CHANGE PRODUCED IN PHONON SPECTRUM OF LEAD BY LATTICE DISTORTION

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We consider in this paper the influence of lattice distortion on the properties of superconductors. The method chosen is that of the tunnel effect, whereby a single experiment yields the width of the gap in the energy spectrum of the superconductor electrons and information on the electron-phonon interaction. The material investigated is lead, whose tunnel characteristics have by now been investigated in greatest detail both experimentally and theoretically [1]. Lattice defects were obtained by low-temperature condensation of the method, whereby samples with maximum lattice distortion were obtained.

The tunnel junctions were produced at helium temperatures by a method described previously [2]. During the course of the experiment we plotted the I - V, dV/dI - V, and d^2V/dI -V characteristics of the junctions in the interval 1 - 10°K. Each lead sample was investigated immediately after condensation at 1.6°K and then after annealing for 12 hours at 80 and 300°K. The thickness of the investigated films ranged from 2 to 8 microns.

The gap width Δ_0 in lead condensed at low temperatures exceeds by about 5% the usual value 1.35 MeV (Fig. 1). This difference remains also when the samples are annealed to 80°K. Since the critical temperature is not increased in the latter case [3], this result indicates that $2\Delta_0/kT_c$ increases as a result of the low-temperature condensation. A noticeable difference between the tunnel charactersitcs of freshly-deposited and annealed samples [plots of dI/dV vs. V - Δ, where $\Delta = \Delta_{Al} + \Delta_{Pb}$] is observed only when V - Δ ≥ 1 mV. The difference is most evident on plots of d^2I/dV^2 vs. V - Δ. The data shown in Fig. 2 were obtained for one

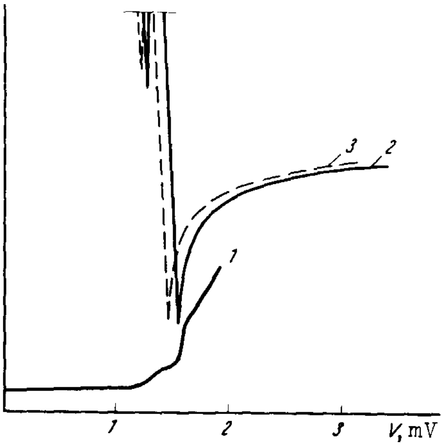

Fig. 1. Curves 1, 2 - I - V and dV/dI - V tunnel characteristics of sample condensed at 1.6°k; 3 - dV/dI - V characteristic of the same sample but annealed at 300°K.

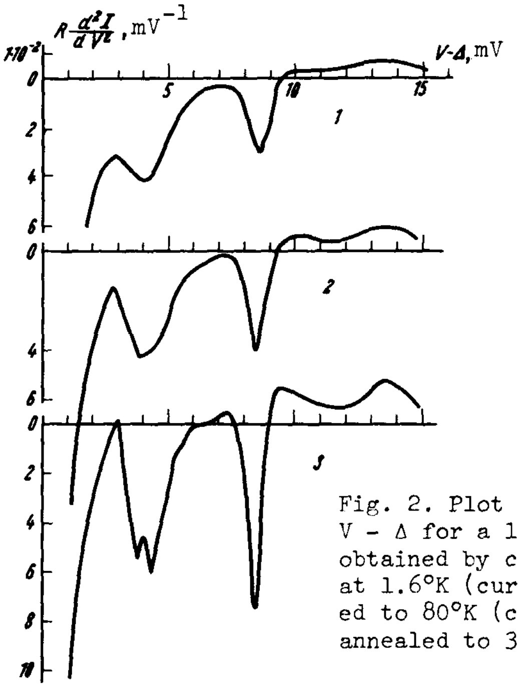

Fig. 2. Plot of d^2I/dV^2 vs. V - Δ for a lead sample obtained by condensation at 1.6°K (curve 1), annealed to 80°K (curve 2), and annealed to 300°K (curve 3)

sample prepared at 1.6°K and then successively annealed to 80 and 300°K. The plot was corrected for the change in the d^2I/dV^2 vs. V characteristics of the tunnel junction in the normal state (see [2]). Similar results were obtained for most investigated samples. A difference was observed only in some details of the characteristics. For example, for a number of samples condensed at helium temperatures the minimum at 4.5 mV was not as strongly pronounced as in Fig. 2, and for samples annealed to 300°K the fine structure of the minimum near 4.5 mV was not resolved. Plots of dI/dV vs. V - Δ are shown in Fig. 3a. The curves may be subject to a systematic error of approximately 0.6%, which shifts the entire curve along the R(dI/dV) axis. We note that the tunnel characteristics of the lead samples annealed to 300°K agree with those obtained earlier in investigations of lead condensed at 300°K.

