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FABRICATION OF A NEW TYPE OF SUPERCONDUCTING JUNCTION

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Abstract. The phenomenon of Josephson tunneling is being used for the detection of low voltages at liquid helium temperature using different types of Josephson junctions such as the tunnel junction, the weak link or superconducting bridge and point contact. A new technique similar to the point contact type has been developed which is comparatively more consistent in its characteristics even after subjecting it to a number of theremalcycles between liquid helium and room temperatures.

In order to detect low voltages produced by specimens of very low resistance at liquid helium temperature, a device which employs the phenomena of Josephson tunneling[1,2] is very sensitive and when used as a null deterctor has a sensitivity of the order of 10^{-14}— with a time constant of 1 sec.

While tunnelling supercurrents through barriers may have been seen in the past.[3] The Josephson effect for DC was clearly observed and characterised by Anderson[4] and Rowell[5] and by a number of other investigators.[6–11] After indirect experimental support had been found for the A.C. effect,[21–16], the emitted radiation was discovered directly by Yanson *et. al.*,[17] in 1965 and by several other authors.[18–21] Josephson effects in superconductivity are discussed in detail by Petley.[22]

There are three basic types of Josephson junction: the tunnel junction, the weak likn or superconducting bridge and the point contact. We are concerned only with the point contact type.

The point contact type consists of two bulk superconductors separated by a thin oxide film, which is under an adjustable pressure. One of the two superconductors is sharpened to a fine point and is adjusted to be in mechanical contact with the plane surface of the second superconductor. The pressure allows the system characteristics to be varied from those of the tunnel junctions to those of superconducting bridges (Fig. 1).

There is another type of junction (Fig. 2) known as solder blob junction which is similar to the point contact junction.

It was first used by Clarke[23] and consists of a thin superconducting wire which is oxidized, on which is formed a drop of solder. Solder is a lead–tin alloy and is also a superconductor. A copper wire is embedded in the blob and this together with the ends of superconducting wire forms a four terminal device. Single, double or multiple junctions may be formed. The room temperature resistance is usually in the range of 0.5–1.0 ohms. This type of junction is of prime concern to this paper.

Fabrication of a New Type of Junction. The junctions made by the use of evaporated film techniques are somewhat difficult to prepare and tend to be destroyed by the mechanical strain involved in cooling them to liquid helium temperatures and warming to room temperature again, so that they cannot be used repeatedly. The Clarke type Josephson junctions can stand thermal cycling between ambient and liquid helium temperatures fewt imes, but the room temperature resistance usually changes after the junction is subjected to thermal cycling. The change in room temperature resistance affects the electrical characteristics of the junction. This seems to be due to the larger area of contact between the solder bead and the niobium superconductor. We have developed a new type of Josephson junction which is similar to Clarke type but can stand appreciable number of thermal cycles without being damaged. A short length of niobium wire of diameter 0.003 in was used as one supercondúctor. The niobium wire was exposed to the atmosphere for few days so that a very thin layer of oxide is formed on it. This wire was then passed through the middle of four or five loops formed by the single copper wire. Molten tin–lead solder to which excess flux had

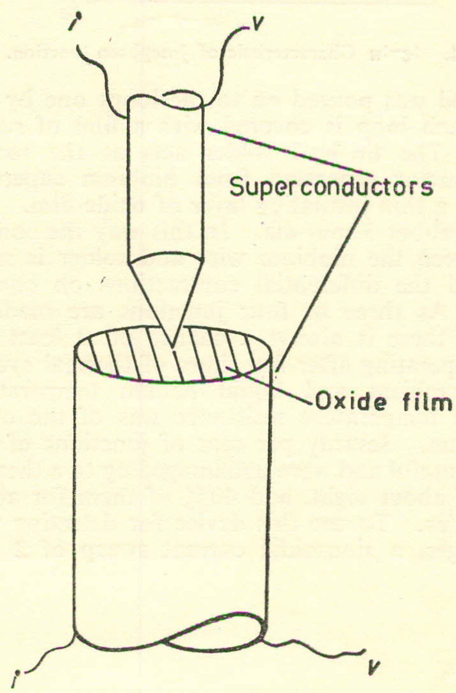

Fig. 1. Point contact type Josephson junction.

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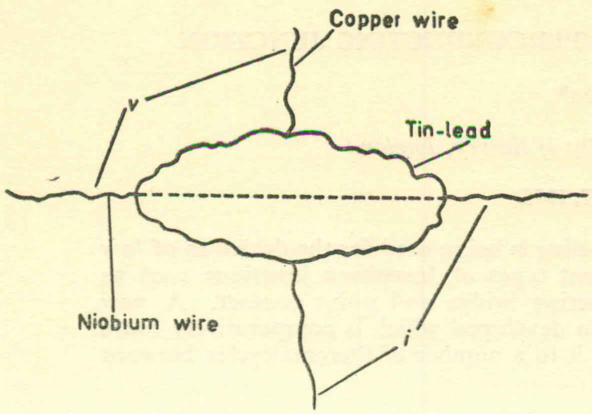

Fig. 2. Solder blob or Clark type of Josephson junction.

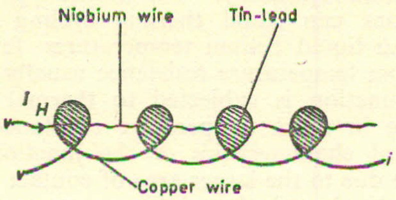

Fig. 3. Solder thin film Josephson junction.

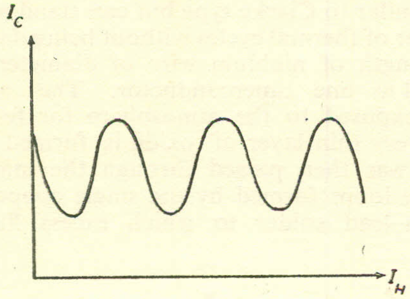

Fig. 4. I_c–I_H Characteristic of Josephson junction.

been added was poured on to the loops one by one so that each loop is covered with a film of solder (Fig. 3). The tin–lead solder acts as the second superconductor separated from niobium superconductor by a thin insulating layer of oxide film. The loops are about 3 mm dia. In this way the contact area between the niobium wire and solder is minimised and the differential contractions on cooling are less. As three or four junctions are made in one piece there is always a chance of at least one of them operating after few times of thermal cycling between ambient and liquid helium temperature. The room temperature resistance was of the order of 0.1 Ohm. Seventy per cent of junctions of this type were useful and were undamaged up to a thermal cycling of about eight, and 40% of them for about fifteen cycles. To use this device for detecting very low voltages, a sinusoidal current sweep of 2 kc/s was applied to the leads (I', Fig. 3), the amplitude of the sweep being always sufficient to drive the junctions on to the finite voltage region of their characteristic. The voltage developed across the junctions (V, Fig. 3) was fed into an electronic system which plots out the critical current directlyy (Fig. 4). The current I_H modulating the critical current was passed along the niobium wire. Using this system it was possible to detect a change of one microampere in the current I_H. If the circuit resistance is reduced to about10^{-8} Ohms then one can detect a voltage of 10^{-14} V with this device. Time constant being less than 1 sec.

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