Signatures of the Berezinskii-Kosterlitz-Thouless Transition in Highly Underdoped $La_{2-x}Sr_xCuO_4$

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Introduction

The superconducting transition in 2D systems is expected to belong to the Berezinskii-Kosterlitz-Thouless (BKT) universality class [1, 2]. However, in systems that are not strictly 2D, such as cuprates, the presence of the BKT transition is still controversial. We investigated the nature of the thermally driven transition to a superconducting state on MBE-grown 100 nm thick $La_{2-x}Sr_xCuO_4$ (LSCO) films with x = 0.07 and 0.08 by studying a) superconducting fluctuations (SCFs), as determined from the magnetoresistance (MR), b) current-voltage (I - V) characteristics, and c) fluctuations of conductance with time (noise) at different temperatures T. Our results show that the transition from the superconductor to the normal state exhibits signatures of the BKT transition.

Experimental

In-plane MR in fields up to 18 T and I-V characteristics in a zero magnetic field were measured on standard Hall bar samples. Noise was studied on narrow (width = 20 μm) samples specifically designed for measurements in the eight-probe double-bridge configuration, at temperatures near their respective zero-resistance (R=0) critical temperatures. Higher-order spectrum analysis has been carried out to probe for possible long-range correlations in the phase fluctuations.

Results and Discussion

We observe: a) the contribution of the SCFs to the conductivity increases monotonically with decreasing T and diverges exponentially at T_{BKT}, where R also goes to zero; b) power-law behavior $V \sim I^{\eta(T)}$, with $\eta(T) \geq 3$ for $T \leq T_{BKT}$; and c) an orders-of-magnitude enhancement of the noise near T_{BKT} (Fig. 1). The higher-order spectrum analysis of the non-Gaussian noise observed near T_{BKT} suggests the presence of correlated conductance fluctuations. It is interesting that the noise results on our LSCO films are similar to those in conventional 2D superconducting films (NbN) near T_{BKT} [3].

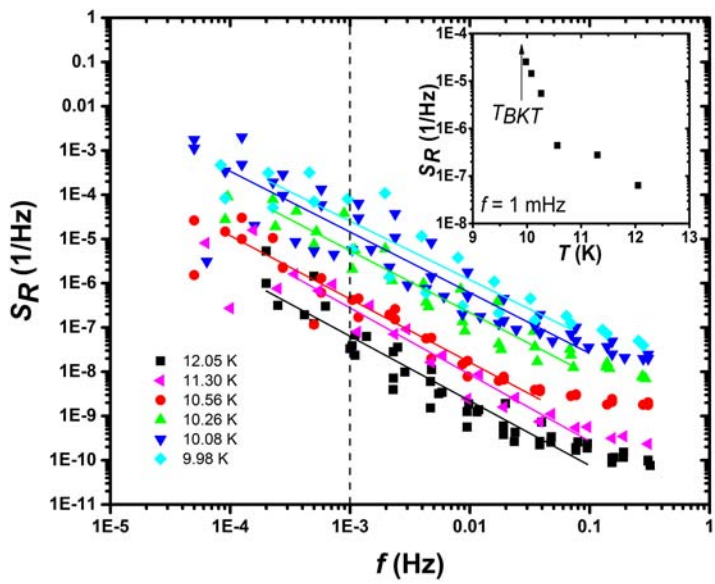

Fig.1 The octave-averaged noise power spectra $S_R(f)$ vs. frequency f for LSCO with x=0.08 at several T. All curves follow a power-law behavior $S_R \sim 1/f^{\alpha}$. Solid lines are linear fits with the slopes α ~ 1.5. An overall increase in the noise magnitude is observed as the temperature approaches T_{BKT} (~9.9 K) from above. Inset: The value of $S_R(f$ = 1 mHz), as a measure of the magnitude of the noise, vs. T.

Conclusions

The superconducting transition in highly underdoped, "bulk" $La_{2-x}Sr_xCuO_4$ films shows signatures of a BKT transition. The results seem consistent with theoretical considerations for layered 3D superconductors with weak interlayer coupling and large vortex-core energy [4].

Acknowledgements

This work was performed at the National High Magnetic Field Laboratory, which is supported by National Science Foundation Cooperative Agreement No. DMR-1157490, the State of Florida, and the U.S. Department of Energy. This work is also supported by NSF DMR-1307075.

References

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