Fabrication of HEB Mixers Using Substrate Heating in Combination with the AlN Buffer Layers

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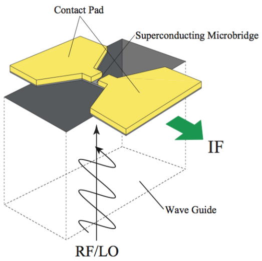
Abstract

Our group has been developing the waveguide-type HEB mixers for astronomical observations in the THz region. We have achieved the noise temperature of 490 K at 1.5 THz by using the 10.8 nm NbTiN film, which is the lowest noise temperature at this frequency. To conduct scientific observations with the HEB mixers, it is important to extend the intermediate frequency range. For this purpose, it is required to improve the quality of the superconducting films so as to make deposition of thinner superconducting films possible. In this study, we have adopted substrate heating. We have investigated the property of superconductivity of the films deposited on glass wafers with and without substrate heating. An additional effect of the AlN buffer layers has been also investigated. Then, the best quality film is found to be produced, when both the substrate heating and the AlN buffer layer are used. The NbTiN film of 3 nm thickness deposited on a glass wafer shows the superconducting critical temperature higher than 10 K. Then, we have fabricated HEB mixers with this film, and have measured the noise temperature by the Y-factor method. The noise temperature of the mixer of 3 nm thickness is as good as that of 10.8 nm thickness which we fabricated without substrate heating. We have also investigated the gain bandwidth. Output signal from two oscillators are fed into the mixer, and the intensity of the beat signal is measured. The gain bandwidth is found to be extended from 1.2 GHz to 2.1 GHz by use of the 3 nm film.

1. Introduction

■ Background

We are developing superconducting hot electron bolometer(HEB) mixers for astronomical observations in the THz region Our HEB mixer uses the NbTiN film as a superconducting material, and employs the waveguide-type coupling. We recently achieved the uncorrected receiver noise temperature of 490 K at 1.5 THz by using a relatively thick NbTiN film (10.8 nm).

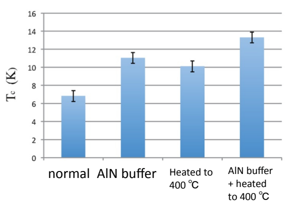


In order to reduce the receiver noise temperature and to extend the IF frequency range, we need a thinner film with high quality.

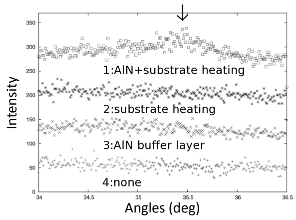
■ Purpose of this study

- Introduction of the substrate heating system for the NbTiN film deposition on the SiO_2 substrate.
- Evaluation of the HEB mixer using the 3 nm thick NbTiN film.

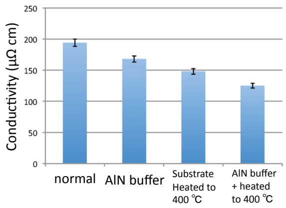
2. Improvement of the superconducting film using substrate heating



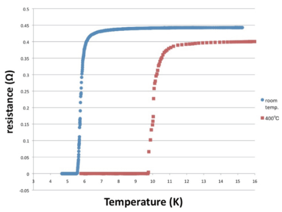
Superconducting critical temperatures of the 6 nm NbTiN films



X ray diffraction measurements of the 8 nm NbTiN films. A weak diffraction can be seen for the case using both of AlN buffer layer and substrate heating.



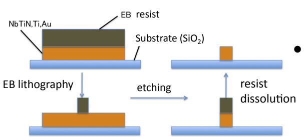
Electric conductivity of the 6 nm NbTiN films



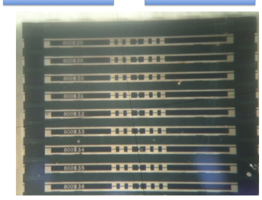
R-T curve of 6 nm NbTiN films.

- The best quality film is obtained when both of the AlN buffer layer and the substrate heating are used.

3. Fabrication of HEB mixers using substrate heating

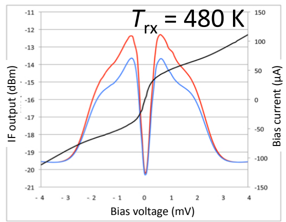


- Making HEB patterns by etching processes instead of lift-off processes in order to use an organic resist material.

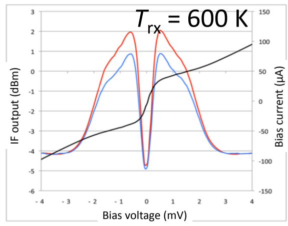


- 3 nm thickness of NbTiN film with the 20 nm AlN buffer layer is deposited on SiO_2 at 400℃
- Left: HEB mixers fabricated by this process

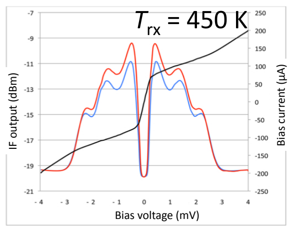
4. Noise performance of the mixers



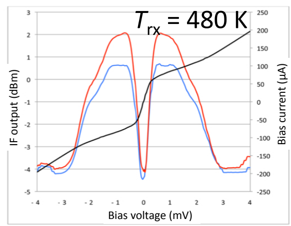
3 nm film with the substrate heating.
IF is 1.1 GHz



3 nm film with the substrate heating.
IF is 2.1 GHz



10.8 nm film without substrate heating.
IF is 1.1 GHz



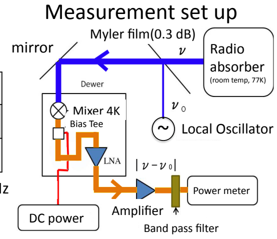
10.8 nm film without substrate heating.
IF is 2.1 GHz

- Noise temperatures by the Y-factor method (@ 0.8 THz)

Band	3 nm(heated)	10.8 nm(not-heated)
1.1 GHz	480 K	450 K
2.1 GHz	600 K	480 K

1.1 GHz band : 1.0-1.2 GHz、2.1 GHz band : 1.8-2.4 GHz

Measurement set up

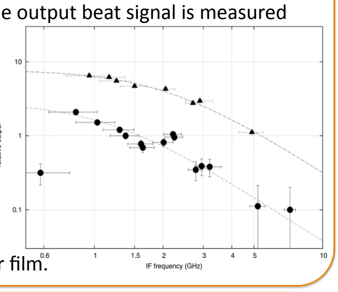


5. Gain Bandwidth measurements

- Outputs from two oscillators with slightly different frequencies are fed into the mixer, and the intensity of the output beat signal is measured as the function of the difference of the two frequencies.

Bandwidth

Thickness of films	Gain bandwidth
3 nm(heated)	2.1 GHz
10.8 nm(not-heated)	1.2 GHz



- Gain bandwidth extends for a thinner film.

6. Conclusion

- We have confirmed that the substrate heating is effective in fabricating high quality NbTiN films. The films are extremely improved when both of the substrate heating and the AlN buffer layers are used.
- We have succeeded in fabricating HEB mixers using the substrate heating with the modified process. The thickness of superconducting film of the mixer is 3 nm.
- Although the thickness of the superconducting film gets thinner than 1/3 of that of previous mixers, the noise temperature is not risen significantly.
- On the other hand, the gain bandwidth gets broader due to the film thinned to thickness of 3 nm, it is broaden by a factor of 2 than that of our previous mixers (10.8 nm).