UNIVERSITI TEKNIKAL MALAYSIA MELAKA

SYNTHESIS OF ALUMINIUM DOPED ZINC OXIDE THIN FILM PREPARED USING CHEMICAL BATH DEPOSITION

This report submitted in accordance with requirement of the University Technical Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Engineering Materials)(Hons.)

By

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirements for the Degree of Bachelor of Manufacturing Engineering (Engineering Materials) (Hons.). The members of the supervisory committee are as follow:

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ABSTRAK

Kajian ini dijalankan bertujuan untuk menghasilkan aluminium terdop filem nipis zink oksida dengan menggunakan pemendapan cecair kimia. Bahan-bahan mentah yang digunakan adalah serbuk zink nitrat, serbuk aluminium nitrat dan larutan amonia. Aluminium nitrat adalah parameter utama untuk meningkatkan kekonduksian elektrik dalam filem nipis zink oksida. Parameter yang digunakan untuk peratusan aluminium nitrat adalah 0.00, 0.02, 0.04, 0.06, 0.08, dan 0.10. Proses yang terlibat semasa sintesis filem nipis zink oksida adalah pencampuran bahan kimia, panaskan larutan kimia dan pensinteran untuk 400°C selama 2 jam. Untuk mengenal pasti ketebalan filem, kaedah perbezaan berat telah digunakan di mana berat dan ketebalan substrat akan diambil sebelum dan selepas pemendapan. Mikroskop imbasan elektron (SEM) juga telah digunakan untuk mencirikan morfologi filem nipis zink oksida bagi mendapatkan imej resolusi tinggi dengan pembesaran 5 hingga 1,000,000x dan pembelauan sinar-X telah dipilih untuk memerhatikan kristalografi filem nipis zink oksida.

ABSTRACT

The aim of this study is to synthesis the aluminium doped zinc oxide thin film prepared using chemical bath deposition. The raw materials used were zinc nitrate powder, aluminum nitrate powder and ammonia solution. The aluminium nitrate ratio is the key parameter to improve the electrical conductivity in the zinc oxide thin films. The parameters used for aluminium nitrate percentage are 0.00, 0.02, 0.04, 0.06, 0.08, and 0.10. Then, the processes involved during synthesis of zinc oxide thin films were solution mixing, heated solution and heat treated in 400°C for 2 hours. The thickness measurement used a weight difference method where the weight and thickness of substrate will be taken before and after deposition. A scanning electron microscope (SEM) was employed to characterize the morphology of the zinc oxide thin films to obtain the high resolution image with magnification of 5 to 1,000,000x and an X-ray diffraction was engaged to observe the crystallography of ZnO thin films.

DEDICATION

Dedicated to
my beloved father, Katimin bin Madiman
my appreciated mother, Jamilah binti Ahmad
my adored siblings, Noraniza, Zurina, Mohd Azreen, and Nurul Asyikin
for giving me moral support, cooperation, encouragement and also understandings.

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LIST OF ABBREVIATIONS

XRD	-	X-ray diffraction
SEM	-	Scanning Electron Microscope
UV-Vis	-	Ultraviolet–visible spectroscopy
CVD	-	Chemical Vapor Deposition
PVD	-	Physical Vapor Deposition
CBD	-	Chemical Vapor Deposition

LIST OF SYMBOLS

$^{\circ}C$	-	Degree Celcius
V	-	Voltage
mm	-	Millimeter
µm	-	Micrometer
mg	-	Milligram
eV	-	Electronvolt
nm	-	Nanometer
%	-	Percentage
Ωcm	-	Ohmcentimeter
λ	-	Wavelength
Å	-	Amstrong
$^{\circ}$	-	Degree
h	-	Plank Constant
E_g	-	Optical Band Gap
v	-	Photon Frequency

CHAPTER 1

INTRODUCTION

1.1 Background Study

ZnO is an exceptionally encouraging substance used for semiconductor maneuver uses. It devours a straight and wide-ranging band gap (3.37 eV) (Karaagac et al. 2012), plus an expansive free-exciton requisite energy, thus that excitonic emanation procedures can hold on at or even beyond room temperature. ZnO crystallizes in the wurtzite structure and accessible as extensive bulk single crystals. The utilization of ZnO in place of a semiconductor in microelectronic tools has remained irritated thru the absence of mechanism over its electrical conductivity. Over the previous era, we have seen a noteworthy change in the nature of ZnO single-crystal substrates plus epitaxial films. Thus, this consumes prompted toward a restoration of utilizing ZnO as per an optoelectronic otherwise electronic substantial in its peculiar particular right. The accessibility of vast single crystal is a major favorable position of ZnO. The epitaxy of ZnO films proceeding local substrates can bring about ZnO layers by the diminished convergence of amplified deformities and, subsequently, well executed in electronic and photonic devices. An additional enormous favorable position is that ZnO is agreeable near damp substance etching. This is especially essential in the implement outline and formation (Janotti and Van de Walle, 2009).

