Proximitized Materials: From Spintronics to Majorana States

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Advances in scaling down heterostructures and atomically-thin two-dimensional (2D) materials suggest a novel approach to systematically design materials as well as to realize exotic states of matter. A given material can be transformed through proximity effects [1] whereby it acquires properties of its neighbors, for example, becoming superconducting, magnetic, topologically nontrivial, or with an enhanced spin-orbit coupling. Such proximity effects not only complement the conventional methods of designing materials by doping or functionalization, but can also overcome their various limitations. In proximitized materials it is possible to realize properties that are not present in any constituent region of the considered heterostructure, as shown in Fig. 1. Unlike the depicted superconducting proximity, which could exceed μm, other proximity effects extend over only several nm. After some background on proximity effects, we discuss implications of magnetism leaking into initially a non-magnetic region [1-3]. We show that gate-tunable band topology allows helicity reversal of the emitted light [4] and novel paths to spin-lasers [5]. Motivated by the search for elusive spin-triplet topological superconductivity hosting Majorana states, which are considered for fault-tolerant quantum computing, we explain the importance of proximity effects. Instead of epitaxially-defined, topological nanostructures could be designed using magnetic textures and combining magnetic and superconducting proximity effects in 2D systems [6]. Measurements of proximity-induced topological superconductivity in planar Josephson junctions [7] provide novel opportunities for controlling Majorana states [8].

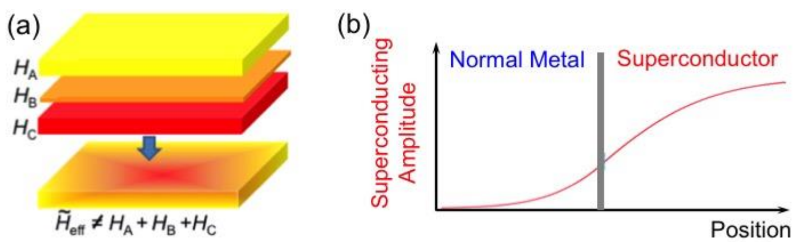

Fig.1 (a) Proximity-modified layer B in the presence of layers A and C, with the respective effective and individual Hamiltonians. (b) Penetration of superconductivity across an interface into a normal (nonsuperconducting) region can exceed μm scale [1].

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