film surface, and an anisotropic gap would be expected to vary slowly with crystal orientation.

We think that the observed double structure arises from the complicated Fermi surface in lead. The form of $\rho_{\text{eff}}(E)$ can be explained if we postulate that two different zones contribute different energy gaps and have different coherence lengths associated with them. This is not inconsistent with Gold's[7] model of the zone structure of lead. He considers four zones: The first is full and the fourth is probably empty. The second and third zones are partially filled and have similar densities of states associated with them. Suhl, Matthias, and Walker[8] have considered the BCS theory for the case of overlapping bands. They suggest that s-p bands exist as such and that s-p scattering may contribute to normal-state resistivity. With a nearly free electron model of lead as proposed by Gold, it would be more correct to consider scattering between zones. For the thick film, electron-phonon interaction may be sufficient to cause both of the zones to exhibit an isotropic energy gap, but insufficient for the scattering between the two zones to make these two gaps identical. In the thin film, increased scattering causes interzone scattering and results in one energy gap for the whole Fermi surface. The temperature dependence of the two energy gaps in thick films near the transition temperature would provide interesting information of the degree of interaction between zones. This has not been attempted because of the experimental difficulty of measuring characteristics accurately near the transition temperature of lead.

We thank Dr. A. H. Lettington, Dr. C. J. Adkins, and Dr. J. Waldrum for stimulating discussions of multiple zone effects in lead, and Mr. P. Myhill for his assistance with the experimental work.

We are grateful to the Admiralty and the Plessey Company (U.K.) Limited for permission to publish this Letter.

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PAIR CORRELATIONS IN SUPERCONDUCTING TANTALUM*

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(Received 22 July 1963)

It has been shown previously[1] that one of the consequences of so-called flux "quantization" in multiply connected superconductors[2,3] is that the transition temperature T_c of the superconductor is a periodic function of the flux enclosed. For a superconductor in which the particles are correlated in pairs as postulated by the theory of Bardeen, Cooper, and Schrieffer,[4] this period is $hc/2e$. An extensive series of measurements by Parks and one of the authors has verified that this is, in fact, the period observed in T_c in all of the soft superconductors studied.[5] On the basis of this and the many other successes of the BCS theory, one might be led to believe that such pair correlations would exist in all superconductors. However, Yang's[6] more general considerations of off-diagonal long-range order point to the possibility of superconductivity occurring where the basic group of correlated particles is not necessarily two, but any even number of fermions. For this reason we felt it important to extend our observation to the transition element superconductors to check whether the periodicity of the transition temperature T_c was $hc/2e$ or hc/ne where n is an even integer. We report here results on a cylindrical sample of tantalum.

In view of the extremely high melting point of tantalum, approximately 3100°C, and the extreme sensitivity of its superconducting properties to gaseous impurities, some modification had to be made in the technique used previously for Sn.

Cylindrical samples of tantalum were made in the following way. Fine soft glass fibers were drawn by pulling $\frac{1}{4}$-in. glass-capillary tubing to approximately 0.010-in. diameter in a flame. A short length of this fine capillary was then hung vertically through the center of a 1 mm diameter two-turn spiral of platinum wire. A half-gram weight was attached to the lower end of the capillary and the platinum heated electrically. As the glass softened, the attached weight drew it into a fiber of about two microns diameter. The fiber was mounted over a 2 mm wide slot in a glass slide and cemented in place with silver paint. Tantalum was evaporated from a water-cooled Cu crucible, by electron bombardment, onto the surface of the fiber while it was rotated about its axis on a "spit" in an ultrahigh vacuum evaporator. The tantalum was 99.7% pure. It was zone-refined before placing it in the evaporator to reduce the subsequent outgassing. During the evaporation the pressure was kept at approximately 6×10^{-9} mm Hg. In this way a cylindrical sample of tantalum was deposited onto a 2 mm long, 1.5×10^{-4} cm diameter fibre; the film was approximately 300Å thick.

