Thin Solid Films 571 (2014) 198–205

Contents lists available at ScienceDirect

Thin Solid Films

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

Improving the uncommon (110) growing orientation of Al-doped ZnO thin films through sequential pulsed laser deposition

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ARTICLE INFO

Article history:
Received 16 January 2014
Received in revised form 3 October 2014
Accepted 6 October 2014
Available online 16 October 2014

Keywords:
Aluminum-doped zinc oxide
Thin films
Sequential pulsed laser deposition
Metallic targets
Room temperature deposition
Amorphous substrate

ABSTRACT

High quality Al-doped ZnO (AZO) films with uncommon (110) orientation are obtained on amorphous substrate by using Sequential Pulsed Laser Deposition technique. The dependence of the structural, optical and electrical properties with dopant concentration and oxygen deposition pressure was investigated systematically. We note a transition from the (002) preferential orientation of crystallites to an uncommon (110) orientation due to a combined effect of doping concentration and deposition pressure decreasing. For constant deposition pressure of 5 Pa the film crystallinity is changed from preferential (002) to polycrystalline when increasing dopant concentration. For the maximum dopant concentration that we have investigated (i.e., 4.4% at.) structural properties of AZO films are changed from a polycrystalline phase to a (110) preferential orientation when the deposition pressure decreases. This uncommon growth mode is accompanied by a change of the morphology from a densely packed granular structure to a more rarefied one. Moreover, the band gap widens up to 3.88 eV and the electrical resistivity drops to $5.4 \times 10^{-2}\ \Omega$ cm. The structural changes were attributed to two mechanisms: a first one, responsible for the (002) phase suppression as a consequence of aluminum ion bombardment during the doping process and, a second one, in charge with (110) phase growth as the diffusion rates of zinc and oxygen atoms are affected by the dopant incorporation and by the decrease of deposition pressure.

1. Introduction

ZnO and impurity doped ZnO films have been intensively studied due to their large potential application demonstrated for organic light emitting diodes [1], solar cells [2], surface acoustic wave devices [3], piezoelectric transducers [4] and gas sensing devices [5].

For some applications, thin films of nonpolar zinc oxide may be better suited. Since ZnO is a piezoelectric material, spontaneous and strain-induced polarization generate electric fields along the *c* axis and the presence of such fields in materials with a wurtzite structure was shown to cause a decrease of the quantum efficiency [6]. For this reason, films in which the *c* axis lies parallel to the films surface could be used to obtain light emitting devices with enhanced performances. Such materials may also be used in the realization of surface acoustic wave devices. Zinc oxide thin films with orientations different from the common (001) are usually obtained by epitaxial growth on substrates like γ-$LiAlO_2$ [7], r-sapphire [8], $LiGaO_2$ [9] or $SrTiO_3$ [10]. Lattice mismatch in these cases is a source of strain and can change some of the characteristics of the material. On amorphous substrates, ZnO tends to grow along the c-axis [11], although the appearance of other orientations has been observed and studied intensely, for example in the case of magnetron sputtering [12].

In spite of the numerous research papers dedicated to impurity doped ZnO films deposition and application testing, there is still an interest investigating this material. In a recent paper, Takayanagi et al. [13] demonstrated the unusual (110) growth of ZnO films on amorphous substrate in a magnetron discharge capacitively coupled plasma. The preferred (110) orientation appeared in the cathode area when the deposition pressure decreases from 1 Pa to 0.1 Pa, as a consequence of the bombardment with oxygen negative ions during film deposition. This type of growth is particularly important due to the anisotropy of the electrical and mechanical properties [14–16]. Usually this type of growth is obtained for different material types in ion beam assisted deposition systems [17–20], where the growth of the film in other directions than that for minimal surface energy (i.e., (002)) is promoted by ion bombardment during deposition. The key of these uncommon oriented materials seems to be the existence of an energetic ion flux

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http://dx.doi.org/10.1016/j.tsf.2014.10.037
0040-6090/