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The effect of the substrate temperatures of Bi_2O_3 buffer layers on the ferroelectric properties of SBT ($SrBi_2Ta_2O_9$) thin films deposited by an R.F. magnetron sputtering method

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Bi_2O_3 buffer layers were deposited on Pt/Ti/SiO_2/Si substrates by an R.F. magnetron sputtering method in order to improve the ferroelectric properties of SBT ($SrBi_2Ta_2O_9$) thin films. The volatility of bismuth brings about an obvious non-stoichiometry of the SBT thin films and causes secondary phases to appear. The Bi_2O_3 buffer layers were found effective in achieving a lower crystallization temperature and in interrupting the diffusion of Pt towards SBT thin films. In this experiment, we have found that the presence of Bi_2O_3 buffer layers was responsible for the enhanced ferroelectric properties and crytallinities of SBT thin films.

Key words: Ferroelectric film, $SrBi_2Ta_2O_9$ (SBT), Bi_2O_3 buffer layer, Substrate temperature.

Introduction

There have already been many researches on ferroelectric thin films as memory devices [1-4]. Among many types of ferroelectric thin films, $SrBi_2Ta_2O_9$ (SBT) thin film is a well known member of a layer-structured family showing promising characteristics-such as fatigue endurance, tendency to leave little imprints, and low leakage current-which raise the film's effectiveness for memory devices [5]. However, there are two major problems to overcome when one wants to apply SBT thin films as memory devices: the low remnant polarization and the high process temperature. The use of many kinds of buffer layer has been studied to enhance the ferroelectric properties of SBT thin films. In this study, we performed experiments in which we tried to repress the volatility of bismuth and the diffusion of Pt by introducing Bi_2O_3 buffer layers. We deposited Bi_2O_3 buffer layers at several substrate temperatures and examined the crystallinities and ferroelectric characteristics arising therefrom.

Experimental Details

We used a 50.8 mm diameter SBT ceramic target and substrates of p-type Si (100) wager of 1-2 Ω. In order to the glue bottom Pt electrodes and Si wafer together, we deposited Ti layers by a D.C. magnetron sputtering method at 300 °C. Also we deposited the bottom Pt electrodes at 300 °C by a R.F. magnetron sputtering method. After that, we deposited the Bi_2O_3 buffer layers on the Pt/Ti/SiO_2/Si(100) substrates. For the deposition of Bi_2O_3 buffer layers, the substrate temperatures were room temperature, 300 °C and 500 °C. Further, we deposited SBT ferroelectric thin films on Bi_2O_3/Pt/Ti/SiO_2/Si(100) substrates. For this deposition, we maintained the substrate temperature at 500 °C and the working pressure at 1.24 Pa. After the deposition, we annealed the films at 800 °C for 2 minutes. The conditions for the deposition of each film are shown at Table 1. We carried out an X-Ray diffraction to analyze the crystal structures and the preferred orientations of the SBT thin films. Also, we measured the ferroelectric behavior of the SBT thin films using Precision LC (Radient Technologies, Inc.) in the range between −7 V and 7 V in voltages. Further we analyzed the composition depth profiles of the SBT/Bi_2O_3/Pt/Ti/SiO_2/Si structures using a glow discharge spectrometer (GDS, JY 10000RF, Jobin Yvon, France).

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Results and Discussion

Fig. 1 shows the XRD patterns of $SrBi_2Ta_2O_9$ (SBT) films deposited on Bi_2O_3Pt/Ti/SiO_2/Si substrates with various

Table 1. Typical Deposition Conditions for Bi_2O_3, $SrBi_2Ta_2O_9$ Thin Films

Thin film	Bi_2O_3	SBT
Base pressure	4.66×10^{-3} Pa	4.66×10^{-3} Pa
Working pressure	1.24 Pa	1.24 Pa
Power	80 W (RF)	120 W (RF)
Sputtering gas	Ar : O_2 (9 : 1)	Ar : O_2 (9 : 1)
Substrate temperature	Room temperature ~500 °C	500 °C

