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14. ABSTRACT

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as of 25-Jul-2022

Agency Code: 21XD

Proposal Number: 73094ELYIP **Agreement Number: W911NF-18-1-0198**
INVESTIGATOR(S):

Name: Cui-Zu Chang
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Principal: Y

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Country: USA
DUNS Number: 003403953 EIN: 246000376

Report Date: 31-Mar-2022 Date Received: 22-Jul-2022
Final Report for Period Beginning 05-Jun-2018 and Ending 31-Dec-2021
Title: In Pursuit of High Temperature Quantum Anomalous Hall State
Begin Performance Period: 05-Jun-2018 **End Performance Period:** 31-Dec-2021
Report Term: 0-Other

Submitted By: Cui-Zu Chang Email: cxc955@psu.edu
Phone: (814) 863-9860

STEM Degrees: 0 **STEM Participants:**

Major Goals: The major goal of this project is to realize the high-temperature quantum anomalous Hall (QAH) state in the topological insulator(TI)/ferromagnetic insulator (e.g. (Bi,Sb)2Te3/TIG) and TI/antiferromagnetic insulator (e.g. (Bi,Sb)2Te3/Cr2O3) heterostructures. More recently, we are also exploring the high-temperature QAH/Chern insulator states in the molecular beam epitaxy(MBE)-grown MnBi2Te4 films/heterostructures.

Accomplishments: During the funding period (06/05/2020-12/31/2021), We have published 19 high-profile papers, including 1 Nature, 1 Science, 2 Nature Materials, 2 Nature Communications, 12 Physical Review Letters, and 4 Nano Letters.
Highlighted important progress:
(1) We successfully fabricated the magnetic TI (Cr doped Sb2Te3) film on AFM Cr2O3 heterostructures and observed the crossover from the positive to negative exchange bias effect under different cooling fields. This observation demonstrated the AFM interfacial coupling between the surface spins of the magnetic TI and Cr2O3 layer. (Wang et al, Nano Lett. 19, 2945-2952 (2019)) (Primary support).
(2) We performed dilution transport measurements on our magnetic TI sandwich samples (i.e. 3QL V-doped TI/5 QL TI/3QL Cr-doped TI). We found that the temperature dependence of the derivative of the longitudinal resistance on the magnetic field at the transition point follows a characteristic power law. This observation indicates a universal scaling behavior for the QAH to axion insulator phase transition. Similar to the quantum Hall plateau to plateau transition, the QAH to axion insulator transition can be understood by the Chalker-Coddington network model. This confirms these two quantum phase transitions are in the same universality class. We extract a critical exponent ???~ 0.38±0.02 in agreement with recent high-precision numerical results on the correlation length exponent of the Chalker-Coddington model at ? ~ 2.6, rather than the generally accepted value of 2.33. (Wu et al, Nature Communications 11, 4532(2020)) (Primary support).
(3) Collaborating with Xiaodong Xu's group of the University of Washington and Yongtao Cui's group of University of California, Riverside, we fabricated the devices using the mechanically exfoliated MnBi2Te4 thin flakes. By combining microwave impedance microscopy, magnetic circular dichroism, bulk resistance, and Hall measurements, we visualize the band crossing accompanied by the change of Chern number in these MnBi2Te4 devices. We found that as the field drives the magnetic state from the layered antiferromagnetic to a canted antiferromagnetic, and eventually to the ferromagnetic states, a branch of the bulk conduction band splits off, crosses the bulk bandgap, and merges with the bulk valence band. We demonstrate that this band crossing corresponds to the occurrence of T-QPT from the C = 0 insulating state to the C = 1 Chern insulator state. (Ovchinnikov et al, Nano Letters 21, 2544-2550(2021)) (Primary support).

