Negative Hall Coefficient in the Normal State of Hole-doped Cuprate Superconductors

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Introduction

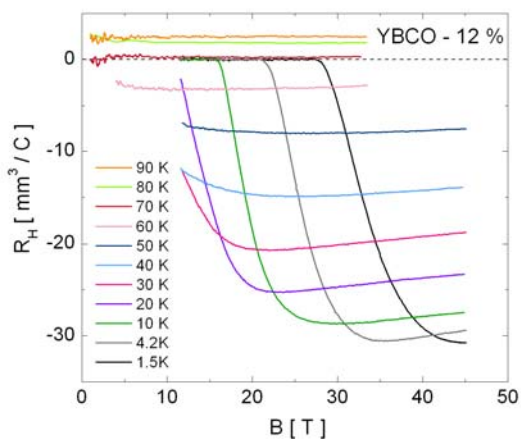
Earlier this year, quantum oscillations in the Hall resistance of the cuprate superconductor $YBa_2Cu_3O_y$ (YBCO) at 10% doping were observed [1], convincingly showing that there is a Fermi surface in underdoped cuprates. Yet, the large magnitude and negative sign of the Hall resistance remained a puzzling issue given that YBCO is a hole-doped material. To understand this problem, we carried out further high-field measurements of the Hall resistance of YBCO.

Experimental

The Hall and longitudinal resistances were measured using a 4-point lock-in method. The samples, grown at UBC, were detwinned chain-ordered YBCO platelets with dopings of 10 and 12%. Measurements were done in the 45 T hybrid magnet in Tallahassee during the week of March 26-30, 2007. The current was long the *a*-axis and the magnetic field along the *c*-axis.

Results and Discussion

In the figure on the right we show the Hall coefficient R_H measured in YBCO at 12% doping as a function of magnetic field up to 45 T. We see that R_H is positive above 70 K, and strongly negative below. Strikingly, at 70 K R_H vanishes at all fields, showing that the sign change is field independent and occurs above the superconducting T_c of 67.5 K. While previous studies on cuprates (see, e.g., [2]) limited to low field below 25 T attributed this sign change to a negative flux flow contribution, our high field data demonstrate that a negative R_H at low temperature is an intrinsic normal-state property. These results obtained at the NHMFL were published in Nature on 22 November 2007. [3]



Conclusions

In order to understand the pronounced temperature dependence and sign change of R_H, one must invoke a scenario where two types of carriers - electrons and holes – with different mobilities are present. Because the quantum oscillations are observed at low temperature when R_H is negative, we conclude that they come from small electron pockets in the Fermi surface of YBCO. This observation can be explained by a reconstruction of the large cylindrical hole Fermi surface into small hole and electron pockets [3], as is believed to occur in electron-doped cuprates because of antiferromagnetic ordering. The nature of the order causing the reconstruction in YBCO remains to be identified.

Acknowledgements

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References

[1] Doiron-Leyraud, N. *et al*., Nature **447**, 565 (2007).
[2] Harris, J.M. *et al.*, Phys. Rev. Lett. **71**, 1455 (1993).
[3] LeBoeuf, D., *et al*., Nature **450**, 533 (2007).

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