Materials and Design 32 (2011) 2370–2373

Contents lists available at ScienceDirect

Materials and Design

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

Short Communication

Magnetoelectric effect in $Pb(Zr_{0.95}Ti_{0.05})O_3$ and $CoFe_2O_4$ heteroepitaxial thin film composite

K. Tahmasebi [a,*], A. Barzegar [a], J. Ding [b], T.S. Herng [b], A. Huang [c], S. Shannigrahi [c]

[a] Department of Materials Engineering, Shiraz University, Shiraz 7134851154, Iran
[b] Department of Materials Science and Engineering, National University of Singapore, Singapore 119260, Singapore
[c] Institute of Materials Research and Engineering (IMRE), 3 Research Link, Singapore 117602, Singapore

ARTICLE INFO

Article history:
Received 9 August 2010
Accepted 20 November 2010
Available online 26 November 2010

ABSTRACT

Multiferroic epitaxial films, include $SrRuO_3/Pb(Zr_{0.95}Ti_{0.05})O_3/CoFe_2O_4$ has been successfully deposited on $SrTiO_3$ substrate by pulsed-laser deposition technique. The results show that the prepared films exhibit a single phase. The $Pb(Zr_{0.95}Ti_{0.05})O_3$ (PZT) film was highly textured with (1 0 0) orientation and gives good ferroelectric properties with saturated polarization of 15 $\mu C/cm^2$. The magnetic coercivity of $CoFe_2O_4$ film on $Pb(Zr_{0.95}Ti_{0.05})O_3$ has been dampened to 0.9 kOe. The anisotropic magnetically behavior of $CoFe_2O_4$ film was changed to isotropic by using high Zr concentrated PZT as underneath layer. Heterostructure films show a good ferromagnetic and ferroelectric coupling that lead to the large magnetoelectricity of 287 mV/cm Oe.

1. Introduction

Magnetism and ferroelectricity are essential phenomena to many forms of current technology and industrial applications and the quest for multiferroic materials. Where these two phenomena are intimately coupled, is of technological and fundamental importance. Magnetoelectric multiferroic materials offer the possibility of manipulating the magnetic state by an electric field or vice versa and are of current interest and potential for tunable multifunctional devices [1–6]. In recent year, much of the excitement regarding multiferroic compounds stems from the observation of magnetoelectric (ME) effect in two phase (heterojunction thin films) composite multiferroic made by combining ferroelectric and ferromagnetic substance together. Typical examples are: $BaTiO_3/CoFe_2O_4$ [7] and $PZT/La_{0.7}Sr_{0.3}MnO_3$ [8]. In comparison to bulk composites, ME composite thin films present some unique advantages. Their phase composition could be modified or controlled at nanoscale, offering a technical way to study the ME physical mechanism in nanoscale and potential applications in microelectronic devices. The ME effect in the multilayer thin film deposited on the stiff substrate would be small due to the clamping effect of the substrate, since the ME coupling in such a composite system is through elastic interactions [9].

Among the ferroelectric materials, bulk PZT has long regarded as best candidate for ferroelectric materials owing to its superior piezoelectric properties, polarization and low leakage current [10–12]. However, most of PZT thin films are not sufficiently insulating and undermine the ferroelectric measurement. Zhou et al. reported the unsaturated ferroelectric loop with considerably leakage current [13]. On the other hand, there is large lattice mismatch between ferromagnetic and ferroelectric layers weakened the magnetoelectric effect. Zhou et al. demonstrated the polycrystalline $PZT/CoFe_2O_4$ with its weak Magnetic-field-induced electric polarization of 2.2 pC/cm^2. Thus, it is essential to improve the insulating properties of PZT and reduce the lattice mismatch between ferroelectric and ferromagnetic layer before deposition of heterojunction magnetoelectric materials. In the previous studies, the commonly used PZT thin film exhibited Zr concentration of ~50 at.% [8,13]. From the current state of semiconductor technology, the ZrO_2 has been widely used as high-κ dielectric materials with negligible current leakage [14]. Taking the advantages of intriguing feature of ZrO_2, that high Zr content is likelihood to increase the insulating properties of PZT film, we fabricated the highly Zr doped PZT film, $Pb(Zr_{0.95}Ti_{0.05})O_3$, in this study. Multiferroic epitaxial films, $Pb(Zr_{0.95}Ti_{0.05})O_3/CoFe_2O_4$ has been deposited on $SrTiO_3$ substrate by pulsed-laser deposition technique. The $CoFe_2O_4$ (CFO) was selected as ferromagnetic materials because of high magnetostriction effect and good coupling with PZT [15]. The ferroelectric, magnetic and magnetoelectric properties of heterojunction thin film composites were studied.

2. Experimental procedure

Heterostructure $CoFe_2O_4/Pb(Zr_{0.95}Ti_{0.05})O_3$ thin film was grown on $SrTiO_3$ substrate via a pulsed-laser deposition (PLD) technique. The stoichiometric targets of $CoFe_2O_4$ and $Pb(Zr_{0.95}Ti_{0.05})O_3$, with excess of 10% mol Pb were prepared through a standard solid

* Corresponding author. Tel.: +98 711 2307293; fax: +98 711 6287294.
E-mail address: tahmasebi@shirazu.ac.ir (K. Tahmasebi).

0261-3069/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.matdes.2010.11.045