Materials Science and Engineering B 156 (2009) 1–5

Contents lists available at ScienceDirect

Materials Science and Engineering B

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

Wide bandgap Mg-doped ZnAlO thin films for optoelectronic applications

R.K. Gupta [a,*], K. Ghosh [a], R. Patel [b], P.K. Kahol [a]

[a] Department of Physics, Astronomy, and Materials Science, Missouri State University, Springfield, MO 65897, USA
[b] Roy Blunt Jordan Valley Innovation Center, Missouri State University, Springfield, MO 65806, USA

ARTICLE INFO

Article history:
Received 2 July 2008
Received in revised form
14 September 2008
Accepted 22 September 2008

Keywords:
Zinc oxide
Magnesium oxide
Thin films
Optical properties
Electrical properties

ABSTRACT

Magnesium-doped ZnAlO thin films were grown on quartz substrate by ablating the sintered target with a KrF excimer laser. The effect of growth temperature from 30 °C to 700 °C on structural, optical, and electrical properties has been studied. These films are highly transparent in visible spectrum with average transmittance of 82%. The films grown at low temperature are amorphous while films grown at high temperature are crystalline in nature. These films are highly oriented along (0 0 2) direction. The electrical conductivity, carrier concentration, and electron mobility is found to increase with increase in temperature and then decreases with further increase in temperature. The bandgap is found to vary from 3.86 eV to 4.00 eV for various films.

1. Introduction

Zinc oxide is an n-type semiconductor with bandgap of 3.3 eV [1]. The n-type conductivity of pure zinc oxide is due to presence of oxygen vacancies and zinc interstitials [2]. However, the electrical conductivity of zinc oxide can be improved by doping with impurities such as Al, Ga, In [3]. Although the conductivity of doped zinc oxide is less than that of indium tin oxide, a widely used transparent electrode, but zinc oxide has other advantages such as less expensive, non-toxic, and highly abundance in nature [4]. Due to these unique properties, doped zinc oxide is a promising material for various applications such as electronic and optoelectronic devices, solar cells, and sensors [5].

Different techniques such as chemical vapor deposition [6], magnetron sputtering [7], spray pyrolysis [8], sol–gel [9], molecular beam epitaxy [10], and pulsed laser deposition [11] have been used for deposition of zinc oxide films on various substrates. Among these techniques, pulsed laser deposition has many advantages such as high deposition rate, ability to maintain target composition in films, control of various deposition parameters, deposition of high quality films, and low cost [12]. Recently, the bandgap of zinc oxide is modified by cationic doping. It is reported that cadmium doping leads to reduction in the bandgap, while doping of magnesium widen the bandgap of zinc oxide [13]. Zhang et al. have reported the structural and optical properties of magnesium-doped zinc oxide films deposited by ultrasonic spray pyrolysis [14]. Sol–gel technique is also used for deposition of magnesium-doped zinc oxide films [15]. Bhattacharya et al. have reported the effect of annealing on optical and structural properties of ZnO/MgO multilayer films deposited by pulsed laser technique [16]. Literature survey reveals that there is no report on detail electrical properties of magnesium-doped zinc oxide films. The electrical properties of zinc oxide films largely depend on growth temperature [17]. In this paper, we report the effect of substrate temperature on structural, optical, and electrical properties of magnesium-doped zinc aluminum oxide films by pulsed laser deposition. We doped zinc oxide with aluminum to enhance the electrical conductivity and magnesium to widen the bandgap of zinc oxide.

2. Experimental details

Magnesium-doped zinc aluminum oxide (ZMAO) thin films were deposited on quartz substrate using a KrF excimer laser (Lambda Physik COMPEX, λ = 248 nm and pulsed duration of 20 ns). The laser was operated at a pulse rate of 10 Hz and an energy of 300 mJ/pulse. The target to substrate distance was 4.0 cm. The laser beam was focused onto a rotating target at a 45° angle of incidence. The target ($Zn_{0.83}Mg_{0.15}Al_{0.02}O$) is prepared by standard solid state reaction method [18]. The films were deposited at different growth temperature by firing 12000 laser pulses under vacuum of base pressure 1×10^{-6} mbar. Before deposition, the substrate was cleaned in ultrasonic bath for 10 min in acetone and isopropanol, respectively.

The structural characterizations of the films were done using X-ray diffraction (XRD) and atomic force microscopy (AFM). The XRD spectra of the films were recorded with Bruker AXS

* Corresponding author. Tel.: +1 417 836 4467; fax: +1 417 836 6226.
E-mail address: ramguptamsu@gmail.com (R.K. Gupta).

