TT 33: Topological Insulators 3 (jointly with HL, MA, and O)

Time: Wednesday 9:15–13:00 Location: H16

TT 33.1 Wed 9:15 H16

Topological Excitonic Superfluids in Three Dimensions — •Ewelina M. Hankiewicz[1], Youngseok Kim[2], and Matthew Gilbert[2] — [1]Wuerzburg University — [2]University of Illinois, Urbana

We study the equilibrium and non-equilibrium properties of topological dipolar intersurface exciton condensates within time-reversal invariant topological insulators in three spatial dimensions without a magnetic field. We elucidate that, in order to correctly identify the proper pairing symmetry within the condensate order parameter, the full three-dimensional Hamiltonian must be considered. As a corollary, we demonstrate that only particles with similar chirality play a significant role in condensate formation. Furthermore, we find that the intersurface exciton condensation is not suppressed by the interconnection of surfaces in three-dimensional topological insulators as the intersurface polarizability vanishes in the condensed phase. This eliminates the surface current flow leaving only intersurface current flow through the bulk. We conclude by illustrating how the excitonic superfluidity may be identified through an examination of the terminal currents above and below the condensate critical current. Reference: Phys. Rev. B 86, 184504 (2012).

TT 33.2 Wed 9:30 H16

Bi_2Te_3: A dual topological insulator — •Tomáš Rauch[1], Markus Flieger[1], Arthur Ernst[2], Jürgen Henk[1], and Ingrid Mertig[1,2] — [1]Martin-Luther-Universität Halle-Wittenberg, Halle, Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany

The class of $\mathcal{Z}_2$ topological insulators requires time reversal symmetry, while topological crystalline insulators require a mirror symmetry (an example is SnTe [1]).

We show that the well-known $\mathcal{Z}_2$ topological insulator Bi_2Te_3 with $\mathcal{Z}_2$ invariant $(1;0\,0\,0)$ is also a topological crystalline insulator with mirror Chern number -1. This dual topological character allows to dope Bi_2Te_3 magnetically, thereby breaking time-reversal symmetry, while keeping the topological crystalline character. As a consequence, magnetized Bi_2Te_3 shows a Dirac state at its (111) surface shifted off the time-reversal invariant momentum $\overline{\Gamma}$, provided the magnetization is perpendicular to a mirror plane.

These fundamental features are elaborated by means of tight-binding calculations of both the bulk and the surface electronic structure as well as of the topological invariants. $\vec{k}\cdot\vec{p}$ model calculations and *ab initio* KKR calculations complement and support these results.

Our findings open a new path toward device applications that rely on topological insulators with magnetically controllable topological character.

[1] L. Fu, Phys. Rev. Lett. **106** (2011) 106802; T. Hsieh *et alii*, Nature Comms. **3** (2012) 982.

TT 33.3 Wed 9:45 H16

Three-dimensional Models of Topological Insulator Films: Dirac Cone Engineering and Spin Texture Robustness — David Soriano[1], •Frank Ortmann[1], and Stephan Roche[1,2] — [1]Catalan Institute of Nanotechnology, Barcelona (Spain) — [2]ICREA, Barcelona (Spain)

Topological insulators feature surface states which exhibit certain robustness to disorder and which can be gapped due to inter-surface tunneling. By designing three-dimensional models of topological insulator thin films, we demonstrate a tunability of surface states and the odd number of Dirac cones on opposite surfaces by modifications of the atomic-scale geometry at the boundaries. [1,2] This enables the creation of a single Dirac cone at the Γ point as well as possible suppression of quantum tunneling between Dirac states at opposite surfaces. We further analyze the robustness of the spin texture to bulk disorder which may help in quantifying bulk disorder in materials with ultraclean surfaces. [2]

[1] L. Fu, C.L. Kane, and E.J. Mele, Phys. Rev. Lett. 98, 106803 (2007)

[2] D. Soriano, F. Ortmann, and S. Roche, Phys. Rev. Lett. (in press)

TT 33.4 Wed 10:00 H16

Transport properties of point contacts between helical edge states — •Christoph P. Orth and Thomas L. Schmidt — University of Basel, Switzerland

We study a 2D topological insulator with helical edges that are connected by local electron tunneling. The edges are in contact with four reservoirs held at different chemical potentials. In contrast to existing theories, we treat the tunneling exactly but apply perturbation theory for the electron-electron interactions to calculate the current. Furthermore, we allow for a slow momentum dependent spin-rotation of the helical fields which can be created, e.g., by Rashba spin-orbit coupling. This allows inelastic spin-flip tunneling processes between the edges. Our results help to understand the interplay between electron-electron and spin-orbit interactions in topological insulators.

