Repeatability and Reliability of the 640 GHz Mixer for JEM/SMILES

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Abstract. We are developing 640 GHz SIS mixer for JEM/SMILES mission. For use in a space experiment, establishing a way to fabricate a reliable SIS mixer is critical. We summarize recent investigations to understand and improve the controllability of SIS device parameters in our process.

1. Introduction

The development of SIS mixers at 640 GHz band is a key issue of JEM/SMILES mission [1], which is an atmospheric observatory to be onboard the International Space Station. Through an early development phase, a good receiver noise performance less than 200 K (DSB) has been achieved with Nb-based Parallel-connected Twin-junction (PCTJ) SIS mixer as a breadboard model [2]. For use in a space experiment, not only a good noise performance, but also to establish a way to fabricate a reliable SIS mixer is critical. This paper summarizes a recent investigation to understand and improve the controllability of SIS device parameters in our process. We also briefly report the result of environmental tests, such as ion irradiation, to confirm the compatibility with the space environment.

2. SIS Device Fabrication

Our Nb/Al-AlOx/Nb junctions are being fabricated at the Nobeyama Radio Observatory. Typical junction area is $1\times1\mu m^2$, and current density of $6-8$ kA cm^{-2}. Considering the space application, we adopted the PCTH-type device to achieve a brad RF impedance matching without troublesome mechanical tuning (Fig. 1)

Fig. 2 shows an example of cross-sectional image of junction portion observed using TEM. Since parameters such as the thickness of layers and the superconductivity of Nb films are directly related to the mixer performance, we should realize their characteristics and improve the controllability in our fabrication process. After several improvements, we

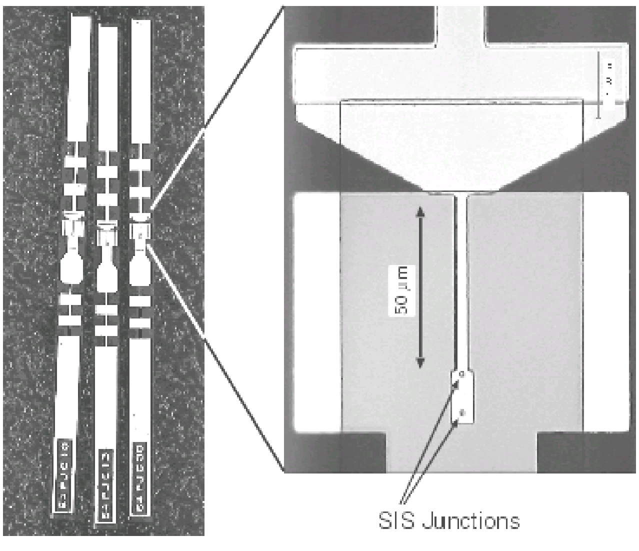

Figure 1: 640-GHz SIS device for JEM/SMILES.

