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Sensors and Actuators B 132 (2008) 290–295
SENSORS AND ACTUATORS B CHEMICAL
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The influence of Mg doped ZnO thin films on the properties of Love wave sensors

Ren-Chuan Chang [a], Sheng-Yuan Chu [a,b,*], Po-Wen Yeh [a], Cheng-Shong Hong [a,c], Po-Ching Kao [a], Yi-Jen Huang [a]

[a] Department of Electrical Engineering, National Cheng Kung University, Tainan 701, Taiwan
[b] Center for Micro/Nano Science and Technology, National Cheng Kung University, Tainan 701, Taiwan
[c] Department of Electrical Engineering, Chienkuo Technology University, Changhua 500, Taiwan

Received 23 April 2007; received in revised form 14 January 2008; accepted 18 January 2008
Available online 31 January 2008

Abstract

The influence of Mg dopants on the crystalline structures of MZO thin films and the properties of Love wave sensors has been studied in this paper. 0–20 mol% Mg doped ZnO films with *c*-axis preferred orientation were deposited on the 64° YX-$LiNbO_3$ substrates by RF magnetron sputtering technique. XRD, SEM, and AFM measurements investigated characteristics of the films. The phase shift and temperature coefficient of frequency of Love wave devices in MZO/$LiNbO_3$ structures are presented. The appropriate addition of Mg dopant will produce a rough surface to raise the sensitivity. Besides, the effects of reflector gratings on the properties of Love wave sensors are also investigated.

Keywords: ZnO; $LiNbO_3$; Love wave; RF sputtering; Sensitivity

1. Introduction

SAW devices have found wide application in sensors for detection in gas and liquid environment [1–3]. In liquid environment, Rayleigh surface waves have a displacement component perpendicular to the substrate, where exist a compressional waves leading to a strong radiation loss [4]. For this reason, shear horizontal (SH) polarized waves are preferred because they do not couple elastically with ideal liquids and make no radiation loss [4–7]. SH modes can be converted into Love modes by means of a layer acting as a guide. The basic structure of Love wave devices is illustrated in Fig. 1. Due to the waveguide effect, Love waves will be very sensitive to surface perturbations and high sensitivity to surface loading can be achieved.

The condition for the existence of Love wave modes is that the shear velocity of the overlay material is less than that of the substrate [4]. Surface skimming bulk waves (SSBW) of ST-cut quartz [4–10], and leaky waves of 36° YX-$LiTaO_3$ [11–16] and 64° YX-$LiNbO_3$ [13,17] have been utilized as substrates. 64° YX-$LiNbO_3$ shows a large electromechanical coupling coefficient ($k^2 = 11.3\%$), fast shear velocity (4478 m/s) and negative temperature coefficient of frequency (TCF) [18]. Fused silica (SiO_2) [4,5,7], and polymethyl-methacrylate (PMMA) [4,15] are relatively used for the guiding layer. However, PMMA shows high acoustic losses as well as poor chemical and temperature resistance [4,5]. Zinc oxide (ZnO) has low acoustic absorption, low loss, and high chemical, mechanical and thermal stability. Besides, the shear velocity of ZnO (2747 m/s) [19] is lower than that of SiO_2 (2850 m/s) [4] making it suitable candidate for the guiding layer.

ZnO films have been targeted as a useful material for developments of electronic, optoelectronic and SAW devices such as: transparent conductive films, solar cell windows, and gas sensors [20,21]. A great deal of research also have been reported that Mg doped ZnO (MZO) films maintain favorable characteristics of wide band gap materials, and possess attractive properties for potential applications in novel optoelectronic and nanoelectronic devices [22–24]. Recently, several groups have regarded the ZnO films used as the guiding layer for Love wave devices [6,11,16,19]. The influence of Ca and Sr doped ZnO/ST-cut quartz on Love wave sensor characteristics has been studied further by Water and Yang [25,26]. Therefore, in this paper

* Corresponding author. Tel.: +886 6 2757575x62381; fax: +886 6 2345482.
E-mail address: chusy@mail.ncku.edu.tw (S.-Y. Chu).

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doi:10.1016/j.snb.2008.01.038

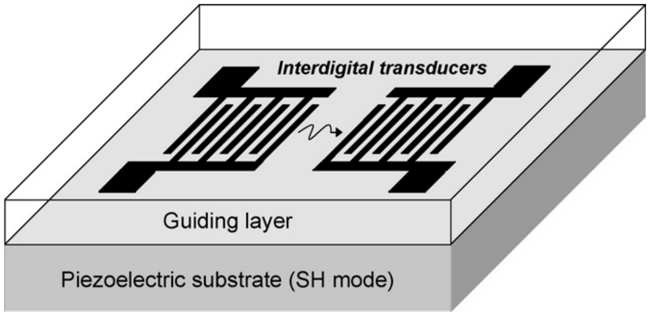

Fig. 1. The basic structure of Love wave devices.

we deposit ZnO thin films with different Mg content on the $LiNbO_3$ substrates and investigate the effects of MZO films on the properties of Love wave devices.

