

**CHEMICAL BATH DEPOSITION AND CHARACTERIZATION OF  
STRONTIUM IODIDE (SrI<sub>2</sub>) 3THIN FILMS AT DIFFERENT MOLAR  
CONCENTRATION AND UNDER SOLAR RADIATION TEMPERATURE  
OF 50°C FOR 7½ HOURS**

**BY**

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**A PROJECT WORK SUBMITTED TO THE DEPARTMENT OF PHYSICS,  
FACULTY OF PHYSICAL SCIENCES, UNIVERSITY OF BENIN, IN  
PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD  
OF BACHELOR OF SCIENCE (B.Sc.) IN PHYSICS**

**MARCH 2024**

## CERTIFICATION

I hereby declare that this project is my own work towards the partial fulfillment of a Bachelor of Science degree and in addition of my knowledge.

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Prof. O.D. Osahon

\_\_\_\_\_  
Date

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Prof. P.O. Ilenikhena  
(Supervisor)

\_\_\_\_\_  
Date

\_\_\_\_\_  
(External Examiner)

\_\_\_\_\_  
Date

## **DEDICATION**

This work is dedicated to the almighty God who has seen me through my time in this school.

## ACKNOWLEDGEMENT

First and foremost, I am immensely grateful to God, who is my source, and without Him, completing this task would have been impossible. His guidance and blessings have been the driving force behind this endeavor.

My profound appreciation goes to my project supervisor Prof. P.O. Ilenikhena whose expertise, patience, positive criticism and insightful feedback significantly contributed to the success of this work.

A special acknowledgement goes to my family, my parents Mr. and Mrs. Richards for their unwavering and enduring love and support in all aspects of my life, including moral, monetary, and spiritual nourishment.

To my siblings, your encouragement, motivation and belief in my abilities spurred me on even during the challenging times. I appreciate you all to my friends and course mates, especially Edisemi, your constant support, collaborative efforts and enthusiasm made this project an enjoyable and fulfilling experience. Thank you for being there whenever I needed a helping hand.

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## ABSTRACT

Thin films of Strontium iodide ( $\text{SrI}_2$ ) were successfully deposited on glass slides at a temperature of  $50^\circ\text{C}$  in a chemical bath for  $7\frac{1}{2}$  hours, using improved solution growth technique (SGT) in different molar concentrations ranging from 0.03M, 0.06M, 0.09M, 0.12M and 0.15M. A Double beam spectrophotometer was used to obtain the spectra absorbance data while the other properties were calculated using the theory. The average optical and solid state properties include Absorbance (A)=0.149-0.541 Reflectance (R)- 0.141-0.203, Transmittance (T)=0.288-0.710, Absorbing Power (a)=0.342- 1.25, Refractive Index (n)=2.20-2.64. Film Thickness ( $t$ )=0.937-0.972, and Band Gap ( $E_g$ )-3.318-3.419. While the Strontium thin films can be used as antireflection coatings, it is observed that thin films with refractive index greater than 1.9 can be used as Construction of Poultry house, solar cells, etc. The deposited thin films have band gap within light energy range from 1.5-3.0 eV of the electromagnetic spectrum and could be useful for applications in solar electricity for rural electrification which improves the standard of living. telecommunication, etc.

## CHAPTER ONE

### 1.0 INTRODUCTION

Solar radiation is radiant (electromagnetic) energy from the sun. It provides light and heat for the Earth and energy for photosynthesis. Solar radiation is a form of moving energy, the movement of the energy brings into place the term frequency. Not all of the radiation emitted from the sun reaches the Earth's atmosphere. Much of it is absorbed, reflected, or scattered in the atmosphere (Jim, 2012).

The energy produced by capturing heat and light from the Sun is known as solar energy. The sun is the planet's power plant and the origin of all energy. It is referred to be a renewable source of energy since there is a plentiful supply of energy on earth as long as the sun is there, the energy can be stored in batteries, so there is no concern about its dependability, and it is a free energy because it is easily captured. Electromagnetic radiation from the sun is converted into helium and then radiates to the earth. A reduced amount of solar energy— $2.0 \times 10^5$  kwh per day or  $7.2 \times 10^{15}$  mj/day—reaches the ground.

The advent of environmentally friendly and pollution-free non-conventional energy resources has emerged as a feasible alternative as the demand for power and energy is rising quickly and the depletion of natural resources is happening at the same pace. To overcome the collapse and negative effects of using too much conventional energy source, non-conventional energy sources such as solar energy through solar thermal conversion and solar photovoltaic conversion systems, wind energy, biomass, and industrial and household wastes will help to a great extent in enhancing the power generation capacity and energy needed for various sectors.

A thin film material surface receives the spectrum of solar energy from the atmosphere as a diverse distribution of photon energies. This spectrum contains photons whose energy are insufficient to excite electrons and absorb solar radiation simultaneously (Seiver, 1979). The solar radiation can be changed into a narrow distribution of photons with energy high enough to cause absorption when it hits the film surface. Selective thin film surfaces can be used to reliably narrow a broad spectral band to a sharp photon distribution (Seiver, 1979). The type of film material has a significant impact on how well a surface narrows the photon distribution.

In the energy sector, ongoing research and development aims to improve the efficiency, cost-effectiveness and scalability of renewable energy technologies. One of which is the development of thin film technology which has the potential to play a vital role in expanding the scope of solar energy and advancing the renewable energy transition. In solar energy, a specific type of thin film, solar thin film, is used in the conversion of the sun's energy to electricity by absorbing sunlight.

One vital step in the production of Solar thin film is the Thin Film Deposition, which is divided into three (3); Physical, Chemical and Atomic Deposition. This step involves the deposition of thin film unto a prepared substrate. In this work, the method used was the Chemical Bath Deposition (Solution Growth Technique). The application of the thin films was determined by the optical and solid state properties which were used to characterize them and find their applications based on the properties found.

## 1.1 LITERATURE REVIEW

Thin film is a thin material created by the crystallization and growth processes of molecular species on a substrate. The microstructure and physical properties of thin films depend on their mode of creation, therefore any film formed from any other process, no matter how thin, is not referred to as thin film. The other method of film formation is usually referred to as thick film technique, which include depositing clusters of microscopic species (by screen printing, electrophoresis, plasma gun, etc.) or by thinning a bulk material. (Chopra, 1983).

Thin films have a thickness of less than 100nm and are made from dielectric transparent materials. They are best defined by the birth process rather than the thickness. (Pentia et al., 2004). When compared with bulk films, thin films exhibit attractive properties which find applications in miniaturized devices from micron to Nano scale (Oh et al., 2010)

The techniques involved in the production of thin films range from simple and cheap to complex and expensive depending on the substrate conducting materials and the performance of the films required. (Quijada et al, 1998.Chopra, 1969)

Different studies related to thin film experiments have been conducted for a several reasons, which include; for giving the efficiency and functionality of thin film, for investigating and understanding the unique physical, chemical, and electrical properties exhibited by thin films, for investigating the nature of deposited material, the process involved in deposition, studying concentration, temperature, time of deposition and varying substrates to know the best conditions for chemical bath deposition (CBD) and solution growth technique (SGT).

Xing Wei He et al, 2011, examined the effects of temperature and time on properties of Cadmium Sulfide (CdS) after preparing CdS and depositing it on Glass microscopic slides using chemical bath deposition.

Zinc Sulfide and Cadmium Sulfide thin films were deposited on Glass slides at 300K and pH values of 8, 10 and 12 using Chemical Bath Deposition method by Ilenikhena et al (2005). The films grown were observed.

