Infrared Physics & Technology 54 (2011) 21–24

Contents lists available at ScienceDirect

Infrared Physics & Technology

journal homepage: www.elsevier.com/locate/infrared

Investigation on preparation and properties of $Pb(Zr_{0.95}Ti_{0.05})O_3$ thin films

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ARTICLE INFO

Article history:
Received 29 July 2010
Available online 2 November 2010

Keywords:
PZT thin films
YBCO
Ferroelectric
Pyroelectric
Infrared detection

ABSTRACT

The preparation process, micro-structure and electrical properties of $Pb(Zr_xTi_{1-x})O_3$ (PZT) thin films were investigated in this paper. The Ag/PZT($x = 0.95$)/YBCO/Si thin films were prepared by pulsed laser deposition (PLD). Si was the substrate; Ag and YBCO were the top electrode and the bottom electrode respectively. The bottom electrode YBCO was deposited on the Si substrate by PLD, and PZT was epitaxially deposited on YBCO also by PLD. After rapidly annealing, the AFM, XRD and the analysis of their electrical characters showed the films had good ferroelectric and pyroelectric properties. At 50 °C, the pyroelectric coefficient (p) was 3.5×10^{-8} C/(cm^2 K), the remanent polarization (P_r) and the coercive field (E_c) were 43.6 μC/cm^2 and 19.3 kV/cm respectively.

1. Introduction

Lead zirconate titanate (PZT) is a perovskite structure ferroelectric material with excellent ferroelectric, piezoelectric and pyroelectric properties, and these properties can be improved by changing the ratio of Zr/Ti and doping [1–4]. PZT films have been widely used in ferroelectric random access memory (FRAM) [5], surface acoustic wave (SAW) devices [6] and infrared detectors. Because of the existence of a low temperature rhombohedral ($F_{R(LT)}$)–high temperature rhombohedral ($F_{R(HT)}$) ferroelectric phase transition in the Zr-rich (Zr > 90 mol%) lead zirconate titanate, when the $F_{R(LT)}$–$F_{R(HT)}$ phase transition is induced by temperature, a nonlinear change of spontaneous polarization occurs, and a large pyroelectric coefficient (p) is obtained. The dielectric constant (ε) and dielectric loss ($\tan\delta$) are low at the same time, and therefore the figure of merit, F_d, as given by

$$F_d = \frac{p}{C_v(\varepsilon \cdot \tan\delta)^{1/2}}$$

is large, where C_v is the molar heat capacity under constant volume. It is well known that there is considerable thermal effect associated with the infrared (IR) radiation. Once the PZT film is heated up by IR radiation, certain amount of pyroelectric current will be observed. Based on the preceding scenario, IR could be detected by measuring the pyroelectric current (showed in Fig. 6). Consequently PZT can be widely used in infrared detection [1,7–10], such as infrared detector and thermal imaging.

Precious metals such as Pt and Au are used as the electrode materials of PZT thin films [11–14]. The main advantages are the better antioxidation, lower specific resistance and greater compatibility with large scale integrated circuits (LSI). But there are many disadvantages such as lattice mismatch with PZT, and PZT thin films also cannot grow epitaxially on them easily. For this reason conductive oxide electrode materials have been paid more attention. Among these, $YBa_2Cu_3O_{7-\delta}$ (YBCO) has excellent electrical conductivity, strong thermal stability, low lattice mismatch with PZT, and PZT thin films can grow epitaxially on it easily. Therefore YBCO is an excellent electrode material for PZT thin films, and special attention has therefore been paid to it, with many investigations on PZT/YBCO heterojunctions having been reported [15,16].

In this work, Ag/PZT($x = 0.95$)/YBCO/Si structured thin films (showed in Fig. 1) were prepared by pulsed laser deposition (PLD). An YBCO buffer layer was deposited on the Si substrate first, and then PZT film was epitaxially deposited on it. The crystalline structure of the PZT films was analyzed by X-ray diffraction (XRD), and the ferroelectric and pyroelectric properties were also measured. The preparation process and the influence of the preparation process on the crystalline structure and properties of PZT films were investigated.

2. Experimental procedures

The PZT film and YBCO buffer layer were prepared by PLD. The laser source was a KrF pulsed excimer laser, and the wavelength was 248 nm. The target was a Zr-rich PZT ceramic, and the Zr/Ti ratio of the target was 95/5. Si was the substrate. YBCO and Ag were the bottom electrode and the top electrode respectively. The background pressure of the vacuum chamber was 10^{-4} Pa using a mechanical pump and turbo-molecular pump, and then O_2 was introduced into the vacuum chamber. During deposition of the YBCO buffer layer, the O_2 pressure was 26 Pa, the substrate

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doi:10.1016/j.infrared.2010.10.003

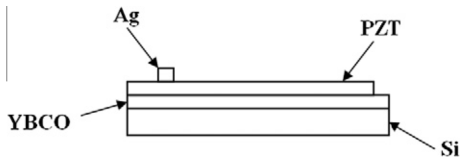

Fig. 1. Ag/PZT/YBCO/Si structured thin film.

