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RESEARCH HIGHLIGHT

New physics in old material: Topological and superconducting properties of stanene

The two-dimensional material stanene, realized by thinning α-Sn down to the atomic limit, provides a promising platform to explore novel quantum physics relevant to topology and superconductivity.

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Tin is one of the oldest materials used by human. Its history can be traced back to the beginning of the Bronze Age, named by the material bronze that is an alloy of copper and tin. White tin (β-Sn) is widely used in everyday life, whereas it will transform into another stable allotrope grey tin (α-Sn) at low temperatures. Such a transformation, called "tin pest", should be avoided in applications. The "unwanted" α-Sn phase, however, has recently been revealed to show intriguingly new quantum physics.

Stanene is an atomic layer of Sn crystallized in a buckled honeycomb lattice, corresponding to an ultathin film of α-Sn(111) [1,2]. Similar as in graphene, Dirac-like linear bands contributed by the p_z orbitals of Sn atoms appear near the K/K′ point, and the opening of Dirac gap by the spin–orbit coupling (SOC) results in the so-called quantum spin Hall (QSH) states [3]. In experiment, the partially occupied p_z bands are easily affected by substrate or adsorbates, which easily destroys the low-energy physics near K/K′. However, by fully saturating the p_z orbitals, the material becomes chemically stable and electrically insulating, and a topological band inversion can happen at Γ, leading to QSH states with large gaps (~300 meV) [2]. Its topological properties can be further controlled by strain, chemical functionalization, film thickness, etc. Moreover, the material has been proposed to provide a platform to study other novel quantum phenomena, including enhanced thermoelectricity, topological superconductivity, the quantum anomalous Hall effect, and type-II Ising superconductivity [4–7].

Impressive experimental progresses on stanene have been achieved recently. Monolayer stanene was first successfully fabricated in 2015 [8]. After that, samples of distinct properties have been synthetized, such as stanene with an insulating gap and ultraflat stanene with topological band inversion [9, 10]. Unexpectedly, though the α-Sn bulk is non-superconducting, two-dimensional superconductivity is observed in few-layer stanene, whose critical temperature increases with layer thickness [11]. Benefitting from the strong SOC and spin–orbital locking, type-II Ising superconductivity is formed in stanene [7, 12], which is robust against in-plane magnetic field and gives upper critical field exceeding the Pauli limit. More importantly, due to the coexistence of topology and superconductivity, few-layer stanene becomes a promising material candidate to explore topological superconductivity.

Recently, Zhao and Jia gave a comprehensive review on topological and superconducting properties of stanene [13]. The interplay of topology, superconductivity and possible symmetry breaking (e.g., time-reversal symmetry breaking) offers opportunities to explore emergent quantum physics, such as unconventional superconductivity, Majorana fermions, and topological magneto–electric effects, which could possibly find applications in quantum computation and low-power electronics.

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