FABRICATION AND CHARACTERIZATION OF DOPED ZINC OXIDE THIN FILMS BY RF MAGNETRON SPUTTER

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DECLARATION

I hereby declare that the work in this thesis is my own except for quotation and summaries which have been acknowledged.

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ABSTRACT

To enhance the productivity of ZnO thin film, the interest in doping ZnO is to explore the possibility of improving ZnO physical and electrical properties. Therefore this research describe the fabrication and characterization of three different materials which is undoped Zinc Oxide (ZnO), Aluminium doped ZnO (Al doped ZnO), and Gallium doped ZnO (Ga doped ZnO) to investigate the effect of Al_2O_3 and Ga_2O_3 into the characteristic of ZnO thin film. RF Magnetron sputtering is used in this study because of the advantages sputter in term of ability to produce high quality thin film with a high density and good adhesion interaction between surfaces, and can be obtained at low substrate temperature with good uniformity of the film thickness in a large scale. In order to analyze the favorable combinations of deposition parameters towards thin film quality deposited by Radio Frequency (RF) Powered Magnetron Sputtering, nominal thickness, substrate temperature and deposition pressure were chosen as variable deposition parameters. The experimental finding shows that present of dopant in ZnO thin film improved it electrical properties. Combination of 400 nm nominal thicknesses, substrate temperature at 250°C and low deposition pressure at 2 mTorr produce high quality of thin film in term of structural, optical, and electrical. Higher substrate temperature decreased the surface roughness value. Analysis of structural structure of doped ZnO thin films reveals ZnO, Ga Doped ZnO and Al doped ZnO thin films has be successfully deposited on glass substrate where all the peak observed indicate ZnO, Ga doped ZnO and Al doped ZnO thin film prepared by RF sputtering are polycrystalline with preferential orientation of (0 0 2) similar to the XRD peak pattern for standard ZnO (JCPDS 36-1451).The largest crystallite grain size obtain is Ga doped ZnO which is 27.9 nm. The transparency were differ in different deposition time, substrate temperature and deposition pressure but still show great transparency of film above 80% for all samples. Optical band gap of all thin films deposited is varied from 3.3 eV to 3.46 eV. The lowest resistivity achieved is 1.25 X 10^{-2} Ω cm. Simple junction diode were fabricated and analysis revealed that for heterojunction for ZnO with Cu_2O have the higher ideality factor of 14.5 compare to 12.31 for heterojunction for Al doped ZnO with Cu_2O and 11.93 for heterojunction for Ga doped ZnO with Cu_2O. Higher ideality factor may cause by limitation of higher series resistance from all samples. Both Ga doped ZnO and Al doped ZnO have lower resistivity and ideality factor from undoped ZnO which is related to the presence of Al^{3+} and Ga^{3+} ions in Ga doped ZnO and Al doped ZnO thin films. Research conclude that in this study of Ga_2O_3 deposited at substrate temperature at 250°C and low deposition pressure at 2 mTorr were favorable dopant compare to Al_2O_3 due to improvement of electrical properties in Ga doped ZnO compare to Al doped ZnO. Smaller difference of ionic radii of Ga^{3+} ions with Zn^{2+} compare with Al^{3+} given Ga_2O_3 priority and minimize the defect and improved thin film quality.

ABSTRAK

FABRIKASI DAN PENCIRIAN FILEM NIPIS ZINK OKSIDA TERDOP MENGGUNAKAN TEKNIK RF PERCIKAN MAGNETRON

Untuk meningkatkan kadar produktiviti ZnO, proses mendopkan ZnO dijalankan bagi meneroka kemungkinan untuk meningkatkan kualiti ZnO dari segi ciri-ciri fizikal dan elektrikal. Oleh itu, kajian ini menerangkan tentang fabrikasi dan pencirian tiga bahan yang berbeza iaitu ZnO yang tidak terdop, dan juga ZnO terdop iaitu Aluminum terdop ZnO (Al Doped ZnO) dan Galium terdop ZnO bagi menyiasat kesan kehadiran bahan Al_2O_3 and Ga_2O_3 ke atas ciri –ciri filem nipis ZnO. Di dalam kajian ini Teknik RF percikan magnetron digunakan disebabkan oleh kelebihan teknik ini dalam menghasilkan filem nipis yang berkualiti tinggi dengan kadar ketumpatan dan kadar interaksi lekatan yang baik antara permukaan substrat kaca yang mana boleh diperolehi dalam suhu yang rendah dan juga kadar keseragaman ketebalan yang tinggi di dalam skala yang besar. Untuk menyiasat kombinasi parameter pemendapan yang sesuai untuk menghasilkan filem nipis yang berkualiti tinggi, ketebalan filem nipis, suhu substrat dan juga tekanan sewaktu prises pemendapan filem nipis digunakan sebagai pemboleh ubah yang dimanipulasi di dalam kajian ini. Hasil penyelidikan menunjukkan bahawa kehadiran dop di dalam ZnO memperbaiki ciri elektrikal ZnO Kombinasi ketebalan filem nipis pada 400 nm, suhu subtrat pada 250 °C dan juga kadar tekanan pada 2 mTorr dapat menghasilkan filem nipis yang berkualiti tinggi dari segi struktur, optikal dan juga elektrikal. Analisa struktur filem nipis zink oksida tidak terdop dan terdop Al dan Ga masing masing menunjukkan ciri poli-kristal padah satah terpilih (0 0 2) merujuk kepada data piawai ZnO (JCPDS 36-1451). Saiz kristalit yang terbesar adalah pada filem nipis zink oksida terdop Ga iaitu 27.9 nm. Kadar telus cahaya untuk kesemua filem nipis adalah di atas 80 %. Jurang jalur optik untuk kesemua filem nipis yang dihasilkan adalah berada diantara 3.3 eV ke 3.46 eV. Kadar kerintangan filem nipis yang yang paling kecil diperolehi adalah $1.25 X 10^{-2}$ Ω cm bagi filem nipis zink oksida terdop Ga. Satu rekaan persimpangan pn telah difabrikasi dan analisa menunjukkan bahawa struktur lapisan ZnO dengan Cu_2O mempunyai faktor idealiti yang paling tinggi iaitu 14.5 berbanding 12.31 untuk struktur laposan Al doped ZnO dan Cu_2O dan 11.93 untuk struktur lapisan Ga doped ZnO dengan Cu_2O. Nilai rintangan yang tinggi menyumbang kepada nilai idealiti diod yang tinggi. Nilai rintangan yang rendah bagi zink oksida terdop Al dan Ga adalah disebabkan oleh kehadiran ion Al^{3+} dan Ga^{3+} di dalam filem nipis. Kajian menyimpulkan bahawa antara kedua jenis dop yang digunakan di dalam kajian ini iaitu Ga_2O_3 yang difabrikasi pada suhu subtrat 250°C dan tekanan pemendapan yang rendah pada 2 mTorr merupakan dop yang ideal berbanding Al_2O_3. Perbezaan saiz jejari ionic antara Ga^{3+} dengan Zn^{2+} yang lebih kecil berbanding Al^{3+} memberikan kelebihan kepada Ga_2O_3 di dalam menghasilkan filem nipis yang lebih berkualiti dan kurang kerosakan.

