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Sputtered Al–N codoped p-type transparent ZnO thin films suitable for optoelectronic devices

Trilok Kumar Pathak[a], Vinod Kumar[a,b], L.P. Purohit[a,*]

[a] Semiconductor Research Lab, Department of Physics, Gurukula Kangri University, Haridwar, India
[b] Department of Physics, University of the Free State, Bloemfontein, South Africa

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ABSTRACT

Aluminum–nitrogen (Al–N) codoped zinc oxide (ZnO) thin films were grown on glass substrate by radio frequency (RF) reactive magnetron sputtering using aluminum doped zinc oxide (AZO, 2.5 wt% Al_2O_3) target and N_2 as reactive gas. The structural, morphology, optical and electrical properties were also investigated with different flow rate of N_2 gas. X-ray diffraction results shows that codoped ZnO thin films have similar wurtzite structure like undoped ZnO film. Al–N thin films have high transparency (T) in visible region as the nitrogen flow rate increases the transparency and band gap decreases. The best p-type codoped sample shows a resistivity and hole concentration of [illegible] Ω cm and [illegible] cm^{-3} at room temperature, respectively. Current–voltage (I–V) characteristics of p-type codoped ZnO thin films are also discussed.

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1. Introduction

ZnO is II–VI direct bandgap semiconductor [1]. ZnO is suitable material for the development of UV optoelectronics devices and short wavelength light emitting diodes due to has large band gap (3.37 eV) and high excitation binding energy (60 meV) [2,3]. ZnO is natural n-type semiconductor and the low solubility of the dopants [4]. To realize the light emitting devices, an important issue is the fabrication of p-type ZnO with a high hole concentration and low resistance. It is very difficult to obtain p-type ZnO due to its self compensation effect of native n-type carrier with dopants, deep acceptor level and the low solubility of the acceptor dopants [5]. In spite of these difficulties, nitrogen is the best dopants for p-type ZnO but various efforts to realize this goal have been disappointing [6]. Yamamoto et al. proposed a donor acceptor codoping method, the donor are Al, Ga or In with N being as acceptor [7]. Recently several co-doping techniques have been reported to prepare p-type ZnO film, such as co-doping of nitrogen (N) and gallium (Ga) [8], nitrogen (N) and beryllium (Be) [9], N and indium (In) [10] and N and Aluminum (Al) [11]. Among these codoping techniques Al–N is best because Al–N and Al–O bonds are stronger [illegible] [12]. There are various techniques which were used to synthesized [illegible] ZnO thin films such as chemical vapor deposition (CVD) [13], pulsed laser deposition (PLD) [14], RF magnetron sputtering [15] and sol–gel technique [16]. Among these techniques RF magnetron sputtering is best technique to obtain p-type conductivity with high carrier concentration and mobility [17–19]. A few literatures are available on codoping method produced p-type nitrogen doped ZnO films by the N–Al codoping method using RF magnetron sputtering with a N_2 sputtering gas using Zn:Al sputtering target. The low resistive p-type codoped ZnO thin films have most application in light emitting devices, transparent photo-voltaic devices and optoelectronic devices. These films can be used in the fabrication of transparent p–n junction that is fundamental structure of these optoelectronic devices.

In this paper, we have deposited low resistive p-type Al–N codoped ZnO thin films by RF sputtering using AZO (2.5 wt% Al) target. Effect of N_2 flow rate on structural, optical and electrical properties of Al–N codoped sputtered ZnO thin films are also investigated at room temperature.

2. Experimental details

ZnO powder (Loba chemical, 99.99% purity) and Al_2O_3 powder (Qualigens, 99.99% purity) were used to formed target of sputtering. 23 g of AZO (ZnO–2.5 wt% Al_2O_3) powder were taken in disc and compress it with pressure 10 Ton using palletize machine to formed ceramic target with 2.5" diameter. The prepared target were sintered at 450 °C for 5 h after sintered the target (Fig. 1) is ready to use in RF sputtering coating unit (planer magnetron

* Corresponding author. Tel.: +91 [illegible]; fax: +91 [illegible]
E-mail address: [illegible] (L.P. Purohit).

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