Table 1
Annealing conditions and thicknesses of three PZT thin films.

Sample	A	B	C
Annealing conditions	550 °C, 20 min, 100 Pa	600 °C, 20 min, 100 Pa	650 °C, 20 min, 100 Pa
Film thickness	285 nm	316 nm	311 nm

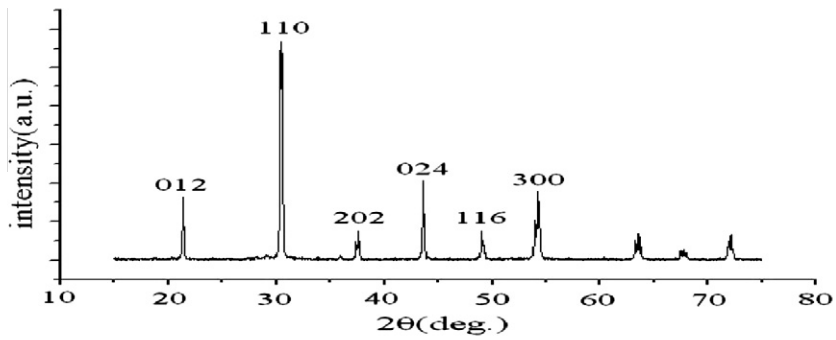

Fig. 2. XRD pattern of $Pb(Zr_{0.95}Ti_{0.05})O_3$ target.

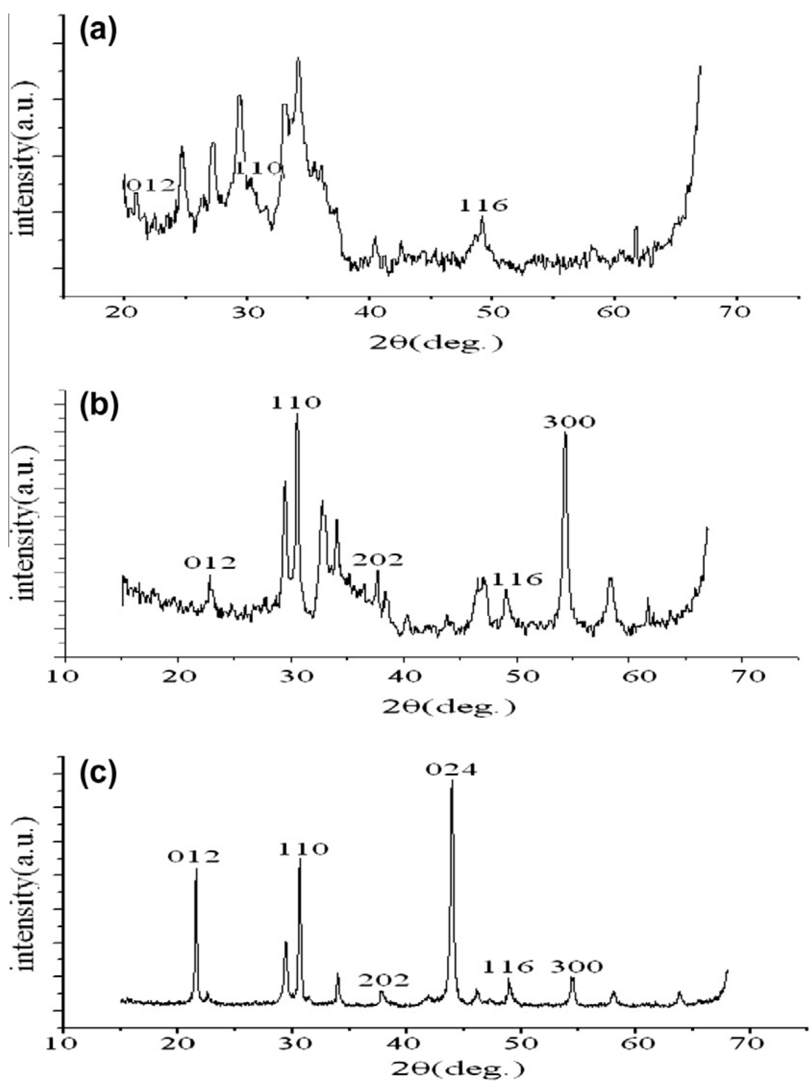

Fig. 3. XRD patterns of three PZT thin film samples. Annealing temperature: (a) 550 °C, (b) 600 °C and (c) 650 °C.