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LIST OF ABBREVIATION

CVD	–	Chemical vapour Deposition
DC	–	Direct current
FWHM	–	Fully Width half maximum
RF	–	Radio Frequency
RMS	–	Root Mean Square
XRD	–	X-Ray Diffraction

LIST OF SYMBOLS

B	–	Diffraction peak
λ	–	Wavelength
μm	–	Micrometer
A	–	Ampere
C	–	Celsius
eV	–	Electron volt
Ts	–	Substrate Temperature
V	–	Voltage
Φb	–	Barrier Height
V_T	–	Turn On Voltage
I_0	–	Saturation Current
n	–	Ideality Factor

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CHAPTER 1

INTRODUCTION

1.0 Introduction

In this thesis, the potential productions of undoped and doped zinc oxide (ZnO) thin film fabricated by Radio Frequency powered Magnetron sputtering were studied. Two types of dopants were used that are Aluminium Zinc Oxide (Al doped ZnO) and Gallium Zinc Oxide (Ga doped ZnO). RF magnetron sputter was used to deposit undoped ZnO and doped ZnO thin film at three different deposition parameters that is nominal films thicknesses, substrate temperature and deposition pressure. The dependence of deposition parameters towards the quality of undoped and doped ZnO thin film were analyzed and discussed.

1.1 Background of Study

The development of electronics devices has become a major concern among researchers due to the evolution of technology that requires more advance technology to handle demand from society. As one of the important elements in electronics devices, fabrication and characterization of thin films have been studied extensively in term of fabrication techniques and, most suitable materials used in as thin films (Burger *et al.*, 2015). Thin film is defined as a layer of materials in various thicknesses in the nanometer to micrometer scale. The characteristic of the thin film is different from bulk materials. The properties of thin films were strongly dependent on the parameters used during the deposition process.

1.2 Zinc Oxide

There are several candidates that suits as thin films materials. Inorganic materials such as carbides, sulfides, nitrides and oxide were suggested as the possible candidates. Among the inorganic materials, oxides are gaining popularity due to their multifunctional potentials for a wide range of electronic device products. The presence of oxygen vacancies in oxides is believed to influence the electrical and magnetic characteristics of their film (Miller and Suzuki, 2010)

Oxide materials often used in in various type of semiconductor devices such as Liquid Crystal Displays (LCDs), Plasma Displays Panels, Electronics Paper Displays, Sensors, Photovoltaic Panels (Ellmer and Mientus, 2008). The example of oxide materials are Indium Tin Oxide (ITO), Silicon Oxide (Si_2O) and also Zinc Oxide (ZnO). The development of semiconductors industry required more innovations and enhancement in semiconductors materials to fulfill the industrial demand. Indium tin oxide (ITO) was the common semiconductor materials used in industry. However, looking at the drastic development in technology, researchers have increased their effort towards the other materials to cope the needs in various applications of semiconductor materials.

A combination of zinc from group II and oxygen from group VI formed an ionic bonding between both atoms named ZnO hence included into II-VI semiconductor group. In recent years, zinc oxide (ZnO) gained a great deal of interest as wide band gap semiconductor materials. Pure zinc oxide colour is white, but in nature ZnO colour differ from yellow to red due to the presence of impurity such as manganese (Klingshirn, 2007).Zinc oxide crystallizes in the hexagonal wurtzite type structure which has a polar hexagonal axis, the c-axis, chosen to be parallel to z- axis where each anion is surrounded by four cation at the corners of a tetrahedron, and vice versa. (Morkoç and Özgür, 2009).ZnO gains interest due to its versatile characteristics which has large potential in various applications. One of the ZnO well known characteristics is wide direct band gap of 3.44 eV at low temperature and 3.37 eV at rooms temperatures which added advantages to be used as optoelectronics as fundamental element in Liquid Crystal Displays (LCDs), Plasma Displays Panels, Electronics Paper Displays, Sensors, Photovoltaic Panels.