Polyimide Buffer Layer for STJ Photon Detector

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Abstract. We have proposed and been developing ultra low noise photon detector using superconducting tunnel junctions (STJs). The STJs are fabricated on polyimide (PI) layer which is prepared on sapphire substrate. The PI is coated on the substrate before making the STJ. It acts as buffer layer to suppress a great deal of phonon events which come from the substrate. For low energy application such as soft X-ray and extreme ultraviolet, the STJs with PI buffer layer is a very attractive detector because the spectrum of low energy photons can be measured clearly without noise that depends on phonon events in the substrate. We fabricated the STJs with PI buffer layer which are different thickness and measured X-ray spectrum of 5.9 keV. We found that polyimide of 100 nm thickness is enough to suppress phonon events in low energy range.

1. Introduction

Superconducting tunnel junctions (STJs) have great potential as photon detector. A theoretical energy resolution of 4 eV is expected to realize using Nb-based STJ. The energy resolution of STJ is about 10 times higher compared to conventional semiconductor photon detectors. It can cover a wide energy range from X-ray to visible light. Therefore, various applications such as X-ray and optics for astronomy, X-ray microscopy are considered [1, 2, 3]. The detection of low energy photon using the STJ is very difficult due to noise of phonon events which come from the substrate [4]. In order to reduce the phonon events, Al₂O₃ films were employed as buffer layer [5]. This method was very effective to reduce phonon events. However, the phonon events did not disappear.

We have attempted recently polyimide (PI) as buffer layer to prevent the phonon events. The PI is known as excellent material which has low dielectric constant and high break down voltage. Moreover it has very low acoustic impedance comparing with conventional buffer materials such as MgO and Al₂O₃. The STJ on PI buffer layer showed sufficiently suppressing of phonon events.

In this paper, we report characteristics of STJ for varying the thickness of polyimide layer. An X-ray irradiation is presented for these STJs.

2. STJ on PI buffer layer

Polyimide polymer was recently developed [6]. It is photosensitive and does not need curing at temperatures higher than 150 °C. It can be used as good insulator and can easily make a contact.
hole using photolithography process like photoresist. We employed the new polyimide as a buffer layer for STJ detectors. The PI films are easily coated using spin coater. The PI thickness is controlled with rotation speed of spin coater. The base PI liquid has the concentration of 18 wt%. To achieve 60, 100 and 300 nm thickness of the PI, the PI was diluted by N-methyl-2-pyrrolidone (NMP). Figure 1 shows relationship between PI film thickness and rotation speed. As is seen in Fig. 1, by changing percentage of polyimide from 18 % to 4.9 %. We can cover in the range of thickness from 100 nm to several thousand nano meter.

Figure 2 shows the cross-sectional view of STJ on PI buffer layer. The PI buffer layer was prepared on sapphire substrates. The STJ was fabricated on the PI buffer layer using sputtering, photolithography and etching process. The STJ itself is fabricated following conventional Nb/Al-AlO\textsubscript{x}/Al/Nb structure. The thickness of Nb base-electrode is 200 nm, the Al top- and base-trapping layer of 60 nm, the Nb top-electrode is 150 nm, the SiO\textsubscript{2} insulator is 350 nm and the Nb wire is 600 nm, respectively. The leakage current was 5 nA at 0.2 mV and at 0.4 K for 100 × 100 µm\textsuperscript{2} junction. Temperature dependence of the leakage current was in good agreement with BCS theory. The critical current density was 200 A/cm\textsuperscript{2}.

3. Experiment of X-ray detection
The X-ray detection experiment of the three types STJ was carried out at 0.4 K using the \textsuperscript{3}He cryostat. Three spectra were obtained using STJ on PI buffer layer of 60 nm, 100 nm and 300 nm. 5.9 keV X-ray was used for irradiation. The spectra data are shown in Fig. 3. In this figure, three peaks corresponds to different thickness of polyimide buffer layer. In the case of 60 nm PI thickness, the phonon events from substrate appeared at very low energy region. The percentage of phonon event was estimated to be 2 %, which reflects with the peak energy of 5.9 keV. On the other hands, the phonon events disappeared in the spectra of STJ with 100 nm and 300 nm PI thickness. Figure 4 shows the comparison of the phonon events percentage using the buffer as Al\textsubscript{2}O\textsubscript{3} and PI buffer layers. As shown in Fig. 4, the opencircle corresponds to no buffer layer on sapphire substrate, the opentriangle is Al\textsubscript{2}O\textsubscript{3} on sapphire, the fullsquares are Al\textsubscript{2}O\textsubscript{3} on Si and the fullcircles are PI on sapphire. From this figure, it can be concluded that 100 nm
thick polyimide buffer layer is sufficiently enough to suppress phonon events in substrate in low energy range.

![Figure 3](image-url)  
**Figure 3.** Spectra obtained by changing PI buffer layer of 60 nm, 100 nm and 300 nm, respectively.

![Figure 4](image-url)  
**Figure 4.** Comparison of the phonon events percentage for the reference peak of 5.9 keV.

### 4. Summary

We have fabricated the STJ on PI buffer which has three different thickness. The spectra of 100 nm and 300 nm PI thickness shows good suppressing of phonon events in substrate. The PI buffer layer can be very useful in low noise photon detector based on STJ technology.

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