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Training Opportunities: This experiment project provides excellent training opportunities not only for the one graduate student (Yi-Fan Zhao) supported by this grant but also for other students and post-docs supported by other sources. In our weekly group meeting, two students (or post-docs) lead a discussion on either their research or on recent papers from other groups. This discussion provides an excellent opportunity for training the students to be good speakers.

Results Dissemination: All the research results are being written in papers and posted on arXiv and published or will be published in high-profile journals, as discussed above.

Honors and Awards: Rustum and Della Roy Innovation in Materials Research Award 2021
Henry W. Knerr Early Career Professorship 2021
Gordon and Betty Moore EPiQS Materials Synthesis Investigator ($1.7M funds) 2019-2024
Macronix Prize (Outstanding Chinese Young Researcher Award) 2019
National Science Foundation (NSF) CAREER Award 2019-2023
MIT Technology Review 35 Innovators Under 35 China 2018
Army Research Office (ARO) Young Investigator Program (YIP) Award 2018-2021
Alfred P. Sloan Research Fellowship 2018-2020

Protocol Activity Status:

Technology Transfer: Nothing to Report

PARTICIPANTS:

Participant Type: PD/PI
Participant: Cui-Zu Chang
Person Months Worked: 1.00 **Funding Support:**
Project Contribution:
National Academy Member: N

Participant Type: Graduate Student (research assistant)
Participant: Yi-Fan Zhao
Person Months Worked: 12.00 **Funding Support:**
Project Contribution:
National Academy Member: N

