Comment on ''Optical Conductivity of High T_c Superconductors: From Underdoped to Overdoped''

In a recent Letter, Puchkov *et al.* [1] argue that the optical conductivity of some overdoped high T_c superconductors (HTSC) exhibits an unexpected behavior: the total low energy spectral weight does not change upon doping. An increase of low frequency conductivity is offset by a decrease of oscillator strength in the energy range of 0.25–1 eV. This is in contrast to other doping experiments (in "underdoped" HTSC, semiconductors, and other materials), where the additional oscillator strength is redistributed on a larger energy scale, corresponding to separate energy bands. According to Ref. [1], overdoping modifies the dynamics of the conduction electrons while the carrier concentration remains fixed. In this Comment we wish to point out that the intriguing behavior reported by Puchkov *et al.* is not universal to HTSC. The IR transmission of overdoped $Bi_2Sr_2CaCu_2O_{8+\delta}$ (Bi2212) shows that the conductivity increases uniformly over the whole frequency range, consistent with the increased carrier concentration seen in dc transport measurements.

IR transmission measured on a sample of fixed thickness at different doping levels provides qualitatively simple information about the changes in the conductivity: a decrease in transmission indicates higher conductivity [2]. For frequencies much below the plasma frequency, the relationship between the optical conductivity σ_1 and the transmission T of a thin metallic film is particularly simple: $T \approx 1/(1 + Z_0\sigma_1 d/2)^2$ where d is the thickness, and $Z_0 = 377\ \Omega$ is the impedance of the vacuum [3].

In Fig. 1 we plot the 300 K IR transmission of a Bi2212 crystal before and after an anneal in air [4]. Previously, the crystal was heated in high pressure oxygen and became significantly overdoped ($T_c = 60$ K); the air anneal reduces the oxygen content to near optimum, but leaves the crystal slightly overdoped ($T_c = 85$ K). Since d is constant, the lower transmission of the overdoped sample is due to the higher conductivity. A detailed analysis, involving the exact transmission formula, yields about a factor of 2 higher total spectral weight (SW) for the oxygenated sample in the 600–6000 cm^{-1} spectral range. Heavily overdoped Bi2212 material yields a SW which lies at about $SW/SW_{opt} \approx 2$ in Fig. 3 of Ref. [1], corresponding to the continuation of the trends seen in underdoped samples [1,5].

The low frequency (below 700 cm^{-1}) IR spectra [6] yield similar conclusions. The increased low frequency spectral weight of the oxygen doped sample suggests higher carrier concentration. The improved conductivity and the reduced Hall effect [7] can be consistently interpreted by assuming a continuous increase of carrier concentration with increasing oxygen content.

The arguments of Puchkov *et al.* are based on their measurements of Tl2201 samples. It is important to recognize that the overdoped Bi2212 crystal used in Ref. [1] has a T_c of 82 K, while our material is more heavily overdoped ($T_c = 60$ K). Therefore, we see no major disagreement in the experimental data on Bi2212. The work on $La_{2-x}Sr_xCuO$ [5], also used in Ref. [1], is not quite relevant to this discussion. For the samples for which T_c was measured [5], the SW is not very different ($SW = 0.19$, 0.21, 0.22 e/Cu for $T_c = 18$, 27, 22 K, respectively). It remains to be seen if Bi2212 follows the "rule" for overdoped high T_c superconductors and Tl2201 is an exception, or vice versa.

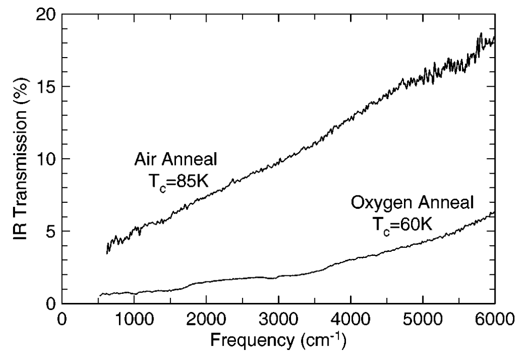

FIG. 1. IR transmission at $T = 300$ K of the same overdoped Bi2212 crystal before and after an anneal in air.

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