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Fabrication Process and Calculated Characteristics of In/(Ba,Rb)BiO_3/Sr(Ti, Nb)O_3 Normal Conductor and Superconductor Base Transistors

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Fabrication process of In/(Ba,Rb)BiO_3/Sr(Ti,Nb)O_3 transistors was studied. It was found that Au and In deposit on BRBO films without the exposure to the air lead to low contact resistance ρ_c and good reproducibility. Dry-eched Sr(Ti,Nb)O_3 surface generated high ρ_c and was recoverd by acid eching. Devices of about 30µm size were successfully fabricated by photolithography and lift-off method. A calculation with experimental results showed that the power gain is much increased by the transition to a superconducting state.

1. INTRODUCTION

Superconducting base transistors have an extraordinary ability due to an extremely low base resistance[1]. We have obtained transistor operation in oxide devices using (Ba,Rb)BiO_3(hereafter BRBO) superconductor films. However, we have not yet observed the improvement in the characteristics by the transition to a superconducting state. To obtain it, we need low contact resistance ρ_c, small-size device, and so on. In this paper, we study the fabrication process to get better performances and the improvement from the point of view of electronic circuit.

2. FABRICATION PROCESS

In order to reduce the influence of process damage on BRBO film , we have used dry and low temperature(<80 °C) process in the fabrication of transistors.

(i) Process with metal deposit through metal mask

We designed a fabrication process as shown in Fig.1. For devices larger than a few hundreds µm size, we could first deposit Au and In films through metal masks on BRBO film to reduce the influence of the degradation of BRBO surface. Nevertheless the exposure of BRBO surface to the air generates the rather high ρ_c and the poor reproducibility of In/BRBO junction. Thus we tried to deposit metal films through metal masks on as-grown BRBO film without the exposure to the air.

We obtained the ohmic contact to BRBO films by the deposit of Au film through metal mask which was put on BRBO film in N_2 atmosphere. ρ_c was 5×10^{-5} Ωcm^2 at 11K, as shown in Fig.2. XPS measurement for as-grown BRBO surface indicated that Ba was a little poor at the surface while Rb was rather constant, as shown in Fig.3. Heating BRBO film in a vacuum at about 520K for 15min. did not bring forth the

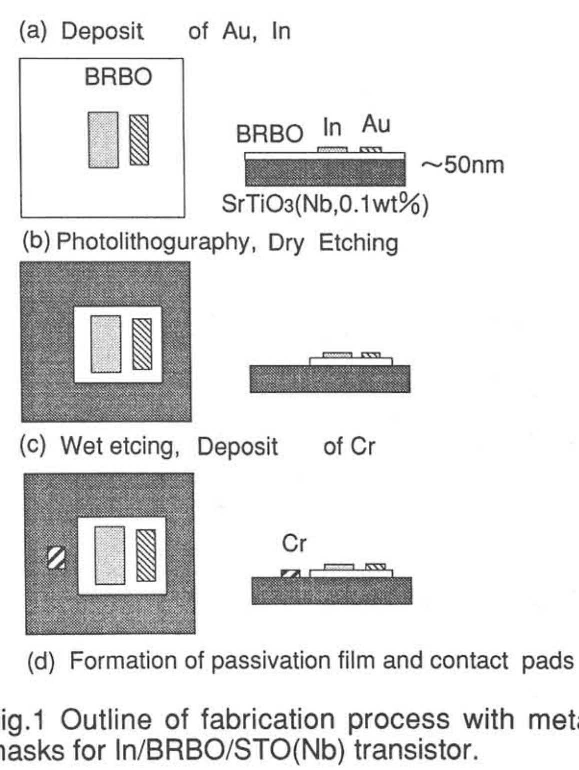


Fig.1 Outline of fabrication process with metal masks for In/BRBO/STO(Nb) transistor.

reduction in ρ_c, resulting in the spread of Ba-poor region. To controll the surface and to select contact metal will lead to lower ρ_c.

Figure 4 shows current-voltage characteristics of an In/BRBO junction at room temperature, which was in situ formed at a background pressure of 10^{-4}-10^{-5} Pa. The junction showed a rectifing property. This indicates that the natural barrier of BRBO surface give little influence on the rectification itself.

The combination of In and Au deposits through metal masks are useful for the fabrication of devices, because the in-situ alignment of metal masks is possible.

It was found that Ar^+ dry etching in the formation of BRBO base region(Fig.1b) degrade the surface of $Sr(Ti,Nb)O_3$(hereafter STO(Nb)) and the surface was recovered by acid wet etching. The temperature dependence of ρ_c in Cr/STO(Nb) contact is shown in Fig.2. ρ_c of 2.5×10^{-5} Ωcm^2 was obtained at 11K.

