

Superconducting transition of indium filaments at 6K

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We succeeded in raising the value of T_c of indium to ~ 6 K by decreasing the dimensionality of the sample (thin filaments of diameter ~ 20 – 30 Å).

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It is known that dispersion of superconductors can raise T_c by a factor that is larger the smaller the electron-phonon interaction parameter in the BCS formula. Superconductors with strong electron-phonon coupling of the Hg or Pb type retain practically the same T_c when dispersed. This has been thoroughly investigated by using as examples thin films or porous glasses inlaid with the metal (characteristic dimension up to ~ 30 Å). Indium, whose electron-phonon interaction parameter is somewhat smaller than that of Hg and Pb, changes its T_c in films and in glasses by ~ 1.3 times (to ~ 4.5 K).^[12] A larger value of T_c could not be obtained in indium films.

Since size effects in thin filaments ("one-dimensionality") should manifest itself more strongly than in films ("two-dimensionality"), we deemed it of interest to measure the superconducting properties of such filamentary objects. In the case of indium this was all the more interesting, because filaments of mercury (a superconductor with strong electron-phonon coupling) reveal practically no change of critical temperature.^[3]

The indium filaments were drawn by an analogous technology. The electric contact with such indium filaments in asbestos channels was through bulky mercury. Two types of sample were prepared, one with filament diameters ~ 20 – 30 Å and the other with diameters ~ 40 – 70 Å. Figure 1 shows the tem-

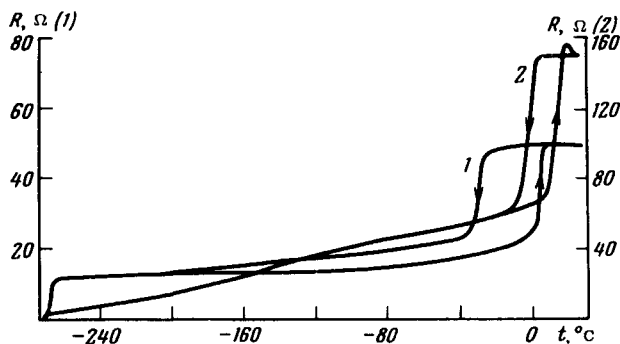


FIG. 1. Temperature dependence of the resistance of In filaments: 1—filaments of ~ 20 – 30 Å diameter; 2— ~ 40 – 70 Å diameter.

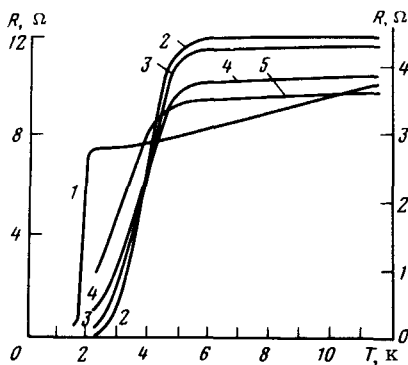


FIG. 2. Superconducting transition of In filament: 1) filaments with diameter $\sim 40\text{--}70 \text{ \AA}$ (current $20 \mu\text{A}$, right-hand scale); 2–5) filaments with diameter $20\text{--}30 \text{ \AA}$ (left-hand scale); 2—current $10 \mu\text{A}$, 3— $100 \mu\text{A}$, 4— $500 \mu\text{A}$, 5— 1 mA .

perature dependence of the resistance for the “thin” (1) and “thick” (2) indium filaments. The diameter value could be qualitatively estimated from 1) the resistance jump upon melting and solidification; 2) the decrease of the melting and solidification temperature and the hysteresis; 3) the temperature dependence of the resistance of the solid In filaments; 4) the smearing of the superconducting transition (see^[3]).

Figures 2 and 3 show plots of the resistance vs temperature in the region of the superconducting transition. The temperature smearing of the transition is $\sim 0.1 \text{ K}$ for the “thick” filaments and $\sim 3 \text{ K}$ for the “thin” ones. Besides the abrupt increase of the width of the transition, which is apparently due to fluctuations,^[3] a noticeable shift of the center of the transition to $\sim 5.9 \text{ K}$ is also observed. This value of the superconducting transition was obtained here for indium for the first time, and the reason, in our opinion, is the dimensionality of the sample (filaments rather than films). This is also apparently the main

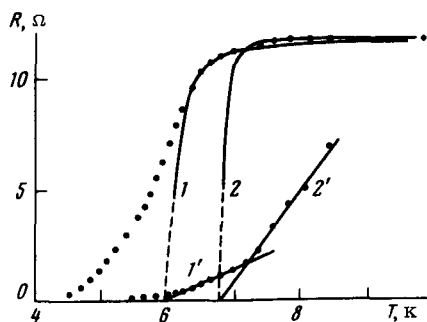


FIG. 3. Superconducting transition of In filaments with diameter $\sim 20\text{--}30 \text{ \AA}$ (current $10 \mu\text{A}$); points—experiment. 1) $R(T)$ corresponds to the relation $\sigma' = 4.1 \times 10^{-1} \sigma_N [T_c / (T - T_c)]^{3/2}$, $T_c = 5.95 \text{ K}$; 2— $R(T)$ corresponds to the relation $\sigma' = 5.5 \times 10^{-2} \sigma_N [T_c / (T - T_c)]^{3/2}$, the same relations plotted with $(\sigma')^{-2/3}$ and the temperature as coordinates. In the latter coordinates T_c is determined by the intercepts of the straight lines with the T axis. (Points—experimental values of $(\sigma')^{-2/3}$.)

reason why the fluctuations assume a greater role. In addition to the increase of T_c , we can point out the following singularities: 1) a decrease of the resistance with increasing current above the transition in the case of "thin" filaments (in analogy with the effect noted for Hg filaments)^[3]—see Fig. 2; 2) the additional fluctuation-induced conductivity in the region above 6.3 K can be satisfactorily described by the relation $\sigma' = A\sigma_N[T_c/(T - T_c)]^{3/2}$ with $A = 4.1 \times 10^{-1}$, $T_c = 5.95\text{K}$ ($\sigma' = \sigma - \sigma_N$, σ_N is the conductivity of the sample in the normal state) up to 7.15 K; beyond the break in the $R(T)$ curve at $T = 7.15\text{ K}$ the conductivity can be described by the same relation, but with $A = 5.5 \times 10^{-2}$, $T_c = 6.77\text{K}$ (see Fig. 3).

This temperature dependence agrees with the results of^[4], but the subdivision of the temperature interval into two regions with different parameter values is surprising. The nature of this phenomenon remains unclear, although a similar behavior was observed by us in Hg and Ga samples.

¹W. Buckel and R. Hilsch, Z. Phys. 138, 109 (1954).

²J. H. P. Watson, Phys. Rev. 148, 223 (1966).

³V. N. Bogomolov and Yu. A. Kumzerov, Pis'ma Zh. Eksp. Teor. Fiz. 21, 434 (1975) [JETP Lett. 21, 198 (1975)].

⁴L. G. Aslamazov and A. I. Larkin, Fiz. Tver. Tela 10, 1104 (1968) [Sov. Phys. Solid State 10, 875 (1968)].