SUPERCONDUCTING SOLENOIDS FOR STRONG MAGNETIC FIELDS USING Nb_3Sn

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Data are presented on superconducting solenoids constructed of Nb_3Sn, and the critical current vs. external magnetic field curve for this superconducting compound is discussed.

THE superconducting intermetallic compound Nb_3Sn having a critical temperature $T_c = 18.06°K$ was discovered some time ago,[1] but only at the beginning of the present year was it established that, although the magnetic field begins to penetrate this material at a relatively low value of the field intensity, the resistance nevertheless remains zero up to 100 koe, while the current density in the sample can reach 10^5 amp/cm^2.[2-4] These data indicate a real possibility for construction of solenoids from this superconductor to generate strong fields.

Practical use of this compound, unfortunately, is impeded by its extreme brittleness. Kunzler et al[2] have described the use of a superconductor based on Nb_3Sn, prepared by filling a tube of niobium with a mixture of powdered Nb and Sn, drawing this combination through a die to a diameter of ~0.4 mm, and then sintering the powder within the capillary thus formed at ~1000°C.

We have developed several alternate techniques for preparing mechanically durable superconducting wires and ribbons using Nb_3Sn, consisting of an inner core of niobium and a relatively thin surface layer of the intermetallic compound. Small short-circuited solenoids containing from 20 to 112 turns were made from compound wire of this type, 0.3 mm in diameter, and the dependence of the field H_x within the coils upon the external field H_0 was investigated. If one uses the values of the residual fields of the solenoids to compute the currents flowing through them, one can obtain the field dependence of the critical current at 4.2°K shown in Fig. 1. In this graph the points corresponding to a field of ~30 koe were obtained from experiments on the destruction of superconductivity in a single wire 0.3 mm in diameter by a current in a constant field, while the point at ~80 koe was obtained from the destruction of superconductivity in a single wire of the same sort in a pulsed coil.

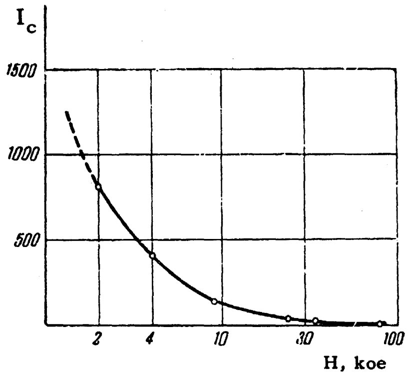

FIG. 1

It is evident that the curve thus obtained is similar to that representing the external magnetic field dependence of the critical current in a binary superconducting alloy (see [5]), and is characterized by an extremely high critical current for zero external field ($I_c \approx 1800$ amp), which corresponds to a critical current-induced field at the surface of the superconductor of ~24 koe. This value is quite close to that of H_{c1}, which may be obtained for Nb_3Sn from measurements of the magnetic moment* (see [6]).

Another feature of this relation is the very slow decrease in critical current with field for strong fields.

The high value for the frozen-in field of the short-circuited solenoid can be illustrated by the photograph in Fig. 2, which shows the helium Dewar containing the coil. Several quite heavy iron bolts are supported freely against the outer surface of the Dewar under the influence of the scattered field (the axis of the coil is horizontal, the number of turns n = 900, and the external dimensions of the coil are d = 18 mm, l = 20 mm). The field within the coil in this experiment

*H_{c1} represents the first critical field of the alloy, corresponding to a change in the induction in the sample as the external field is increased.

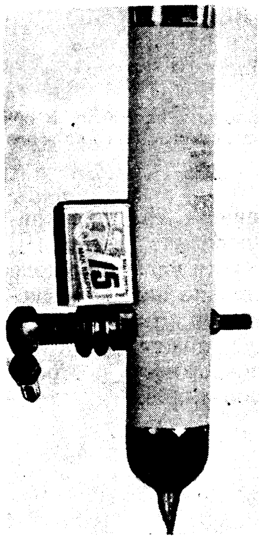

FIG. 2

amounted to ~15 koe. It should be mentioned that this value for the field is not the limiting one for this coil, and was determined by the parameters of the magnet used to excite the magnetic field in the coil.

In addition to short-circuited coils, we have also constructed small externally-supplied coils. With these, we used as lead-in conductors superconducting busbars prepared by a method analogous to that proposed by Kunzler, et al,[2] with the exception that copper tubing was used in place of niobium.

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