0921-5107/$ – see front matter
doi:10.1016/j.mseb.2008.09.051

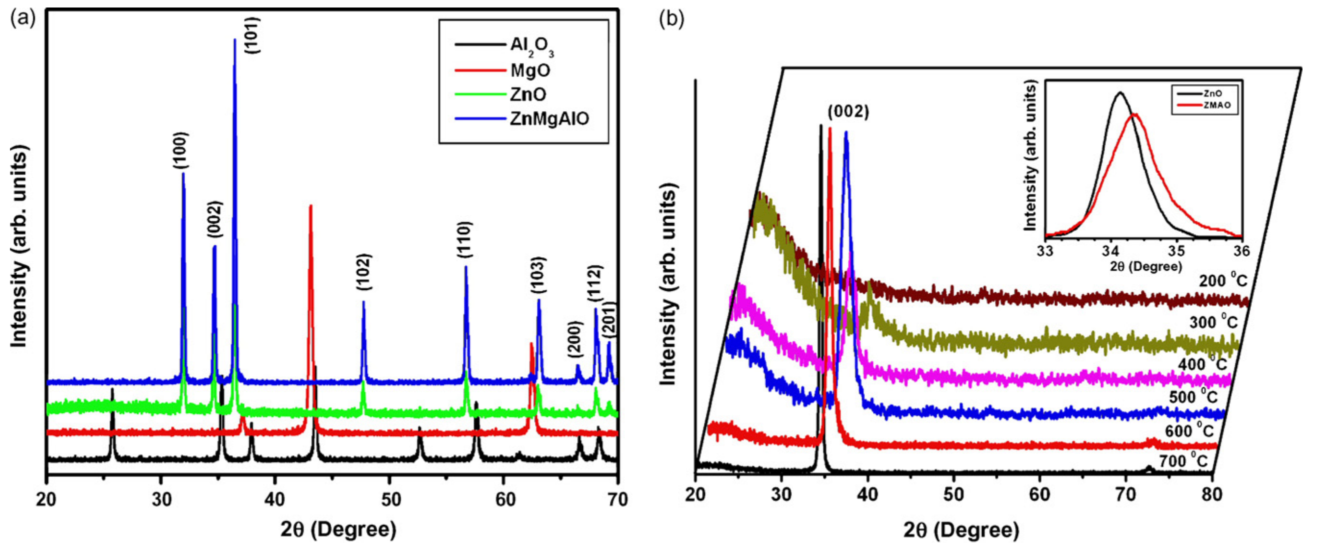

Fig. 1. (a) XRD patterns of powder samples and (b) XRD patterns of ZMAO films grown at different temperatures (the inset figure shows the normalized XRD patterns of ZnO and ZMAO films grown at 500 °C).

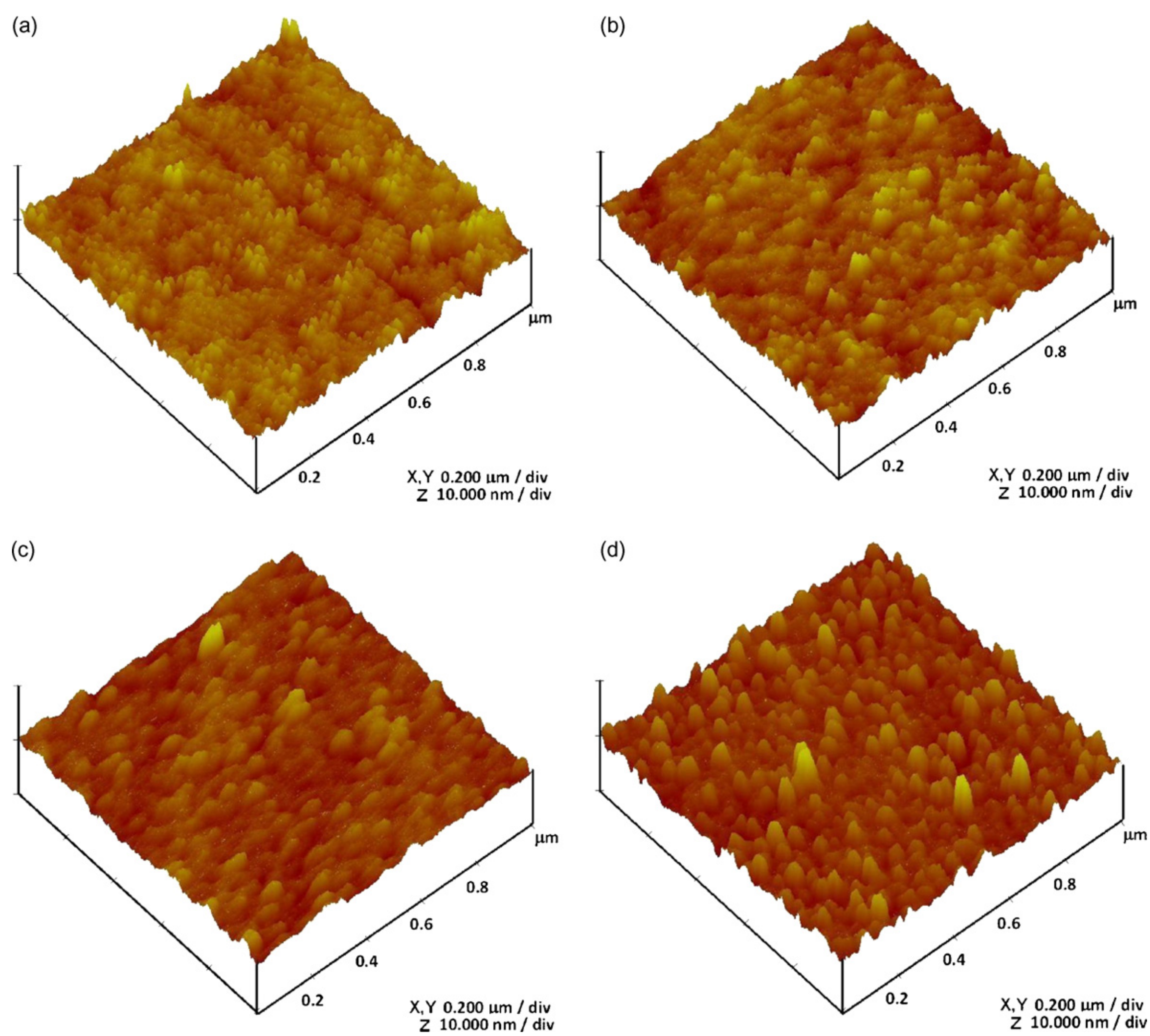

Fig. 2. AFM images of ZMAO films grown at: (a) 30 °C, (b) 200 °C, (c) 400 °C, and (d) 600 °C.