TEMPERATURE DEPENDENCE OF THE CHANGE OF RATE OF PLASTIC DEFORMATION OF LEAD IN SUPERCONDUCTING TRANSITIONS

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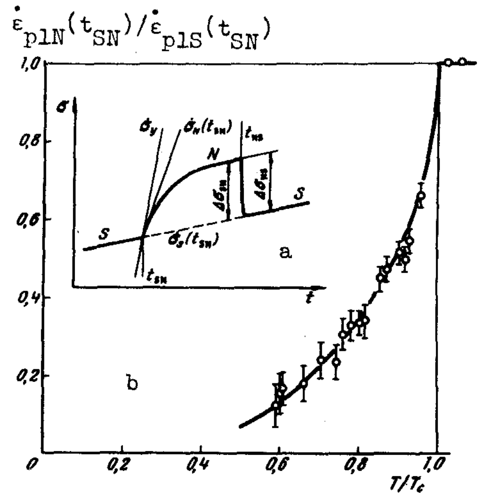
It follows from the agreement between the temperature dependences of the experimentally determined ratio of the rates of plastic deformation of lead in the normal (N) and superconducting (S) states in SN transitions, on the one hand, and the function describing the ratio of the electronic viscosities in the S and N states, on the other, that the plastic deformation of Pb at helium temperatures is determined by electronic drag of the dislocations.

Moving dislocations can interact not only with other imperfections of the crystal structure, but also with phonons and electrons. The concept of viscous drag of dislocations was introduced theoretically and it was shown that at low temperatures the electronic drag can exceed the phonon drag [1].

A possible manifestation of electron viscosity is assumed to be the change of the deforming stress σ in superconductors that are plastically deformed at a constant rate of displacement of the slide of the testing machine S in superconducting (SN and NS) transitions (e.g., [2]). So far, various workers have measured only the changes of σ ($\Delta\sigma_{SN}$ and $\Delta\sigma_{NS}$ in Fig. a). However, in addition to the changes $\Delta\sigma_{SN}$ and $\Delta\sigma_{NS}$ after SN and NS transitions, the slope of the deformation curve $\dot{\sigma} = d\sigma/dt$ also underwent changes at the instants of these transitions (t_{SN} and t_{NS} in Fig. a). It was shown in [3] that such a change of $\dot{\sigma}$ is due to the change of the rate of plastic deformation $\dot{\varepsilon}_{pl}$ at the instants t_{SN} and t_{NS}. Using the results of [3], we can write for the SN transition the ratio of the rates of the plastic deformation in the N and S states at the instant t_{SN}, in the form

$$\Gamma(t_{SN}) = \frac{\dot{\varepsilon}_{plN}(t_{SN})}{\dot{\varepsilon}_{plS}(t_{SN})} = \frac{\dot{\sigma}_y - \dot{\sigma}_N(t_{SN})}{\dot{\sigma}_y - \dot{\sigma}_S(t_{SN})}, \quad (1)$$

where $\dot{\sigma}_N(t_{SN})$ and $\sigma_S(t_{SN})$ are the slopes of the deformation curve in the N and S states at the instant t_{SN} and $\dot{\sigma}_{el}$ is the slope of the deformation curve in the case of elastic deformation of the "testing machine + sample" system. A similar expression can be written for $\Gamma(t_{NS})$.



a) Measurement scheme; b) dependence of the ratio of the rates of plastic deformation $\dot{\varepsilon}_{plN}(t_{SN})/\dot{\varepsilon}_{plS}(t_{SN})$ on the temperature T normalized to the critical temperature T_c. Solid line - dependence of the function (3) on T/T_c.

At the instant t_{SN}, the change of $\dot{\varepsilon}_{pl}$ is the consequence of the SN transition only, and is not connected with the change of σ and with the degree of plastic deformation ε_{pl}. The expression customarily used for the rate of plastic deformation is

$$\dot{\varepsilon}_{pl} = \rho BV \tag{2}$$

(ρ is the density of the mobile dislocations, V is their average velocity, and B is the Burger's vector). The ratio $\Gamma(t_{SN})$ makes it therefore possible to compare the fluxes ρV of the moving dislocations in the S and N states at the same values of σ and ε_{pl}, since a comparison of the results of the measurements of $\Delta\sigma_{SN}$ with the theoretical models calls for assumptions regarding the character of the dependence of ρ and V on σ and ε_{pl} (see, e.g., [3, 4]).

