Spin-Orbit Coupling tuning Fano-Feshbach Resonant Multigap Superconductivity

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We present a scenario where the interactions leading to room temperature superconductivity is driven by the lattice effects at nanoscale while for 35 years the major theoretical proposals have been based on exotic interaction is a homogneous macroscopic lattice. We show that the room temperature superconductivity can be reached in a three-dimensional (3D) superlattice of metallic nannoscale modules (stripes or layers). The presence of a confinement potential along the direction orthogonal to the modules is reflected in an electronic multiband structure which leads to multigap superconductivity and amplification of the critical temperature.

In mulilayers, interfacing different materials in the direction of confinement breaks the spatial inversion symmetry allowing a Rashba spin-orbit coupling (RSOC) The electrons in-plane are, thus, subjected to an effective magnetic field which orients the spin in a direction orthogonal to the momentum. This is reflected in a spin-splitting of the subbands that characterize the superlattice.

We study the combined effect of multigaps superconductivity and RSOC and to see how, by appropriately varying the intensity of the Rashba coupling, the structural characteristics of the system it is possible to obtain an amplification of the critical temperature. The interplay of the RSOC and superlattice structure leads to an extended van Hove singularity in the density of states (DOS) at the Brillouin zone edge with an unconventional Lifshitz transition for one of the two helicity states of the spin-orbit split electron spectrum giving an amplification of the gaps and critical temperature. The evaluation of the superconducting gap and the critical temperature is done by including in the Bogoliubov equation the quantum configuration interaction between the gaps. In the small fermi surface the electron-phonon interaction dependent both on the band indices and on the wavevectors along the confinement direction. Therefore, unlike the Bardeen–Cooper–Schrieffer (BCS) theory, the superconducting coupling is not constant but has a matrix structure giving the amplification of the superconducting critical temperature due to the resoance between different condensates in different coupling regimes.

Our results allow to reconstruct the superconducting dome typical of materials at high critical temperatures and to obtain critical temperatures close to room temperature. Moreover our rsults provide a roadmap to effectively vary the effect of the RSOC via the tuning of the superlattice structure, Finally we provide precise indications on the values of the parameters involved in view of possible practical realizations in a way potentially relevant for spintronics functionalities in several existing experimental platforms and materials.

Key words: superconductivity, Fano-Faschbach resonance, topological matter, Lifshitz transition, Rashba spin-orbit coupling.

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