

Superconducting Spintronics for Racetrack Memory

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Superconducting spintronics is a highly interesting area of research which allows, for example, for the formation of unconventional superconducting states via proximity induced superconductivity in certain magnetic materials. We have shown that Josephson junctions fabricated from conventional s-wave superconductors that have barriers formed from an intrinsic noncollinear antiferromagnet¹ or from magnetic multilayers designed to have magnetic layers with orthogonal magnetizations² show very high supercurrent critical densities that are indicative of the formation of triplet supercurrents. Another highly interesting finding is the observation of a Josephson Diode effect (JDE)³⁻⁵ in both lateral and vertical Josephson junctions where the barrier is formed from a material that breaks both time reversal symmetry and inversion symmetry. The simplest case is perhaps that of the pure metal platinum that is magnetized at one surface by proximity to an insulating ferromagnet in a direction perpendicular to the supercurrent that is created by niobium electrodes at the opposing surface⁶. We find large asymmetries in the supercurrent critical density that increase with decreasing temperature below that of the superconducting ordering temperature of niobium. A more exotic case is where the barrier in lateral Josephson junctions is formed from a type II Dirac semi-metal, NiTe₂³. The superconducting critical current density shows large asymmetries for current flowing in opposite directions of up to 80% in the presence of small magnetic fields transverse to the supercurrent direction. The barriers can extend to almost a micron in extent and yet still allow for the passage of supercurrents. Similar results are found for barriers formed from PtTe₂⁴. Vertical junctions formed from WTe₂ also show a diode-like behavior in the presence of a magnetic field but only when the field is along a direction perpendicular to a mirror plane in the orthorhombic crystal structure of this unusual van der Waals material⁵. The JDE could form a novel device for reading magnetic nanoscopic objects at ultra low temperatures. Triplet supercurrents that carry spin angular momentum could potentially be used to manipulate magnetization. Together these two superconducting spintronic effects are highly interesting for potential applications in cryogenic logic and memory that could support quantum computing systems. One of the most interesting applications is for a novel cryogenic form of racetrack memory^{7*}.

References

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