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TEMPERATURE DEPENDENCE OF THE JUMP OF THE DEFORMATION STRESS IN A SUPERCONDUCTING TRANSITION

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A superconducting transition changes the deformation stress of a metal quite strongly. The stress jump $\Delta\sigma = \sigma_n - \sigma_s$ is appreciable (σ_n and σ_s are the deformation stresses of the metal in the normal and superconducting states, respectively) and has been observed in a number of metals (Pb, Nb, In, Sn) by indirect or direct methods [1 - 6]. This new result is attributed to differences in the deceleration of the dislocations by the conduction electrons in the normal and in the superconducting states. It is therefore very important to relate the observed change of the macroscopic characteristics of plastic deformation with the fundamental properties of the superconductor, for example, by measuring the temperature dependence of the jump in the stress. Such bulk measurements, which are needed for a reliable establishment of the type of temperature dependence, have never been performed. As shown in [6], in Pb at temperatures below $0.58T/T_c$, the value of $\Delta\sigma$ changes insignificantly with temperature. A sharp dependence of $\Delta\sigma$ was observed in Pb [4] near T_c, and it was asserted that this dependence is the same as for the critical field, i.e., $\Delta\sigma \sim 1 - (T/T_c)^2$. However, as shown in [5], such a statement is ambiguous.

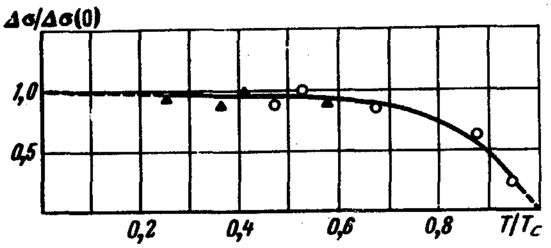

Fig. 1. Temperature dependence of the jump of the deformation stress $\Delta\sigma = \sigma_n - \sigma_s$, normalized to $\Delta\sigma(0)$: Δ - Pb, 0 - In.

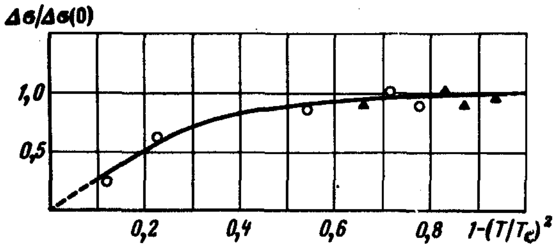

Fig. 2. Dependence of the normalized deformation-stress jump on $1 - (T/T_c)^2$: Δ - Pb, 0 - In.

We undertook the present investigation in order to establish the character of the temperature dependence of the deformation-stress jump as the metal goes over from the superconducting to the normal state. The transition at each measurement temperature was realized by turning on and off the magnetic field of a superconducting solenoid, inside of which the sample was continuously deformed. The objects of the investigation were 99.9995% pure Pb and 99.999% pure

In. In the measurement-temperature interval 1.6 - 4.2°K this made it possible to cover a wide range of ratios T/T_c (0.24 - 0.94), and to perform measurements on both metals in the interval $(0.4 - 0.6)T/T_c$.

The stress jump $\Delta\sigma$ in the interval $(0.24 - 0.6)T/T_c$ changes insignificantly, whereas for $T/T_c = 0.6 - 0.94$ $\Delta\sigma$ decreases sharply to zero at T_c. Figure 1 shows therefore the temperature dependence of $\Delta\sigma$, normalized to the stress jump $\Delta\sigma(0)$ in the temperature-independent region. As a result of such a normalization, it was possible to average each point of Fig. 1 over 5 - 6 values of $\Delta\sigma(T)/\Delta\sigma(0)$ obtained at different values of the deformation ε = 10, 20, 25, and 30%, from the plots of $\Delta\sigma(T)$ against ε (in analogy with [6]), which in turn were plotted from the jumps of the deformation stress obtained for no less than 50 - 60 s-n transitions.

Figure 2 shows $\Delta\sigma(T)/\Delta\sigma(0)$ as a function of $1 - (T/T_c)^2$. In these coordinates, as stated in [4], the dependence should be linear. It is clearly seen that this is not the case, i.e., the set of experimental data for Pb and In does not confirm the statement that the temperature dependence of $\Delta\sigma$ is the same as the temperature dependence of the critical magnetic field H_c of the superconductor.

