FIELD DEPENDENCE OF THE CRITICAL CURRENT IN AN ALLOY WITH A DISPERSED SUPERCONDUCTING PHASE

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It is shown that for a superconductor in which the dispersed particles of the superconducting phase (Nb_3Al) situated in a normal matrix form a multiply connected system of current paths the field dependence of the critical current obeys a power law and high values of the critical current density are attained (up to 3.5×10^5 A/cm^2).

THE variation of the density of the critical current was investigated in an alloy of niobium containing 15 atomic % of aluminum. This alloy in accordance with the phase equilibrium diagram[1] at temperatures above 1400°C exists in a state of solid α-solution based on niobium with a body-centered cubic lattice. At temperatures below 1400°C the alloy in the equilibrium state consists of two phases. The second phase is the β-phase on the basis of the compound Nb_3Al with a lattice of the type β-W (or Cr_3Si).

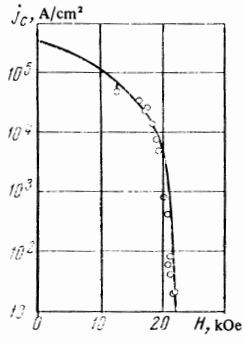
In our experiments the alloy was cooled after crystallization sufficiently rapidly to prevent the process of the separation of the β-phase. Then a deformation was produced by means of rolling with a rolling reduction of ~80% and recrystallizing annealing was carried out at a temperature of approximately 1700°C with a subsequent rapid cooling. The samples so obtained were rolled into a ribbon of width 3–4 mm and of thickness 80–100 μ (the degree of deformation is ~70%), were coated at the ends with copper by a galvanic method and were annealed at 900°C for a period of 10 hours in vacuo (~10^{-5} Torr). Investigations carried out by us previously have shown that under such treatment there occurs in the alloy a process of aging of the initial supersaturated metastable solid solution. The phase separated out consists of the intermetallic compound Nb_3Al impoverished in aluminum in comparison with the stoichiometric compound. Data of transmission electron microscopy allow us to suppose that the dispersed depositions of the β-Nb_3Al phase are located at the dislocation boundaries of the cell structure which is formed in a more or less defined manner when the deformed samples are annealed.

Measurements of electrical resistance carried out on the ribbon samples in liquid helium have shown that in the initial deformed state no superconductivity is observed, while after annealing at 900°C the samples have zero resistance at 4.2°K. Measurements of electrical resistance in hydrogen with pumping (from 20.4 to 11.9°K) of samples aged at 900°C have enabled us to establish that the transition to the superconducting state begins at 14°K and is so stretched out that down to 11.9°K the resistance falls only by 6% (i.e., $R_{11.9}/R_{14.0} = 0.94$). But this is not the usual temperature dependence of electrical resistance, since $R_{14.0}/R_{20.4} = 1.0$. Such a low critical temperature for the β-Nb_3Al phase is explained by its significant impoverishment in aluminum[1)]. Moreover, the lowering of T_c and the smearing out of the transition are apparently associated with a manifestation of the nearness effect the contribution of which can be noticeable due to the dispersed nature of the particles of the precipitated superconducting phase.

Measurements of the critical current were carried out in a transverse magnetic field produced by a superconducting solenoid at 4.2°K. While the measurements were being carried out the field was maintained constant, and the current through the sample increased smoothly. The value of the critical current was determined at the moment when a difference of potential appeared across the sample which was recorded by a potentiometer circuit with a sensitivity of ≥ 0.1 μV.

The diagram gives on a semilogarithmic scale the experimentally obtained values of the density of the critical current. The solid line shows the graph of the dependence $j_c(H) = j_c(0)(1 - H/H_{c2})^{1.8}$ by means of which the experimental data can be satisfactorily approximated if we assume that $j_c(0) = 3.5 \times 10^5$ A/cm^2, while $H_{c2} = 22$ kOe. The maximum current which can be sent through the sample with the given source of supply was equal to 126 A. With such a current a sample of 80 μ thickness and of 3 mm width remained superconducting in a field of 12.6 kOe.

Thus, it has been shown that in a superconductor which has a filmlike or filamentary structure of the dispersed superconducting phase in a nonsuperconduct-



[1)]The concentration of aluminum in the β–Nb_3Al phase separated out in the aging process determined by X-ray data amounts to ~20 atomic %.

ing matrix the field dependence of the critical current obeys a power law as has been predicted in theoretical papers (for example,[2]).

In conclusion the author takes this occasion to thank L. S. Lazareva for aid in carrying out the measurements of the critical current.

[1] N. Svechnikov, V. M. Pan, and V. I. Latysheva, Collection of articles Metallofizika (Metal Physics), issue 22 (Phase Transformations), "Naukova Dumka", 1968, p. 54.

[2] V. V. Schmidt, Collection of articles "Metallovedenie i metallofizika sverkhprovodnikov" (Metal Science and Metal Physics of Superconductors), "Nauka", 1965, p. 17.

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192