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Comparison of the effect of PLT and PZT buffer layers on PZT thin films for ferroelectric materials applications

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Abstract

In order to study the effect of different buffer layers on the $Pb(Zr_{0.52}Ti_{0.48})O_3$ (PZT) thin films, 10-nm thick $(Pb_{0.72}La_{0.28})Ti_{0.93}O_3$ (PLT) and $Pb(Zr_{0.52}Ti_{0.48})O_3$ buffer layers have been deposited on the Pt(1 1 1)/Ti/SiO_2/Si substrates by pulsed laser deposition, respectively. The top buffer layers were also deposited on PZT thin films with the same thickness of the seed layers in order to enhance the fatigue characteristics of PZT thin films. We compared the results of dielectric constant, hysteresis loops and fatigue resistance characteristics. It was found that the dielectric properties of PZT thin films with PLT buffer layers were improved by comparing with PZT thin films with PZT buffer layers. The polarization characteristics of PZT thin films with PLT buffer layers were observed to be superior to those of PZT thin films using PZT buffer layers. The remanent polarization of PZT thin films showed 36.3 $\mu C/cm^2$ and 2.6 $\mu C/cm^2$ each in the case of use PLT and PZT buffer layers. For the switching polarization endurance analysis, PZT thin films with PLT buffer layers showed more excellent result than that of PZT thin films with PZT buffer layers.

Keywords: PZT thin films; Buffer layers; Ferroelectric characteristics

1. Introduction

In recent years, many applications studies have been carried out for the ferroelectric materials in the development of new materials for the Ferroelectric Random Access Memory (FRAM) technology fields. Lead zirconate titanate, $Pb(Zr_{0.52}Ti_{0.48})O_3$ (PZT) ferroelectric thin film capacitors have been studied over the past few years as candidates for use in non-volatile memories [1,2]. Because of their excellent ferroelectric properties, such as high remanent polarization [3] and low coercive filed, PZT thin film can be possible to use in non-volatile memories. The larger remanent polarization determines the abilities of information data storage, and the lower coercive field can lead the lower operating switching voltage. However, the poor fatigue resistance which is related to the reliable polarization cycling must be overcome before practical application for the FRAM memories [4–6]. In order to improve the polarization fatigue characteristics of PZT thin films, many studies on a donor doping with trivalent cation, such as La^{3+}, Eu^{3+} and Ce^{3+}, have been carried out extensively [7].

The $Pb(Zr_{0.52}Ti_{0.48})O_3$ thin films which are regarded as the next generation materials with the buffer layers for the FRAM have the excellent characteristics of remanent polarization and fatigue resistance. It has been reported that the $(Pb_{0.72}La_{0.28})$-$Ti_{0.93}O_3$ (PLT) as buffer layers played a suitable role for the enhancement of the ferroelectric property of PZT films as reported by Lee et al. [8]. This is mainly due to the similarity in chemical and structural characteristics between PLT buffer layers and PZT thin films. These properties are helpful to form the better crystallization of PZT thin films. Because PLT buffer layers have perovskite structure which PZT thin films have, it can make the perovskite phase of PZT thin films strong and the ferroelectric properties enhance. Additionally, the existence of La^{3+} of PLT materials decreases the drift mobility of oxygen vacancies which cause the fatigue degradation and could attain the purpose to improve the fatigue resistance endurance.

In this study, we examined the effect of the double-sided 10-nm thick PLT and PZT buffer layers on PZT thin films, respectively. To confirm the epitaxial growth, the crystalline orientation of PZT thin films was investigated by general X-ray

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diffraction measurement. The dielectric constants, effective polarization and fatigue characteristics of PZT thin films have been investigated with the comparative analysis of experimental data.

2. Experimental

Two kinds of the capacitors were prepared for this study. Each capacitor has the sandwich structure, one is PLT/PZT/PLT heterostructure and the other one is PZT/PZT/PZT homostructure. PLT and PZT thin films were deposited by pulsed laser deposition (third-harmonic 355 nm Quantel Brilliant Q-switched Nd:YAG laser) method [9]. The laser power was fixed at 0.7 W and the repetition rate was controlled at 5 Hz. Both PZT films and PLT buffer layers were deposited by use a laser with an energy density of 3 J/cm^2. A quartz lens located outside the chamber was used to adjust the laser-beam fluence on the target surface. The substrate was positioned 5 cm away from the target. To fabricate PLT/PZT/PLT heterostructure, PZT thin films were deposited for 10 min and PLT buffer layers were deposited for 15 s before or after deposition of PZT thin films [8]. In the process of deposition, the substrate temperature of 550 °C at the oxygen pressure of 200 mTorr was controlled by MFC controller. PZT/PZT/PZT homostructure was also fabricated under the same process condition as PLT/PLT/PLT capacitor, except the deposition time of PZT buffer layers controlled for 10 s was different from that of PLT buffer layers, which was followed by the deposition rate of materials. Each of the PZT layers was annealed for 10 min at oxygen ambient after deposition. The thickness of PLT and PZT buffer layers was estimated to be about 10 nm and that of PZT was about 600 nm, based on their deposition rate per pulse. For electrical measurements, Au dots were thermally evaporated for being used as a top electrode on the deposited films.

