TT 55: Topology and Symmetry Protected Materials (joint session O/TT)

Time: Wednesday 15:00–17:45 Location: HL 001

TT 55.1 Wed 15:00 HL 001

Interaction Effects in a 1D Flat Band at a Topological Crystalline Step Edge — •Souvik Das[1], Glenn Wagner[2], Johannes Jung[3], Artem Odobesko[3], Felix Kuester[1], Florian Keller[3], Jedrzej Korczak[4], Andrzej Szczerbakow[5], Tomasz Story[4], Ronny Thomale[6], Titus Neupert[2], Matthias Bode[3], Paolo Sessi[1], and Stuart S. P. Parkin[1] — [1]Max Planck Institute of Microstructure Physics, Halle 06120,Germany — [2]Department of Physics, University of Zürich, 8057 Zürich, Switzerland — [3]Physikalisches Institut, Experimentelle Physik II, Universität Würzburg, 97074 Würzburg, Germany — [4]Institute of Physics and International Research Centre MagTop, Institute of Physics, Polish Academy of Sciences, 02-668 Warsaw, Poland — [5]Institute of Physics, Polish Academy of Sciences, 02-668 Warsaw, Poland — [6]Institut für Theoretische Physik und Astrophysik Universität Würzburg, 97074 Würzburg, Germany

We utilize scanning tunneling microscopy and spectroscopy to explore the behavior of the 1D step-edge channels in PbSnSe, a topological crystalline insulator, under the influence of doping. By doping distinct 3d adatoms in PbSnSe we observed that once the energy position of the step edge is brought close to the Fermi level, a new correlation gap starts to open. Our experimental findings are rationalized in terms of enhanced interaction effects since the electron density of states condenses into a 1D channel. This enables us to realize a unique system to study how topology and many-body electronic effects intertwine.

TT 55.2 Wed 15:15 HL 001

Quantifying the Electronic Structure of at the Boundary of Topological Insulators by Means of Combined STM and AFM — •Christoph S. Setescak[1], Adrian Weindl[1], Andrea Donarini[2], and Franz J. Giessibl[1] — [1]Institute of Experimental and Applied Physics, University of Regensburg, Universitätstraße 31, 93080 Regensburg, Germany — [2]Institute of Theoretical Physics, University of Regensburg, Universitätstraße 31, 93080 Regensburg, Germany

We show that combined STM and AFM can characterize the surface electronic structure of topological insulators in the Bi2Se3-family. The electronic structure is described by an effective tight-binding Hamiltonian, which is derived from a GW-DFT calculation. A circumspect application of Bardeens model of tunneling current enables us to rigorously interpret tunneling spectroscopy experiments and thus identify characteristic points in the halfspace bandstructure. Furthermore, our experiments demonstrate, that spatially resolved maps of the local density of states can resolve individual electronic degrees of freedom energetically as well as spatially. We observed quasiparticle interference in the topological boundary mode of Bi2Te3 at one-dimensional defects, which enables us to quantify subtle hexagonal warping terms in the dispersion relation of the boundary mode. Our recent measurements, in combination with the ability to structurally characterize defects and the crystal structure at the picometer scale, underscore the potential of combined AFM and STM in exploring the evolution of topological phases amidst varying degrees of disorder.

TT 55.3 Wed 15:30 HL 001

Discovery of Segmented Fermi Surface — •Hao Zheng — Shanghai Jiao Tong University, Shanghai, China