We measured the ratio $\Gamma(t_{SN})$ of lead single crystals in the temperature interval from 4.2°K to the critical temperature T_c = 7.18°K. Pb (<110>, 99.99%) samples measuring 3 × 3 × 10 mm were cut by the electric spark method, chemically polished to remove the work-hardening layer, and then deformed by compresssion ($\dot{S} = 8.3 \times 10^{-5}$ mm/sec). The temperature was varied by slow heating in helium vapor and was measured with a carbon resistance thermometer in contact with the sample. The change of temperature during individual measurements of $\Gamma(t_{SN})$ did not exceed 0.01°. The SN transition was effected by a magnetic field $H > H_c$ (H_c is the critical magnetic field). The time of the SN transition was <0.5 sec (we monitored the time of penetration of the magnetic flux into the sample).

The experimental values of $\Gamma(t_{SN})$, determined by using (1), are shown in Fig. b. The main error in the determination of $\Gamma(t_{SN})$ is connected with the accuracy with which $\dot{\sigma}_{el} - \dot{\sigma}_N(t_{SN})$ is determined. $\dot{\sigma}_N(t_{SN})$ is the average slope of the deformation curve in the N state near t_{SN} and was determined by graphic differentiation. The averaging time was <2 sec. The change of σ during this time (even at small $\Delta\sigma_{SN}$) was $< 0.1\Delta\sigma_{SN}$. The values of $\dot{\sigma}_N(t_{SN})$ were monitored by extrapolating $\Gamma_N(t)$ to t_{SN}. The results of extrapolation within the limits of the measurement errors yield the same values of $\dot{\sigma}_N(t_{SN})$. $\Gamma(t_{SN})$ was measured with the samples deformed up to 15%. No dependence of $\Gamma(t_{SN})$ on ε_{pl} was observed within the limits of the measurement errors.

The solid curve in Fig. b corresponds to the function

$$f(T) = \frac{2}{1 + \exp\frac{\Delta(T)}{kT}} \tag{3}$$

with $2\Delta(0)/kT_c = 3.52$ ($\Delta(T)$ is the energy gap, $\Delta(T)/\Delta(0)$ after BCS [5]). Such a function, as shown in [6], describes the temperature dependence of the ratio B_S/B_N of the electron viscosities in the S and N states. Thus, the temperature dependence of $\Gamma(t_{SN})$, which coincides with (3) at $2\Delta(0)/kT_c = 3.5^{+0.7}_{-0.5}$ within the limits of errors in the investigated temperature range, coincides with the temperature dependence of B_S/B_N. If the density ρ of the mobile dislocations does not change at the instant of the SN transition (which is perfectly probable, since σ and ε_{pl} are the same in the S and N states at the instant t_{SN}), then it follows apparently from this agreement, when account is taken of (2), that the plastic deformation of Pb at helium temperatures is determined by the electronic drag of the dislocations and corresponds to those dislocation-motion models in which $V \sim (1/B_e)$, where B_e is the electronic voscisity (e.g., the viscous model).

The fact that the values of $2\Delta(0)/kT_c$ that ensure agreement of (3) with the temperature dependence of $\Gamma(t_{SN})$ do not differ, within the limits of the experimental error, from the values of $2\Delta(0)/kT_c$ measured by the known methods (see, e.g., [5]), may possibly indicate that the energy gap in Pb does not change noticeably in the elastic fields of the moving dislocations.

B_S/B_N is described by the function (3) if the electron viscosity B_N in the N state is independent of the temperature, as in [1], and if the electric pairs are not destroyed during the motion of the dislocations (i.e., the dislocation velocities are not very large, see [6]). Thus, it can apparently be concluded that B_N of the employed Pb samples does not depend on the temperature, and that the motion of the dislocations in plastic deformation of Pb does not cause destruction of the electron pairs.

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PROBABILITY OF RESONANT 23.8-keV γ RADIATION FROM Sn^{119} AND ANHARMONICITY OF ATOMIC VIBRATIONS IN FERROELECTRICS OF THE PEROVSKITE TYPE

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Precision NGR measurements were made on the impurity Sn^{119} nuclei in the ferroelectrics $BaTiO_3$ and $PbTiO_3$ and in the antiferroelectric $PbZrO_3$. The character of the temperature dependence of the Mossbauer-effect probability has made it possible to conclude that low-temperature anharmonicity is present in the lattice vibrations of $BaTiO_3$ and $PbTiO_3$ in the entire temperature range of existence of these crystals.

One of the central problems of ferroelectricity is the development of a quantum-mechanical theory that takes anharmonic effects into account. There are no experimental data, however, on the character of the anharmonicity in ferroelectrics. NGR is capable of yielding valuable and in a number of cases unique information on this subject. Knowledge of the absolute value of the