The fundamental preferred standpoint of having brilliant extensive single crystal of ZnO accessible is that ZnO thin films can on a essential level be epitaxially developed with decreased consortiums of broadening imperfections, without effluence as of the substrate, and short of a thermal bungle. This is particularly significant on behalf of optoelectronic devices in which the execution is profoundly touchy towards the crystalline nature of the layers (Janotti and Van de Walle, 2009). The thin film development procedure includes a few stages, for example, thermal settlement, adsorption of metal atoms on the substrate and nucleation took after by crystallization or the arrangement of microstructure. For every situation, development route (gathering of sub-atomic building pieces) is distinctive prompting to fluctuation in nucleation, development direction, crystallographic orientation (atomic stacking vitality), pressing density, interfacial energy and width of the crystallites (Shankar et al. 2015).

Translucent microelectronic are a rising innovation for the up and coming era of optoelectronic tools. Oxide semiconductors are single of best intriguing materials for an assortment of uses. In recent times, non-doped ZnO has been suggested by way of dynamic divert in thin film transistors. Some of the critical preferences is great electron versatility, which take into account the necessities of advanced drive currents plus quicker implement working velocities aimed at thin film transistors. In this way, ZnO channel layers must remained kept utilizing substrate heating or annealed as a part of request to expand the crystallinity of ZnO layer as well as film's versatility. Moreover, the mobility of ZnO based Thin Film Transistors (TFTs) has been exhibited to be higher extent TFTs, which is a specific preferred standpoint for complex drive currents plus quicker tool working paces. The some of the favorable circumstances is that ZnO by a wide band gap sort out not to corrupt on presentation to obvious light. As of late, here has remained huge enthusiasm for the unwavering quality of straightforward adaptable TFTs beneath low temperature manufacture. (Wang, 2012). As indicated by Shinde et al. (2005), thin films of ZnO can remain utilized by way of a window layer and additionally any of the terminals in solar cells. Alongside these uses, ZnO thin films have remained utilized as a part of varistor, gas sensor, solar cell transparent dealings creation and some more.

In the direction of achieve the ZnO thin films, the synthesis way is very important. The parameters involved in the synthesis of ZnO thin films exist greatly inclined the thickness, structures, also properties of the ZnO thin films. There remain several methods which are commonly used for processes of ZnO thin films for examples chemical vapor deposition (Zhang et al. 2010), physical vapor deposition (Sarjidan et al. 2010), sol-gel method (Al-Ghamdi et al. 2014), electrodeposition (Chevva et al. 2015), chemical bath deposition (Hou and Li, 2016) and etc.

1.2 Problem Statement

The properties of Zinc oxide (ZnO) such as good constancy in hydrogen plasma ambient, good thermal stability after doped by group III elements, non-toxicity, wide band gap 3.37 eV, great conductivity and also simple doping. ZnO also has a small material price and low deposition temperature. The zinc oxide thin films have higher electrical resistivity. Thus, the electrical conductivity of ZnO thin films can remain improved by creating oxygen vacancies through doping of other elements such as Aluminium (Al), Galium (Ga), and Indium (In). In this project, Al will be used and Al acts as the impurities that be added into semiconductor or zinc oxide for the purpose increasing the concentration and change its properties. Al is choosen because it attracted much attention to be as the doping material in ZnO. It is for the reasons that Al can increase the electrical conductivity and electrical toughness of ZnO. As known also, Al can be obtained easily with low-priced and has simply doping process. Through this project, I would like to study more on the chemical deposition of ZnO thin film doping with the Al and consider the effects of Al on the properties of ZnO.