To investigate the nature of chemical bath deposition of copper sulfide (CuS) thin films and the process involved in the deposition process, Munce (2008) deposited copper sulfide (CuS) thin films onto several substrates including silicon wafers, glass slides and gold and platinum electrodes using the chemical bath deposition method.

Solution Growth Technique was used for deposition of cadmium sulfide (CdS) thin films by Ilenikhena et al 2002, to several glass slides. The effects of temperature of 500C and time 7½ hours were examined at a pH 7-12.

Thin films are used in various ways. In electronics, thin films are used in photo-emissive surfaces, piezoelectric transducers, and radiation detectors, passive inactive electronic components from transistor or resistor capacitor networks to such specialized devices as magnetic storage bits, photo sensors and cryotrons. The industrial applications of thin films include decorative finishing of plastics, optical coatings of various kinds (mainly anti-reflection coatings, reflection increasing films, multi-layer interference filters and fluorescent coatings). Thin films of thickness less than 100 nm serves as anti-reflection coatings on solar energy collectors. (Ilenikhena, 2006)

## **1.2 CHOICES FOR CHEMICAL BATH DEPOSITION (CBD) METHOD**

- The chemical and apparatus needed for deposition are simple to set up and readily available.
- Electricity is not necessarily needed for this method
- Less casualties during experiment
- Accurate result is given with the duration of deposition
- Different shapes of plate or object (uniform or irregular) can be used for deposition.

## **1.3 AIMS AND OBJECTIVES**

### **1.3.1 AIM**

The aim of this work is to grow Strontium Iodide (SrI<sub>2</sub>) thin films using chemical bath deposition (CBD) method at different molar concentrations (0.03M, 0.06M, 0.09M, 0.12M and 0.15M) of Cadmium chloride monohydrate (CdCl<sub>2</sub>.H<sub>2</sub>O) in bath solution at 50°C for 7½hours.

### **1.3.2 OBJECTIVES**

Objectives of this work are to:

- Obtain the optical and solid state properties of SrI<sub>2</sub> thin films grown.
- Identify the possible application of SrI<sub>2</sub> thin films based on their properties.

## **CHAPTER TWO**

### **2.0 THEORY**

Solar energy is radiant light and heat emitted by the Sun that can be harnessed and converted into various forms of usable energy. It is a renewable and sustainable source of power, as the Sun will continue to radiate energy for billions of years. Solar energy can be captured and utilized through various technologies, such as solar photovoltaic (PV) systems, solar thermal systems, and solar water heaters.

The Sun is a special star that provides almost all the energy on the Earth. It provides a non-conventional source of energy which helps to reduce Greenhouse effect on global climate created by fossil fuels known as Solar Energy. The sun has surface temperature of approximately 5800K, its mass is considered to be almost

330,000 times Earth’s mass. The distance between the sun and the earth is approximately an average of  $1.5 \times 10^8$  Km, or 8.31 minutes using the speed of light. (Sami, 2005).

## 2.1 SOLAR RADIATION

Solar radiation refers to the electromagnetic energy emitted by the Sun. It encompasses a broad spectrum of wavelengths, including visible light, infrared, ultraviolet, and other forms of electromagnetic radiation. Solar radiation is the primary source of energy that drives various processes on Earth, such as photosynthesis in plants, weather patterns, ocean currents, and the Earth's climate.

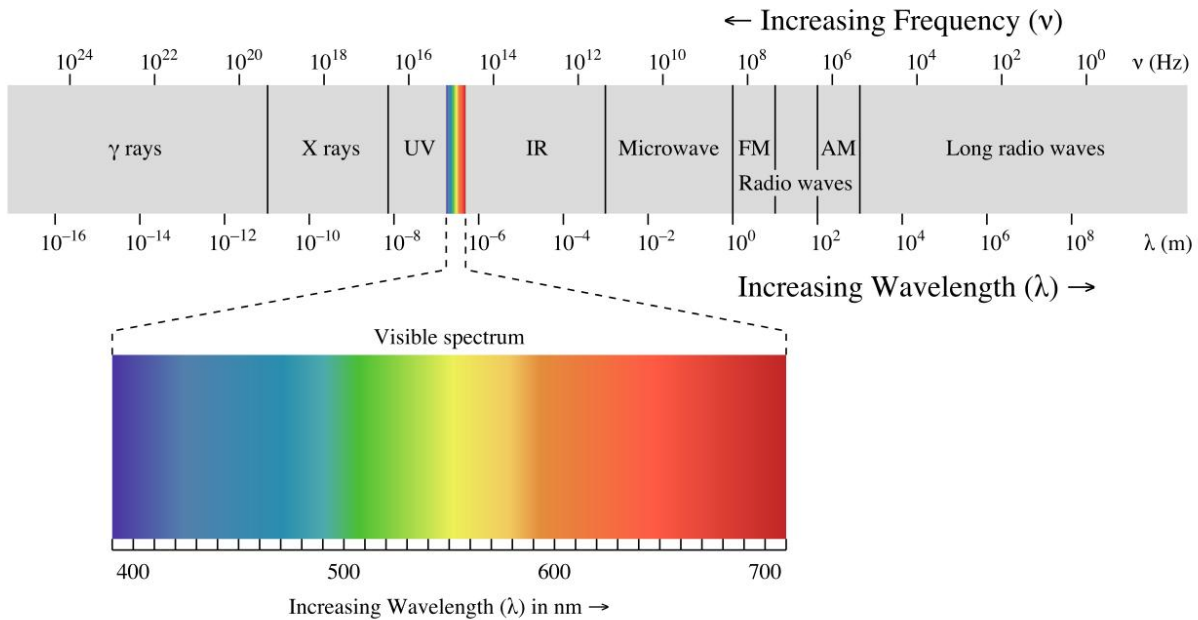


Figure 2. 1 Electromagnetic spectrum

(<https://www.japanistry.com/electromagnetic-spectrum/>)

The solar radiation reaching the Earth's outer atmosphere is known as the solar constant, which is approximately 1361 watts per square meter ( $\text{W}/\text{m}^2$ ). However, the actual amount of solar radiation that reaches the Earth's surface varies depending on factors such as the angle of sunlight, atmospheric conditions, and geographic location.

Solar radiation can be harnessed and converted into usable energy through various technologies, such as solar panels in photovoltaic systems and solar thermal collectors for heat generation. These technologies play a vital role in renewable energy production and reducing greenhouse gas emissions.

## **2.2 SOLAR RADIATION INTERACTION WITH THE EARTH'S ATMOSPHERE**

Solar radiation interacts with the Earth's atmosphere in several ways, influencing the distribution of energy, climate patterns, and weather phenomena. The interactions with the Earth's atmosphere play a critical role in determining the amount of solar energy that reaches the surface and regulates the planet's overall energy balance.

Some of the incoming solar radiation is absorbed by the Earth's atmosphere, particularly by molecules like water vapor, carbon dioxide, and ozone. This absorption contributes to the heating of the atmosphere. Other solar radiation is scattered in various directions by air molecules and aerosols, altering the direction of light and giving rise to phenomena such as Rayleigh scattering (responsible for the blue color of the sky). Part of the solar radiation is reflected back into space by the atmosphere before reaching the Earth's surface. This reflection depends on the angle of incidence and the properties of the atmospheric particles. A significant portion of the absorbed solar radiation is re-emitted by the Earth's surface as infrared radiation (heat). Greenhouse gases in the atmosphere, such as water vapor,

carbon dioxide, methane, and nitrous oxide, absorb and re-radiate some of this infrared radiation back towards the Earth's surface, preventing excessive cooling and helping to maintain a habitable temperature range (the greenhouse effect). However, human activities have led to an increase in greenhouse gas concentrations, contributing to global warming and climate change.

