Nanoelectronics with proximitized materials

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Proximity effects can transform a material through its adjacent regions to become superconducting, magnetic, or topologically nontrivial, enabling unexplored device opportunities. In bulk materials, the sample size often dwarfs the characteristic lengths of proximity effects allowing their neglect. However, in 2D materials such as graphene, transition-metal dichalcogenides (TMDs), and 2D electron gas (2DEG), the situation is drastically different: even short-range magnetic proximity effects exceed their thickness and strongly modify transport and optical properties [1,2]. Experimental confirmation by the Geim [3] and Kawakami [4] groups of our prediction of bias-controlled spin polarization reversal in Co/BN/graphene [1] suggests that tunable magnetic proximity effects may obviate the need for an applied magnetic field and magnetization reversal to implement graphene-based spin logic [5]. Lasing in TMDs [6] could be spin-enhanced and tunable using magnetic proximity effects to convert dark into bright excitons [2]. A combination of magnetic and superconducting proximity effects could enable peculiar Majorana bound states (MBSs) [7] for fault-tolerant quantum computing, intensively explored at Microsoft. Unlike fermions or bosons, exchanging (braiding) MBSs yields a noncommutative phase, a sign of non-Abelian statistics and nonlocal degrees of freedom protected from local perturbations. Such MBSs could be manipulated in proximity-induced superconductivity in a 2DEG with magnetic textures from magnetic tunnel junction (MTJ) fringing fields [8,9]. These magnetic textures can be tuned by changing the MTJ magnetization as implemented in commercial magnetic hard drives and magnetic RAM. We will discuss related experimental progress and outstanding challenges.

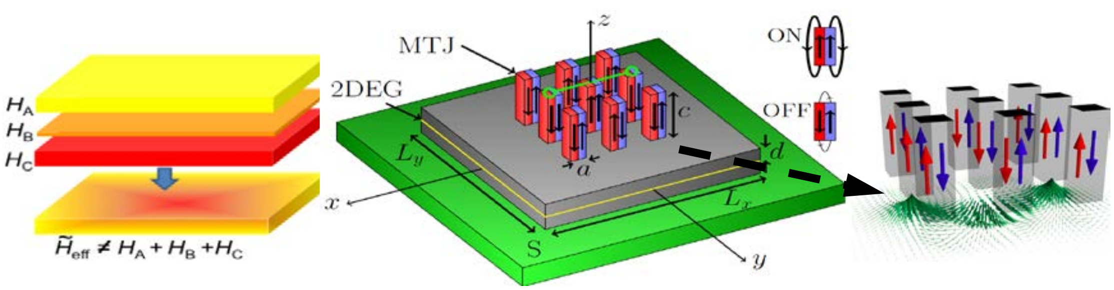

Fig. 1. Left: New features in proximity-modified layer B due to layers A and C, with the respective effective and individual Hamiltonians. Right: 2DEG grown on a superconductor (S). An MTJ array produces a magnetic texture, tunable by switching individual MTJs to parallel (ON) or antiparallel (OFF) configurations. Two MBSs form at the ends of the middle row (green curve) produced by the MTJ array fringing fields.

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