Comment on "Observation of a Far-Infrared Sphere Resonance in Superconducting $La_{2-x}Sr_xCuO_{4-y}$ Particles"

In a recent Letter Noh *et al.*[1] describe the absorption coefficient of $La_{2-x}Sr_xCuO_{4-y}$ ceramic powders imbedded in Teflon. A resonant absorption was observed in the far infrared when the particles were superconducting, whereas none occurred in the normal state. These data were interpreted in the following way. In the normal state the damping of the free-carrier absorption prevents the resonance. The appearance of an energy gap in the superconductive state removes this damping, making the resonance visible. This interpretation implies that the energy-gap frequency exceeds the particle resonant frequency.

In this Comment, we show that the data presented by Noh *et al.* can be simply described using already existing far-infrared data for ceramic $La_{2-x}Sr_xCuO_{4-y}$. No conclusions regarding the position of an energy gap can be reached from their results.

As discussed by Noh *et al.*, the effective dielectric function for a composite of small particles imbedded in a host material can be described using a Maxwell-Garnett[2] (MG) dielectric function. For small concentrations of spheres, MG predicts a resonance when the host and inclusions (particle) dielectric functions, ϵ_h and ϵ_{inc}, meet the condition $\epsilon_{inc} \approx -2\epsilon_h$. For the Teflon host, $\epsilon_h = 2.25 > 0$, so the requirement for resonance is $\epsilon_{inc} \sim -4.5$.

Noh *et al.* prepared $La_{2-x}Sr_xCuO_{4-y}$ particles by grinding sintered ceramic material into a powder. It is likely that these particles will have properties close to those of the bulk ceramic. Now, the far-infrared response for sintered $La_{2-x}Sr_xCuO_{4-y}$ has been determined by Bonn *et al.*[3] from Kramers-Kronig analysis of reflectivity measurements. In the normal state, the real part of the dielectric function, ϵ_1, is large and positive over 30–200 cm^{-1}. Consequently, no particle resonance is to be expected, independent of the degree of damping from the free-carrier conductivity. In contrast, well below T_c, Bonn *et al.* found that the infinite zero-frequency conductivity of the superconducting condensate causes ϵ_1 to cross zero near 70 cm^{-1}. Just below this frequency, the condition for a particle resonance exists. Note that the existence of this zero crossing, a consequence of the infinite zero-frequency conductivity and the Kramers-Kronig relations between ϵ_1 and σ_1, is independent of the presence of a gap in the superconducting spectrum.

To illustrate our point, we have used the results of Bonn *et al.* in the MG expression to calculate the absorption coefficient of 1% $La_{2-x}Sr_xCuO_{4-y}$ particles imbedded in Teflon. The result is shown in Fig. 1. This calculation contains no adjustable parameters, and yet is remarkably similar to the experimental results of Noh *et al.*

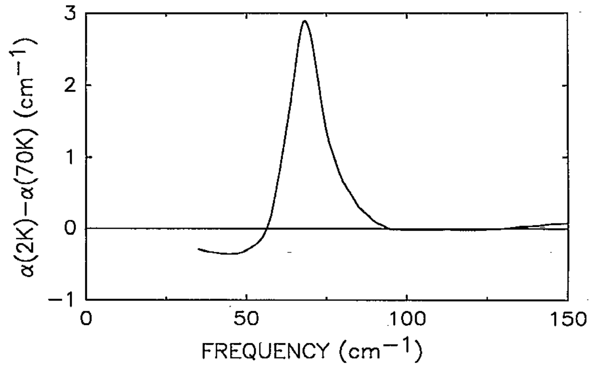

FIG. 1. Difference of superconducting and normal-state absorption coefficients calculated for $La_{2-x}Sr_xCuO_{4-y}$ using the Maxwell-Garnett theory and the measured bulk ceramic dielectric functions of Bonn *et al.*

Since the superconducting-state conductivity of Bonn *et al.* has no distinct gap, yet a strong resonance occurs in the MG theory for the superconducting state, we conclude that the observation by Noh *et al.* of this resonance provides no information about the position of an energy gap. The resonance is absent in the normal state because there is no frequency in the normal-state dielectric function for which $\epsilon_{inc} \approx -2\epsilon_h$. Even if the particles were single crystals, this form for ϵ_1 is plausible for purely *a-b* plane response, given a high-background dielectric constant, low-carrier concentration, and sufficient damping. Additional support for our interpretation comes from the work of Sherwin *et al.*,[4] who show that the zero crossing in ϵ_1 (when superconducting) moves toward lower frequencies as the temperature is raised toward T_c, causing the particle resonance to mimic the temperature dependence of the energy gap.

In conclusion, we show that the results of Noh *et al.* can be simply described using the previously reported response for $La_{2-x}Sr_xCuO_{4-y}$. No assumptions about the magnitude of the superconductive energy-gap behavior are required. Indeed, the resonance is governed by dispersive effects (i.e., the real part of the dielectric function) rather than by absorption. A fully developed gap in the excitation spectrum is unnecessary.

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