AVS Quantum Science Workshop
Room Redondo - Session AQS-FrA1

AVS Quantum Science Workshop: Topological Quantum Materials

Moderator: Erika Janitz, ETH Zürich

2:00pm **AQS-FrA1-1 Topological Materials, a New Quantum State of Matter*, Luis A. Jauregui,*** University of California Irvine **INVITED**

Topological order and materials have been at the center of attention in condensed matter physics and engineering. Topological materials, a new quantum state of matter, are a family of quantum materials with boundary states whose physical properties are robust against disorder. Therefore, there have been few examples of a topological phase transition realized experimentally, and even fewer cases of an in-situ tuning of the topological phase. I will discuss our results and methods to apply uniaxial strain in topological van der Waals quantum materials and how it influences its electrical properties. Our results point towards a topological phase transition of the system tuned by in situ uniaxial strain. By measuring the electrical properties of high-quality thin topological heterostructures, we observe that the non-zero Berry curvature enables an anomalous Hall effect in our samples and its influence can be tuned by the carrier density, temperature, and magnetic field. Our results could pave the way towards creating and controlling topological phases of matter by strain and heterostructure engineering in quantum materials at the same time they would enable the creation of novel quantum electronic devices.

2:40pm **AQS-FrA1-9 Probing Topologically Protected Quantum States with Scanning Tunneling Microscopy*, An-Ping Li,*** Center for Nanophase Materials Sciences, Oak Ridge National Laboratory **INVITED**

Topological quantum materials are a promising platform to investigate the interplay of dimension, symmetry, magnetism, and topology. In this talk, I will present a few examples to illustrate how scanning tunneling microscopy (STM) and 4-probe STM can be used to assess a variety of quantum states in topological magnet $MnBi_2Te_4$ (MBT). First, using Sb substitutions at Bi sites, we are able to tune the Fermi level of $MnBi_{2-x}Sb_xTe_4$ so that the bulk carrier density is minimized to allow for access to the surface states. A surface band gap has been revealed around the Dirac point inside the bulk band gap [1]. In situ transport spectroscopy using our unique 4-probe STM has confirmed the surface nature of the carriers at the Fermi level through the exhibition of 100 % surface-dominant conductance [2]. The surface band gap is found to be topologically protected and robust against magnetic field up to 9 T [1]. Second, the exchange is shown to vary widely across the surface due to the chemical disorder, which reconciles the conflicting reports on the existence of such a gap in the literature. By mapping the local density of states in the topological surface state, we are able to pinpoint nanoscale fluctuations in the local surface gap and doping level and disentangle the roles of the individual types of defects on the electronic properties of the compound [3]. Third, by employing $MnBi_2Te_4$ films with varying film thickness, we can systematically study thickness-dependent electronic properties as well as edge states as the film changes layer thickness. The band inversion is observed as the film thickness increases continuously from one to six septuple layers. The inverted band gaps oscillate with thickness, indicative of alternating QAH and axion insulator phases as corroborated by extensive theoretical calculations. At step edges, we observe localized electronic states, in agreement with axion insulator and QAH edge states, respectively, indicating topological phase transitions across the steps [4]. These results highlight the role of nanoscale control over novel quantum states, reinforcing the necessity of local probing techniques in understanding quantum materials.

[1] W. Ko et al, Phys. Rev. B 102, 115402 (2020).

[2] W. Ko et al, Phys. Rev. Lett. 121, 176801 (2018).

[3] F. Lüpke et al, arXiv:2208.13374.

[4] F. Lüpke et al, Phys. Rev. B 105, 035423 (2022).

This research was conducted at the Center for Nanophase Materials Sciences, which is a DOE Office of Science User Facility.

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