Resistivity Measurements on Bulk $Bi_2Sr_2CaCu_2O_{8+\delta}$: Contribution of Vortices at Low Magnetic Fields

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ABSTRACT

The behavior of high-temperature superconductors in the presence of an external magnetic field is of particular interest in light of its technological application and commercialization. In this paper, we perfonned resistivity measurements on bulk superconducting pellets of $Bi_2Sr_2CaCu_2O_{8+\delta}$ in the presence of external magnetic fields below 0.5T. The broadening of the transition region below Tc in the resistivity plots, was attributed to the residual resistance imparted by flux flow in the sample. From 1-V measurements at 50 K at fields below 0.6T, the contribution of vortices was quantitatively measured as a flux flow resistivity which range from 0.1231 to 1.700 (m(-mm) for applied magnetic fields from 0.04T to 0.6T. The increase in the flux flow resistivity with increasing applied field was due to the increase in the number of vortices moving in steady state motion brought about by the interaction of the vortices with the transport current.

!\erworc/s: superconductors, resistivity, vortices, flux flow resistivity, magnetoresistance

INTRODUCTION

As expedient as high critical temperature superconductors (HTSC) are, their properties in the presence of an external magnetic field should inexorably be studied since these materials would necessarily be exposed to these fields in technological use.

An applied magnetic field penetrates a superconductor in the mixed state. The pendration occurs in the form of tubes, called vortices, which serve to confine the flux. The interaction between vortices is repulsive so that they arrange themselves as far away from each other, as in a flux lattice in clean samples or as vortex glass in the presence of randomly distributed pinning centers. The pinning centers may be point defects, grain boundary or intra/intergranular non-superconducting regions. On the other hand, transport currents and thermal fluctuations can both induce flux motion, due to the Lorentz force, and produce dissipation. This can involve, for example, the release and transportation of vortices to other pinning centers, and the pinning and depinning of flux bundles. Flux flow can be viewed as a rate of change of flux which, by faraday's law, produces a voltage drop in the superconductor along the direction of the transport current. The resistance associated with this motion provides a mechanism for heat dissipation (Poole et aI., 1995).

In this study, the contribution of these vortices were investigated through resistivity measurements in varying magnetic fields. This contribution was quantitatively determined as the flux flow resitivity.

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METHODOLOGY

The samples were bulk superconducting pellets of $Bi_2Sr_2CaCu_2O_{8+\delta}$ which were prepared via the solid state reaction method. The pellets were cut into 3.Ox8.0x 1.0 mm rods. The electrical contacts used were gold wires attached by pressed indium solder. The transport measurements were done using the in-line contact configuration to minimize errors from leads and contact resistances (Ison, 1999).

After the sample was cooled down to ~10K, using a closed-cycle helium cryostat, resistivity measurements were done using a current of SOmA in different magnetic fields below 0.5T.

The contribution of the vortices when the resistivity measurements were done with an external magnetic field was determined through I-V measurements with fields below 0.6T.

RESUL 1'S AND DISCUSSION

From the resistivity measurements performed at varying fields below 0.5T (Fig. 1), a broadening of the transition region below the critical temperature (T_c) was observed. This is attributed to the residual resistance imparted by flux flow in the sample. Also, it can be seen that the plots coincide in the high temperature region above Te since there are no more defined vortices in the sample when it is in its normal state (Bishop et aI., 1993).

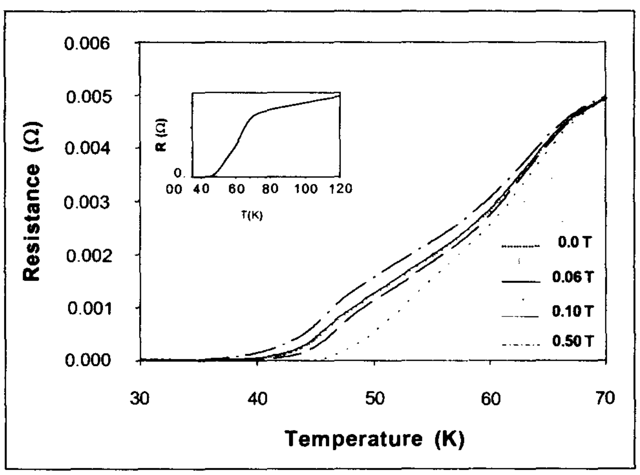

Fig. I. The resulting resistivity plots at varying magnetic fields below 0.5 T. Inset shows a typical resistivity plot at 0 T

This residual resistance termed as flux flow resistance was quantitatively determined from:

$$(1)\quad V = R_{ff}\,(I - I_c)$$

In equation (I), Ie is the critical current which was determined through I-V measurements done at 50 K for varying magnetic fields.

