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Observation of a New Phenomenon in Superconducting-Normal Junctions

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We have observed a new effect in superconducting - normal junctions. The junction consists of a crossing of two narrow thin films, with one in superconducting state, the other in normal state (Fig.1). Typical dimensions of the films are about 2mm in length, 30μ-200μ in width, and a few thousand angstroms in thickness. The experiments were mainly done at 4.2K for lead samples and at approximately 2K for tin samples. The effect is quite a stimulating one and seems to occur in any S-N type junctions. The basic characteristics of the junctions are listed below:

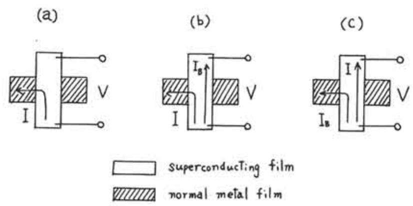

Fig.1

(1) When the current is given between superconducting and normal strips(Fig.1a), the voltage appears along the superconducting strip at the well-defined critical current (Fig.2, curve A). This critical current is usually of an order of 1mA or 10mA for our geometry, which is a much smaller value than that of the superconducting strip itself (for lead film at 4.2K, usually of order of 100mA). The effect occurs for all S-N junctions we have tested so far (Super film: Pb, Sn($T< T_c$), Normal film: Ni-Cr alloy, Cu, Sn($T> T_c$). It also occurs even for super-super junctions unless the junction is purely shorted. Note that there is almost no hysterisis for the curve of type A. The curve B in Fig.2, which is taken for same sample, exhibits usual quasi-particle tunneling behavior between superconducting and normal films.

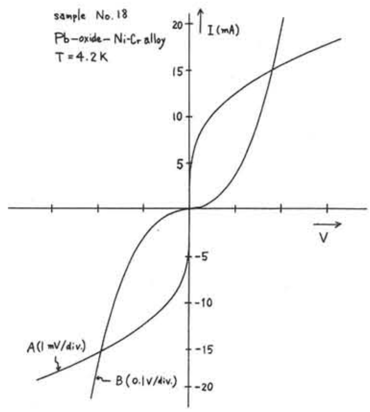

Fig.2

(2) The second characteristic is that the critical current of the superconducting strip is drastically reduced if another current I_B is given between superconducting and normal strips (Fig.1c). In Fig.3, we show such an example. When the bias current is increased to a few milliamperes, there appears the voltage along the superconducting strip, although its critical current is very high (order of a few hundred milliamperes). This means that it is possible to control the high critical current of the super-

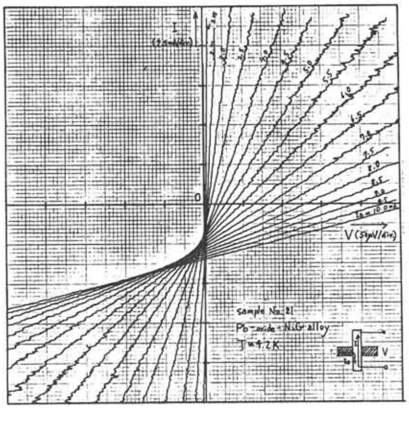

Fig.3

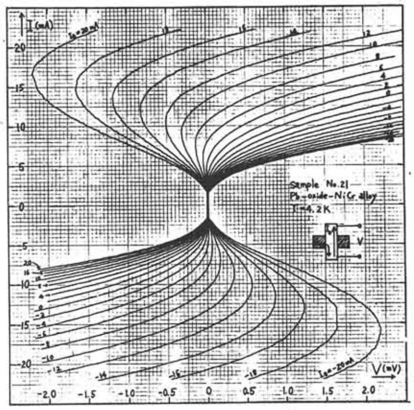

Fig.4

conducting strip by adding a small bias current.

(3) The third characteristic is that the current-voltage characteristics of curve A in Fig.2 is greatly modified by the influence of another current I_B passing through the superconducting strip (see Fig.1b). In Fig.4, we show one of these results. It is remarkable that there is a turning point in I - V characteristics for the bias current higher than a certain value.

In addition to the above features, we also obtained another different I - V characteristics, in which I corresponds to the current in the superconducting strip and V corresponds to the voltage between two strips. Temperature dependence of the critical current was also studied especially for tin samples. Since the effect seems to appear generally in any type of S-N crossings, we consider that the geometrical effect due to the asymmetric S-N boundary is primarily important. When the current flows from one strip to the other strip, the current should be bent greatly. Then the current distribution in the superconducting strip will be drastically changed near the S-N boundary in order to minimize the magnetic energy. The current concentrates near the super-normal edge , thereby producing very high current density enough to destroy superconductivity at that point. Once the local resistive state appears, it spreads out with the increase of the current until the whole cross section of a part of the film becomes resistive. This probably determines the critical current in (1). If we increase the current further, the resistive part develops along the superconducting film, yielding non-linear I-V characteristics. The detailed analysis is now going on.

Anyway, the mechanism of this effect consists in superconducting-normal transition. Therefore it may be possible to use this phenomenon as a swithing element or other devices. We expect the switching time will be much faster than the usual cryotron because the inductance of the junction is very low.