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Characteristics of All-Nb Thin Film Microbridges by Nanometer Fabrication

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We have fabricated the all-Nb thin film microbridges by our developed nanometer process. These microbridges have high sensitivity of radiation and reliability. It is observed that the properties of devices change by varying the sizes of bridge-region. We have also fabricated the series arrays and observed that they operate coherently.

§1. Introduction

From the beginning of the discovery of Josephson effect, Josephson weak links have been investigated because the structure of devices is quite simple compared to tunnel junctions and it is easy to fabricate.[1] However the performance of weak links largely depends on the structure of the bridge-region (bridge length L, width W, and its thickness t as shown in Fig. 1). Especially, the bridge length is restricted within several times of the coherence length (38 nm for Nb). Hence it is necessary that sizes of bridge-region are within 100 nm. This is because it is difficult to fabricate all-Nb thin film microbridges. For this reason, a lot of typical techniques (step-edge junction etc.) are used.[2]

We have recently developed the fabrication technique by the accuracy of nanometer, and succeeded to fabricate all-Nb thin film microbridges. In the following sections, we have shown the fabrication of the all-Nb thin film microbridges. Fabricated devices have properties determined by the sizes of bridge-region. Hence if these microbridges can be fabricated as the same sizes of bridge-region, they are suitable for an integrated circuit. We have also shown the series array of two microbridges for the first step attempt of integration.

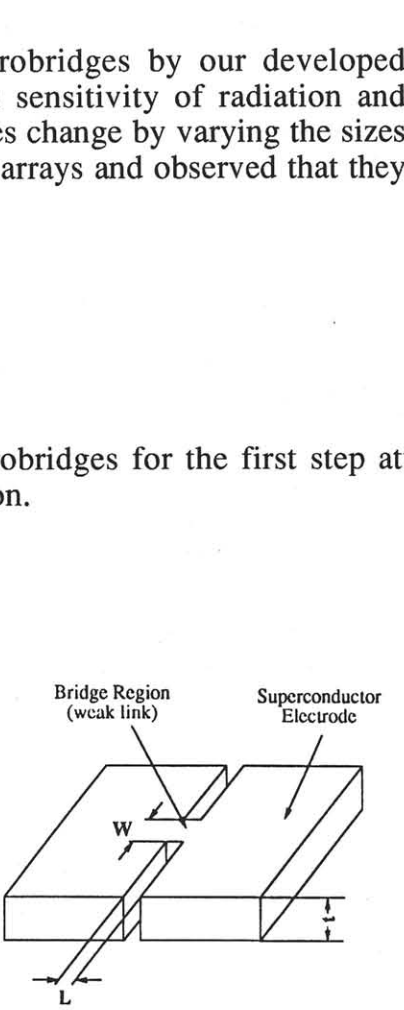

Fig.1. Structure of a thin film microbridge.

§2. Fabrication Process

We have investigated each process in detail in order to fabricate device by the size of several ten nanometer and improved on the following points: (a) use of our produced electron-beam (EB) resist which has the strong resistance against plasma damages,[3] (b) use of $CBrF_3$ for the reactive ion etching (RIE), and

(c) the improvement of crystallization of Nb thin films. Decreasing the thickness of resist, the line width become narrow because of decrease of back scattering. CF_4 is usually used for the etching of Nb, but it is possible to get high anisotropic etching and give less damage by using $CBrF_3$ in stead of CF_4. By improvement of DC magnetron sputtering apparatus, even the Nb thin films of 40 nm thickness are oriented polycrystal and have the critical temperature of bulk (9.2 K). Figure 2 shows the SEM view of trench in Nb thin film by using $CBrF_3$ reactive ion etching.

The fabrication process is the following way: Nb thin film is deposited on cleaned Si substrate by DC magnetron sputtering. Light resist OFPR is coated on Nb film and the electrode figure is patterned by using light lithography. After development, the electrode is etched by RIE. Next our produced new EB resist is coated on Nb electrode and bridge-region is patterned by EB lithography (JEOL JBX-5D). By using RIE again, bridge-region is etched and the device is accomplished after lift-off.

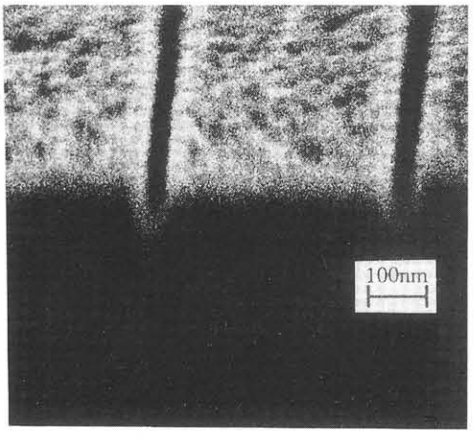

Fig. 2. SEM view of trench in Nb thin film

§3. Properties of Devices

Figure 3 shows the SEM view of a fabricated microbridge. The bridge width and length are 50 and 40 nm, respectively. These devices have a high sensitivity of radiation compared to ordinary planar-type junctions. Under irradiation of 70 GHz millimeter wave, we have observed up to the 11th Shapiro step as shown in Fig. 4.

