O 122: Topology and Symmetry Protected Materials II

Time: Friday 10:30–13:00 Location: WIL A317

O 122.1 Fri 10:30 WIL A317

Coupling of topologically protected edge states on the TCI (Pb,Sn)Se(001) — •Johannes Jung, Robin Boshuis, Artem Odobesko, and Matthias Bode — Physikalisches Institut, Lehrstuhl für Experimentelle Physik II, Universität Würzburg, Am Hubland, 97074, Würzburg, Germany

In a recent publication [1] we reported on the existence of one-dimensional (1D) edge states at odd step edges of the (001) surface of the topological crystalline insulator (Pb,Sn)Se, which were found to be extraordinarily robust against high temperatures and magnetic fields. It was also observed, that the edge states vanish if two steps merge into each other. In this contribution we present a systematic STM and STS study of converging, wedge-shaped step edges. Our results elucidate a distance-dependent coupling between adjacent 1D edge states. Three regimes with qualitatively different electronic structures are found: (i) At step–step distances larger than about 20 nm the tunneling spectrum of either step features a single peak at the Dirac point, which—within our signal-to-noise level—is indistinguishable from individual 1D edge state. In contrast, (ii) wherever the inter-step distance decreases below this value, we observe a splitting into a double peak. (iii) As the distance decreases below a critical limit of about 5 to 10 nm, the double peak vanishes and the 2D surface spectra remains. The results will be discussed in terms of the crystal structure and the symmetry at odd step edges.

[1] P. Sessi *et al.*, Science **354**, 1269 (2016).

O 122.2 Fri 10:45 WIL A317

Topological transport quantization by dissipation in fast Thouless pumps — •Zlata Fedorova, Haixin Qiu, Stefan Linden, and Johann Kroha — Physikalisches Institut, Rheinische Friedrich-Wilhelms-Universität Bonn, Nussallee 12, 53115 Bonn, Germany.

Quantized particle pumping in a slowly varying one-dimensional potential has played a prominent role in the development of topology as a concept in condensed matter physics. In the adiabatic regime, the net particle transfer per pumping cycle is an integer given by the Chern number, i.e., a topological invariant, and therefore is robust against topology-preserving perturbations. However, at finite driving frequencies the system becomes topologically trivial due to the coupling between forward- and backward-propagating states. As a result, the particle transport deviates from perfect quantization, which poses a problem for the experimental observation of Thouless pumping. Here, on the example of the driven Rice-Mele model we introduce time-periodic modulation of dissipation as a new concept to overcome this problem. The basic idea is to selectively suppress transport in one direction, while allowing it in another by making use of the distinct spatial and temporal amplitude distributions of the eigenstates moving in the corresponding directions. Restoration of quantized pumping under such periodic losses is confirmed by the Floquet analysis and by the experiments based on plasmonic waveguide arrays.

O 122.3 Fri 11:00 WIL A317

First-principles investigation of strained Weyl semimetals — •Yangjun Lee[1,2,3] and Cheol-Hwan Park[1,2,3] — [1]Department of Physics and Astronomy, Seoul National University, Seoul 08826, Korea — [2]Center for Correlated Electron Systems, Institute for Basic Science, Seoul 08826, Korea — [3]Center for Theoretical Physics, Seoul National University, Seoul 08826, Korea

A Weyl semimetal is characterized by pairs of Weyl points, which are topologically protected band degeneracies. Weyl semimetals host interesting phenomena such as Fermi arc surface states and chiral anomaly. There have been fascinating theoretical studies on strained Weyl semimetals, e.g., Refs. [1-3]. In this talk, we present the results of our first-principles calculations on the electronic structure of strained Weyl semimetals. From these results, we provide some of the relevant materials parameters related to the electron-phonon coupling in Weyl semimetals.

[1] Cortijo, Alberto, et al, Physical Review B 94.24 (2016): 241405. [2] Arjona, Vicente, and María AH Vozmediano, Physical Review B 97.20 (2018): 201404. [3] Chernodub, M. N., and María AH Vozmediano, arXiv preprint arXiv:1904.09113 (2019).

