Extended Abstracts of the 1998 International Conference on Solid State Devices and Materials, Hiroshima, 1998, pp. 102-103

Ultra Thin $SrBi_2Ta_2O_9$ Ferroelectric Films Grown by Liquid Source CVD Using BiOx Buffer Layers

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Abstract

We have developed ultra thin $SrBi_2Ta_2O_9$ (SBT) by liquid source chemical vapor deposition (LS-CVD) using BiO_x buffer layer. Bi deficient region was found in the SBT films near the bottom Pt electrode interface. Our developed BiO_x buffer layer eliminated the Bi deficient region and drastically improved the crystalline quality of the SBT films. No pyrochlore structure was observed even in 45-nm thick SBT films with BiO_x layer. Thinner than 50 nm SBT films applicable for Gbit FeRAM can be grown by our growth method.

1. Introduction

SBT is a promising ferroelectric material for FeRAM (ferroelectric RAM) because of its low switching voltage and high read/write endurance[1]. Very thin ferroelectric films with high quality and good step coverage are needed for the Gbit scale FeRAM production. LS-CVD is effective for obtaining thin ferroelectric films with good step coverage[2,3]. However, crystalline quality of thin SBT films is not necessarily sufficient because Bi deficient region exists near the SBT/Pt bottom electrode interface. Bi deficiency in SBT films induces pyrochlore structure resulting in the capacitor performance degradation. So, We propose a BiO_x buffer layer inserting between SBT and Pt bottom electrode to compensate the deficient Bi. The purpose of this paper is to present very thin (45 nm) SBT films grown by LS-CVD using BiO_x buffer layer. Our developed SBT film is possibly used for Gbit scale FeRAM.

2. Experiments

SBT films and BiO_x buffer layers were deposited on a $Pt/Ti/SiO_2$ coated Si substrates using LS-CVD. Solid sources of $Sr(DPM)_2$, $Bi(C_6H_5)_3$, and $Ta(O\text{-}iC_3H_7)_4(DPM)$ dissolved in the tetrahydrofuran were vaporized and delivered to a deposition chamber. Deposition temperature and pressure were 400-450℃ and 5-10 Torr, respectively. The deposited SBT/ BiO_x films were annealed at 850℃ with RTA and at 750 ℃ in a furnace. After 0.5-mm diameter Pt upper electrodes were deposited by sputtering through a metal mask, SBT films were annealed at 800℃ in a furnace again.

3. Results and Discussion

Bi composition of the SBT film decreased with decreasing the film thickness as shown in fig. 1. Figure 2 shows XRD intensities of a Bi-layered perovskite structure (BLS) and of a pyrochlore structure in the SBT film. Pyrochlore structure was found to exist predominantly in the Bi deficient region near the SBT/Pt interface. SIMS analysis revealed that the Bi diffusion into the Pt electrode decreased Bi composition of the SBT films.

Figure 3 shows XRD pattern of a BiO_x layer deposited on the Pt electrode, which indicates the deposited BiO_x is BiO with a tetragonal structure or Bi_2O_3 with a cubic structure. Then we examined optimum thickness of the BiO_x buffer layer. Figure 4 shows XRD intensity of a BLS and a pyrochlore structure obtained in 80-nm thick SBT layers on 2.5-20-nm thick BiO_x buffer layers. No pyrochlore structure was found in the SBT grown on 5 nm or thicker BiO_x buffer layers. It is supposed that thinner than 5 nm BiO_x buffer layer does not completely cover the Pt surface due to island growth of the BiO_x. No XRD signal from pyrochlore structure was observed in even 45-nm thick SBT film grown on 10-nm thick BiO_x buffer layer as shown in fig. 5. These data indicate that thinner than 50 nm SBT for Gbit scale FeRAM production can be produced by our growth method.

Summary

We have developed high quality SBT films by liquid source CVD using BiO_x buffer layer. BiO_x buffer layer. is found to eliminate the Bi deficient layer existing near the SBT/Pt interface. Thinner than 50 nm SBT films applicable to Gbit scale FeRAM will be produced by optimizing our growth method.

References

[1] C. A. Paz de Araujo et al., International Patent Publication WO93/12542 (1993).
[2] T. Ami et al., Mat. Res. Soc. Symp. Proc. **415**, p. 195 (1996).
[3] T. Jimbo et al., Proc. 15th Meet.

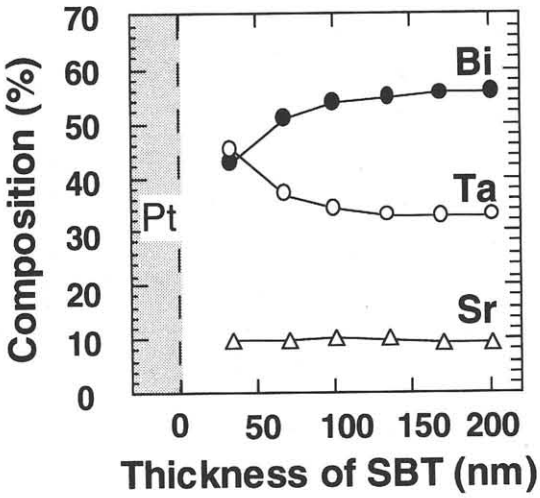

Fig. 1. SBT thickness dependence of the Sr, Bi and Ta composition ratio obtained by ICP atomic emission spectrometry. Bi ratio decreases near the SBT/Pt interface.