(ii) Process with photolithography and lift-off method

For the fabrication of smaller devices, we have developed the process with photolithography and lift-off method. An outline of the process is shown in Fig.5. Lift-off method was useful in reducing the process damage to BRBO film and simplifying the process. We used LMR resist because of the good lift-off and the waterless use. Indium was first deposited through a metal mask on BRBO film to reduce process damage(a). After the formation of a

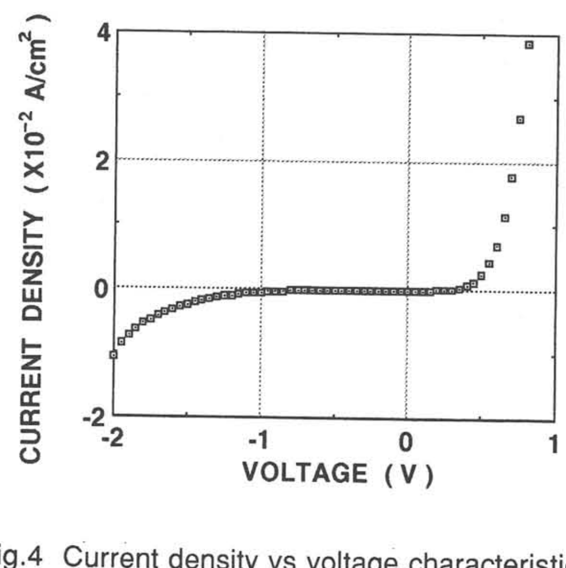


Fig.4 Current density vs voltage characteristics in In/BRBO junction at room temperature. Indium film was in situ deposited on BRBO film and was positively biased.

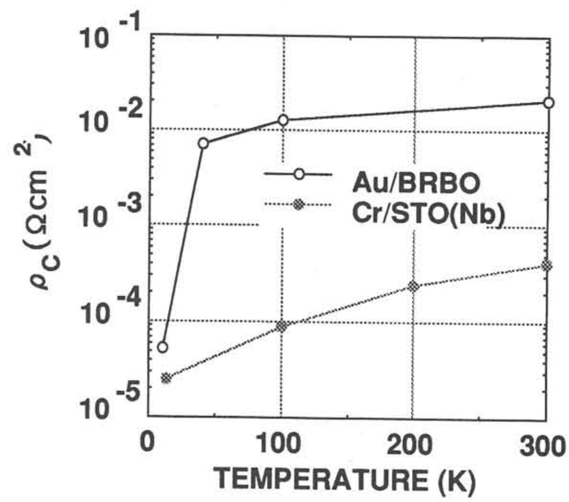


Fig.2 Contact resistance of Au/BRBO and Cr/STO(Nb) as a function of temperature.

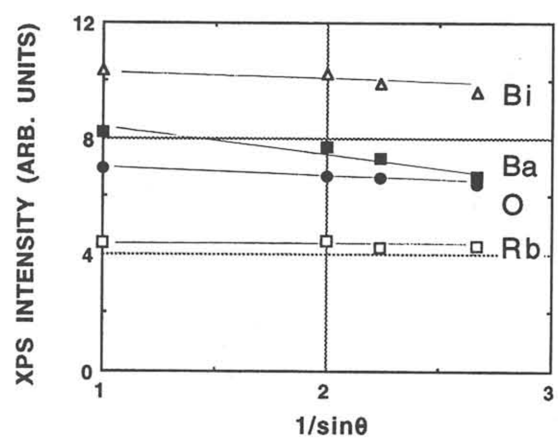


Fig.3 XPS intensities of Ba4d(90eV), Rb3d(110eV), Bi4f(160eV) and O1s(530eV) as a function of 1/sinθ.
θ is an angle between the sample surface and the detection direction.

base region(b,c), SiO_2 passivation film pattern was formed by the photolithography and lift-off method(c,d). SiO_2 was deposited by electron-beam method. Ohmic contact and contact pad patterns were formed in the same way(e-g). Considering the adhesion to SiO_2 film, we used Au alloy as an ohmic contact to BRBO film and used Au/Cr as an ohmic contact to STO(Nb) and an contact pad to In. Figure 6(a) shows a top view of a device. Small, medium, large and largest rectangles are the windows of the SiO_2 passivation film, the In film, the ohmic contact(contact pads) and the BRBO film respectively. In the device, Au/BRBO contact had rather high ρ_c.

