Quantum anomalous Hall effect in an intrinsic magnetic topological insulator

Supported by the National Natural Science Foundation of China, the research team led by Zhang YuanBo (张远波) and Wang Jing (王靖) from the Department of Physics at Fudan University, and Chen XianHui (陈仙辉) from the Department of Physics, University of Science and Technology of China, observed the quantum anomalous Hall (QAH) effect in an intrinsic magnetic topological insulator for the first time. The research was published in *Science* (2020, 6480: 895—900).

Generally speaking, the resistance of a material depends on its geometry. Quantum mechanics, however, allows the existence of thin-film materials whose resistance is not affected by details such as shape or defect configuration of a specific specimen. In particular, the transverse resistance of the thin film is solely determined by a fundamental constant h/e^2, where h is the Planck constant and e the charge of an electron. Such an effect, termed QAH effect, was first discovered in chromium-doped $(Bi,Sb)_2Te_3$ by Xue Qikun group at Tsinghua University in 2013. The quantized transverse resistance implies a dissipationless edge conduction channel that may be useful in low-power electronic devices and metrology. It is also anticipated that QAH materials may play a role in future topological quantum computing.

The experimental observation of the QAH effect in chromium-doped $(Bi,Sb)_2Te_3$ represents a triumph in topological quantum material research. However, the fine-tuning of the ratio of multiple elements poses a challenge for material growth; additionally, the randomly distributed magnetic dopants act as impurities that limit the quality of the specimens.

The difficulties with the above extrinsic magnetic topological insulators prompt the team to focus on intrinsic magnetic topological insulator $MnBi_2Te_4$ which has an innate magnetic order. Bulk $MnBi_2Te_4$ is a layered van der Waals crystal that can be viewed as a few stacked layers of the single crystal. The team fabricated three, four and five layers of $MnBi_2Te_4$ devices and observed rich magnetic structures resulting from the interlayer antiferromagnetic coupling in an external magnetic field. More importantly, when the team probed a five-layer specimen, they observed the QAH effect at a temperature of 1.4 Kelvin. This is the first time that the QAH effect is observed in an intrinsic magnetic topological insulator. In addition, the team observed the conventional quantum Hall effect in the same specimen.

These observations demonstrate that the quality of the intrinsically magnetic $MnBi_2Te_4$ is now able to match the best magnetically doped topological insulators; there is ample room for improvement in the future. The team anticipates that van der Waals heterostructures integrating $MnBi_2Te_4$ with other magnetic/superconducting 2D materials will provide fertile ground for exploring exotic topological quantum phenomena.

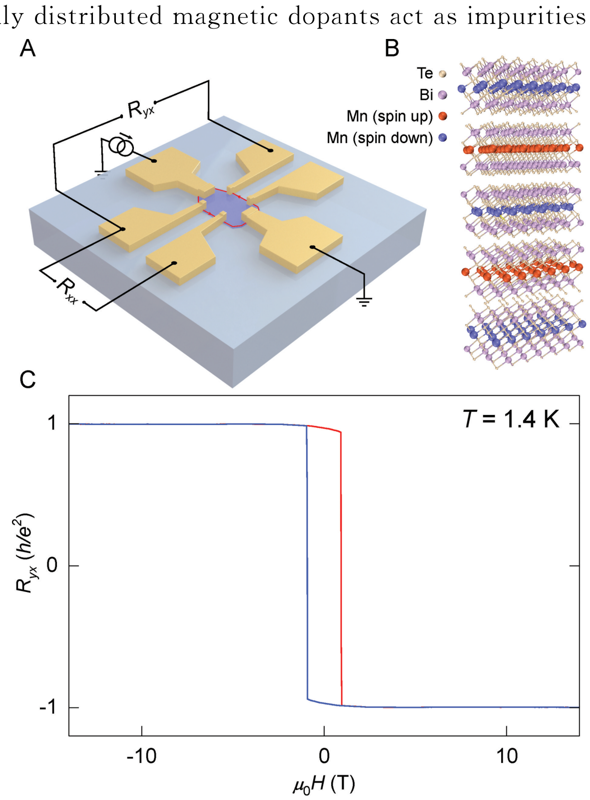

Figure A, Charge transport device for few-layer $MnBi_2Te_4$ flakes; B, atomic structure of a five-layer $MnBi_2Te_4$ flake; C, QAH effect in a five-layer $MnBi_2Te_4$ flake.