Pramāṇa – J. Phys., Vol. 30, No. 4, April 1988, pp. L345–L346. © Printed in India.

# On the pairing interaction in high $T_c$ superconductors

P CHADDAH

Nuclear Physics Division, Bhabha Atomic Research Centre, Bombay 400 085, India

MS received 20 January 1988

**Abstract.** It is argued, from the dependence of the critical current density and of $T_c$ on applied magnetic field, that the pairing interaction in high $T_c$ superconductors must be strongly field-dependent.

**Keywords.** High $T_c$ superconductors; pairing.

**PACS Nos** **74·20; 74·60**

We have earlier shown (Ravi Kumar and Chaddah 1988a, b) that the existing magnetization data on high $T_c$ superconductors is explained by a critical current density $J_c$ that decays exponentially with applied field. Since data on single crystal $YBa_2Cu_3O_7$ are also consistent with $J_c \approx J_{c0} \exp(-H/H_0)$, we have considered this behaviour to be intrinsic to high $T_c$ superconductors. Farrell *et al* (1987) have observed a zero field $J_c \simeq 2 \times 10^7$ A/cm$^2$ at 4·2 K, and this is close to the depairing limit of $\approx 10^8$ A/cm$^2$. Their sample also shows an exponential decay of $J_c$ with field. One possible reason for the observed decay of $J_c$ with $H$ could be that the depairing current itself decays exponentially with field. Within the BCS model this would correspond to the isotropic and $k$-independent pairing interaction $V$ varying with field as $1/(H+K)$ where $K$ is a constant. Such a variation is not possible for phonon-mediated interactions, but could be visualized in a pairing interaction mediated by local spin configurations as modelled, for example, by Emery (1987).

Such a pairing interaction would result in a sharp decay of the superconducting gap with increasing field, but no field dependent measurements of the gap have so far been reported. The dependence of $T_c$ on the applied field is, however, available from the $H_{c2}$ data. It will now be argued that the $H_{c2}$ data also indicates a field dependent pairing interaction.

It has been reported in literature (Orlando *et al* 1987) that for $La_{2-x}Sr_xCuO_4$ and $RBa_2Cu_3O_7$ compounds the resistive transition broadens rapidly with increasing applied field. A second feature is not emphasized but is apparent from the published data and is more important. The curvature of $T_c$ vs $H$ (or that of $H_{c2}$ vs $T$) is concave near $T_c$. Such a curvature is contrary to the BCS result (or even WHHM theory) which yields a convex curvature for a field-independent $V$. Since this feature is not emphasized in literature we will discuss it in some detail.

Since the first non-trivial solution to the BCS gap equation will occur at the temperature where resistivity is zero (and not at the midpoint of the resistive transition), the $H_{c2}(T)$ relevant to any discussion strictly corresponds to the temperature at which $\rho = 0$. A close look at the reported resistive transitions in $La_{1\cdot 85}Sr_{0\cdot 15}CuO_4$ (Kwok *et al*

1987) and in $YBa_2Cu_3O_7$ (Maple 1987) shows that the $H_{c2}$ *vs* $T_c(\rho=0)$ data is concave. Both these data are on polycrystalline samples, and tentative explanations can be offered on why $T_c(\rho=0)$ may not be intrinsic to the material. $H_{c2}(T)$ data on single crystal $YBa_2Cu_3O_7$ are now available (Moodera *et al* (1987)) with the crystal showing little twinning. The concave curvature of $H_{c2}$ vs $T$ is apparent and is seen in both the basal plane and along *c*-axis. This feature is irrespective of whether $T_c$ is defined as where one has 10% or 50% or 90% of the normal state resistivity, and the curvature is a better approximation to an exponential decay as the definition of $H_{c2}$ is shifted towards the zero resistivity condition. An exponential decay would again imply a strong field dependence in $V$.

Our argument that the concave curvature implies a field-dependent $V$ and thus a spin-dependent pairing interaction is strengthened by the fact that such a concave curvature was seen by Sarkissian and Tholence (1986) in $Y_9Co_7$ where strong spin correlations are known to precede superconductivity.

The most important experimental data now required is a measurement of the superconducting gap as a function of applied field. This can yield the $H$-dependence of the pairing interaction.

**Acknowledgements**

The author is grateful to Dr A K Grover, G Ravi Kumar, Dr P Bhattacharya and Dr B A Dasannacharya for helpful comments.

**References**

Emery V J 1987 *Phys. Rev. Lett.* **58** 2794

Farrell D E, Chandrasekhar B S DeGuire M R, Fang M M, Kogan V G, Clem J R and Finnemore D K 1987 *Phys. Rev.* **B36** 4025

Kwok W K, Crabtree G W, Hinks D G, Capone D W, Jorgenson J D and Zhang K 1987 *Phys. Rev.* **B35** 5343

Maple M B 1987 *Chinese J. Phys.* (submitted)

Moodera J S, Mersrvey R, Tkaczyk J E, Hao C X, Gibson G A and Tedrow P M, 1987 *Phys. Rev.* **B** (submitted)

Orlando T P, Delin K A, Foner S, Mc Kinnon W R and Hull G W 1987 *Phys. Rev.* **B35** 5347

Orlando T P, Delin K A, Foner S, Mc Kinnon W R and Hull G W 1987 *Phys. Rev.* **B36** 2394

Ravi Kumar G and Chaddah P 1988a *Phys. Rev. Lett.* (submitted)

Ravi Kumar G and Chaddah P 1988b *Phys. Rev.* **B** (submitted)

Sarkissian B V B and Tholence J L 1986 *J. Magn. Magn. Mater.* **54–57** 1525

Senoussi S, Oussena M and Collin G 1987 *Phys. Rev. Lett.* (submitted)