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The surface morphologies of (Pb,Sr)TiO_3 thin film fabricated on Si-buffered Pt/Ti/SiO_2/Si substrate

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Abstract: (Pb,Sr)TiO_3 (PST) thin film are fabricated by RF magnetron sputtering on Si-buffered Pt/Ti/SiO_2/Si substrates with different buffer layer deposition time. Surface morphologies of the buffer layer indicate an improving surface roughness and larger grains with the prolongation of sputtering time. Deposition of PST thin films shows excellent surface fluctuation filling ability to improve the surface roughness of substrates. PST surface morphologies exhibit apparently different grain forms according to the preparation time durance of buffer layer.

Key words: (Pb,Sr)TiO_3 thin film, Si buffer layer, RF magnetron sputtering

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1 Introduction

(Pb,Sr)TiO_3(PST) thin film has great potentials in the application of microelectronic devices such as tunable microwave filters, infrared detectors, DRAM, etc[1-3]. Preparation of PST thin films can be achieved by many methods including PLD and sol-gel[4]. Perovskite thin film such as (Ba,Sr)TiO_3(BST) prepared on Pt/Ti/SiO_2/Si substrates has considerably higher dielectric loss compared with corresponding bulk materials, O^{2-} vacancies generated on the interfaces between electrode and the thin film are considered to be the main course. The doping of SiO_2 or the adopting of SiO_2 buffer is reported to improve the dielectric loss of BST thin film significantly[5]. PST has the same perovskite structures as that of BST. Dielectric loss of PST applied near transmission temperature is higher than that of BST thin film, so we tried to fabricate PST thin film on Si-buffer-layer fabricated at oxidation environments. In this paper, we investigated the surface structures of the buffer layer and the surface morphology evolution of PST thin films fabricated on Si-buffer layer with different sputtering times.

2 Experimental

2.1 Preparation of substrates

Pt/Ti/SiO_2/Si substrates were prepared by traditional microelectronic process, including the thermal-oxidation of SiO_2 layer, the deposition of Ti and Pt by magnetron sputtering, finally fast-heat-treated at 700℃ for 1 minute. Thickness of Ti and Pt layer is 70nm and 120nm, respectively. Si layer was deposited

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on the surface of prepared Pt electrode by RF magnetron sputtering. Si(100) single crystal was adopted as the sputtering target, with a thickness of 3mm and a radius of 68mm. Buffer layer were prepared on Pt/Ti/SiO_2/Si substrates by RF magnetron sputtering for 0.5 hour, 1 hour and 2 hours, respectively. These buffered substrates were named as substrate-1, 2 and 3, respectively. The deposition was carried out at low temperature as 300℃ in order not to worsen the surface of the electrodes.

2.2 Preparation of PST thin films

PST thin films were fabricated by sputtering PST targets with Ar/O_2 mixed gases at 400℃ for 8 hours, on the buffered substrates prepared with different sputtering time. The sputtering target was prepared by traditional ceramics process, in the size of Φ68 mm×3 mm. The ratio Pb/Sr in PST is 3/7 to be suitable for applications at room temperature[6].

Detailed processing parameters of buffer layer and PST thin films are listed in Table 1.

Table 1 Processing parameters to prepare Si and PST thin films

	Substrate Tem./℃	Ar /($cm^3 \cdot min^{-1}$)	O_2 /($cm^3 \cdot min^{-1}$)	Sputtering pressure/Pa	Distance between target & substrates/mm	RF power /W	Sputtering time/h
Si	300	14.1	20	2.0	50	60	0.5, 1, 2
PST	400	17.6	12.5	1.5	40	60	8

2.3 XRD and AFM morphology observations

X-ray diffraction was carried out on Philips APD—10 type diffractometer. Surface morphologies of the thin films were observed by AJ—III type AFM.

3 Results and discussion

3.1 XRD of buffer layer

Typical θ—2θ scan XRD pattern of the buffered substrates prepared at 300℃ with a sputtering power of 50W for 0.5, 1 and 2 hours are shown in Fig.1. With short sputtering time as half an hour, the XRD pattern of the substrates shows only the Pt (111) and Pt (200) peaks. When preparation time exceeds 1 hour, the diffraction peak of Si(200) becomes apparent. For substrate-1, diffraction peak of buffer layer is invisible, which maybe attributed to the low sputtering power and insufficient grain growth.

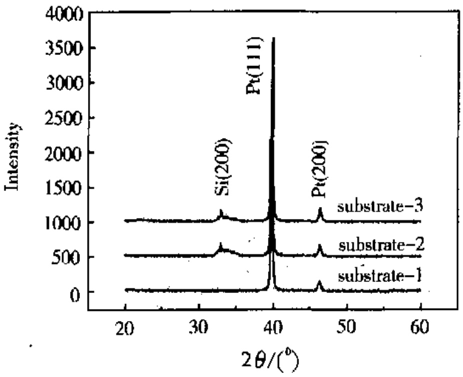

Fig.1 XRD patterns of Si-buffered Pt/Ti/SiO_2/Si substrates

3.2 Surface morphology of buffer layer

Fig.2 gives the AFM surface observation results for the buffered substrates. Surface roughness of the substrate surface is improved with the increasing of sputtering time. For substrate-1, maximum surface fluctuations is about 100 nm and the form of grain alignments is not apparent; for substrate-2 and substrate-3, maximum surface fluctuations are reduced to near 80nm. Larger size grains could be found on the surface of substrate-3, which corresponds to the apparent diffraction peaks of buffer layer in XRD pattern with increasing sputtering time.

