HL 11: Topological insulators II (joint session HL/TT)

Time: Monday 15:00–17:30 Location: A 151

HL 11.1 Mon 15:00 A 151

Advanced MBE techniques for improved Bi2Se3 thin film growth — •Sarah Schmitt, Peter Schüffelgen, Abdur Jalil, Michael Schleenvoigt, Tobias Schmitt, Jonas Kölzer, Daniel Rosenbach, Thomas Schäpers, Gregor Mussler, and Detlev Grützmacher — Peter Grünberg Institut, Forschungszentrum Jülich & JARA Jülich-Aachen Research Alliance, D-52425 Jülich, Germany

Topological Insulators (TIs) are semiconductors with an inverted bulk band gap, but topologically protected states at their surface. The surface states exhibit promising features, useful for example for spintronic and quantum computing applications. In this study, we focus on the binary 3D TI Bi2Se3, which is unique due to its large bulk band gap and its freestanding Dirac point that lies in between valence and conduction band. However, binary compounds suffer from high back ground doping due to crystal defects in the bulk. To reduce defects in Bi2Se3, the quality of the thin films grown by molecular beam epitaxy (MBE) on Si(111) has been optimized. By varying the Bi, Se and substrate temperature as well as using InP as alternative substrate. The best conditions for low roughness, homogeneous domains and reduction of defects were investigated.

For transport measurements Hall bar structures were designed. To avoid defect formation during device fabrication, electrodes were deposited in-situ via stencil lithography. Still in-situ, the stencil mask was removed and the thin film capped with a thin dielectric layer to conserve the sample before taking it to ambient conditions. This technique allows the access to clean ultra-thin TI films by means of MBE.

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Interplay of Chiral and Helical states in a Quantum Spin Hall Insulator Lateral Junction — •M. R. Calvo[1,2,5], F. de Juan[2], R. Ilan[2], E. J. Fox[3], A. J. Bestwick[3], P. Leubner[4], J. Wang[3], C. Ames[4], S. C. Zhang[3], H. Buhmann[4], L. W. Molenkamp[3], and D. Goldhaber-Gordon[4] — [1]CIC Nanogune, San Sebastián, Spain — [2]Unversity of California, Berkeley, USA — [3]Stanford University, Stanford, USA — [4]Wuerzburg University, Wuerzburg, Germany — [5]Ikerbasque, Basque Foundation for Science, Bilbao, Spain

We study the electronic transport across an electrostatically gated lateral junction in a HgTe quantum well, a canonical 2D topological insulator, with and without an applied magnetic field. We control the carrier density inside and outside a junction region independently and hence tune the number and nature of 1D edge modes propagating in each of those regions. Outside the bulk gap, the magnetic field drives the system to the quantum Hall regime, and chiral states propagate at the edge. In this regime, we observe fractional plateaus that reflect the equilibration between 1D chiral modes across the junction. As the carrier density approaches zero in the central region and at moderate fields, we observe oscillations in the resistance that we attribute to Fabry-Perot interference in the helical states, enabled by the broken time reversal symmetry. At higher fields, those oscillations disappear, in agreement with the expected absence of helical states when band inversion is lifted.

HL 11.3 Mon 15:30 A 151

Topological transport in dimer chains — •Sina Böhling[1], Georg Engelhardt[1], Gernot Schaller[1], and Gloria Platero[2] — [1]Institut für Theoretische Physik, Technische Universität Berlin, Berlin, Germany — [2]Instituto de Ciencia de Materiales de Madrid, CSIC, Madrid, Spain

In many fields, dimer chains have aroused great interest - not least because of the emergence of topologically protected edge states, localized to the two ends of the chain and promising lossless long-range transfer of particles. [1] Our work provides insight into properties of a dimer chain that is subject to dissipation. Applying an exact Green's function formalism applicable for any coupling strength, we investigate transport properties of a finite Su-Schrieffer-Heeger model, a paradigmatic model for a one-dimensional topological insulator, which is coupled to fermionic reservoirs at its ends.

For long chains, we observe that current and noise strongly decrease in the topologically non-trivial phase. This can be understood as a topological fingerprint, namely the occupation of edge states which are stronger coupled to the reservoirs than the conducting modes but do hardly contribute to the transmission. We show how to exploit this behavior to dissipatively prepare an edge state, while all other modes are practically unoccupied. Moreover, we discuss thermodynamic properties of the system by subjecting it to both, a potential and a thermal gradient, and discover regimes where the chain serves either as a heat engine or as a refrigerator.

