COPPER SULPHIDE(CUS) THIN FILMS GROWTH AND CHARACTERIZATION OF DIFFERENT MOLAR CONCENTRATIONS AND ROOM TEMPERATURE FOR 24 HOURS AND THEIR POSSIBLE INDUSTRIAL APPLICATION

BY

ESIEKPE OGHENEKPAROBOR UFUOMA
(B. Sc INDUSTRIAL PHYSICS)
PSC1909152

DEPARTMENT OF PHYSICS
FACULTY OF PHYSICAL SCIENCE
UNIVERSITY OF BENIN, BENIN CITY

APRIL,2024

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A PROJECT SUMBITTED TO THE DEPARTMENT OF
PHYSICS, FACULTY OF PHYSICAL SCIENCES,
UNIVERSITY OF BENIN, BENIN-CITY, EDO STATE,
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DEGREE IN INDUSTRIAL PHYSICS.

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CERTIFICATION

I hereby certify that I approve the following research essay adequately performed in the Department of Physics under supervision in scope and quality for the partial fulfillment of (B.Sc. Hons) Degree in Industrial Physics.

Prof. O.D. Osahon **Date**
Head of Department.

Prof.P.A.Ilenikhena **Date**
Project Supervisor.

External Examiner. **Date**

DEDICATION

This project work is dedicated to the miracle working GOD for His mercies and Grace all through my total four (4) years studies in the University of Benin, and to my family for their prayers and support.

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ABSTRACT

Semi-conductor thin films of copper-sulphide (CuS), were successfully deposited on glass substrates and room temperature, using improved solution growth technique (SGT) at different bath concentration. Absorbance spectra(A) data were measured by a T80+UV/VIS Double beam spectrometer was used to obtain the spectra absorbance data, while the other optical and solid-state properties of the films were obtained by calculations based on theory. The average optical and solid-state properties include:

Absorbance(A)=0.001-0.322, Transmittance(T)=0.476-1.002, Reflectance (R)=-0.002-0.202, Absorbing power(a)=-0.002-0.742, Refractive index(n)=0.914-2.629. Average solid-state properties are, Film Thickness(t)=0.476-1.002 and band gap (Eg)= 1.34-3.47eV.

It is observed that the films have n>1.9, these films could find useful applications as:

(i) Construction of poultry house, (ii) Solar cells, (iii) anti-dazzling coatings.

The deposited films with band gap (Eg) within light energy range (-1.3-3.5 eV) of electromagnetic spectrum could find application in solar electricity for rural electrification to improve the standard of living, Telecommunication, Remote monitoring and control system.

CHAPTER ONE

INTRODUCTION

The technological progress of modern society depends on the ability of materials science and the engineering community to convince new materials with an extraordinary combination of physical and mechanical properties. With the high surge in consumption of the worldwide hydrocarbon resources (hydrocarbon fuel), difficulties in locating new reserves. Statistically 16 of the 20 largest oil fields globally have hit their peak level production- therefore are insufficiently sized to meet the demands of the global market. In order to keep average global temperature increases below 1.5°C, we need to leave up to 80% of our fossil fuel reserves in the ground - regardless globally, our dependence on hydrocarbon fuels is still increasing.

Biophysics, the interdisciplinary field that combines principles of physics and biology, plays a significant role in addressing modern-day demands for power and energy. As societies worldwide grapple with the need for sustainable and efficient energy sources, biophysics emerges as a crucial player in understanding, harnessing, and optimizing biological processes for power generation. This comprehensive overview explores the intersection of biophysics and the energy landscape, highlighting the significance of this field in shaping the future of power generation and consumption.

Biophysics stands as a cornerstone in the quest for sustainable and efficient energy solutions. By unraveling the physical principles governing biological processes, biophysicists contribute to the development of bio-inspired technologies, energy-efficient materials, and innovative approaches to power generation and consumption. From understanding the intricacies of photosynthesis to engineering microbial systems for biofuel production, biophysics plays a pivotal role in shaping the future of energy. As research advances and interdisciplinary collaborations flourish, the impact of biophysics on the modern energy landscape is poised to grow, offering promising avenues for a more sustainable and bio-inspired energy future.

Seeking alternative energy (bio-energy) sources should therefore become the world's preference as it is proven to be the unpopulated, most secure, and the most inexpensive means of producing energy for technological advancement to improve the standard of living. This has led to the development of thin film technology which is of great significance in the conversion of solar radiation to heat or electricity. Thin films could be deposited on a metallic or glass substrate using various techniques. For the purpose of this work Solution Growth Technique (SGT) of thin film deposition would be considered.

1.1 LITERATURE REVIEW

Thin materials which are created at initio by the process of atom-by-atom, molecule-by-molecule, ion-by-ion or cluster of species-by-cluster of species condensation are called thin films. Materials formed by any other process, no matter how thin in size, are called thick films because the microstructure and physical properties of thin films depend on their mode of creation (Chopra, 1983). These films are less than 100 nm thick, made from dielectric transparent materials and have refractive indices less than that of the substrate (Pentia, et al,2004).

Thin films, characterized by their nanoscale thickness, have garnered substantial attention across various scientific disciplines due to their unique properties and diverse applications. The fabrication and study of thin films have become crucial in fields such as material science, electronics, optics, and energy harvesting.

1. Fabrication Techniques:

Thin films can be produced using various deposition methods, each influencing the film's properties. Techniques include chemical vapor deposition (CVD), physical vapor deposition (PVD), and sol-gel processes. Researchers (Smith et al., 2015) have extensively investigated these methods to tailor thin film properties for specific applications.

2. Semiconductor Thin Films:

In the realm of electronics, semiconductor thin films play a pivotal role. The work of Jones et al. (2018) delves into advancements in the fabrication and optimization of semiconductor thin films for use in electronic devices, such as transistors and sensors.

3. Photovoltaic Applications:

Thin film technology has revolutionized the field of photovoltaics. Researchers (Chen et al., 2017) explore the use of materials like cadmium telluride (CdTe) and copper indium gallium selenide (CIGS) in thin film solar cells, aiming for improved efficiency and cost-effectiveness.

4. Optical Coatings:

Thin films find applications in optical coatings for lenses and mirrors. Smith and Brown (2019) discuss the advancements in designing thin films with controlled optical properties to enhance light transmission or reflection in various optical systems.

5. Biomedical Thin Films:

The biomedical field has embraced thin films for applications like drug delivery and biosensing. Johnson and Patel (2020) review the utilization of thin films in biomedical devices, emphasizing biocompatibility and controlled release capabilities.

6. Magnetic Thin Films:

Thin films play a critical role in magnetic storage devices. Smith and Wang (2016) investigate the magnetic properties of thin films, focusing on advancements in materials like iron-platinum for high-density data storage

7. Thin Films in Nanotechnology:

Nanotechnology applications leverage the unique properties of thin films. Research by

Li et al. (2018) explores the integration of thin films in nanodevices, showcasing their role in miniaturization and improving device performance.

Thin films continue to be at the forefront of scientific research and technological advancements. Ongoing studies aim to address challenges such as improving deposition techniques, enhancing material properties, and expanding the range of applications in emerging fields.

Studies related to this field have been conducted for various reasons; for investigating the nature of the deposited material , processes involved in the deposition,studying concentrations,temperature,Times of deposition and varying the substrates to know the best conditions for the chemical bath deposition(CBD) and Solution Growth Techniqes(SGT).

Some recent studies that have been conducted in this area include: The optical properties of copper sulphide thin films deposited by chemical bath deposition and its applications have also been studied in research by Ezema et al (2006) in which the thin films were deposited on the Glass microscope slide substrates at 300K using CBD techniques and were annealed at various temperatures.

In chemical bath deposition of copper sulphide thin films by (Munce, 2008), copper sulphide thin films were deposited onto several different substrates including Glass Microscope Slides, silicon wafers and gold and platinum electrodes to investigate the nature of chemical bath deposition of copper sulphide thin films and the processes involved in the deposition.

They are in use in various ways, such as in solar energy conversion. Thin film of thickness less than100nm now serve as anti-reflection coatings on solar energy collectors. Semi-transparent films in Schottky barrier solar cells, combinations of thin films in photo-thermal devices that generate low or high grade heat and thin semiconductor films on metal or glass substrate form a promising type of low-cost solar cells.