Leads were attached with silver paint at each end of the fiber in order to measure the electrical resistance of the tantalum. The sample was then mounted at the center of a solenoid which produced a magnetic field along the axis of the cylinder. The whole assembly was suspended in a bath of liquid helium.

The transition to the superconducting state was broad beginning at 4.1°K and being complete at about 1.5°K. Over a small region of temperature between 2.4°K and 2.2°K the characteristic periodic variations of the resistance of the fiber due to the variation in T_c could be seen as the magnetic field (and consequently the flux through the cylinder) was varied sinusoidally. This is shown in Fig. 1. The distance between the minima of the parabola was found to be 12.1 gauss. The diameter of the fiber was determined in an optical microscope which has previously been calibrated with fibers whose diameters had been measured in an electron microscope. The diameter was 1.5 ± 0.1 microns which gives a value for the period of the field of 11.6 ± 1.0 gauss if the flux quantum is $hc/2e$. Thus, we have excellent agreement between the observed period and $hc/2e$, thereby showing through the factor $2e$ that the electrons are indeed correlated in pairs in this transition element superconductor.

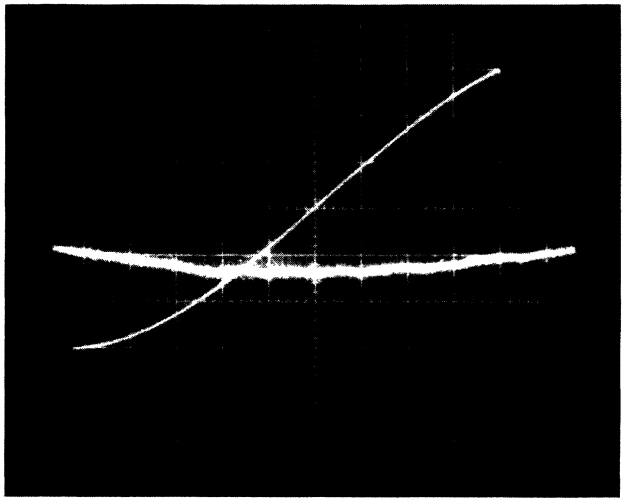

FIG. 1. Periodic variations of the resistance of a cylinder of tantalum at its superconducting transition temperatures as a function of the magnetic field. Upper curve: Magnetic field sweep.

It is interesting to observe that the parabolas only became visible when the resistance had dropped to approximately (1/10) of its normal value indicating that the superconducting regions enveloped the fiber and thus became multiconnected only below this point. It was also interesting to observe that when the parabolas first appear upon cooling down they are symmetric about their minima, but as the temperature is further reduced hysteresis is observed and finally, at still lower temperatures, the sample sticks in a particular state and leaves it only by a discontinuous jump.

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*Work supported in part by the National Science Foundation, Advanced Research Projects Agency, and the Office of Naval Research.

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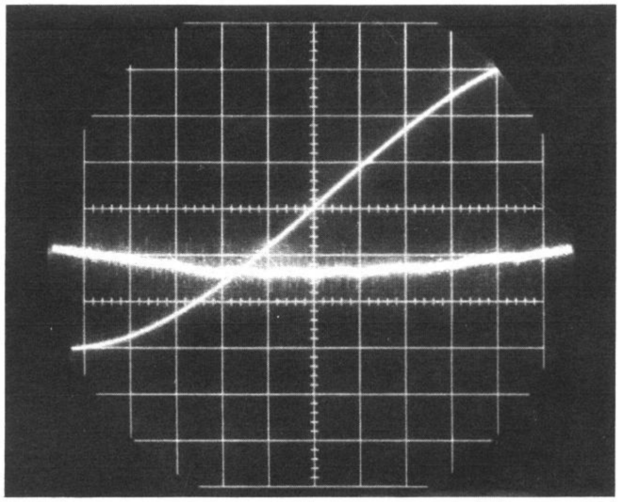

FIG. 1. Periodic variations of the resistance of a cylinder of tantalum at its superconducting transition temperatures as a function of the magnetic field. Upper curve: Magnetic field sweep.