ELECTRON ABSORPTION OF LONGITUDINAL ULTRASOUND IN TIN SINGLE CRYSTALS OF VARIOUS PURITY NEAR THE SUPERCONDUCTIVITY TRANSITION POINT

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The temperature dependences of electron absorption of ultrasound in tin single crystals with the wave vector parallel to the fourfold axis are investigated by the pulse method at frequencies between 50 and 250 MHz. It is found that near T_c the experimental dependences can be described by the existing theory, whereas the energy gap in the spectrum of a tin single crystal containing 0.01 or 0.02 at % of indium does not differ from that for absolutely pure tin, $2\Delta(0) = 3.2\ kT_c$.

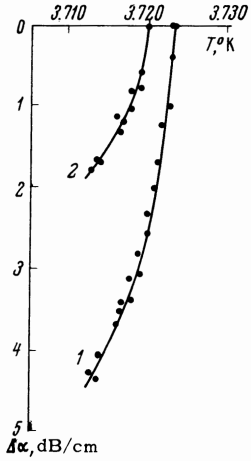
A great deal of attention has recently been paid to the study of the electronic absorption of ultrasound in superconductors.[1] Such experiments, particularly in pure metals (for $kl > 1$), allow us to determine the minimum energy gap at 0°K, equal to $2\Delta(0)$ on the lines $\mathbf{k} \cdot \mathbf{v} = 0$ of the Fermi surface—one of the fundamental characteristics of the superconducting state of the metal[2] (**k** is the wave vector of the ultrasound, l and **v** are the length of the mean free path and the velocity of the electron).

At the phonon energy $\hbar\omega = 2\Delta$ (hypersonic frequencies), quantum processes of decay of the phonon into a pair of quasiparticles are possible, which ought to lead to singularities in the sound absorption due to the electrons;[3] however, because of the difficulties of hypersonic experiments, attempts at experimental observation of such processes have been without success to date.[4] On the other hand, so far as we know, another interesting possibility of the discovery of such processes remains to date entirely unexplored, namely a careful investigation of the temperature dependence of the electronic absorption of the ultrasound in the immediate vicinity of the superconducting transition temperature of the metal (i.e., satisfaction of the condition $\hbar\omega = 2\Delta(T)$ by decrease in the energy gap in the spectrum as $T \to T_c$).

In this connection, we have carried out, by means of a pulse method and in the frequency range 50—250 MHz (together with investigations similar to the foregoing[5]), precision measurements of the electronic absorption of longitudinal ultrasound in the neighborhood of T_c in single crystals of pure tin (impurity concentration $< 10^{-4}\%$) and of tin containing 0.01 and 0.02 at. % indium (of high degree of purity). The alloys were carefully prepared by the method of successive dilutions, while the single crystals were grown by the Obreimov-Shubnikov method. The concentration of impurity was also monitored by means of the residual electrical resistance,[1)] in accord with the data of Aleksandrov.[6] The orientation of the wave vector of the ultrasound was chosen parallel to a fourfold axis of the tin single crystals. In such a case the earliest appearance of the effects in which we are interested can be expected, inasmuch as the measured value of the gap in the energy spectrum of tin is minimal here.[7]

Measurements of ultrasonic absorption were performed by a method whose chief features have been described earlier;[8] in the present research, use of two detection channels and an S1-15 oscillograph (with pre-amplifier S1-15/3, designed for the independent investigation of two processes) made it possible to carry out simultaneous measurements on two single crystal samples (pure tin and one of the solid solutions of indium in tin), located side by side in the dewar at the same level relative to the liquid helium surface. The magnetic field of the earth was carefully compensated for, the temperature was determined by measuring the pressure of the saturated helium vapor by means of a mercury manometer (T_{58} scale) with the aid of a KM-8 cathetometer (with accuracy of ± 0.0002°K near T_c); the change of temperature due to the hydrostatic

1)V. L. Polunin and T. A. Sverbilova, students of Kharkov University, took part in preparation of the specimens and measurement of the electrical resistance.



Simultaneous measurements of the change in the coefficient of electronic absorption of longitudinal ultrasound $\Delta\alpha = \alpha_n - \alpha_s$ with temperature in the superconducting transition of a single crystal of pure tin (1) and tin containing 0.02 at. % indium (2). The frequency of the ultrasound was 215 MHz, **k** ∥ [001] on lower left of drawing, $\Delta\alpha$, dB/cm.

pressure of the column of liquid helium was taken into account.[9]

The figure shows the data obtained in the simultaneous measurement of the absorption of longitudinal ultrasound of frequency 215 MHz in pure tin and in tin containing 0.02 at. % indium. It is seen that in the change of the temperature dependence of the coefficient of electronic absorption of ultrasound no peculiarities appear in the doped sample other than the well-known decrease in T_c (see, for example,[10]). The temperature dependences of the coefficient of electronic absorption of the ultrasound have a similar form throughout the entire frequency range 50—250 MHz. (The results of the investigation of a tin single crystal with the addition of 0.01 at. % indium have the same character.) Thus, at ultrasonic frequencies up to 250 MHz, no special effects have been observed either in pure tin or in the indium-doped alloy of tin (to an accuracy within ±0.0002°K) that could be connected with the presence in the superconductor of processes of the decay of a phonon into a pair of quasiparticles; this result is in accord with the existing theoretical ideas.[3] For the discovery of these effects by the described method, further increase in the accuracy of measurement or an investigation of superconductors with a strongly reduced energy gap (for example, under the influence of a paramagnetic impurity[11]) is necessary.

The temperature of the superconducting transition of pure tin was found to be equal to 3.7235°K from ultrasonic measurements (the accepted value from calorimetric measurements is 3.722°K[12]), which can be attributed to the high sensitivity of the electronic absorption of the high frequency ultrasound (for $kl \gg 1$) to the transition of the metal into the superconducting state.

The measurement of the temperature dependence of the coefficient of electronic absorption of ultrasound in the temperature range 4.2—1.0°K has revealed that the magnitude of the minimum energy gap in the spectrum of single crystal tin containing 0.01 and 0.02 at. % indium does not differ from the value of this quantity in very pure tin ($3.2 \pm 0.1\ kT_c$), thus confirming the results of[13].

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