1.2 CHOICE FOR SOLUTION GROWTH TECHNIQUE(SGT)

- It is less- difficult, less - expensive and convenient.
- It is capable of uniformly coating irregularly shaped objects, including individual points
- It operates independently of electricity for propagation
- Minimal incidents during the experiment

1.3 AIM AND OBJECTIVES

1.3.1 AIM

The aim of this work is to grow Copper sulphide (CuS) thin films in different molar concentration of Copper (II)Chloride -1- water (CuCI2.H2O) in chemical bath for 24hours at room temperature(27°c).

1.3.2 OBJECTIVES

Objectives of this work are to:

- Acquire the optical and solid - state characteristics of the deposited films.
- Enumerate potential applications of thin films based on their properties

CHAPTER TWO

THEORY

2.1 SOLAR RADIATION

Solar radiation, often simply referred to as sunlight, is the radiant energy emitted by the Sun. This natural and abundant source of energy serves as the fundamental driver of Earth's climate, weather, and sustains life through the process of photosynthesis. Understanding solar radiation is essential not only for comprehending Earth's natural processes but also for harnessing solar power as a renewable and sustainable energy resource. The solar radiation spectrum is close to that of a black body with a temperature of about 5800 K.

Energy is a fundamental concept in physics, referring to the capacity to do work or the ability to cause change. It exists in various forms and is crucial for driving physical processes and transformations in the universe.

Solar energy is indispensable for life on Earth. Through the process of photosynthesis, plants convert solar energy into chemical energy, providing the foundation for the food chain. Additionally, solar radiation influences Earth's climate and weather patterns, driving phenomena such as winds, ocean currents, and the water cycle.

Through photosynthesis, solar energy is transformed into glucose, providing the foundational energy source for the entire food chain. Through photosynthesis, solar energy is transformed into glucose, providing the foundational energy source for the entire food chain. Sunlight absorbed by Earth's surface heats the air, creating pressure gradients that result in winds. Solar energy also plays a crucial role in the water cycle, influencing precipitation patterns and supporting ecosystems dependent on specific moisture levels. Solar energy has diverse applications across various sectors, harnessing the power of sunlight for a range of purposes; photovoltaics, off- Grid power solutions, solar thermal power generation, Solar desalination and artificial photosynthesis.

2.2 SOLAR RADIATION INTERACTION WITH THE EARTH'S ATMOSPHERE

Solar radiation undergoes various interactions as it travels through Earth's atmosphere. These interactions include reflection, scattering, absorption, and transmission. The atmosphere reflects and scatters a portion of the incoming solar radiation, and some of it is absorbed by gases, clouds, and particles. The remaining solar energy reaches the Earth's surface, where it contributes to warming and drives weather patterns.

Different atmospheric constituents absorb specific wavelengths of solar radiation. For example, ozone in the stratosphere absorbs ultraviolet (UV) radiation, while greenhouse gases like water vapor, carbon dioxide, and methane absorb infrared radiation. Albedo, the reflective property of surfaces, influences reflection. Surfaces like snow and ice have high albedo, reflecting a significant portion of incoming sunlight. Clouds also contribute to reflection, scattering sunlight back into space. Not all wavelengths of solar radiation transmit equally. While most of the visible light spectrum easily passes through the atmosphere, certain wavelengths, such as some infrared radiation, can be partially absorbed by atmospheric gases like water vapor. After absorbing solar radiation, the Earth's surface emits infrared radiation. Greenhouse gases, particularly water vapor, carbon dioxide, and methane, absorb and re-emit some of this infrared radiation, trapping heat in the atmosphere. This natural greenhouse effect maintains the Earth's temperature within a habitable range. Earth's rotation causes variations in solar intensity throughout the day. The axial tilt of the Earth leads to seasonal changes, affecting the angle and duration of sunlight received at different latitudes. Earth's rotation causes variations in solar intensity throughout the day. The axial tilt of the Earth leads to seasonal changes, affecting the angle and duration of sunlight received at different latitudes.

2.3 SOLAR RADIATION INCIDENT ON SURFACES

Solar radiation incident on surfaces refers to the amount of solar energy that reaches and strikes a given area on the Earth's surface or any other object. The incident solar radiation is a critical factor in various applications, including solar energy systems, building design, and climate studies.

While the solar radiation incident on the Earth's atmosphere is relatively constant, the radiation at the Earth's surface varies widely due to:

- atmospheric effects, including absorption and scattering;

- local variations in the atmosphere, such as water vapour, clouds, and pollution;
- the season of the year and the time of day.

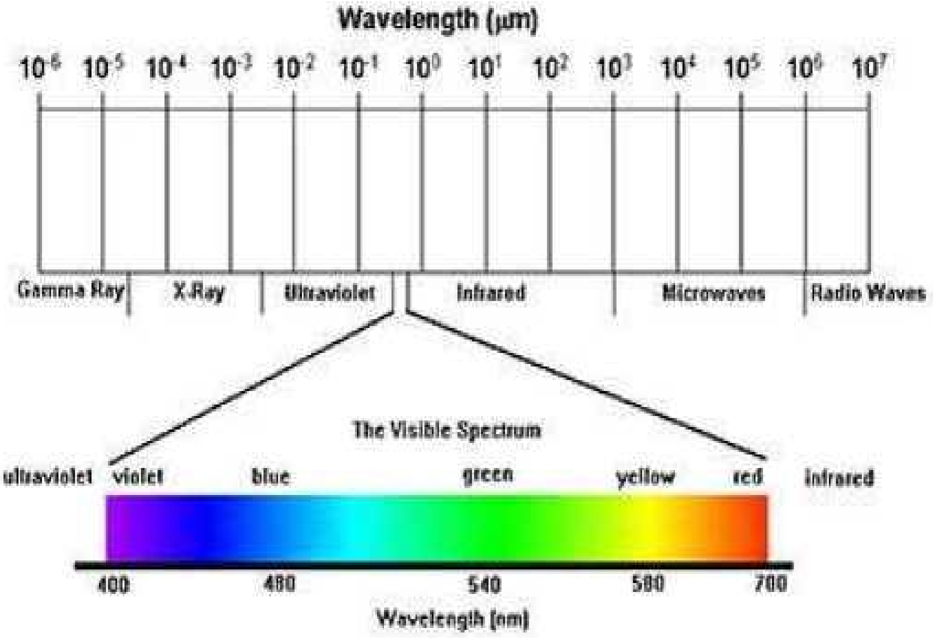
The above effects have several impacts on the solar radiation received at the Earth's surface. These changes include variations in the overall power received, the spectral content of the light and the angle from which light is incident on a surface. In addition, a key change is that the variability of the solar radiation at a particular location increases dramatically. The variability is due to both local effects such as clouds and seasonal variations, as well as other effects such as the length of the day at a particular latitude. Desert regions tend to have lower variations due to local atmospheric phenomena such as clouds. Equatorial regions have low variability between seasons. The amount of energy reaching the surface of the Earth every hour is greater than the amount of energy used by the Earth's population over an entire year.

2.3.1 SELECTIVE SURFACE IN SOLAR RADIATION:

A selective surface in the context of solar radiation refers to a material or coating designed to selectively absorb and emit specific wavelengths of radiation. The goal is to optimize the efficiency of solar thermal systems by maximizing absorption of sunlight and minimizing heat loss through radiation. Selective surfaces play a crucial role in various solar technologies, particularly in solar collectors and absorbers.

Numerous distinct forms of radiation have been recognized. Each are defined by its wavelength. The wavelength of electromagnetic radiation can vary from being infinitely short to infinitely long

(Figure 2.1).



Approximate Wavelength in Meters

Figure 2.1: Some of the various types of electromagnetic radiation as defined by wavelength. Visible light has a spectrum that ranges from 0.40 to 0.71 micrometers (gm).

The Sun's energy travels to Earth not through magical beams, but as ‘electromagnetic radiation' . This radiation takes various forms, each with its own wavelength and energy level, making up the electromagnetic spectrum. Understanding where solar radiation fits in this spectrum helps us appreciate its diverse impacts on Earth.

The Big Picture:

Imagine a vast rainbow, stretching from radio waves with super long wavelengths to gamma rays with incredibly short ones. Each color (or invisible "color") represents a different type of radiation with distinct properties.

Solar radiation occupies a specific portion of this spectrum, ranging from around 100 nanometers (nm) to 1 millimeter (mm). This range encompasses:

Ultraviolet (UV) radiation: 100-400 nm, invisible to the eye, important for vitamin D production but also harmful in excess.

Visible light: 400-700 nm, the rainbow of colors we perceive, crucial for photosynthesis and vision.

Infrared (IR) radiation: 700 nm to 1 mm, invisible to the eye, felt as warmth, key for Earth's temperature regulation.