Participant Type: Postdoctoral (scholar, fellow or other postdoctoral position)
Participant: Fei Wang
Person Months Worked: 3.00 **Funding Support:**
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Publication Type: Journal Article Peer Reviewed: Y **Publication Status:** 1-Published
Journal: Physical Review B
Publication Identifier Type: DOI Publication Identifier: 10.1103/PhysRevB.98.094404
Volume: 98 Issue: 9 First Page #: 094404
Date Submitted: 8/14/19 12:00AM Date Published: 9/1/18 4:00AM
Publication Location:
Article Title: Unconventional planar Hall effect in exchange-coupled topological insulator–ferromagnetic insulator heterostructures
Authors: David Rakhmilevich, Fei Wang, Weiwei Zhao, Moses H. W. Chan, Jagadeesh S. Moodera, Chaoxing Liu
Keywords: topological insulator, magnetic insulator; magnetic proximity effect; planar Hall effect
Abstract: The Dirac electrons occupying the surface states (SSs) of topological insulators (TIs) have been predicted to exhibit many exciting magnetotransport phenomena. Here we report the experimental observation of an unconventional planar Hall effect (PHE) and a gate-tunable hysteretic planar magnetoresistance in EuS/TI heterostructures, in which EuS is a ferromagnetic insulator (FMI) with an in-plane magnetization. In such exchange-coupled FMI/TI heterostructures, we find a significant (suppressed) PHE when the in-plane magnetic field is parallel (perpendicular) to the electric current. This behavior differs from previous observations of the PHE in ferromagnets and semiconductors. Furthermore, as the thickness of the 3D TI films is reduced into the 2D limit, in which the Dirac SSs develop a hybridization gap, we find a suppression of the PHE around the charge-neutral point indicating the vital role of Dirac SSs in this phenomenon. To explain our findings, we outline a symmetry argument that
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Volume: 98 Issue: 11 First Page #: 115165
Date Submitted: 8/14/19 12:00AM Date Published: 9/1/18 12:00PM
Publication Location: United States
Article Title: Electronic fingerprints of Cr and V dopants in the topological insulator
Authors: Wenhan Zhang, Damien West, Seng Huat Lee, Yunsheng Qiu, Cui-Zu Chang, Jagadeesh S. Moodera,
Keywords: topological insulator, scanning tunneling microscopy; the quantum anomalous Hall effect
Abstract: By combining scanning tunneling microscopy/spectroscopy and first-principles calculations, we systematically study the local electronic states of magnetic dopants V and Cr in Sb2Te3. Spectroscopic imaging shows diverse local defect states between Cr and V, which agree with our first-principle calculations. The unique spectroscopic features of V and Cr dopants provide electronic fingerprints for the co-doped magnetic TI systems with enhanced QAH effect. Our results also open the door to the exploration of the mechanism of the enhanced QAH temperature in Cr/V co-doped TIs.
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Date Submitted: 8/14/19 12:00AM Date Published: 12/1/18 12:00AM
Publication Location: United States
Article Title: Signatures of long-range-correlated disorder in the magnetotransport of ultrathin topological insulators
Authors: D. Nandi, B. Skinner, G. H. Lee, K.-F. Huang, K. Shain, Cui-Zu Chang, Y. Ou, S.-P. Lee, J. Ward, J. S. I
Keywords: topological insulator; thin films; linear magneto-resistance; electrical transport
Abstract: In an ultrathin topological insulator (TI) film, a hybridization gap opens in the TI surface states, and the system is expected to become either a trivial insulator or a quantum spin Hall insulator when the chemical potential is within the hybridization gap. Here we show, however, that these insulating states are destroyed by the presence of a large and long-range-correlated disorder potential, which converts the expected insulator into a metal. We perform transport measurements in ultrathin dual-gated topological insulator films as a function of temperature, gate voltage, and magnetic field, and we observe a metalliclike nonquantized conductivity, which exhibits a weak antilocalizationlike cusp at low magnetic fields and gives way to a nonsaturating linear magnetoresistance at large fields.We explain these results by considering the disordered network of electron- and hole-type puddles induced by charged impurities. We argue theoretically that such disorder can produce an insulator-to
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Publication Identifier Type: DOI Publication Identifier: 10.1103/PhysRevB.99.064423
