STUDY OF TIME DEPOSITION DEPENDENCE OF Cu_2O FILMS, FABRICATED BY SPUTTERING METHOD

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I hereby confirmed that this dissertation was based on my original work except for the quotations and citations which had been duly acknowledged.

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ABSTRACT

This research was conducted to fabricate films using p-types oxides. In this research, glass which has good transparency, is used as a substrate while Cu_2O is used as p-type semiconductor target. Cu_2O films were deposited on glass substrates by Radio Frequency (RF) sputtering method at different duration time of 10, 20, 30, 40 and 50 minutes and the effect of duration time on surface, structural and optical of the films was presented. The surface properties were characterized by using profilometer. The film structures were studied by X-ray diffraction (XRD). To obtain information about structural properties in detail, the grain size (D) and FWHM were calculated. Optical properties of the films were analyzed by transmission, linear absorption coefficient and the optical method was used to determine the band gap of the films. So, it was determined that duration time has a strong effect on the structural, surface and optical properties of CU_2O films.

ABSTRAK

Kajian ini dijalankan untuk mengfabrikasi filem dengan menggunakan oksida jenis-p. Dalam kajian ini, cermin yang mempunyai ketelusan yang tinggi, akan digunakan sebagai substrat manakala Cu_2O akan digunakan sebagai jenis-p semikonduktor. Cu_2O akan diselaputi pada substrat kaca dengan menggunakan kaedah pemercikkan Frekuansi Radio (RF) pada masa penyelaputan yang berbeza iaitu 10, 20, 30, 40 dan 50 minit dan kesan masa penyelaputan terhadap permukaan, struktur dan optik bagi filem telah ditemukan. Ciri-ciri permukaan telah dikarakterkan dengan menggunakan profilometer. Struktur filem dikaji dengan kaedah XRD. Bagi mendapatkan maklumat tentang ciri-ciri struktur secara keseluruhan, saiz bijih dan nilai FWHM telah dikira. Ciri-ciri optik bagi filem telah dianalisis dengan menggunakan transmisi dan kadar penyerapan, dan kaedah optik juga digunakan untuk menentukkan jurang tenaga bagi filem ini. Jadi, ia telah ditentukan bahawa masa penyelaputan mempunyai pengaruh yang kuat pada struktur, permukaan dan ciri-ciri optic of Cu_2O filem.

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XRD	X-ray Diffraction
°	Degree
&	And
nm/sec	Nanometer per second
μm	Micrometer
θ	Theta
$CuGaO_2$	Copper Gallium Oxide
TSO	Transparent Semiconducting Oxide
ZnO	Zinc Oxide
$CuAlO_2$	Copper Alluminium Oxide
%	Percentage
eV	Electro Volt
nm	Nanometer
CIDs	Charge Integrated Devices
IC	Integrated Circuit
MBE	Molecular Beam Epitaxy
CVD	Chemical Vapor Deposition
RF	Radio Frequency
Å	Armstrong

kV	Kilo volt
mA	Milli Ampere
SCCM	Standard Cubic Centimeters per Minute
Cu_2O	Cuprous oxide
$SrCu_2O_2$	Strontium Cuprous Dioxide
PECs	Photo-Electro-Chemicals Cells
Uv-vis	Ultraviolet-Visible
cm^{-3}	Centimeter per Cubic
Torr	Unit of Pressure
Watt	Unit of Power (SI)
3D	Three Dimension
RMS	Root Means Square
AFM	Atomic Force Microscopy
α	Absorption Coefficient
K	Scherrer Constant
FWHM	Full Width at Half Maximum

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter discussed about introduction of research including background research, problem statements related to research, objective to be achieve, research scope and hypothesis. Introduction to this research was meant to give explanation about the target of this research.

1.2 Background Research

The development of p-type semiconductors is one of the key technologies for p-n junction devices such as optoelectronics devices, diodes, transistor, solar cell and light emitting diodes. Cu_2O, $CuAlO_2$, $CuGaO_2$ and $SrCu_2O_2$ are known to show p-type conductivity (Kose *et. al*, 2008). Cuprous oxide (Cu_2O) thin films have wide range of applications in energy harvesting and storage such as solar cells, photo-electro-chemicals cells (PECs), photocatalysts and lithium ion batteries (Jayatissa *et al.*,2009). Cuprous oxide have their unique features such as non-toxic, economic, abundant availability and relatively simple formation of oxide (Ghosh *et al.*, 2000). The cuprous oxide thin films have been synthesized using various methods such as reactive magnetron sputtering, reactive evaporation, RF sputtering, ion beam sputtering, plasma evaporation, chemical and thermal oxidation.

