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A proposal to realizing Majorona Fermions in strongly correlated nanowire without magnetic fields

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The topological superconductivity with Majorona zero modes (MZM) is of fundamental scientific importance, due to their proposed application in the braiding-based quantum computing [1]. The first theoretical proposal for the realization of the MZM was involved placing an one dimensional (1D) quantum wire with spinless electrons on a p-wave superconductors [2]. However, from the material science point of view this conceptually simple model is hard to realize as spinless electron does not exist in nature, and p-wave superconductors are, at best, rare. Later several proposals were put forward to eliminate these difficulties by ingeniously combining the proximity induced s-wave superconductivity, the Rashba spin-orbit coupling (RSOC), and the broken time reversal (TR) symmetry [3]. The RSOC is needed for the spin-momentum locking [4]. TR symmetry breaking is needed to create, in effect, the spinless electrons. Using aforementioned ideas, broadly three types of platforms have been engineered by placing [5]: (i) topological insulators on superconductor [6, 7], (ii) semiconductor with strong spin-orbit coupling on superconductor [8], or (iii) chain of magnetic atoms on superconductor[9, 10]. Despite these experimental successes, several concerns remain; mainly the requirements of the strong RSOC and the external magnetic field. The former limits the candidate materials which can be placed over the superconductor; the later limits the possible superconducting substrate. Moreover the crystal symmetry consideration greatly shrink the possible superconductors supporting topological characters [11]. The external magnetic field is the principal hindrance, as most of the experiments use s-wave superconductors in which strong enough magnetic field will destroy the superconductivity. Hence, naturally the question arises, can we get rid of the constraint possessed by the magnetic field? It is the goal of this work to suggest a different route to realizing MZM without magnetic field and RSOC.

We show that the 1D topological superconductivity can be placed in the context of phenomena associated with strongly correlated electron systems. Here we propose a system consisting of a one-dimensional chain of strongly correlated fermions placed on a superconducting (SC) substrate that exhibits a spin-singlet extended s-wave pairing. Strong electron correlation is shown to transform an extended s-wave SC into a topological SC. In contrast to the approaches based on the mean-field treatment, no Zeeman or exchange magnetic field is needed to produce such an effect.

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