Volume: 99 Issue: 6 First Page #: 064423
Date Submitted: 8/14/19 12:00AM Date Published: 2/1/19 5:00AM
Publication Location: United States
Article Title: Do topology and ferromagnetism cooperate at the
Authors: J. A. Krieger, Y. Ou, M. Caputo, A. Chikina, M. Döbeli, M.-A. Husanu, I. Keren, T. Prokscha, A. Suter, C
Keywords: topological insulator; magnetic insulator; magnetic proximity effect
Abstract: We probe the local magnetic properties of interfaces between the insulating ferromagnet EuS and the topological insulator Bi2Se3 using low energy muon spin rotation (LE-?SR). We compare these to the interface between EuS and the topologically trivial metal, titanium. Below the magnetic transition of EuS, we detect strong local magnetic fields which extend several nm into the adjacent layer and cause a complete depolarization of the muons. However, in both Bi2Se3 and titanium we measure similar local magnetic fields, implying that their origin is mostly independent of the topological properties of the interface electronic states. In addition, we use resonant soft x-ray angle resolved photoemission spectroscopy (SX-ARPES) to probe the electronic band structure at the interface between EuS and Bi2Se3. By tuning the photon energy to the Eu antiresonance at the Eu M5 pre-edge we are able to detect the Bi2Se3 conduction band, through a protective Al2O3 capping layer andthe EuS layer.
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Volume: 5 Issue: 5 First Page #: eaaw3988
Date Submitted: 8/14/19 12:00AM Date Published: 5/1/19 4:00AM
Publication Location: United States
Article Title: Selective trapping of hexagonally warped topological surface states in a triangular quantum corral
Authors: Mu Chen, Ye-Ping Jiang, Junping Peng, Huimin Zhang, Cui-Zu Chang, Xiao Feng, Zhenguo Fu, Fawei Z
Keywords: topological insulator; surface states; scanning tunneling microscopy
Abstract: The surface of a three-dimensional topological insulator (TI) hosts two-dimensional massless Dirac fermions (DFs), the gapless and spin-helical nature of which leads to their high transmission through surface defects or potential barriers. Here, we report the behaviors of topological surface states (TSS) in a triangular quantum corral (TQC) which, unlike a circular corral, is supposed to be totally transparent for DFs. By real-space mapping of the electronic structure of TQCs, both the trapping and detrapping behaviors of the TSS are observed. The selection rules are found to be governed by the geometry and spin texture of the constant energy contour of TSS upon the strong hexagonal warping in Bi2Te3. Our work indicates the extended nature of TSS and elucidates the selection rules of the trapping of TSS in the presence of a complicated surface state structure, giving insights into the effective engineering of DFs in TIs.
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Journal: Nano Letters
Publication Identifier Type: DOI Publication Identifier: 10.1021/acs.nanolett.9b00027
Volume: 19 Issue: 5 First Page #: 2945
Date Submitted: 8/14/19 12:00AM Date Published: 4/1/19 4:00AM
Publication Location: United States
Article Title: Observation of Interfacial Antiferromagnetic Coupling between Magnetic Topological Insulator and Antiferromagnetic Insulator
Authors: Fei Wang, Di Xiao, Wei Yuan, Jue Jiang, Yi-Fan Zhao, Ling Zhang, Yunyan Yao, Wei Liu, Zhidong Zhar
Keywords: Topological insulators, antiferromagnetic insulators, exchange coupling effect, antiferromagnetic coupling, exchange bias effect
Abstract: Inducing magnetic orders in a topological insulator (TI) to break its time reversal symmetry has been predicted to reveal many exotic topological quantum phenomena. The manipulation of magnetic orders in a TI layer can play a key role in harnessing these quantum phenomena towards technological applications. Here we fabricated a thin magnetic TI film on an antiferromagnetic (AFM) insulator Cr2O3 layer and found that the magnetic moments of the magnetic TI layer and the surface spins of the Cr2O3 layers favor interfacial AFM coupling. Field cooling studies show a crossover from negative to positive exchange bias clarifying the competition between the interfacial AFM coupling energy and the Zeeman energy in the AFM insulator layer. The interfacial exchange coupling also enhances the Curie temperature of the magnetic TI layer. The unique interfacial AFM alignment in magnetic TI on AFM insulator heterostructures opens a new route toward manipulating the interplay between topological states
