Dynamics of Josephson Vortex Chains Probed by Microwave Excitation

Gilho Lee and Hu-Jong Lee
Department of Physics, Pohang University of Science and Technology, Pohang 790-784, Republic of Korea

Atomically tailored intrinsic Josephson junctions (IJJs) are formed in $Bi_2Sr_2CaCu_2O_{8+x}$ single crystals, which consist of stacks of CuO_2 superconducting layers weakly coupled with each other. We fabricated long stack of IJJs with a lateral size of 1 μm × 10 μm with double-side-cleaving technique. Applied with the in-plane magnetic field (~4.5 T) penetrating into the long side of the stack, current-voltage characteristic curve shows multiple Josephson vortex flow branches at low bias regime, of which switching corresponds to a depinning process of Josephson vortex chains out of the pinning potential. We investigated the *switching current distribution* of the last branch with lowering temperature from 8 K to 0.3 K. Down to the crossover temperature, T_{cr} ~ 3.8 K, the current distribution width gets smaller, which is in good agreement with theoretical fit to a thermal activation (TA) process out of the microresistor-type pinning potential. Below T_{cr} the distribution width is almost insensitive to the bath temperature, which is presumably due to a macroscopic quantum tunneling (MQT) process as a depinning mechanism. At base temperature of 0.3 K we examined the possibility of the *energy level quantization* in the pinning potential by applying microwave to the stack. With the appropriate conditions of microwave frequency and power, we could observe evolving feature of the depinning current distribution, which consists of the primary and the resonance peaks. The resonance peak position (I_r) data with the microwave frequency (f) fit well to a theoretical relation of $f = f_0/n(1-(I_r/I_c))^{1/4}$, where n is the number of photons involved and f_0 is a small-oscillation frequency (~ 81 GHz) and I_c is the critical current in the absence of any fluctuations. Although genuine MQT behavior of multi-vortex system is not clear yet, the double peak feature of the depinning current distribution under microwave excitation indicates the quantized energy levels in the pinning potential

Keywords: Josephson vortex flow branches, macroscopic quantum tunneling, microwave excitation, energy level quantization