Chapter 1

Introduction

Transparent conductive zinc oxide (ZnO) thin films have received much attention in recent years because of their low electrical resistivity and high optical transparency. The ZnO thin films have possible applications in electronic devices [1] such as ultraviolet light emitting diodes (UV-LEDs), blue luminescent devices, UV lasers, flat panel displays, piezoelectronic, etc. ZnO are II-VI semiconductor materials with wide and direct band gap of wurtzite structure [2, 3]. They become a new type of transparent conductive oxide suitable for making window layer in $Cu(In,Ga)Se_2$ thin film solar cells [4]. The films have been prepared by using various types of deposition techniques such as metal-organic chemical vapor deposition (MOCVD) [5], ion planting [6], thermal evaporation [7], sol-gel [8], spray pyrolysis [9, 10], pulsed laser deposition (PLD) [11, 12], magnetron sputtering [13, 14], etc. Among those methods, magnetron sputtering is the most practical technique because of its capability to deliver high deposition rate on large area substrates [15]. In the addition, ZnO thin films prepared by this technique are also nontoxic and relatively easy to fabricate.

The electrical behavior of ZnO thin films can be improved by doping with group III elements, which are donor atoms and have higher number of valence electrons. Group III elements, such as B, Al, Ga and In, are well known as an effective n-type dopant in ZnO [16]. Most of the works related to ZnO use Al as a dopant. Nevertheless, Al presents a very high reactivity leading to oxidation during growth. Ga is somewhat less reactive and more resistant to oxidation compared to Al [14, 17]. At present, Ga doping is more interesting because there are many research groups studying Ga-doped ZnO thin films fabrication for making low resistivity window layer of Cu(In,Ga)Se_2 based thin film modules with a $Zn(O,S,OH)_x$ buffer layer [4, 13, 18]. Since lower resistivity and lower sheet resistance were obtained by depositing Ga-doped ZnO thin films instead of Al-doped ZnO thin films [17, 18], deposition of Ga-doped ZnO window layer has attracted more attention. Furthermore, a damp-heat test of the sputtered Ga-doped ZnO films was carried out. It was found that the films had good stability of electrical properties and showed a very small change of sheet resistance compared to B-doped ZnO thin films prepared by MOCVD technique [13]. The Ga-doped ZnO thin films were reportedly employed for a window layer to guarantee a long-term stability in Cu(In,Ga)Se_2 based thin film modules [4, 18]. These are the reasons why sputtered Ga-doped ZnO thin films have become a potential candidate for window layers.

The objective of this thesis is to prepare Ga-doped ZnO thin films by the RF magnetron sputtering and characterize their properties. The structural, electrical and optical properties of the films were investigated using X-ray diffraction (XRD), Hall measurement and transmission spectroscopy in the UV/VIS/NIR range, respectively. We study the effects of Ga content and sputtering conditions, i.e the RF power and working gas (Ar) pressure, on the properties of Ga-doped ZnO thin films. This is basically necessary for further development of a window layer of Cu(In,Ga)Se_2 thin film solar cells.

The procedures in this research can be described briefly as the followings. Firstly, the ZnO targets were fabricated with varied Ga_2O_3 contents. Secondly, the Ga-doped ZnO thin films were prepared at various sputtering conditions. The structural, electrical and optical properties of the Ga-doped ZnO thin films were then characterized. Finally, the properties dependent on Ga doping and sputtering conditions were analyzed and concluded.

This thesis is divided into six chapters. In the following chapter, chapter 2, the theoretical background of the ZnO properties and the RF magnetron sputtering technique are briefly described. In chapter 3, the theoretical aspects of analysis of structural, electrical and optical properties of Ga-doped ZnO thin films are given.

The experimental procedures involving the preparation of the sputtered targets and Ga-doped ZnO thin films, including the method for characterization of the film properties are given in chapter 4. Chapter 5 describes the experimental results and discussions for the deposition and the properties of Ga-doped ZnO thin films. The final chapter of this thesis, chapter 6, is the conclusions of the thesis.