OPTICAL ANALYSIS OF COPPER ZINC THIN SULPHIDE THIN FILMS DEPOSITED BY CHEMICAL BATH DEPOSITION FOR PHOTOVOLTAIC APPLICTIONS

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Abstract

Solar cells fabricated from silicon are very expensive because of the high cost of production of silicon waivers. Thin film solar cells require a thin absorbing layer. CdTe and CIGS contained toxic and rare elements which have limitations in their usages. CZTS thin films were deposited as absorber layers of thin film solar cells by the CBD technique. The sources of Cu, Zn, Sn and S were Copper nitrate, zinc nitrate, tin chloride and thiourea, respectively. The copper concentrations varied between 0.2 M and 0.5 M while the concentration of every other constituent of the film was constant. The concentration effect of copper was studied on optical parameters such as absorbance, transmittance, reflectance and band gap energy. The analysis revealed that the films had high absorbance, low reflectance and transmittance between 400 and 700 nm of electromagnetic radiation. The bandgap energy was between 1.56 and 1.62 eV

Keywords: Thin films, CZTS, transmittance, bandgap**.**

Introduction

The growth and sustainability of every nation depend on the availability and usage of energy. Energy is needed in industry and the everyday activities of man (Mitwallyová, 2014). Conventional energy sources such as coal, fuel and all other fossil fuels have two major limitations which are the non-renewable nature of the source and all sorts of pollution from the point of production to the point of usage (Netravati & Venkanagowda, 2015). As the human population continues to rise, it is necessary to have alternatives to conventional energy sources. There are several alternative energy sources these include hydrothermal, biomass, wind and solar energy. Among alternative energy sources, solar energy is the chief of all because the energy is generated from the sun which is a limitless source and it is cheaply available (Mitwallyová, 2014). Sun radiates out marvellous volumes of energy as heats and radiations every day. Solar energy can be converted to heat energy by using either flat plates or focusing collectors. The energy from the sun can be converted to electrical energy by photovoltaic devices or solar cells. The term ‘‘photovoltaic’’ derives from the word photo Means ‘‘light’’, and ‘‘voltaic’’, means electric, to honour an Italian physicist Volta after whom the volt is named. The photovoltaic effect was first recognized in 1839 by French physicist A.E. Becquerel (Rhodes & Actions, 2014). The photovoltaic PV effect is defined as the creation of electric voltage between two electrodes joined to a system produced by striking light on the system. Virtually all photovoltaic cell has a junction called PN across which a photovoltage is generated. PV cells are categorized into three major generations: first-generation, second-generation and third-generation cells (Hayat et al., 2019).

Photovoltaic energy conversion plays a significant function in promoting energy solutions. There are three main generations of photovoltaic cells (PC): Silicon, thin film and organic solar cells. Currently, the most commonly used solar cells (SC) are photovoltaic based on silicon technologies (Mazur et al., 2021).

The first ever photovoltaic device is made from silicon dioxide (SiO2) which is the second most abundant element on the earth's surface besides oxygen. However, the production of the device involves many technologies which include purification of the sand and a thick layer of silicon waiver is also required this made the production cost highly expensive. This first device to convert solar radiation to electricity is called the first-generation solar cell. Although, the device has high efficiency. However, the low high cost of production called for researchers to fabricate a thin thickness of absorbing light materials which term thin films.

A thin film is a material created by random nucleation and growth of species of atoms, molecules and ions on a mechanical support called a substrate which could be glass, plastic or steel. However, thin film technology is still being researched daily since it is a major player in the twenty-first century growth of new materials and or an artificial superlattice. The researches on thin films have significant effects on the development of many new areas of research in applied physics and material science, engineering and chemistry which are built on singularities and exceptional characteristics of the thickness, shape and assembly of the film. Thin films have very motivating advantages that are quite made of. as the films become more important than bulks. This is because every atom in the film is very close to the surface and therefore may not have too many atoms surrounding it. The thicknesses of the films are between a few nanometers (nm) and several micrometres. A solar cell made from thin films is called a second-generation solar cell.

