correspond to the respective frequency dependence of the absorption coefficient.

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INFLUENCE OF HYDROSTATIC COMPRESSION ON THE SUPERCONDUCTING TRANSITION TEMPERATURE OF Nb_3Sn

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It has been found recently that ruthenium does not exhibit the isotopic effect: the superconducting transition temperature (T_c) is, within the experimental error, the same (0.493 ± 0.0015°K) for the ruthenium isotopes with mass numbers from M = 99 to M = 104.[1] Also, a very small isotopic effect has been observed for Nb_3Sn, for which T_c varies not as $M^{-1/2}$, as required by the electron phonon interaction mechanism, but as $M^{-1/12}$.[2]

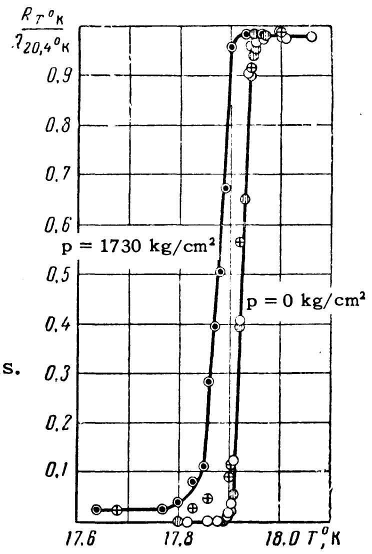
It was considered to be of very great interest to investigate the properties of such superconductors. We investigated one of these properties: the sensitivity to hydrostatic compression.

Samples of Nb_3Sn were prepared by diffusion growth of a film of this compound on the surface of a niobium wire (containing 99.5% niobium) immersed for this purpose in tin for several hours at about 1000°C.

A pressure of 1730 kg/cm^2 was produced by the ice technique described earlier.[3]

The figure shows the superconducting transition curves of Nb_3Sn with and without pressure. The transition temperature was reduced by the 1730 kg/cm^2 pressure by $(4.5 \pm 0.5) \times 10^{-2}$ deg, i.e., $\partial T_c/\partial p = -(2.5 \pm 0.3) \times 10^{-5}$ deg/atm.

Thus it is seen that the effect of pressure has the same sign (minus) as in the majority of superconductors, and its magnitude is close to the effect in such good superconductors as tin ($\partial T_c/\partial p = -4.6 \times 10^{-5}$ deg/atm)[4] or mercury (according to our measurements and published data[5] $\partial T_c/\partial p = -3.6 \times 10^{-5}$ deg/atm), for which T_c is nearly proportional to $M^{-1/2}$.



Superconducting transition in Nb_3Sn under pressure (dots with black centers) and without pressure (before application of pressure and after its removal); the latter case is represented by various symbols.

For these samples of Nb_3Sn we also determined the value of $(\partial H_c/\partial T)_{T_c} = -15.5 \times 10^3$ G/deg (this value agrees well with the results of Kunzler[6]).

The results obtained confirmed once again that Nb_3Sn is a superconductor of alloy type, i.e., the fields at the beginning of penetration into a superconductor and at the destruction of superconductivity are very different. The values of $\partial T_c/\partial p$ and $\partial H_c/\partial T$ (and hence also $\partial H_c/\partial p$) allow us to use the well-known thermodynamic relationships to obtain such quantities as, for example, the jumps in the thermal expansion coefficient ($\Delta\alpha$) and specific heat (ΔC) at the transition. Such estimates give grossly exaggerated values ($\Delta\alpha \approx 5 \times 10^{-4}$ deg^{-1}, $\Delta C \approx 100$ cal/deg) which probably indicates that the measured values of $\partial H_c/\partial T$ and $\partial T_c/\partial p$ refer to a very small part of the volume of Nb_3Sn. This agrees with measurements of other properties of this superconductor.[7,8] However, it is possible that the depth of penetration of the magnetic field in Nb_3Sn and similar superconductors may be very great.

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DIFFERENT EFFECTS OF IMPURITIES AND PLASTIC DEFORMATIONS ON THE SUPERCONDUCTING TRANSITION TEMPERATURE OF A METAL

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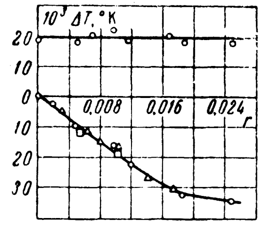
RECENTLY a number of papers have been published concerned with the effect of impurities on the temperature T_K of the superconducting transition in tin, indium, aluminum and thallium.[1-3] For these metals, apart from thallium, there is observed for small impurity concentrations a decrease of the transition temperature with increasing concentration, which, as shown by Pippard,[4] is possibly related to the change in the mean free path of conduction electrons. From this point of view, diminishing the mean free path of electrons by another mechanism—lattice distortion—should also reduce T_K. However, deformation (strong, it is true) of tin, thallium and indium at liquid helium temperature increases T_K in these metals.[5]

It appeared important to study on the same specimens the effect on the transition temperature of lattice distortions caused by impurities and deformation. The variation of T_K with antimony concentration c was measured in tin for concentrations up to 0.5%.

The transition temperatures of specimens made in the usual way from a melt agreed well with the known variation of T_K with impurity concentration (see the figure, lower curve). The residual resistance ($r = R_{4.2°K}/R_{20°C}$) served as a measure of concentration.



The dependence of the transition temperature shift on residual resistance for tin: lower curve – our data for annealed (o) specimens and for specimens obtained from a melt (Δ); □ – data from [1]; upper curve – for deformed specimens

To make deformed specimens with equal degrees of deformation, pieces of the alloys (and pure tin with $r = 2 \times 10^{-5}$) were pressed at room temperature through a die of 0.18 mm dia. After measuring in the deformed state, the specimens were annealed at t = 80°C for ~ 20 hours to remove the distortions. The transition temperature of the specimens after the anneal also agreed well with the lower curve of the figure, which proves the complete removal of distortion due to deformation by the anneal.

There was a completely different variation of T_K with impurity concentration in the deformed specimens—the transition temperature at all concentrations increased by a constant amount, $\Delta T_K = 0.020°K$, relative to T_K for pure undeformed tin (upper curve). Meanwhile the deformation contribution to the electrical resistance amounts for pure tin to practically the entire residual resistance (0.3×10^{-3}). This contribution changes little in the range of concentrations corresponding to the linear portion of the lower curve (from 0.4×10^{-3} for c = 0.18% Sb to 1.4×10^{-3} for c = 0.38% Sb).

The results obtained show that, at least for tin,[1)] the changes in electron mean free path due to impurities and to lattice deformation distortions affect T_K by completely different mechanisms. Further, the deformation mechanism (as is seen from the figure) completely eliminates the impurity effect.

The observed increase of temperature may be related to the fact that plastic deformation of a metal reduces the Debye temperature,[7] i.e., weakens the elastic properties of a metal. The latter in its turn increases the electron-phonon interaction,[8] i.e., increases T_K.

The authors thank B. G. Bar'yakhtar for discussion and T. A. Ignat'eva for help in the experiments.

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