O 122.4 Fri 11:15 WIL A317

Dichroic spin- and angle-resolved soft X-ray photoemission on a Weyl semimetal TaAs — •Maximilian Ünzelmann[1], Tim Figgemeier[1], Philipp Eck[2], Matthias Kalläne[3], Kai Rossnagel[3,4], Domenico Di Sante[2], Giorgio Sangiovanni[2], Hendrik Bentmann[1], and Friedrich Reinert[1] — [1]Experimentelle Physik 7, Universität Würzburg — [2]Theoretische Physik 1, Universität Würzburg — [3]Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel — [4]Deutsches Elektronen-Synchrotron DESY

The interplay of inversion symmetry breaking (ISB) and spin-orbit coupling (SOC) lifts the spin degeneracy of electronic states in solids. In Weyl semimetals (WSM) structural ISB leads to spin-splittings in their bulk band structure, a key requirement for the formation of topologically protected Weyl points. Here we use angle-resolved soft x-ray photoemission to study the bulk electronic structure of the paradigmatic WSM TaAs. By means of spin-resolved measurements, we directly demonstrate the expected spin-splitting of the bulk bands. Moreover, circular dichroic measurements are in excellent agreement with the calculated momentum dependent orbital angular momentum (OAM). In contrast to spin angular momentum (SAM), OAM shows a parallel alignment in the spin-split states. This behavior is expected in materials where the characteristic energy scale of the ISB dominates over SOC [1,2].

[1] V. Sunko et al., Nature 549, 492 (2017), [2] J.-H. Park et al., Phys. Rev. B 85, 195401 (2012)

O 122.5 Fri 11:30 WIL A317

Terahertz driven nonequilibrium dynamics of Dirac fermions in Cd_3As_2 — •Semyon Germanskiy, Chris Reinhoffer, Paul H. M. van Loosdrecht, and Zhe Wang — Institute of Physics II, University of Cologne, 50937 Cologne, Germany

Cd_3As_2 is a well-established three-dimensional Dirac semimetal material with intriguing non-linear and nonequilibrium dynamical properties. By using intense terahertz pump pulses, we study the driven dynamics of Dirac fermions in Cd_3As_2 with various probe techniques. Particularly, we observe a very efficient generation of terahertz high-order harmonics, which reflects the unconventional nonequilibrium dynamical properties and is associated with the characteristic linear dispersion relation of the Dirac fermions.

O 122.6 Fri 11:45 WIL A317

Fermi arc transport in nanowires of Dirac and Weyl semimetals — •Pavlo Sukhachov[1], Mykhailo Rakov[2], Olena Teslyk[3], and Eduard Gorbar[3,4] — [1]Nordita, KTH Royal Institute of Technology and Stockholm University, Roslagstullsbacken 23, SE-106 91 Stockholm, Sweden — [2]Institut für Mathematische Physik, Technische Universität Braunschweig, Mendelssohnstraße 3, 38106 Braunschweig, Germany — [3]Faculty of Physics, Kyiv National Taras Shevchenko University, 64/13 Volodymyrska st., 01601 Kyiv, Ukraine — [4]Bogolyubov Institute for Theoretical Physics, 03680 Kyiv, Ukraine

The electron states and transport properties in cylinder nanowires of topological Dirac and Weyl semimetals are investigated. The presence of the Fermi arc surface states makes the electric charge and current density distributions in nanowires strongly nonuniform. By using the Kubo linear response approach, both direct and alternating current conductivities are calculated and it is found that their spatial profiles are nontrivial. By explicitly separating the contributions of the surface and bulk states, it is shown that when the electric chemical potential is small, the conductivity is determined primarily by the Fermi arcs and is much higher at the surface than in the bulk of the wire. Due to the rise of the surface-bulk transition rate, the relative contribution of the surface states to the total conductivity gradually diminishes with the increase of the chemical potential and the frequency. A nontrivial spatial profile of the conductivity in the case of the alternating current response might allow for a novel Fermi arc skin effect, where the localization is significantly enhanced.

O 122.7 Fri 12:00 WIL A317

Probing non-trivial topology at Weyl nodes by dichroic photoemission — •Hendrik Bentmann[1], Maximilian Ünzelmann[1], Tim Figgemeier[1], Philipp Eck[2], Chul Hee Min[3], Jeniffer Neu[4], Theo Siegrist[4], Domenico Di Sante[2], Giorgio Sangiovanni[2], and Friedrich Reinert[1] — [1]Experimentelle Physik VII and Würzburg-Dresden Cluster of Excellence ct.qmat, Universität Würzburg — [2]Theoretische Physik I and and Würzburg-Dresden Cluster of Excellence ct.qmat, Universität Würzburg — [3]Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel — [4]National High Magnetic Field Laboratory, Tallahassee, USA

Weyl nodes are topologically protected intersections between nondegenerate bands and constitute the defining feature of Weyl semimetals. At these special points in momentum space the Bloch wave functions show a special behavior: in the bulk the Weyl nodes constitute monopoles of Berry flux and at the surface their projections define the termination points of Fermi-arc surface states. In this contribution we discuss how these effects can be addressed experimentally by use of dichroic angle-resolved photoemission spectroscopy (ARPES). In particular, we have studied the Weyl semimetal TaAs by VUV and soft X-ray ARPES to probe the surface and bulk electronic structure, respectively. Analyzing the linear and circular dichroism in comparison to first-principles calculations we observe direct indications of the topological behavior at the Weyl nodes [1]. [1] C. H. Min, HB, et al., Phys. Rev. Lett. 122, 116402 (2019).