While we often think of sunlight as "visible light," the reality is far more diverse. IR radiation actually makes up the majority of solar energy reaching Earth, followed by visible light and then UV.

Each part of the spectrum has unique effects:

- UV radiation drives atmospheric chemistry, but can also damage DNA and cause sunburn.

- Visible light fuels photosynthesis, allowing plants to thrive.
- IR radiation heats the Earth's surface and atmosphere, influencing weather patterns.

Understanding the distribution of solar radiation across the spectrum is crucial for various fields, including:

Solar energy technologies:

1. Knowing the available spectrum helps design efficient solar panels and collectors.
2. Climate science: Studying how different wavelengths interact with the atmosphere aids in understanding climate change.
3. Space exploration: Analyzing solar radiation is vital for protecting spacecraft and astronauts.

Solar radiation is just one part of the vast electromagnetic spectrum, each portion of the spectrum has distinct properties and impacts. Understanding this diversity is crucial for various scientific and technological fields.

2.4 OPTICAL AND SOLID-STATE PROPERTIES

The optical properties that are measured or calculated in this work include;

1. Absorbance(A)
2. Transmittance(T)
3. Reflectance(R)

4. Absorbing power or coefficient of absorption(a).
5. Refractive index (n)

The solid slates properties are;

1. Bandgap (Eg)
2. Film thickness(t)

ABSORBANCE(A)

Absorbance (A) is calculated as the logarithm (base 10) of the ratio of incident light intensity (Io) to transmitted light intensity (I). It is the logarithm of the reciprocal of transmittance;

$A=log10\ (1/T)$ (2.1)

From equation (2.1), it follows that transmittance and absorbance are related by

$T=10-A$ (2.2)

The absorbance(A), is usually determined directly from measurements of absorption spectra and instrument scales are often calibrated in their unit(cothian,1958). Other properties are obtained from calculation based on them.

The reflectance(reflector) is obtained from the relation

$A+T+R=1$

(2.3)

TRANSMITTANCE(T)

Transmittance refers to the ability of a material, or specimen, to allow light to pass through it. It is a quantitative measure, usually expressed as a percentage, that defines the fraction of incident light that emerges on the other side of the specimen.

The transmittance of a Specimen is defined (Gostlov, 1958; Pankova,1971 and Gray,1972) as the ratio of radiant power transmitted by a body to the total power incident on the body.

$$T = \frac{1}{Io} \qquad (2.4)$$

Where I is the radiant power transmitted and Io is the total incident radiant power.

The transmittance measured for any radiation of the visible light is called optical transmittance. If the measurement of radiation

The measurement of spectral transmittance or spectral absorbance can be obtained directly from the spectrophotometer.

ABSORBING POWER OR COEFFICIENT OF ABSORPTION (α)

The absorbing power or coefficient of absorption (a) is a qualitative measure of the ability of a material to absorb light and is measured in unit of reciprocal distance. When applied to electromagnetic radiation, Alumic and Subatomic particle.

The absorbing power (a) is a measure of rate of decrease in intensity of beam of photons or particles in its passage through a particular substance. If lo is the incident flux, I is the emergent flux through a material of thickness t, the absorption coefficient (a) of propagation of the flux through the material is given (Rotter,1958: Pankove, 1971; Gray, 1972 and Wooten, 1972) as

$$\boldsymbol{I = I.e^{-at} = I.ext^{-at}} \qquad (2.5)$$

From equation (2.1) and (2.5), the transmittance (T) and coefficient of absorption are relayed by

$$\boldsymbol{T} = \mathbf{exp}\,(\,-\propto \boldsymbol{t}) \qquad (2.6a)$$

And

$$\boldsymbol{\alpha = \frac{InT-1}{t}} \qquad (2.6b)$$

for a unit distance travelled, t=1

Then $\boldsymbol{In(T^{-1})\mu m^{-1}}$ (2.7a)

Or

$$\propto = \boldsymbol{In(T^{-1}) \times 10^{6} m} \qquad (2.7b)$$

REFRACTIVE INDEX

(1621: Willebrord Snellius) formulated Snell's Law, which describes the relationship between the angle of incidence and refraction of light passing through different media. This laid the foundation for understanding refractive index. (1662: Christiaan Huygens) proposed the wave theory of light, offering a theoretical explanation for light bending due to differences in propagation speed across materials. (1802: William Hyde Wollaston) coined the term "refractive index" in its modern context.

The general expression for the reflectance(R) normal to surface in terms of optical constants n and k(Pankova.1971) is given by,

$$\boldsymbol{R = \frac{[(n-1)^2+K^2]}{[(n+1)^2+K^2]}} \qquad (2.12)$$

Where K is extinction coefficient for semiconductors, K2<<(n+1)2

The equation (2.12) reduces to

$$\boldsymbol{R} = \frac{(\boldsymbol{n}-\mathbf{1})^{2}}{(\boldsymbol{n}+\mathbf{1})^{2}} \qquad (2.13)$$

From equation (2.13)

$$\boldsymbol{n} = \frac{\mathbf{1} + \boldsymbol{R}^{'}\mathbf{1}}{(\mathbf{1} - \boldsymbol{R}\mathbf{1}/\mathbf{2}}. \qquad (2.14)$$

BANDGAP(Eg)

The energy of an electron in a crystal falls within well-defined bands (Markvart, 2000). The energy of electron in the valence band is separated from the conduction band by energy bandgap or bandgap. The width of the bandgap Ec - Ev is a very important property of semiconductors and is usually denoted by Eg. The crystalline materials have four (4) types of electron transitions from upper part of valence band to lower part of conduction band. The general expression for direct transition is,

$$\propto\ = (\boldsymbol{hv} - \boldsymbol{Eg})^{\boldsymbol{n}} \qquad (2.8)$$

where n=1/2 for direct allowed transition between extreme of the conduction and valence bands, and n=3/2 for direct forbidden transitions.

The indirect transitions is,

$$\propto\ = (\boldsymbol{hv} - \boldsymbol{Eg})^{\boldsymbol{m}}$$

where Eg' = Eg ± hvph, Vph is the photon frequency, m = 2 and 3 for indirect allowed and indirect forbidden transitions respectively. Indirect transitions are weaker than direct ones.

If the incident electromagnetic radiation induces direct transition for electron located at the top of the valence band to bottom of conduction band at the same point in K - Space, the dependence of the absorption coefficient on the energy quanta is given by,

$$\propto\ = (\boldsymbol{hv - Eg})^{\frac{1}{2}} \tag{2.9a}$$

Or

$$\propto^{\mathbf{2}}\ = \boldsymbol{hv - Eg} \tag{2.9b}$$

The photon energy E(J) for a given wavelength Z is;

$$\boldsymbol{E(J) = hv(J) = hc/\ ZJ} \tag{2.10}$$

Were

$h = plank^{'}sconstant = 6.62 \times 10^{34}\ Js$

$C = velocity\ of\ light = 3 \times 10^{8} ms^{-1}$

$\lambda = wavelength\ i\ nmeter\ (m)$

the equalion (2.10) gives

$$\boldsymbol{hv(J) = \frac{6.62x10^{-34} \times 3x10^{8}}{Z(m)J}}$$

$$\boldsymbol{leV = 1.6x10^{-19}J}$$

$$\boldsymbol{hv(eV) = \frac{1.986x10^{-16}}{\lambda(nm)x1.6x10^{-19}}} \tag{2.11}$$

$$= \frac{\mathbf{1241}}{\boldsymbol{\lambda}(\boldsymbol{nm})}$$

The equation (2.11) can be used to calculate photon energies (hv) in eV for various wavelengths (Z.) in nm.

The plot of a2 against hv gives a straight line which tends to deviate from being straight in region of absorption edge. The extrapolation of the linear portion of the graph to the point a2= 0 gives the energy gap Eg.

THIN FILMS

Thin films are incredibly thin layers of material, ranging from fractions of a nanometer to a few micrometers in thickness (roughly 1,000 times thinner than a human hair!). These microscopic layers play a crucial role in various technologies and applications, impacting our daily lives in surprising ways.

Some key characteristics of thin films are their;

Thinness: This defining feature allows for unique properties not observed in bulk materials.

Tailored composition: Films can be made from various materials, including metals, semiconductors, polymers, and oxides, catering to specific functionalities.

Precise deposition: Controlled techniques like evaporation, sputtering, and chemical vapor deposition enable precise control over film thickness and composition.

