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Surface Bogoliubov-Dirac cones and helical Majorana hinge modes in superconducting Dirac semimetals

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In the presence of certain symmetries, three-dimensional Dirac semimetals can harbor not only surface Fermi arcs, but also surface Dirac cones. Motivated by the experimental observation of rotation-symmetry-protected Dirac semimetal states in iron-based superconductors, we investigate the potential intrinsic topological phases in a C_{4z}-rotational invariant superconducting Dirac semimetal with $s_{\pm}$-wave pairing. When the normal state harbors only surface Fermi arcs on the side surfaces, we find that an interesting gapped superconducting state with a quartet of Bogoliubov-Dirac cones on each side surface can be realized, even though the first-order topology of its bulk is trivial. When the normal state simultaneously harbors surface Fermi arcs and surface Dirac cones, we find that a second-order time-reversal invariant topological superconductor with helical Majorana hinge states can be realized. The criteria for these two distinct topological phases have a simple geometric interpretation in terms of three characteristic surfaces in momentum space. By reducing the bulk material to a thin film normal to the axis of rotation symmetry, we further find that a two-dimensional first-order time-reversal invariant topological superconductor can be realized if the inversion symmetry is broken by applying a gate voltage. Our work reveals that diverse topological superconducting phases and types of Majorana modes can be realized in superconducting Dirac semimetals.

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