CRITICAL FIELDS OF SUPERCONDUCTING BISMUTH AT HIGH PRESSURE

E. M. COMPY
U.S.Naval Research Laboratory, Washington, D.C.

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Although bismuth is not normally a superconductor, Chester and Jones [1] in 1953 found that bulk bismuth when subjected to high pressure is superconducting below about 7°K. They assumed that the bismuth had undergone a polymorphic transition as indicated by its phase diagram according to Bridgman [2]. Brandt and Ginzburg [3] showed that the superconductivity was due to the high pressure modification Bi III, which at room temperature exists for pressures above 27 kilobar. Later they measured the critical fields of Bi III near the transition temperature [4]. This present paper reports measurements of the critical fields of Bi III from 1.8°K to 4.2°K and the transition temperature in zero magnetic field.

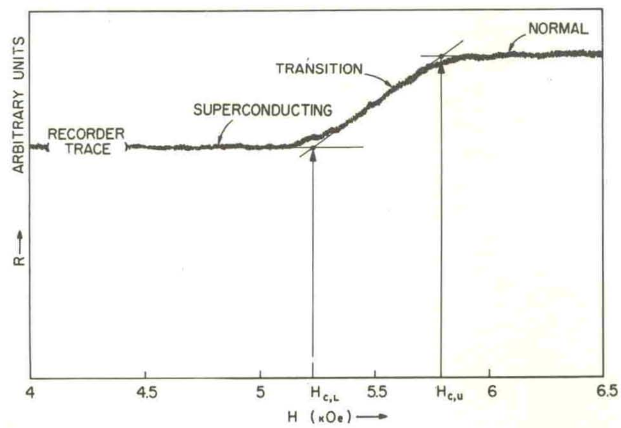

Fig. 1. A typical recorder trace showing resistance versus applied magnetic field and the method of determining $H_{c,u}$ and $H_{c,l}$. This trace was taken at 4.2°K and approximately 37 kilobar.

The high pressure apparatus has been described previously [5]. It is essentially a piston-cylinder device employing silver chloride as a pressure transmitting medium. Temperatures were measured with a carbon resistor calibrated

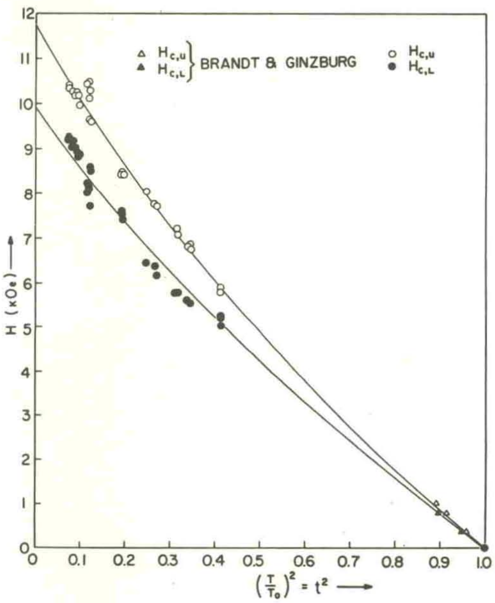

Fig. 2. The superconducting critical field, H_c, versus the square of the reduced transition temperature, $t^2 (= T^2/T_0^2)$, for Bi III at pressures of approximately 37 kilobar. For the samples used in this experiment, T_0, the transition temperature in zero magnetic field, was found to be 6.55 ± 0.2°K. In plotting the data of Brandt and Ginzburg, their value of $T_0 \approx 7$°K was used.

against the vapour pressure of liquid helium (T_{58} scale). The magnetic field was supplied by a calibrated solenoid magnet.

Pressures were applied at 77°K and held constant as the temperature was lowered. Then the electrical resistance of the sample was measured as a function of temperature or magnetic field. The measuring current was 500 mA.

Two samples of bismuth were used, both with stated purity 99.999 percent. The samples were in the form of rectangular parallelepipeds with dimensions 0.036" × 0.029" × 0.075". Each was mounted in the high pressure cell so as to have its long axis perpendicular to the applied magnetic field and parallel to the direction of current flow.

Due to the broadness of the transition, two critical fields, $H_{c,l}$ and $H_{c,u}$, are used in describing the results. The method of determining the lower critical field $H_{c,l}$ and the upper critical field $H_{c,u}$ is shown in fig. 1.

In fig. 2, $H_{c,u}$ and $H_{c,l}$ are plotted against $t^2 (= T^2/T_0^2)$ for pressures of approximately 37 kilobar. T_0 is the transition temperature for $H = 0$. The solid curves were fitted to the data and are given by $H_{c,l} = H_{0,l}[1 - (1.4925)t^2 + (0.4925)t^3]$ and $H_{c,u} = H_{0,u}[1 - (1.5873)t^2 + (0.5873)t^3]$, with H in kOe. From several experimental determinations, T_0 was found to be 6.55 ± 0.2°K. By extrapolating the solid curves for $H_{c,l}$ and $H_{c,u}$ to $T = 0$°K, one obtains $H_{0,l}$ = 9.91 ± 0.4 kOe and $H_{0,u}$ = 11.75 ± 0.4 kOe. A few data points obtained from the low field work of Brandt and Ginzburg [5] are also shown. It should be noted that they report T_0 to be approximately 7°K, which is the value used in plotting their data in fig. 2.

There are undoubtedly strains in the samples due to pressure inhomogeneities, and therefore these results are considered preliminary. Measurements on unstrained samples would probably yield lower critical fields.

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