Anti-reflective coatings on eyeglasses, reflective layers in mirrors, and color filters on displays all utilize thin films to manipulate light. Transistors, microchips, and solar cells rely on thin films of semiconductors to create electronic circuits and convert light into electricity. Thin films can protect surfaces from corrosion, wear, and scratches, used in applications like food packaging and cutting tools. Films can be designed to react to specific stimuli like pressure, temperature, or gas molecules, enabling various sensor applications.

Some thin film applications are the ;

Scratch-resistant lenses: A thin film of oxide applied to glass lenses enhances their durability. Touchscreens: Indium Tin Oxide (ITO) films provide electrical conductivity and transparency, essential for touch functionality. Photovoltaic cells: Silicon thin films absorb sunlight and convert it into electricity in solar panels. Thermal management: Thin films with specific thermal properties can be used for heat dissipation in electronics.

‘Multilayer' is the term used for a stack of thin films.

THIN FILM DEPOSITION METHODS

Thin film deposition methods are techniques used to create thin layers of material onto a substrate. These thin films have applications in various fields, including electronics, optics, coatings, and photovoltaics. Several deposition methods are employed to achieve precise control over film thickness, uniformity, and composition. Here are some common thin film deposition methods:

1. Physical bath Deposition (PBD):

- Techniques:

  - Evaporation:

  Heating a material to create a vapor that condenses onto a substrate.

  -Sputtering:

  Bombarding a target material with ions, causing atoms to be ejected and deposited on a substrate.

  - Applications:

  Semiconductor manufacturing, optics, decorative coatings.

2. Chemical bath Deposition (CBD):

- Principle: Chemical reactions occur on the substrate surface, leading to the deposition of a thin film.
- Techniques:

- Low-Pressure CBD (LPCBD): Operates at reduced pressures.
- Plasma-Enhanced CBD (PECBD): Uses a plasma to enhance reaction rates.
- Applications: Semiconductor fabrication, coatings, and thin film solar cells.

Other deposition methods are; Atom layer deposition (ALD), Molecular beam epitaxy (MBE).

CHEMICAL BATH DEPOSITION (CBD) METHODS

Chemical Bath Deposition, also called Chemical Solution Deposition and CBD, is a method of thin film deposition (solids forming from a solution or gas), using an aqueous precursor solution. Chemical Bath Deposition typically forms films using heterogeneous nucleation (deposition or absorption of aqueous ions onto a solid substrate), to form homogeneous thin films of metal chalcogenides (mostly oxides, sulfides, and selenides) and many less common ionic compounds. Chemical Bath Deposition produces films reliably, using a simple process with little infrastructure, at low temperature (<100°C), and at low cost. Furthermore, Chemical Bath Deposition can be employed for large-area batch processing or continuous deposition. Films produced by CBD are often used in semiconductors, photovoltaic cells, and super-capacitors, and there is increasing interest in using Chemical Bath Deposition to create nano materials.

Composition and physical structure can be tailored by the control of chemistry and deposition conditions. The fundamental principles of Chemical bath deposition (CBD) revolve around controlled precipitation of a desired material onto a substrate from a chemical solution. Here's a breakdown of the key principles:

1. Chemical Reactions:

* The precursor solution contains dissolved metal ions (e.g., Zn^{2+}) and other components like complexing agents and buffers.

* When the substrate is immersed in the solution, chemical reactions occur at the surface.

* Complexing agents control the availability of metal ions, influencing deposition rate and film composition.

* Buffers maintain a constant pH, crucial for specific precipitation reactions.

* Depending on the materials and chosen reactions, various mechanisms like hydrolysis, complexation, and reduction-oxidation contribute to film formation.

2. Supersaturation and Precipitation:

* The solution is initially in a state of equilibrium between dissolved ions and the solid phase of the desired material.

* Adjusting parameters like temperature, concentration, or pH can tip the balance towards supersaturation, where the solution can't hold all the dissolved ions.

* This supersaturation drives the precipitation of the material onto the substrate surface, forming the thin film.

3. Nucleation and Growth:

* The initial formation of small, stable clusters of atoms or molecules on the substrate is called nucleation.

* These nuclei then serve as sites for further deposition of atoms or ions, leading to film growth.

* Factors like surface properties, solution composition, and temperature influence the nucleation and growth processes, impacting film morphology and properties.

4. Diffusion and Mass Transport:

* Metal ions and other components involved in the deposition process need to diffuse within the solution and reach the substrate surface for reactions to occur.

* The rate of diffusion and mass transport can affect the deposition rate, uniformity, and thickness of the film.

* Stirring the solution or adjusting its viscosity can influence these transport processes.

5. Substrate Interaction and Adhesion:

* The film adheres to the substrate through physical and chemical interactions.

* Cleaning and pre-treating the substrate are crucial for ensuring good adhesion and preventing film delamination.

* Depending on the materials and desired properties, specific adhesion promoters might be used in the solution.

Chemical bath deposition (CBD) emerges as a versatile and accessible technique for depositing thin films due to its simplicity, cost-effectiveness, and suitability for various materials. This translates into a wide range of applications across different fields:

* For Semiconductors;

Photovoltaic cells: CBD is used to deposit thin films of materials like cadmium sulfide (CdS) and zinc sulfide

(ZnS) as buffer layers in solar cells, enhancing their efficiency and stability.

Transistors: Indium tin oxide (ITO) thin films deposited via CBD find applications in transparent electrodes for thin-film transistors used in displays and other electronic devices.

- For Metal Oxides;

Sensors: CBD-deposited metal oxide films like tin dioxide (SnO?) and zinc oxide (ZnO) exhibit sensitivity to various gases and environmental conditions, making them valuable for gas sensors, humidity sensors, and biosensors.

Coatings: Anti-reflection coatings based on CBD-deposited titanium dioxide (TiO?) can improve the performance of optical devices like lenses and solar cells.

- For Corrosion Protection;

CBD offers a simple and cost-effective way to deposit protective coatings on various materials, preventing corrosion and extending their lifespan. Examples include zinc coatings on steel and nickel-boron coatings on tools.

- CBD Biomedical Applications;

Biocompatible coatings like hydroxyapatite (HA) can be deposited on implants using CBD, promoting bone ingrowth and osseointegration.

Drug delivery systems utilizing biodegradable polymer films deposited via CBD offer controlled release of therapeutic agents.

2.4.1 ADVANTAGES OF CHEMICAL BATH DEPOSITION (CBD)

The Chemical bath technique (CBD) technique offers many advantages over the more suitable vapour phase routes to semiconducting thin films.

In this technique, it is possible to control the film thickness and chemical composition by varying the deposition parameters such as temperature, precursor concentration, complexing agents used, and the pH of the solution. The ability of this method to coat large areas in a reproducible and low-cost process is its most attractive advantage. This method depends on the deposition of thin films from aqueous solutions either by passing a current or by chemical reactions under appropriate conditions.

Chemical bath deposition (CBD) boasts several advantages that make it a versatile and attractive technique for creating thin films:

<u>Simplicity and Cost-Effectiveness:</u>

Requires minimal and often readily available equipment, unlike complex and expensive setups needed for other methods like PVD or CVD. Utilizes simple chemical reactions at ambient temperatures, reducing energy consumption and overall cost.

Versatility and Tailoring:

Applicable to a wide range of materials, including metals, semiconductors, oxides, and even polymers. Offers some control over film composition and morphology by adjusting precursor solution components and deposition parameters.

Conformal Deposition:

Excellently coats complex shapes and achieves uniform thickness on non-planar substrates, unlike some line- of-sight techniques. This makes it valuable for microfluidics, sensors, and intricate geometries.

Low-Temperature Process:

Operates at moderate temperatures (typically below 100°C), suitable for delicate substrates incompatible with high-temperature methods. This opens doors for depositing on polymers, plastics, and other heat-sensitive materials.

2.5 THIN FILM MEASUREMENTS AND TECHNIQUES

The effectiveness and applications of thin films hinge on crucial measurements like thickness, optical characteristics, and solid-state properties. The techniques used for these measurements vary from basic chemical and mechanical methods to intricate electronic and spectroscopic approaches. Additional methods encompass simple chemical analysis;

- gravimetric
- spectrometric
- spectrophotometric techniques.

