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Fabrication and Properties of In/(Ba, Rb)BiO_3/$SrTiO_3$(Nb) Three Terminal Device

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We have studied the electrical properties of a three terminal device using the (Ba,Rb)BiO_3 thin film. We have succeeded in fabricating a three terminal device with a large current transfer ratio in the device structure like a metal-base transistor. A common base current transfer ratio α>0.8 was obtained at 20K.

1.Introduction

The electronic devices using the high-Tc superconductors for application have been actively studied[1,2]. The superconducting base transistor is one of the promising devices in the future. The device simulation indicates that the hot electron type superconducting base transistor (SBHET) can be operated at much higher frequency with a large current gain than the hetero-junction bipolar transistor (HBT)[3].

We have studied thin film growth of the (Ba,Rb)BiO_3 superconductor (BRBO) by molecular beam epitaxy (MBE) using distilled ozone[4,5]. BRBO has an isotropic crystal structure and a large coherent length, and the BRBO films can be formed at lower temperature. In order to fabricate the SBHET, we need to prepare the superconductor / semiconductor Schottky-like junction.

In the previous work, we reported the good Schottky-like electrical property of the BRBO/$SrTiO_3$(Nb-doped) (STO(Nb)). Recently, we found a rectifying electrical property in an In / BRBO junction[6,7]. By using the BRBO / STO(Nb) junction as a base-emitter and the BRBO / In junction as a base-collector, we are succeeded in fabricating the transistor with a large current transfer ratio of α>0.8 in a common base configuration.

In this paper, we report on fabrication of the transistor of In/BRBO/STO(Nb) and its electrical properties.

2.Experimental

We prepared the BRBO thin films on the STO(100) substrate at the substrate temperature (Ts) of 370°C by MBE using distilled ozone. Deposition speed of the BRBO thin film was 0.3~1.0Å / s, and the film thickness was 600~700Å. The zero resistance was obtained at 28K.

Figure 1 shows the schematic drawing of the

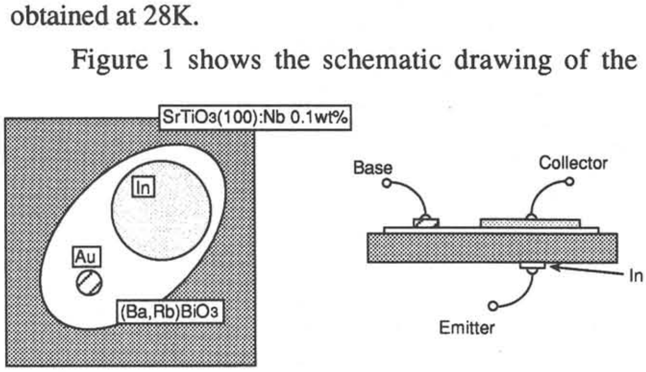

Figure 1 Schematic view of the In /BRBO /STO(Nb) three terminal device (not to scale)

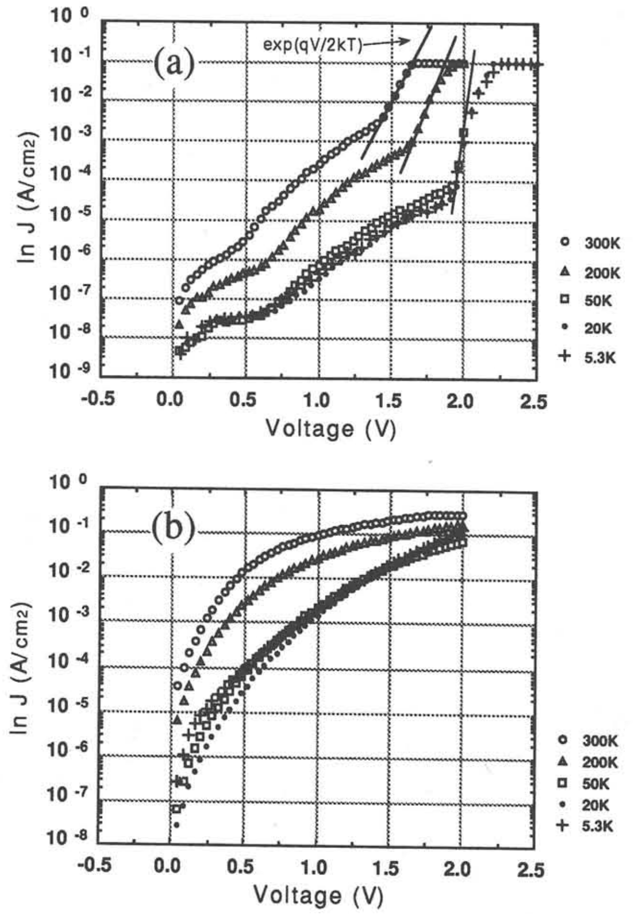

Figure 2 I-V characteristics of the BRBO / In junction ((a)) and BRBO / STO(Nb) junction ((b)) measurement at 300, 200, 50, 20 and 5.3K.

