PHYSICAL REVIEW B VOLUME 54, NUMBER 21 1 DECEMBER 1996-I

COMMENTS

Comments are short papers which criticize or correct papers of other authors previously published in **Physical Review B.** *Each Comment should state clearly to which paper it refers and must be accompanied by a brief abstract. The same publication schedule as for regular articles is followed, and page proofs are sent to authors.*

Comment on ''Observation of a possible oxygen isotope effect on the effective mass of carriers in $YBa_2Cu_3O_{6.94}$''

Vladimir Z. Kresin
Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720

Stuart A. Wolf
Material Physics Branch, Naval Research Laboratory, Washington, DC 20375

(Received 5 September 1995)

In a recent paper [Phys. Rev. B **51**, 16 487 (1995)] Zhao and Morris argued that the oxygen isotope substitution affects the value of the effective mass of the carrier, and such effect is manifested in the isotopic dependence of the penetration depth. The aim of this Comment is to point out serious inconsistencies in their analysis and to clarify the situation. [S0163-1829(96)07734-X]

The value of the penetration depth δ in cuprates can be affected by the isotopic substitution of the apical oxygen ($O^{16}\rightarrow O^{18}$), since such a substitution affects the charge transfer, and, correspondingly, the in-plane carrier concentration.[1] The authors[2] claim that they observed the isotope shift in δ by observing the change in the Meissner fraction near T_c. Here we point out the inconsistencies in their analysis and indicate a different approach.

(1) The authors measure, for YBaCuO, the isotopic shifts in the slope of the magnetic susceptibility near T_c for different values of magnetic field. The analysis was reduced to a set of two equations [see Eqs. (2) and (5), Ref. 2]; each of them contains the terms proportional to Δn_s and Δm^* (n_s is the pair density, m^* is the carrier effective mass). The numerical solution of these equations based on the parameters obtained in Ref. 2, resulted in the conclusion that the change in the carrier effective mass m^* is a dominant factor, whereas the relative change in the pair density $\Delta n_s/n_s$ is negligibly small. However, even the evaluation of the equations contain a number of flaws. For example, the authors assume that the temperature dependence of δ_{ab} and δ_c near T_c are the same, and this is in a total contradiction with experimental data, particularly near T_c (see e.g., Ref. 3). Reference 4 cited in the paper by Zhao and Morris,[2] established the relation between these parameters ($\delta_c=5\delta_{ab}$) in the low temperature region well below T_c. One should note that this assumption is a very important ingredient in the author's evaluation. This is particularly true, since the effects are quite small, thus they are very sensitive to these factors. A change in the nature of the dependencies $\delta_{ab}(T)$ and $\delta_c(T)$ will lead to a substantially different structure of Eq. (2) and, therefore, different conclusions.

(2) The analysis does not take into account the fact that $YBa_2Cu_3O_{7-x}$ contains two subsystems, planes and chains. In addition to the different dimensionality of these subsystems, each of them can be characterized by its own order parameter, energy gap, coherence length;[5] as a result, there are two pair densities, $n_{s;pl}$ and $n_{s;ch}$. The screening is provided by both subsystems, and this factor has to be considered with special care (see Ref. 6).

(3) Zhao and Morris[2] are trying to explain the origin of the isotopic dependence of m^*. Their explanation is based on the equation $m^*=m^0(1+\lambda)$, where m^0 is the band value of the mass, and λ is the coupling constant. For the authors information, this relation was first obtained in Ref. 7 (see also, e.g., Ref. 8). We also find that the replacement $m^0\rightarrow N(0)$ is hard to understand. The authors use the BCS expression for λ:$\lambda=N(0)V$, and they are trying to explain the isotopic dependence m^* by the interaction of the carriers with some phonon modes, and the corresponding change in $N(0)$. But it is important to realize that all the parameters on the right-hand side of the relation for m^* are unrenormalized, that is, they are for the frozen lattice (see, e.g. Ref. 8, p. 476). It is obvious that the periodic electric field formed by such a lattice, will not be affected by the isotope substitution. Therefore, the dependence of the carrier effective mass on the isotopic substitution as described by Zhao and Morris cannot be correct.

(4) According to our model,[1] the isotope substitution of the apical oxygen affects the charge transfer between the chains and the planes. Zhao and Morris[2] note that the mechanism, proposed in Ref. 1, leads only to the redistribution of the total pair density, and concluded that the value of δ is not affected. But the authors totally ignore the fact that the planes and chains provide different contributions to the screening (see above), and the charge transfer does lead to a change in total δ. As was noted above, the presence of two subsystems with different values of parameters, including the

pair densities, has to be taken into account.[6]

(5) The data presented in Figs. 1 and 2 of Ref. 2 is also suspect. For example, to estimate P_1 for the O^{16} sample the slope was evaluated between 91.5 and 92.5 K in a field of 10 Oe. To evaluate P_2 for this sample at 150 Oe the temperature range was 92–93 K. At a higher field the corresponding region to evaluate the slope should be at a slightly *lower* not higher temperature. Since the lower temperature data were not presented it was probably not linear. This provides further evidence against the validity of Eqs. (2) and (5) in Ref. 2. In fact, in the derivation of Eq. (5) the temperature dependence of κ (Ref. 9) was ignored.

These flaws make the derivation and evaluation of the equations for the slopes incorrect and therefore invalidate the conclusions about the relative isotopic shifts on the effective mass and the superfluid density.

---

[1] V. Z. Kresin and S. A. Wolf, Phys. Rev. B **49**, 2652 (1994).

[2] Guo-meng Zhao and D. E. Morris, Phys. Rev. B **51**, 16 487 (1995).

[3] J. Mao *et al.*, Phys. Rev. B **51**, 3316 (1995); A. Neminskii and P. Nikolaev, Physica C **212**, 389 (1993).

[4] B. Pumpin *et al.*, Physica C **162–164**, 151 (1988).

[5] V. Kresin and S. Wolf, Phys. Rev. B **46**, 6458 (1992); R. Klemm and S. Liu, Phys. Rev. Lett. **74**, 2343 (1995); A. Golubov *et al.*, Physica C **235-240**, 2383 (1994); N. Klein *et al.*, Phys. Rev. Lett. **71**, 3355 (1993); D. Basov *et al. ibid*. **74**, 598 (1995); H. Edwards *et al. ibid*. **75**, 1387 (1995).

[6] S. Adrian *et al.*, Phys. Rev. B **49**, 2652 (1994).

[7] A. B. Migdal, Sov. Phys. JETP **7**, 996 (1958).

[8] D. Scalapino, in *Superconductivity*, edited by R. Parks (Marcel Dekker, New York, 1969), p. 449.

[9] E. Helfand and N. Werthamer, Phys. Rev. **147**, 288 (1966); D. Saint-James, G. Sarma, and E. Thomas, *Type II Superconductivity* (Pergamon, Oxford, 1969).