2.5.1 MEASUREMENT OF FILM THICKNESS

Since thin film thickness is generally of the order of a wavelength of light, various types of optical interference phenomena have been used to measure film thickness. There are also some other optical techniques like ellipsometry and absorption spectroscopy, which can be used to measure thickness. The measurement of film thickness of this work is restricted to two methods namely;

A. The gravimetric method
B. The optical method

A. The gravimetric method is given by:

Density = mass/volume

2.15

$P = m2 - ml / 2At = m/2lbt \qquad (2.16)$

$t = m/2lbp$

Where; t = film thickness

$m = m2 - m1$ is mass of film deposited, m2 and m1 are the mass of the glass slides after and before deposition.

A = Area of the film on rectangular glass substrate of length I, and width b.

B. The optical method:

The optical method for measuring thin film thickness involves utilizing the interaction of light with the thin film. By analyzing the interference or reflection patterns of light waves that pass through or reflect off the film, researchers can deduce the film's thickness. This can be achieved through techniques like ellipsometry or spectrophotometry. The interference patterns arise due to the phase differences between the light waves interacting with the film's surfaces. Precise analysis of these optical characteristics allows for accurate determination of thin film thickness.

Spectral reflectance measures the amount of light reflected from a thin film over a range of wavelengths, with the incident light normal (perpendicular) to the sample surface.

Ellipsometry is similar, except that it measures reflectance at non-normal incidence and at two different polarizations. In general, spectral reflectance is much simpler and less expensive than ellipsometry, but it is restricted to measuring less complex structures. The optical method based on light absorption coefficient is given by;

$$T=(1-R)2\exp\ (at) \tag{2.17}$$

Where R is the reflectance and t the film thickness

Taking the natural logarithm on both sides of equation 2.17 gives;

$$t = In[(1 - R)2/T]/a \qquad (2.18)$$

This equation is used to compute film thickness with absorbance A>0.10 in this work

1.5.2 MEASUREMENTS OF THIN FILM OPTICAL PROPERTIES

Thin film optical properties are measured through techniques such as ellipsometry or spectrophotometry, leveraging the interaction of light with the film. Analysis of interference or reflection patterns provides insights into parameters like thickness. This optical method relies on precise examination of phase differences in light waves interacting with the film's surfaces, enabling accurate determination of the thin film's optical characteristics.

In this research work, a T80+ double beam spectrophotometer was used to determine the absorbance of the coated glass slide in the ultraviolet (UV), visible (VIS) and near infrared (NIR) region of this work. In order to measure the absorbance of the film the coated glass slide was placed on sample holder while the sample beam was made incident on it. The standard or coated glass slide was mounted along the path of the reference beam for compensation. The absorbance was obtained from the absorbance spectral. Other optical properties were obtained from thin based theory.

2.6 APPLICATIONS OF THIN FILMS

Thin films technology has historically been used in a wide range application going from decorative purposes in its early stage, evolving for optical purposes latter on, and an almost endless range of applications with the appearance of advanced deposition techniques, supported by the rapid development of vacuum technology and electrical power. Overall, thin films are used to enhance the properties of bulk materials by depositing a layer with the desired physical and chemical characteristics to improve their functionality. In the following section a brief description of the most technological relevant fields of application of thin films is presented.

2.6.1 ADVANCED ELECTRONICS-OPTOELECTRONIC DEVICES

Advanced electronics-optoelectronic devices have become an important field for the application of a number of thin film types. In particular, MOSFET and CMOS absorb a great amount of the technological development in semiconductor thin films. The fabrication of MOSFETs requires the use of dielectric thin films, i.e. silicon dioxide (SiO2) to insulate the conducting channel from the gate. This thin film has been used due to its ease of fabrication, high impedance due to a large band gap, resistance to high temperatures and chemicals. Also, metallic films are required for the fabrication of multiple microelectronic devices, opto-electronics and optical devices. Al thin films are usually deposited in the channel between the source and drain of MOSFETs to allow the voltage for its operation. Instead, Cu thin films are commonly used in CMOS as gate metallization due to its high electrical conductivity and higher resistance to electromigration. Thin films have also played an important role in data storage devices due to their good magnetic properties in an attempt to replace the traditional flash memory devices for non-volatile memory devices. Thin films such as BiFeO3, lead-zirconium titanate films, amorphous Si, organic compounds among others are being explored as candidates as based- material for this application.

2.6.2 PHOTOVOLTAIC

The use of thin films in the photovoltaic sector (PV) is conceived as a potential solution to reduce the cost per watt in the generation of electricity. This sector has been experiencing a rapid market penetration due to the accelerated achievement of higher efficiencies and the development of thin film structures with better stability. In fact, record efficiencies about 23.3% and 22.1% have been reached using copper indium gallium selenide (CIGS) and CdTe thin films as based materials, respectively. Overall, the advantages of thin films in the PV

sector is related to the high absorption coefficient of the absorber layer, which permits to reduce considerably the material thickness, contributing to the reduction of material cost; also, thin film technology allows the deposition of multiple-juntion devices to capture most of the solar spectrum to increase the conversion efficiency. Additionally, thin films can be deposited into flexible substrate for roll-to-roll manufacturing of PV modules. The state-of-the art of thin films for PV application was initially dominated by amorphous silicon, but evolved into the more efficient CdTe and CIGS, and lately organic and perovskite-based PV cells are under investigation due to its reduced processing cost and feasibility to deposit at low temperatures in flexible substrates.

2.6.3 COATING APPLICATIONS

Thins films and coating applications are involved in a large number of fields including optics, and in sectors where the improvement of the mechanical and chemical properties of bulk materials provides a better functionality or larger lifespan. Optical thin films are widely employed in eyeglasses to improve the vision through the use of a polymer-based optical element that is coated to the spectacles. In addition, the undesired transmission of ultraviolet light and undesired reflection are prevented by the use coatings materials able to absorb wavelengths lower than 400 nm, and the use of antireflective coatings usually made of dielectric materials. Architectural glazing has drawn on thin film coatings to enhance the energy efficiency in office buildings. The heat transfer can be managed from outside and inside the buildings by a suitable filtering of the spectral regions of light. Only transmission of visible light from the outside, and reflection of infrared radiation from inside can be set by making the windows to become a multifunctional device-like with thin films with different spectral response, saving energy from air conditioning and heating for the former and latter cases, respectively. Coatings as a means to increase the wear resistance and reduction of friction in cutting tools can be obtained by multilayer deposition of ceramic coatings, i.e. TiN, TiC . Coatings for corrosion resistance are widely spread in numerous sectors including pipes coated with SiC, stainless steel components coated with oxides, i.e. SiO2, Al2O3, engine parts coated with high temperature corrosion protection such as MoSi2 among others.

2.6.4 ORGANIC THIN FILMS

Organic thin films have attracted a great attention owing to certain unique properties, in particular, flexibility and low-cost material processing which are essential to expand the scope of application of many technologies.

In photovoltaics for example, although still low, the efficiency has been improved considerably from 0.04% up to about 8.3% in organic-polymer based modules, but its evolution remains fuelled by the low cost of material processing, i.e. printing, spraying, and the possibility to fabricate flexible modules. Likewise, the intrinsic complex fabrication process and rigidity of Si-based field-effect transistors can be somehow overcome by organic thin films field-effect transistors. The use of organic thin film have already been proven in various applications such as memory devices, sensors, electronic papers, and smart cards .

2.6.5 BIOMEDICAL APPLICATIONS

The use of thin films has gained a considerable space in biomedical applications due to their ability to provide biocompatible and functional properties, for example, invasive devices, tissue engineering substrates, drug delivery, and antimicrobial coatings, to name a few. The surface of implants has to comply special chemical and mechanical properties, and Ti6Al4V thin films appear to provide appropriate conditions for femur implants. This structure apart from offering a good adhesion and harness, promotes the formation of a calcium layer through a chemical interaction with the biological fluids, improving the osseointegration. Polymer-based thin films have demonstrated to have a good resistance to protein adsorption, which is essential to provide a biocompatible behavior to implants. In this respect, poly (ethylene glycol) PEG, PEGylated thin films are suitable for bone, dental implants and for tissue engineering purposes. Composite thin films have also been used to provide the appropriate mechanical and biological properties to implants in neuronal applications. For example, silicon-based implants have been coated with a nanostructure formed by amorphous silica with fillers of aluminum, silicon dioxide or silver in order to provide microbial protection. Inorganic thin films with piezoelectric properties deposited on flexible substrates are also being investigated for the fabrication of nanogenerators and nano-sensors for biomedical applications. These piezoelectric devices have the capacity to convert mechanical energy provided by the movement of internal organs into electrical energy to power for example pacemakers or nano-sensors. Due to the high sensitivity to mechanical movement these devices can also be used to monitor the cell deformation at nanoscale. Higher performance piezoelectric devices have been fabricated using perovskite such as BaTiO3, PZNT, and PMN-PT .

