Ferroelectrically Switchable Chirality in Topological Superconductivity

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The searching for the topological superconductivity, particularly chiral topological superconductivity (CTSC), has been a subject of intense research interest in recent years, due to its emergent chiral Majorana physics and potential applications in topological quantum computation and topological quantum information processing. However, existing approaches to realize CTSC, such as doped topological insulators (TIs) combined with quantum anomalous Hall (QAH) systems, face significant challenges. These systems require precise fine-tuning of parameters to achieve the topologically non-trivial phase, posing a major obstacle to experimental realization and practical applications. Luckily, the recent discovery of the 2D ferroelectric materials and in particular, the polar stacking bilayer MnBi2Te4 offers a new opportunity to realize CTSC in a more controllable and feasible manner. Referring to the phase with spontaneous net electric polarization, ferroelectricity shares much similarity with ferromagnetism, like the tunability by external fields and symmetry breaking as the prerequisite, while differing in electric rather than magnetic, and inversion rather than time-reversal, and leads to various functional device applications. When cooperating with magnetism, multiferroic or magnetoelectric materials can be realized, with coexisting ferroic orders and even couplings between, promising for intersecting manipulations. This brings us to the previously mentioned multiferroic polar stacking bilayer MnBi2Te4, which exhibits both ferroelectricity and antiferromagnetism, making it a promising platform for realizing CTSC in the proximity of superconducting pairing. In this work, we propose the heterostructure of a polar stacking antiferromagnetic bilayer MnBi2Te4 in close proximity to an s -wave superconductor Fe(Se,Te). When the Fermi surface intersects a single band to form an isolated Fermi loop, this system exhibits CTSC with switchable chirality, controlled by the spontaneous polarization direction arising from the ferroelectricity induced by interlayer spin-orbital coupling due to sliding in the magnet. As we will demonstrate, this prospect is made possible by the deep cooperation between inversion P -breaking ferroelectricity and antiferromagnetism in the system. We further endow a guideline for realizing of CTSC in superconducting multiferroic materials, where the Chern number N of the superconducting states is determined by the residual chirality summation over all the Fermi loops: $N=\sum\_{i}^{}sgn(σ\_{H}^{i})$. The residual chirality of Fermi loop for band $i$, denoted by $sgn(σ\_{H}^{i})$ , encodes the sign of the anomalous Hall conductivity arising from all occupied states of this band, thus dictating the direction of the Hall current.

Reference:

K. Z. Bai, B. Fu, and S. Q. Shen, Ferromagnetically switchable chirality in topological superconductivity: Bilayer MnBi2Te4 /Fe(Se,Te) heterostructure, arXiv: 2505.01759 (2025)