Evolution Towards a Conventional Vortex-Solid to Vortex-Liquid Phase Boundary with Oxygen Doping in $Y_{0.8}Ca_{0.2}Ba_2Cu_3O_x$ Films

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Introduction

From recent work at the NHMFL in which the vortex glass melting line, $H_g(T)$, of $Y_{1-x}Pr_xBa_2Cu_3O_{7.5}$ film samples were investigated, a model was developed describing the vortex glass melting transition with unprecedented accuracy [1, 2]. By extending magneto-transport measurements to magnetic fields of 35 tesla, we have been able to examine the vortex melting transition of $Y_{0.8}Ca_{0.2}Ba_2Cu_3O_x$ film samples ($6.45 \leq x \leq 7.0$) over a field-temperature range larger than heretofore reported.

Experimental

The films were grown at UCSD by the pulsed laser deposition method on $LaAlO_3$ substrates with a $<001>$ orientation. All electrical transport measurements were made with the applied magnetic field $H \parallel c$. For measurements made at the NHMFL in the 35 tesla magnet system the temperature was held fixed with the magnetic field swept at 2-3 tesla per minute.

Results and Discussion

It was found in this work that the shape of $H_g(T)$ evolves from a very shallow low-field temperature dependence to an extremely rapid high field temperature dependence in the highly under-doped regime. However, in the lightly over-doped regime, $H_g(T)$ displays an increasingly steep low-field temperature dependence followed by a lessening of the steepness of the high-field region as oxygen content increases. This trend suggests that the boundary of the dissipation-less superconducting region of this unconventional high-$T_c$ cuprate based compound is evolving in the over-doped state towards a form that is consistent with what is observed in conventional superconductors. For clarity, the vortex glass melting lines of three representative samples are shown in Fig. 1. The melting lines were analyzed in the context of the model of the vortex-solid to vortex-liquid transition developed in Refs. [1] and [2]. Values of the Lindemann number, $c_L = 0.31$, are consistent with that found for other hole-doped cuprate-based superconductors [1, 2]. The quantum parameter, $Q$, is seen to systematically decrease into the over-doped region, again suggesting a trend towards conventional superconducting behavior.

Conclusions

The changing shape of $H_g(T)$ of films of $Y_{0.8}Ca_{0.2}Ba_2Cu_3O_x$ with increasing oxygen doping suggests that the superconducting properties in the over-doped region are evolving towards a more conventional nature.

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References