ANISOTROPIC SUPERCONDUCTIVITY AND FERMI LIQUID BEHAVIOR IN BULK CaC_6

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Introduction and Experiment

The intercalated graphite superconductor CaC_6 with T_c ~ 11.5 K has been synthesized and characterized with susceptibility and magnetoresistance measurements [1]. Above T_c, the inter-plane resistivity follows a T^2 dependence up to 50 K, indicative of Fermi liquid behavior. Above 50 K, the Bloch-Gruneisen model provides a Debye temperature of θ_D = 263 K. By using the McMillan formula, we estimate the electron-phonon coupling constant to be λ = 0.85, indicating an intermediate-coupling regime. The angular dependence of the upper critical field parallel and perpendicular to the superconducting planes shows anisotropic superconductivity. Our results are consistent with BCS-like superconductivity.

CaC_6 samples were prepared using highly-oriented pyrolytic graphite with a liquid-solid reaction. A lithium-calcium alloy (ratio 3:1) was prepared in an argon glove box at 220 degrees C, and thin sheets of pristine graphite were inserted. The entire sample mixture was sealed in a stainless-steel reaction container, and placed on a hot plate at 350 degrees for 10 days. The samples were extracted from the molten solution inside of the glove box, and only very thin samples with shiny metallic surfaces were used for the measurements. The size of a single sample was 1.5 mm x 1 mm x 0.2 mm thick. The transition temperature T_c = 11.5 K was confirmed with DC susceptibility measurements in a field of 50 G applied parallel to the ab-plane, as shown in Fig. 1. From the saturation of the diamagnetic signal, the volume fraction of the superconducting phase s was estimated to be 95(5) percent. The resistivity data were measured using a conventional ac four-probe method with current applied along c-axis, as shown in Fig. 1b for zero field. A rotator probe was used to carry out the angular dependent critical field measurements (not shown – see Ref. [1]), and the inflection points of the magnetoresistance were taken as the critical fields for the angular dependent data shown in Figs. 1c and 1d.

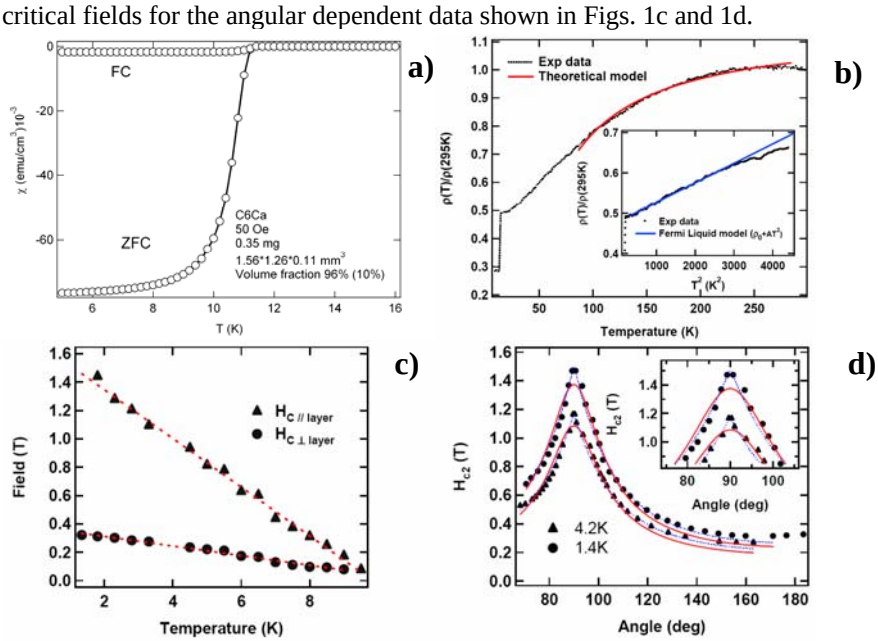

Fig. 1:
a) DC Susceptibility of CaC_6 vs. temperature showing superconducting transition.

b) Resistance vs. temperature. Inset: T^2 dependence above T_C.

c) Critical fields H_c determined from the inflection points of the magnetoresitance for fields parallel and perpendicular to the planes.

d) Critical field anisotropy. The blue lines are the 2D Lawrence-Doniach model, and the red lines are the 3D anisotropic effective mass model.

Results and Discussion

The main results of this work are that CaC_6 is characteristic of a Fermi liquid in the metallic state, that the superconductivity is BCS in the medium coupling limit, and that the critical fields are relatively anisotropic. Although the 2D superconductivity model gives the best fit to the data in Fig. 1d, we cannot confirm that the superconductivity is indeed 2D. Because the resistive superconducting transition is incomplete in the sample, additional anisotropy may be present in the form of a minority of non-stoichiometric layers, although Fig. 1a indicates that the majority of the sample is superconducting.

Acknowledgements

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References

[1] E. Jobiliong et al., cond-mat/0604062 (2006), and to be published.