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Symmetry-driven anisotropic coupling effect in antiferromagnetic topological insulator: Mechanism for a quantum anomalous Hall state with a high Chern number

Antiferromagnetic (AFM) topological insulators (TIs), which host magnetically gapped Dirac-cone surface states and exhibit many exotic physical phenomena, have attracted great attention. Here, we find that the coupled surface states can be intertwined to give birth to a set of $2n$ unique new Dirac cones, dubbed intertwined Dirac cones, through the anisotropic coupling enforced by crystalline n-fold ($n = 2, 3, 4, 6$) rotation symmetry C_{nz} in the presence of a PT-symmetry breaking potential, for example, an electric field. Interestingly, we also find that the warping effect further drives the intertwined Dirac-cone state into a quantum anomalous Hall phase with a high Chern number ($C = n$). Then, based on first-principles calculations, we have explicitly demonstrated six intertwined Dirac cones and a Chern insulating phase with a high Chern number ($C = 3$) in $\mathrm{MnBi_2Te_4/(Bi_2Te_3)_m/MnBi_2Te_4}$ heterostructures, as well as the $C = 2$ and $C = 4$ phases in HgS and α-$\mathrm{Ag_2Te}$ films, respectively. This work discovers the intertwined Dirac-cone state in AFM TI thin films, which reveals a mechanism for designing the quantum anomalous Hall state with a high Chern number and also paves a way for studying highly tunable high-Chen-number flat bands of twistronics.

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