Since the early days of Bardeen-Cooper-Schrieffer theory, it has been predicted that a sufficiently large supercurrent can close the energy gap in a superconductor and create gapless Bogoliubov quasiparticles through the Doppler shift of quasiparticle energy due to the Cooper pair momentum[1]. In this gapless superconducting state, zero-energy quasiparticles reside on a segment of the normal state Fermi surface, while its remaining part is still gapped. However, the segmented Fermi surface of a finite-momentum state carrying a supercurrent has never been detected directly. We use quasiparticle interference (QPI) technique to image field-controlled Fermi surface of Bi2Te3 thin films proximitized by the superconductor NbSe2. By applying a small in-plane magnetic field, a screening supercurrent is induced which leads to finite-momentum pairing on topological surface states of Bi2Te3[2]. Our measurements and analysis reveal the strong impact of finite Cooper pair momentum on the quasiparticle spectrum, and thus pave the way for STM study of pair density wave and FFLO states in unconventional superconductors. [1] Phys. Rev. 137, A783-A787 (1965) [2] Science 374, 1381-1385(2021)

TT 55.4 Wed 15:45 HL 001

Carrier Injection Observed by Interface-Enhanced Raman Scattering from Topological Insulators on Gold Substrates. — Sarah Scheitz, Tomke Eva Glier, Christian Nweze, •Malte Felix van Heek, Isa Moch, Robert Zierold, Robert Blick, Nils Huse, and Michael Rübhausen — Institute of Nanostructure and Solid-State Physics, University of Hamburg, Hamburg, 22761, Germany

The electron-phonon interaction at the interface between topological insulator (TI) of bismuth/tellurium and gold substrate as a function of TI nanoflakes thickness is studied with a sub-micron Raman spectroscopy. We show the presence of interface-enhanced Raman Scattering and strong phonon renormalization induced by carriers injected from the gold substrate into the topological surface in contact with the gold substrate. The associated electron-phonon coupling shows an approximate linear behavior as function of nanoflake thickness. The strongly nonlinear change of the Raman scattering cross-section as a function of flake thickness can be associated with band bending effects at the metal-TI interface. This provides spectroscopic evidence for strongly modified band structure in the first few quintuple layers of bismuth selenide and tellurium selenide TI.

TT 55.5 Wed 16:00 HL 001

Plasmonic Hot carrier Injection from Single Gold Nanoparticles into Topological Insulator (Bi_2Se_3) Nanoribbons — Christian Nweze[1], Tomke Eva Glier[1], •Mika Rerrer[1], Sarah Scheitz[1], Yalan Huang[2], Robert Zierold[2], Robert Blick[2], Wolfgang Parak[2], Nils Huse[2], and Michael Rübhausen[1] — [1]Institut für Nanostruktur- und Festkörperphysik, Centre for Free Electron Laser Science (CFEL), Universität Hamburg, Luruper Chaussee 149, 22761, Hamburg, Germany — [2]Institut für Nanostruktur- und Festkörperphysik, Centre for Hybrid Nanostructures (CHyN), Universität Hamburg, Luruper Chaussee 149, 22761, Hamburg, Germany

Plasmonic gold nanoparticles (AuNP) injecting hot carriers (HC) into the topological insulator (TI) are studied with sub-micron spatially resolved Raman spectroscopy. We study the impact of single AuNP with sizes between 40 nm–140 nm on the topological surface states of single nanoribbons. In resonance at 633 nm excitation wavelength, we find phonon renormalization in the E_g^2- and A_{1g}^2- modes that we attribute to plasmonic hot carrier injection filling the Dirac cone of the Bi_2Se_3 TI. The phonon modes are enhanced by a factor of 350 when tuning the excitation wavelengths into interband transition of the Bi_2Se_3 TI and in resonance with the localized surface plasmon of AuNP. AuNP size-dependent Raman studies show strongest HC injection for particles with a size of 108 nm in agreement with the resonance energy of the localized surface plasmons in AuNP. HC injection opens the opportunity to locally manipulate the electronic properties of the TI.