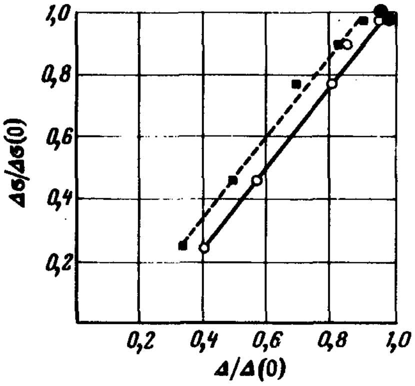

Fig. 3. Normalized stress jump as a function of the energy gap: o - from tunnel experiments [7], ■ - from the BCS theory [8].

Let us compare the dependence of the stress jump $\Delta\sigma$ on the temperature in an s-n transition with the temperature dependence of the energy gap (Fig. 3). The experimental values of the energy gap, obtained by tunnel measurement on Pb, In, and Sn, were taken from [7], and the theoretical ones were taken from [8]. For $T/T_c = 0.94 - 0.6$, where the abrupt changes of the stress jump and of the energy gap make it possible to assess the character of the temperature dependence with maximum accuracy, a linear connection is observed between $\Delta\sigma(T)/\Delta\sigma(0)$ and $\Delta(T)/\Delta(0)$. Favoring this assumption is also the linear connection between $\Delta\sigma(T)/\Delta\sigma(0)$ and $[1 - (T/T_c)]^{1/2}$ [9] in the same temperature interval.

As shown theoretically [10], the electron deceleration of the dislocation in a superconductor has a more complicated dependence on the dislocation velocity than in a normal metal [11], and depends on the temperature. These features of the dynamics of dislocations in a superconductor are connected with the presence of a gap in the energy spectrum of the electrons. The agreement between the temperature dependences of $\Delta\sigma(T)/\Delta\sigma(0)$ and $\Delta(T)/\Delta(0)$ is apparently a reflection of this circumstance.

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METAL-INSULATOR TRANSITION IN V_2O_3 IN A STRONG ELECTRIC FIELD

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The most interesting physical properties of V_2O_3 are the insulator-metal phase transition at T = 150°K and the anomaly of the temperature dependence of the electric conductivity near 530°C [1]. A recent communication reported a metal-insulator transition in V_2O_3 with chromium admixture upon variation of the concentration of the chromium and of the pressure [2].

We have observed a similar metal-insulator phase transition under the influence of an electric field on the V_2O_3 crystal. The influence of the electric field on the properties of V_2O_3 was investigated by the electroreflection (ER) method [3]. The ER spectra was measured in the photon energy interval $1.1 \leq \hbar\omega \leq 6.0$ eV, at different temperatures $300° \leq T \leq 360°$K. For comparison, we recorded the spectrum of the usual reflection $R(\hbar\omega)$ in the region $0.5 \leq \hbar\omega \leq 6.0$ eV (Fig. 1).

As seen from Fig. 1, the ER peaks shift noticeably along the $h\omega$ scale when the fixed bias U_b is varied, but the intensity of the ER spectrum depends little on U_b when $U_b < 1.7$ V. The large amplitude of the signal and the shifts of the ER peaks differ strongly from the corresponding values for typical semiconductors [3], but are in agreement with the ER spectra of ferroelectrics above and below the Curie point [4]. A certain disparity between the structure of the spectra of the ER and $R(h\omega)$ in Fig. 1 at $U_b = 0$ is obviously connected with the shift of the bands in the electric field of the surface barrier. For values $U_b \geq 1.8$ V, the amplitude dR/RdU increases sharply in the ER spectra in the region $\hbar\omega < 2.5$ eV and the shifts of the peaks $\Delta h\omega$ increase appreciably in the region $\hbar\omega > 2.5$ eV. Thus, a change of U_b of 0.1 V near $U_b = 2$ V yields $\Delta\hbar\omega \approx 0.18$ eV, whereas at $0 \leq U_b \leq 1.7$ V the corresponding shift amounts to only 0.025 eV. Near $U_b = 1.8$ V the peaks 1 and 2 (Fig. 1) merge into one, and with further increase the number of peaks remains constant ($\hbar\omega > 3$ eV).

Figure 2b shows the dependence of the interval $\Delta\hbar\omega$ between the peaks 1' and 3 on U_b. The strongest change in the ER signal amplitude with increasing U_b is observed for $\hbar\omega \leq 2.5$ eV (see Figs. 1 and 2). Whereas at $U_b < 1.8$ V the amplitude of the ER is practically independent of U_b, near $U_b = 2$ V it increases by almost one order of magnitude in the narrow interval $\Delta U_b = 0.1$ V.