TT 33.5 Wed 10:15 H16

Exotic magnetic properties of diluted magnetic binary chalcogenides — •Maia G. Vergniory[1], Xabier Zubizarreta[1], Mikhail M. Otrokov[2], Igor V. Maznichenko[3], Juergen Henk[3], Evgueni V. Chulkov[4], and Arthur Ernst[1] — [1]Max Planck Institute of Microstructure Physics, Halle, Germany — [2]Tomsk State University, Tomsk, Russia — [3]Martin-Luther-University, Halle-Wittenberg, Germany — [4]Donostia International Physics Center, Donostia-San Sebastian, Spain

Using first-principles Green function approach we studied electronic and magnetic properties of diluted magnetic binary chalcogenides A_2B_3, doped with transition metals substituing the A element. The electronic structure of the impurities in the chalcogenides is mainly featured by the crystal field splitting. We found that two main mechanisms are responsible for long-range magnetic order in these materials: hole mediated magnetism within the layer of A atoms and indirect interaction between magnetic moments via a B atom. We also estimated Curie temperature of these systems, which was found in good agreement with the available experimental data. Our results shed light on the understanding of magnetic interaction and control in toplogical insulators.

TT 33.6 Wed 10:30 H16

Quasiparticle study of the bulk topological insulators Bi_2Se_3, Bi_2Te_3, and Sb_2Te_3 including spin-orbit coupling. — •Irene Aguilera, Christoph Friedrich, Gustav Bihlmayer, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany

We present GW calculations of the topological insulators Bi_2Se_3 and Bi_2Te_3 within the all-electron FLAPW formalism and compare them with previous calculations. We extend the study to the topological insulator Sb_2Te_3, which poses additional problems when studied with GW based on non-relativistic density functional theory (DFT) as it exhibits a negative DFT band gap. In contrast to the previous GW calculations, we fully take into account spin-orbit coupling (SOC) allowing spin-off-diagonal elements in the Green function and the self-energy, and we discuss the differences to a simpler perturbative approach (*i.e.*, treating SOC on DFT level *a posteriori*). Additionally, we show that the inclusion of SOC induces fundamental changes in the Green function G, whereas changes in the screened interaction W are negligible. We also discuss the influence of off-diagonal elements of the self-energy matrix.

After inclusion of quasiparticle effects, we observe a direct band gap at the Γ point for Bi_2Se_3, in disagreement with predictions from DFT but in accordance with experiment. For all compounds, in the most critical case of the band-inversion region around the Γ point, we show that the GW effective masses are significantly different from DFT ones.

Funding was provided by the Alexander von Humboldt Foundation.

TT 33.7 Wed 10:45 H16

Controllable magnetic doping of the surface state of a topological insulator — •A. Eich[1], T. Schlenk[1], M. Bianchi[2], M. Koleini[3], O. Pietzsch[1], T.O. Wehling[3], T. Frauenheim[3], A. Balatsky[4], J.-L. Mi[5], B. B. Iversen[5], J. Wiebe[1], A.A. Khajetoorians[1], Ph. Hofmann[2], and R. Wiesendanger[1] — [1]Institute for Applied Physics, Universität Hamburg, Germany — [2]iNano, Aarhus University, Denmark — [3]Bremen Center for Computational Materials Science, Universitiy of Bremen, Germany — [4]NORDITA, Stockholm, Sweden — [5]Center for Materials Crystallog-

raphy, iNano, Aarhus University, Denmark

A combined experimental and theoretical study of doping individual Fe atoms into Bi_2Se_3 is presented. It is shown through a scanning tunneling microscopy study that single Fe atoms initially located at hollow sites on top of the surface (adatoms) can be incorporated into subsurface layers by thermally-activated diffusion. Angle-resolved photoemission spectroscopy in combination with ab-initio calculations within density functional theory suggest that the doping behavior changes from electron donation for the Fe adatom to neutral or electron acceptance for Fe incorporated into substitutional Bi sites. According to the calculations, these Fe substitutional impurities retain a large magnetic moment thus presenting an alternative scheme for magnetically doping the topological surface state. For both types of Fe doping, we see no indication of a gap at the Dirac point.

