Macroscopic Quantum Tunneling and Thermal Activation Switchings in Nanometer-Thickness PbBi2212 Intrinsic Josephson Junctions

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The switching dynamics of $Pb_{0.1}Bi_{1.9}Sr_2CaCu_2O_{8+\delta}$ (PbBi2212) stacked intrinsic Josephson junctions (IJJs) are studied up to 0.4 K. Utilizing e-beam lithography and Ar ion milling techniques, we prepare mesa structures with dimensions of 1×1 μm^2 in the *ab*-plane and a few unit cells along the *c*-axis on PbBi2212 single crystals grown by the self-flux method. The substitution of Pb for Bi in BSCCO superconductors makes anisotropy parameter γ lower, which results in larger *c*-axis critical current density J_c. Sample A shows heavily under-damped IV characteristics with five branches equally separated in voltage with almost identical J_c, indicating that the mesa contains five IJJs consist of CuO_2 double layers and (Pb, Bi)O_2 block layers. The width of the switching probability distribution (SPD) from the superconducting ($R \simeq 0$) to the first resistive branch does not depend on temperature below 4 K while the SPD between 5 and 30 K fairly agrees with the thermal activation (TA) model. It is considered that the macroscopic quantum tunneling (MQT) is observed below 4 K. According to the single junction model, the fluctuation-free critical current $I_{c0} = 65$ μA gives the crossover temperature as 1.3 K, which considerably lower than the experimental result. In sample B with inhomogeneous J_c, SPD results show large deviation from the TA model in the temperature dependent region. The difference among two mesas can be understood by applying the long junction model to the sample B.