Thin Solid Films 517 (2009) 6414–6417

Contents lists available at ScienceDirect

Thin Solid Films

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

Effect of oxygen pressure of SiO_x buffer layer on the electrical properties of GZO film deposited on PET substrate

Byung Du Ahn [a], Young Gun Ko [b], Sang Hoon Oh [a], Jean-Ho Song [c], Hyun Jae Kim [a,*]

[a] School of Electrical and Electronic Engineering, Yonsei University, Seoul 120-749, Republic of Korea
[b] School of Materials Science and Engineering, Yeungnam University , Gyeongsan 712-749, Republic of Korea
[c] LCD Technology, LCD Business, Samsung Electronics, Gyeonggi-Do 446-711, Republic of Korea

ARTICLE INFO

Available online 9 March 2009

Keywords:
Ga-doped ZnO
Polyethylene telephthalate
SiO_x buffer
Electrical resistivity

ABSTRACT

The present work was made to investigate the effect of oxygen pressure of SiO_x layer on the electrical properties of Ga-doped ZnO (GZO) films deposited on poly-ethylene telephthalate (PET) substrate by utilizing the pulsed-laser deposition at ambient temperature. For this purpose, the SiO_x buffer layers were deposited at various oxygen pressures ranging from 13.3 to 46.7 Pa. With increasing oxygen pressure during the deposition of SiO_x layer as a buffer, the electrical resistivity of GZO/SiO_x/PET films gradually decreased from 7.6×10^{-3} to 6.8×10^{-4} Ω·cm, due to the enhanced mobility of GZO films. It was mainly due to the grain size of GZO films related to the roughened surface of the SiO_x buffer layers. In addition, the average optical transmittance of GZO/SiO_x/PET films in a visible regime was estimated to be ~90% comparable to that of GZO deposited onto a glass substrate.

1. Introduction

In recent years, transparent conducting oxide (TCO) thin films whose substrate materials were rigid glasses have been widely applied for in a variety of optoelectronic devices, such as solar cells, flat panel displays, *etc.*, since they showed a good combination of electrical conductivity at ambient temperature and optical transparency in a visible region [1–3]. Considering the current move to use flexible TCO thin films where light weight and safety were also required, using stiff glasses was undesirable in selecting condensed substrates [4]. To this end, stainless steel foils [5], ultra-thin glass sheets [6], and deformable plastic films [7–10] have been regarded as favorable candidate materials for the substrates of flexible thin films. Among these materials, poly-ethylene terephthalate (PET) was one of the materials attractive for actual plastic display applications owing to its optical properties when compared to other substrates [7]. Despite the commercial potential, however, only limited data have been available for the electrical properties of GZO films deposited on PET [10,11]. Furthermore, due to the poor thermal stability of PET substrates in nature, it is inevitable for such films to be processed at low temperatures, resulting in resultant thin films having poor electrical conductivity in turn. Recently, Pei et al. [12] reported that an Al_2O_3 as an inorganic buffer layer was used between Al:ZnO (AZO) film and PET substrate. Unfortunately, the electrical resistivity of AZO/Al_2O_3/PET films could not meet the requirement for application. Qiu et al. [13] proposed an IZO (In-doped ZnO)/SiO_x/PET multilayered structure by controlling the amount of oxygen during the deposition of interfacial layer. To drive down the production cost, however, the use of In element in the IZO film seemed undesirable.

Therefore, the main purposes of this study are to investigate the effect of oxygen pressure during the deposition of the SiO_x buffer layer on the electrical properties of GZO/SiO_x/PET films, where Ga element was more economical than In element, and to discuss the transport mechanism of the free electrons in relation to grain size of the present thin films.