[1] Bello, Creffield, Platero, Scientific Reports 6, 22562 (2016)

HL 11.4 Mon 15:45 A 151

Direct −1 to +1 Hall conductivity transitions in HgTe quantum wells — •Wouter Beugeling[1,2,3], Jan Böttcher[2], Christoph Brüne[1,4], Andreas Budewitz[1], Hartmut Buhmann[1], Ewelina M. Hankiewicz[2], Cristiane Morais Smith[5], and Laurens W. Molenkamp[1] — [1]Physikalisches Institut (EP3), Universität Würzburg, Würzburg, Germany — [2]Institut für Theoretische Physik und Astrophysik (TP4), Universität Würzburg, Würzburg, Germany — [3]Lehrstuhl für Theoretische Physik I/II, Technische Universität Dortmund, Dortmund, Germany — [4]Department of Physics, Norwegian University of Science and Technology, Trondheim, Norway — [5]Institute for Theoretical Physics, Utrecht University, Utrecht, The Netherlands

Mercury telluride (HgTe) quantum wells have been one of the primary platforms for realization of topological states, due to its 'inverted' band structure. Typically, transport measurements of HgTe quantum well samples in a magnetic field show Hall quantization. The quantum spin Hall effect manifests itself as a special type of 'zero conductivity' Landau plateau.

We present remarkable transport measurement results, where the zero-conductivity plateau is absent, and where the Hall conductivity jumps from $-e^2/h$ to e^2/h directly. We provide a theoretical explanation, connecting this exotic transition to the 'second inversion', i.e., between the first electron (E1) and second heavy-hole (H2) subbands. We also discuss the effect of the exchange interaction induced by manganese (Mn) doping.

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Parallel conduction channels in topological insulator thin films: Determination of conductance through bulk, interface and surface states — •Sven Just[1,2], Felix Lüpke[1,2], Peter Schüffelgen[1,2], Tristan Heider[1,2], Vasily Cherepanov[1,2], Gregor Mussler[1,2], Lukasz Plucinski[1,2], Detlev Grützmacher[1,2], Claus M. Schneider[1,2], F. Stefan Tautz[1,2], and Bert Voigtländer[1,2] — [1]JARA-FIT, Forschungszentrum Jülich, Germany — [2]Peter Grünberg Institute (PGI-3, PGI-6, PGI-9), Forschungszentrum Jülich, Germany

Topological insulator (TI) thin films can exhibit multiple parallel conduction channels for current transport. Beside the topological protected surface states (TSS) on top and bottom side of the film there can be more parasitic channels, i.e. the interior (bulk) of the not perfectly insulating TI film, the interface layer and the substrate. It is a crucial task to determine and minimize the influence of these parasitic parallel channels on the total current transport for taking advantage of the special TI properties in electronic devices. By using gate-dependent surface-sensitive four-probe measurements performed with a multi-tip STM and ARPES measurements in combination with theoretical calculations of the near-surface band-bending in the TI thin film, it is possible to disentangle the contributions of the different parallel conduction channels and to determine the conductivities of the interface reconstruction and the film bulk, as well as the charge carrier densities and mobilities of the top and bottom TSS for TI materials grown by van-der-Waals epitaxy, e.g. the ternary system $(Bi_{0.53}Sb_{0.47})_2Te_3$.

15 min. break.

HL 11.6 Mon 16:30 A 151

Quantum interference phenomena in selectively grown topological insulator nanoribbons — •Jonas Kölzer[1], Daniel Rosenbach[1], Tobias Schmitt[1], Christian Weyrich[1], Peter Schüffelgen[1], Michael Schleenvoigt[1], Sarah Schmitt[1], Abdur Rehman Jalil[1], Gregor Mussler[1], Vincent Sacksteder[2], Detelev Grützmacher[1], and Thomas Schäpers[1] — [1]PGI-9, Forschungzentrum Jülich and JARA-FIT, Germany — [2]Royal Holloway University of London, United Kingdom

Quantum topology offers a lot of intriguing physical phenomena and has a huge potential to realize robust quantum computing. Selectively deposited nano devices grown by means of molecular beam epitaxy (MBE) are a first step towards scalable topological insulator (TI) quantum computation.

