Zero-Magnetic-Field Phase-Decoherence Transition in Underdoped $La_{2-x}Sr_xCuO_4$

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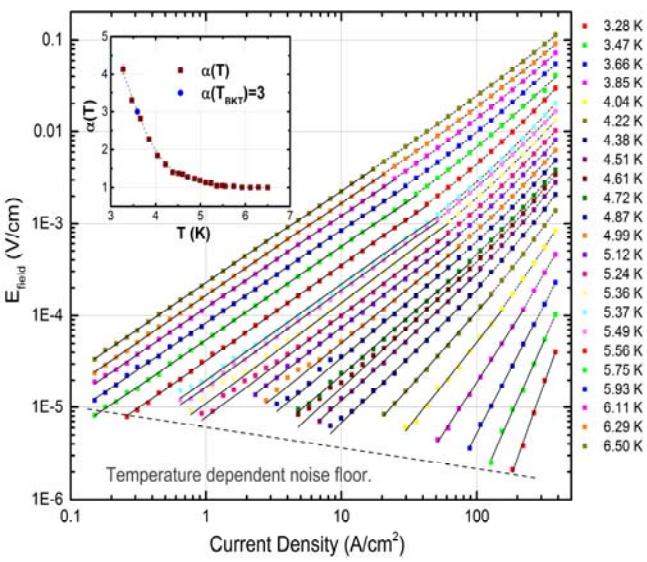
Introduction

There is currently no consensus on the origin of the pseudogap regime in the cuprate superconductors. One of the proposed explanations is that Cooper pairs persist above the zero-resistance critical temperature (T_c) without phase coherence [1]. Therefore, understanding the nature and the extent of superconducting fluctuations (SCFs) above T_c is of key interest. The present study on underdoped $La_{2-x}Sr_xCuO_4$ (LSCO) uses magnetoresistance (MR) measurements to track the SCF contribution to conductivity ($\Delta\sigma_{SCF}$) and current-voltage (*I*-*V*) behavior near T_c. The results are consistent with the presence of a phase-decoherence transition similar to a Berezinskii-Kosterlitz-Thouless (BKT) transition, in which vortex-antivortex pairs unbind above T_c.

Experimental

The samples were MBE-grown LSCO films with x=0.07 (T_c=4.2 ± 0.3 K) and x=0.08 (T_c=8.7 ± 0.2 K). In-plane current-voltage (*I*-*V*) curves were measured using dc techniques in zero magnetic field (*H*=0) near the respective critical temperatures of the two samples.



Results and Discussion

$\Delta\sigma_{SCF}(H=0)$ was determined from our earlier MR measurements at *H* high enough to recover the normal state resistivity. $\Delta\sigma_{SCF}(H=0)$ diverges exponentially near T_c, as expected for phase fluctuations [2]. Furthermore, the *I*-*V* curves exhibit a power-law behavior, $V \sim I^{\alpha(T)}$, consistent with a BKT transition in which a universal jump in the superfluid density is expected to occur due to the sudden onset of vortex-antivortex unbinding. This is reflected in a jump in α(T) from $\alpha(T_{BKT})=3$ to $\alpha(T>T_{BKT})=1$. Figure 1 shows that, in LSCO, α(T) exhibits a broadened jump over the transition region, but T_{BKT} can still be estimated by $\alpha(T_{BKT})=3$ [2]. In both samples, the obtained T_{BKT} is in reasonable agreement with the zero-resistance T_c: T_{BKT}=3.6 ± 0.1 K for x=0.07 and T_{BKT}=8.5 ± 0.1 K for x=0.08.

Fig. 1 *I*-*V* measurements at constant *T* for x=0.07. The data are converted to electric field and current density to normalize for the sample dimensions. Solid lines are fits; dashed lines guide the eye. The dashed line at the bottom marks the *I*-*V* measurement noise floor, which is dependent on relative *T* fluctuations. The inset shows α(T) determined from the slope of the log(*I*)-log(*V*) data.

Conclusions

Two types of transport measurements, the SCF contribution to the conductivity $\Delta\sigma_{SCF}(H=0)$ and the power-law *I*-*V* behavior, show evidence for a BKT-like phase fluctuation transition that occurs at the zero-resistance T_c in underdoped $La_{2-x}Sr_xCuO_4$. The results are also in agreement with recent work on LSCO with higher doping (x ≥ 0.11) obtained using *I*-*V* techniques [3].

Acknowledgements

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References

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