Incipient Superconductivity in Titanium

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According to the measurements of Meissner and his co-workers[1,2] and of de Haas and van Alphen,[3] wires of titanium undergo a transition into superconductivity at either 1.3° or 1.78°K. Shoenberg,[4] on the other hand, using a permeability measurement, found that down to 1.0°K only a very small fraction of the metal appeared to become superconducting.

The specimens in all measurements referred to above were prepared in the Philips Laboratory at Eindhoven by means of thermal decomposition of the vapor of titanium iodide, causing the metal to precipitate on a hot tungsten wire.[5] More recently, the U. S. Bureau of Mines[6,7] has developed methods for comparatively large scale production of ductile titanium using the method of Kroll[8] in which the chloride of titanium is reduced with magnesium at about 1000°C in the presence of pure argon.

The Bureau of Mines has kindly supplied us with a wire of this material, 0.055 inch in diameter and containing the following impurities: magnesium, 0.25 percent; silicon, 0.02 percent; iron, 0.03 percent; hydrogen, less than 0.01 percent.

The ends of this wire were copperplated and potential and current leads attached. The specimen was placed vertically in direct contact with liquid helium which allowed resistance measurements to be made at temperatures between 1.1°K and 4.23°K. The current and potential were determined with a Leeds and Northrup Type K potentiometer and the resistance was calculated differentially to minimize error due to thermal e.m.f.

Figure 1 shows the ratio of the resistance, R, to the resistance at room temperature, R_t. From this figure it is seen that the resistance stayed effectively constant in the region 4.2° to 3.2°K. Between 3.2° and 1.5° the resistance dropped sharply to about half its value at 4.2°K. At 1.1°K, the lowest temperature obtainable with our apparatus, the resistance appeared to be leveling off again.

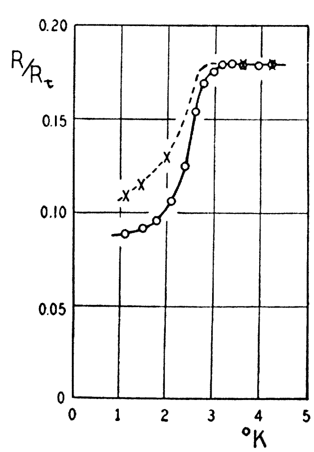

FIG. 1. The resistance of the titanium wire from 1.1 to 4.2°K in zero magnetic field (solid curve) and in a logitudinal magnetic field of 1200 gauss (broken curve).

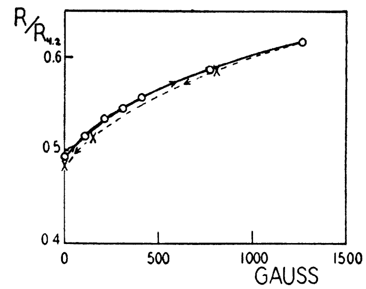

FIG. 2. Dependence of the resistance on logitudinal magnetic field at 1.1°K.

No trace of the transitions into superconductivity previously observed at 1.8° and 1.3°[1,2,3] was evident in our specimen.

The effect on the resistance of longitudinal magnetic fields of intensity up to 1400 gauss was determined. At temperatures above 3.2°K, the effect was negligible. Below 3.2°K the resistance became strongly sensitive to magnetic field, establishing the theory that the drop in resistance was due to incipient superconductivity. The dotted curve in Fig. 1 gives the resistance of the wire in a field of 1200 gauss. Figure 2 shows the resistance of the specimen as a function of magnetic field at 1.1°K. The hysteresis appearing in this figure also appeared at 1.4°K and, to a lesser extent, at 2.0°K.**

As only a small part of the metal need be superconducting to short circuit the remainder and give a zero resistance, it seems reasonable to conclude that the incipient superconductivity observed in these measurements is due to an impurity—probably an alloy of titanium with magnesium or iron. The superconductivity observed by Meissner[1,2] and by de Haas and van Alphen[3] possibly has a similar origin, perhaps an alloy or compound of titanium with tungsten formed at the surface of the hot tungsten wire.

Since titanium appears to have a number of superconducting alloys and since the position on the periodic table and the atomic volume of titanium are favorable,[9] it seems possible that pure titanium may have a transition into superconductivity at some temperature below 1.1°K.

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** A similar hysteresis has been observed by us in measurements on the alternating field permeability of superconducting vanadium. Further details will be given in a future publication.

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