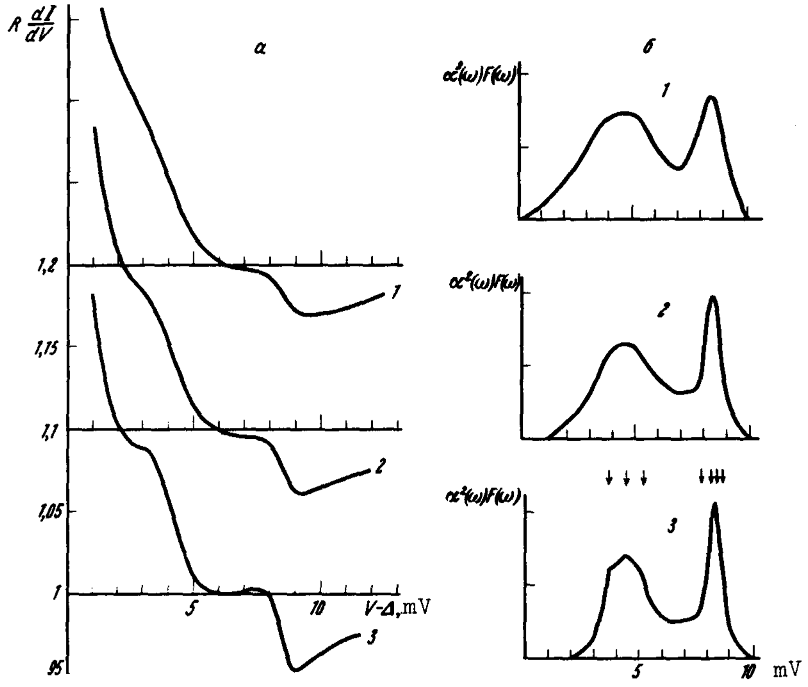

Fig. 3. a - dI/dV vs. V - Δ, b - $\alpha^2(\omega)F(\omega)$. Curves 1 - lead condensed at 1.6°K, 2 - annealed to 80°K, 3 - annealed to 300°K. Curve 3b was taken from [1]. The arrows indicate the van Hove singularities of lead in accord with the data of [6].

The nonmonotonic character of the variation of the tunnel characteristics when $V > \Delta$ is due to the singularities of the phonon spectrum of the superconductor [1, 4]. Consequently, to explain the observed data it must be assumed that the low-temperature condensation causes a change in the spectrum of the lead. Let us assume that for the samples with large numbers of lattice defects the connection between $\Delta(\omega)$ and the characteristics of the phonon spectrum is described by Eliashberg's equations [5] written in integral form, such as in [2]. Then, using the obtained relation between R(dI/dV) and V - Δ, we can reconstruct the distribution density of the phonon spectrum of lead, or more accurately the function $\alpha^2(\omega)F(\omega)$, where $F(\omega) = \int dq^3\, \delta(\omega_q - \omega)$ and $\alpha^2(\omega)$ is a function of the electron-phonon interaction. The results of the first-approximation reconstruction of the function $\alpha^2(\omega)F(\omega)$ are shown in Fig. 3b. For samples annealed to 300°K we used the data of [1]. The arrows denote the Van-Hove singularities in the phonon spectrum of lead, as obtained by neutron-diffraction measurements [6]. The maxima of $\alpha^2(\omega)F(\omega)$ near 4.5 and 8.5 mV are due respectively to transverse and longitudinal oscillations of the lead lattice.

As can be seen from Fig. 3b, the presence of lattice defects broadens the maximum of $\alpha^2(\omega)F(\omega)$ near 8.5 mV by a factor of more than 2. Since the electron mean free path* even in the most deformed sample is $\ell >> 1/q$, this change cannot be attributed to the function $\alpha^2(\omega)$. The broadening of the maxima is obviously due to the smearing of the Van Hove singularities in the strongly distorted lattice. Such a result follows qualitatively also from a theoretical analysis of the spectrum of the disordered system [7]. The most significant change is experimenced by the function $\alpha^2(\omega)F(\omega)$ in the region of low energies, where a more intense smearing of the maxima takes place down to $\omega \to 0$, and where, in addition, an increase takes place in the function $\alpha^2(\omega)F(\omega)$. It is obvious that such a change in the function $\alpha^2(\omega)F(\omega)$ should lead to a change in such characteristics of lead as the specific heat or the electron effective mass, and to an increase in the ratio $2\Delta_0/kT_c$. The presence of the latter effect follows from the foregoing experimental data. These effects will be examined in greater detail after the reconstructed function $\alpha^2(\omega)F(\omega)$ is established more precisely.

The increased role of oscillations with large energies in the electron-phonon interaction, observed in the case of lead condensed at helium temperature, is apparently typical for metals with a crystal lattice distorted to the limit.

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*The electron mean free path was 3×10^{-7} and 5×10^{-7} cm respectively for samples condensed at 1.6°K and annealed to 80°K. For samples annealed to 300°K, the mean free path ranged from 1.4×10^{-6} to 5×10^{-6} cm.

NONLINEARITY OF MEDIA DUE TO INDUCED DEFORMATION OF MOLECULES, ATOMS, AND PARTICLES OF A MEDIUM

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The appearance of powerful laser sources of light makes it urgent to investigate new mechanisms effecting the change of polarizability of a medium in powerful beams. Such phenomena can cause self-focusing (see [1-4] and a number of succeeding papers), nonlinear beam interaction, etc. In this article we consider new nonlinear effects whereby the polarizability of a medium is increased by induced defromation of molecules or particles.

1. Deformation and Increase in Polarizability of a Molecule in a Strong Light Field

The averaged electric pressure $P_{el} = E^2/8\pi$ in a laser beam can reach hundreds of thousands of atmospheres, making appreciable deformation of the molecules possible (even at ten