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The Analysis of the Junction Characteristics of In/(Ba, Rb)BiO_3/$SrTiO_3$(Nb) Transistor

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The AC characteristics of the In/BRBO and BRBO/STO(Nb) junctions were studied. The equivalent circuit model of these junctions was proposed. The admittance - frequency and admittance - voltage characteristics of the junction were carefully analyzed. The improvement of these junction for higher frequency operation were discussed.

1. INTRODUCTION

Various oxide superconducting devices have been studied. The superconducting base transistor is one of the promising device. We fabricated In / (Ba,Rb)BiO_3 (BRBO) /Nb doped $SrTiO_3$ (STO(Nb)) transistor and a common base current gain $h_{FB} > 0.8$ was obtained at 20K[1]. The study of the high frequency operation of the improved In/BRBO/STO(Nb) transistor is need.

The admittance - frequency (Y-F) characteristics of the In/BRBO and BRBO/STO(Nb) junctions were studied. The equivalent circuit model of these junctions was proposed. The AC characteristics of the junction were carefully analyzed. The improvement of these junctions for higher frequency operation was discussed.

2. EXPERIMENTAL

The BRBO thin films were prepared on the STO(100) substrate by MBE using distilled ozone. This thin film is c-axis oriented. The BRBO film thickness was 150nm. The zero resistance was obtained at 28K. We deposited Au and In on BRBO. The Au electrodes on BRBO were ohmic contacts. The In/BRBO junction shows a rectifying electrical property[2]. For ohmic contacts of STO(Nb), indium droplet was deposited. We patterned these junctions by usual photo lithography and Ar dry etching. Fig.1 shows the schematic drawing of the structure of In/BRBO/STO(Nb) transistor. The junction areas of BRBO/STO(Nb) were 2.0×10^{-3} (junction 1) and that of In/BRBO was 1.8×10^{-2} cm^2 (junction 2). We used In to connect the electrodes of samples with a wire. The quality of the BRBO thin films were kept in these processes. In Y-F measurement, we used an impedance analyzer. The applied voltage was from -2V to 2V. The measurement frequency was 50Hz to 1MHz.

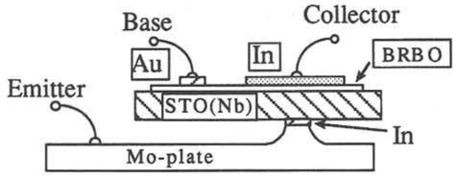

Fig.1 The schematic drawings of the structure of In/BRBO /STO(Nb) transistor

3. RESULTS

The experimental results of current - voltage (I - V) and capacitance - voltage (C - V) characteristics show that the BRBO/STO(Nb) junction was the Schottky-like junction[1]. Fig.2 shows the Y-F characteristics of BRBO/STO(Nb) (junction 1) at -1.0, 0.0 and 1.0V bias. The conductance (G) and susceptance (B) became larger over 100KHz. The clear temperature dependence of these characteristics was not observed. As the frequency was higher, the junction was more leaky.

These characteristics were analyzed using the usual Schottky diode equivalent circuit model (Fig.3)[3,4]. Table 1 shows the parameters of equivalent circuit at room temperature. We decide these parameters by the admittance data at 10KHz and 100KHz. Fig.4 shows the Y-F characteristics of junction 1 by this equivalent circuit analysis. The analyzed characteristics agree with the measured characteristics.

Fig.5 shows the Y-F characteristics of In/BRBO junction. The conductance and susceptance became larger over 100KHz. This suggests the equivalent circuit of this junction is similar to that of BRBO/STO(Nb) junction. The Rj and Cj of In/BRBO junction do not satisfy the usual Schottky relation[3]. From the I - V characteristics, In/BRBO was similar to the tunnel junction with low barrier[2].

4. DISCUSSION

The BRBO/STO(Nb) junction is improved for higher frequency operation, when Rj × Cj and Rs

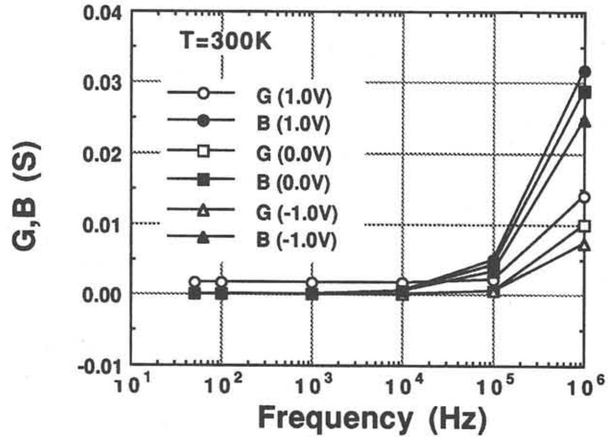

Fig. 2 The Admittance - frequency characteristics of BRBO/STO(Nb) (junction 1) at V=-1.0,0.0 and 1.0V

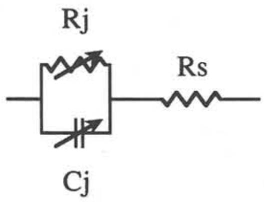

Fig.3 The equivalent circuit of the usual Schottky diode. The equivalent circuit includes junction capacitance Cj, junction resistance Rj and series resistance Rs.

