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Fabrication and Investigation of Electrical Property of Schottky Junction Using (Ba, Rb)BiO_3 Thin Film

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BRBO/STO(Nb) diode was fabricated and their electrical property was measured. Barrier height ϕ_B deduced from I-V and C-V are consistent with each other: $\phi_B \sim 1.7$ eV for BRBO/STO(Nb:0.05wt%). Electrical property of BBO(Rb) semiconducting thin films was investigated in order to fabricate BRBO/BBO(Rb). BBO(Rb)/BBO(Rb) was preliminarily fabricated and its I-V was measured. This is the first test for application of BBO(Rb) to a junction.

1.Introduction

Fabrication of a superconductor /semiconductor junction with suitable barrier height [1] is desired for a three terminal device using superconductor. We are studying preparation of (Ba,Rb)BiO_3 superconducting thin film (BRBO) by molecular beam epitaxy (MBE) [2]. High quality BRBO and (Ba,K)BiO_3 (BKBO) thin film have been prepared at some laboratories [3] and applied to fabricate some kinds of devices . BBO is semiconductor and its electric property is often interpreted by variable range hopping model [4]. Non-superconducting BRBO (BBO(Rb)) as well as BBO is semiconductor . BBO(Rb) is one of possible materials for an oxide-superconductor/semiconductor junction. Only a few studies on electrical property of BBO and BBO(Rb) thin films , however, has been performed. In this study, we investigated electric property of the BBO and BBO(Rb) thin films. Furthermore we fabricated BBO(Rb)/BBO(Rb) junction and measured its electrical property. In order to fabricate a three terminal device, we studied electrical property of BRBO, Au/STO(Nb) diode as well.

2.Experimental

2.1 BRBO thin film

BRBO was prepared by MBE using distilled ozone (O_3). BRBO were formed on STO(100) and MgO(100) substrates at Ts~370C. Ts was calibrated with melting points of In and Bi, and it was monitored with a pyrometer. Growth speed of the BRBO thin film was ~0.3 A/s, and film thickness is 500~1000 A. Composition ratio was deduced by Rutherford backscattering (RBS) and energy dispersive X-ray analysis (EDX).

Growth process of BRBO on STO(100) was studied in order to fabricate high-quality junction. A reflection high energy electron diffraction (RHEED) pattern, X-ray photoelectron spectroscopy (XPS) spectrum were measured during film growth. BRBO thin films of 10~200 A were observed with atomic force microscope (AFM) in order to measure change of roughness during BRBO film growth.

2.2 BRBO/STO(Nb) diode

BRBO of ~1000 A was formed on STO(Nb) (0.05 wt% Nb doped) at Ts~370C. STO(Nb) was etched by ~10% HF before deposition of BRBO and Al electrode on STO(Nb). Current-voltage (I-V) and capacity-voltage (C-V) characteristic of BRBO/STO(Nb) and their temperature dependence were measured. In order to get knowledge on Schottky barrier formed on STO(Nb), a Au/STO(Nb) diode was also fabricated and measured its electrical properties. It should be noted that BRBO and Au were deposited on STO(Nb) cleaned by O_3 in MBE chamber without exposure of STO(Nb) to atmosphere.

2.3 BBO(Rb) thin films

BBO and BBO(Rb) of ~500 A were formed in growth speed of ~0.3 A/s. BBO(Rb) was formed at Ts~370C at various Rb beam flux intensity. R(T) of BBO and BBO(Rb) was measured.

A BBO(Rb)/BBO(Rb) junction (BBO(Rb)

films of different resistivity) was fabricated on MgO(100) at Ts~370 C. BBO(Rb) of 2400 A was formed on MgO(100) and BBO(Rb) of 1200 A (different Rb composition) was deposited on it. I-V of BBO(Rb)/BBO(Rb) was measured.

