SUPERCONDUCTIVITY OF Nb_3Sn IN PULSED FIELDS OF 185 KILOGAUSS*

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We have observed the superconductivity of a Nb_3Sn wire in pulsed magnetic fields of 185 kgauss. When extrapolated to negligible measuring current, the critical field of this specimen appears to be about 188 kgauss at 1.6°K.

The wire was prepared by the NBS Metallurgy Division. They followed the procedure outlined by Kunzler et al.,[1] except that the wire was swaged rather than drawn to final diameter (0.50 mm). The 12-cm long specimens were annealed in a vacuum for 16 hours at 1000°C, after which the sample ends were etched in $2H_2SO_4 + 2HNO_3 + HF$ and then immediately tinned in a bath of molten indium. Current and potential leads were attached using indium solder. The sample was oriented parallel to the field of a pulsed magnet having an i.d. = 1.4 cm and a length of 6.4 cm. Current and potential leads to the sample were thus completely outside of the magnet.

The magnetic field as a function of time is shown as the upper trace in Fig. 1. The field rises to a peak of 185 kgauss in 7 msec. The lower trace in the figure is the voltage across the sample with a small steady current flow. However, most of the data were obtained using square current pulses of 2 msec or less duration initiated after controlled time delays from the start of the field pulse. This procedure reduces the undesirable effects of Joule heating in the current leads. A transient voltage signal is seen at the beginning of the trace when the field pulse is initiated. Superconductivity is destroyed when the voltage finally reappears. We interpret the continuously increasing voltage with time as a spread of the normal region to the outer ends of the wire where the applied field is small.

The results of a number of such measurements are plotted in Fig. 2. The results are limited by the maximum of 23 amperes obtainable from the current source which was used. This corresponds to a current density in the core of approximately 10^5 amp per cm^2. The noise on the sample potential leads during the field pulse is

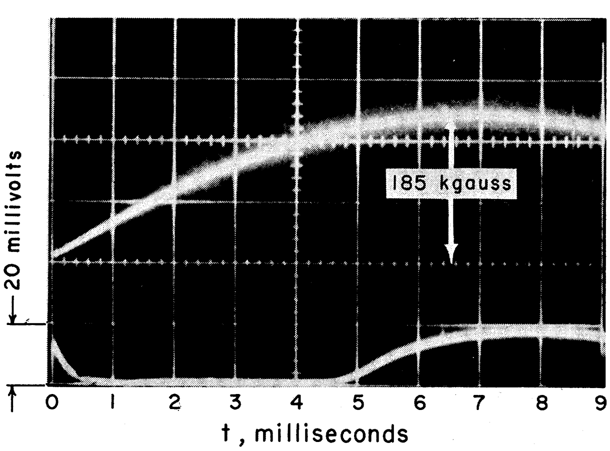

FIG. 1. Upper trace: magnetic field as a function of time. Lower trace: sample voltage as a function of time with 3-amp current.

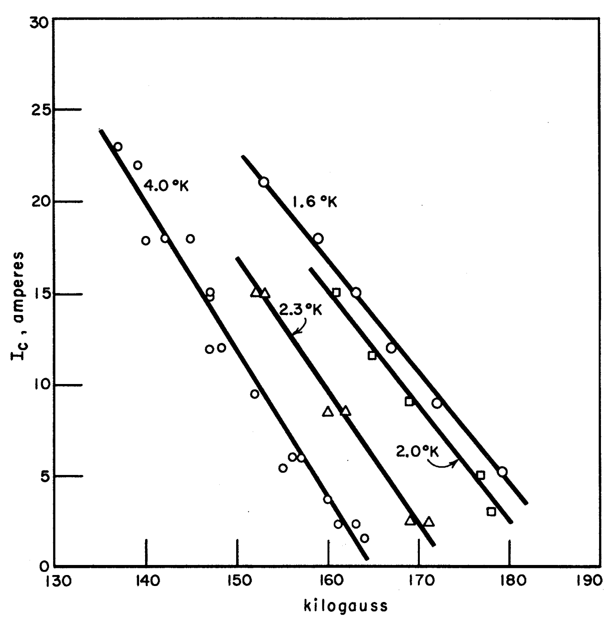

FIG. 2. Critical current versus magnetic field.

the order of 0.5 millivolt, so that the sensitivity of this pulse method of determining sample resistance is about 10^4 times less than the dc method used by Kunzler.