The expanding potential applications of thin films include transparent thin films transistors, light emitting diodes, solar cell and semiconductor lasers. New search for alternatives p-types materials are very much desired to fulfill expanding potential applications of thin films. Thus, in order to fabricate p-n junction in the future, Cu_2O is proposed as p-type material.

In this work, Cu_2O films will be deposited using sputtering method. Glass which is known to have good transparency, will be used as a substrate. The structure of the films will be examined by X-ray diffraction (XRD). The optical band gap of the films will be estimated from the absorption edge characteristics by assuming a direct band gap and transmittance of the films will be done using Uv-vis spectrophotometer. The thickness of thin films and also the surface roughness will be checked by using profilometer.

1.3 Problem Statement

Semiconductor material possess its own advantange but it is usually in n-type form. Thus:

I. Difficult to obtain p-type films due to low impurity solubility, excessive accepter ionization energy and possible compensating mechanisms.
II. Need p-type to fabricate p-n junction-based oxide devices.

1.4 Objective

The objectives of this project are:

I. Fabricate the Cu_2O films by sputtering method.
II. Investigate the optical and physical properties of the Cu_2O films based on time duration fabrication.

1.5 Research Scope

This research focused on fabrication of p-type Cu_2O films by using RF sputtering method. It also consist of analyzing structural thin films by using XRD. The optical properties will be analyzed using UV-Vis spectrophotometer. Lastly, for thickness and surface roughness, it will be analysed using profilometer.

1.6 Hypothesis

As the research succeed, study of time deposition dependence of Cu_2O films, fabricated by sputtering method can be obtained. This will develop to the expanding potential of p-type Cu_2O thin films entirely, as p-n junction is one of the important component in the electronic device.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Semiconductor

Semiconductor are a group of materials having conductivities between those of metals and insulators. Two general classifications of semiconductors are the elemental semiconductor materials, found in group 4 of the periodic table and compound semiconductor materials from group 3 and group 5 elements. The semiconductor is in general a single crystal material. Semiconductor surfaces are particularly interesting, because of the covalent bonding nature of the bulk material (Fritsch & Schroder, 1999). The electrical properties of a single crystal material are determined not only by the chemical composition but also by the arrangement of atoms in solid. Current flow in semiconductor devices is generally assumed to consist of drift and diffusion (Alan & Karel, 1977).

In an insulator like glass, the outer electrons are tightly bound to atoms, often in covalent bonds between pairs of atoms. In conductors like copper, the outer electrons are only loosely bound to atoms, so they can flow freely though the material if a voltage is applied across it.

2.2 Structure p-n junction of Semiconductor

It is important to realize that the entire semiconductor is a single crystal material in which one region is doped with acceptor impurity atom to form p-type and the other one is doped with donor atoms to form n-type. The interface separating between the n and p type is referred as the metallurgical junction. At metallurgical junction, there is a very large density gradient in both the electron and hole concentration. Due to the difference, majority carrier electron in n region will diffuse to the p region while majority carrier of hole in p region will begin diffusing into the n region. As electron diffuse from the n region, positively charge donor atoms are left behind. Same goes to holes, when it diffuse to n region they uncover negatively charged acceptor atoms. The net positive and negative charges in the n and p regions induce an electrostatic field in the region near the metallurgical junction, in the direction from positive to the negative charge as shown in Figure 2.1.

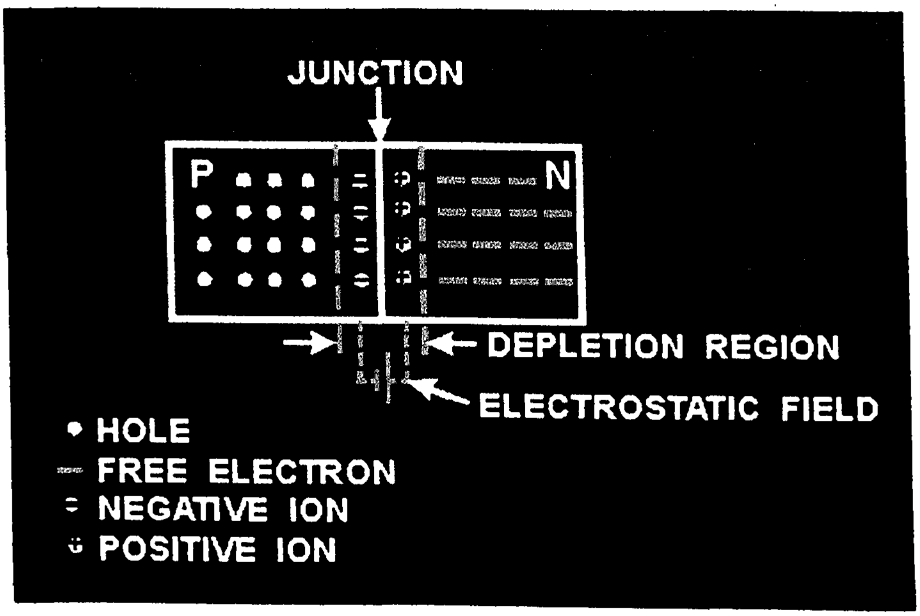

Figure 2.1 Metallugical junction structure and depletion region. (Source: http://www.tpub.com/)

