Theory of superconducting proximity effect in hole-based hybrid semiconductor-superconductor devices

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Hybrid superconductor-semiconductor systems have received a great deal of attention in the past few years because of their potential for quantum engineering, including novel qubits and topological devices. The proximity effect, the process by which the semiconductor inherits superconducting correlations, is an essential physical mechanism of such hybrids. Recent experiments have demonstrated the proximity effect in hole-based semiconductors, but, in contrast to electrons, the precise mechanism by which the hole bands acquire superconducting correlations remains an open question. In addition, hole spins exhibit a complex strong spin-orbit interaction, with largely anisotropic responses to electric and magnetic fields. We analyze this physics with a focus on germanium-based two-dimensional gases. Specifically, we develop an effective theory supported by full numerics, allowing us to predict different types of superconducting correlations including nonstandard forms of singlet and triplet pairing mechanisms with nontrivial momentum dependence, as well as different Zeeman and Rashba spin-orbit contributions. This, together with their precise dependence on electric and magnetic fields, allows us to make specific experimental predictions, including the emergence of f-type superconductivity, Bogoliubov Fermi surfaces, and gapless regimes caused by large in-plane magnetic fields.

References

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Figures

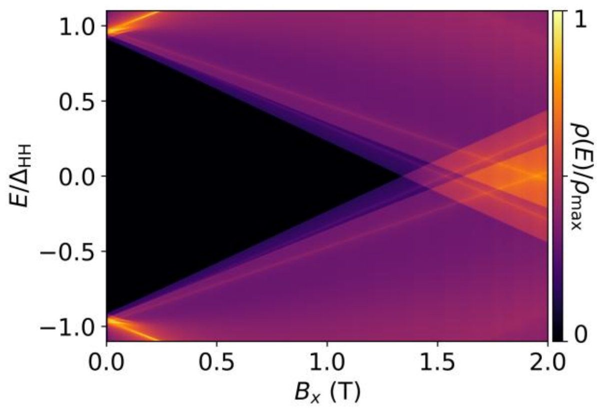

Figure 1: Density of states as a function of in-plane magnetic field. Anisotropies in the induced pairing introduce van Hove singularities.

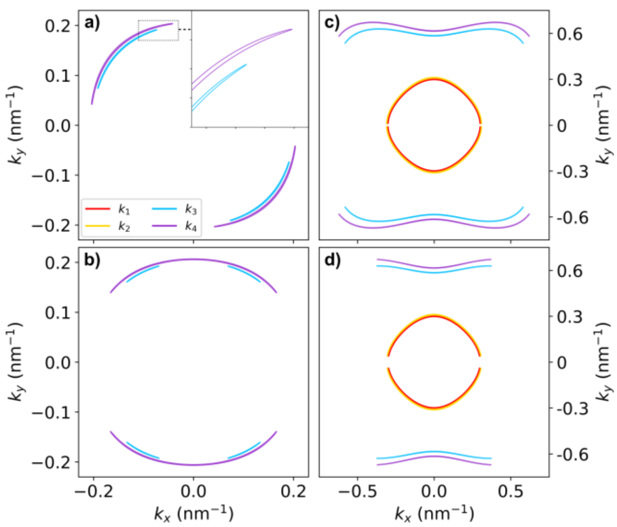

Figure 2: Bogoliubov-Fermi surfaces for different magnetic field orientations.