# Development of Terahertz SIS Mixers Using Nb/AlN/Nb Tunnel Junctions Integrated with All NbTiN Tuning Circuits

Y. Uzawa[1, 2*], M. Kroug[2], T. Kojima[2], K. Makise[1], A. Gonzalez[2], S. Saito[1], Y. Fujii[2], K. Kaneko[2], H. Terai[1], and Z. Wang[1]

[1]*National Institute of Information and Communications Technology, Koganei, Tokyo,184-9795, Japan*
[2]*National Astronomical Observatory of Japan, Mitaka, Tokyo, 181-8588, Japan*
* Contact: uzawa@nict.go.jp

***Abstract***—We are developing ultra-sensitive superconductor-insulator-superconductor (SIS) mixers at terahertz frequencies such as the Atacama Large Millimeter/submillimeter Array (ALMA) Band 10 (0.787-0.95 THz). Current SIS mixers for the Band 10 receivers employ high-quality Nb/AlOx/Nb tunnel junctions and low-loss Al/SiO2/NbTiN tuning circuits and have shown excellent noise performance compliant with the stringent ALMA requirements of less than 5 hf/k for all of our mass-produced 73 receivers. To further improve the noise performance, our approach is to replace the normal metal Al wiring in the tuning circuit with the superconducting material NbTiN. We have so far investigated the superconducting properties of NbTiN films deposited on sputtered SiO2 layers to make all NbTiN microstrip transmission lines (i.e. NbTiN/SiO2/NbTiN structure) at terahertz frequencies and confirmed that the properties of NbTiN films on SiO2 are as good as those of NbTiN films directly sputtered on quartz substrates, showing a critical temperature of 14 K and a gap frequency of 1.2 THz. However, it is known that I-V characteristics of Nb SIS junctions embedded in all NbTiN circuits are degraded because of quasi-particle trapping in the Nb electrodes of the junctions due to the superconducting gap difference between Nb and NbTiN. This brings about an effective temperature increase in the junctions and thus results in a reduction of the gap voltage. To solve this issue, it would be effective to increase the volume of the Nb electrodes. We have fabricated Nb/AlN/Nb tunnel junctions with relatively thin (~ 50 nm) and thick (~ 200 nm) counter electrodes contacting the NbTiN wirings and compared their I-V curves. We observe that the gap voltage reduction is smaller for the junctions with the thick Nb counter electrode, hence the heating effect is lessened. This indicates that SIS mixers employing Nb junctions with thick electrodes and embedded in an all NbTiN tuning circuits may work well at terahertz frequencies.

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