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CRITICAL MAGNETIC FIELDS OF SUPERCONDUCTING NIOBIUM FILMS

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Thin superconducting niobium films were prepared. It was found that the critical fields of the films were much higher than those of the bulk metal, and that they depended on the film thickness. Estimates were made of the critical fields for films of two thicknesses and of the critical temperatures of the films. A possible connection between the high critical parameters of hard superconducting alloys and the superconducting properties of films is indicated.

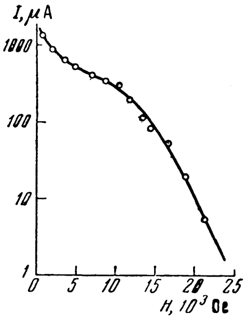
DATA[1-3] are available on the critical temperatures of thin niobium films. However, it is also important to know the critical magnetic fields of niobium films because of their ever-increasing practical applications and because of the development of a treatment of the characteristics of the superconductivity of metals of the transition group in the periodic table. The present communication reports data on the critical magnetic fields of niobium films, 2×10^{-5} and 5×10^{-5} cm thick, prepared by condensation.

The properties of niobium, like those of other metals of the transition group, are very sensitive to gaseous impurities,[4] which enter the metal from the vacuum apparatus and from the substrate. Therefore, several precautions were taken to reduce as much as possible this harmful influence: adsorption pumping was employed,[5] the walls of part of the vacuum system were cooled with liquid nitrogen,[6] the substrate was heated before and during condensation to 200—300°C, the niobium wire used as the evaporation source was first heated for a long time at 2000—2200°C to remove the majority of the volatile impurities; and the pressure in the apparatus was $\sim 10^{-7}$ mm Hg.

Pyrex glass or mica was used as the substrate and the substrate plates were provided with silver current and potential contacts.

The transition temperatures of the films lay in the region between liquid helium and liquid hydrogen temperatures. Therefore, the transition temperature was measured in a copper block enclosing the sample, a thermometer and a heater, which was itself placed in vapor above the surface of the liquid helium. The magnetic field was directed at right angles to the measuring current and parallel to the plane of the sample.

Since the critical field H_c of such films depends strongly on the value of the measuring current, it was determined by extrapolation to zero measuring current. The figure presents data for a film of thickness $d = 5 \times 10^{-5}$ cm, at 4.2°K. For this film $H_c \approx 25{,}000$ Oe, i.e., it is one order of magnitude greater than for bulk niobium. For a film 2×10^{-5} cm thick, the critical field H_c at $T_c = 4.2$°K, was considerably higher and could not be determined in our measurements since the external field was limited to 22,000 Oe. To determine $\partial H_c/\partial T$ near T_c, the transition curves were recorded: i.e., the values of T_c were determined first without a field and then in a field of 8000 Oe. The shift of T_c (determined at points $R/R_N = 0.5$) by this field showed that for a film $d = 2 \times 10^{-5}$ cm thick $\partial H_c/\partial T \approx 23{,}000$ Oe/deg, and for a film $d = 5 \times 10^{-5}$ cm thick $\partial H_c/\partial T \approx 9000$ Oe/deg.



Dependence of the critical current on the field for a niobium film, $d = 5 \times 10^{-5}$ cm thick, deposited on mica.

The transition temperatures of niobium films, as in earlier work,[1] decreased on reduction of the film thickness and were 6.5° and 7.5°K for films of $d = 2 \times 10^{-5}$ and 5×10^{-5} cm, respectively. For a wire of the original niobium, $T_c = 9.1$°K. Obviously, our conditions for the preparation of films did not yield sufficient purity.

The results obtained are interesting on two counts. First, from these results, in accordance with the theoretical representations,[7] we can estimate the depth of the field penetration into niobium: it was found to be $\sim 10^{-4}$ cm, i.e., an order of magnitude higher than for "soft" superconductors. Secondly, they reveal thin superconducting paths as the real cause of the high critical magnetic fields of niobium alloys. In fact, even the critical field for niobium films 2×10^{-5} cm thick is about 90,000 Oe near 0°K (the field varies as the square of temperature) i.e., it is close to that observed for Nb–Zr and Nb–Ti alloys.[8]

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