3. Results and discussion

3.1 BRBO thin film

BRBO is c-axis orientation and no other reflection peaks appear in the XRD pattern. Figure 1 shows R(T) of BRBO on STO(100). Superconducting transition temperature (T_C) was 28K. This is the highest Tc of ~500A thin film formed by MBE. Figure 2 shows the RHEED patterns of BRBO on MgO(100). As seen in Fig. 2, streak pattern was observed. As for the RHEED patterns during film growth of BRBO on STO(100), a spot pattern appeared at first and it changed to elongated spot pattern after 100~200 A deposition. After 200 A deposition, the RHEED pattern was roughly independent of film thickness. These features are consistent to AFM observation. Figure 3 shows AFM observation of BRBO during film growth; film thickness is ~20, 40, 60, 100 and 200 A. Film thickness is the average value estimated from deposition time and average deposition speed. As seen in Fig. 3, BRBO is relatively smooth up to d~100 A. Roughness of BRBO increases rapidly over ~100 A. Results of EDX analysis indicate that large roughness arises from educed Ba and/or Rb.

Figure 4 shows XPS intensity for Ba,Bi,Rb, Ti and O as a function of average thickness of BRBO on STO(100). In Fig. 4, Ba intensity increases more rapidly compared to the other elements of Ba and Rb. This may indicate that adsorption factor of Ba on STO is larger than that of Bi and Rb especially at the

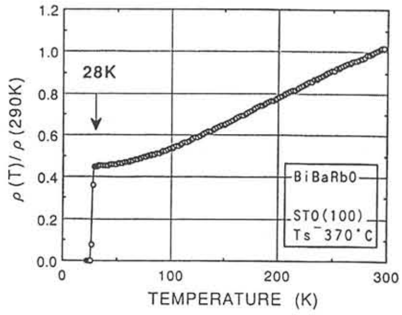

Fig. 1 R(T) of BRBO formed on STO(100).

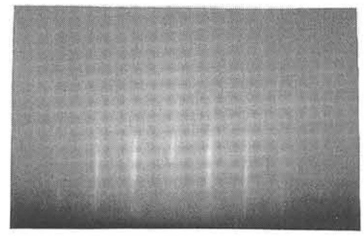

Fig. 2 RHEED pattern of BRBO on MgO(100).

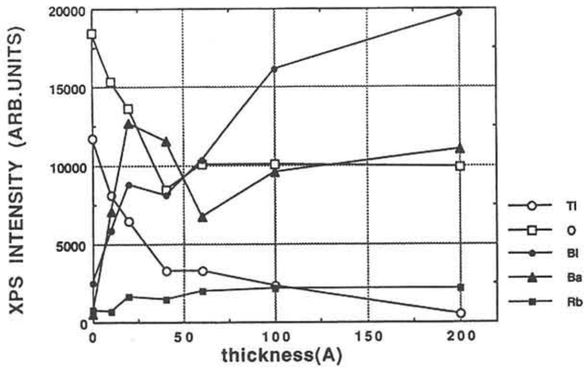

Fig. 4 XPS intensity as a function of average thickness of BRBO on STO(100).

