# Development of NBCO Coated Conductor by using Superconductor Technology

Sang-Heon Lee
*Department of Electronics Information and Communication Engineering, Sun Moon University, Asan, Chung Nam 336-840, Korea*

E-mail : shlee@sunmoon.ac.kr

(Received 16 May 2003, Accepted 19 June 2003)

NBCO thin films have been fabricated by magnetron sputtering technique on heated $SrTiO_3$ substrates. The oxidation and crystallization of the films were strongly dependent on the distance between the targets and the substrate, as well as on the oxygen partial pressure. The critical temperatures were above 80K for the films prepared under the condition of a small target to substrate gap, in spite of a very low oxygen pressure of 0.2Pa. The results suggest the importance of the activated oxygen uptake into the films during sputtering.

*Keywords* : NBCO, Magnetron sputtering, Thin films, $SrtiO_3$, Oxidation

## 1. INTRODUCTION

NBCO($Nd_1Ba_2Cu_3O_y$) high Tc superconducting (HTS) films have been prepared by various techniques, including sputtering[1], electron beam deposition[2], laser deposition[3], and molecular beam deposition[4]. In all cases, post annealing in oxygen at about 900℃ was necessary to obtain films with a high Tc. However, these films were not necessarily suited for use in electronic devices because the post-annealing processing caused a number of problems : for example, generation of cracks in the film, variation in the film composition and degradation of the film surface by exposure to air. Achieving the levels of current carrying capacity in the oxide superconductor required for such applications has spurred a substantial development effort to optimize processing strategies and to refine processing parameters [5-7]. It has been pointed out that the introduction of an effective oxidation process is important for the epitaxial growth of high temperature superconducting films. Oxygen plasma activated by radiofrequencies or microwaves, oxygen ions activated by electron cyclotron for the superconducting properties as grown films. In this paper, we present our results on fabricating NBCO films on the $SrTiO_3$ substrates by magnetron sputtering.

## 2. EXPERIMENTAL PROCEDURE

NBCO superconducting thin films were deposited by rf magnetron sputtering with NBCO bulk target onto $SrTiO_3$ substrates. The substrate temperatures were in the range of 900□-950□. The gap between the targets and the substrates was varied from 120mm to 80mm and the oxygen ratio in the sputtering gas was in the range of 100 to 5% and was insensitive to sputtering parameters such as the gap, the oxygen pressure,and substrate temperature. The deviation from the stoichiometric composition was kept to less than 3%. The 4 inch target were placed outside the circumferences at a radius of 80mm. Therefore, it is possible to avoid the irradiation of negative ions from the targets to the substrates.

## 3. RESULTS AND DISCUSSION

Figure 1 shows the resistance versus temperature relations for films prepared on $SrTiO_3$ (100) substrates when the gaps were 80mm and 120mm. The sputtering gas pressure was 0.65Pa and the oxygen ratio was 50%. The critical temperature (Tc) was above 80K for the films prepared under on 80mm gap while the Tc was as low as 50K for those prepared under a 120mm gap. This result suggest oxygen uptake is enhanced when the substrate are close to the targets. The geometrical configuration for the targets and substrate will protect the film surfaces from negative ions. Thus, the substrate is likely to be exposed to more activated oxygen produced in the oxygen plasma just above the targets for a small gap than for a large gap. After sputtering, the films were cooled in the same atmosphere that used during sputtering. Therefore, effective oxidation is thought to progress during sputtering. The deposition under a small gap seems to promote not only oxidation but also film crystallization. Furthermore, well crystallized films with c-axis orientation were formed on the $SrTiO_3$ (100) surface, However, a-axis oriented films were formed under a gap of 120mm and the superconductivity was deteriorated.

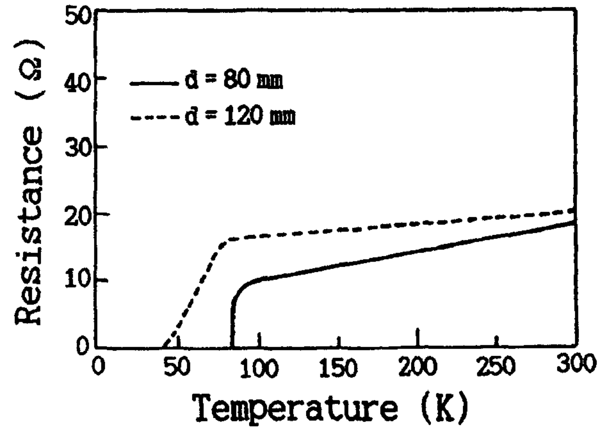


Fig. 1. Resistance versus temperature dependence for films on $SrTiO_3$ substrates. D is the substrates – target distance. NBCO thickness is about 2000Å .

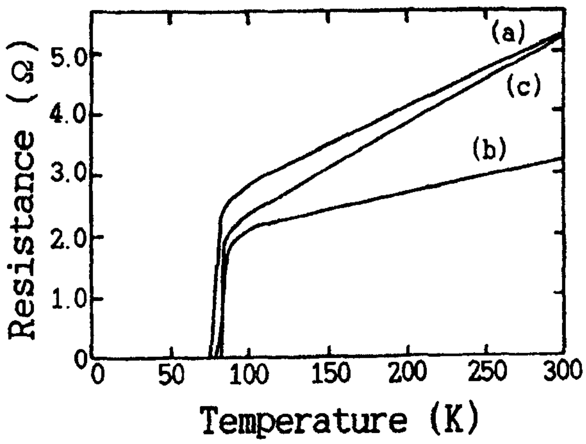


Fig. 2. Resistance versus temperature dependence for films prepared at different oxygen ratios: (a) 50% oxygen, (b) 30% oxygen, and (c) 20% oxygen.