T. Schlenk et al., arXiv: 1211.2142v1 (2012) [cond-mat.mtrl-sci]
J. Honolka et al., PRL **108**, 256811 (2012)

Coffee break

TT 33.8 Wed 11:15 H16

Induced superconductivity in the topological surface state of mercury telluride (HgTe) — •Luis Maier, Manuel Grimm, Peter Schüffelgen, Daniel Knott, Christopher Ames, Christoph Brüne, Philipp Leubner, Jeroen Oostinga, Hartmut Buhmann, and Laurens W. Molenkamp — Physikalisches Institut (EP3), Universität Würzburg, 97074 Würzburg

It has been recently demonstrated, that a strained grown layer of of HgTe is a 3D topological insulator (TI) exhibiting a single family of Dirac cone states at its surface. Since the bulk has nearly no carriers left, the transport through these structures is strongly dominated by the surface states [1].

Because of the prediction of creation of Majorana bound states [2] we are looking at a superconductor-TI interface. This talk presents our results on highly transparent S-TI-S junctions where we observe unusual behaviour in the Josephson current.

Preliminary results of this project are published in [3].

[1] C. Brüne et al., Phys. Rev. Lett. 106, 126803 (2011)
[2] L. Fu and C. L. Kane, Phys. Rev. Lett. 100, 096407 (2008)
[3] L. Maier et al., Phys. Rev. Lett. 109, 186806 (2012)

TT 33.9 Wed 11:30 H16

Strained bulk HgTe as a 3D topological insulator — •Cornelius Thienel, Christopher Ames, Philipp Leubner, Christoph Brüne, Hartmut Buhmann, and Laurens W. Molenkamp — Universität Würzburg, Lehrstuhl für experimentelle Physik III

HgTe is a semimetal that has an inverted band structure. We show that strained on CdTe the HgTe opens a bandgap and becomes a 3D topological insulator (TI). By magnetotransport measurements we confirm the existence of a 2D topological state and observe QHE from the surface. An analysis of SdH oszillations allows us to distinguish between two TI surfaces perpendicular to the magnetic field that have different charge carrier densities due to different electrostatic environments. When structuring a top gate on the sample, we are able to match the carrier densities of the surface states and therefore see a sequence of odd integer Hall plateaus, as predicted by Dirac physics.

TT 33.10 Wed 11:45 H16

Comparing scattering processes in topological insulators and giant Rashba semiconductors — •Peter Lemmens[1], Vladimir Gnezdilov[2], Dirk Wulferding[1], Patrik Recher[3], Helmuth Berger[4], Yoichi Ando[5], Angela Möller[6], R. Sankar[7], and Fang-Cheng Chou[7] — [1]IPKM, TU-BS, Braunschweig — [2]ILTPE, Kharkov, Ukraine — [3]IMAPH, TU-BS, Braunschweig — [4]EPFL, Lausanne, Switzerland — [5]ISIR, Osaka, Japan — [6]Dept. of Chemistry, Univ. Houston, USA — [7]CCMS, National Taiwan Univ., Taipei, Taiwan

Using Raman scattering experiments we probe scattering processes in BiTeI and topological insulators. In the former systems the surface termination, either by Iodine - Bi or Tellur - Bi determines the low energy scattering properties. A comparison of these surface induced signals with effects seen in topological insulators leads to a considerable gain of understanding of scattering mechanisms and the respective role of symmetry. Work supported by DFG, B-IGSM and NTH School for Contacts in Nanosystems.

TT 33.11 Wed 12:00 H16

Local photocurrent generation in thin films of the topological insulator Bi_2Se_3 — •Christoph Kastl[1], Tong Guan[2], Xiaoyue He[2], Kehui Wu[2], Yongqing Li[2], and Alexander Holleitner[1] — [1]Walter Schottky Institut and Physik-Department, Technische Universität München, Am Coulombwall 4a, 85748 Garching, Germany — [2]Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China

We report on the optoelectronic properties of thin films of the three-dimensional topological insulator Bi_2Se_3 grown by molecular beam epitaxy. In spatially resolved scanning photocurrent experiments, we observe submicron photocurrent patterns with positive and negative amplitude [1]. The patterns are independent of the applied bias voltage, but they depend on the width of the circuits. We interpret the patterns to originate from a local photocurrent generation [2] due to potential fluctuations [3]. Furthermore, we verify and discuss the impact of the circular photogalvanic effect in optoelectronic Bi_2Se_3-based circuits [4].

