Comment on "Excitonic Absorption and Superconductivity in $YBa_2Cu_3O_{7-y}$"

In their recent Letter,[1] Kamarás *et al.* reported reflectivity, R, versus optical frequency, ω, in polycrystalline samples of $YBa_2Cu_3O_{7-y}$. They found that Kramers-Kronig (KK) analysis of their R spectra revealed a peak in conductivity, $\sigma(\omega)$, at 3000 cm^{-1} (0.37 eV). Similar conclusions were reached from experiments on polycrystalline samples of superconducting $La_{2-x}Sr_xCuO_4$.[2,3] Recently there have been several reports of R measured on highly aligned thin films,[4] and single crystals,[5] where the incident electric field, $\mathbf{E}_i$, is parallel to the highly conducting $\hat{a}$-$\hat{b}$ plane. In these experiments the maximum σ was found near $\omega = 0$, in contrast with results on polycrystalline samples. In this Comment we offer an explanation of this discrepancy which is based on the properties of wave propagation in anisotropic crystals.

In the optical experiments on a polycrystalline sample, light is reflected from an ensemble of randomly oriented crystallites. If $\lambda < L$, where λ is the wavelength of light in the medium and L is the typical crystallite dimension, then the total R is the sum of contributions from individual crystallites. For $L \simeq 10$ μm this range corresponds to $\hbar\omega > 0.05$ eV, which is the range in which the peak in $\sigma(\omega)$ has been observed. In the following we discuss first the optical properties of a single crystallite, and then the ensemble average of their reflectivities.

We model the high-T_c superconductors as optically uniaxial crystals with principal components of the dielectric tensor $\epsilon_\parallel$ and $\epsilon_\perp$, for the $\hat{c}$ axis and $\hat{a}$-$\hat{b}$ plane, respectively. When the direction of propagation, in this case parallel to the surface normal, $\hat{n}$, is not parallel to $\hat{c}$ there are two distinct modes of propagation, the ordinary, o, and extraordinary, e, modes. The component of $\mathbf{E}_i$ perpendicular to the $\hat{n}$-$\hat{c}$ plane couples to the o mode, while the in-plane component launches the e mode. The effective dielectric functions are $\epsilon_\perp$ and $\epsilon_\perp\epsilon_\parallel/(\epsilon_\parallel\cos^2\theta + \epsilon_\perp\sin^2\theta)$, for the o and e modes, respectively, where θ is the angle between $\hat{n}$ and $\hat{c}$.[6] The $\sigma(\omega)$ for these modes is plotted in Fig. 1 for a quasi-2D metallic crystal with $\epsilon_\parallel = \epsilon_0$, and $\epsilon_\perp = \epsilon_0 - \omega_p^2/\omega(\omega + i\gamma)$, and ϵ_0, $\hbar\omega_p$, and $\hbar\gamma$ given by 4.5, 2.5, and 0.6 eV, respectively.[7] For the o mode, $\sigma(\omega)$ has the Drude form. The $\sigma(\omega)$ for the e mode is the same as the o mode for $\theta = 0$, but for nonzero θ it develops a peak near $\omega = (\omega_p/\sqrt{\epsilon_0})\sin\theta$.[8,9]

To find an effective ensemble-averaged conductivity, $\langle\sigma\rangle$, we first calculated $\langle R\rangle$ within this model and then determined $\langle\sigma\rangle$ by KK transformation. $\langle R\rangle$ is given by $\frac{1}{2}[R_o + \int_0^{\pi/2} d\theta\, R_e(\theta)\sin\theta]$, where R_o and R_e are the reflectivities of the o and e modes, respectively. The $\langle\sigma\rangle$ obtained from KK analysis of $\langle R\rangle$ is plotted as dot-dashed lines in Fig. 1. It is clear that $\langle\sigma\rangle$ closely resembles σ obtained in experiments on polycrystalline samples. On the basis of this striking similarity we believe that the effects of optical anisotropy account for the pronounced peak in $\sigma(\omega)$ seen in polycrystalline samples of high-T_c superconductors. Finally, we note that the similar effects can be relevant to experiments performed on single crystals when light waves do not propagate parallel to a principal axis.

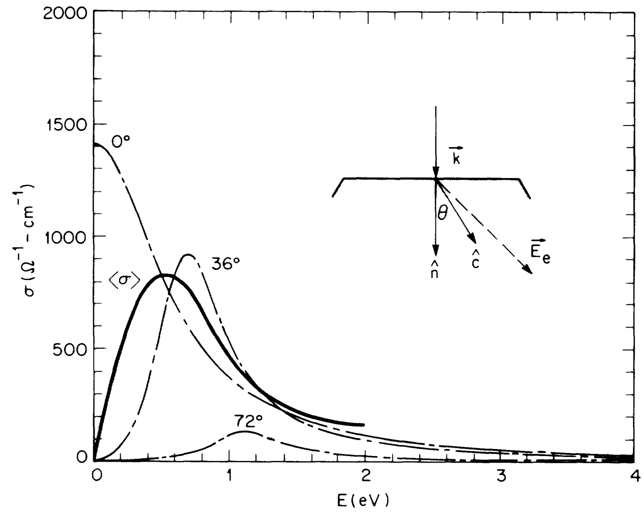

FIG. 1. Photon-energy-dependent conductivity, σ, for the model quasi-2D metallic crystal described in the text. The dot-dashed lines show σ corresponding to the e mode (electric field in the $\hat{n}$-$\hat{c}$ plane, as in inset) for three values of θ. For $\theta = 0°$ σ for the e mode equals that of the o mode, and both follow Drude behavior. The solid line shows $\langle\sigma\rangle$ obtained by Kramers-Kronig transformation of the ensemble-averaged reflectivity, $\langle R\rangle$.

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