Layer-by-layer construction of electronic band topology

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Abstract: Layered quantum materials are building blocks to realize exotic topological physics. For instance, by programmably stacking magnetic $MnBi_2Te_4$ and non-magnetic Bi_2Te_3 layers, one can realize a plethora of fascinating topological quantum effects such as the quantum anomalous Hall effect (QAHE) and quantum spin Hall effect (QSHE). However, the realization of those effects in $(MnBi_2Te_4)_m(Bi_2Te_3)_n$ has met tremendous challenges. In our 2DCC user project, we first employ time- and angle-resolved photoemission spectroscopy on bulk $MnBi_2Te_4$ [1], $MnBi_4Te_7$ [2], and $MnBi_6Te_{10}$ [3] to reveal the electronic origins of these challenges. Subsequently, we use molecular beam epitaxy to establish two-quintuple-layer Bi_2Te_3 films and $MnBi_2Te_4/Bi_2Te_3$ heterostructures as *building blocks of the future* with atomic-layer controlled thicknesses and a unique morphology: the films extend coherently over millimetre scales with minimal disruptions by the substrate step edges [4]. We reveal the digitally varied electronic structures of $(Bi_2Te_3)_n$ and $MnBi_2Te_4/(Bi_2Te_3)_n$ and reach excellent agreement with theoretical predictions layer-by-layer. By modulating the interlayer distance in two-quintuple-layer Bi_2Te_3 using time-resolved photoemission, we elucidate the perturbative band dynamics which suggests an inverted bandgap. This result is corroborated by scanning tunneling spectroscopy measurements unveiling edge states between topologically trivial and nontrivial areas. The inverted gaps of two-quintuple-layer Bi_2Te_3 films and $MnBi_2Te_4/Bi_2Te_3$ heterostructures are 100 and 150 meV, respectively, suggesting possibilities for near-ambient-temperature QSHE.

[1] Nguyen *et al. Science Advances* **10,** eadn5696 (2024)

[2] Lee *et al. Nature Physics* **19,** 950 (2023)

[3] Nguyen *et al. Nanoscale Advance Article* (2025)

[4] Lee *et al. In Review* (2025)