In the previous study, there have used different technique to obtain ZnO thin films as an example, chemical vapor deposition (CVD) (Zhang et al. 2010), sol gel method (Al-Ghamdi et al. 2014) , physical vapor deposition (PVD) (Sarjidan et al. 2010), and etc. But, those methods above needed a complex setup and it is also costly. There also the technique that is hard to dominate the thickness of thin film. So, within this project, the method used to produce thin film is used Chemical bath deposition (CBD). CBD is a technique founded on the precise chemical reaction in bath which leads to the development of the thin films. It is very suitable for produce large area thin films. According to Shinde et al. (2005), CBD has its own advantages compared to the other methods such as non-hazardous, simple, cost effective and etc. It is also does not require the complicated and expensive instrument to be used. By applying this method, the thin film can be create. Thus, this study will focus on development of Al doped with ZnO thin film prepared using chemical deposition.

1.3 Objectives

The objectives of the project are as follows:

a) To synthesis Al-doped ZnO thin film using chemical bath deposition.

b) To study the properties of Al-doped ZnO thin film.

c) To investigate the effects of Al on the properties of ZnO.

1.4 Scope

This research work scopes are synthesis and characterizing of aluminium doped ZnO thin films prepared using chemical bath deposition (CBD) with specified amounts of aluminium nitrate percentage which are 0.00, 0.02, 0.04, 0.06, 0.08, and 0.10. The aluminium nitrate ratio is the key parameter to develop the electrical conductivity in the ZnO thin films. The raw materials were zinc nitrate powder, and ammonia solution. The processes involved during synthesis of ZnO thin films are solution mixing, heated solution and heat treated. Structural properties such as type of elements, thickness size, crystalline size, microstructure, and morphology of ZnO thin films were characterized with dissimilar methods to investigate the outcomes of each parameter. The thickness measurement will use a weight difference method where the weight of substrate will be taken before and after deposition and micrometer screw gauge was used to measure the thickness of thin film before and after deposition. A scanning electron microscope (SEM) was employed to characterize the morphology of the ZnO thin films to obtain the high resolution image with magnification of 5 to 1,000,000x. An X-ray diffraction was engaged to observe the crystallography of ZnO thin films where the measurements were taken over diffraction angle ranges of 2θ values = 20° to 80° by step scanning width of 0.01°.

1.5 Project Significance

The project significance is detailed as follows:

a) The electrical conductivity of ZnO thin films can stay improved by creating oxygen vacancies through doping of elements that is Al. This is because, by doping Al with ZnO thin film the electrical conductivity and toughness might be enhanced. This research is to study on how the Al doped ZnO thin film improves the properties of thin films.

b) Develop more information and also deep understanding about the role of ZnO thin films when it doped to the Al to develop the properties of the thin films.

c) To gain new knowledge for multi-scale thin films by carrying out some related testing.

d) To develop an alternative semiconductor material that possesses a lower cost and high performance attributes.

1.6 Conclusion

To summarize, in background study, the fundamentals of zinc oxide were being told in details. Besides, the effect of Al-doped ZnO thin film also been discussed with their applications such as varistor, transistor, solar cells and how to synthesis the thin films. For part in the problem statement, the cause of choosing Al as a doping material was discussed and why used chemical bath deposition to synthesis the thin films. Then, the objectives of this research were stated following with the scope of the project, which is summarized in this report. Lastly, the significance of the project was listed about how this project affects.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the general properties of ZnO thin film will be introduced in details in the section 2.2. While, in the section 2.3., the applications of ZnO will be discussed due to their various applications used in the industry. The synthesis method for ZnO thin film in various techniques for an example chemical vapor deposition, electrodeposition, sol gel method plus so on will be discussed. The chosen method in this study, which are chemical bath deposition will be studied in details in the section 2.4.5. One of the most important obstacles is to recover the electrical conductivity and optical limpidity of metal oxides. So, doping of ZnO thin film with various materials will be discussed to improve those problems in section 2.5. Then, the materials choose which is Aluminium to doped with ZnO thin film was discussed in section 2.6. Characterization of ZnO thin film, which are X-ray diffraction (XRD), scanning electron microscope (SEM), ultraviolet visible spectroscopy (UV-Vis) and thickness measurement will discussed.