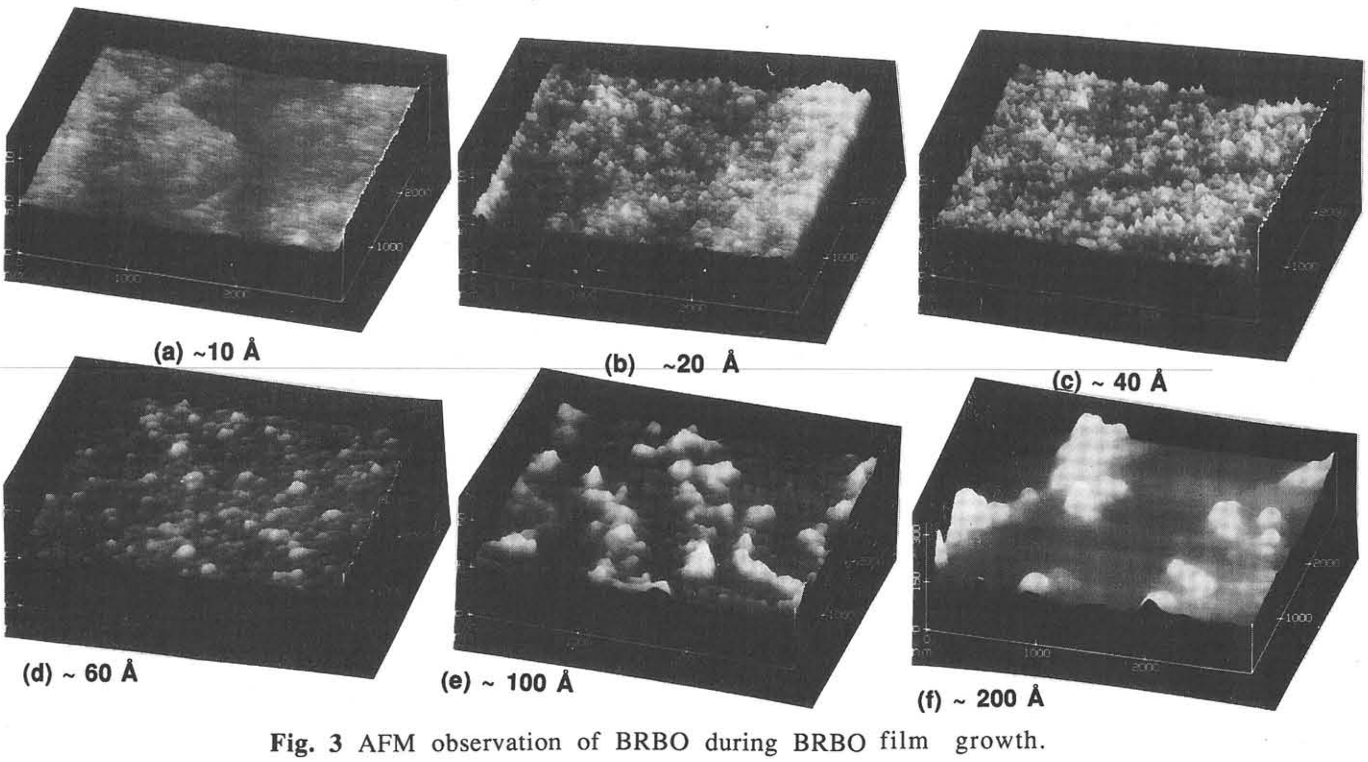

Fig. 3 AFM observation of BRBO during BRBO film growth.

early stage of BRBO growth on STO. XPS intensity of Bi, Ba and Rb are roughly constant over ~100 A. This implies that BRBO grows in roughly constant composition ratio over ~100 A.

3.2 BRBO/STO(Nb) and Au/STO(Nb)

Figure 5 shows the representative I-V and C-V curves of BRBO/STO(Nb) measured at room temperature. Voltage at which current increases rapidly did not depend strongly on temperature. As seen in Fig. 5, diode characteristic was obtained. ϕ_B deduced from I-V measurement is 1.7 eV. n-value is 1.4. ϕ_B evaluated from C-V measurement is also 1.7 eV. Carrier concentration in STO(Nb) estimated from C-V measurement is $N_d \sim 5\times10^{18}$ /cm^3, which agrees with Hall measurement. In the case of BRBO/STO(Nb) as well as Au/STO(Nb), barrier height deduced from I-V agrees well with that deduced from C-V. These results indicate that we need not necessarily to take into account an unknown dielectric layer between STO(Nb) and BRBO. ϕ_B of ~1.7 eV is roughly equivalent to ϕ_B of YBCO/STO(Nb) and BSCCO/STO(Nb) reported elsewhere. This may imply that band-gap level of STO due to Ti^{3+} (energy level ~ 1.7 eV) is related to ϕ_B of BRBO/STO(Nb).

