Superconducting NbN Hot Electron Bolometer with an Nb_5N_6 Buffer Layer

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***Abstract*—In this paper, the superconducting NbN hot electron bolometer terahertz detector with an Nb_5N_6 buffer layer was fabricated on the Si substrate. The Nb_5N_6 buffer layer can significantly improve the superconductivity of ultra-thin NbN films. Preliminary results show that with a 30-nm-thick buffer, the zero resistance superconducting transition temperature of a 6-nm-thick NbN film device is 12.6 K, and the superconducting critical current of the device is increased by four times. The noise temperature, IF bandwidth and direct detection sensitivity of the device will be further characterized in following experiments.**

I. Introduction

DURING the last decade the hot electron bolometer (HEB) was established as the device of choice for terahertz (THz) detection [1-4]. In this paper, we describe the fabrication process and show preliminary results from Nb_5N_6-buffered NbN bolometer. Our previous work [5] has proved that Nb_5N_6 buffer layers can improve the superconducting properties of NbN films on Si substrates by strain optimization. Nb_5N_6 buffer layer does not exhibit superconductivity above 2 K. Fig. 1(a) shows that the resistance of Nb_5N_6 film at 4.2 K is more than 1 MΩ. The zero resistance superconducting transition temperature of 6-nm-thick NbN with a 30-nm-thick buffer is 12.6 K as shown in Fig. 1(b). And this may increase the device's operating temperature, signal to noise ratio and IF bandwidth. The Nb_5N_6 buffer layer is about 30-nm thick and nearly transparent to THz at low temperature, which would not affect the coupling of the signal.

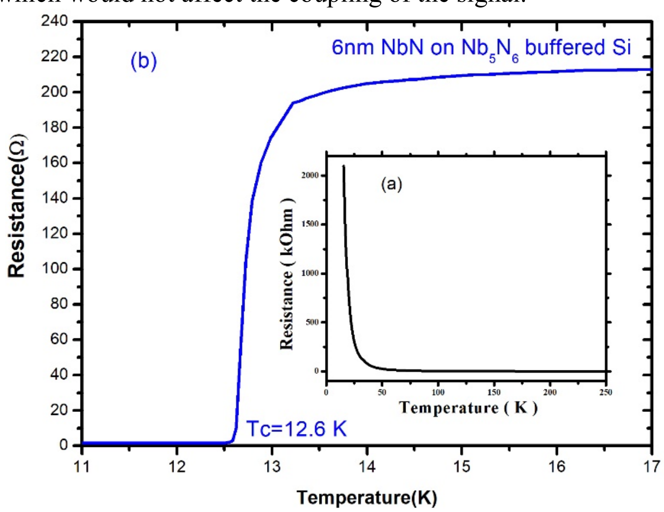

Fig. 1. (a) Resistance–temperature curve of the HEB; (b) Resistance of Nb_5N_6 film versus temperature.

II. Methods

The fabrication process of Nb_5N_6-buffered NbN bolometer is shown in Fig. 2, which was fabricated on a 350 μm thick high resistivity silicon substrate. The Nb_5N_6 film was firstly deposited using RF magnetron sputtering. With a niobium target, 4 inches in diameter and a purity of 99.999%, the deposition took place in a mixture of Ar and N_2 gases at the total pressure of 12 mTorr. The optimal condition for the introduction of N_2 and Ar were 3:1. The RF power was kept at 400 W and the deposition rate of Nb_5N_6 film was about 0.33 nm s^{-1}. Then the 6-nm-thick NbN ultrathin film was deposited *in situ* by DC magnetron sputtering, N_2 and Ar were mixed with a ratio of 1:8 and the constant current was 1.8 A. The deposition rate was about 1.2 nm s^{-1}. The length of the bolometer bridge equals the spacing between the two Ti/Au spiral antenna pattern formed by electron-beam lithography (EBL) and a subsequent lift-off process. The final lithography defines the width of the bolometer bridge by means of EBL and reactive ion etching (RIE). An etching in CF_4/Ar gas mixture was used to transfer the stripe pattern, and the etching process is 60 s at a power of 50 W. Fig. 3 shows a photograph of the HEB device using a scanning electron microscope (SEM).

