Digest of Tech. Papers The 13th Conf. on Solid State Devices. Tokyo

B-3-6 Quasiparticle-Injected Superconducting Weak Link Device

Shigeki SAKAI and Hiroshi TATENO

Electrotechnical Laboratory

Umezono, Sakura-mura, Niihari-gun, Ibaraki 305, Japan

This study concerns a new triode type device named "Quasiparticle-Injected Superconducting Weak Link Device", having a current gain much larger than conventional Josephson switching devices. In a Josephson switching device, a large current gain is very important as well as a high switching speed and a low dissipation power. The switching devices so far reported[1-3] show a current gain of at most 2 and additionally they require more than two Josephson elements, which is disadvantageous in fabricating an integrated circuit. However, our new device shows a current gain more than 40 by connecting a third electrode to the weak link part of the weak link type Josephson device to control I-V relation by the injection of quasiparticles from the third electrode, and this device requires only one Josephson element.

The following is an experimental result of a typical example of our device. In this experiment, as in Fig.1, a heavily-doped semiconductor Si was used as the third electrode; a constriction type microbridge as the Josephson weak link part; and Nb as the superconductor because of its high superconducting transition temperature and less degradation against heat cycle. Through the Nb/Si super-Schottky contact, quasiparticles were injected to the weak link part. The fabrication process is as follows. The surface of a phosphorus-doped Si wafer with a resistivity between 0.001 to 0.002 Ωcm was thermally oxidized in dry oxygen atmosphere to form SiO_2 layer of 1500Å thickness. On the layer a window of 3.75x3.75 μm^2 dimensions was opened by using conventional photolithographic technique and chemical etching. The photoresist pattern of the microbridge was formed by the same technique. Nb was deposited on the surface at a pressure of 3.4×10^{-8} Torr to form a film of 500Å thickness by the electron beam evaporation method, and subsequently, Au was evaporated by the resistance heating to form a film of 200Å thickness for the passivation of the Nb film surface. The Nb microbridge was formed by the standard lift-off method. The demension of the bridge of the example was 1.0 μm long and 1.6 μm wide.

The result of the measurement is as follows. The superconducting transition temperature was 8.6K. The static characteristic at 7.5K was as in Fig.2. Figure 2(a) shows the characteristic in the case the injection current I_j from the third electrode to the weak link part is plus, and Fig.2(b) in the case,minus. The dependence of the threshold current I_t between zero voltage state and voltage state upon the injection current I_j at the same temperature was as in Fig.3(a). The I_t vs I_j relation in the second and third quadrants proves a very large current gain, G_I=41. Here the current gain is $G_I = |I_t^m/I_j^m|$, where I_t^m is the value of I_t at I_j=0 and I_j^m is the value of I_j at I_t=0. At 7.5K, as shown in Fig.2, the variation of I-V curves between zero voltage state and voltage state was smooth. However, at a lower temperature, when $|I_j|$ was small, the variation was not smooth but abrupt (sometimes with hysterisis). Figure 3(b) shows the I_t vs I_j relation at 5.3K, where the part of abrupt variation is marked with ■ and that of smooth variation, marked with ● . From Fig.3(b), it is found that in the latter the effect of the injection of quasiparticles is much larger than in the former. These switching mechanisms are considered to much depend upon the relation between the coherence length $\xi(T)$ and the size of the microbridge,[4] although it still requires to be investigated in detail, e.g. as for the I-V relation in the presense of microwave irradiation.

From the above, the superiority of the new device in the current gain is clear. In addition, Chi et al[5] theoretically show that the switching speed ultimately becomes very fast in the case of Nb. Therefore, we believe, this device will be applicable to a logic integrated curcuit, a low noise amplifier and others.

Acknowledgment: We would like to thank S.Kataoka and T. Tsurushima for constant encouragement, and Y.Hayashi for his help in Si thermal oxidization process.

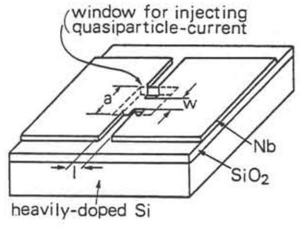

Fig.1 Schematic drawing of Quasiparticle-Injected Weak Link Device. a= 3.75μm l= 1.0μm, w= 1.6μm

References

1. H.H.Zappe, Appl. Phys. Lett., 27(1975) 432.
2. T.R.Gheewala, Appl. Phys. Lett., 33(1978) 781.
3. S.Takada, S.Kosaka and H.Hayakawa, Japan. J. Appl. Phys., Supplement 19-1(1980) 607.
4. K.K.Likharev, Rev. Mod. Phys., 51(1979) 101.
5. C.C.Chi, M.M.T.Loy, D.C.Cronemeyer and M.L.Thewalt, IEEE Trans., MAG-17(1981) 88.

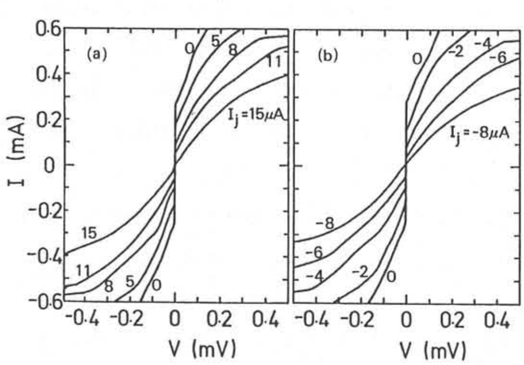

Fig.2 Static characteristics of the new device at 7.5K. (a) $I_j \geq 0$ (b) $I_j \leq 0$

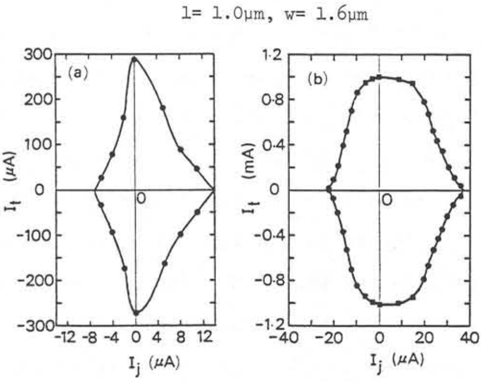

Fig.3 I_t vs. I_j relation (a) at 7.5K and (b) at 5.3K.