The thin film photovoltaic cell is made up of different layers performing different tasks, The layers are front contact, absorbing, window, buffer and back contact layers. Among these layers absorbing layer is the heart of them because it is the layer where photo absorption and conversion of light to electricity take place. There are different absorbing materials such as Cadmium telluride (CdTe) films have been researched and developed but the toxicity of cadmium and scarcity of tellurium are the limitations to the usage of this film. Aside from Cadmium telluride (CdTe) , films copper indium gallium disulphide (CIGS) thin films, the CIGS films also contained indium and gallium which are expensive and scarce. The films of copper zinc tin disulphide (CZTS) are currently being researched because it contains cheap and available element.
Several methods have been employed by researchers to deposit the films of CZTS. These include thermal vacuum evaporation (Alkhalifah et al., 2020; Fouad et al., 2018; Sarsici et al., 2021), spluttering techniques (Dhakal et al., 2014), spin coating method (Sifawa & Shehu, 2021), evaporation technique (Chamekh et al., 2020) and chemical bath deposition technique which is simple, economical and no sophisticated
equipment is required. Several parameters can be varied while depositing thin films by a CBD method such as pH of precursor, time and temperature of deposition, and molarities of the films. In this study, CZTS thin films were deposited by a CBD method and concentrations of copper were varied and the effect of the concentrations were studied on optical analysis of the films.

MATERIALS AND METHODS

Materials
Soda-lime glass (SLG) was used as substrates, the precursor solutions were made from the dissolution of Copper nitrate (Cu(NO3)2, zinc nitrate (Cu(NO3)2, tin chloride (SnCl4) and thiourea (CH4N2S) in methanol. Triethanolamine served as a complexing agent.

Method
Cleaning of Substrates
The soda lime glass substrates were allowed to stay in HCl acid for 12 hrs., cleaned with detergent, rinsed with distilled water and oven-dried.

Preparation of Precursors
Four different precursors were made from copper nitrate of varying concentrations of 0.2 M, 0.3M, 0.4 M and 0.5 M were prepared, zinc nitrate and tin chloride of 0.2 M each were also prepared, and thiourea at constant concentrations of 1.0 M.
20 mL of copper solution was mixed with 20 ml of zinc, tin and thiourea under continuous stirring and 20 ml of TEA was added to the precursor. The solutions were heated and stirred for 1 hr. This was done for various copper concentrations.

Deposition of CZTS thin films
A pre-cleaned glass was vertically inserted into four different 100 ml chromatography tanks. The prepared precursors at different copper concentrations were poured into the chromatography tank at room temperature. The glass substrates were then removed after 1 hr, rinsed with distilled water and annealed in an oven at 2500C for 6 hrs.

Material characterization
The optical transmittances of the thin films were measured with an Avantex UV Spectrophotometer in the wavelength between 239.534 nm and 999.495nm. The transmittance data were obtained from the spectrophotometer and other optical features such as absorbance, reflectance, and optical band gap energy were measured.

Results and discussions
The absorbance of the films at varying copper concentrations is presented in Fig. 1.0 The transmittance and reflectance were obtained from relations 1.0 and 2.0 respectively. The transmittance and reflectance spectra were presented in Fig.2 0 and 3.0, respectively.

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$$T = 10^{-A} \quad (1)$$

$$R = 1 - A - T \quad (2)$$

The absorption coefficient (α) was calculated using relation 3.0

$$\alpha = \frac{\ln\frac{1}{T}}{t} \quad (3)$$

The photon energy in eV was determined from relation 4.0

$$E = \frac{1243}{\lambda} \quad (4)$$

The energy gaps of the films were deduced from the plot $(\alpha h\nu)^2$ of against the photon energy in eV according to relation 5.0