The net positively and negatively charged regions known as the space charge regions (depletion region). We can determine the distance that the space charge region extends into the p and n regions from the metallurgical junction. This distance is known as the space charge width, W.

$$w = [\frac{2\epsilon_s}{e}\left(\frac{N_{a+N_d}}{N_d N_a}\right)(V_{bi} + V_R]^{1/2}\,\mu\text{m} \qquad (2.1)$$

Where ϵ_s is the electric field, *e* is the mass of electron, V_{bi} is the built-in potential barrier, V_R is reverse bias voltage, N_d is donor doping and N_a is acceptor doping.

2.3 Semiconductor Structure

Semiconductor structure consist of two types which is homostructure and heterostructure.

2.3.1 Homostructure Semiconductor

A junction formed by two different electrical types of the same (band gap) material can be classified as a homostructure. These types of junction structures are well known and extensively discussed in the literature. A common example for a homostructure is the silicon p-n junction as shown in Figure 2.2. This emphasis is on crystalline semiconductor homostructure, especially Si. Since almost all the circuit components, such as resistors, capacitors, transistors, diodes, charge integrated devices (CIDs), shift registers, and detectors, could be fabricated using standard Si technology, putting all those components in one single chip to fabricate an integrated circuit (IC) is a major advantage of using Si.

Semiconductor homostructure structures, have been studied for a very long time and have been used in a variety of applications. The advent of the molecular beam epitaxy (MBE), chemical vapor deposition (CVD), and other thin film techniques has advanced both homostructure and heterostructure design and fabrication to new levels (Walter & Robert, 1985). However, studies in recent years have demonstrated that even simple structures can exhibit a variety of new electrical and optical phenomena. The fact that the same semiconductor material (with different dopants or concentrations) is used in the homostructure makes the fabrication of these samples much simpler than heterostructure (Shankar *et al.*, 1997).

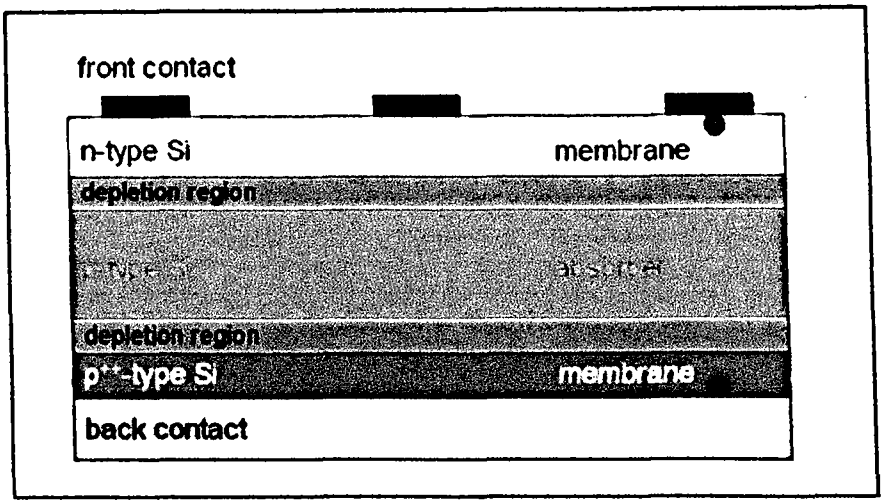

Figure 2.2 Homostructure semiconductor for silicon.

(Source:http://theopenacademy.com/)

2.3.2 Heterostructure Semiconductor

Similarly, a heterostructure is formed by two chemically different semiconductor materials are used to form a junction. The complete analysis of heterostructure involves quantum mechanics and detailed calculations. Since the two materials used to form a heterostructure will have different energy band gap, the energy band will have discontinuity at the junction interface. Semiconductor heterostructure interfaces exhibit interesting and useful electronics properties associated with the discontinuity in the local band structure at the interfaces (Tersoff, 1984). In order to get a useful heterostructure, the lattice constant of the two materials must be well matched. The lattice match is important because any lattice mismatch can introduce dislocations resulting in interface states. In the formation of heterostructure between narrow-band gap material and wide-bandgap material, the alignment of the bandgap energies is important in determining the characteristic of the junction. There are three possible cases for heterostructure semiconductor that are straddling, staggered and also broken band gap as shown in Figure 2.3. The staddling case is applied to most of heterostructure semiconductor.