2. Experimental details

The GZO and SiO_x films were deposited at room temperature by means of a pulsed laser deposition (PLD) technique. In the PLD process, the laser power and repetition rate were 0.7 W and 5 Hz. And, the targets for the GZO and SiO_x thin films were a sintered GZO pellet containing 3 wt.% Ga_2O_3 and a high purity silicon target (99.95% Si). The depositions were performed onto 1.25×1.25 cm^2 PET substrates with the laser energy density of 1 J/cm^2 and 2.5 J/cm^2 for GZO and SiO_x thin films, respectively. After the SiO_x buffer layer was deposited on PET substrate, the GZO film was subsequently deposited on the SiO_x buffer layer to fabricate the GZO/SiO_x/PET heterogeneous multi-layered structure. The values of the film thickness in SiO_x and GZO films measured via an Alpha Step 500 profilometer were 50 and 200 nm, respectively.

For microstructural observation, atomic-force microscope (AFM) was operated in a contact mode to obtain topographic images and surface roughness of the SiO_x films. X-ray photoelectron spectroscopy (XPS) was used to analyze the quantitative composition of SiO_x film

* Corresponding author.
E-mail address: hjk3@yonsei.ac.kr (B.D. Ahn).

0040-6090/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.tsf.2009.02.057

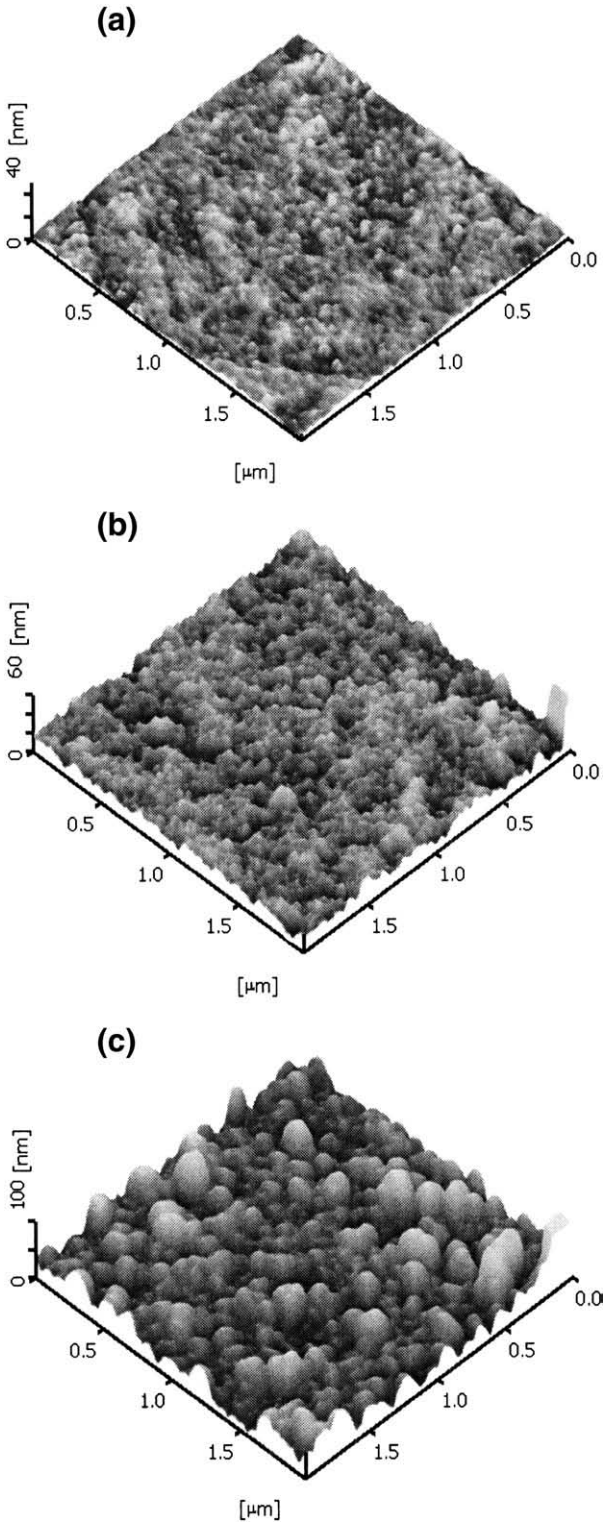

Fig. 1. AFM images of SiO_x films deposited on PET substrates with three different oxygen pressures. (a) SiO_x (13.3 Pa)/PET, (b) SiO_x (26.7 Pa)/PET, and (c) SiO_x (46.7 Pa)/PET.

with regard to the oxygen pressure during deposition. In addition, field emission scanning electron microscope (FE-SEM) was used to measure the grain size of the GZO films. The electrical properties of GZO/SiO_x/PET films were examined by Hall measurements in the van der Pauw configuration under a magnetic field ($B = 1$ T) at ambient temperature. For optical properties, an UV-near IR grating spectrometer was used in this study.

