INVESTIGATION OF RESISTIVE LOSSES IN TYPE II SUPERCONDUCTORS

Abstract

by

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For low-T_C materials, the superconducting transition temperature (T_C) is depressed by the application of a magnetic field. In contrast, one of the remarkable features of cuprate high-T_C materials is that the superconducting transition is broadened by the application of a magnetic field. Tinkham presented a model for the field-dependent resistive transition of high-T_C materials, arising from "phase slippage at a complicated network of channels." Coffey & Clem did not include this field-broadening effect in their sophisticated model for the field and temperature dependence of the surface resistance in type-II superconductors. Nevertheless, Yeh *et al.* attempted to extend the Coffey-Clem model to polycrystalline cuprate thin films. These authors also presented experimental data on Nd-Ce-Cu-O, which show field-broadening effects, and these data appear to be well described by their "modified" Coffey-Clem model. From the model by Lee & Stroud, treating Josephson Junction-coupled superconducting segments, it is concluded that doped, layered superconductors are certain to have a field-broadened superconducting transition. This effect can be identified by measurements of the resistivity as a function of temperature, magnetic field strength, angle of field with respect to the crystal axis as well as with respect to an induced current density. The iron pnictide materials such as $Ba_{0.6}K_{0.4}Fe_2As_2$ (BaK122) have chemical layers with different compositions, differentiating them from elemental type-II superconductors such as niobium, and also from cuprates, by the absence of copper. Experimental data on BaK122 indicate a field-broadened transition in conjunction with a field-depressed superconducting transition temperature. In this work, techniques associated with Electron Spin Resonance (ESR) spectroscopy were used to measure the temperature and field-induced changes in the surface resistance of single-crystal BaK122 samples. In addition, polycrystalline foils of niobium and a NbTi (70/30) alloy were measured using the same techniques to provide comparison. Measurements were taken as a function of applied magnetic field, temperature, *rf* field intensity, and angle of the applied field with respect to the *rf*-induced current. BaK122 sample field-dependent surface resistance measurements were taken with the applied field along the *ab* plane and along the *c* axis. With both configurations, data on the superconducting surface resistance of the crystalline samples exhibited a nearly-linear dependence on the applied field; the field-dependent change increases in magnitude as the temperature approaches T_C from below; the field-dependent changes vanish in the normal state. By varying the angle ϕ between the applied field and the current, the microwave signal exhibited a $sin^2(\phi)$ behavior superimposed on a field-dependent background. As the transition temperature is approached from below, the angular-dependent response becomes convoluted. The $sin^2(\phi)$ amplitude of the signal is generally consistent with the behavior of flux-flow resistivity; however, the presence of a field-dependent change in the $\phi = 0$ field configuration is not described by flux-flow, but is attributed to phase slip in the crystal. The signal with $H \parallel J$ (the phase slip signal) as $T \rightarrow T_C$ is roughly 10 times the magnitude of the flux-flow signal. For the niobium foils, the field-dependent changes were also observed in the $\phi = 0$ configuration superimposed with a signal consistent with flux-flow resistivity. The results of these studies are consistent with the picture of BaK122 as a layered superconducting material that contains Josephson-coupled segments generally consistent with the model of Lee & Stroud, which identifies but does not explore the temperature- and field-dependence

of phase slip. However, the presence of phase slip in the polycrystalline Nb and NbTi foils is not explained by this model.