$$\alpha h\nu = A(h\nu - Eg)^{1/2} \quad (5)$$

The measured absorbance from Figure 1.0 revealed that the maximum absorbance occurred at 525 nm which falls within the visible range of the electromagnetic spectrum, The films deposited at various copper concentrations of 0.2, 0.3, 0.4 and 0.5 absorbed 54.9, 63.0, 77.9 and 36.6 % of incident radiations, respectively. The films transmitted low radiation at 525 nm, the maximum transmittance of 43.0 %was obtained for the film deposited at 0.5 M of copper concentration. While transmittance of the films deposited at 0.4 M of copper was 16.6 %, 23.4 % transmittance was obtained for the film deposited at 0.3 M of copper, the film deposited at 0.2 M of copper transmitted 28.2 % as revealed in Figure 2.0 measured in the between 400 and 700 nm of electromagnetic radiation. The reflectance spectral in Figure 3.0 revealed that the CZTS thin films reflected very low electromagnetic radiation at 525 nm which is in the range of UV visible. The film deposited at 0.4 M reflected minimum radiation of 5.4% while the film deposited at 0.5 M of copper reflected maximum radiation of 20.3 %. The optical band gap energy extrapolated from 4.4 showed that the band gap energy was between 1.56 and 1.64 eV. The optical results showed that CZTS thin film as varying copper concentrations had low reflectance, transmittance, high absorbance and low band gap energy. The result obtained was in good agreement with (Olgar et al., 2017; Sultana et al., 2022; Xia et al., 2013). The optical results showed that copper concentration had little influence on its optical properties due to non-stoichiometric in the formation of films precursor.

