# Light-induced heating of electrons and the time of the inelastic electron-phonon scattering in the YBaCuO compound

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The time of the energy relaxation of electrons due to electron-phonon interaction in the films of a high-temperature superconductor YBaCuO has been measured for the first time. The results show that the electron-phonon interaction strength in this compound increases considerably in comparison with that of the ordinary superconducting metals.

The time of the energy relaxation of electrons, $\tau_{eph}$, as a result of electron-phonon interaction is one of the fundamental parameters of a superconductor which determines its properties in the nonequilibrium state and which gives the strength of the electron-phonon interaction. Study of $\tau_{eph}$ may yield valuable information on the nature of high-temperature superconductivity. It is also important in determining the maximum-attaninable parameters of several cryoelectronic devices.

We studied the energy relaxation of electron in films of the YBaCuO compound

  

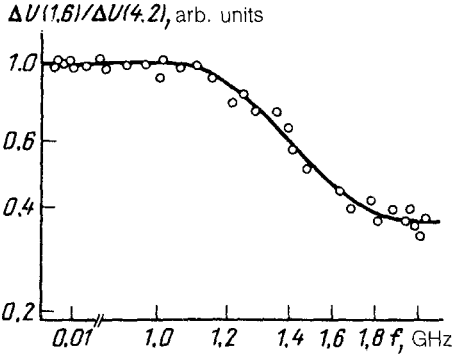


FIG. 1.

by measuring the time $\tau$ it takes the electron subsystem to cool down when a superconductor in the resistive state is exposed to light. This method was used previously to determine $\tau_{eph}$ in thin Nb and Al films.[1] We used films of the compound $Y_1Ba_2Cu_3O_{7-x}$ fabricated by magnetron rf sputtering of a ceramic target on a polycrystalline leucosapphire substrate in argon atmosphere. The thickness $d$ of the films was varied between 0.3 $\mu$m and 1 $\mu$m and the length and width were 10 mm and 1 mm, respectively. The films were annealed in such a way that they would have an extended resistive transition to the superconducting state over a temperature interval $T = 10$–$80$ K. At a temperature below the critical temperature, the resistive state was attained by a current 1–10 mA and by a magnetic field $\sim 50$ kOe directed perpendicular to the film plane. The energy relaxation time was measured by beating 2-mm waves which were generated by two backward-wave tubes. The best frequency $f$ was varied by fixing the output frequency of one of the backward-wave tubes and using the supply voltage to vary the other within the required limits. A light-induced change in the voltage of the sample, $\Delta U$, was measured (while holding the bias current consant) at the best frequency by a spectrum analyzer in the frequency range 0.01–2 GHz. (The measurement method is described in greater detail in Ref. 1.) To eliminate the effect of the frequency characteristic of the detection channel, we calculated the ratio of the values of $\Delta U(f)$ measured at two temperatures. Figure 1 is a plot of the $\Delta U(f)$ curve measured at $T = 1.6$ K and normalized to the same value which was measured at $T = 4.2$ K. These data show that at $T = 1.6$ K the relaxation time is $\tau \simeq 10^{-10}$ s.

Let us discuss the result which we obtained. In rather thick YBaCuO films the time it takes a phonon to escape from the film is $\tau_{es} \approx 4d/u \gtrsim 10^{-9}$ s ($u$ is the velocity of sound), which is much longer than the experimental value of $\tau$ given above. The observed constancy of $\Delta U$ at $f \lesssim f_0$, where $f_0 \simeq 1$ GHz, is $\gg (2\pi\tau_{es})^{-1}$ and the decay of $\Delta U$ at higher frequencies may occur if the following condition is satisfied: $\tau_{eph} < \tau_{es}, \tau_{phe}$ [$\tau_{phe} = (C_{ph}/C_e)\tau_{eph}$ is the phonon lifetime which is limited by the electron-phonon interaction, and $C_{ph}$ and $C_e$ are the phonon and electron specific heats]. The inequality $\tau_{eph} < \tau_{phe}$, which does not hold for ordinary superconducting metals in the temperature range under study, may be valid in metal oxide superconductors: In these superconductors the electron specific heat per unit volume is, as recent experiments have shown (see, e.g., Ref. 2), much lower.

If $\tau_{eph}$ is the shortest time of those times under discussion, the experimentally measured time $\tau$, which corresponds to the fastest stage of the energy relaxation, will be equal to $\tau_{eph}$, irrespective of the relationship between $\tau_{es}$ and $\tau_{phe}$. If $\tau_{es} < \tau_{phe}$, the phonons in the film are a heat sink for electrons and the relaxation is described by a single time $\tau_{eph}$. If $\tau_{eph} < \tau_{phe} < \tau_{es}$, the specific heat of the phonon subsystem is much greater than that of the electron subsystem and, because of this circumstance, the phonons also are a heat sink at the initial stage of the relaxation.

At $T \sim 1$ K the characteristic values of $\tau_{eph}$ of ordinary superconducting metals are $\sim 10^{-8}$ s. The energy relaxation time $\tau_{eph}$ determined for the compound YBaCuO is much shorter, suggesting a marked increase of the electron-phonon interaction in metal oxide superconductors at comparable Debye temperatures. The results which we obtained show that the outlook for the use of YBaCuO as a material for various high-speed cryoelectronic devices is promising.

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