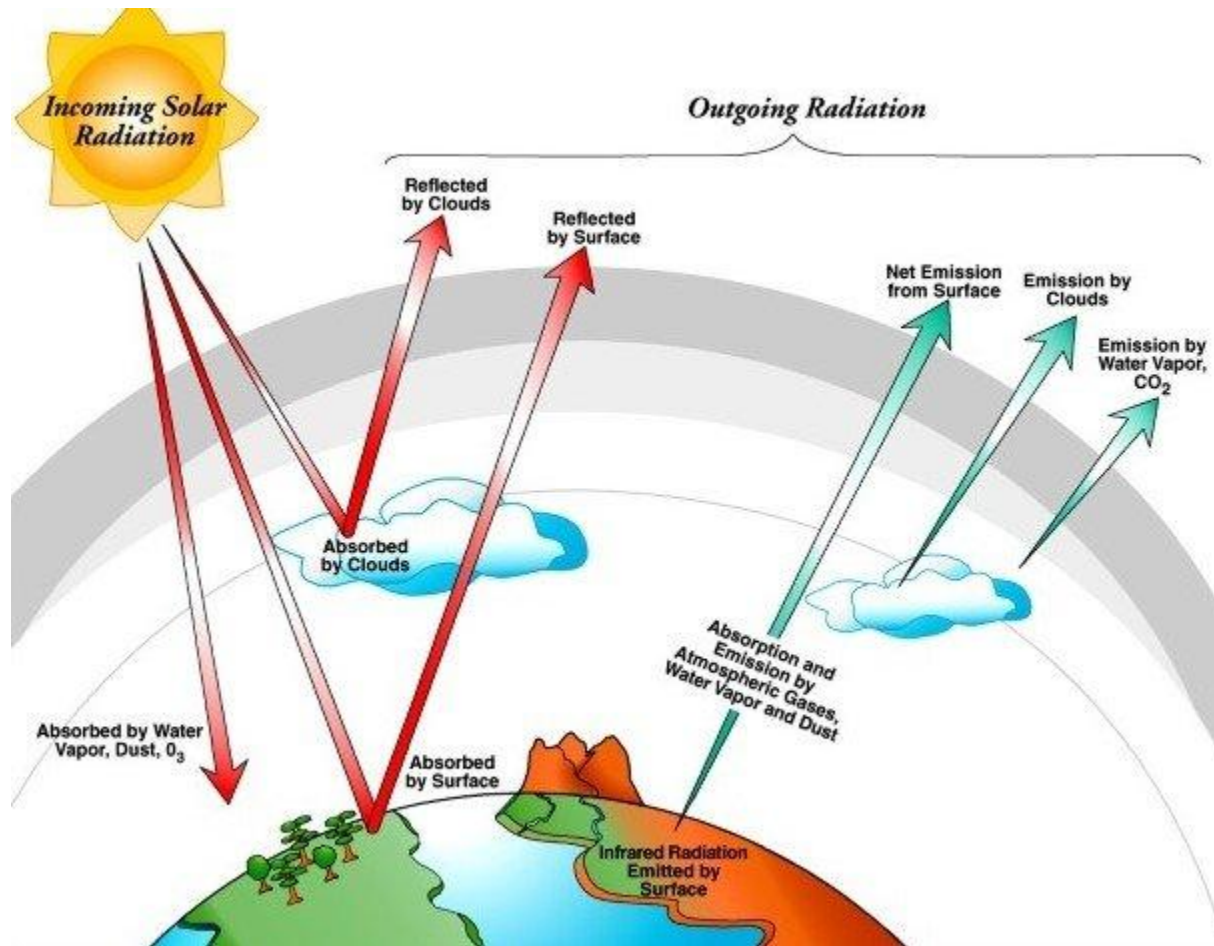


Figure 2. 2. Solar Radiation interaction with the Earth's surface  
(<https://www.energy.gov/science/doe-explainsatmospheric-radiation>)

### 2.3 SOLAR RADIATION INCIDENT ON SURFACES

Solar radiation on the Earth's surface refers to the electromagnetic energy emitted by the Sun that reaches and interacts with the Earth's atmosphere and land. The solar constant represents the average solar radiation at the top of the Earth's atmosphere, approximately  $1361 \text{ W/m}^2$ .

The angle of incidence varies with location, time, and season, influencing the amount of solar energy reaching the surface. Cloud cover affects solar radiation levels, and solar energy utilization includes applications like solar photovoltaic and solar thermal technologies.

Global radiation  $G_g$ , (global solar radiation or total solar radiation) ( $\text{W/m}^2$ ), refers to the total amount of solar energy received per unit area at the Earth's surface from the entire hemisphere of the sky. It represents the total solar energy available for various applications, including solar power generation, heating, and supporting ecological processes like photosynthesis. It includes all forms of solar radiation, such as direct radiation ( $G_d$ ), diffuse radiation, and reflected radiation ( $G_b$ ).

The interplay between these components affects the overall solar radiation incident on the Earth's surface.

### **2.3.1 SELECTIVE SURFACE**

Selective surfaces are surfaces for solar thermal absorbers that reduce irradiation losses and, hence, increase thermal efficiency of collectors.

Such surfaces give opportunity to increase maximal effectiveness of solar receiver in sun radiation exchange. For effective photo thermal conversion solar receiver surface should have high solar absorption ( $\alpha$ ) and low heat loss ( $\epsilon$ ) at the operational temperature.

Selective surfaces take advantage of the differing wavelengths of incident solar radiation and the emissive radiation from the absorbing surface by optimizing their optical properties to selectively absorb and transmit specific wavelengths of light. The goal is to maximize the absorption of solar energy in the visible and near-infrared regions while minimizing thermal emission in the mid-infrared region. This selective behavior allows these surfaces to efficiently convert solar energy into usable forms, such as heat or electricity, while reducing heat losses.

## **2.4 THIN FILMS**

A thin film is a layer of material with a thickness ranging from nanometers to micrometers. It is deposited on a substrate using various techniques such as physical vapor deposition (PVD), chemical vapor deposition (CVD), and others. Thin films find applications in diverse fields, including electronics, optics, solar cells, displays, sensors, and coatings. (Hass, G., and Weber, E. R., 1963)

### **2.4.1 THIN FILM DEPOSITION METHODS**

There are different techniques used to create thin films by applying a layer of material onto a substrate. These techniques can be generally divided into two (2)

- **Physical Vapor Deposition (PVD):** PVD involves the transfer of material from a solid source to the substrate through physical means. It includes techniques like thermal evaporation, sputtering, and electron beam evaporation.
- **Chemical Deposition Methods:** Chemical deposition methods can be broadly divided into two main categories based on the processes involved:
  - i. **Chemical Vapor Deposition (CVD):** Chemical Vapor Deposition involves the use of gaseous precursor molecules that react and deposit onto the substrate surface. In CVD, the substrate is exposed to one or more precursor gases, and chemical reactions occur on the substrate surface to form a solid film. It

includes techniques like Low-Pressure Chemical Vapor Deposition (LPCVD), Plasma-Enhanced Chemical Vapor Deposition (PECVD), Metal-Organic Chemical Vapor Deposition (MOCVD) and Atomic Layer Deposition (ALD).