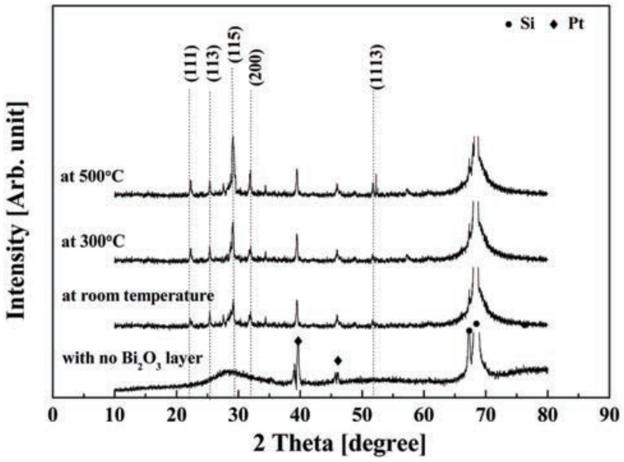

Fig. 1. The XRD patterns of SBT(450 nm) / Bi_2O_3(45 nm) / Pt / Ti / SiO_2 /Si structures annealed by the rapid thermal annealing (RTA) at 800 °C for 2 minutes.

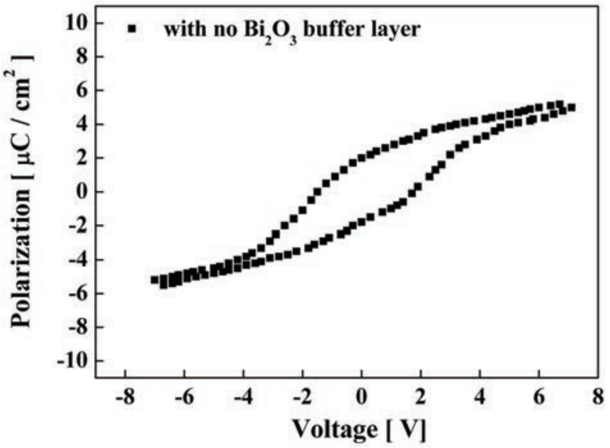

Fig. 2. The polarization curve of SBT(450 nm) / Bi_2O_3(45 nm) / Pt / Ti / SiO_2 /Si structure annealed by RTA at 800 °C for 2 minutes with no Bi_2O_3.

substrate temperatures of the Bi_2O_3 buffer layer. The lowest pattern of Fig. 1 is that of a SBT with no Bi_2O_3 buffer layer. The $SrBi_2Ta_2O_9$ (SBT) films with no buffer layer were amorphous. However the SBT films with Bi_2O_3 buffer layers crystallized, and the SBT thin films with Bi_2O_3 buffer layers deposited at 500 °C were observed to have good crystallinity. With the Bi_2O_3 temperature at 500 °C, the patterns showed the (111), (113), (200) and (115) peaks of the perovskite SBT thin film. The (115) and (200) peaks were more prominent than the (111) and (1113) peaks. Fig. 2 shows the P-E hysteresis loop of the SBT thin film with no Bi_2O_3 buffer layer, and shape indicates an incomplete saturation. The SBT thin film deposited with no Bi_2O_3 buffer layer was observed to have a poor ferroelectric property. The SBT thin films have a shortcoming that their remnant polarization is low, and this fact is well borne out by Fig. 2. Fig. 3 shows the P-E hysteresis loops of the SBT thin films with Bi_2O_3 buffer layers deposited at various substrate temperatures. Clearly, The SBT thin films with Bi_2O_3 buffer layers

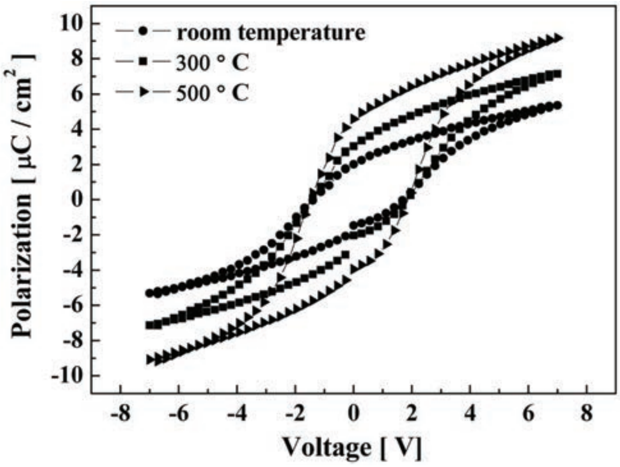

Fig. 3. The polarization curves of SBT(450 nm) / Bi_2O_3(45 nm) / Pt / Ti / SiO_2 /Si structures annealed by RTA at 800 °C for 2 minutes with Bi_2O_3 at various substrate temperatures, room temperature, 300 °C and 500 °C.