CHAPTER THREE

EXPERIMENTAL WORK AND MEARSUREMENT

3.1 PREPARATION OF GLASS SLIDES

Five samples of glass slide typically 75 by 26mm and about 1mm thick where prepared by degreasing them in concentrated hydrochloric acid for three days. After three days, the degreased samples of glass slides were scrubbed in cold detergent solution using rubber sponge to avoid scratching their surfaces thereafter, rinsed in distilled water. The glass slides were dip dried in air, labelled using masking tape and weighed by an electronic weighing balance.

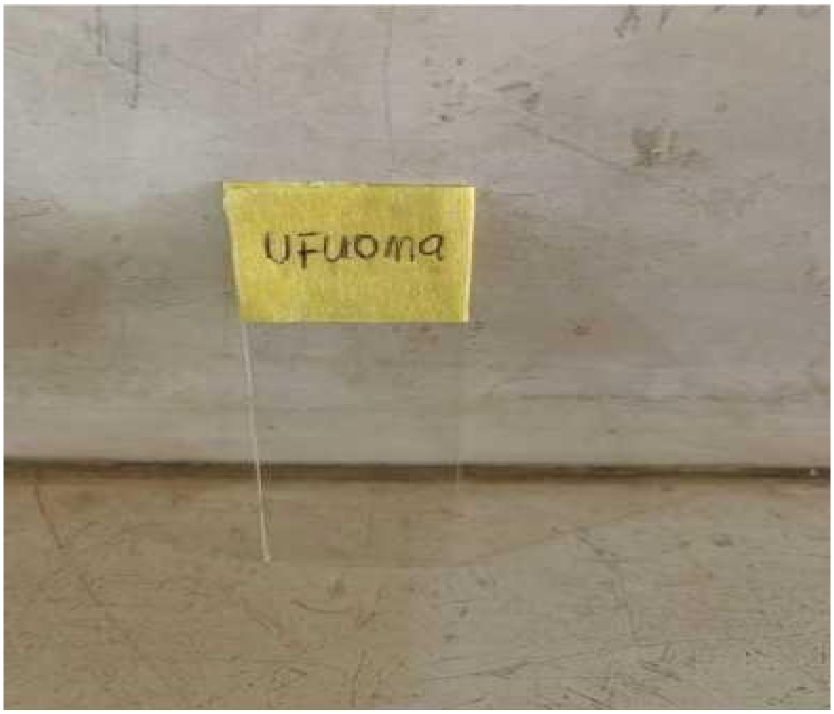


Fig 3.1: Degreased and labelled uncoated glass slide

3.2 PREPARATION OF SOLUTE REAGENT SOLUTION

The mass of each solute reagent was calculated from the following equation

$m = M \times W \times Vol / 1000$

where;

M= Molar concentration

W= Molecular weight of chemical reagent

V= Volume of distilled water required for the solution

m= mass

3.2.1 PREPARATION OF COPPER(II)CHLORIDE -1- WATER SOLUTION

The total mass of Copper (II)Chloride -1- water needed for the experiment was prepared at once to prevent inconvenience in preparing the Copper (II)Chloride -1- water solution at separate times. Extra volume of Copper (II)Chloride -1- water was also prepared to ensure sufficient amount in the case of error. The total mass of Copper (II)Chloride -1- water prepared was calculated as follows;

$m = 0.5 \times 170.48 \times 75 / 1000$

$= 6.39g$

A clean and dry measuring beaker was used to weight the mass of 6.39 g of Copper (II)Chloride -1- water on an electronic weighing balance. It was transferred into a 100ml beaker. The Copper (II)Chloride -1- water is dissolved with the measured 100ml distilled water for dissolution.

3.2.2 PREPRATION OF SODIUM HYDROXIDE SOLUTION

The same technique was applied in the preparation of 35ml of sodium hydroxide

m = 2 x 40 x 35 / 1000. = 4.2g

4.2g of sodium hydroxide is weighed by using measuring beaker and dissolved in a clean and dry flat bottom flask with distilled water, covered for the night to ensure thorough dissolution.

3.2.3 PREPRATION OF THIOUREA SOLUTION

The same technique was applied in the preparation of 75ml of Thiourea

m=0.8x7612x100 / = 6.0896g

13.7g of Thiourea is weighed by using measuring beaker and dissolved in a clean and dry flat bottom flask with distilled water, covered for the night to ensure thorough dissolution.

3.3 PREPARATION OF SOLVENT REAGENTS SOLUTION

For solvent reagents, the volume (V) of the solvent for a given molarity M was calculated using the relation;

V = M x Wt x 100 / d.p X Vt / 1000

where;

M= Molarity required

V= Total volume of ammonia solution

Wt= Molecular mass

Vt= Total volume required

d= Density and specific gravity

p= Percentage array

V = 10 x 17.03 x 100 / 0.88 x 33 X 21 / 1000

=12.32g

Volume of distilled water was obtained using;

VT = V H_2O + V NH_3

V H_2O = VT - V NH_3

= 21 - 12.32 = 8.68ml

3.4 PREPARATION OF DEPOSITION BATH SOLUTION

The deposition bath were five glass beakers of 60ml volumes each. Reagents used for the deposition of Copper Sulphide thin films were different volumes of 0.5M $CuCI_2.H_2O$,10M NH_3 used as a complexing agent, 0.8M $SC(NH_2)_2$ and 3M NaOH solutions. Different volumes of distilled water were added to each beaker to raise the volume to the required volume (i.e. 60ml). This was done so that the required molar concentration in each beaker would be achieved as shown in Table 3.1

Table 3.1 Chemical bath constitution for deposition of Copper Sulphide (CuS) thin films in different molar concentration at room temperature for 24hours for different deposition time.

Glass slide NO	Deposition Room. Temp. (°c)	(hrs	CuCI2.H2 M = 0.5 Vol (ml)	NH3 M=10 Vol (ml)	NaOH M = 3 Vol	SC(NH2) M = 0.8 Vol (ml)	Distill H2O Vol (ml)	Total Solutio Vol. (ml)	Molarity CuCI2.H2 in solution M (mol/dm3
1	27	24.0	3.0	3.0	2.0	5.0	37.0	50.0	0.03
2	27	24.0	6.0	4.0	3.0	8.0	29.0	50.0	0.06
3	27	24.0	9.0	4.0	3.0	11.0	23.0	50.0	0.09
4	27	24.0	12.0	5.0	4.0	14.0	15.0	50.0	0.12
5	27	24.0	15.0	5.0	4.0	17.0	9.0	50.0	0.15

3.5 THIN FILM DEPOSITION

A glass slide was suspended vertically in each of the five bath solutions, with the aid of a plastic peg and a hard paper cover at the centre of the beaker (placed in a position that it would have no contact with the bottom or sides of the beaker) for 24hours at different molarity.

Thereafter, the glass substrate coated with CuS was removed, rinsed with distilled water,

and dried in open air at room temperature. The thin film obtained at the end of the deposition was well adherent and yellow in colour.at room temperature(27c).

Fig 3.2: Copper sulphide (CuS) deposition on glass slides in deposition bath concentration of different molarity

Fig3.3: Glass slides coated with Copper sulphide(CuS) thin films.

3.6 MEASUREMENT

3.6.1 OPTICAL AND SOLID-STATE DETERMINATION

The optical properties calculated in this work includes the absorbance (A), transmittance (T) and reflectance(R), and absorbing power (a) and refractive index (n). The solid-state measurements carried out on the films was the energy band gap (Eg), film thickness (t).

The measurement of the spectral absorbance was done in the laboratory of Biochemistry department, of the University of Benin, Benin City, Nigeria, A T80+ UV/VIS Double beam UV/VIS Spectrophotometer was used to determine the absorbance of the films in the ultraviolet (UV), visible (VIS), and near infrared regions of the electromagnetic spectrum (i.e. a wide range of wavelength). The spectral absorbance was read directly from the instrument. Other properties such as transmittance, reflectance, refractive index, absorbing power, etc. were calculated from the absorbance spectral.

The spectral transmittance was obtained from Eqn(2.4), spectral reflectance was obtained using Eqn(2.3),absorbing power was computed from Eqn(2.7), while the band gap of the deposited thin films were computed using Eqn(2.11), and obtained from extension of linear part of the plots of absorbing power(a2) against photon energy(hu). The refractive index of the films was computed using Eqn(2.14). The film thickness (t) was computed by optical method using Eqn(2.18) for films with absorbance A>0.1.