In order to probe the evidence of topologically protected surface states, magneto conductance measurements are performed. In detail we studied quantum interference effects in the magneto conductance on selectively grown TI nanoribbons at low temperatures. From the conductance modulations we could trace distinct electron paths using FFT analysis in angular dependent measurements. Temperature dependent measurements reveal the quantum nature of the oscillations observed, since they vanish for increasing temperatures.

The next step in characterizing the material system will be to selectively grow Aharonov-Bohm ring structures to characterize quantum oscillations inside the van der Waals layer system.

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THz conductivity of charge puddles in the topological insulator BSTS — •Yu Mukai, Suqin He, Zhiwei Wang, Markus Grüninger, Yoichi Ando, and Paul H. M. van Loosdrecht — II, Physikalisches Institut, Universität zu Köln, Cologne, Germany

Strong Coulomb disorder in the compensation doped topological insulator $BiSbTeSe_2$ (BSTS) leads, at low temperatures, to the formation of charge puddles and consequently a non-monotonic temperature dependence of mid-infrared optical conductivity [1]. In contrast, the DC conductivity shows a monotonous decrease with temperature, as expected for an insulator [1]. To experimentally reconcile these observations we performed time domain THz spectroscopy on BSTS over the wide frequency range of 0.3 - 6 THz, thereby largely filling the gap between the DC and mid-infrared experiments. We present the temperature dependence of the conductivity spectrum in this energy range and discuss contributions from the charge puddles and thermally activated free carriers.

[1] Borgwardt et al., Phys. Rev. B 93, 245149 (2016).

HL 11.8 Mon 17:00 A 151

Topological design applied to the control of acoustic phonons — •Martin Esmann, Omar Ortiz, Fabrice R. Lamberti, Pascale Senellart, Aristide Lemaitre, and Daniel Lanzillotti-Kimura — CNRS Centre de Nanosciences et de Nanotechnologies (C2N), 91460 Marcoussis, France

The control and manipulation of acoustic phonons in the GHz-THz range appears as a new resource in the engineering of nanodevices. Here, we introduce the use of spatial mode symmetries of Bloch modes in a semiconductor superlattice to confine and control the propagation of phonons. We generate confined topological modes that are described by topological invariants and a topological transition upon band gap inversion [1]. This topological interface state between two finite size superlattices of different topology is a concept readily extendable to 3D in micropillars [2,3].

We experimentally evidence such a topologically confined nanophononic interface state in a planar structure both by coherent phonon generation (pump-probe) measurements and high resolution Raman scattering spectroscopy. Nanophononic topological interface states like the ones presented here could be at the base of developing single phonon sources, phononic sensors and phonon lasers, whose optical counterparts all led to key advances in applied photonics.

[1] M. Xiao et al., Phys. Rev. X 4, 021017 (2014).
[2] F. R. Lamberti et al., Opt. Express 25, 24437-24447 (2017).
[3] M. Esmann et al., submitted (2017).

HL 11.9 Mon 17:15 A 151

Low-dimensional topological Josephson junctions on selectively grown topological insulator nanoribbons — •Tobias W. Schmitt[1], Daniel Rosenbach[1], Peter Schüffelgen[1], Michael Schleenvoigt[1], Abdur R. Jalil[1], Chuan Li[2], Gregor Mussler[1], Stefan Trellenkamp[1], Alexander Brinkman[2], Detlev Grützmacher[1], and Thomas Schäpers[1] — [1]Peter Grünberg Institute 9, Forschungszentrum Jülich & JARA-FIT, 52425 Jülich, Germany — [2]MESA+ Institute for Nanotechnology, University of Twente, 7500 AE Enschede, The Netherlands

At the interface of a topological insulator and a s-wave superconductor, exotic Majorana modes are predicted to arise. In lateral topological Josephson junctions comprised of two superconducting leads on top of a topological insulator thin film, possible Majorana assisted transport is expected to occur in addition to conventional Andreev bound states. The latter superimpose the indications of Majorana excitations in Shapiro response measurements and make their detection more difficult. As the number of conventional Andreev bound states depends on the total number of conducting modes, their impact can be reduced in low-dimensional Josephson junctions. In our recent work, we focus on the realization of low-dimensional topological Josephson junctions by (I) selectively depositing TI nanoribbons of reduced width and (II) increasing of the Fermi wavelength by adjusting the Fermi level to the Dirac point of the linear disperse surface states. Such junctions have been prepared and characterized electrically at low temperatures, including their Fraunhofer diffraction pattern and their Shapiro response.