Figure 2 shows typical resistance versus temperature relations for films prepared at different oxygen ratios under 80mm gap. The total pressure for the sputtering gas fixed to 0.65Pa. Although the highest critical temperature was 75K for films prepared at 50% oxygen, Tc was above 80K for films prepared at 30% or 20% oxygen. The oxygen partial pressure was 0.2Pa for the sputtering gas of 0.65Pa with 20% oxygen. Although the oxygen partial pressure seemed to be too low, the c-axis parameter was 11.68Å , and the highest Tc (80K) was obtained. Thus, more oxygen was taken into the films for 20% oxygen than for 50% oxygen. However, a-axis oriented films were formed when pure oxygen was used, and no superconducting films was obtained. Furthermore, at 5% oxygen, the films had c-axis orientation, and the lattice parameter was extremely expanded. The films indicated zero resistance below 40K. These results can be explained as follows : when the ratio of argon to oxygen is increased, the ratio of dissociated atomic oxygen to oxygen molecules will increase, owing to collisions between activated argon atoms and oxygen molecules. Thus, the activated oxygen is likely to be atomic oxygen. As a result, the increase in the argon ratio promoted the oxidation of films. However, an extreme decrease in the oxygen partial pressure will decrease the absolute amount of dissociated atomic oxygen, so films with low Tc were obtained at 5% oxygen. Therefore, activated oxygen speices were most effectively supplied to the films at 20% oxygen under an 80mm gap.

At higher sputtering gas pressures, films with a-axis oriented grains were formed under a small gap over the entire range of oxygen ratio from 50 to 20%.

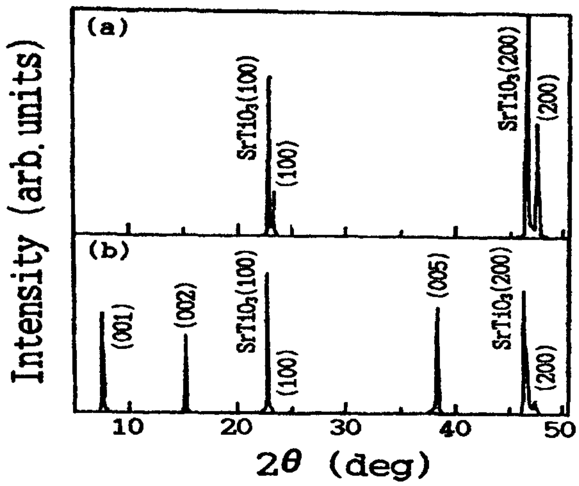


Fig. 3. X ray diffraction patterns of films fabricated at (a) 0.9Pa and (b) 0.65Pa.

Figure 3 (a) and (b) show X ray diffraction patterns of films prepared at 0.9Pa and 0.65Pa with 20% oxygen. The a-axis parameter for the film shown in Fig.3 (a) was 3.83Å . Thus, the oxygen uptake was considerably enhanced. However, the film exhibited zero resistance at 50K. On the other hand, the Tc for the film shown in Fig.3 (b) was 82K. This film is the same as that shown in Fig.2 (c). Since both oxidation and crystallization are important for preparing excellent superconducting films, the difference in critical temperature between the films in Fig.3 (a) and (b) seems to indicate that crystallization by activated oxygen was not effective at higher sputtering gas pressures, even under a small gap.

## 4. CONCLUSION

We have demonstrated that the uptake of activated oxygen, produced in the plasma just above the targets, promotes the oxidation and the crystallization of NBCO films during growth by rf magnetron sputtering and improves the superconducting properties. The uptake was successfully realized by decreasing the substrate target separation at a low oxygen partial pressure.

## ACKNOWLEDGMENTS

This paper was supported by the 2003 research fund of Sun Moon University.

## REFERENCES

[1] J. Yang, D. Shi, X. Wang, A. Liu, and G. Yuan, "Fabrication of YBCO coated conductors using magnetron sputtering", Physica C, Vol. 341, p. 2499, 2000.

[2] G. Celentano, C. Annio, V. Boffa, L. Cioneta, F. Fabbri, Gambradella, V. Galluzzi, and A. Mancini, "Superconducting and structural properties of YBCO thick films grown on biaxialy oriented architecture", Physica C, Vol. 341, p. 2501, 2000.

[3] Z. Lu, J. K. Truman, and G. C. Liang, "Large area doble sided YBaCuO films grown by single source metal organic chemical vapor deposition", Appl. Phys. Lett., Vol. 67, No. 5, p. 712 , 1995.

[4] M. K. Beisebekov, A. K. Toktabaeva, Zh. A. Abilov, G. Sh. Burasheva, and D. W. Soh, "Immobilization Of alchidine on polyvinyl alcohol gels", Trans. on EEM, Vol. 4, No.1 p. 11, 2003.

[5] H. S. Ha, S. S. Oh, D. W. Ha, K. D. Sim, S. C. Kim., and K. S. Ryu, "Critical current properties of Bi-2223/Ag tapes with respect to axial strain", J. of KIEEME(in Korean), Vol. 14, No. 1, p. 69, 2001.

[6] J. H. Kim, K. T. Kim, J. H. Joo, and W. S. Nah, "A Study on joining method of BSCCO(2223) mutifilamentary tape", J. of KIEEME(in Korean), Vol. 14, No.6, p. 511, 2001.

[7] S. R. Foltyn, R. E. Muenchausen, and D. W. Cooke, "Large area two sided YBaCuO films deposited by pulse laser deposition", Appl. Phys. Lett., Vol. 59, No. 11, p. 1374 , 1991.