Mechanisms of Current Transport and Vortex Dynamics and Pinning on Grain Boundaries in High-T_c Superconductrs

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Abstract

We consider mechanisms which can account for the observed rapid decrease of the critical current density $J_c(\theta, H)$ through grain boundaries (GB) with the misorientation angle θ and magnetic field H in HTS. Due to the proximity of HTS to the metal-insulator transition, the strains and excess ion charge of the GB dislocation structure can locally induce dielectric regions near dislocation cores and cause progressive overall suppression of the order parameter ψ on GB with θ. A solution of the Ginzburg-Landau equation for $J_c(\theta)$, which takes into account the charge effects and the dislocation structure of low-angle GB, well describes the observed quasi-exponential drop of $J_c(\theta)$ with θ at small θ, while the symmetry of ψ only weakly affects $J_c(\theta)$. The field dependence of $J_c(\theta, H)$ is determined by vortex dynamics and pinning on GB which is strongly affected by the change of the vortex core by periodic structure of current channels on GB. Calculations of the core structure of static and moving vortices on GB have shown that the normal vortex core disappears, turning into a Josephson phase kink of length $l < \lambda$ along GB. Interaction of the weakly pinned vortex chain on GB with strongly pinned bulk vortices and periodic macroscopic inhomogeneities along GB can give rise to a nonmonotonic field dependence of $J_c(H)$ and matching peaks in $J_c(H)$. The latter were recently observed on YBCO bicrystals with periodic GB facet structures [X.Y. Cai, *et al.*, Phys. Rev. B**57**, 10951 (1998)].