Connection between the semiconductor–superconductor transition and the spin-polarized superconducting phase in the honeycomb lattice

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The realization of the honeycomb lattice in graphene draws a lot of attention of the scientific community. The extraordinary properties of the honeycomb lattice are mainly associated with massless Dirac fermions, which are located in the corners of the Brillouin zone. As a consequence, fermions in this lattice manifest a semiconducting behavior below some critical value of the onsite attraction, U_c. However, above U_c, the superconducting phase can occur. This lattice exhibits also topological properties manifested by the existence of zero-energy edge states or in the quantum Hall effect, associated to the finite Berry curvature in these systems. The electronic properties of the honeycomb lattices has opened new avenues of research in which applications play a very important role, i.e., spintronics or valleytronics.

Here, we discuss an interplay between the semiconductor–superconductor transition and the possibility of realization of the spin-polarized superconductivity (the so-called Sarma phase) [1]. We show that the critical interaction can be tuned by the next-nearest-neighbor (NNN) hopping in the absence of the magnetic field. Moreover, a critical value of the NNN hopping exists, defining a range of parameters for which the semiconducting phase can emerge. In the weak coupling limit case, this quantum phase transition occurs for the absolute value of the NNN hopping equal to one third of the hopping between the nearest neighbors. Similarly, in the presence of the magnetic field, the Sarma phase can appear, but only in a range of parameters for which initially the semiconducting state is observed. Both of these aspects are attributed to the Lifshitz transition, which is induced by the NNN hopping as well as the external magnetic field.

References:

[1] A. Cichy, K. J. Kapcia, A. Ptok, Phys. Rev. B **105**, 214510 (2022)