- ii. Chemical Solution Deposition (CSD): Chemical Solution Deposition involves the use of liquid chemical solutions or precursor solutions that react and deposit onto the substrate surface. In CSD, the substrate is immersed or coated with the chemical solution, and the film forms through chemical reactions and nucleation on the substrate surface. This includes techniques like Chemical Bath Deposition (CBD), Sol-Gel Process, Spin Coating, and Dip Coating.

The deposition method used in this experiment is the Chemical Bath Deposition Method (CBD).

#### **2.4.2 Chemical Bath Deposition Method (CBD)**

Chemical Bath Deposition (CBD) is a chemical solution deposition technique used to deposit thin films or coatings on a substrate. It involves immersing the substrate into a liquid chemical bath containing metal ions or precursor compounds. Through a series of chemical reactions, the metal ions are reduced and deposited onto the substrate surface, forming a thin film. (Lakshminarayanan, V. et al., 2019)

The CBD technique is known for its simplicity, low cost, and ability to coat complex shapes and porous substrates. It has been widely used for depositing various materials, including metal oxides, sulfides, and chalcogenides, which find applications in solar cells, sensors, and optoelectronic devices. (Lakshminarayanan, V. et al., 2019)

## **2.5 THIN FILMS MEASUREMENT TECHNIQUES**

The measurement of the optical and solid state properties of a thin film as well as the thickness of the film deposited on the substrate is used to determine its effectiveness and applications. The techniques employed in the measurements of thin films range from chemical and mechanical to the very complex electronic and spectroscopic methods. The methods for measurements of thin films include;

- Spectrophotometric method,
- Simple chemical analysis method,
- Spectrometric method,
- Gravimetric method,
- Optical method.

### **2.5.1 MEASUREMENTS OF THIN FILM OPTICAL PROPERTIES**

In this research work, a 7565 UV-VIS spectrophotometer was used to determine the absorbance of the coated glass slide in the ultraviolet (UV), visible (VIS) and near infrared (NIR) region of the electromagnetic region. In order to measure the absorbance of the film the coated glass slide was placed on sample holder while the sample beam was 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 the thin based theory equation.

## **2.6 OPTICAL AND SOLID STATE PROPERTIES**

The optical properties that are calculated for this work includes;

- Absorbance (A)
- Transmittance (T)

- Reflectance(R)
- Absorbing power or coefficient of absorption ( $\alpha$ ).
- Refractive index (n)

The solid states properties are;

- Band gap (Eg)
- Film thickness(t)

### 2.6.1 ABSORBANCE (A)

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. A UV/VIS Spectrophotometer was used to obtain the spectral absorbance of the thin film deposit.

### 2.6.2 TRANSMITTANCE (T)

A specimen's transmittance is defined by (Cothian, 1958; Pankova, 1971 and Gray, 1972) as the ratio of radiant power transmitted by a body to the total power incident on the body.

$$T = \frac{I}{I_o} \quad (2.1)$$

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

Transmittance measured for any radiation of the visible light is called optical transmittance. The relationship between the Absorbance (A) and Transmittance

(T) is:

$$T = 10^{-A} \quad (2.2)$$

### 2.6.3 REFLECTANCE(R)

The reflectance is obtained from the relation:

$$A + T + R = 1 \quad (2.3)$$

Then,

$$R = 1 - (A + T) \quad (2.4)$$

### 2.6.4 ABSORBING POWER OR COEFFICIENT OF ABSORPTION ( $\alpha$ )

The absorbing power or coefficient of absorption ( $\alpha$ ) 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, Atomic and Subatomic particle, the absorbing power ( $\alpha$ ) is a measure of rate of decrease in intensity of beam of photons or particles in its passage through a particular substance.

If  $I_0$  is the incident flux,  $I$  is the emergent flux through a material of thickness  $t$ , the absorption coefficient ( $\alpha$ ) of propagation of the flux through the material is given (Cothian, 1958; Pankova, 1971; Gray, 1972 and Wooten, 1972) as

$$I = I_0 e^{(-\alpha t)} \quad (2.5)$$

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

$$T = e^{-\alpha t} \quad (2.6a)$$

And

$$\alpha = \frac{(\ln T^{-1})}{t} \quad (2.6b)$$

For a unit distance transverse,  $t = 1$

Then,

$$\alpha = \ln (T^{-1}) \mu m^{-1} \quad (2.7a)$$

or

$$\alpha = \ln (T^{-1}) \quad (2.7b)$$

### 2.6.5 REFRACTIVE INDEX(n)

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

$$R = \frac{[(n - 1)^2 + K^2]}{[(n + 1)^2 + K^2]} \quad (2.8a)$$

Where K is extinction coefficient for semiconductors,  $K^2 \ll (n+1)^2$

$K^2$  is negligible

The equation (2.8a) then reduces to

$$R = \frac{(n - 1)^2}{(n + 1)^2} \quad (2.8b)$$

From equation (2.8b)

$$n = \frac{1 + R^{\frac{1}{2}}}{1 - R^{\frac{1}{2}}} \quad (2.8c)$$

### 2.6.6 BANDGAP

**(Eg)**

The energy of an electron in a crystal lies within well-defined bands (Markvart, 2000). The energy of electron in the valence band is separated from the conduction band by energy band gap or Band gap. The width of the band gap ( $E_c - E_v$ ) 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,

$$\alpha \propto (h\nu - E_g)^n \quad (2.9)$$

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,

$$\alpha \propto (h\nu - E'_g)^m$$

Where  $E'_g = E_g \pm h\nu_{ph}$ .  $\nu_{ph}$  is the photon frequency,  $m = 2$  and  $3$  for indirect velocity 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,

$$\alpha = (h\nu - E_g)^{\frac{1}{2}} \quad (2.9a)$$

Or

$$\alpha^2 = h\nu - E_g \quad (2.9b)$$

the photon energy  $E$  (J) for a given wavelength is;

$$E(J) = h\nu(J) = hc/\lambda(J) \quad (2.10)$$

Where;

$h$  = plank's constant =  $6.62 \times 10^{-34}$  Js

$c$  = velocity of light =  $3 \times 10^8$  ms<sup>-1</sup>

$\lambda$  = wavelength in meter (m)

The equation (2.10) gives

$$hv(J) = (6.62 \times 10^{-34} \times 3 \times 10^8) / \lambda (m) J$$

But, 1 eV =  $1.6 \times 10^{-19}$  J

$$hv(eV) = 1241 / \lambda(nm) \quad (2.11)$$

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

The plot of  $\alpha^2$  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  $\alpha^2=0$  gives the energy gap  $E_g$

## 2.6.7 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. Absorption spectroscopy can be used to measure thickness. The measurement of film thickness of this work is restricted to two methods namely;

- The gravimetric method
- The optical method

### 2.6.7.1 The Gravimetric Method

$$Density = \frac{mass}{volume} \quad 2.12$$

$$\rho = \frac{m_2 - m_1}{2At} = \frac{m}{2lbt} \quad 2.13$$

$$t = \frac{m}{2lbp} \quad 2.14$$

Where; t = film thickness and p is density.

∴ m = m<sub>2</sub> – m<sub>1</sub> is mass of film deposited,

m<sub>2</sub> and m<sub>1</sub> are the mass of the glass slides after and before deposition.