O 122.8 Fri 12:15 WIL A317

Experimental observation and spin texture of a Dirac node arc in tetradymite topological metals — •Ji Dai[1,2], Emmanouil Frantzeskakis[1], Kuan-Wen Chen[3,4], Franck Fortuna[1], Taichi Okuda[5], François Bertran[6], Julien Rault[6], Patrick Le Fèvre[6], Ryan Baumbach[3,4], and Andrés Felipe Santander-Syro[1] — [1]CSNSM, Université Paris-Sud, Orsay, France — [2]Institute of Condensed Matter Physics, Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland — [3]National High Magnetic Field Laboratory, Florida State University, USA — [4]Department of Physics, Florida State University, USA — [5]Hiroshima Synchrotron Radiation Center, Hiroshima University, Higashi-Hrioshima, Japan — [6]Synchrotron SOLEIL, Gif-sur-Yvette, France

Topological metals of the tetradymite family M_2Te_2X (with M=Ti, Zr or Hf and X=P or As) have been recently proposed to possess multiple Dirac cones, different topological characteristics and a Dirac node arc [1-4]. Here we use spin- and angle-resolved photoemission spectroscopy to directly probe the electronic dispersion and -for the first time- the spin texture of the topological surface states in Hf_2Te_2P and Ti_2Te_2P. Our results confirm a persistent spin polarization of these states along a high symmetry direction of the Brillouin zone, thereby establishing the presence of a Dirac node arc, regardless of the weak (Hf_2Te_2P) or strong (Ti_2Te_2P) character of the topological invariant.

[1] H. Ji, et al., Physical Review B **93**, 045315 (2016).
[2] K.-W. Chen, et al., Physical Review B **97**, 165112 (2018).
[3] M. M. Hosen, et al., Nature Communication **9**, 3002 (2018).

O 122.9 Fri 12:30 WIL A317

Unconventional Surface Conductivity in Correlated Honeycomb Transition Metal Oxide Mott Insulators — •Thomas Dziuba[1], Máté Stark[1], Ina Pietsch[2], Philipp Gegenwart[2], and Martin Wenderoth[1] — [1]IV. Physikalisches Institut, Georg-August-Universität Göttingen, Germany — [2]Lehrstuhl für Experimentalphysik VI, Zentrum für Elektronische Korrelationen und Experimentalphysik, Universität Augsburg, Germany

The correlated honeycomb transition metal oxides attract large attention for the theoretical prospect of topological non-triviality as well as being a possible realization of the magnetic Kitaev exchange model. The Mott insulating sodium iridate Na_2IrO_3 is prototypical among these materials with the promising prospect to bridge the field of strongly correlated systems with topology [1]. By using home-built STM and STS combined with macroscopic conductivity measurements of freshly cleaved Na_2IrO_3 surfaces in UHV we measure the properties provided by the sample surface. We report on the rather unconventional linear-dispersion in-gap conductivity found by tunneling spectroscopy. The addressability of such states strongly depends on the electronic properties of the probe and local surface structures. We will further discuss the found conductivity of the Na_2IrO_3 surface in the light of macroscopic measurements, complementing previous (bulk) results [2].

References
[1] Phys. Rev. B 91, 041405(R) (2015)
[2] Phys. Rev. B 82, 064412 (2010)

O 122.10 Fri 12:45 WIL A317

MBE Growth of 3D Topological Insulators on Sapphire — •Christoph Ringkamp, Gregor Mussler, and Detlev Grützmacher — PGI-9, Forschungszentrum Jülich & JARA Jülich-Aachen Research Alliance, Germany

Topological insulators (TI) possess topologically protected, conducting surface states, which are predicted to show Majorana signatures in conjunction with superconductors (SC). A prerequisite for this is a high transparency between the TI and the SC, and that is why an in-situ fabrication of the TI/SC heterostructures is crucial. On Si(111) substrates, we have already established the selective area growth and a shadow mask technique to fabricate such heterostructures via molecular-beam epitaxy (MBE) [1]. However, one major problem in transport experiments still poses the impact of the Si substrate, as the Si/TI interface may serve as an additional conducting channel. Hence, we intend to grow the TI/SC heterostructures on sapphire, as it is a purely insulating substrate which may allow to investigate the topological properties of the TI films in transport experiments in more detail.

I will report on the MBE growth of Bi2Te3, Bi2Se3, Sb2Te3 and its alloys on sapphire substrates, and I will show a substantial reduction of crystal defects in the TI films on sapphire compared to Si(111). Furthermore, I will present first results of selective area growth of TIs on sapphire, using a combination of lithographically defined SiO2 and Si3N4 structures as a growth mask.

[1] Schüffelgen et al., Nature Nanotechnology 14, 825 (2019)