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Fatigue Characteristics of $(Bi,La)_4Ti_3O_{12}$ Thin Films by RF Magnetron Sputtering

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It is well known that Bi-layer compound, $SrBi_2Ta_2O_9$ shows good fatigue characteristic which is one of the important properties for FRAM applications. In this paper, we report on fatigue characteristics of $(Bi,La)_4Ti_4O_{12}$ thin films on Pt(100)/MgO(100) and Pt(111)/glass substrates prepared by rf magnetron sputtering. The thin film on Pt(100)/MgO(100) substrate has comparatively good fatigue characteristics in the following; initial state, Pr=7.5 $\mu C/cm^2$, Ec=174kV/cm and 10^9 pulsed state, Pr=5.7 $\mu C/cm^2$, Ec=117kV/cm.

1. INTRODUCTION

The interest in the use of the ferroelectric thin films for memory applications has increased in the recent years.[1] If they will be used as a capacitor of DRAM, films with relatively small dielectric constants are required. On the other hand, films with relatively small dielectric constants are useful for application to non-volatile ferro-DRAM(FRAM). Therefore, precise control of the film composition is essential for both applications.

It is well known that among these ferroelectric materials, Bi-layer compound such as $SrBi_2Ta_2O_9$(Y-1) shows good fatigue characteristic which is one of the important properties for FRAM[2]. In this paper, we report on fatigue properties of Bi-layer compound; $(Bi,La)_4Ti_3O_{12}$ thin films prepared by rf magnetron sputtering for FRAM applications.

2. EXPERIMENTAL

$(Bi,La)_4Ti_3O_{12}$(BTL) thin films were prepared using a conventional rf-magnetron sputtering with ceramic powder target under the condition as listed in Table 1. The target powder was fired at 1023K for 2h. A gold film was sputtered for the top electode.

The chemical composition of the films was determined by the inductively coupled plasma method (ICP). Thin-film crystallography was performed by X-ray diffraction (monochromatized CuKα radiation). The typical film thickness by the surface profilometer was about 400nm.

The dielectric constant was measured with a Hewlett-Packard (HP-4194A) impedance analyzer at 1kHz. Ferroelectric properties were measured using a Radiant Technology RT66A tester operating in the virtual ground mode. The period of measurement of the hysterisis loop was 9.6ms.

Table 1 Sputtering condition

Target	Bi_2O_3 : La_2O_3 : TiO_2 =2.065 : 0.25 : 3
Substrates	MgO(100),glass, Pt(100)/MgO(100), Pt(111)/glass
Substrate temp.	888 K
Sputtering gas	Ar : O_2=9 : 1
Gas pressure	0.39 Pa
RF input power	100 W

3. RESULTS AND DISCUSSIONS

Figure 1 shows the crystal structures of the films. Only perovskite structure is found in these figures. The ICP analyses represent that this film has the composition of $(Bi_{3.56}La_{0.57})Ti_3O_{12}$. The orientations of the thin films are affected by the kinds of substrates. The films on MgO(100) and glass have good c-axis orientation. However, the films on Pt(100)/MgO(100) and Pt(111)/glass have the mixed (117) plan and c-axis orientation.

The dielectric constant(ε_r) for the BLT thin films on Pt(100)/MgO(100) and Pt(111)/glass were 112 and 161, respectively. It is noted that the films on Pt(100)/MgO(100) have lower ε_r compared to the films on Pt(111)/glass, which was attibuted to the difference in the film orientation.

D-E hystresis loops of the BLT thin films deposited on Pt(100)/MgO(100) and Pt(111)/glass before and after 10^9 switching cycles, are shown in Fig.2. Pr decreased and loop shifted to the right. Similar shifts were observed in the other films[3].

