Topological matter as a platform for novel device physics

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The field of "topological matter" classifies properties of solids in momentum space and identifies non-trivial topological materials based on their band structure. New phenomena that emerge in the study of topological matter suggest that they may provide novel platforms for device physics, including low-impedance interconnects, unique switching devices, or provide basic building blocks for topological quantum computing systems. Furthermore, they may provide new routes for higher temperature magnets and superconductors.

For example, a "topological insulator" (TI) has a full energy gap in the bulk and contains gapless surface states, with Dirac-like dispersion, that cannot be backscattered by nonmagnetic impurities because of time reversal symmetry. When a thin magnetic layer is applied on the surface, a full insulating gap is opened, and an electric charge close to the surface is predicted to induce an image magnetic monopole. When a thin superconducting layer is applied on the surface, this "topological superconductor" (TS) system is predicted to exhibit elementary excitations in the form of Majorana fermions.

Zero-gap topological matter can also be realized with its own unique possibilities. For example, three-dimensional (3D) noncentrosymmetric superconductors with time-reversal symmetry may host unique zero-energy Andreev surface states. Some of these boundary modes in nodal superconducting phases are dispersionless, that is, they form a topologically protected "flat band" and may host Majorana surface modes. Another class 3D systems is made up of "Weyl semimetals" (WS), which are characterized by topologically protected edge states, but a gapless bulk. These WS edge states may also exhibit the flat band phenomenon. The importance of flat bands for higher T_C superconductivity is analogous to the importance of van-Hove singularities (VHS), that is a saddle point in the energy-momentum dispersion. While a VHS leads to an enhanced density of states, a true flat-band system exhibits an infinitely large density of states, where the critical temperature depends linearly on the pairing interaction and can be thus considerably higher than the exponentially small bulk critical temperature.

In this talk we will review several concepts of topological materials, highlighting applications related to topological insulators and superconductors.