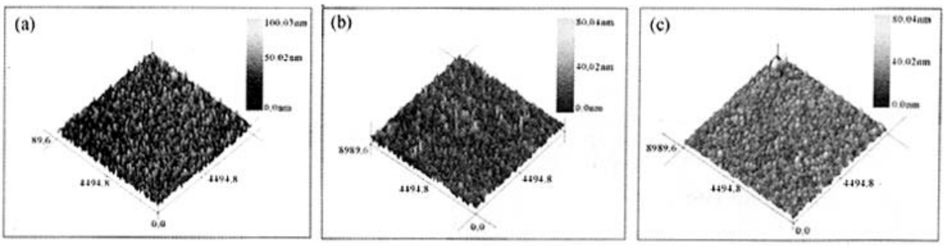

Fig.2 AFM surface morphologies of Si-buffered Pt/Ti/SiO_2/Si substrates(a), (b) and (c)

3.3 PST thin films

X-ray diffraction patterns of PST thin films fabricated on Si-buffered Pt/Ti/SiO_2/Si substrates are illustrated in Fig. 3. Diffraction peak intensity of PST(100), (111) and (200) is not as high as that of thin film fabricated directly on Pt electrode, which indicates a weaker crystallinity. (111) preferred orientation Pt electrodes has good compatibility with PST thin films because the d-space value between Pt(111) and PST(111) differs not so much. It can be concluded that the sputtering time of Si buffer layer should be appropriate to be sufficiently crystallized and provide possibility of better crystallization for afterward prepared PST thin films at the same time.

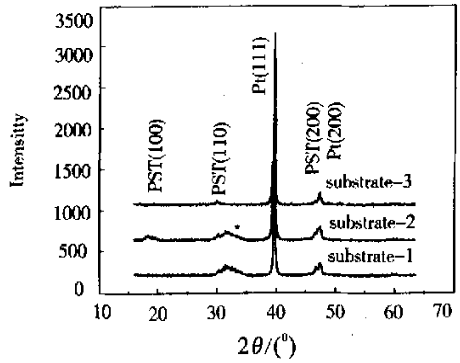

Fig.3 XRD pattern of PST thin films fabricated on Si-buffered Pt/Ti/SiO_2/Si substrates

AFM surface morphologies of PST thin films fabricated on Si-buffered substrates are shown in Fig. 4. It can be clearly seen that the deposition of PST thin films on Si buffer layer significantly improved the surface roughness of the samples, showing excellent surface fluctuation filling abilities. The *rms* for the three samples is 5.602, 4.215 and 3.792 nm respectively, which is also in accordance to the improvements of buffer layer surface morphologies with the increasing of sputtering time.

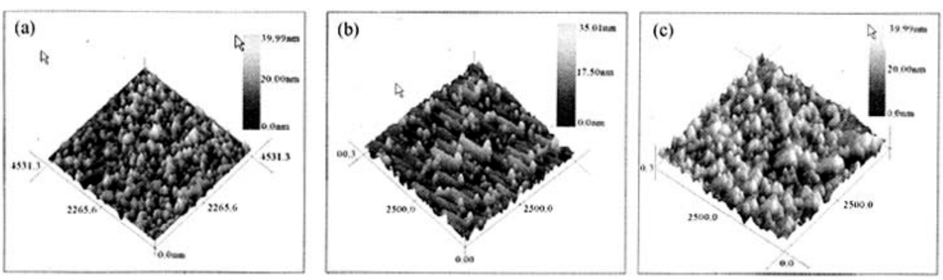

Fig. 4 AFM surface morphologies of PST thin film fabricated on Si-buffered Pt/Ti/SiO_2/Si substrates(a), (b) and(c)

It can also be noticed that PST thin film fabricated on substrate(a) shows grains with even sizes. For PST thin films deposited on substrate(b), column like grains appears, most part of them aligns on parallel direction with the thin film plane, with other small grains distributing inside. For PST thin films prepared on substrate(c), grain sizes become larger, and the column grains are aligning along the direction nearly vertical to the thin film plane. The origin of PST surface morphology evolution on these buffered substrates is yet known. From the XRD results in Fig.3 and the similarity between Fig.4(a) and Fig.4(c), PST(110) peak near Si(200) for thin film fabricated on substrate(b) may have decisive influences.

4 Conclusions

We prepared PST thin films by RF magnetron sputtering on Si-buffered $Pt/Ti/SiO_2/Si$ substrates. The influence of sputtering time of buffer layer on crystallinity and surface morphologies of PST thin films are discussed. Experimental results indicate a better crystallinity and surface roughness of buffer layer with the prolongation of sputtering time. Deposition of PST thin films on buffered substrates exhibits excellent surface fluctuation filling effect. PST thin films on different buffered substrates show column grains with different size and different alignment directions to the reference of thin film surface plane.

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