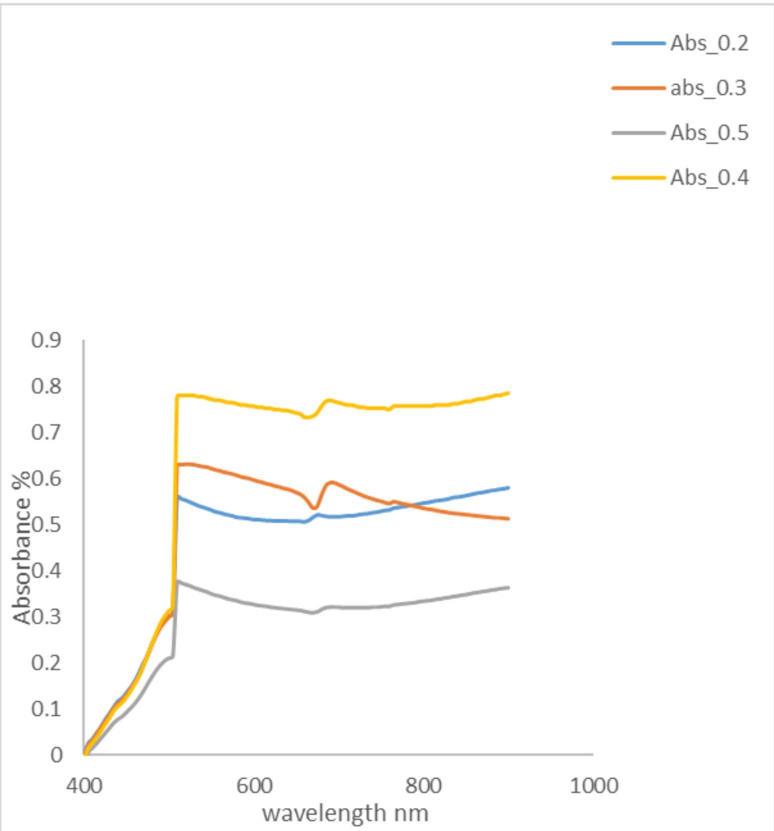

Fig 1.0 : The Absorbance Spectral

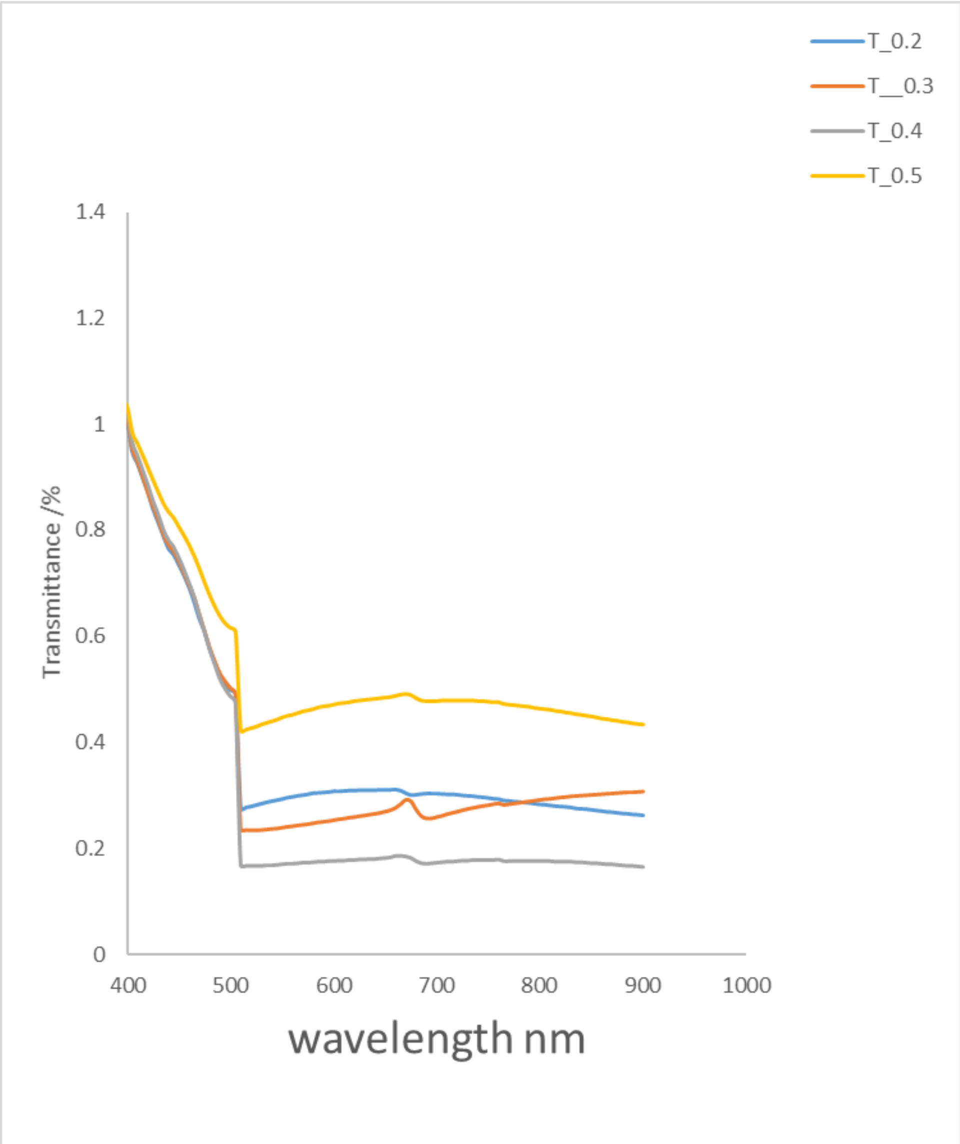

Fig 2.0 : The Transmittance Spectral

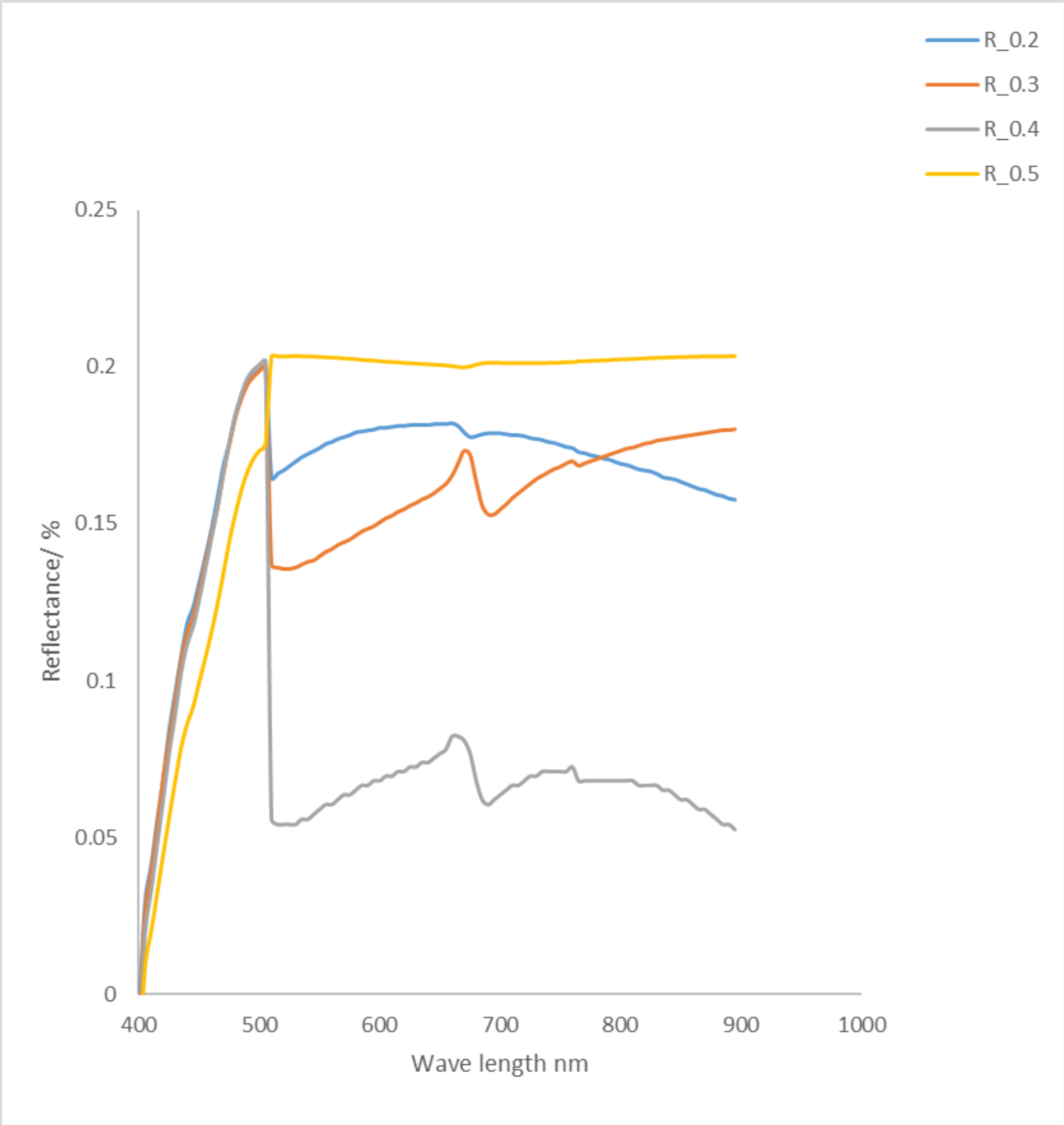

Fig 4.0 : The Reflectance Spectral

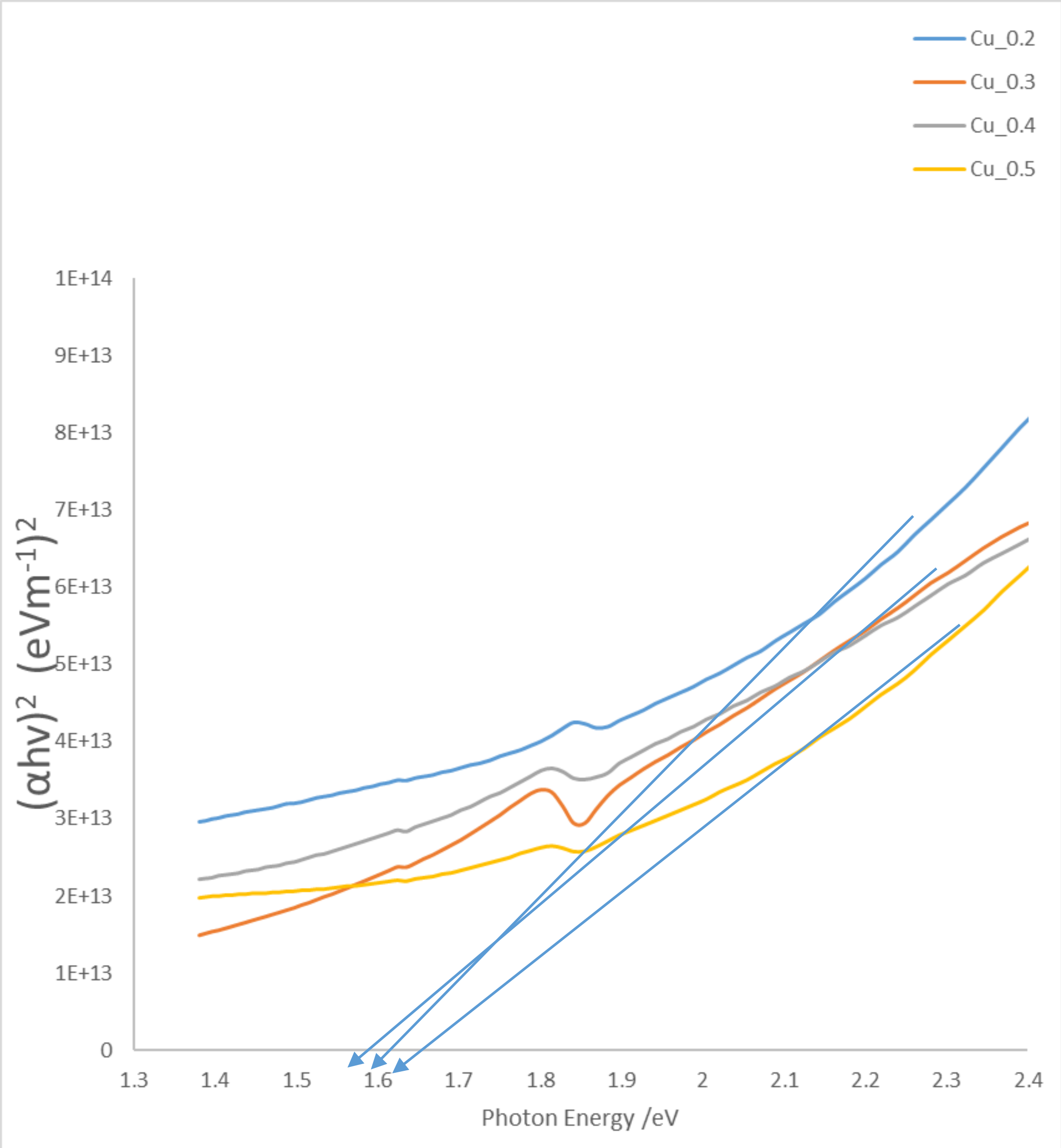

Fig 5.0 : The Taut plot

Conclusion

The copper concentrations effect on the nucleation of CZTS thin films deposited by a CBD method was studied on optical analysis of the films. The optical measurement was done by a visible spectrophotometer and it was detected that the films had low reflectance, transmittance, and high absorbance in the UV visible region of electromagnetic radiation. The films deposited at 0.4 M of copper showed maximum absorbance of 77 .9% and minimum transmittance and reflectance of 16.6% and 5.4 % respectively. The films deposited at 0.5 M of copper exhibited minimum absorbance, highest transmittance and reflectance of 36.6 %,43.0 % and 20.3 % respectively. In terms of band gap energy, all the films exhibited low band gap energy between 1.56 and 1.62 eV. But the film deposited at 0.4 M was close to the optimum band gap energy of 1.5 0 eV for CZTS as an absorbing material of thin film solar cells. The film deposited at 0.4M of copper is suitable for absorber layer of thin film photovoltaic.

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