Reflectance Measurements and Superconductivity in MgB_2

In a recent Letter, Marsiglio [1] observes that a straightforward fitting of the measured optical reflectivity [2] with the standard Drude model produces an anomalously small plasma frequency ($\omega_{pl} \sim 1.7$ eV), which yields an electron-phonon coupling (EPC) constant, $\lambda \approx 0.2$. To reconcile this fact with the high critical temperature, he introduces a high-energy excitation which provides for the missing pairing strength, but does not affect the optical properties. While this model is capable of explaining the results of [2] and $T_c = 39$ K, it is not compatible with a variety of other experiments and is at odds with some straightforward theoretical considerations. We argue that Marsiglio's observations, while being correct, do not cast doubt on the conventional EPC mechanism of superconductivity in MgB_2, as he concludes, but rather on the simple Drude analysis that produced such a small plasma frequency.

Some experiments are in direct contradiction with the model of [1]: (1) Angular resolved photoemission and de Haas-van Alphen on single crystals [3] are in excellent agreement with the band structure calculations. Since the calculated $\omega_{pl}^{calc} \approx 7$ eV, assuming $\omega_{pl} \approx 1.7$ eV requires renormalization of the Fermi velocity by a factor of 5, easily detectable in both experiments. (2) As mentioned in Ref. [1], in the proposed model all superconducting properties ought to be very BCS-like, which is not observed [4]. (3) Weak T dependence of the resistivity in clean samples [5] (Fig. 1, inset) is hard to reconcile with the model of Ref. [1], while the two-band EPC model has a potential for such a reconciliation [6].

Furthermore, one needs to consider indirect evidence, such as (1) the model of Ref. [1] results in an isotope effect $\alpha \lesssim 0.16$. One has to imply a factor of 2 anharmonic *enhancement* to explain the observed $\alpha \approx 0.31$ [7], as opposed to a 40% *suppression* for the conventional model [8]. (2) Even in highly correlated systems such as cuprate superconductors, the renormalization of the ω_{pl} is less than a factor of 3.

Since the assumption that $\omega_{pl} \approx 1.7$ eV is in a manifest contradiction with other experiments and our general knowledge about MgB_2, the question arises, can one interpret optical data *without* it? It is instructive to repeat the calculations presented in Fig. 1 of Ref. [1], but with a set of parameters more compatible with the first principles calculations [9]. Figure 1 compares the experimental data [2] with Ref. [1] and with our calculations, without the Lorentzian, but keeping $\lambda_{tr} = 0.6$. We used $\gamma_{imp} = 600$ cm^{-1} and $\omega_{pl} = 7$ eV [9] and introduced $\epsilon_\infty = 3$ to account for the interband transitions. While neither fit is perfect, clearly, there is no decisive argument from the quality of the fitting which set of parameters is preferable.

It remains to explain why the experiment apparently observes small $\omega_{pl} \approx 1.5$–1.7 eV [2,6]. The key is that the π bands are much more sensitive to defects in the Mg plane (which is chemically much more prone to defects than the B sublattice) than the σ bands. A model [6] that takes this into account allows for a realistic description of the optical conductivity. If one uses the calculated plasma frequencies and calculated anisotropic EPC [10], the σ-band derived peak corresponds to an apparent $\omega_{pl} \approx 2$ eV, in good agreement with experiment [6].

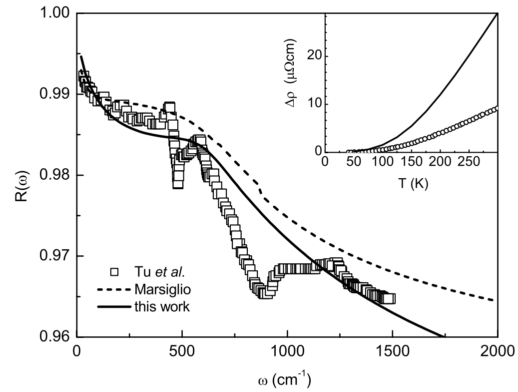

FIG. 1. Experimental reflectivity [2] at $T = 45$ K, compared with the calculations using parameters from Ref. [1] and from first principles calculations (see text). Inset: dc resistivity calculated in the model of Ref. [1], compared with the clean wires experiment [5].

We conclude that the optical experiments provide no reliable evidence in favor of an anomalously small total plasma frequency and, correspondingly, against electron-phonon superconductivity in MgB_2.

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