Fig3.5 : T80+UV/VIS Double beam Spectrophotometer

CHAPTER FOUR

4.0 EXPERIMENTAL RESULTS

Table 4.1: Spectral absorbance (A), transmittance (T), reflectance(R), and absorbing power (∝) of CuS thin films deposited on glass slides at 0.03 molar concentration and room temperature (°C) for 24Hours.

λ(nm)	A	T	R	$\propto \times 10^{6}(m^{-1})$
794	0.009	0.979	0.012	0.021
799	0.009	0.979	0.012	0.021
806	0.009	0.979	0.012	0.021
812	0.009	0.979	0.012	0.021
819	0.009	0.979	0.012	0.021
822	0.009	0.979	0.012	0.021
824	0.009	0.979	0.012	0.021
831	0.009	0.979	0.012	0.021
833	0.009	0.979	0.012	0.021
839	0.009	0.979	0.012	0.021
843	0.009	0.979	0.012	0.021
846	0.009	0.979	0.012	0.021
853	0.008	0.982	0.010	0.018
856	0.008	0.982	0.010	0.018
858	0.008	0.982	0.010	0.018
871	0.008	0.982	0.010	0.018
884	0.008	0.982	0.010	0.018
889	0.008	0.982	0.010	0.018
891	0.008	0.982	0.010	0.018
895	0.008	0.982	0.010	0.018
897	0.008	0.982	0.010	0.018
905	0.008	0.982	0.010	0.018
913	0.008	0.982	0.010	0.018
924	0.007	0.984	0.009	0.016
927	0.007	0.984	0.009	0.016
933	0.007	0.984	0.009	0.016
948	0.007	0.984	0.009	0.016
958	0.007	0.984	0.009	0.016
966	0.007	0.984	0.009	0.016
969	0.007	0.984	0.009	0.016

Table 4.2: Spectral absorbance (A), transmittance (T), reflectance(R), and absorbing power (∝) of CuS thin films deposited on glass slides at 0.06 molar concentration and room temperature (°C) for 24Hours.

λ (nm)	A	T	R	$\propto \times 10^{6}(m^{-1})$
843	0.001	0.998	0.001	0.002
845	0.001	0.998	0.001	0.002
859	0.001	0.998	0.001	0.002
861	0.001	0.998	0.001	0.002
867	0.000	1.000	0.000	0.000
870	0.000	1.000	0.000	0.000
874	0.000	1.000	0.000	0.000
887	-0.000	1.000	0.000	0.000
890	-0.000	1.000	0.000	0.000
892	-0.000	1.000	0.000	0.000
901	-0.000	1.000	0.000	0.000
907	-0.001	1.002	-0.002	-0.002
909	-0.001	1.002	-0.002	-0.002
914	-0.001	1.002	-0.002	-0.002
922	-0.001	1.002	-0.002	-0.002
925	-0.001	1.002	-0.002	-0.002
931	-0.001	1.002	-0.002	-0.002
938	-0.001	1.002	-0.002	-0.002
944	-0.001	1.002	-0.002	-0.002
947	-0.002	1.005	-0.003	-0.005
954	-0.002	1.005	-0.003	-0.005
959	-0.002	1.005	-0.003	-0.005
962	-0.002	1.005	-0.003	-0.005
964	-0.002	1.005	-0.003	-0.005
969	-0.002	1.005	-0.003	-0.005
974	-0.002	1.005	-0.003	-0.005
979	-0.002	1.005	-0.003	-0.005
981	-0.002	1.005	-0.003	-0.005
983	-0.002	1.005	-0.003	-0.005
987	-0.002	1.005	-0.003	-0.005

Table 4.3: Spectral absorbance (A), transmittance (T), reflectance(R), and absorbing power (∝) of CuS thin films deposited on glass slides at 0.09 molar concentration and room temperature (°C) for 24Hours.

λ(nm)	A	T	R	$\propto \times 10^{6}(m^{-1})$
365	0.132	0.738	0.130	0.304
368	0.105	0.783	0.110	0.242
370	0.105	0.785	0.110	0.242
380	0.094	0.805	0.101	0.217
382	0.094	0.805	0.101	0.217
386	0.094	0.805	0.101	0.217
388	0.093	0.807	0.100	0.214
393	0.093	0.807	0.100	0.214
396	0.092	0.809	0.099	0.212
402	0.093	0.807	0.100	0.214
506	0.077	0.838	0.085	0.177
753	0.052	0.887	0.061	0.119

Table 4.4: Spectral absorbance (A), transmittance (T), reflectance(R), and absorbing power ($\propto$) of CuS thin films deposited on glass slides at 0.12molar concentration and room temperature (°C) for 24Hours.

λ(nm)	A	T	R	$\propto \times 10^6 (m^{-1})$
343	0.296	0.506	0.198	0.681
346	0.293	0.509	0.198	0.675
350	0.292	0.511	0.197	0.671
365	0.327	0.471	0.202	0.753
370	0.279	0.526	0.195	0.642
680	0.127	0.746	0.127	0.293

Table 4.5: Spectral absorbance (A), transmittance (T), reflectance(R), and absorbing power ($\propto$) of CuS thin films deposited on glass slides at 0.15 molar concentration and room temperature (°C) for 24Hours.

λ(nm)	**A**	**T**	**R**	$\propto \times 10^6 (m^{-1})$
346	0.299	0.502	0.199	0.689
362	0.322	0.476	0.202	0.742
370	0.258	0.552	0.190	0.594

Table 4.6: Average Optical and solid-state properties (at wavelength (2.) of 660nm) of CuS thin films deposited by improved solution growth technique (SGT) in bath solution for different molarity at room temperature for 24hours

Average optical and solid-state properties	**Deposition Bath**		**Different molarity of CuS in Bath Solution**				
	Hours	**Temp. (°C)**	**0.03M**	**0.06M**	**0.09M**	**0.12M**	**0.15M**
A	24	27	0.008	-0.001	0.094	0.309	0.322
T	24	27	0.982	1.002	0.806	0.491	0.476
R	24	27	0.010	-0.002	0.101	0.199	0.202
$\propto \times \mathbf{10^{6}}(\boldsymbol{m^{-1}})$	24	27	0.018	-0.002	0.216	0.712	0.742
n	24	27	1.222	0.914	1.933	2.610	2.629
Average solid state properties							
$F(\mu m)$	24	27	4.015	0.001	1.933	0.607	0.589
Eg (eV)	24	27	1.446	1.346	3.215	3.466	3.428

