conduction band, whereas when all the transitions are taken into account the result would naturally not depend on the gauge of the potentials.

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EFFECT OF IMPURITIES ON THE TOPOLOGY OF THE FERMI SURFACE OF INDIUM

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We report here the results of an investigation of the effect of Cd impurity on the behavior of T_c of In under pressure. Experiments of this type were performed so far only on Tl [1], where a nonlinear dependence of $\partial T_c/\partial p$ on the impurity concentration was observed. It was shown that this nonlinear dependence is connected with a change in the number of cavities (topology) of the Fermi surface of the metal [2]. Indium is the second metal in which a change in the Fermi-surface topology is observed.

We investigated In-Cd solid solutions with up to 4.5 at.% Cd. In this concentration range, the residual resistance is linear in the impurity concentration. The initial In and Cd had residual resistances r = 0.6 x 10^{-4} and 2 x 10^{-5}, respectively. The solid solutions were produced as follows: A solution with maximum impurity concentration 4.5 at.% was prepared, and the solutions with lower concentration were obtained by diluting the maximum solution with pure In. The samples were annealed for 7 - 12 days at 130°C. The investigated solutions were sufficiently homogeneous, as evidenced by the small difference between the widths of the superconducting transitions of the pure In (2 x 10^{-3} °K) and of the samples (2 - 5 x 10^{-3} °K). The plot of the superconducting transition under pressure was similar to that without pressure. The pressure was produced by an "ice" technique [3].

The shift of the transition temperature T_c from the residual resistance without and with pressure was measured relative to T_c of a pure indium sample in one experiment. The temperature of the superconducting transition was determined accurate to (1 - 2) x 10^{-3} °K. In the pressure interval 0 - 1730 kg/cm^2, a linear decrease of the superconducting-transition temperature was observed for both the In-Cd alloys and the pure In.

Figure 1a shows the dependence of ΔT_c on the residual resistance of the In-Cd alloys. This dependence is monotonic and has no singularities [4,5].
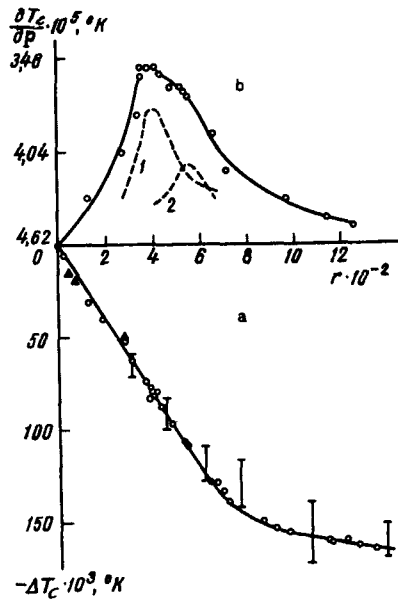

Fig. 1. Temperature of the superconducting transition of In-Cd alloy vs. the residual resistance (triangles - results of [4], bars - results of [5], circles - our results); b - $\partial T_c/\partial p$ of In-Cd alloys vs. the residual resistance.
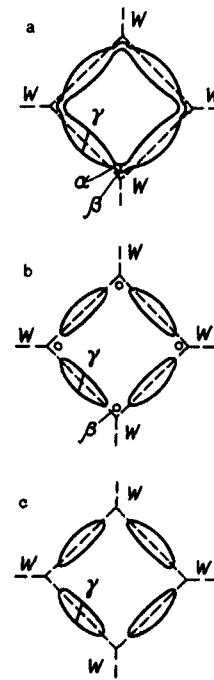

Fig. 2. Sections of the Fermi surface of indium in the third zone by the plane (100) - toroids (joined β-tubes [8]) a - pure indium; b - indium with 1.2 at.% Cd; c - with $\approx$1.9 at.% Cd.

The presence of changes in the topology of the Fermi surface can be deduced from the dependence of the pressure effect of the investigated alloys on the residual resistance. Figure 1b shows a plot of $\partial T_c/\partial p$ of the alloys against the residual resistance [ΔT_c(p = 1730 kg/cm^2) of pure In is -80 x 10^{-3} °K]. We see that $\partial T_c/\partial p$ of In-Cd alloys varies nonlinearly with increasing residual resistance (impurity concentration). The nonlinear addition is positive relative to the pressure effect of pure In. A positive nonlinear addition to $\partial T_c/\partial p$ is possible in two very simple topological cases [2] - the rupture of the bridge joining the individual cavities of the Fermi surface, or the vanishing of one of the cavities.

The real Fermi surface of indium lies in the second and third Brillouin zones. The volume of the Fermi surface in the third zone is much smaller than in the second (the Hall constant differs from unity by not more than 5%) [6]. Therefore the possible topological changes must be related to the electronic surface in the third zone. The electronic surface in the third zone consists of toroids in the (100) plane (Fig. 2a) and individual ellipsoids in the planes (010) and (001) [7,9].

To explain the experimental data on the nonlinear dependence of $\partial T_c/\partial p$ on the impurity concentration, it becomes necessary to assume that the toroids break up into individual el-

lipsoids.

Indeed, when Cd up to 4 at.% is added, the Fermi energy ϵ_F of In decreases by approximately 0.8% ($\Delta\epsilon_F/\epsilon_F = (2/3)(\Delta Z/Z)c = 8 \times 10^{-3}$, where ΔZ is the difference in the valence between the impurity and the host atoms and c is the impurity concentration.

This change in energy is apparently sufficient to break the toroids in the (100) plane. Since sections α and β are different [7], the surface breaks in the section β (Fig. 2b), and with further increase of impurity concentration the remaining cavities of the Fermi surface near the points W are eliminated (Fig. 2c). Recognizing that the topological transition in the superconductivity is smeared by the electron-phonon interaction by an amount $2\Theta_D$ [2] (Θ_D is the Debye temperature, equal to 100°K for In), the experimentally observed dependence of $\partial T_c/\partial p$ can be represented as a sum of two curves (dashed in Fig. 1b).

Curve 1 (Fig. 1b) is connected with the elimination of the β sections of the third-zone Fermi surface, occurring under the influence of the impurity at approximately 1.3 at.%, while curve 2 is connected with the vanishing of the remaining cavities at the points W at 1.9 at.% (Figs. 2b,c). Since the effective masses of the electrons in these directions differ little (0.18 and 0.2) [7], the singularities in the state density, connected with the elimination of sections α and β, should become manifest to an approximately equal degree in the dependence of $\partial T_c/\partial p$ on r. This is apparently the reason why the maximum of the experimentally observed anomaly in $\partial T_c/\partial p$ corresponds to ~1.3 at.% Cd, and with respect to the magnetic properties of these alloys to ~2 at.% [10].

It is of interest to note that a similar dependence of $\partial T_c/\partial p$ on the impurity concentration can be observed also for Al, which has an electronic structure similar to In. This follows from observation of the de Haas – van Alphen effect in Al with Zn impurity, which shows that the sections β and α can vanish at 2 and 3 at.% respectively [11].

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