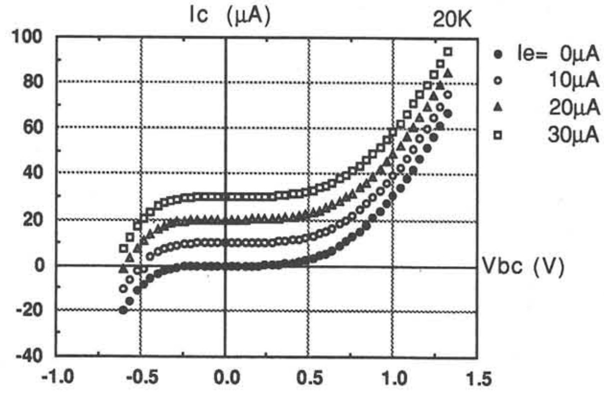

Figure 3 Typical collector current-voltage characteristic curves in the common-base configuration as a function of an emitter current (20K)

structure of the In / BRBO / STO(Nb) three terminal device. For the collector, indium(In) was deposited on the BRBO thin films at the room temperature (R.T). Gold(Au) was evaporated onto BRBO at the R.T as the base electrode. In deposited on the reverse side of the substrate against BRBO film was used as the emitter electrode. The unknown transition oxide layer may be formed at the interface between In and BRBO. The current-voltage (I-V) characteristics of the junctions and transistor dc characteristics were measured in the temperature range from 300K to 5K.

3.Results and Discussion

(i) Diode characteristics

Figure 2 (a) shows the lnJ-V curve of the BRBO/STO(Nb) junction.Analysis of the slope of the straight line reveal that the value of the diode ideal factor n is around 2.0 at 300K. The value of n is increased with decreasing a measurement temperature.The barrier height (ϕ_B) of BRBO/STO(Nb) at 20K is estimated to be about 1.8~1.9eV. Figure 2 (b) shows the diode characteristics of the In/BRBO junction. From the rectifying lnJ-V curve shown in Fig.2(b), the non-ohmic electrical property was observed.

(ii) Transistor characteristics

We used the BRBO/STO(Nb) junction as the emitter/base and the BRBO/In junction as the base/collector, because ϕ_B of BRBO/STO(Nb) is higher than ϕ_B of BRBO/In. Figure 3 shows the representative collector-currents (Ic) versus the base-collector voltage (Vcb) as a function of the emitter current (Ie) of the In/BRBO/STO(Nb) device measured at 20K in the common-base configuration. The saturation region exists below Vcb~-0.4V, and breakdown begins over Vcb~0.5V. Therefore the range of the active region is about 0.8V. In this active region (-0.4V<Vcb<+0.4V), the following equation can be applied;

$$Ie = \alpha Ic + Icbo$$

(Ie:emitter-current Ic:collector-current α:current transfer ratio Icbo:collector cut-off current)

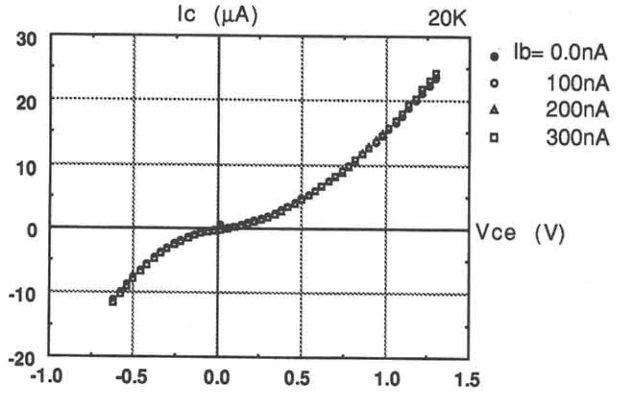

Figure 4 Typical collector current-voltage characteristic curves in the common-emitter configuration as a function of an base current (20K)

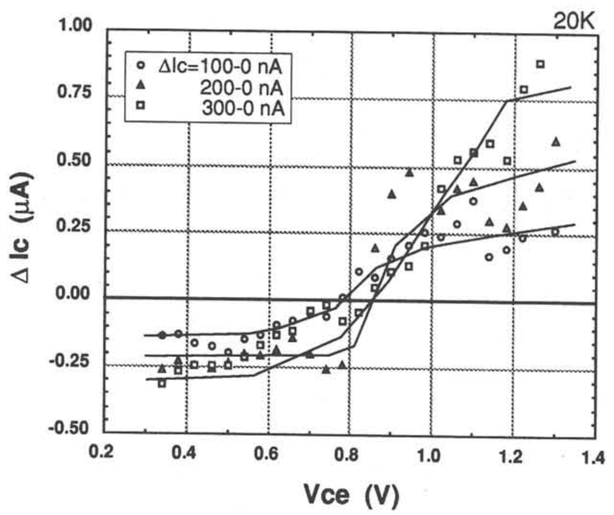

Figure 5 Differences between Ic=0 and Ic with base current injection versus collector voltage

Figure 4 shows Ic-Vce characteristics in the common emitter configuration. As the figure shows, a soft breakdown is observed due to the In/BRBO junction. Figure 5 shows differences between Ic curves with input base current as a parameter and Ic=0. This result clearly shows the current which was observed to flow between emitter and collector at an emitter-collector bias of more than Vce=1.1V. A common emitter current gain $\beta>2.5$ was obtained at Vce=1.2V.

4.Conclusions

We fabricated the In/BRBO/STO(Nb) transistor with the large current transfer ratio of $\alpha>0.8$. The studied in detail in the temperature range from 300K to 5K. Further studies on the smaller-size In/BRBO/STO(Nb) device is now in progress.

Acknowledgement

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