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Effects of Randomly Oriented Columnar Defects on Vortex Pinning in High-T_c Superconductors: the Current Density and Equilibrium Magnetization

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For pinning of vortices in high-T_c superconductors, some form of correlated disorder is most effective. Irradiation with highly penetrating 0.8 GeV protons produces randomly oriented columnar defects (CD's) in HTS cuprates containing Hg, Tl, Pb, and Bi. Absorbing the energetic proton causes the heavy nucleus to fission, and the recoiling fission fragments create amorphous tracks. The randomly oriented CD's provide enhanced vortex pinning, as evidenced by large increases in the persistent current density and an elevated irreversibility line. Additional discoveries include (1) significant quantum tunneling of vortices in Bi-2212 tapes (leading to a temperature-independent decay rate for the current at low temperatures); and (2) an effective rescaling and refocusing of the angularly distributed CD's in Hg-cuprates toward the c-axis, which leads to a recovery of the variable range hopping (VRH) of vortices in the most anisotropic Hg-1223 material. In Tl-2212 materials, (3) the equilibrium magnetization $M_{eq}(H,T)$ decreases substantially when random CD's are added and it deviates strongly from the usual London dependence that $M_{eq}(H) \propto \ln(H)$. These results have been successfully modeled using theory that includes vortex-defect interactions, as well as vortex-vortex interactions.

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