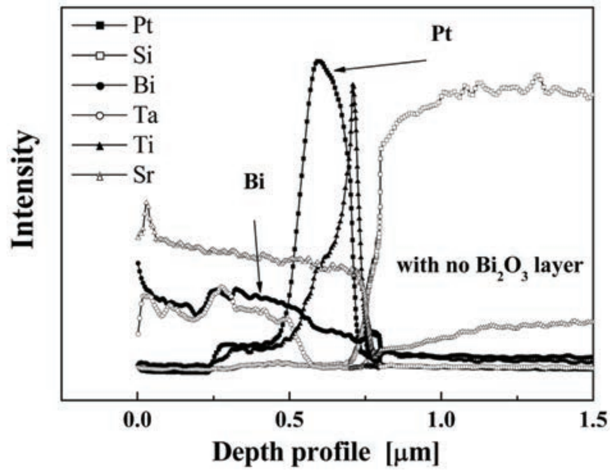

Fig. 4. The GDS (glow discharge spectrometer) results of SBT / Pt / Ti / SiO_2 / Si structures.

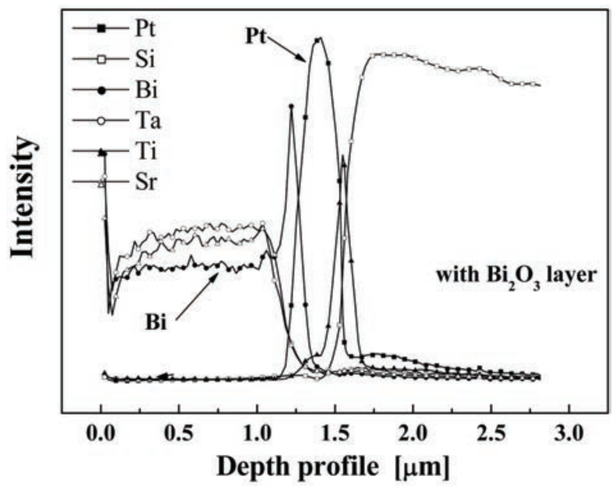

Fig. 5. The GDS (glow discharge spectrometer) results of SBT / Bi_2O_3 / Pt / Ti / SiO_2 / Si structure with a Bi_2O_3 buffer layer deposited at the substrate temperature of 500 °C.

deposited at 500 °C showed more superior ferroelectric properties. Fig. 4 shows the GDS profiles of SBT/Pt/Ti/SiO_2/Si films and Fig. 5 shows the GDS profiles of SBT/Bi_2O_3/Pt/Ti/SiO_2/Si films. The bismuth on the surfaces of the SBT is very volatile during the annealing process. Therefore, it is important to prevent bismuth from volatilizing. It is also important to prevent Pt from diffusing into a SBT thin film. From the results of the GDS analysis, we conclude that the presence of Bi_2O_3 buffer layers interrupts the diffusion of Pt into the SBT thin films and the volatilization of bismuth from SBT thin films.

Conclusions

In this paper, we studied the effect of Bi_2O_3 buffer layers on the crystallinities and the ferroelectric properties of SBT thin films from the perspective of substrate temperatures of Bi_2O_3 buffer layers. We found that the presence of Bi_2O_3 buffer layers help enhance the crystallization of SBT thin films, and that the crystallinities and ferroelectric properties improved as the substrate temperatures of Bi_2O_3 was increased. From these findings, it seems to us that the Bi_2O_3 layer between SBT thin films and Pt electrodes prevents the diffusion of Pt into the SBT thin films and the volatilization of bismuth from the SBT thin films.

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