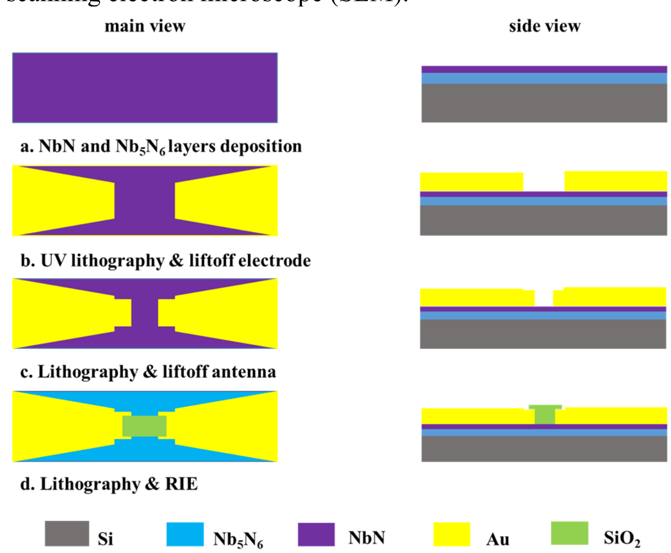

Fig. 2. Flow chart of fabrication of Nb_5N_6-buffered NbN bolometer.

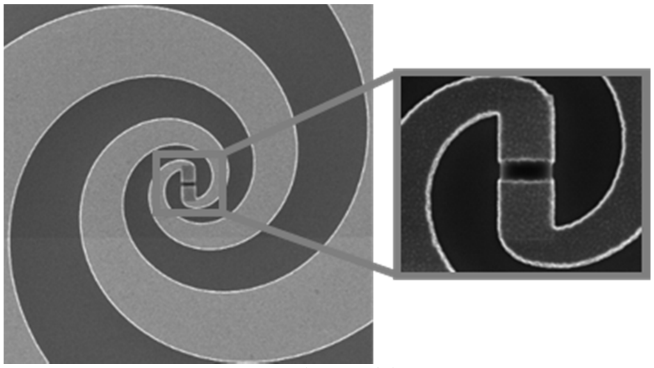

Fig. 3. SEM image of the HEB.

III. Results

We fabricated HEB devices with and without buffer layers respectively. The size of bolometer bridges are both 0.2 × 0.6 μm. A representative current-voltage characteristic curve for these HEB chips is given in Fig. 4. The superconducting critical current of Nb_5N_6-buffered HEB is 340 μA, and it's about 4 times higher than ordinary NbN devices. Normal state (300 K) resistance of Nb_5N_6-buffered device is about 110 Ω and the contact resistance is about 3.5 Ω.

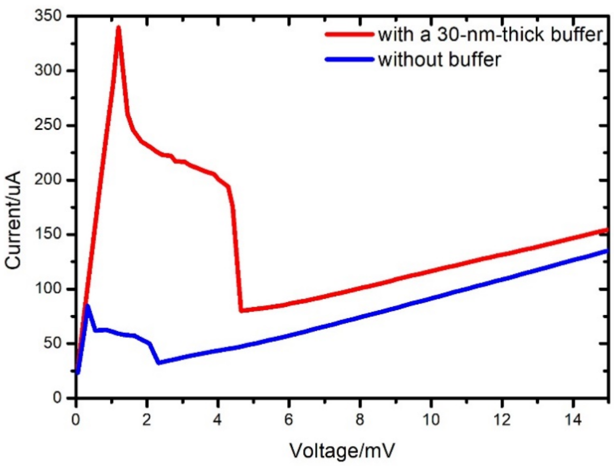

Fig. 4. Current-voltage curves of the HEB devices with and without buffer layers measured at 4.2K.

We have successfully fabricated superconducting NbN hot electron bolometer with an Nb_5N_6 buffer layer. Investigation of the heterodyne and direct detection sensitivity will be proceeding in following experiments.

References

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