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Publication Identifier Type: DOI Publication Identifier: 10.1088/1361-6463/ab2fe8
Volume: 52 Issue: 40 First Page #: 404001
Date Submitted: 8/14/19 12:00AM Date Published: 10/1/19 4:00AM
Publication Location:
Article Title: Interfacial oxygen-octahedral-tilting-driven electrically tunable topological Hall effect in ultrathin SrRuO
Authors: Youdi Gu, Yi-Wen Wei, Kun Xu, Hongrui Zhang, Fei Wang, Fan Li, Muhammad Shahrukh Saleem, Cui-Z
Keywords: topological Hall effect; oxide film; Dzyaloshinskii–Moriya (DM) interaction
Abstract: Topological spin textures as an emerging class of topological matter offer a medium for information storage and processing. The recently discovered topological Hall effect (THE) is considered as a fingerprint for electrically probing the Dzyaloshinskii–Moriya (DM) interaction and corresponding non-trivial spin-textures. In this paper, the THE and its electrical control are observed in ultrathin (?8 unit cells. u.c.) 4D ferromagnetic SrRuO3 films grown on SrTiO3(0 0 1) substrates, indicating the existence of gate-bias-tunable DM interaction in the single SrRuO3 layer without contacting 5D oxide SrIrO3 layer. High-resolution lattice structure analysis revealed that the interfacial RuO6 octahedral tilting induced by local orthorhombic-to-tetragonal structural phase transition exists across the SrRuO3/SrTiO3 interface, which naturally breaks the inversion symmetry.
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Journal: Nature Materials
Publication Identifier Type: DOI Publication Identifier: 10.1038/s41563-019-0454-9
Volume: Issue: First Page #:
Date Submitted: 8/14/19 12:00AM Date Published: 8/1/19 4:00AM
Publication Location:
Article Title: Spin chirality fluctuation in two-dimensional ferromagnets with perpendicular magnetic anisotropy
Authors: Wenbo Wang, Matthew W. Daniels, Zhaoliang Liao, Yifan Zhao, Jun Wang, Gertjan Koster, Guus Rijnde
Keywords: 2D ferromagnet; magnetically doped topological insulator; topological Hall effect
Abstract: Non-coplanar spin textures with scalar spin chirality can generate an effective magnetic field that deflects the motion of charge carriers, resulting in a topological Hall effect (THE). However, spin chirality fluctuations in two-dimensional ferromagnets with perpendicular magnetic anisotropy have not been considered so far. Here, we report evidence of spin chirality fluctuations by probing the THE above the Curie temperature in two different ferromagnetic ultra-thin films, SrRuO3 and V-doped Sb2Te3. The temperature, magnetic field, thickness and carrier-type dependence of the THE signal, along with Monte Carlo simulations, suggest that spin chirality fluctuations are a common phenomenon in two-dimensional ferromagnets with perpendicular magnetic anisotropy. Our results open a path for exploring spin chirality with topological Hall transport in two-dimensional magnets and beyond.
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Date Submitted: 8/28/20 12:00AM Date Published: 1/3/20 5:00AM
Publication Location:
Article Title: Absence of evidence for chiral Majorana modes in quantum anomalous Hall-superconductor devices
Authors: Morteza Kayyalha, Di Xiao, Ruoxi Zhang, Jaeho Shin, Jue Jiang, Fei Wang, Yi-Fan Zhao, Run Xiao, Lin
Keywords: QAH insulator, chiral Majorana Fermion, superconducting proximity effect
Abstract: A quantum anomalous Hall (QAH) insulator coupled to an s-wave superconductor is predicted to harbor chiral Majorana fermions. A recent experiment interprets the half-quantized two-terminal conductance plateau as evidence for these excitations in a millimeter-size QAH-Nb hybrid device. However, non-Majorana mechanisms can also generate similar signatures, especially in disordered samples. Here, we studied similar hybrid devices with a well-controlled and transparent interface between the superconductor and the QAH insulator. When the devices are in the QAH state with well-aligned magnetization, the two-terminal conductance is always half-quantized. Our experiment provides a comprehensive understanding of the superconducting proximity effect observed in QAH-superconductor hybrid devices and shows that the half-quantized conductance plateau is unlikely to be induced by chiral Majorana fermions in samples with a highly transparent interface.
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Date Submitted: 8/28/20 12:00AM Date Published: 7/1/20 4:00AM
Publication Location:
Article Title: Concurrence of quantum anomalous Hall and topological Hall effects in magnetic topological insulator sandwich heterostructures
