C-1-2   Properties of cross-shaped proximity effect weak link device.

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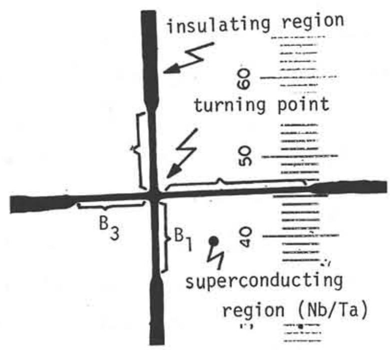
Josephson effect has been an object of study from the viewpoint of application to computer devices[1]. It has been theoretically shown that Josephson lines can be interconnected in certain direct ways so that complete logic capability can be achieved with networks of Josephson lines alone[2]. In design of the logic circuit Josephson line branching is especially important. It is expected that flux quanta propagating toward the turning point on one line of the branches will initiate flux quanta on only one connected line, and the determining which line the flux quanta propagate down depends upon the bias current of each line and the junction characteristics. This paper reports on the properties of the proximity effect weak link device[3] having a selective turning point with four bridge branches B_1, B_2, B_3, and B_4. A photomicrograph of the proximity effect weak link device used for experiments is shown in Fig.1. This device is fabricated in double layered film of 250 Å of Ta under 240 Å of Nb. The geometry of the superconducting, insulating, and weak regions are shaped with a previously reported photoresist and anodization techniques[4,5]. Potential and current leads are provided for each bridge branch of the device.

The maximum supercurrent of our device measured at 4.2 K is diffraction modulated by magnetic field, similar to the magnetic modulation of a conventional Josephson tunnel junction. This behaviour, in the weak-coupling limits, means that the current-phase relationship in our weak link is similar to the Josephson relation $J = J_c \sin\phi$,[3] and it is expected that the flux quanta propagate down passing through the bridge branches at finite voltages. The relation of $I_{c1} = I_{c2} < I_{c3} < I_{c4}$ are obtained, where I_{c1}, I_{c2}, I_{c3}, and I_{c4} are the critical currents of the branches B_1, B_2, B_3, and B_4, respectively. In our experiments a driving current I_d and a bias current I_b are applied to the device by using the current leads of the branches B_4 and B_1, respectively, in the presence of magnetic field applied perpendicular to the film surface. The bias current I_b is fixed at a value and the driving current I_d is swept. A small ac signal is added to the driving current only and the voltages across each branch are monitored with a lock-in amplifier. The critical values I_{dc}'s of current I_d at which the voltages appear and disappear across each bridge branch of the device are measured in the presence of magnetic field of 6 mG as a function of the bias current I_b and are shown in Fig.2. The cross line in a circle in this figure is the symbolic representation of our device and arrows on the lines denote the propagating directions of flux quanta on the bridge branches at finite voltage. The directions of positive I_d, I_b, and external magnetic field are illustrated in the inset of Fig.2. As is seen from this figure when I_d is increased at $I_b = 0$, the voltages appear first across the bridge branches B_1, B_2, and B_4 simultaneously and then across the branch B_3. In the case of $I_b \neq 0$, various flux quanta transmitting states can be obtained by changing I_b. The voltage having negative sign across B_1 or B_2 is observed with respect to the driving current I_d in the hatched regions of Fig.2. Differential resistances, dV/dI_d's, of each bridge branch at I_b= 6 μA are shown in Fig.3 as a function of I_d. As is seen from this figure , the voltages across the bridge branches of the device have the positive sign with respect to the current I_d except that the voltage across B_1 have the negative sign at the positive I_d ranging from 20 μA to 34 μA. The I_{dc}- I_b characteristics of this device applied magnetic field of -3.2 mG are similar to that of 6 mG for the positive sign voltages. However the region observed the negative sign voltage across B_1 is shifted to the region of I_d< 0. This result is explained by the propagation of the flux quanta with a sign which is the same as that of the applied magnetic field in the bridge branches. The behaviour of this device implies that we can select the bridge branches on which the flux quanta propagate by applying suitably the bias current, the driving current, and the external magnetic field. It may be mentioned that the Josephson devices having a turning point with branches as our device have potential as the microwave and computer[6] elements.

(References)

1) H.H.Zappe; IEEE Trans. Magnetics. MAG-13, 41 (1977)
2) K.Nakajima, Y.Ogawa, and Y.Onodera; J. Appl. Phys. 47, 1620 (1976)
3) J.E.Mercereau; Proc. Inter. Conf. on Superconducting Quantum Devices, ed. by H.D.Hahlbohm, H.Lubbig (Walter de Gruyter, Berlin, New York. 1977) p.101.
4) D.W.Palmer and S.K.Decker; Rev. Sci. Instrum. 44, 1621 (1973)
5) T.Kobayashi and Y.Onodera; Oyo Butsuri. 45, 777 (1976)
6) K.Nakajima, Y.Ogawa, and Y.Onodera; Denshi Tsushin Gakkaishi(D), 60D, 232 (1977)



1 μm/div.

Figure 1

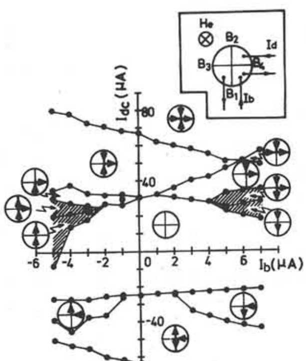


Figure 2

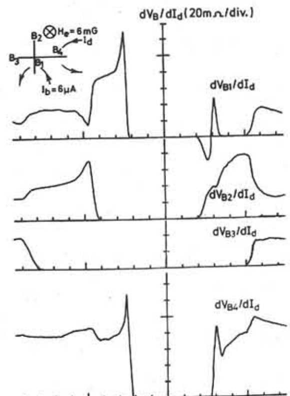


Figure 3