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

#### 2.6.7.2 The optical method.

When measuring film thickness, optical method is more acceptable because they are accurate, nondestructive, and require little sample preparation. The two most common optical measurement types are spectral reflectance and ellipsometry.

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;

$$T = (1 - R)^2 e^{-at} \quad 2.15$$

Where R is the reflectance and t the film thickness taking the natural logarithm on both sides of equation 2.15 gives;

$$t = \frac{\ln \left[ \frac{(1 - R)^2}{T} \right]}{\alpha} \quad 2.16$$

## 2.7 APPLICATIONS OF THIN FILMS

Thin films are employed in;

- I. **Semiconductor Devices:** Thin films are crucial in the fabrication of semiconductor devices, such as transistors, diodes, and integrated circuits. They are used as active components or as passivation and insulation layers to enhance device performance and miniaturization.
- II. **Solar Cells:** Thin films play a significant role in solar cell technology. They are used as light-absorbing layers in thin-film solar cells, including amorphous silicon (a-Si), cadmium telluride (CdTe), and copper indium gallium selenide (CIGS) solar cells.
- III. **Optoelectronics and Photonics:** Thin films are used in various optoelectronic and photonic devices, such as light-emitting diodes (LEDs), lasers, waveguides, and optical filters.
- IV. **Display Technology:** Thin films are essential in liquid crystal displays (LCDs), organic light-emitting diode displays (OLEDs), and other flat-panel display technologies.
- V. **Thin Film Coatings:** Thin films are widely used as coatings to improve the mechanical, optical, electrical, or chemical properties of materials. Examples include anti-reflective coatings, protective coatings, and wear-resistant coatings.

- VI. Sensors: Thin films are employed in various sensors, including gas sensors, biosensors, and humidity sensors, to detect and measure specific physical or chemical properties.
- VII. Magnetic Storage Devices: Thin films of magnetic materials are used in magnetic storage devices like hard disk drives and magnetic tapes.

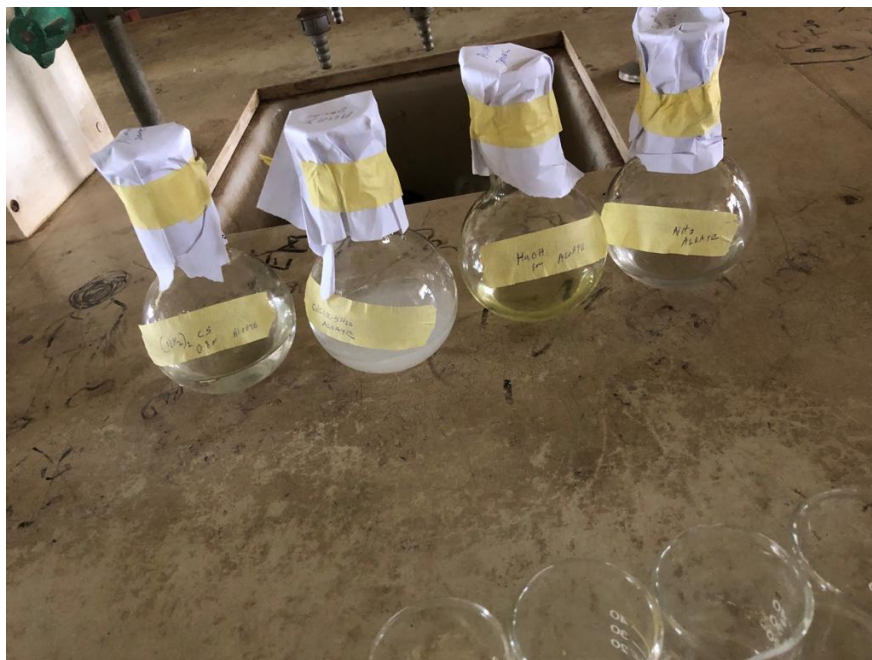
## CHAPTER 3

### 3.0 MATERIALS AND METHODS

#### 3.1 PREPARATION OF GLASS SLIDES

Three glass slide samples were prepared by degreasing them in strong hydrochloric acid for three (3) days. The glass slide samples were typically 75 by 26mm and about 1mm in thickness. The degreased slides were then cleaned in a cold detergent solution using a sponge (rubber sponge to prevent scratching the surfaces) for three days and then rinsed in distilled H<sub>2</sub>O. The glass slides were labelled with cello-tapes, dip-dried in air and weighed on an electrical scale.

#### 3.2 PREPARATION OF SOLUTE AND REAGENT SOLUTION



*Figure 3. 1 Chemical Reagents Deposition Bath Solution*

The following equation was used in computing the mass of each solute reagent.

$$m = \frac{M \times W \times V}{1000}$$

Where;

m= mass

M= Molar concentration

W= Chemical reagent's molecular weight

V= Required Volume of distilled H<sub>2</sub>O for the solution

### 3.2.1 PREPARATION OF STRONTIUM IODIDE SOLUTION (SrI<sub>2</sub>)

To save time and the trouble of making Strontium Iodide at different times, the entire amount needed was made at once. To ensure that enough of the solute reagent (SrI<sub>2</sub>) in the event of accidents or errors during the experiment, additional volume of the solute reagent was also prepared. These calculations were made to determine the prepared mass of Strontium Iodide;

$$\begin{aligned} m &= \frac{M \times W \times V}{1000} \\ &= \frac{0.5 \times 99 \times 100}{1000} \text{ g} \\ &= 4.95 \text{ g} \end{aligned}$$

On an electric balance, 4.95g of  $\text{SrI}_2$  was weighed from a measuring beaker. It was then placed into a 300ml beaker, where it was then dissolved by adding a measured 220 ml of distilled  $\text{H}_2\text{O}$  to form a solution.

### 3.2.2 PREPARATION OF SODIUM HYDROXIDE (SOLVENT)

The same method as in the above was used in the preparation of 80ml of Sodium hydroxide.

$$m = \frac{2 \times 40 \times 80}{1000}$$

$$= 6.4\text{g}$$

In order to ensure that complete dissolution occurred, 6.4g of the solvent was weighed using a measuring beaker and was dissolved in distilled water.

### 3.2.3 PREPARATION OF POTASSIUM IODIDE

The same process was used to prepare 190ml of Potassium Iodide (KI)

$$m = \frac{0.8 \times 166 \times 190}{1000}$$

$$= 25\text{g}$$

In order to that it completely dissolved, 25g of the solution was weighed using a measuring beaker and was dissolved in distilled water.