2.2 ZnO Thin Film

With developing technological progressions, there is a nonstop demand for semiconductor materials. Researchers are working on to plan new materials or enhance the properties of definitely known materials by doping or different techniques. Zinc oxide is one of the semiconductor material having potential applications in various fields. Zinc oxide (ZnO) nanostructures must for some time remained picking up consideration because of their fascinating properties, for example, wide plus direct band gap (3.37eV) at room temperature and synchronous disclosure of great electrical, optical, and piezoelectric execution (Thanh et al. 2016).

Figure 2.1 shows that, at surrounding weight and temperature, ZnO takes shape in the wurtzite structure. It is a hexagonal cross section, having a place with the planetary aggregate P63mc, and is designated thru binary intersecting sublattices of Zn^{2+} and O^{2-}, to such an range that every Zn particle is incorporated by tetrahedra of O particles, and the other way around. This tetrahedral synchronization suggestions ascend to glacial equilibrium sideways the hexagonal pivot. This limit is in charge of some of the properties of ZnO, with its piezoelectricity plus unconstrained polarization, and is also a important consider crystal development, carving and imperfection era (Coleman and Jagadish, 2006).

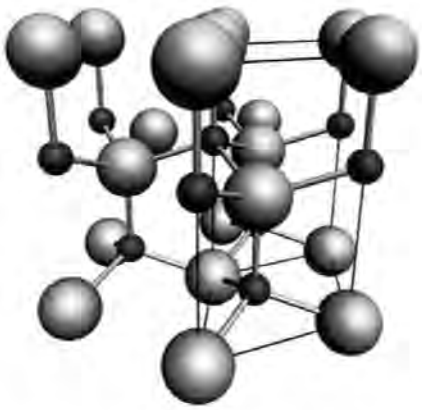

Figure 2.1: The hexagonal wurtzite arrangement of ZnO. O atoms as large white spheres, Zn atoms as smaller black spheres. (Coleman and Jagadish, 2006).

Pure and/or doped zinc oxide films have have pulled in a considerable measure of consideration as a result of their physical, chemical, electrical and optical properties, such as acessibility in environment, nontoxicity, great visual limpidity in the noticeable area, varied band and low resistivity (Kenanakis et al. 2014). ZnO thin films additionally must stayed contemplated as the lively strait material in thin film transistor growth as of its displaying n-type semiconductor characteristics plus incredible thermal stability and can remain very much oriented crystalline on different substrates (Ali, 2011). Besides, ZnO thin films have pulled in extensive consideration since they can stay customized to have great electrical conductivity and great visible transmittance through various coating methods. For instance, ZnO films need remained kept in place of photoelectrodes in dye sensitized solar cells and buffer layers aimed at Cu(In, Ga)Se2 thin film solar cells. In this situation, ZnO films through very much adjusted pieces, rods, or wires might show improved execution, on account of quick and viable way for electron conveyance. In this manner, it is basic to develop great quality c-axis oriented ZnO films for potential uses (Chu et al. 2009).

2.3 ZnO Application

ZnO is some of the semiconductor consuming the great chemical solidity compared to hydrogen plasma as well as appropriate for photovoltaic uses due to its great electrical conductivity and optical transmittance in the obvious section of the solar spectrum, which is main significance in solar cell creations. Thin films of ZnO can stay utilized as a window layer and in addition any of the electrodes in solar cells. Alongside these uses, ZnO thin films need stayed utilized in varistor, gas sensor, solar cell transparent contact production , and so on (Shinde et al. 2005). Furthermore, ZnO nanostructures must create uses in the arenas of piezoelectric transducers, photovoltaic devices, biosensors, transistors, plus optoelectronic devices (Thanh et al. 2016). ZnO also have huge exciton binding energy of 60 meV, which creates it a desirable candidate for creation of UV photodetector as well as UV light emitting diodes (Shaikh et al. 2016) and also widely used in electronic and photonic uses counting plasma displays and liquid crystal displays (Hou and Li, 2016).

Existing technology is additionally being reformed with ZnO nanoparticles, which obligate prompted towards the improvement of enhanced sun cream, dyes, coatings and others. Moreover, the emission toughness of ZnO to MeV proton illumination creates it a perfect contender for area applications. Along these lines ZnO whilst as of now having a extensive request base, has tremendous chances on behalf of humanity and production alike because of its exceptional properties which remain presently being investigated and applied. The upcoming in which ZnO devices turn out to be a piece of our regular day existences is as of now moving toward reality (Coleman and Jagadish, 2006).