Study of superconducting fluctuation regime of the high-temperature superconductor (La,Sr)2CuO4

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Theory

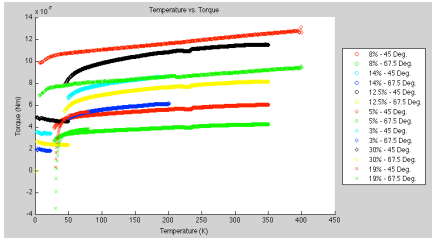
The superconducting fluctuation regime is a temperature region observed in the cuprate superconductors in which signs of superconductivity emerge before the superconducting transition-temperature (T_c) has been reached. This project studies the extent of the fluctuation regime observed in (La,Sr)2CuO4 (LSCO).

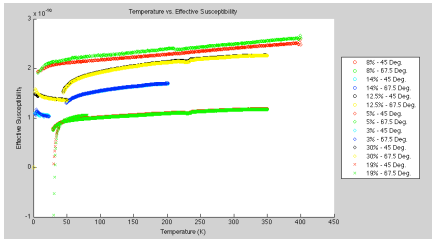
Investigations into the origin of the superconducting fluctuation regime are incredibly important to a more complete understanding of the pseudogap phenomena observed in the cuprate superconductors, an incredibly complex problem in condensed matter physics that has been extensively studied for many years.

Measurements

Samples were first characterized to determine quality and doping levels using the magnetic properties measurement system (MPMS) from Quantum Design. After grown samples were characterized, torque magnetometry measurements were taken with the Quantum Design physical properties measurment system (PPMS). The Raw data that was obtained was subject to an extensive analysis.

Results

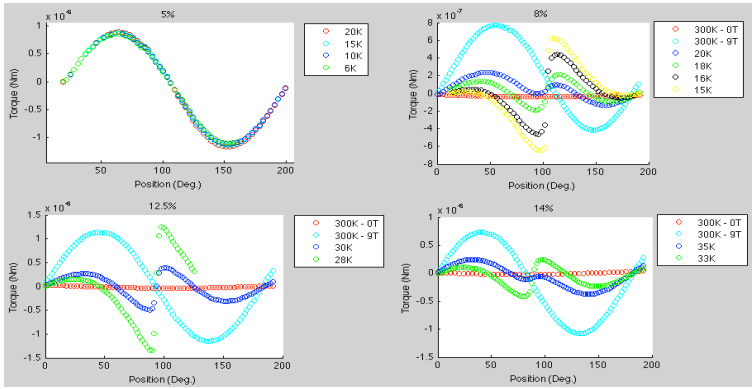




Raw data from torque magnetometry measurements was used to produce both of the figures found directly to the left. The torque vs. temperature figure was used to produce the effective susceptibility vs. temperature figure by using the relation:

$$\chi_{torque} = \frac{2\tau}{\mu_o H^2 \sin(\theta)}$$

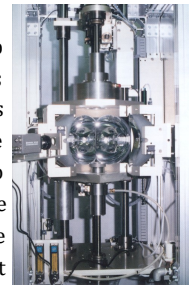
where τ is the torque observed, μ is the permittivity of free space and θ is the angle of the crystalline c-axis with respect to the applied magnetic field.



The superconducting fluctuation regime is characterized by the deviation from a sin(2θ) fit in the position vs. torque figures. The fluctuation regime is the temperature range which starts when deviations from this form begin to be observed.

Crystal Growth

Large (La,Sr)2CuO4 single-grain crystals of high quality were grown using a traveling solvent floating zone technique. This method is preferable over any other for the growth of large single-grain crystals as growth conditions are incredibly well controlled.



Our research group has three image furnaces from Crystal Systems Inc. Growth can take anywhere from ten to thirteen days to produce a single crystal, and the process is quite difficult to learn.

Conclusion

The extent of the superconducting fluctuation regime was studied for several LSCO samples. However , as I was only able to measure four different doping values, I was unable to determine the true extent of the superconducting fluctuation regime over the entirety of the LSCO phase diagram.

This experiment could be improved upon by measuring the fluctuations for samples covering the entire LSCO phase diagram.

[1] "University of Maryland Materials Research Science and Engineering Center." Web. <http://mrsec.umd.edu/images/SEF/FZF-lg.jpg>.

[2] "Physical Property Measurement System (PPMS®)." *Quantum Design, Inc.* Web. <http://www.qdusa.com/products/ppms.html>.

[3] Yu, G. et al., "Universal superconducting fluctuations and the implications for the phase diagram of the cuprates." To be resubmitted to *Nature Physics* (2013).