### 3.2.4 PREPARATION OF SOLVENT REAGENTS SOLUTION

For the solvent reagents, the volume of the solvent for a given molarity is calculated by using this equation;

$$V = \frac{M \times W_t \times 100}{d \times p} \times V_t$$

Where;

M = Molarity

W<sub>t</sub> = Total Molecular mass

V<sub>t</sub> = Total volume

d = Density and specific gravity

Glass	Sr(NO <sub>3</sub> ) <sub>2</sub>	NaOH	KI	Distilled	Total	Molarity
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p = Percentage array

$$V = \frac{8 \times 17.03t \times 100 \times 16}{0.88 \times 33 \times 1000}$$

$$= 7.50 \text{ ML}$$

The volume of distilled H<sub>2</sub>O was measured using;

$$V_T = V_{H_2O} + V_{NH_3}$$

$$V_{H_2O} = V_T - V_{NH_3}$$

$$= 16 - 7.50 = 8.50 \text{ ml}$$

slide No.	m= 0.5 Vol.(ml)	m= 3 Vol.(ml)	m= 0.8 Vol.(ml)	water Vol.(ml)	volume of sol. Vol.(ml)	of Sr(NO3)2 In solution. M (mol/dm3)
1	3.0	3.0	5.0	39.0	50.0	0.03
2	6.0	6.0	5.0	33.0	50.0	0.06
3	9.0	9.0	4.0	28.0	50.0	0.09
4	12.0	5.0	14.0	19.0	50.0	0.12
5	15.0	5.0	17.0	13.0	50.0	0.15

### 3.3 PREPARATION OF DEPOSITION BATH SOLUTIONS

The deposition bath was made up of three glass beakers with total volume or amount of 60 ml each. Various volumes of solutions containing 0.6M SrI<sub>2</sub>, 8M NH<sub>3</sub> (commonly employed as a complexing agent), 0.6M SC(NH<sub>2</sub>)<sub>2</sub>, and 2M NaOH were utilized as reagents for the breakdown of strontium iodide films. The volume was increased to the appropriate level by adding distilled water. The sequence in which the necessary molar concentration was attained is displayed in the table below.

Table 3.1: Chemical bath constituent for the deposition of SrI<sub>2</sub> thin films at Different molarity under solar radiation for 7½ hours

### 3.4 THIN FILM DEPOSITION

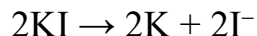
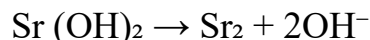
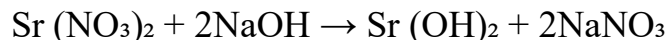
There were three (3) bath solutions and each of them contained a vertically suspended glass slide, while using a plastic peg and hard paper cover placed in the middle of the beaker (to avoid the glass from having contact with the sides or bottom of the beaker) for various deposition of times of  $7\frac{1}{2}$  hours using the same molarity of 0.12M.

The glass substrate that had been treated with  $\text{SrI}_2$  was taken out and then cleansed or rinsed with distilled water and allowed to dry at room temperature. After the deposition, a thin, yellow coating was achieved which was well-adherent.

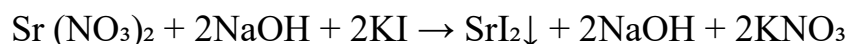


*Figure 3. 2 Thin films deposited in Strontium Iodide with molar concentration of 0.12 mol/dm<sup>3</sup> and at room temperature.*

The chemical bath reaction equation is as follows:



**The total deposition equation becomes**



### 3.5 MEASUREMENT

#### 3.5.1 OPTICAL AND SOLID STATE DETERMINATION

The absorbance (A), the absorbing power ( $\alpha$ ), reflectance (R), transmittance (T), and refractive index are the optical parameters calculated in this research. The solid state measurements evaluated on these films are the thickness (t), energy band gap (Eg) and the refractive index (n).

A 756S UV-VIS double beam spectrophotometer was used in this experiment to measure the films absorbance in the visible (VIS), near infra-red regions of the electromagnetic spectrum and the ultra violet region. The measurement was obtained from the laboratory of the Department of Biochemistry at the University of Benin, Edo State. While other properties such as the reflectance, transmittance, absorbing power, refractive index, etc. were derived from the absorbance spectral and the corresponding absorbance spectral from the spectrophotometer



*Fig 3.3 A 756S UV-VIS double beam spectrophotometer*

## CHAPTER FOUR

### 4.0 RESULTS & DISCUSSIONS

Table 4.1: Spectral absorbance (A), transmittance (T), reflectance (R), and absorbing power ( $\alpha$ ) of SrI2 thin films deposited on different glass slides at a molar concentration of 0.3 M and at room temperature for deposition time of 7½ hours.

$\lambda(\text{nm})$	A	T	R	$\alpha \times 10^6 \text{ m}^{-1}$	$h\nu(\text{eV})$	$\alpha^2 \times 10^{10} \text{ m}^{-2}$
352	0.278	0.527	0.195	0.641	3.52	41.1
362	0.301	0.500	0.199	0.693	3.428	48.0
370	0.241	0.574	0.185	0.555	3.354	30.8
375	0.237	0.579	0.184	0.547	3.309	29.9
402	0.217	0.607	0.176	0.499	3.087	24.9
506	0.188	0.649	0.163	0.432	2.453	18.7

Table 4.2: Spectral absorbance (A), transmittance (T), reflectance (R), and absorbing power ( $\alpha$ ) of SrI2 thin films deposited on different glass slides at a molar concentration of 0.6 M and at room temperature for deposition time of 7½ hours.

$\lambda(\text{nm})$	A	T	R	$\alpha \times 10^6 \text{ m}^{-1}$	$h\nu(\text{eV})$	$\alpha^2 \times 10^{10} \text{ m}^{-1}$
350	0.342	0.455	0.203	0.787	3.546	61.9
352	0.338	0.459	0.203	0.779	3.526	60.7
363	0.375	0.422	0.203	0.863	3.419	74.5
366	0.372	0.425	0.203	0.856	3.391	73.3

402	0.278	0.527	0.195	0.641	3.087	41.1
435	0.264	0.545	0.191	0.607	2.853	36.8
506	0.250	0.562	0.188	0.576	2.453	33.2
678	0.224	0.597	0.179	0.516	1.830	26.6

Table 4.3: Spectral absorbance (A), transmittance (T), reflectance (R), and absorbing power ( $\alpha$ ) of SrI2 thin films deposited on different glass slides at a molar concentration of 0.9 M and at room temperature for deposition time of 7½ hours.

$\lambda(\text{nm})$	A	T	R	$\alpha \times 10^6$ m <sup>-1</sup>	h $\nu$ (eV)	$\alpha_2 \times 10^{10}$ m <sup>-1</sup>
347	0.473	0.337	0.190	1.088	3.576	118.4
364	0.541	0.288	0.171	1.25	3.409	155.0
435	0.377	0.420	0.203	0.868	2.853	75.3

Table 4.4: Spectral absorbance (A), transmittance (T), reflectance (R), and absorbing power ( $\alpha$ ) of SrI2 thin films deposited on different glass slides at a molar concentration of 0.12 M and at room temperature for deposition time of 7½ hours.

