Effects of Intrinsic and Extrinsic Pinning on the Josephson Vortex Phases and Dynamics of Superconducting Cuprates

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Abstract

A defect-independent 3D-XY phase transition, characterized by the universal critical exponents $\nu = 0.70 \pm 0.05$ and $z = 3.0 \pm 0.3$, has been verified for Josephson vortices in $YBa_2Cu_3O_7$ single crystals. Detailed comparison of our experimental results with recent theoretical studies and Monte-Carlo simulations suggests that the 3D-XY transition of Josephson vortices at $T_s(H)$ is analogous to a high-temperature liquid to low-temperature "smectic" phase transition as the result of intrinsic pinning of the CuO_2 layers in cuprate superconductors. The smectic phase is found to be very sensitive to any dynamic perturbation along the crystalline c-axis, suggesting that the helicity modulus of Josephson vortices along the c-axis, , $_z$, is at best very small at $T <\sim T_s$. In addition, the smectic phase appears to persist to very low temperatures in the case of untwinned and weakly twinned $YB_2Cu_3O_7$ single crystals. In contrast, we find supporting evidence for a *disorder-induced* smectic-to-glass Josephson vortex transition at a temperature T_G substantially lower than T_s in $YB_2Cu_3O_7$ single crystals with columnar defects. The vortex phase diagram and the dynamic response of Josephson vortices for $YBa_2Cu_3O_7$ single crystals with different degrees of disorder will be presented. Comparison with data from other cuprates such as $Bi_2Sr_2CaCu_2O_{8-x}$ will be discussed.