3.3 BBO(Rb)

Figure 6 shows R(T) as a function of Rb composition. R(T) curves of BBO(Rb) show semiconducting behavior: resistance increases with decreasing temperature. Resistance of BBO(Rb) and slope of R(T) curve decreases with increasing Rb composition ratio. The activation energy deduced from R(T) curve for BBO is ~0.1 eV. In log R-$1/T^4$ plot for R(T) of BBO(Rb) with x~0.3 resistance deviates from a straight line. Fitting of a straight line: $R=R_0\exp[-(T_0/T)^4]$ to the data in the range of $1/T^4<0.35$ resulted in $T_0 \sim 10^6$ K. This is very small compared to the

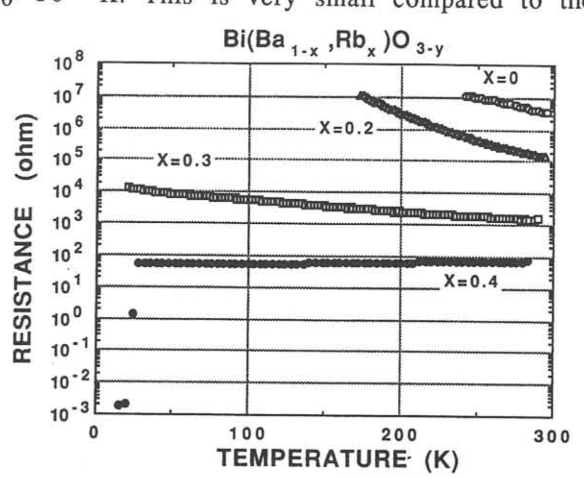

Fig. 6 R(T) as a function of Rb composition ratio.

case of BKBO shown in ref. 4. These features implies that R(T) of BBO(Rb) thin film is not necessarily interpreted by the variable range hopping model.

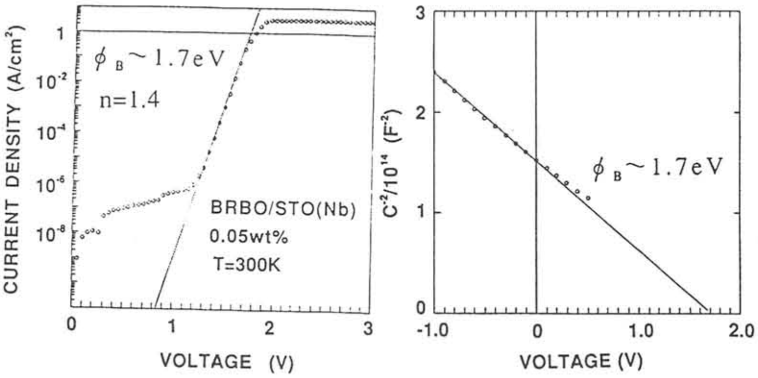

Fig. 5 I-V and C-V of BRBO/STO(Nb)

4. conclusions

We fabricated Au, BRBO/STO(Nb) diode and measured their electrical property. Barrier height deduced from I-V agrees well with that from C-V. This implies that we need not necessarily to take into account an unknown dielectric layer at the interface. Further investigation is required to clarify origin of such large ϕ_B as 1.7 eV.

In order to form BRBO/BBO(Rb), BBO(Rb) was formed and its electrical property was measured. As the results, semiconducting property was observed for BBO(Rb). It is not necessarily concluded that R(T) of BBO(Rb) thin film is well interpreted by the variable range hopping model. BBO(Rb)/BBO(Rb) was preliminarily fabricated and its I-V property was measured. In this case, observable diode characteristics was not obtained. A problem is whether suitable barrier is formed in BRBO/BBO(Rb). Fabrication of BRBO/BBO(Rb) and its electrical property would be reported.

Acknowledgement

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