It is observed that the properties of the fabricated microbridges are changed by varying the bridge-region parameters (W, L, and t). Especially,when the thickness of Nb electrode is thin (40 nm), the behavior of this device is similar to that of point contact.[4] This is because the sizes of bridge-region are compared to the coherence length.

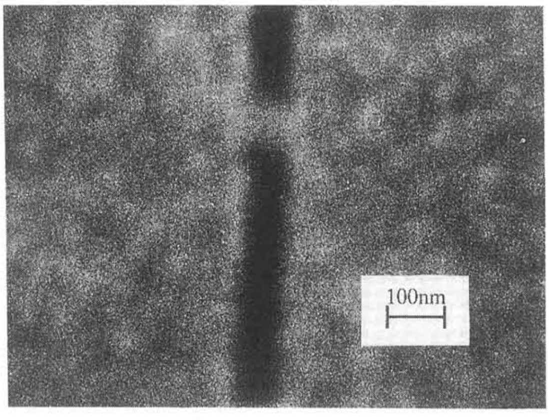

Fig. 3. SEM view of the all-Nb thin film microbridge.

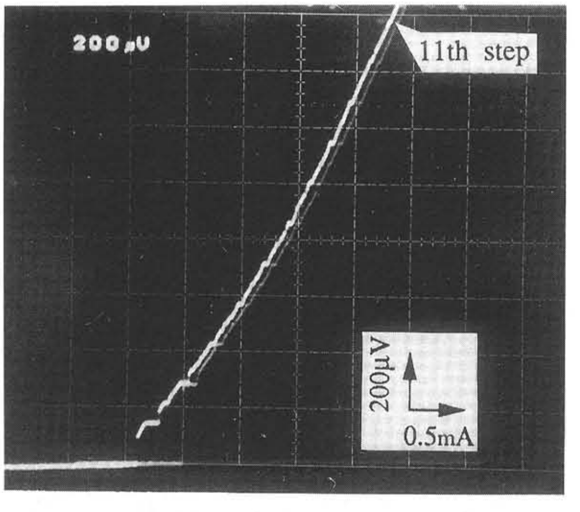

Fig. 4. I-V characteristics of the all-Nb microbridge under irradiation of 70 GHz wave.

In the devices which are designed as the same sizes of bridge-region the deviations from the mean of these normal resistances is within 15 %. Therefore we have fabricated the series array of two microbridges as shown in Fig. 5. The I-V characteristics of array under irradiation of 70 GHz millimeter wave as shown in Fig. 6. The voltage between steps corresponds to 140 GHz. This indicates that this array operates coherently. The low normal resistance of microbridges is most striking problem to use as the detector of sub-millimeter wave. If the array which are composed of many microbridges as shown in Fig. 6 operates coherently, it can use the good detector of sub-millimeter wave instead of the point contact devices.

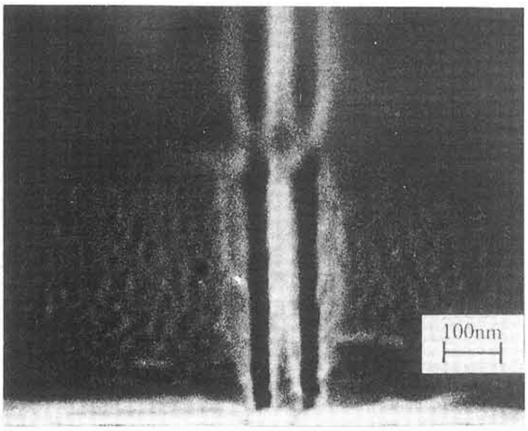

Fig. 5. SEM view of the series array of microbridges.

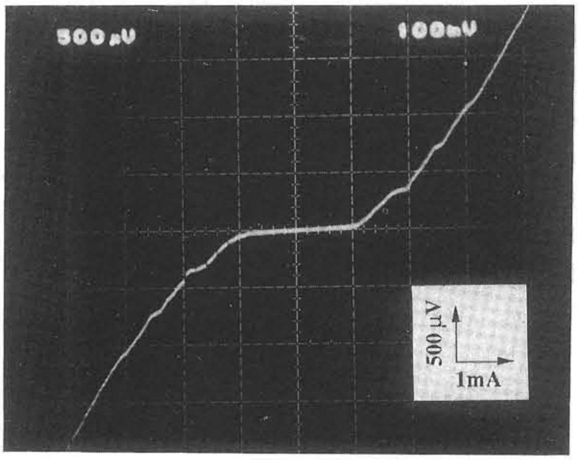

Fig. 6. I-V characteristics of array under irradiation of 70 GHz millimeter wave.

§5. Conclusion

We have fabricated the all-Nb thin film microbridges by using our developed nanometer process. These devices have high sensitivity for radiation and the 11th Shapiro step have been observed. For the first step of integrated arrays, we have fabricated the series arrays and observed the coherent operation.

References

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