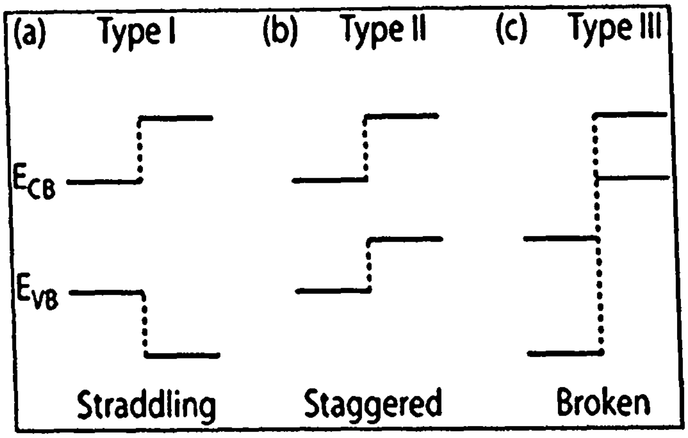

Figure 2.3 Types of Heterostructure Band Energy (Source:http://pubs.rsc.org/)

2.4 Semiconductor Applications

We often hear that we are living in the information age. Large amounts of information can be obtained via internet and also over long distances via satellite communication systems. It is because of greatest explosion of IC technology has occurred during the last two or three decades. The development of the transistor and the integrated circuit (IC) has lead to this extraordinary capabilities.

Up to this point, each component in electronic circuit had to be individually connected by wires. In September 1958, Jack Kilby of Texas Instruments demonstrated the first integrated circuit, which was fabricated in germanium. At about the same time, Robert Noyce of Fairchild semiconductor introduced the integrated circuit in silicon using a planar technology. All of expanding technology are related to expand of semiconductor technology (Naeman, 2003).

2.5 Sputtering System

Sputtering is a term used to describe the mechanism in which atoms are ejected from the surface of a target when that surface is stuck by sufficiency energetic particles. First discovered in 1852, and developed as a thin film deposition technique by Langmuir in 1920 (Ticky, 2009). Sputtering is one of most versatile technique used for the deposition when quality films are required compared with other techniques. Sputtering technique have its own advantages such as can be operated at low temperature, source and substrate can be spaced close together. It also can give uniform deposition surface.

The sputtering process involves the creation of a gas plasma by applying voltage between a cathode and anode. The cathode is used as a target holder and the anode is used as substrate holder. Usually gas used is inert gas such as argon gas. Argon, having a relatively high atomic weight which provides a suitable source of ions for effective bombardment with the target material. In this technique, Argon gas was supplied to the chamber of sputtering system. Argon gas is charge ions are accelerated toward a target material by utilizing electric fields. Target material is subjected to intense bombardment by positive charge ion gas. By momentum transfer, ions are ejected from the surface of cathode and diffuse way from it. Ions condense and form a thin film on substrate (Hartnagel, 1995). Figure 2.4 shows the overall sputter process occur in the vacuum chamber and Photo 2.1 shows the vacuum chamber in sputtering machine.

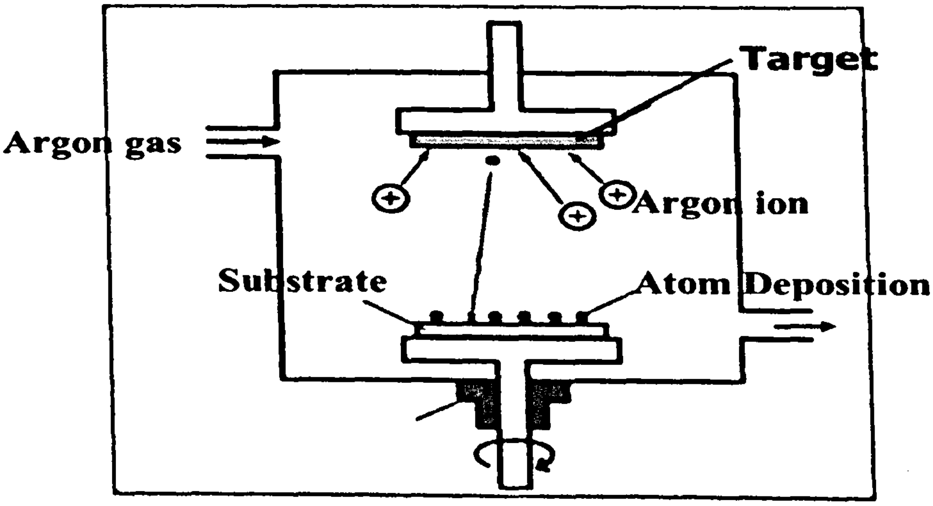

Figure 2.4 Schematic of sputtering process in vacuum chamber (Source: http://www2.warwick.ac.uk)

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