We have made an estimate of eddy current heating in the sample during the field pulse. Above the lambda point (2.17°K) the sample might warm by as much as 1°K. Below the lambda point the high heat transfer rate to superfluid helium should restrict the temperature rise to less than 0.5°K. The temperatures indicated in Fig. 2 are those of the helium bath. The shift in critical field from just above to just below the lambda point indicates that heat exchange to the bath has a measurable but not important effect on the data.

The attenuation of the pulsed field through the niobium sheath can be calculated from equations given by Kosevich.[2] It turns out to be the order of 1 gauss and so is completely negligible.

The great interest in Nb_3Sn wire is, of course, for use in superconducting magnets. In this application it is necessary to know the critical field transverse to the current flow, rather than parallel to it as in our experiment. For a "soft" perfectly diamagnetic specimen the transverse critical field (which restores the first trace of resistance) is one half of the longitudinal critical field. For a hard superconductor, in which flux penetration is nearly complete, these two critical fields are nearly the same. The measurements reported here certainly set an upper limit on the critical field for transverse measurements on this specimen. Kunzler[1] reports that the critical current in their samples scales with diameter in a manner intermediate between that of soft and that of hard superconductors. We are continuing our measurements, and hope to obtain transverse critical fields in the near future.

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[1]J. E. Kunzler, E. Buehler, F. S. Hsu, and J. H. Wernick, Phys. Rev. Letters 6, 89 (1961).

[2]A. M. Kosevich, J. Exptl. Theoret. Phys. U.S.S.R. 33, 735 (1958) [translation: Soviet Phys.—JETP 6, 564 (1958)].

ULTRASONIC CYCLOTRON RESONANCE IN GALLIUM

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Mikoshiba[1] suggested that a cyclotron resonance of metallic electrons could be induced by ultrasonic waves in which the attenuation of the sound waves should be a maximum whenever the frequency of the sound wave is an integral multiple of the cyclotron frequency, $\omega = n\omega_c$. This type of resonance has been seen in the semimetal bismuth[2] but not in any true metal, because the condition required—that $\omega\tau$ be greater than unity—has not been met. This requirement makes severe demands on metal purity; for example, at 100 Mc/sec an electron mean free path of approximately one cm is required to obtain $\omega\tau = 5$.

Single crystals of the metal Ga, kindly prepared and supplied by Kramer and Foster,[3] have been shaped by careful machining techniques into oriented ultrasound specimens about 1 cm in thickness. The electronic grade Ga from which the crystals were grown had a room temperature to 4.2°K resistivity ratio of about 50 000 determined by dc four-probe methods.

Standard ultrasonic pulse techniques[4] were used with a single transducer for transmission and detection. The bonding agent was a silicone fluid with viscosity of 20 000 centistokes.

In Fig. 1 the reflected pulse amplitude is plotted as a function of field for a longitudinal, 115-Mc/sec sound wave traveling along the c_0 axis at 1.6°K. Two types of resonance behavior are present. The first consists of a geometric resonance with a maximum (indicated by a minimum in the pulse amplitude) at 80 oe and additional members of the series occurring at equal intervals of $(1/H)$. About 30 maxima have been ob-

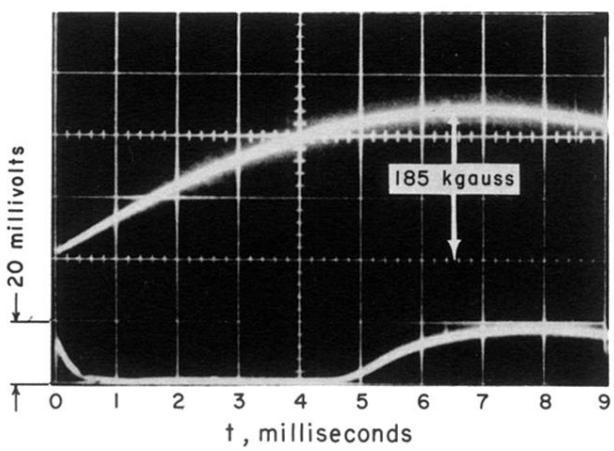

FIG. 1. Upper trace: magnetic field as a function of time. Lower trace: sample voltage as a function of time with 3-amp current.