Emergent flat band in quasi-one-dimensional Indium Telluride

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Two-dimensional (2D) materials have been extensively studied ever since the successful isolation of graphene. The typical graphene-like 2D families such as hexagonal boron nitride (hBN), phosphorene,and transition metal dichalcogenides possess many fancy properties owing to their unique structures and are widely used in various nanoelectronic devices. The class of chalcogenide semiconductors (MX,M=Ga, In; X=S, Se, Te) represents a family of layered semiconductors which have attracted attention for their electronic structures and optoelectronic properties. Recently, new fascinating physical properties have been discovered in anisotropic semiconductors such as Indium telluride (InTe), in which the in-plane anisotropy of the electronic band structure is often due to low crystallographic symmetry[1,2]. InTe material has 1D chains structure, from which intriguing properties arise. In this study, by combining angle-resolved photoemission spectroscopy (ARPES) and density functional theory (DFT) calculations we demonstrate that InTe is stable in the tetragonal crystal structure and presents a semiconducting character with an indirect electronic band-gap and an intrinsic p-type doping. We investigated in-plane directional dependence of the effective hole masse of the VBM of InTe in the vicinity of the Fermi level. The hole effective mass of the M valley exhibits a strong anisotropy along the $(InTe2)^-$ chains, c-axis, compared to the perpendicular direction. The in-plane anisotropy of the hole effective masses in InTe is larger than that in black phosphorus which also shows anisotropic optical and electronic properties [3]. InTe can be considered a quasi 1D material in terms of the low energy hole carrier dynamics, which makes this material a promising thermoelectric candidate for 1D semiconducting electronics.

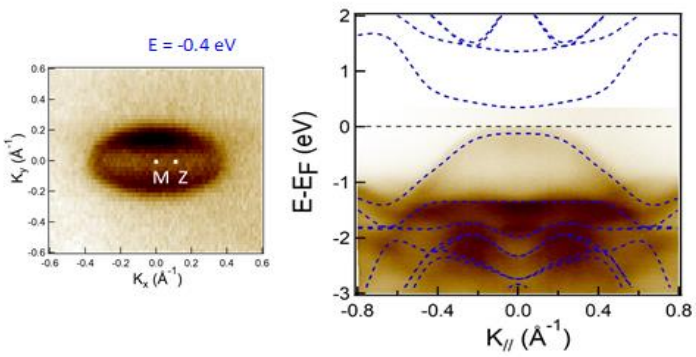

Fig 1: Constant ARPES energy surfaces for InTe taken at -0.4 eV and a map measured along the $\bar{Z}$-$\bar{M}$-$\bar{Z}$ high symmetry direction compared with theoretical electronic band structure (T = 30 K and hv = 50 eV).

[1] Zhang, J. et al. Direct observation of one-dimensional disordered diffusion channel in a chain-like thermoelectric with ultralow thermal conductivity. Nat. Commun. 12, (2021).

[2] Misra, S. et al. Reduced phase space of heat-carrying acoustic phonons in single-crystalline InTe. Phys. Rev. Res. 2, (2020).

[3] Meryem Bouaziz, Aymen Mahmoudi, Geoffroy Kremer, et al, Intrinsic defects and mid-gap states in quasi-one-dimensional Indium Telluride, Physical Review Research, 2023.