3. Results and discussion

The surface morphologies of SiO_x films on PET substrates with respect to oxygen pressure are characterized through AFM technique, and are shown in Fig. 1. The root mean square values of initial surface roughness for PET were 0.9 nm and those of different three samples deposited under 13.3, 26.7, and 46.7 Pa were measured to be 1.4, 4.2, and 15.4 nm, respectively. According to He et al. [14], the surface morphology of SiO_x films was closely related to the oxygen pressure when other experimental conditions, such as deposition temperature and laser energy, were fixed. Thus, it was reasonable to anticipate that the surface roughness of SiO_x film would tend to increase with increasing oxygen pressure during the PLD deposition since the growth of SiO_x thin films were affected by the oxygen pressure. This fact was also consistent with that reported by Lin et al. [15]. Under the condition of high oxygen pressure, the species ejected from the target would suffer from more collisions with the oxygen molecules in a chamber than those under low oxygen atmosphere. Then, prior to coming toward the surface of PET substrate, a number of vapor species could form large clusters, thereby causing the grain coarsening in SiO_x film. Moreover, more collisions accompanied by high oxygen pressure decreased the kinetic energy of the species and/or clusters, resulting in decreasing the mobility of the species as well as increasing the surface roughness.

In order to figure out the chemical composition of SiO_x films, XPS analyses were carried out. Fig. 2 presents the XPS spectra of the Si2*p* and O1*s* core level found in the SiO_x films with respect to the oxygen pressure. No peak regarding Si–Si bonding (99.4 eV [16]) appeared.

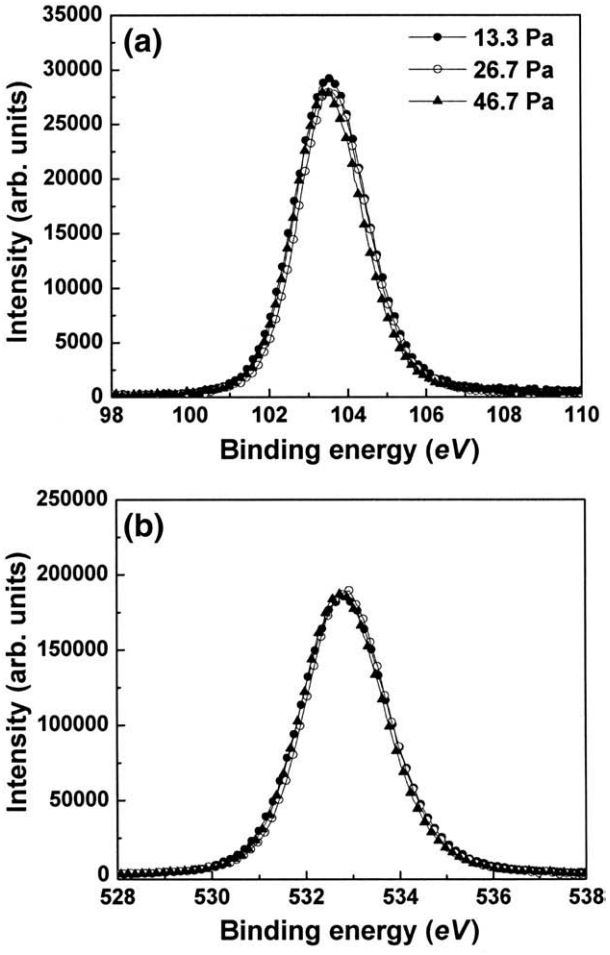

Fig. 2. XPS spectra of the (a) Si2*p* and (b) O1*s* core level of SiO_x films deposited on PET substrates with three different oxygen pressures.