[1] C. Kastl et al., arxiv: 1210.4743 (2012).
[2] J. C. W. Song and L. S. Levitov, arxiv:1112.5654 (2011).
[3] H. Beidenkopf et al., Nat. Phys. 7, 939 (2011).
[4] C. Kastl et al. (2013).

TT 33.12 Wed 12:15 H16

$Bi_{1-x}Sb_x$(110): A non-closed packed surface of a topological insulator — Lucas Barreto, Wendell Simoes da Silva, Malthe Stensgaard, Søren Ulstrup, Marco Bianchi, •Xie-Gang Zhu, Matteo Michiardi, Maciej Dendzik, and Philip Hofmann — Department of Physics and Astronomy, Interdisciplinary Nanoscience Center Århus University, 8000 Århus C, Denmark

Topological insulators are characterised by an insulating bulk band structure, but topological considerations require their surfaces to support gap-less, metallic states. Meanwhile, many examples of such materials have been predicted and found experimentally, but work has concentrated on the closed-packed (111) surface of the topological insulators. Thus, the theoretical picture of an insulating bulk embedded in a metallic surface from all sides of a crystal still needs to be confirmed. Here we present angle-resolved photoemission spectroscopy results from the (110) surface of the topological insulator $Bi_{1-x}Sb_x$ ($x \approx 0.15$). The observed band structure and Fermi contour is in excellent agreement with theoretical predictions and slightly different from the electronic structure of the parent surface Bi(110), in particular around the X_1 time-reversal invariant momentum. We argue that the preparation of surfaces different from (111) opens the possibility to tailor the detailed electronic structure and properties of the topological surface states.

TT 33.13 Wed 12:30 H16

Charge screening at the surface of a topological insulator: Rb on Bi_2Se_3 — •Peter Löptien, Lihui Zhou, Jens Wiebe, Alexander A. Khajetoorians, and Roland Wiesendanger — Institute of Applied Physics, University of Hamburg, Germany

Adsorption of Rb atoms on Bi_2Se_3 leads to the formation of a two-dimensional electron gas (2DEG) in the conduction band at the surface of the topological insulator [1]. We investigated the coverage dependent distribution of the singly charged Rb atoms by low temperature STM. By a statistical analysis of the interatomic distances between the adatoms we quantitatively derived the pair interaction [2], which fits a screened Coulomb potential. Interestingly, screening length and dielectric constant turn out to be rather small, due to the contribution of the 2DEG and topological surface state.

[1] M. Bianchi, R. C. Hatch, Z. Li, P. Hofmann, F. Song, J. Mi, B. B. Iversen, Z. M. Abd El-Fattah, P. Löptien, L. Zhou, A. A. Khajetoorians, J. Wiebe, R. Wiesendanger, and J. W. Wells, ACS Nano 6, 7009 (2012)
[2] J. Trost, T. Zambelli, J. Wintterlin, and G. Ertl, Phys. Rev. B 54, 17 850 (1996)

TT 33.14 Wed 12:45 H16

Fabrication and characterization of thin Bi_2Se_3 topological insulators — •Srujana Dusari[1], Philipp Meixner[1], Anna Mogilatenko[2], Saskia F. Fischer[1], Jaime Sanchez-Barriga[3], Lada V. Yashina[4], Florian Kronast[3], Sergio Valencia[3], Akin Ünal[3], and Oliver Rader[3] — [1]Novel Materials, Humboldt Universität zu Berlin, D-12489 Berlin — [2]Ferdinand Braun Institut, D-12489 Berlin — [3]Helmholtz-Zentrum Berlin für Materialien und Energie, D-

12489 Berlin — [4]Dep. Chemistry, Moscow State University, Russia

Topological insulators (TIs) have electrically insulating states in the bulk and robust conducting states along the edges [1, 2]. The real-life TI samples available today contain residual bulk charge carriers that hinder exploiting their surface properties in device form. The aim of our work is to investigate the controlled combination of dimensionality and designed impurity and metallic defect structures on the quantum transport properties of well known Bi_2Se_3 TIs, in particular with respect to the implications for devices. Here we report preparation and characterization of exfoliated Bi_2Se_3 flakes. The samples are characterized using atomic force microscopy, transmission electron microscopy, and energy-dispersive X-ray spectroscopy. Surface stability and composition are determined using photoemission electron microscopy. Low temperature transport measurements are presented.

[1] C. L. Kane, and E. J. Mele, Phys. Rev. Lett. 95, 226801 (2005).

[2] M. Z. Hasan and J. E. Moore, Annu. Rev. Condens. Matter. Phys. 2: 55-78 (2011).