Magnetic Penetration Depth of $YBa_2Cu_3O_7$

In a recent Letter by Krusin-Elbaum *et al.*,[1] the magnetic susceptibility χ of a $YBa_2Cu_3O_7$ crystal interpreted to give results consistent with the BCS temperature-dependent penetration length $\lambda(T)$. Our central criticism of this paper concerns the model-dependent manner in which selected subsets of the data are analyzed. For example, conclusions about the zero-temperature penetration length $\lambda(0)$ are made by assuming a two-fluid temperature dependence (Fig. 4 of Ref. 1) and then restricting the analysis to a selected subset of the data spanning less than 4 K near T_c. A different subset of data with a more extended temperature range $(0.7 \leq T/T_c \leq 1)$ is then used in the inset of Fig. 4 to show that a weak-coupled BCS dependence[2] can also be fit to the data. The confusion caused by this arbitrary selection of different subsets of the same data to show consistency with different models is compounded by the variety of estimates for $\lambda(0)$ (three values are mentioned) and the arbitrariness in choosing T_c (midpoint or onset).

To clarify in a more precise way the conclusions which can be inferred from these data, we present an analysis of *all* of the susceptibility data shown in Fig. 2 of Ref. 1. We optimize the three parameters, T_c, $\lambda(0)$, and the baseline susceptibility χ_0, by a least-squares fit with $\chi(T)/\chi_0 = 1 - 2\lambda(T)/d$,[1] where the crystal thickness $d = 43\ \mu$m. The solid line in Fig. 1(a) is obtained using the weak-coupled BCS temperature-dependent $\lambda(T)$ with $T_c = 88.89$ K, $\lambda(0) = 0.0879\ \mu$m, and $\chi_0 = -6.911 \times 10^{-2}$ emu cm^{-3}. An *equally good* fit is found [Fig. 1(b)] using the two-fluid (approximate strong-coupling[3]) dependence $\lambda(T) = \lambda(0)/[1-(T/T_c)^4]^{1/2}$ with $T_c = 89.65$ K, $\lambda(0) = 0.1705\ \mu$m, and $\chi_0 = -6.936 \times 10^{-2}$ emu cm^{-3}. As expected, the value of T_c is insensitive to the functional form chosen for $\lambda(T)$ whereas the values of $\lambda(0)$ and χ_0 are strongly correlated. The smaller value for $\lambda(0)$ in the weak-coupling BCS fit [Fig. 1(a), inset] requires a larger χ_0 than does the two-fluid fit [Fig. 1(b), inset].

Krusin-Elbaum *et al.*[1] do not discuss how they determine χ_0. It is possible that an independent determination of χ_0 could confine the allowed values to a range sufficiently small enough to exclude one model in favor of another. We note, however, that the difference χ_0 (two-fluid) $- \chi_0$(BCS) $= 0.025 \times 10^{-2}$ emu cm^{-3} is less than 3% of the difference between ideal $(\chi_0 \cong -1/4\pi = -7.958 \times 10^{-2}$ emu cm$^{-3})$ and actual behavior. Stated in another way, the failure to achieve 100% flux expulsion imposes a large uncertainty on χ_0. Thus the conclusions about the BCS dependence of $\lambda(T)$ are problematical at best since χ_0 cannot be determined to sufficient accuracy. Hence, a non-BCS dependence could describe the data equally well.

The problem of baseline in earlier ac screening measurements of λ in the thin-film geometry[4] is considerably alleviated since the baseline appears as an additive constant, which is zero in the limit of perfect screening, rather than as a multiplicative constant (i.e., χ_0), which is nonzero and large in this same limit. The results $\lambda(0) = 0.146\ \mu$m from a weak-coupling fit[4] and $\lambda(0) = 0.218\ \mu$m from a two-fluid fit are in good agreement with the μ^+SR (muon-spin-rotation) result[5] $\lambda(0) = 0.1415 \pm 0.0030\ \mu$m. As the values of $\lambda(0)$ obtained from μ^+SR are not sensitive to baseline and are independent of assumptions regarding the T dependence of λ, they represent the best absolute measurements of $\lambda(0)$ and confirm a consistency with s-wave pairing.

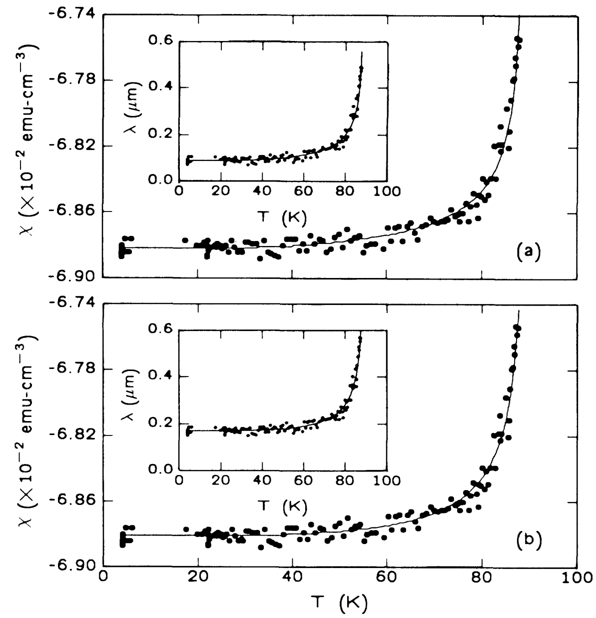

FIG. 1. Temperature-dependent susceptibility $\chi(T)$ taken from Fig. 1 of Ref. 1 (points) and analyzed (curves) according to (a) a BCS weak-coupling model dependence for $\lambda(T)$ and (b) a two-fluid "strong-coupling" model dependence for $\lambda(T)$. The corresponding calculated data (points) and theoretical (curves) dependences of $\lambda(T)$ are shown, respectively, for the two models in the insets.

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