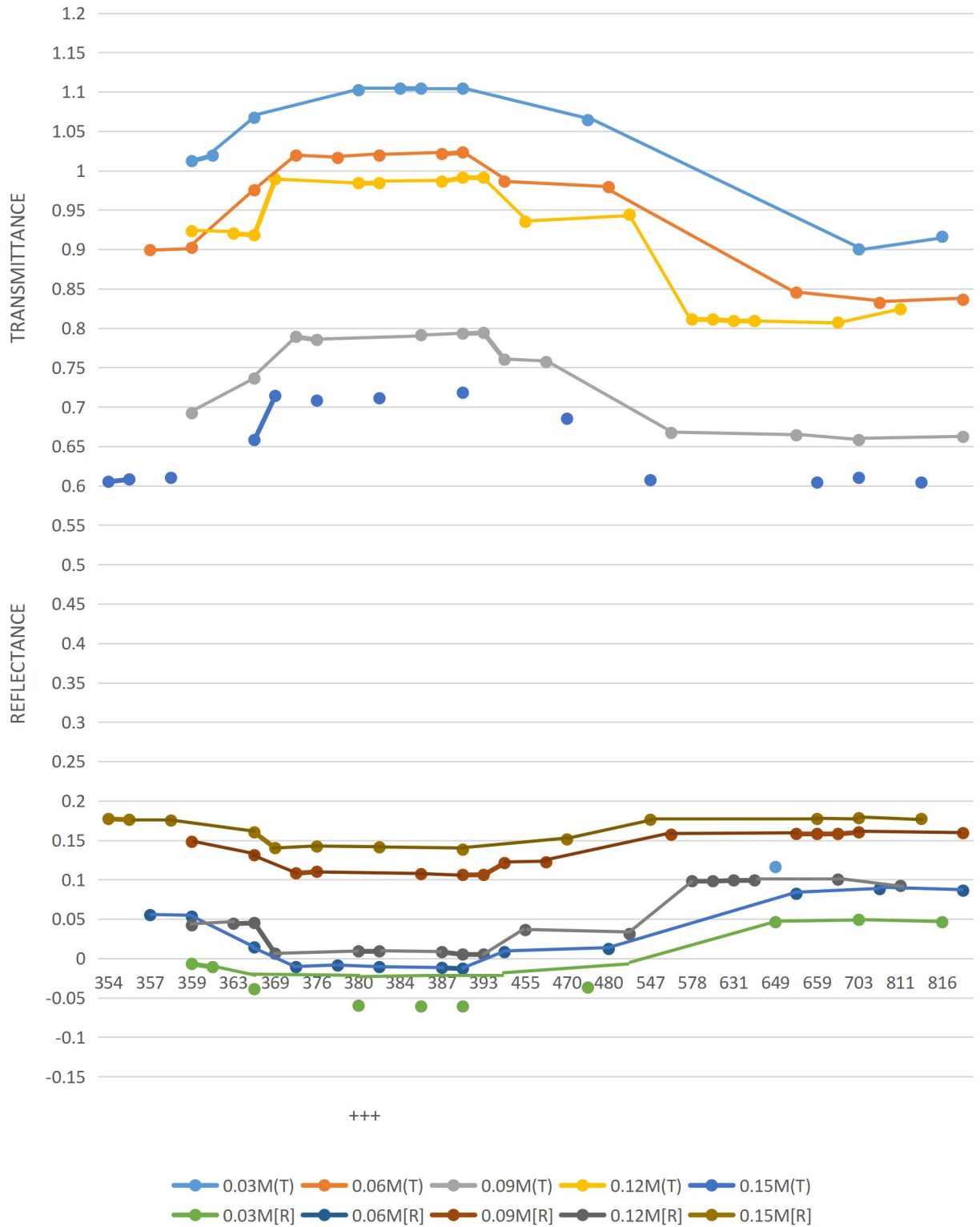
$\lambda(\text{nm})$	A	T	R	$\alpha \times 10^6$ m <sup>-1</sup>	h $\nu$ (eV)	$\alpha_2 \times 10^{10}$ m <sup>-1</sup>
347	0.164	0.685	0.151	0.378	3.576	14.3
349	0.161	0.690	0.149	0.371	3.556	13.8
352	0.159	0.693	0.148	0.367	3.526	13.5
363	0.172	0.673	0.155	0.396	3.419	15.7
365	0.168	0.679	0.158	0.387	3.400	15.0
370	0.150	0.708	0.142	0.345	3.354	11.9

374	0.149	0.710	0.141	0.342	3.318	11.7
378	0.149	0.710	0.141	0.342	3.283	11.7
390	0.143	0.719	0.138	0.330	3.182	10.9
394	0.141	0.722	0.137	0.326	3.150	10.6
399	0.139	0.726	0.135	0.320	3.110	10.2
450	0.129	0.743	0.128	0.297	2.585	8.80
506	0.127	0.746	0.127	0.293	2.453	8.60
663	0.120	0.759	0.121	0.276	1.872	7.60
702	0.120	0.759	0.121	0.276	1.768	7.60

Table 4.5: Spectral absorbance (A), transmittance (T), reflectance (R), and absorbing power ( $\alpha$ ) of SrI2 thin films deposited on different glass slides at a molar concentration of 0.15M and at room temperature for deposition time of 7½ hours.

$\lambda(\text{nm})$	A	T	R	$\alpha \times 10^6$ $\text{m}^{-1}$	$h\nu(\text{eV})$	$\alpha^2 \times 10^{10}$ $\text{m}^{-2}$
363	0.380	0.417	0.203	0.875	3.419	76.6

FIG 4.1: Transmittance, Reflectance spectra of Srl thin film deposited on glass substrate by solution growth technique at different molar concentration for 7½ hours at 50°C



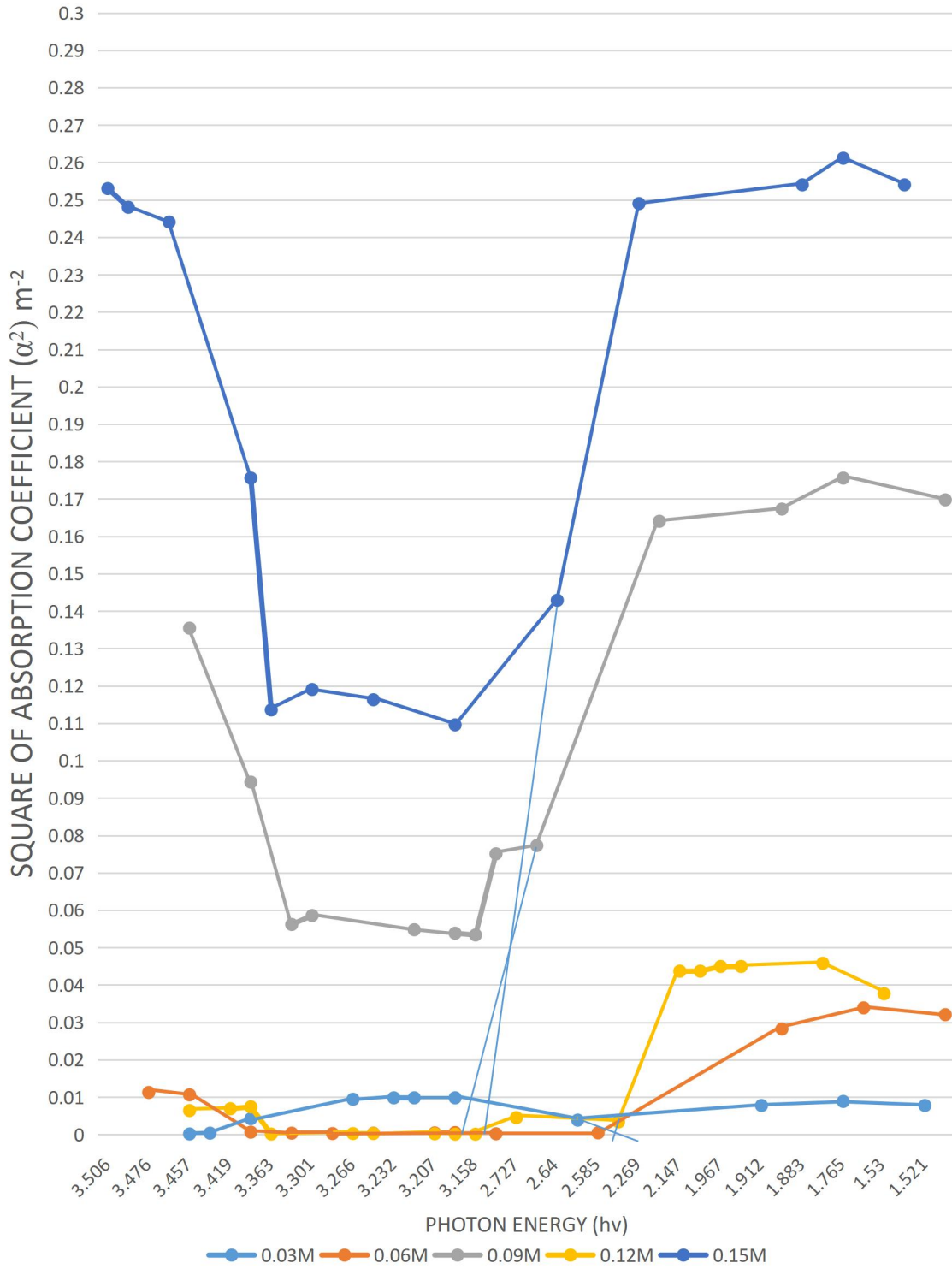
The average optical and solid state properties (at a wavelength of 678nm) of Strontium Iodide thin films after it was deposited using an improved solution growth technique (SGT) in a bath solution for various times of deposition of a constant molar concentration of 0.12M are given in the table below.