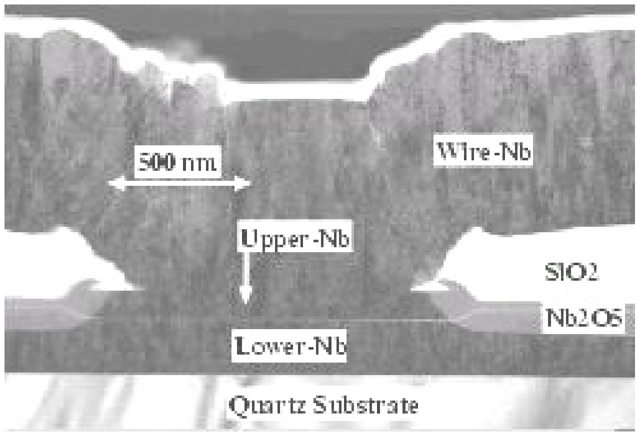

Figure 2: Cross-sectional image of SIS junction

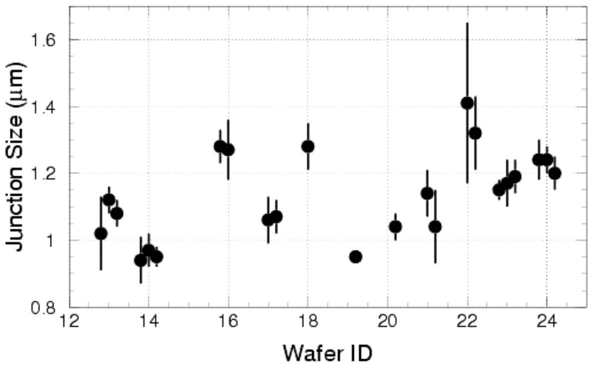

Figure 3: Mean junction size with 1-σ deviation in a wafer

attained moderately stable fabrication, and succeeded in increasing the yield of good junctions.

One of difficulties in fabrication is to control the junction size. As shown in Fig. 3, the deviation in size is sometimes up to 10 % even in the same wafer, which corresponding to a $\approx 3\%$ shift in center frequency. Although some problems still remains to be solved, we obtained the SIS devices which show an excellent receiver noise performance with ≈ 150 K.

3. Environmental Tests

The space environment is hostile to operating a sensitive measurement system in many ways. We carried out various tests with SIS mixers to confirm their compatibility with the space environments. Following describes some topics:

Cosmic Ray Particles: We performed a proton irradiation test with cooling the SIS device below 4 K. Although some changes in DC characteristics were observed after extremely high fluence irradiation (Fig. 4), we confirmed the tolerance of SIS device against the cosmic ray was far higher than the total dose expected in the orbit.

Thermal Cycles: The SIS mixer is expected to experience some thermal -30 to $+60$ C cycles in orbit during power-off period of mechanical cooler system. Moreover, baking of cryostat system is scheduled to reduce outgas before launch. In our test, an increase of normal resistance by ≈ 10 % (corresponding to $\approx 1\Omega$) was observed after one week of 80 C load. It is probably due to the increase of tunnel barrier potential by the reacting of unbound oxygen with Al atoms.

Launch Vibrations: The vibration load 4 K stage of cryostat is estimated to about 40 G_{RMS} for our launcher. We have performed a vibration test on the SIS mixer with the same level. As the result, no change in DC and RF performance was

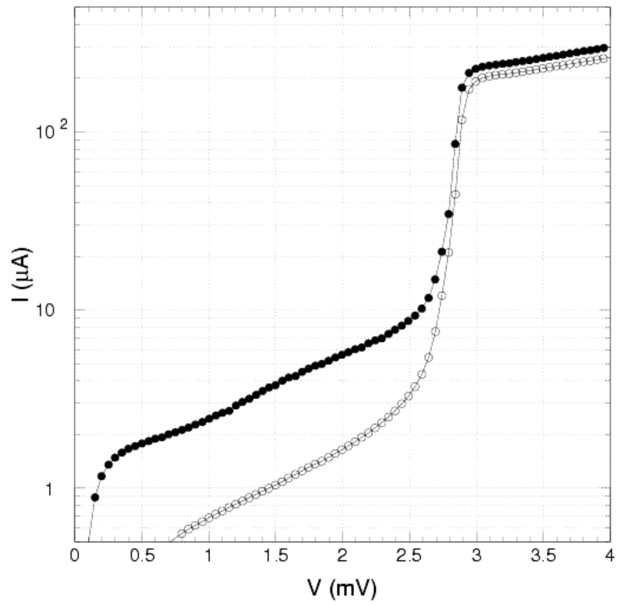

Figure 4: An example of I-V curve before (open circles) and after 3.2×10^{16} protons cm^{-2} irradiation (filled circles) at 1.9 K.

found.

References

[1] SMILES science team and SMILES mission team, "JEM/SMILES Mission Plan (version 2.1)," 2002 (available at http://smiles.tksc.nasda.go.jp/index.shtml)

[2] Y. Fujii, K. Kikuchi, J. Inatani, Y. Irimajiri, M. Seta, S. Ochiai, T. Manabe, H. Masuko, T. Noguchi, K. Narasaki, S. Tsunematsu, and T. Shirota, "Space-borne 640-GHz SIS Receiver Based on 4-K Mechanical Cooler," SPIE, 4013, 90, 2000.