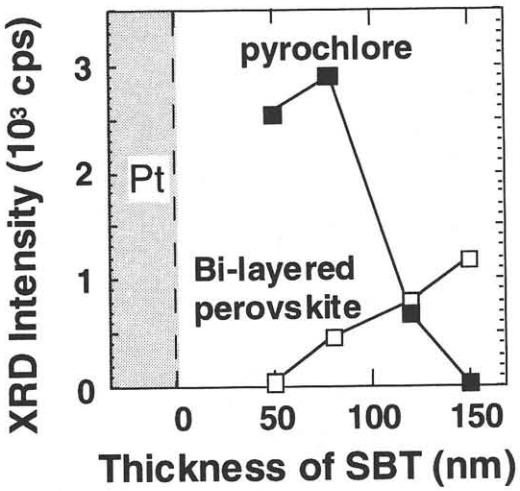

Fig. 2. X-ray diffraction intensities of (222) pyrochlore structure and Bi-layered perovskite structure in the SBT. Pyrochlore structure predominantly exists near the SBT/Pt interface.

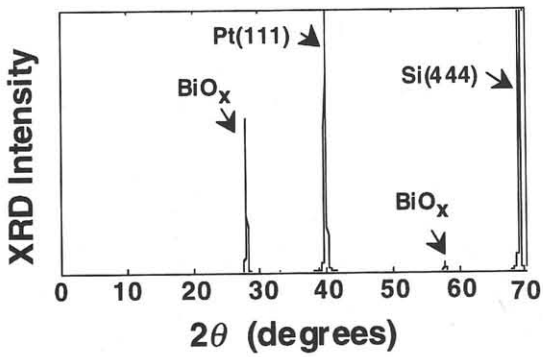

Fig. 3. X-ray diffraction pattern of the BiOx buffer layer. Highly oriented crystaline BiOx is found to grown on Pt. This BiOx can be identified with a tetragonal BiO or a cubic Bi_2O_3.

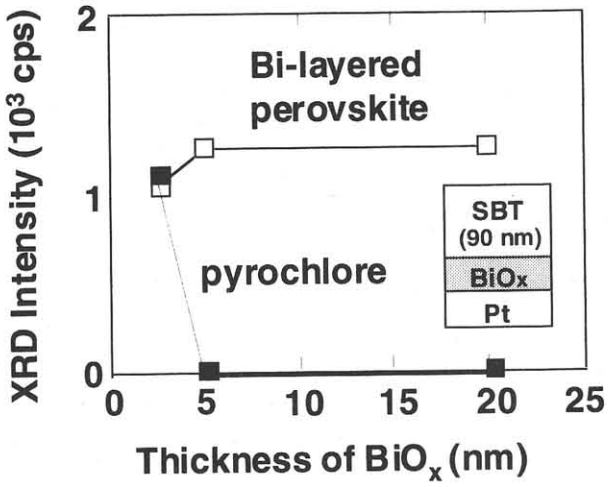

Fig. 4. Relation between BiOx buffer layer thickness and X-ray diffraction intensities of (222) pyrochlore structure and (105) Bi-layered perovskite structure taken from 90-nm thick SBT on BiOx buffer layer. There is no pyrochlore structure in SBT on 5 nm or thicker BiOx.

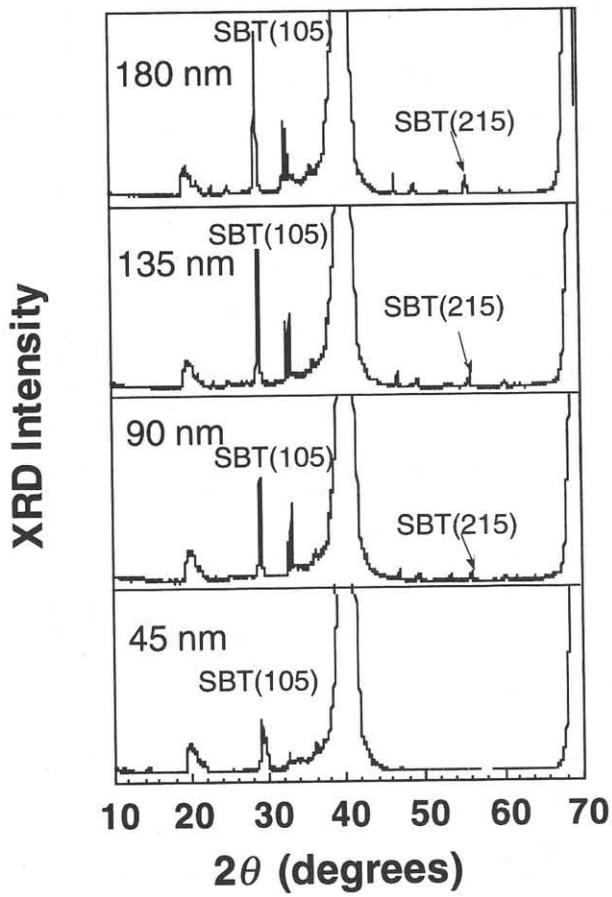

Fig. 5. X-ray diffraction pattern of 45-180 nm thick SBT films deposited on 10-nm thick BiOx buffer layers. No pyrochlore structure is observed even in a 45-nm thick SBT film.