Table 4.2:

Average Optical Properties	MOLARITY OF SrI <sub>2</sub> IN BATH SOLUTION				
	0.03M	0.06M	0.09M	0.12M	0.15M
A	0.241	0.372	0.541	0.149	0.380
T	0.574	0.425	0.288	0.710	0.417
R	0.185	0.203	0.171	0.141	0.203
$\alpha \times 10^6 \text{m}^{-1}$	0.555	0.856	1.25	0.342	0.875
n	2.51	2.64	2.41	2.20	2.64

Average Solid state Properties	MOLARITY OF SrI2 IN BATH SOLUTION				
	0.03M	0.06M	0.09M	0.12M	0.15M
t(um)	0.937	0.956	0.972	0.943	0.952
Eg(eV)	3.354	3.391	3.409	3.318	3.419

FIG 4.2 : plot of square of Absorption coefficient ( $\alpha^2$ ) against photon energy ( $h\nu$ ) for Srl thin film by solution growth technique at different molar concentration for 7½ hours at 50°C.



## CHAPTER FIVE

### 5.0 DISCUSSION, RECOMMENDATION AND CONCLUSION

#### 5.1 DISCUSSION

The absorbance spectral for the deposited Strontium Iodide (SrI<sub>2</sub>) thin films grown at different molar concentration and 50°C for 7½ hours (as shown in Table 4.1) shows that Strontium Iodide (SrI<sub>2</sub>) films have high transmittance (T), low reflectance (R) and low absorbance (A). The film produced at molarity 0.03M has the highest transmittance (T), lowest reflectance (R) and lowest absorbance (A). While the film produced at molarity 0.15M has the lowest transmittance (T), highest reflectance (R) and highest absorbance (A).

From Table 4.1, it shows that the absorbance (A) decreases as the wavelength increases. As the absorbance (A) decreases the Reflectance (R) also decreases with an increase in Transmittance (T) of the film. The highest transmittance (T) of 1.104 corresponds to the minimum absorbance of -0.043 for wavelengths 384nm, 386nm and 391nm. The minimum transmittance (T) of 0.604 corresponds to the highest absorbance (A) of 0.219 at wavelength 815nm.

The high transmittance (T) and low reflectance (R) properties of the Strontium Iodide (SrI) 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 coating for cold climates when coated on glass to reduce reflection loss and enhance transmission of light into buildings (Ilenikhena et al, 2005).

Two (2) of the films produced had refractive index greater than 1.8 and one film had its refractive index less than 1.8.

Films with refractive index greater than 1.8 can be used for eye glass coating while films with refractive index less than 1.8 can be used as anti-dazzling coatings.

### **5.1.1 POSSIBLE APPLICATIONS**

The Possible applications of the characterized deposited Strontium Iodide (SrI<sub>2</sub>) thin films on glass substrates are as follows;

Optical properties show that the thin films produced at molarity of 0.12M have high spectral transmittance (T) in the ultraviolet (UV), visible (VIS) and near infrared regions of the electromagnetic regions with corresponding low reflectance (R) in the ultraviolet (UV), visible (VIS) and near infrared region and refractive index (n) less than 1.8 ( $n < 1.8$ ). These thin films could find useful applications in:

- I. Solar thermal devices- as antireflection (AR) coatings on transparent covers (or windows) to improve their efficiencies.
- II. Electronic industry- as transparent contacts or electrodes for photo-activated and photo-electrochemical cells (P.E.C).
- III. Architectural industry- as thermal control window coatings for cold climates when coated on glasses to reduce reflection loss and enhance transmission of light into buildings.
- IV. Architectural industry- as heat mirror coatings for temperature regions with very cold winter to reduce thermal losses from the heated interior to exterior. (Ilenikhena et al, 2005)

The films produced at molarity 0.09M and 0.15M which have highest absorbance (A) and highest reflectance (R) in the ultraviolet (UV), visible (VIS) and near infrared regions and refractive index (n) greater than 1.8 ( $n > 1.8$ ) could find useful applications in;

- I. Agricultural Industry- for the construction of poultry houses to allow enough infrared radiation to warm the very young chicks during the day and reduce cost of energy consumption through lamps, stoves, electric bulbs, etc. and hazards associated with them and at the same time protecting the chicks for ultraviolet radiation.
- II. Optical Industry- for the production of eye glass coatings to protect the skin around the eye from ultraviolet (UV) radiation.
- III. Car Industry- for the production of anti-dazzling coating for windscreens and driving mirrors of cars to reduce dazzling effect of light at night.
- IV. Architectural Industry- for the production of cold mirror coatings for tropical and temperate regions with very hot summer to cool the interior by increasing the thermal losses from the heated interior to exterior and screening the interior from excess thermal energy from incoming solar radiation during summer while at the same time providing adequate illumination.
- V. Electronic Industry- for the manufacture of thin film transistors. (Ilenikhena et al, 2005)

## 5.2 RECOMMENDATION

The deposition of Strontium Iodide ( $\text{SrI}_2$ ) thin film can be produced with;

- Different molar concentrations at room temperature for 7½ hours
- Same molar concentration for different deposition times
- Different molar concentration for 24 hours at room temperature.

### 5.3 CONCLUSION

Strontium Iodide (SrI<sub>2</sub>) thin films were successfully deposited on glass slides using improved Chemical Bath Deposition Method (CBD) in different molar concentrations of 0.03M, 0.06M, 0.09M, 0.12M and 0.15M at 50°C for 7½hours.

A 756S UV-VIS Spectrophotometer was used to obtain the Spectra Absorbance data, while other optical and solid state properties of the films were obtained by calculations based on theory. The average optical include; absorbance (A): -0.043- 0.148, transmittance (T): 1.104- 0.711, reflectance (R): -0.061- 0.141, absorbing power ( $\alpha$ ): -0.099- 0.341, and refractive index (n): 1.152- 2.203. The average solid state properties are: Film thickness (t): -0.1968- 0.1088  $\mu\text{m}$  and Band gap (E<sub>g</sub>): 2.1-3.21 eV.

The deposited thin films with band gap (E<sub>g</sub>) within light energy range ( $\approx 1.5 - 3.0\text{eV}$ ) of electromagnetic spectrum, could find applications in telecommunications, solar electricity for rural electrification to improve the standard of living, remote monitoring and control systems.

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