2. Experimental

ZnO thin films were deposited on the polished 64° YX-$LiNbO_3$ substrates by RF magnetron sputtering using 0–20 mol% Mg doped ZnO (99.9%) targets. The target was prepared by adding MgO (99.5%) and sintering in air at 1200 °C for 4 h. The substrates were thoroughly cleaned and degreased with organic solvents and distilled water successively in an ultrasonic bath, and then dried with nitrogen gas. Sputtering was carried out in argon and oxygen mixed gas atmosphere by supplying RF power. The deposition rates ranged form 0.4 to 0.55 μm/h, depending on the Mg content. Prior to deposition process, the target was presputtered about 20 min to remove any contamination on the surface. The sputtering condition of Mg doped ZnO film deposition is listed in Table 1.

In order to investigate the properties of the ZnO films, the crystallographic study was confirmed by X-ray diffraction (XRD) using Cu Kα (λ = 0.154 nm) radiation with a Seimens

Table 1
The sputtering condition of Mg doped ZnO film deposition

Target composition	0–20 mol% Mg doped ZnO
Substrate	64° YX-$LiNbO_3$
Target–substrate distance (mm)	50
Sputtering gas	Ar 80% + O_2 20%
RF power (W)	60
Sputtering pressure (mTorr)	20
Substrate temperature (°C)	Unheated
Deposition rate (μm/h)	0.4–0.55
Thickness (μm)	~1.6

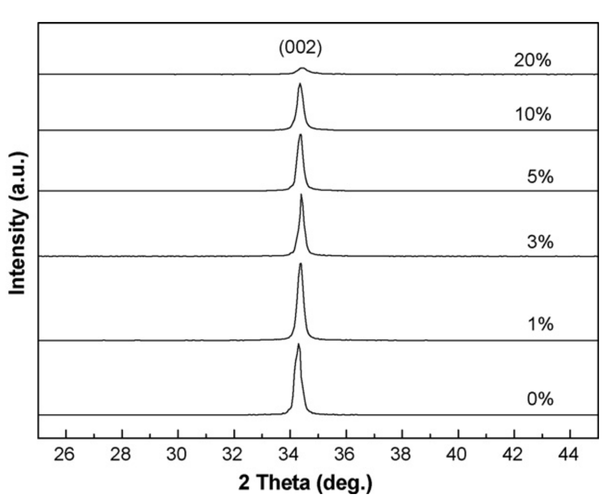

Fig. 2. X-ray diffraction patterns of the ZnO films with different Mg content.

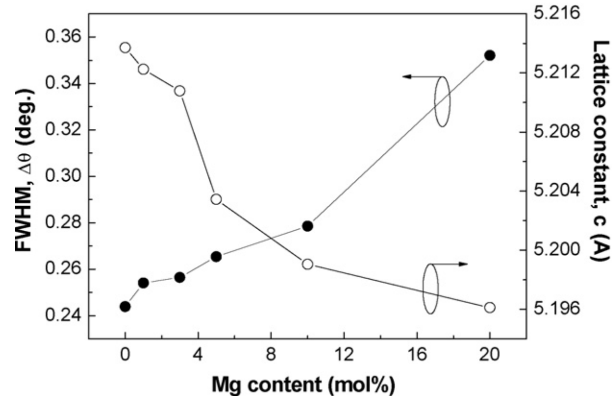

Fig. 3. Variation of FWHM and lattice constant for *c*-axis orientation with respect to Mg content.

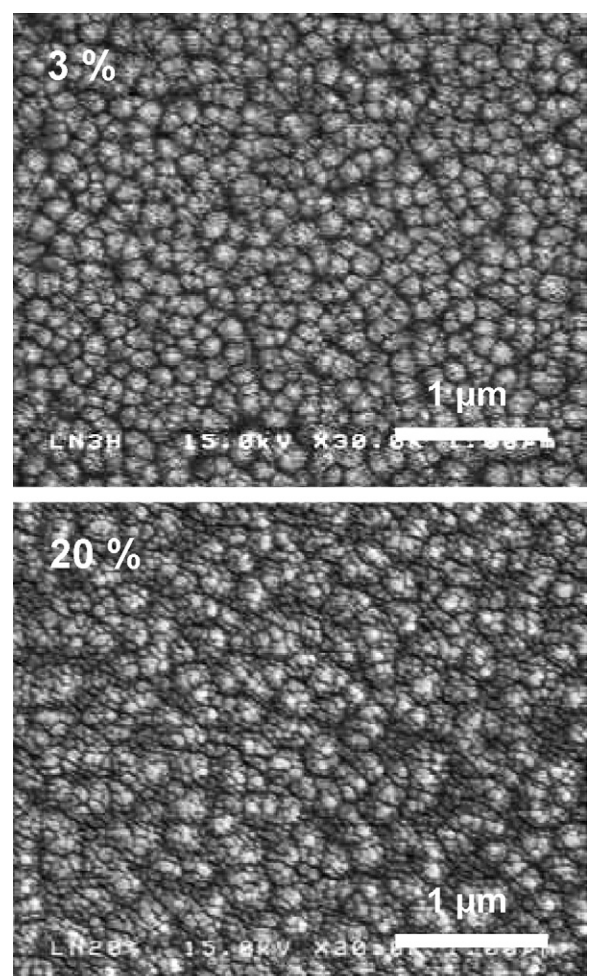

Fig. 4. The SEM images of Mg doped ZnO films.