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Quantum effects in correlations between graphene pseudo-Majorana fermions : A high-energy $\vec{k}\cdot\vec{p}$ tight-binding approximation

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At present, the discovery of anomalous charge carrier transport in an atom-thin carbon atom layer called graphene and in other graphene-like two-dimensional (2D) semimetals has been the impetus to develop a new generation of quantum devices for quantum computing. The anomalous electrical, magnetic, and optical properties of graphene are stipulated by non-Abelian statistics of its quasiparticle excitations. One of the most attractive graphene fermion models with non-Abelian statistics is the Majorana-like configurations of pairs of $\pi(p_z)$-electrons, since only in this case the scattering of graphene charge carriers by p-n (n-p) graphene junctions brings about Klein resonances to form the quantum devices called graphene quantum dots [1]. A Hubbard-type Hamiltonian model (the Hartree approximation without account of the Fock exchange term) is proposed to describe the breaking of the $\pi(p_z)$-electron configurations through correlations in a pair of high-energy electrons with different spins (see [2] and references therein). But, competing with the Hartree self-consistent field, the Fock exchange prevents the repulsion process (see [3] and references therein) and, correspondingly, greatly reduces the probability of these types of two-particle states formation. We use the quasi-relativistic high-energy $\vec{k}\cdot\vec{p}$ tight-binding approximation to study the effects of the correlation interaction in graphene because the electron correlation effect is strengthened by the relativistic effect (see [4] and references therein). We show that in the flattened high-energy electronic bands being feature of the 2D materials, the charge carrier density rises sharply due to van Hove singularities. As a result, the Majorana-like configurations are formed and the strong correlations between electrons, when their spins align in parallel, appear in frustrating the dimeric structure. Lattice quantum field theory methods are used to analyze the damping of the pseudo-Majorana modes due to the correlation interaction.

References

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