O 4: Topology and Symmetry-Protected Materials

Time: Monday 10:30–11:30 Location: H6

O 4.1 Mon 10:30 H6

Tracing a Weyl Nodal Line in 3D-k-space via ARPES — •Tim Figgemeier[1], Maximilian Ünzelmann[1], Philipp Eck[2], Jakub Schusser[1], Jennifer Neu[3,4], Theo Siegrist[3,5], Domenico Di Sante[6], Giorgio Sangiovanni[2], Hendrik Bentmann[1] und Friedrich Reinert[1] — [1]EP VII, Universität Würzburg, Germany — [2]TP I, Universität Würzburg, Germany — [3]NHMFL, Tallahassee, FL, US — [4]Nuclear Nonproliferation Division, ORNL, Oak Ridge, Tennessee 37831, US — [5]FAMU-FSU, Tallahassee, FL, US — [6]Center for Computational Quantum Physics, Flatiron Institute, New York 10010, US

In contrast to the more conventional Dirac nodal lines, Weyl nodal lines (WNL) are only twofold-degenerate and this degeneracy is robust against strong spin-orbit coupling [1]. The occurance of WNL is guaranteed by the combination of a glide plane and time-reversal symmetry (TRS).

In this talk we will present a soft x-ray angle-resolved photoemission (ARPES) study where we will trace a WNL in 3D k-space throughout the Brillouinzone over a wide range of photon energies. The experimental results are compared to density functional and photoemission calculations. By utilizing dichroic ARPES experiments, we will moreover address the characteristics of the electronic wave functions around the WNL.

[1] M. Hirschmann et al.; Symmetry-enforced band crossings in tetragonal materials: Dirac and Weyl degeneracies on points, lines, and planes; Phys. Rev. Mat **5**; 054202 (2021)

O 4.2 Mon 10:45 H6

Momentum space signatures of Berry flux monopoles in a Weyl semimetal — •Maximilian Ünzelmann[1,3], Tim Figgemeier[1,3], Philipp Eck[2,3], Begmuhammet Geldiyev[1,3], Domenico Di Sante[2,3], Giorgio Sangiovanni[2,3], Hendrik Bentmann[1,3], and Friedrich Reinert[1,3] — [1]Experimentelle Physik 7, Universität Würzburg — [2]Theoretische Physik 1, Universität Würzburg — [3]Würzburg-Dresden Cluster of Excellence ct.qmat

An intriguing property of Weyl semimetals (WSM) is that they feature topologically protected crossings of the spin-polarized valence and conduction bands in their three-dimensional bulk band structure. These crossing points – the Weyl points (WP) – can be considered as 'magnetic' monopoles, which, however, are not located in real space but rather in momentum space. The topological (monopole) character manifests itself in the momentum-dependence of the electronic wave functions, which is investigated in the paradigmatic WSM TaAs, using bulk-sensitive soft X-ray angle-resolved photoelectron spectroscopy combined with spin-resolved measurements and circular dichroism (CD) [1]. The latter addresses the local orbital angular momentum (OAM), which exhibits a non-trivial winding around the WP, similar to the Berry curvature, i.e., the k-space magnetic field. The momentum-dependent modulation of the OAM around the WP – observed in density functional theory calculations and CD-ARPES – thus denotes a direct signature for the Berry flux monopoles in TaAs.

[1] M. Ünzelmann et al., Nat. Commun., 12, 3650 (2021)

O 4.3 Mon 11:00 H6

Lifting the Spin-Momentum Locking in Ultra-Thin Topological Insulator Films — Arthur Leis[1], Jonathan Hofmann[1], Michael Schleenvoigt[2], Vasily Cherepanov[1], Felix Lüpke[1], Peter Schüffelgen[2], Gregor Mussler[2], Detlev Grützmacher[2], •Bert Voigtländer[1], and F. Stefan Tautz[1] — [1]Peter Grünberg Institut (PGI-3), Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Peter Grünberg Institut (PGI-9), Forschungszentrum Jülich, 52425 Jülich, Germany

3D topological insulators are known to carry 2D Dirac-like topological surface states in which spin-momentum locking prohibits backscattering. When thinned down to a few nanometers, the hybridization between the topological surface states at the top and bottom surfaces results in a topological quantum phase transition, which can lead to the emergence of a quantum spin Hall phase. Here, the thickness-dependent transport properties are studied on the example of BiSbTe3 films, with a four-tip scanning tunneling microscope. The findings reveal an exponential drop of the conductivity below the critical thickness. The steepness of this drop indicates the presence of spin-conserving backscattering between the top and bottom surface states, effectively lifting the spin-momentum locking and resulting in the opening of a gap at the Dirac point. Moreover, we probe the edge state conductance these films. The experiments provide a crucial step toward the detection of quantum spin Hall states in transport measurements.

O 4.4 Mon 11:15 H6

Simultaneous AFM and STM measurements of native point Defects in the topological insulator Bi_2Se_3 — •Christoph Setescak, Alexander Liebig, Adrian Weindl, and Franz J. Giessibl — Institute of Experimental and Applied Physics, University of Regensburg, Regensburg, Germany

The main properties of topological insulators (TIs) can be derived from the fact that their band structure is "twisted" compared to normal insulators, leading to the creation of gapless states at the surface. To observe these states and make them viable for application in novel technologies it is crucial that the materials delicate electronic structure is not disturbed by defects. So far, experimental characterization of the native point defects relies on scanning tunneling microscopy (STM) and accompanying density functional theory [1]. Here, we present simultaneous atomic force microscopy (AFM) and STM measurements of surface and subsurface defects in Bi_2Se_3. We find not only rarely-observed single Se surface vacancies, but also larger defects that are composed of multiple surface vacancies. The AFM channel furthermore allows us to determine the relative relaxation of surface atoms in proximity of subsurface defects and to determine the polarity of surface defects by means of Kelvin probe force spectroscopy. This is especially valuable as surface Se vacancies contribute to unwanted charge doping of the TI. [1] J. Dai et al., PRL 117, 106401 (2016)