Authors: Jue Jiang, Di Xiao, Fei Wang, Jae-Ho Shin, Domenico Andreoli, Jianxiao Zhang, Run Xiao, Yi-Fan Zhac
Keywords: QAH effect, Topological Hall effect, Chiral domain wall
Abstract: The quantum anomalous Hall (QAH) effect is a consequence of non-zero Berry curvature in momentum-space. The QAH insulator harbors dissipation-free chiral edge states in the absence of an external magnetic field. On the other hand, the topological Hall (TH) effect, a hallmark of chiral spin textures, is a consequence of real-space Berry curvature. Here, by inserting a TI layer between two magnetic TI layers , we realized the concurrence of the TH effect and the QAH effect through electric field gating. The TH effect is probed by bulk carriers, while the QAH effect is characterized by chiral edge states. The appearance of TH effect in the QAH insulating regime is a consequence of chiral magnetic domain walls that result from the gate-induced Dzyaloshinskii-Moriya interaction and occur during the magnetization reversal process in the magnetic TI sandwich samples. The coexistence of chiral edge states and chiral spin textures provides a platform for proof-of-concept dissipationless spin
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Publication Identifier Type: DOI Publication Identifier: 10.1038/s41467-020-18312-z
Volume: 11 Issue: 1 First Page #:
Date Submitted: 7/24/21 12:00AM Date Published: 9/1/20 4:00AM
Publication Location:
Article Title: Scaling behavior of the quantum phase transition from a quantum-anomalous-Hall insulator to an axion insulator
Authors: Xinyu Wu, Di Xiao, Chui-Zhen Chen, Jian Sun, Ling Zhang, Moses H. W. Chan, Nitin Samarth, X. C. Xie
Keywords: quantum anomalous Hall effect, axion insulator state, magnetic topological insulator, scaling behaviors
Abstract: The phase transitions from one plateau to the next plateau or to an insulator in quantum Hall and quantum anomalous Hall (QAH) systems have revealed universal scaling behaviors. A magnetic-field-driven quantum phase transition from a QAH insulator to an axion insulator was recently demonstrated in magnetic topological insulator sandwich samples. Here, we show that the temperature dependence of the derivative of the longitudinal resistance on magnetic field at the transition point follows a characteristic power-law that indicates a universal scaling behavior for the QAH to axion insulator phase transition. Similar to the quantum Hall plateau to plateau transition, the QAH to axion insulator transition can also be understood by the Chalker–Coddington network model. We extract a critical exponent ? ~ 0.38 ± 0.02 in agreement with recent high-precision numerical results on the correlation length exponent of the Chalker–Coddington model at ? ~ 2.6, rather than the generallyaccepted value of
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Volume: 588 Issue: 7838 First Page #: 419
Date Submitted: 7/24/21 12:00AM Date Published: 12/1/20 5:00AM
Publication Location:
Article Title: Tuning the Chern number in quantum anomalous Hall insulators
Authors: Yi-Fan Zhao, Ruoxi Zhang, Ruobing Mei, Ling-Jie Zhou, Hemian Yi, Ya-Qi Zhang, Jiabin Yu, Run Xiao,
Keywords: magnetic topological insulator, Chern number, quantum anomalous Hall insulators, chiral edge states
Abstract: A quantum anomalous Hall (QAH) state is a two-dimensional topological insulating state that has a quantized Hall resistance of h/(Ce2) and vanishing longitudinal resistance under zero magnetic field (where h is the Planck constant, e is the elementary charge, and the Chern number C is an integer)1,2. The QAH effect has been realized in magnetic topological insulators3–9 and magic-angle twisted bilayer graphene10,11. However, the QAH effect at zero magnetic field has so far been realized only for C = 1. Here we realize a well quantized QAH effect with tunable Chern number (up to C = 5) in multilayer structures consisting of alternating magnetic and undoped topological insulator layers, fabricated using molecular beam epitaxy. The Chern number of these QAH insulators is determined by the number of undoped topological insulator layers in the multilayer structure. Moreover, we demonstrate that the Chern number of a given multilayer structure can be tuned by varying either the magnetic dop
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Date Submitted: 7/24/21 12:00AM Date Published: 3/1/21 5:00AM
Publication Location:
Article Title: Intertwined Topological and Magnetic Orders in Atomically Thin Chern Insulator MnBi