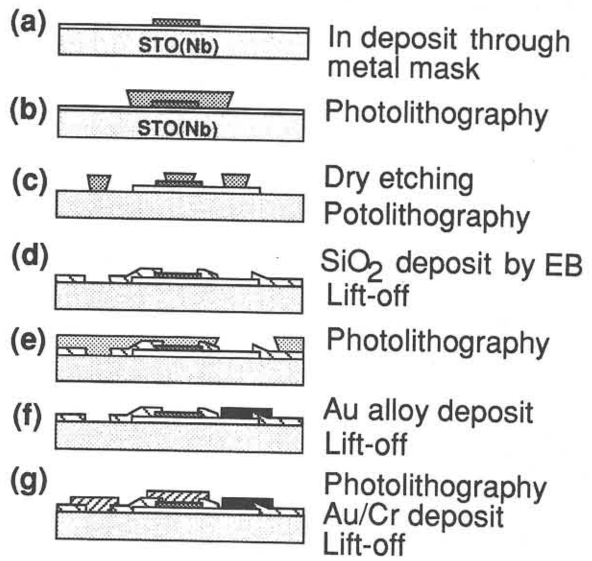


Fig.5 Outline of process of smaller-size devices by photolithography and lift-off method.

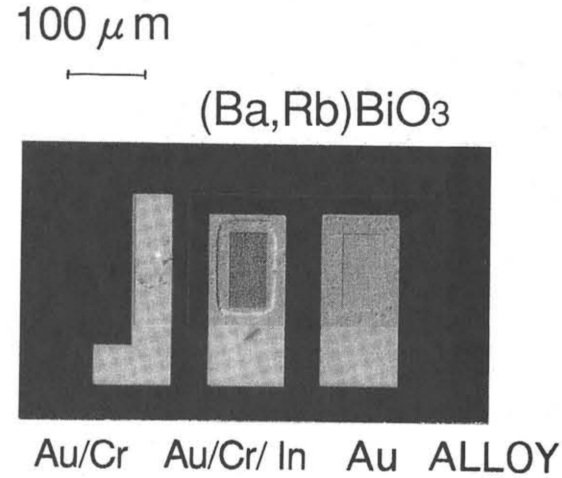
To reduce ρ_c, it is desirable that Au alloy should be deposited at the early stage of the process. The size of device is limited by the size of metal mask. Device structures of ~30 μm size were successfully fabricated without the first In deposit through metal mask. Figure 6(b) shows a part of the device.

3. CALCULATED CHARACTERISTICS

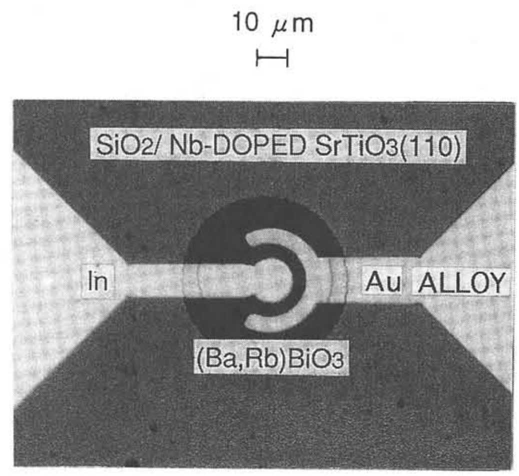
We have already measured DC and AC charactristics of BRBO/STO(Nb), In/BRBO junctions [2] and DC characteristics of In/BRBO/STO(Nb) transistor. From the result, we calculated the maximum available power gain G of the transistor using an equivalent circuit model[1] by D.J. Frank et.al. It was found that G in a superconducting state(<29K) is 12 times as large as that in a normal conductor state(>29K) in a device of 25x100 μm size and a contact resistance ρ_c of $10^{-6}\Omega cm^2$ though G is 6 times in a device of 400x500 μm size and ρ_c of $10^{-4}\Omega cm^2$.

4. CONCLUSION

Fabrication process of In/(Ba,Rb)BiO_3 /Sr(Ti,Nb)O_3 transistors was studied. In-situ metal deposit was useful for the reduction in contact resistance ρ_c and the good reproducibility. The etching of dry-eched Sr(Ti,Nb)O_3 surface with an acid also led to the reduction in ρ_c . Devices of about 30μm size were successfully fabricated by photolithography and lift-off method. The calculation with experimental results showed that the power gain of the device is much increased by the transition to a superconducting state.



(a)



(b)

Fig.6 Top views of In/BRBO/STO(Nb) devices fabricated with metal mask deposit of In (a) and without it(b).

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