TT 55.6 Wed 16:15 HL 001

Phase-resolved near-field mapping of tight-binding lattices — •Hans-Joachim Schill, Anna Sidorenko, and Stefan Linden — Physikalisches Institut, Universität Bonn, D-53115-Bonn, Germany

The propagation of light in coupled arrays of dielectric loaded surface plasmon polariton waveguides (DLSPPWs) closely resembles the dynamics of a lattice Schrödinger equation, making it an excellent platform for simulating condensed matter lattice systems. The real and momentum space intensity distributions can be simply recorded by leakage radiation microscopy. In order to also capture the local near-field amplitude and phase with sub-wavelength resolution, we employ scattering-type scanning near-field optical microscopy in transmission mode. As an example, to discuss the capabilities of this dual-technique approach, we investigate the topological edge state in a plasmonic variant of the Su-Schrieffer-Heeger model. The topological nature of this state has been shown previously by spectral imaging of the edge mode residing in the band gap [1], but the characteristic electric field oscillation remained elusive, until now.

[1] F. Bleckmann, Z. Cherpakova (Fedorova), S. Linden and A. Alberti, "Spectral imaging of topological edge states in plasmonic waveg-

uide arrays", Phys. Rev. B 96, 045417 (2017)

TT 55.7 Wed 16:30 HL 001

The Trimer Chain: Robust Chiral Edge Mode in Artificial Electronic Lattices — •Rian Ligthart[1], Amber Visser[1], Dario Bercioux[2], and Ingmar Swart[1] — [1]Debye Institute for Nanomaterials Science, Utrecht University, the Netherlands — [2]Donostia International Physics Center, 20018 Donostia-San Sebastian, Spain

Artificial electronic lattices are a promising tool to study topology on an atomic scale. The Scanning Tunnelling Microscope (STM) allows to build the topological lattices by manipulating single atoms with nanoscale precision and to probe their electronic properties. Here, the semiconductor InAs(111)A surface with adsorbed Cs atoms is studied. Vertical and lateral manipulation allow to place multiple Cs-adatoms in vicinity of each other. Lines of positively charged Cs atoms create a potential well that confines the surface state electrons of InAs due to local band bending. The confined state acts as an artificial atom and can be used to construct a variety of structures. [1]

Artificial atoms can therefore be used as a platform to study the topological properties of model systems such as the SSH [2] and trimer chain. The trimer chain is similar to the SSH chain but has an extra atom in its unit cell. The extra hopping term introduces an extra degree of freedom in the system allowing to separate the the edge modes on the left and right side of the chain in energy. The trimer chain can therefore host a robust chiral edge mode on one side of the chain.

[1] E. Sierda, et al. Science 380, 1048-1052(2023)
[2] Van Dong Pham, et al. Phys. Rev. B, 105, 125418

TT 55.8 Wed 16:45 HL 001

Manipulating Sunken Adatoms on Topological Insulator Bi_2Se_3 — Emma Grasser, •Adrian Weindl, Alfred J. Weymouth, and Franz J. Giessibl — Faculty of Physics, University of Regensburg, D-93053 Regensburg, Germany

Topological insulators (TIs) are a class of materials whose bulk is insulating, while their surface houses gapless topological boundary modes. These surface states possess a linear, spin-polarized dispersion relation and are thus protected from back-scattering by time-reversal symmetry. An open question remains whether surface doping of magnetic elements can suppress this topological protection. Nanostructures made from magnetic adatoms are proposed to enhance the magnetic scattering and may enable the observation of backscattering and the emergence of exotic quantum well states on the surfaces of topological insulators.

To this end, we study the manipulation characteristics of Fe adatoms on the surface of topological insulator Bi_2Se_3 with atomic force microscopy (AFM). The Fe adatoms adsorb in a sunken position in both hollow sites, rendering manipulation difficult. Nonetheless, we find a manipulation mechanism where the Fe atom is pulled from its sunken adsorption site towards the tip. We propose that the Fe atom develops a chemical bond to the probe tip while still bound to the surface as well. This state is stable for tip-sample distances of up to several hundreds of pm and can be used for controlled lateral manipulation. We demonstrate the controllability of manipulation by the construction of a small nanostructure.