Authors: Dmitry Ovchinnikov, Xiong Huang, Zhong Lin, Zaiyao Fei, Jiaqi Cai, Tiancheng Song, Minhao He, Qianr
Keywords: band-crossing, topological magnets, Chern insulator, chiral edge states
Abstract: MnBi2Te4, a van der Waals magnet, is an emergent platform for exploring Chern insulator physics. Its layered antiferromagnetic order was predicted to enable even?odd layer number dependent topological states. Furthermore, it becomes a Chern insulator when all spins are aligned by an applied magnetic field. However, the evolution of the bulk electronic structure as the magnetic state is continuously tuned and its dependence on layer number remains unexplored. Here, employing multimodal probes, we establish one-to-one correspondence between bulk electronic structure, magnetic state, topological order, and layer thickness in atomically thin MnBi2Te4 devices. As the magnetic state is tuned through the canted magnetic phase, we observe a band crossing, i.e., the closing and reopening of the bulk band gap, corresponding to the concurrent topological phase transition in both even- and odd-layer-number devices. Our findings shed new light on the interplay between band topology and magnetic or
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Publication Identifier Type: DOI Publication Identifier: 10.1038/s41467-020-20349-z
Volume: 12 Issue: 1 First Page #:
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Publication Location:
Article Title: Interface-induced sign reversal of the anomalous Hall effect in magnetic topological insulator heterostructures
Authors: Fei Wang, Xuepeng Wang, Yi-Fan Zhao, Di Xiao, Ling-Jie Zhou, Wei Liu, Zhidong Zhang, Weiwei Zhao,
Keywords: anomalous Hall effect, magnetic topological insulator, interface engineering
Abstract: The Berry phase picture provides important insights into the electronic properties of condensed matter systems. The intrinsic anomalous Hall (AH) effect can be understood as the consequence of non-zero Berry curvature in momentum space. Here, we fabricate TI/magnetic TI heterostructures and find that the sign of the AH effect in the magnetic TI layer can be changed from being positive to negative with increasing the thickness of the top TI layer. Our first-principles calculations show that the built-in electric fields at the TI/magnetic TI interface influence the band structure of the magnetic TI layer, and thus lead to a reconstruction of the Berry curvature in the heterostructure samples. Based on the interface induce AH effect with a negative sign in TI/V-doped TI bilayer structures, we create an artificial “topological Hall effect”-like feature in the Hall trace of the V-doped TI/TI/Cr-doped TI sandwich heterostructures. Our study provides a new route to create the Berry curvature
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Volume: 21 Issue: 2 First Page #: 1108
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Publication Location:
Article Title: Chiral-Bubble-Induced Topological Hall Effect in Ferromagnetic Topological Insulator Heterostructures
Authors: Wenbo Wang, Yi-Fan Zhao, Fei Wang, Matthew W. Daniels, Cui-Zu Chang, Jiadong Zang, Di Xiao, Wei
Keywords: topological Hall effect, chiral bubble, ferromagnetic topological insulator, magnetic force microscopy
Abstract: We report compelling evidence of an emergent topological Hall effect (THE) from chiral bubbles in a twodimensional uniaxial ferromagnet, V-doped Sb2Te3 heterostructure. The sign of THE signal is determined by the net curvature of domain walls in different domain configurations, and the strength of THE signal is correlated with the density of nucleation or pinned bubble domains. The experimental results are in good agreement with the integrated linear transport and Monte Carlo simulations, corroborating the emergent gauge field at chiral magnetic bubbles. Our findings not only reveal a general mechanism of THE in two-dimensional ferromagnets but also pave the way for the creation and manipulation of topological spin textures for spintronic applications.
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Article Title: Even–Odd Layer-Dependent Anomalous Hall Effect in Topological Magnet MnBi
Authors: Yi-Fan Zhao, Ling-Jie Zhou, Fei Wang, Guang Wang, Tiancheng Song, Dmitry Ovchinnikov, Hemian Yi,
Keywords: topological magnet, anomalous Hall effect, thin film, antiferromagnetic material, molecular beam epitaxy growth