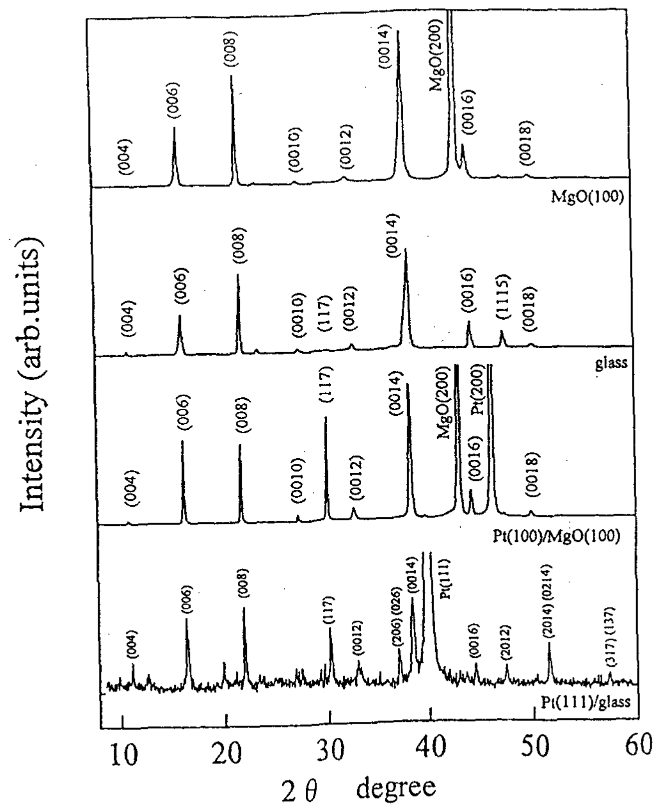
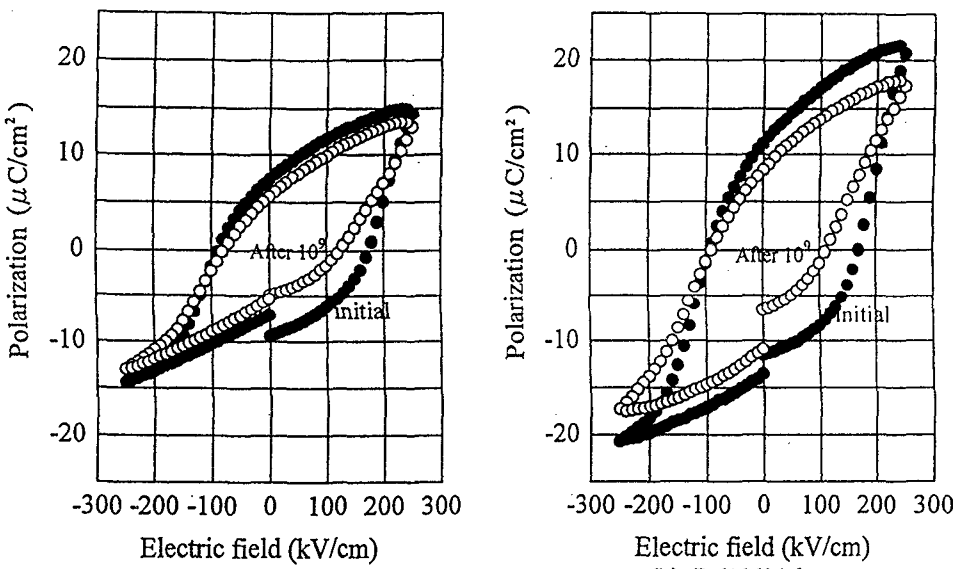


Fig. 1 X-ray diffraction patterns of $(Bi,La)_4Ti_3O_{12}$ thin films on various substrates.

Figure 3 represents fatigue chractristics of the BLT thin films deposited on various substrates. Pr* and Pr^ refer to switched and non-switched remanent polarization, respectively. The difference (Pr*-Pr^) is equivalent to 2Pr(assuming a symmetric loop). After 10^9 switching cycles, (Pr*-Pr^) of the films on these substrates decreased slightly due to fatigue. It is found from these figures that the thin film on Pt(100)/MgO(100) substrate has fairly good fatigue characteristics after application of 10^9 pluses.

The scheme for minimizing fatigue with ordinary metal electrode (for example Pt) is to modify the



(a) Pt(100)/MgO(100) (b) Pt(111)/glass

Fig. 2 D-E hysteresis loops of $(Bi,La)_4Ti_3O_{12}$ thin films on (a) Pt(100)/MgO(100) and (b) Pt(111)/glass substrates before and after fatigue.

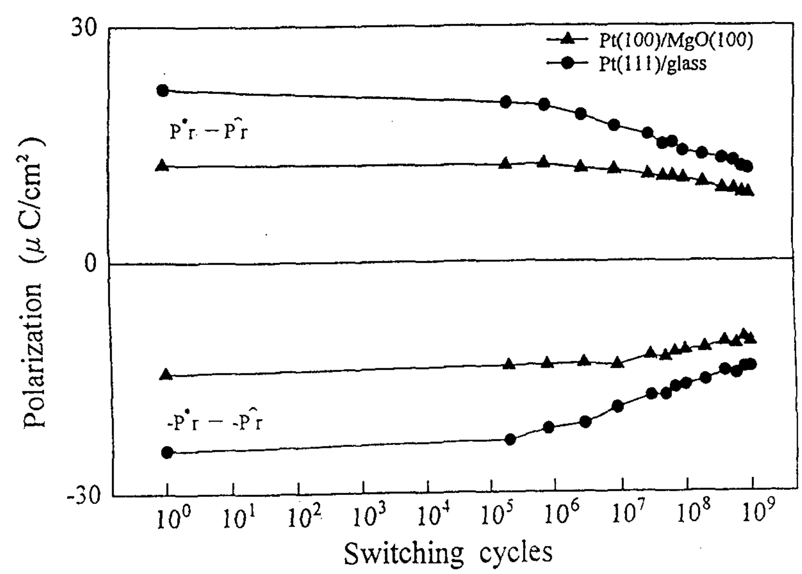


Fig. 3 Fatigue properties of $(Bi,La)_4Ti_3O_{12}$ thin films on Pt(100)/MgO(100) and Pt(111)/glass substrates.

ferroelectrics. Such modification can be done by employing a more complicated ferroelectrics of the layered-structure provskite oxide family epitomized by $SrBi_2Ta_2O_9$ and $SrBi_2NbTaO_9$[4]. $(Bi,La)_4Ti_3O_{12}$ based thin films are also expected to be adeqate materials for non-volatile RAM device applications because of lack of fatigue.

4. CONCLUSIONS

We will summarize our results as follows;

1) Single perovskite type compound of $(Bi_{3.56}La_{0.57})Ti_3O_{12}$ was prepared by rf sputtering method.

2) C-axis orientation was obtained for MgO(100) and glass substrates.

3) The thin film on Pt(100)/MgO(100) substrate showed fairly good fatigue properties in the following; initial state Pr=7.5 $\mu C/cm^2$, Ec=174kV/cm and 10^9 pulsed state, Pr=5.7 $\mu C/cm^2$, Ec=117kV/cm.

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