TT 55.9 Wed 17:00 HL 001

Giant tunable out-of-plane spin polarization in topological antimonene — •Polina Sheverdyaeva[1], Conor Hogan[2,3], Gustav Bihlmayer[4], Jun Fujii[5], Ivana Vobornik[5], Matteo Jugovac[1,6], Asish K. Kundu[1,7], Sandra Gardonio[8], Zipporah Rini Benher[8], Giovanni Di Santo[9], Sara Gonzalez[9], Luca Petaccia[9], Carlo Carbone[1], and Paolo Moras[1] — [1]ISM-CNR, Trieste, Italy — [2]ISM-CNR, Roma, Italy — [3]Dipartimento di Fisica, Università di Roma "Tor Vergata", Roma, Italy — [4]PGI and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, Jülich, Germany — [5]IOM-CNR, Trieste, Italy — [6]PGI, Forschungszentrum Jülich, Jülich, Germany — [7]ICTP, Trieste, Italy — [8]University of Nova Gorica, Ajdovščina, Slovenia — [9]Elettra - Sincrotrone Trieste S.C.p.A.,Trieste, Italy

We show first-principles calculations and angle- and spin- resolved photoemission studies of a heterointerface built of a single bilayer of β-antimonene and a bulk bismuth selenide. The trivial insulator β-antimonene inherits the topological surface state of the substrate as a result of a topological proximity effect. The new topological state exhibits an unusually high, almost complete out-of-plane spin polarization within the substrate gap, that we explain by a symmetry-protected band crossing of spin-polarized surface states. The spin polarization can be finely and reversibly tuned from nearly full out-of-plane to nearly full in-plane by electron doping. Our findings pave the way towards advanced spintronics applications exploiting the giant out-of-plane spin polarization of topological surface states.

TT 55.10 Wed 17:15 HL 001

Orbital-momentum locking in chiral topological semimetal CoSi — •Stefanie Suzanne Brinkman[1], Xin Liang Tan[1,2], Øyvind Finnseth[1], Anders Christian Mathisen[1], Ying-Jiun Chen[2], Christian Tusche[2], and Hendrik Bentmann[1] — [1]Center for Quantum Spintronics, Department of Physics, NTNU, Norway — [2]Forschungszentrum Jülich, Peter Grünberg Institut, Jülich, Germany

The chiral topological semimetal CoSi has a rich electronic structure in which unconventional chiral fermions and long surface Fermi arcs are observed near the Fermi level [1]. We studied the bulk electronic structure in CoSi using soft X-ray angle-resolved photoemission (ARPES) experiments via the ASPHERE endstation at PETRA III (DESY, Hamburg). We investigated the orbital character of the electronic states using circular dichroism in ARPES. Our results reveal the effect of the chiral crystal symmetry on the orbital structure in momentum space, and provide evidence of orbital-momentum locking as recently theoretically predicted [2]. This chirality-driven orbital texture with an accompanying large orbital Hall effect [2] paves the way towards applications of topological semimetals in spin- and orbitronics.

[1] Rao, Z. et al. Observation of unconventional chiral fermions with long Fermi arcs in CoSi. Nature 567, 496-499 (2019).
[2] Yang, Qun et al. Monopole-like orbital-momentum locking and the induced orbital transport in topological chiral semimetals. PNAS 120, 48 (2023).

TT 55.11 Wed 17:30 HL 001

Boundary-induced delocalization of vortices in the topological superconductor — •Qiao-Yan Yu — Shanghai Jiao Tong University, Shanghai, China

Planar defects are predicted to induce a delocalization of Abrikosov vortices in superconductors. These delocalized vortices are perturbated by the supercurrent and thus might carry a fraction of a flux quantum. In this work, we constructed a topological superconductor heterostructure by growing Bi2Te3 thin films with molecular beam epitaxy on the superconductor NbSe2. We reveal that the domain boundary induced partial spatial distribution of vortex and screened in-gap bound states within the vortex which crossing the boundary. Our results show the signature of impact of domain boundary on the Majorana zero mode.