Observation of Macroscopic Quantum Depinning of Josephson Vortices

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We have studied the dynamics of Josephson vortex lattice in $Bi_2Sr_2CaCu_2O_{8+x}$ (Bi-2212) high-T_c superconducting single crystals with atomically layered structure. Current-voltage characteristics of a stack of Bi-2212 intrinsic Josephson junctions in a crystal were obtained in an in-plane magnetic field up to 6.5 T. As increasing magnetic field the quasi-particle branches were continuously suppressed. At higher magnetic fields above 2.0 T vortex-flow branches started to appear in the low-bias regime. Each branch is characterized by a maximum current, above which a jump takes place to a next higher-voltage branch. This switching between vortex-flow branches may correspond to a depinning of Josephson vortices in each junction.

The switching current distribution was measured for the last vortex-flow branch with decreasing temperature down to 300 mK. Electrical measurement leads were carefully filtered by RC low-pass filters and pi filters. Also the battery-powered current source was used to reduce the electrical noise. The switching-current distribution becomes narrower as lowering temperature. Below the crossover temperature T_c of ~3 K the width of the switching-current distribution becomes temperature independent. Above T_c, the thermal activation from the pinning potential due to thermal fluctuation plays a major role in the switching events. Below T_c, however, a temperature-independent depinning mechanism such as macroscopic quantum tunneling (MQT) out of the pinning potential is supposed to become dominant. Therefore, the switching-current distribution of the Josephson-vortex-flow branches is expected to provide valuable information about the collective pinning interaction between Josephson vortices and the pinning elements such as pancake vortices, which may exist in Cu-O planes for any tilted application of an external magnetic field.

Keywords: Josephson vortex flow branches, macroscopic quantum tunneling, collective pinning potential