Table 1 The fitting data of equivalent circuit of BRBO/STO(Nb) junctions.

	junction 1
Cj (F)	7.3×10^{-9}
Rj (ohm)	2.9×10^{4}
Rs (ohm)	26
S (cm^2)	2.0×10^{-3}

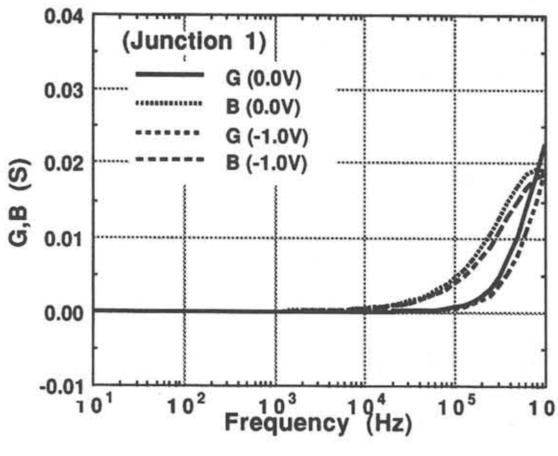

Fig. 4 The caliculated Y-F characteristics of BRBO/STO(Nb)

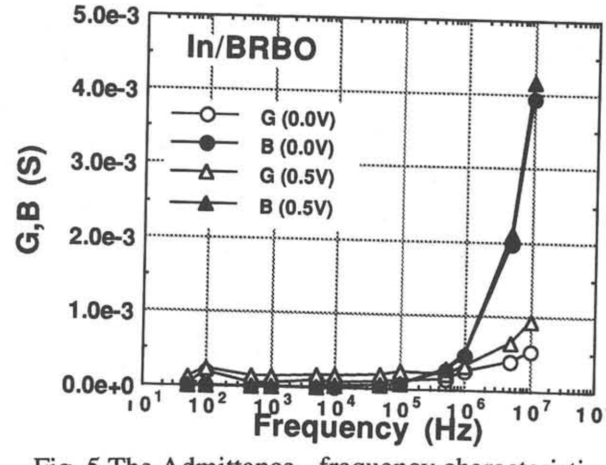

Fig. 5 The Admittance - frequency characteristics characteristics of In/BRBO junction.

reduced. Fig.6 shows the I-V characteristics of the Schottky diode with the series resistance. The junction current of the Schottky barrier exponentially depends on the voltage. The Rj is inversely proportional to the junction current. The Rj decreases exponentially with the voltage, while the Cj^{-2} decreases linearly with voltage. The Rj×Cj is reduced as Vj is higher. The junction works as a diode in the region of Rs < Rj.

Fig.7 shows the schematic drawing of the improved structure of the BRBO/STO(Nb) junction. As the Rj×Cj of the junction 1 (experimental) was 2.1×10^{-4}, the maximum operating frequency was about 3.0×10^{4} Hz. To operate the BRBO/STO(Nb) junction at ~GHz, the Rj×Cj and Rj should be reduced 6.3×10^{-9} and 0.9Ω. So, the Rs should be less than about 0.1Ω. The Vj is increased by 0.4V at 300K and 0.01V at 10K, where the ideality factor is 1.5. The improved Rs is mainly the contact resistance between Au and BRBO (R_{AB}) and STO(Nb) resistance (R_{STO}). The contact resistance between Au and BRBO (ρ_{AB}) is ~10^{-2} at 300K and ~10^{-4} at 10K. The R_{AB} is ~5 ohm at 300K and ~5×10^{-2} Ω at 10K. The ρ_{AB} should be smaller than 10^{-4} Ωcm^2. The lower resistivity ohmic contact must be developed. The R_{STO} is ~2.6 ohm at room temperature and ~2.6×10^{-3} ohm at under 10K when junction area is 2.0×10^{-6} cm^2 and the thickness of the substrate is 500μm[5]. When the current path is shortened from 500μm to 10μm, the R_{STO} is ~0.05Ω. The junction area is reduced from 2.0×10^{-3} to 2.0×10^{-7}, the current is reduced to 10^{-4} in the order of magnitude. The current density increases by 10^5, then the operating frequency expand to 10^5 in the order of magnitude. These results discussed above concludes that the reduction of the junction area can improve the performance of the diode at higher frequency.

5. CONCLUSION

1) The equivalent circuit of BRBO/STO(Nb) was the Schottky diode.

2) The improved structure of BRBO/STO(Nb) junction for higher frequency operation was proposed, when both the junction area and Rs reduced.

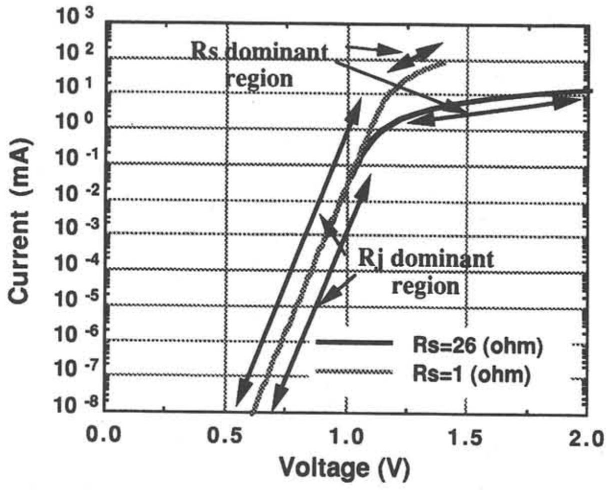

Fig. 6 The I-V characteristics of the Schottky diode with series resistance.

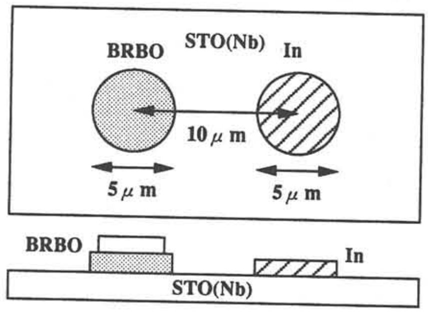

Fig. 7 The improved structureof the BRBO/STO(Nb) junction

ACKNOWLEDGMENT

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