Electrically Tunable Quantum States in Graphene-based Josephson Junctions

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Graphene-based Josephson junctions (GJJ's), consisting of a graphene layer in contact with two superconducting electrodes, provide a unique system to investigate superconducting proximity effect with in-situ tunable Josephson coupling energy. We investigated the stochastic switching behavior of the supercurrent in this system, which has not been seriously studied yet although the phase-coherent behaviors of GJJ's under the external magnetic field and microwave irradiation have been reported previously.[1] Here, we present the three different escaping regimes for a phase particle from a washboard potential of GJJ's, including macroscopic quantum tunneling (MQT), thermal activation (TA), and phase diffusion (PD). The crossover temperature (T^*_{MQT}) between the classical to quantum regime can be controlled by the electrostatic gating, implying that the discrete energy level of a phase particle in the potential well is also gate-tunable. Moreover, direct observation of energy level quantization (ELQ) by microwave spectroscopy shows the consistent gate dependence of T^*_{MQT}. A new class of quantum devices such as a gate-tunable phase qubit is potentially realized by utilizing the MQT and ELQ behavior of the GJJ's.

[1]H. B. Heersche *et al.*, Nature **446**, 56 (2007); D. Jeong *et al.* Phys. Rev. B **83**, 094503 (2011).