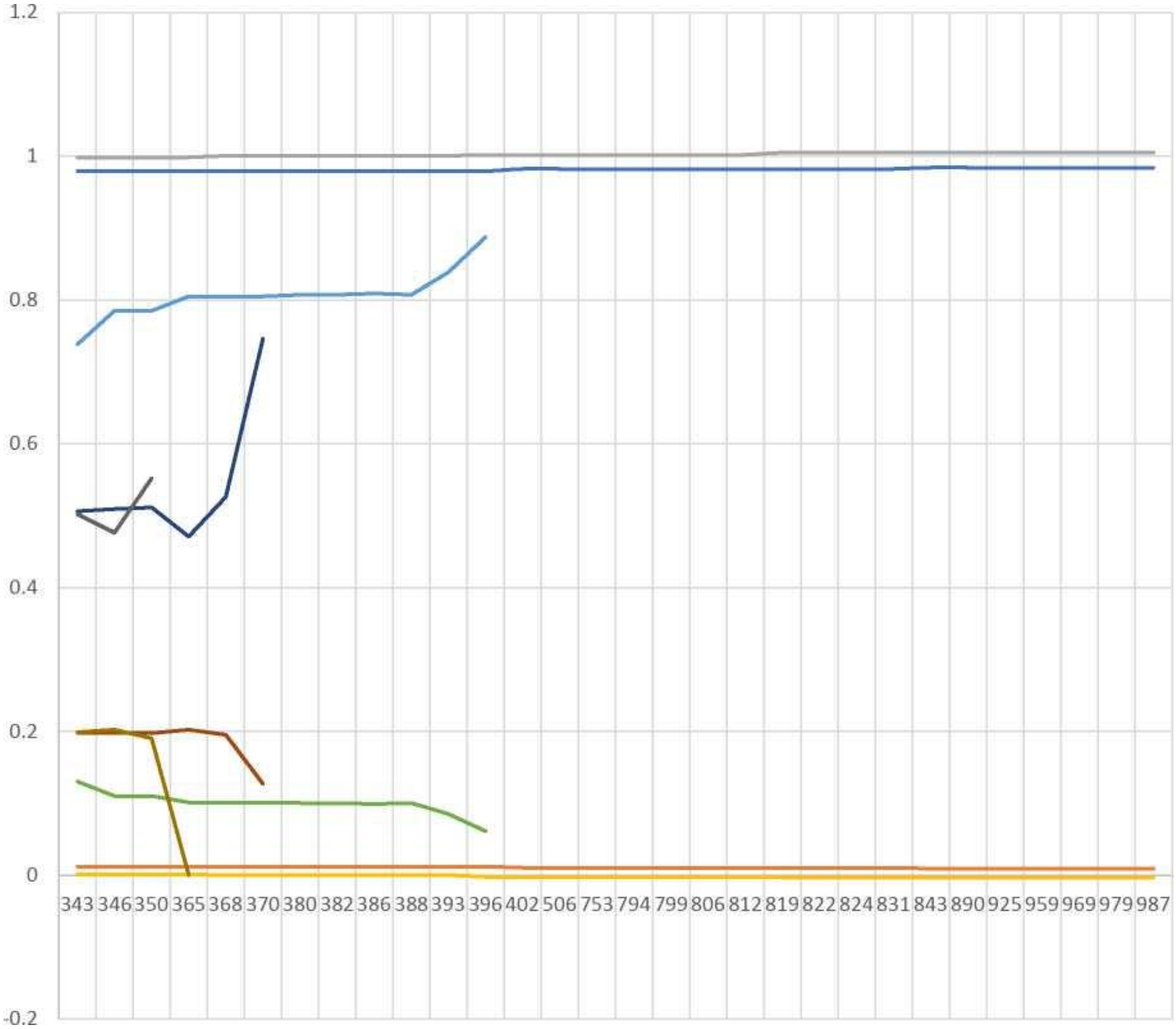
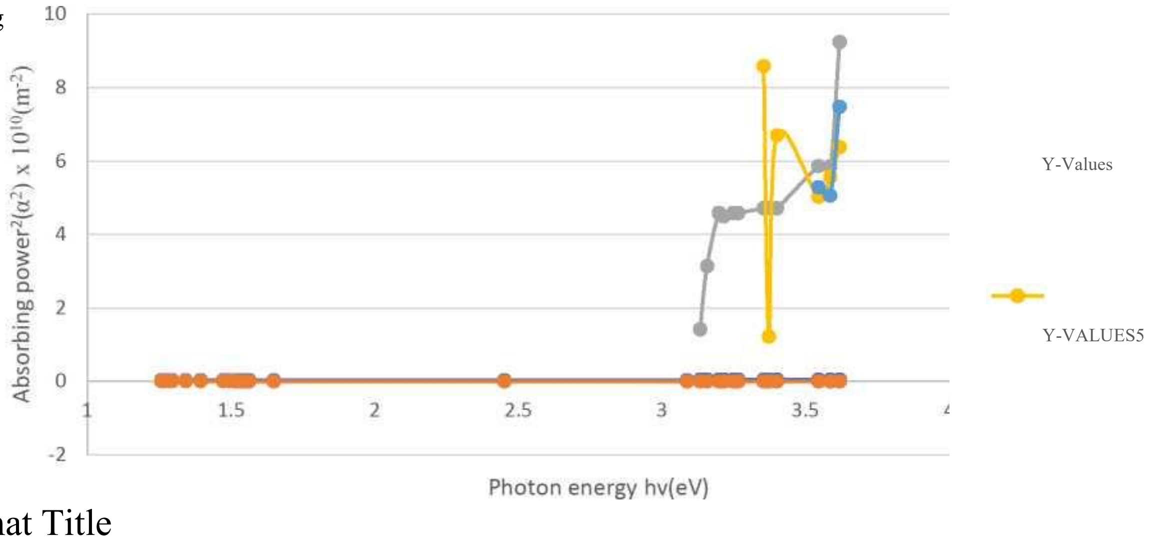


Fig 4.1: Transmittance -Reflectance spectra of Copper sulphide (CuS) thin films deposited on glass slides by improved solution growth technique in deposition bath concentration of

Fig



. 4.2: Plots of a' against hv for copper sulphide (CuS) thin films deposited on glass by solution growth technique at different molar concentration of copper sulphide (CuS) in bath solution at room temperature for24 hours.

CHAPTER FIVE

DISCUSSION, RECOMMENDATION, AND CONCLUSION

5.1 DISCUSSION

The absorbance spectra for the deposited copper sulphide thin films grown in a deposition bath concentration and room temperature(°C) for different molar concentrations are displayed in Table 4.1. It shows that the CuS thin films have high transmittance (T) and low reflectance(R).

The transmittance (T) of the films produced increases as the wavelength increases for a particular deposition time, but decreases with increase in deposition time at the same bath concentration. The absorbance (A)decreases as the wavelength increases, but increases as the deposition time increases. As the absorbance (A)decreases the reflectance (R) also decreases with an observed increase of the transmittance (T) of the films produced. Transmittance (T) and reflectance (R), depends on the film absorbance, in the wavelength range of 340nm to 980nm. The highest transmittance of 0.984 corresponds to minimum absorbance of 0.007 obtained at wavelength of 969nm for film produced at 0.03M for 24hours at room temperature. The minimum transmittance (T) 0.979 corresponds to absorbance of 0.009 obtained at a wavelength 831nm for thin film produced at deposition time of 24hours. The highest reflectance (R) 0.012 corresponds to absorbance of 0.009 obtained at a wavelength 831nm for thin film produced at deposition time of

24hours. The high transmittance (T) and low reflectance (R) properties of the Copper Sulphide (CuS) thin films in the ultraviolet, visible. And near infrared regions of the electromagnetic spectrum could be used to produce anti reflection coatings for transparent covers of solar thermal devices to improve their efficiencies, eye glass coatings to reduce reflection and improve the transmittance of light and thermal control window coatings for cold climates when coated on glass to reduce reflection loss and enhance transmission of light into buildings (Ilenikhena etai.2005). It can be also observed from Table 4.I that as the deposition time of the film increases the transmittance (T) reduces, while the absorbance (A) and reflectance (R) increases.

Absorption coefficient method was applied to obtain the band gap of the CuS films produced.

5.1.1 POSSIBLE APPLICATIONS

Optical properties show that the thin films produced at pH of 7-11 have high spectral transmittance (T) in the ultraviolet (UV), visible (VIS), and near infrared (NIR) regions of electromagnetic regions with corresponding low reflectance (R) in the ultraviolet (UV), visible (VIS) and near infrared (NIR) regions and refractive index(n) less than 1.8 ($n<1.8$). These thin films could find useful applications;

(i) In solar thermal devices as antireflection (AR) coatings on transparent covers (or windows) to improve their efficiencies.

(ii) In electronic industry as transparent contacts or electrodes of photactivated and photoelectrochemical cells (P.E.C).

(iii) In architectural industry as heat mirror coatings for temperate regions with very cold winter to reduce thermal losses from the heated interior to exterior.

5.2 RECOMMENDATION

Copper sulphide (CuS) thin film can be produced with:

- Different molar concentration values
- Same molar concentration under solar radiation for different deposition times
- Same molar concentration at higher temperature for 3 hours.
- Different molar concentrations for 24 hours at room temperature.

5.3 CONCLUSION

Thin films of copper sulphide (CuS) were successfully deposited on glass slides at room temperature, using improved solution growth technique (SGT) in bath concentrations for different molar concentrations (0.03,0.06, 0.09. 0.12, 0.15) at room temperature of 27°C.

A T80+L,V/VIS Double beam spectrophotometer was used to obtain the spectra absorbance data, while the other optical and solid state properties of the films were obtained by calculations based on theory. The average optical and solid properties include: Absorbance(A)=0.001-0.322, Transmittance(T)=0.476-1.002, Reflectance (R)=- 0.002-0.202, Absorbing power(a)=-0.002-0.742, Refractive index(n)=0.914-2.629. Average solid-state properties are, Film Thickness(t)=0.476-1.002 and bandgap (Eg)= 1.34-3.47eV.

It is observed that these films could find useful applications as: (i) construction of poultry house, (ii) solar cells (iii) anti-dazzling coatings.

The deposited thin films with band gap (Eg) within light energy range (~ 1.5-3.0 eV) of electromagnetic spectrum could find application in solar electricity for rural electrification to improve the standard of living, telecommunication, remote monitoring and control system.

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