Universität Würzburg, Würzburg, Deutschland — [2]Radboud Universität Nijmegen, Nijmegen, Holland

It has been demonstrated recently, that the semimetal HgTe opens a band gap of approximately 20 meV when grown strained on a CdTe substrate and thus becomes a three dimensional topological insulator (3D TI)[1].

We show that it is possible to increase the mobility of the surface states by an order of magnitude, if HgTe is sandwiched between epitaxial layers of HgCdTe. The topological insulator is investigated in transport measurements at low temperatures and magnetic fields up to 30 T. Through the enhanced surface mobilites we are able to observe a Dirac specific quantum hall effect. The experimental data suggest, that it has to be discussed within a two surface model for Dirac fermions.

[1] C. Brüne et al., Phys. Rev. Lett. 106, 126803 (2011)

MA 49.10 Thu 17:00 P1

Heteroepitaxial Li_2IrO_3 Thin Films Grown by Pulsed Laser Deposition — •Marcus Jenderka, Heiko Frenzel, Rüdiger Schmidt-Grund, Marius Grundmann, and Michael Lorenz — Institut für Experimentelle Physik II, Universität Leipzig, Linnéstraße 5, D-04103 Leipzig. Germany

The layered perovskite oxides A_2IrO_3 (A = Na, Li) have been studied in recent years in terms of a physical realization of spin-liquid [1] and topological insulator [2] phases, desired within certain quantum computation proposals. We report on the pulsed laser deposition of heteroepitaxial Li_2IrO_3 films on ZrO_2:Y(001) single crystalline substrates. As in Na_2IrO_3 [3], X-ray diffraction confirms a preferential (001) out-of-plane crystalline orientation with a defined in-plane epitaxial relationship. Resistivity between 35 and 300 K is dominated by a three-dimensional variable range hopping mechanism. Infrared optical transmission from 0 to 1.85 eV, measured by Fourier transform infrared spectroscopy (FTIR), reveals a small optical gap $E_{go} \approx 300$ meV together with a splitting of the $5d$-t_{2g} manifold caused by the interplay of spin-orbit coupling and electronic correlations. By means of infrared spectroscopic ellipsometry, the dielectric function (DF) is presented in the spectral range between 0.03 and 3.50 eV. The calculated absorption coefficient confirms the value for E_{go}.

[1] J. Chaloupka *et al.*, Physical Review Letters **105**, 027204 (2010).
[2] H.-S. Kim *et al.*, Physical Review B **87**, 165117 (2013).
[3] M. Jenderka *et al.*, Physical Review B **88**, 045111 (2013).

MA 49.11 Thu 17:00 P1

Epitaxial growth of $LaNiO_3$ and $LaAlO_3$ thin films and multilayers by PLD — •Haoming Wei, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig, Germany

As predicted by recent theoretical study, the superlattices (SLs) consisting of paramagnetic metal $LaNiO_3$ (LNO) and band insulator $LaAlO_3$ (LAO) may exhibit exotic topological phases[1]. We have grown LNO, LAO films and LNO/LAO heterostructures by plused laser deposition (PLD). All the films show good out-of-plane and inplane crystalline orientation and definite epitaxial relationship. The lattice constant and strain of LNO films could be controlled by adjusting growth conditions. The LNO films have an excellent metallic conductivity and the resistivity is related to strain. The low resistivity is about $300\mu\Omega\cdot$cm at 300 K, which is low enough for use as an electrode material. The LAO films obtained by interval PLD exhibit terraced surface even when grown at a low temperature. The height of the terraces is about 0.4 nm in accord with the calculated result from XRD pattern. Further, LNO/LAO multilayer structures were fabricated. Atomic force microscopy (AFM) together with reflection high-energy electron diffraction (RHEED) images show that the multilayers have a smooth surface with the root mean square roughness about 3.2 nm.

[1] K. Y. Yang, et al. Physical Review B 84, 201104(R) (2011).

MA 49.12 Thu 17:00 P1

Combined XMCD and STS study of transition metal adatoms adsorbed on the surface of prototypical 3D topological insulators — •Jonas Warmuth[1], Martin Vondráček[2], Matteo Michiardi[3], Lucas Barreto[3], Cinthia Piamonteze[4], Andreas Eich[1], Alexander Khajetoorians[1], Jian-Li Mi[3], Bo Brummerstedt Iversen[3], Philip Hofmann[3], Jens Wiebe[1], and Roland Wiesendanger[1] — [1]Institute of Applied Physics, Uni Hamburg, Germany — [2]Institute of Physics ASCR, Prague, Czech Republic — [3]iNano, Aarhus University, Denmark — [4]Laboratory of Condensed Matter Physics, PSI, Switzerland

The spin of Dirac electrons in topological surface states is rigidly locked to the direction of their momentum leading, e.g., to prohibited backscattering. Their interaction with magnetic impurities is currently a matter of debate, because it can destroy this effect, heavily depending on the magnetic properties of the impurities. Using x-ray magnetic circular dichroism techniques we investigated 3d transition metal adatoms adsorbed on the surface of different prototypical 3D topological insulators. We compare our results to crystal field multiplet calculations [1] of the 3d states. For some of the adatom species, we find a considerable magnetic anisotropy, which depends crucially on the coupling of their 3d states to the substrate electrons. Furthermore, we investigate the interaction of the adatoms and the Dirac electrons by Fourier-transform scanning tunneling spectroscopy [2], which reveals shifts of the linear dispersion due to surface doping effects.

[1] J. Honolka et al., PRL 108, 256811 (2012)