Vortex Pinning in High-T_c Materials via Randomly Oriented Columnar Defects, Created by GeV Proton-Induced Fission Fragments

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For pinning of vortices in high-T_c superconductors (HTS), some form of correlated disorder has proven to be most effective. We have shown that irradiation with 0.8 GeV protons can produce randomly oriented columnar defects (CD's) in a large number of HTS materials, specifically those cuprates containing the heavy elements Hg, Tl, Pb, and Bi. Absorbing the incident proton causes the nucleus of these species to fission, and the recoiling fission fragments create amorphous tracks, i.e., CD's. The tracks are randomly distributed in angle, due to the isotropic nature of the fission process. The 0.8 GeV protons are very penetrating, with a range of ~60 cm in a typical HTS.

The randomly oriented columnar defects provide enhanced vortex pinning, as evidenced by large increases in the persistent current density and an elevated irreversibility line. In addition to these generally observed features, several further, interesting phenomena have been discovered. These include significant quantum tunneling of vortices in Bi-2212 tapes (leading to a temperature-independent decay rate for the current at low temperatures); an effective 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; and significant changes in the equilibrium magnetization $M_{eq}(H)$ of Tl-2212 materials, due to vortex pinning.

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