Fermi Surface Reconstruction in the Model Cuprate Superconductor $HgBa_2CuO_{4+\delta}$

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Introduction

Competing ordered states shape the phase diagram of cuprates and the identification of those states is currently a central challenge of high-temperature superconductivity. The observation of a small electron pocket in the Fermi surface of underdoped $YBa_2Cu_3O_y$ (YBCO) [1] showed that a phase with charge and/or spin density-wave order is present. This prompted an intense search, which led to the observation of charge-density wave (CDW) modulations in YBCO by NMR [2] and X-ray diffraction [3]. Such density-wave order has so far been observed only in cuprates with some degree of distortion in their CuO_2 plane, such as the low-temperature tetragonal phase of La_2CuO_4-based cuprates and orthorhombic YBCO. The fundamental question, then, is whether such charge modulations are stabilized by these particular forms of unidirectional distortion, or are a universal property of cuprates with a square CuO_2 lattice. To examine that question we have turned to $HgBa_2CuO_{4+\delta}$ (Hg1201), a model cuprate with a tetragonal crystal structure and the highest maximal T_c of all single-layer cuprates (97 K).

Experimental

We have measured the Seebeck coefficient S of thermopower in ultraclean crystals of Hg1201 as a function of magnetic field up to 45 T at different temperatures T. As seen in Figure 1a, at high temperatures above 20 K, S/T saturates at a positive value. As the temperature is lowered, S/T shows a drop at high fields and becomes negative at the lowest temperatures. In Figure 1b we plot the high-field normal-state data as a function of temperature, showing clearly a sign change at a temperature of about 10 K.

Results and Discussion

As seen in Fig. 1b, the same sign change was observed in YBCO [4] where it is unambiguously caused by a high mobility electron pocket in the Fermi surface. Indeed, like in the Hall effect, the sign of the charge carriers governs the sign of the Seebeck effect, and we therefore conclude that an electron pocket is also present in the Fermi surface of Hg1201 at low temperatures. In both YBCO and Hg1201, such an electron pocket is not expected from the band structure and therefore implies a Fermi-surface reconstruction by some density-wave order. This was confirmed by the observation of CDW order in YBCO. Our findings in Hg1201 point to a similar CDW order in Hg1201.

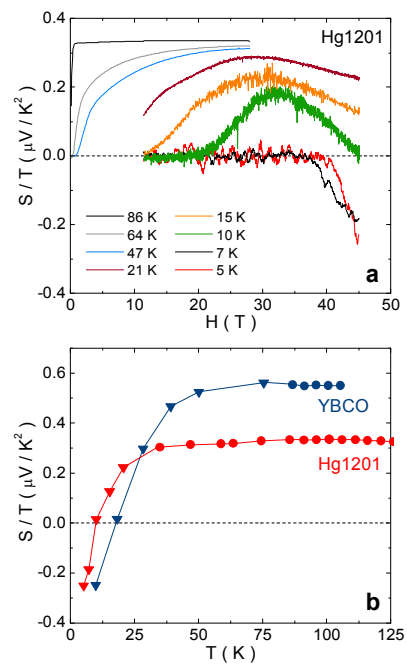

Figure 1: Seebeck coefficient of Hg1201 with T_c = 65 K, as a function of magnetic field at various temperatures (a) and as a function of temperature at high field (b). Corresponding data for YBCO at p = 0.10 are shown, from [4].

Conclusions

Our measurements provide the first evidence for Fermi-surface reconstruction and density-wave order in the clean model cuprate Hg1201 [5], suggesting that these are universal properties of hole-doped cuprates. Following our work, quantum oscillations were observed in Hg1201 [6], confirming the existence of a small electron Fermi surface. We anticipate that CDW order will be detected in Hg1201.

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References

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