Abstract: Recently, MnBi2Te4 has been demonstrated to be an intrinsic magnetic topological insulator and the quantum anomalous Hall (QAH) effect was observed in exfoliated MnBi2Te4 flakes. Here, we used molecular beam epitaxy (MBE) to grow MnBi2Te4 films with thickness down to 1 septuple layer (SL) and performed thickness-dependent transport measurements. We observed a nonsquare hysteresis loop in the antiferromagnetic state for films with thickness greater than 2 SL. The hysteresis loop can be separated into two AH components. We demonstrated that one AH component with the larger coercive field is from the dominant MnBi2Te4 phase, whereas the other AH component with the smaller coercive field is from the minor Mn-doped Bi2Te3 phase. The extracted AH component of the MnBi2Te4 phase shows a clear even–odd layer-dependent behavior. Our studies reveal insights on how to optimize the MBE growth conditions to improve the quality of MnBi2Te4 films.
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Article Title: Elucidating proximity magnetism through polarized neutron reflectometry and machine learning
Authors: Nina Andrejevic, Zhantao Chen, Thanh Nguyen, Leon Fan, Henry Heiberger, Ling-Jie Zhou, Yi-Fan Zha
Keywords: proximity effect, machine learning, topological insulator
Abstract: Polarized neutron reflectometry is a powerful technique to interrogate the structures of multilayered magnetic materials with depth sensitivity and nanometer resolution. However, reflectometry profiles often inhabit a complicated objective function landscape using traditional fitting methods, posing a significant challenge for parameter retrieval. In this work, we develop a data-driven framework to recover the sample parameters from polarized neutron reflectometry data with minimal user intervention. We train a variational autoencoder to map reflectometry profiles with moderate experimental noise to an interpretable, low-dimensional space from which sample parameters can be extracted with high resolution. We apply our method to recover the scattering length density profiles of the topological insulator–ferromagnetic insulator heterostructure Bi2Se3/EuS exhibiting proximity magnetism in good agreement with the results of conventional fitting. We further analyze a more challenging refle
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Article Title: Zero Magnetic Field Plateau Phase Transition in Higher Chern Number Quantum Anomalous Hall Insulators
Authors: Yi-Fan Zhao, Ruoxi Zhang, Ling-Jie Zhou, Ruobing Mei, Zi-Jie Yan, Moses H.?W. Chan, Chao-Xing Liu,
Keywords: magnetic topological insulator, quantum phase transition, high Chern number
Abstract: Here, we synthesized the magnetic topological insulator (TI)/TI penta-layer heterostructures with different Cr doping concentrations in the middle magnetic TI layers using molecular beam epitaxy (MBE). By performing transport measurements, we found a potential plateau phase transition between C=1 and C=2 QAH states under zero magnetic field. In tuning the transition, the Hall resistance monotonically decreases from h/e2 to h/2e2, concurrently, the longitudinal resistance exhibits a maximum at the critical point. Our results show that the ratio between the Hall resistance and the longitudinal resistance is greater than 1 at the critical point, which indicates that the original chiral edge channel from the C=1 QAH state coexists with the dissipative bulk conduction channels. Subsequently, these bulk conduction channels appear to self-organize and form the second chiral edge channel in completing the plateau phase transition.
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Article Title: Local manifestations of thickness-dependent topology and edge states in the topological magnet
Authors: Felix Lüpke, Anh D. Pham, Yi-Fan Zhao, Ling-Jie Zhou, Wenchang Lu, Emil Briggs, Jerzy Bernholc, Ma
Keywords: magnetic topological insulator, scanning tunneling microscopy and spectroscopy, quantum phase transition
Abstract: Here, we report local signatures of the thickness-dependent topology in intrinsic magnetic topological insulator MnBi2Te4 (MBT), using scanning tunneling microscopy and spectroscopy on molecular beam epitaxy grown MBT thin films. A thickness-dependent band gap is revealed, which we reproduce with theoretical calculations. Our theoretical results indicate a topological quantum phase transition beyond a film thickness of one monolayer, with alternating QAH and axion insulating states for odd and even layers, respectively. At step edges, we observe localized electronic states, in general agreement with axion insulator and QAH edge states, respectively, indicating topological phase transitions across the steps.
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