The flux flow resistance, R_{ff}, was denved as the slope of the linear part of the corresponding I-V curves. Knowing the dimensions of the sample, the corresponding flux flow resistivity (r_{ff}), was calculated usmg:

$$(2)\quad \rho_{ff} = R_{ff}\,\frac{\sigma}{dL}$$

where 0" is the sample cross-section and *dL* is the separation of the voltage contacts.

Fig. 2 shows that the critical current decreases with increasing magnetic fields. This is because, the external magnetic field destroys the superconductivity in the sample resulting in the lowering of the amount of supercurrent that the sample can carry.

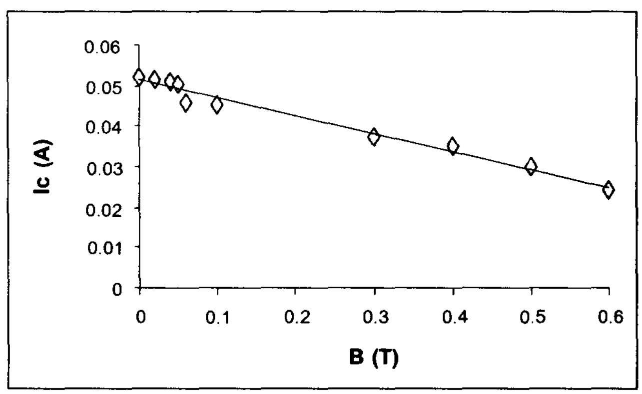

Fig. 2. Magnetic field dependence of the transport critical current ofa bulk Bi,Sr,CaCup8+& sample determined at 50 K

Fig. 3 shows that the flux flow resistivity increases with respect to the magnitude of the applied magnetic field. This increase in the resistance indicates that the vortices are interacting with the transport current (Poole et aI., 1995; Bishop, 1993). If the Lorentz force on the vortices due to the transport current is large enough to unpin

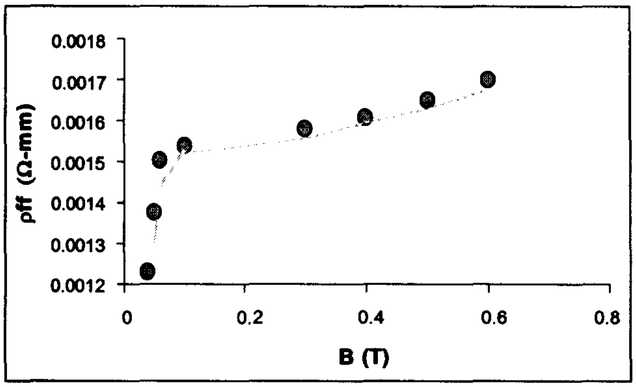

Fig. 3. Magnetic field dependence of the flux flow resistivity of $Bi_2Sr_2CaCu_2O_{8+\delta}$ for transport at 50 K

the vortices so that they move from one pinning center to the next, then the resistance effectively increases. On the other hand, the granular nature of the sample would establish that the vortices would remain pinned due to the random orientation of the supercooducting planes. Therefore, the increase in the resistance implies that there is an increase in the number of vortices in the liquid phase, present in the sample. The increase in the flux flow resistivity corresponds to an increase in the amOlmt of field that was able to penetrate the sample. Since vortices are quantized, an increase in the internal field would be due to the addition of vortices moving in steady-state motion.

The dependence of the critical current and the flux flow resistivity on the externally applied magnetic field, as detennined in this investigation, conformed with previous studies (poole et al., 1995; Ison, 1993; Yeshurun, 1996).

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