The structural properties of the sample were investigated by using X-ray diffraction (XRD) where a Ni-filtered Cu Kα ($\lambda = 1.5418$ Å) source was used. Dielectric properties were investigated from the *C–V* observation with the applied voltage of −10 V to +10 V by the HP4284 (Hewlett Packard, USA) tester. Hysteresis and fatigue were observed by the RT-66A ferroelectric tester. The fatigue tests were performed by use a square wave with the amplitude of −10 V to +10 V and a frequency of 1 MHz. The square wave was produced by a function generator externally connected to the RT-66A tester.

3. Results and discussion

Fig. 1(a and b) shows X-ray diffraction patterns of double-sided buffer layers of PLT or PZT on the PZT thin films. (1 1 1) orientation was found at 38.5° both in PLT/PZT/PLT and PZT/PZT/PZT capacitors. (1 1 1) orientation mostly contributes to polarization which indicates the information storage capacity

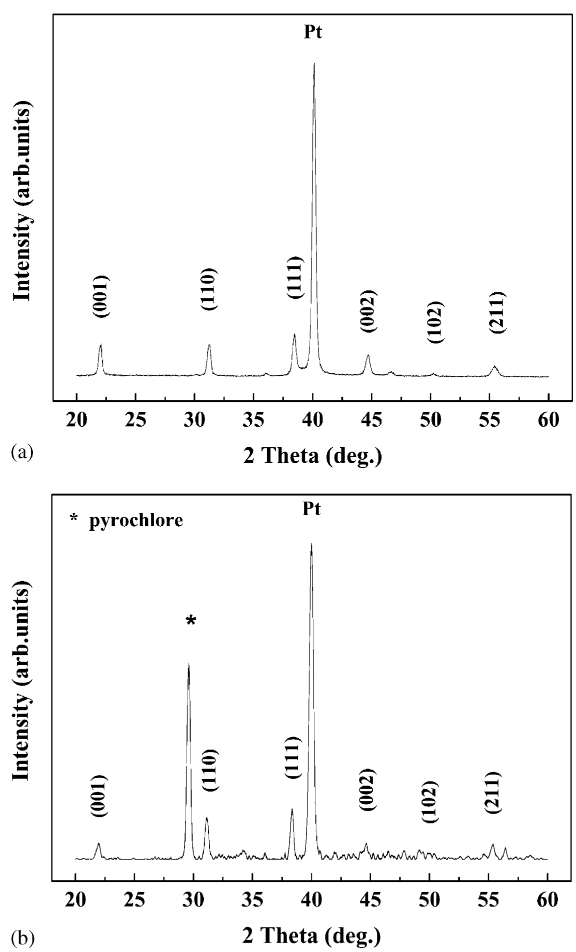

Fig. 1. XRD patterns of: (a) PLT/PZT/PLT and (b) PZT/PZT/PZT capacitors.

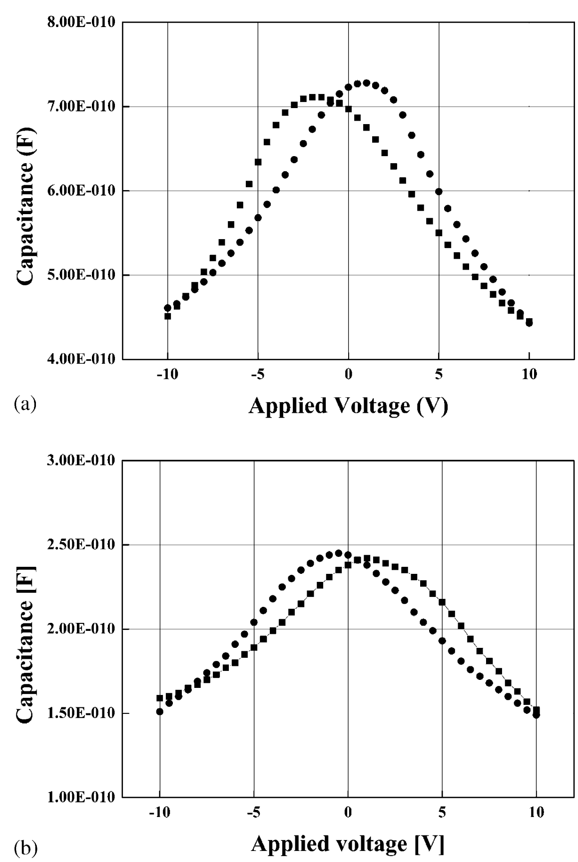

Fig. 2. Capacitance–voltage characteristics of: (a) PLT/PZT/PLT and (b) PZT/PZT/PZT capacitors.