Superconducting-State Thermal Transport in $YBa_2Cu_3O_{7-\delta}$

The in-plane thermal conductivity $\kappa = \kappa_e + \kappa_L$ (κ_e and κ_L are the electronic and lattice components, respectively) of $YBa_2Cu_3O_{7-\delta}$ (YBCO) increases dramatically for temperatures T below the superconducting transition temperature T_c and displays a maximum at $T \approx 40$ K [1-3]. Yu *et al.* [2] attributed this feature to an increase in κ_e. Here we point out inconsistencies in the authors' analysis and demonstrate that the enhancement is more plausibly associated with κ_L.

(1) The authors assume a phonon-phonon scattering rate $\tau_u^{-1} \propto T$ throughout the range $T > 15$ K. This form has its origin in the high-temperature approximation for the phonon population and implies the limit $T > \Theta_D$ (experimentally $T > \Theta_D/4$) [4]. For YBCO ($\Theta_D \approx 400$ K) we should not anticipate the applicability of this form at temperatures much lower than 100 K. A realistic low-T form for τ_u^{-1} should account for umklapp scattering; thus $\tau_u^{-1} \propto \exp(-\Theta_D/bT)$, where $b \approx 1$ [4]. The assumption that $\tau_u^{-1} \propto T$ for $T > 15$ K is inappropriate.

(2) An increase in κ_e at $T < T_c$ implies that κ_e is dominated by inelastic scattering. Elastic scattering leads to a decrease in κ_e for $T < T_c$ [5,6]. The authors inconsistently assume κ_e is constant in the normal state according to the Wiedemann-Franz law implying *elastic* scattering of electrons [4]. An alternative method of estimating κ_e by simply subtracting κ measured in insulating YBCO from that of the superconductor is not justified given that the presence of electrons not only introduces additional scattering of phonons, but also alters the phonon spectrum.

The assumption by Yu *et al.* that κ_L is unaffected by the superconducting transition conflicts with calculations of κ_L for YBCO [3,7] using a BCS model for superconductivity [5,6]. Figure 1 compares the authors' estimate of κ_L with a curve we calculated using the model discussed in Ref. [7]. The scattering parameters employed in the fit [7,8] were adjusted so that κ_L agreed with the authors' estimate in the normal state and with their measurements for $T < 20$ K where we anticipate $\kappa \approx \kappa_L$. These parameters indicate that roughly 50% of the lattice thermal resistivity near T_c arises from phonon-defect scattering with phonon-electron and phonon-phonon scattering accounting for 25% each—the enhancement in κ_L is substantial *even when phonon-electron scattering does not predominate.* We have made no assumptions regarding the mechanism for superconductivity; the only presumption is that there is *some* electron-phonon coupling relevant to transport. Our analysis is also free from the above-mentioned inconsistencies. These results clearly highlight the inadequacy of the assumption by Yu *et al.* that κ_L is unaffected by the superconducting transition.

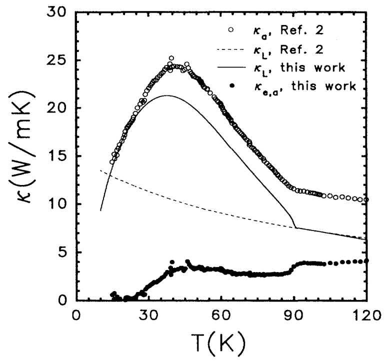

FIG. 1. Thermal conductivities vs temperature. The subscript a refers to the a axis of YBCO. Solid line: calculated κ_L [7,8] with $\Delta(0)/\Delta_{BCS}^{(0)} = 1.8$.

The corresponding electronic thermal conductivity $\kappa_{e,a} = \kappa_a - \kappa_L$ implied by our calculation (Fig. 1) *decreases* for $T < T_c$ with a local maximum near 45 K. This behavior is very different from that predicted by Yu *et al.*

The authors suggest several weaknesses of a phononic interpretation; however, all such criticisms can be easily addressed [8]. Indeed, we find nothing in the body of experimental data on YBCO that is inconsistent with a phononic explanation of the κ enhancement.

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