THE INFLUENCE OF TEMPERATURE ON OPTICAL CHARACTERISTICS OF COPPER TIN SULPHIDE (CTS) THIN FILMS USING CHEMICAL BATH DEPOSITION TECHNIQUE

***Babatunde Rasaq Ayinla & Agboluaje Ayanfe Emmanuel**
Department of Science Laboratory Technology, The Federal Polytechnic, Ilaro, Nigeria

***Corresponding author email: rasaq.babatunde@federalpolyilaro.edu.ng**

Abstract

The most popular absorber layers for thin-film solar cells are cadmium telluride (CdTe) and copper indium gallium diselinede (CIGS).However, cadmium is a hazardous metal. Since indium and gallium are rare elements, copper zinc tin sulphide (CZTS) is a good substitute since it is readily available and environmentally friendly but its high rigorous reactivity. This study was motivated to grow copper tin sulphide (CTS) thin films as a replacement to CZTS absorber layer in thin-film photovoltaics' and investigated the effect of deposition temperature on the properties CTS films. The films were deposited on soda lime glass substrate at constant bath parameters and deposition temperature was varied between room temperature and 70^{o}C. The structural, morphological and optical properties were investigated using x-ray diffractometer, scanning electron microscopy and uv- visible spectrophotometer, respectively. The band gap energy increases as deposition temperature increases. The XRD revealed that the films were polycrystalline with many peaks the intensity of the peaks increases as deposition temperature increases

Keywords: absorber,bandgap, thin films,

Introduction

Solar cells are systems that use the photovoltaic effects to generate an electric current. A photovoltaic cell, often known as a solar cell, is a device utilizing semiconductors like gallium arsenide, cadmium telluride, and silicon to directly convert sunlight into energy. When sunlight is absorbed by solar cells, free electrons and holes are created at the positive/negative junctions. Based on semiconductor and production technique, solar cells can be divided into three main generations which are the first generation which are silicon based solar cells; second generation which based on thin film materials and the third generation which based on organic materials... (Chander, Krishna, & Srikanth, 2015)

The two types of crystalline silicon photovoltaic modules are single crystalline silicon, also called mono-crystalline silicon, and multi-crystalline silicon, also called polycrystalline silicon. While both types of PV modules have higher conversion efficiencies on average, ranging from about 10 to 12 percent, the polycrystalline silicon PV module has a lower efficiency. In comparison to crystalline silicon photovoltaic modules, amorphous silicon photovoltaic modules, sometimes referred to as thin-film silicon photovoltaic modules, are able to absorb light more efficiently and can be made thinner. It can be applied in any situation where low cost is crucial an high efficiency is not necessary .(Mayberry & Chandrasekaran, 2019)

Amorphous silicon Around 6% is the PV module. silicon hybrid. PV modules combine thin-film and monocrystalline technology. Silicon Great sensitivity to indirect or lower level light is provided by PV modules. With a conversion efficiency of almost 17%, it has the greatest level. Since silicon is commonly obtained in nature, does not pollute the environment, and is easily melted, handled, and shaped into monocrystalline silicon form, it is currently the most semi-conductor material used to produce solar cells. (Zhang et al., 2017). However, the silicon based solar cells are costly to produce because they require thick silicon waiver before absorption of photons take place.

Through the use of thin film technology, the second-generation (2G) solar cells were created with the intention of lowering the high costs associated with the first generation. The idea was to save money on bulk material costs while significantly reducing the quantity and quality of the material used, as well as theof increasing thin film absorption to make up for the thinner photoactive layers. (Adeoye, Adeaga, Technical, Africa, & Akpan, 2024).

The enhanced efficiency of thin-film solar cells in transforming sunlight into electrical energy is one of its main advantages. Amorphous silicon (a-Si), copper indium gallium selenide (CIGS), and other thin-film materials (Wei, Liu, Zhuang, & Zhao, 2013) , and cadmium telluride (CdTe) (Mazur, Prokopiv, Mazur, & Pysklynets, 2021) are a few of the numerous topics that engineers and scientists are researching and developing continuously. Since each of these materials has distinct properties, there are chances for improvement. Additionally, thin-film technologies enable more eco-friendly solar panels that can tolerate temperature and shadow changes. Their longevity makes them suitable for a variety of uses, including building-integrated photovoltaics (BIPV), wearable technology, and portable electronics. Additionally, due to the ease of manufacturing and scalability of thin-film solar cells (Prasad & Mohan, 2024).

The common absorber layers for thin films solar cell are CdTe and CIGS but cadmium is a toxic element. Also, indium and gallium are rare elements, the alternative to them is CZTS due to its availability and environmentally friendly (Shinde, Betty, Atomic, & Bhosale, 2012) but the reactivity of CZTS is rigorous this necessitated this study to grow CTS thin films as an absorber layer of thin film photovoltaic (Shelke, Lokhande, Kim, & Lokhande, 2017),

Materials and Method

Soda lime glass (SLG) served as the substrates, copper nitrate ($Cu(NO_3)_2$) , tin chloride ($SnCl_2$) and thiourea (CH_4N_2S) were served as the sources of copper, tin and sulphur, respectively. Methanol (CH_3OH) was used as the solvent. Triethylenamine (TEA) was used as the complex agent. The substrates were cleaned ultrasonically and the precursor solution was formed by dissolution of copper, tin and sulphur sources in 50 ml methanol in ratio 2:1:4, respectively. The precursor solution was heated at 70°C and under continuous stirring for 2 Hrs. TEA was added. The solution was shared into three (3) 50 ml chromatographic tanks. A precleaned glass substrate was inserted vertically into each of the tank and each tank was placed in a water bath at 70°C,50°C and room temperature, respectively. After 2 Hrs the substrates were removed and found coated with the films, rinsed with the distilled water and annealed in an oven (Gen Lab) at 200°C for 1 Hr. Avantex UV visible spectrophotometer was used to measure the thin films' optical absorbance in the wavelength range of 200.00 nm to 999.00 nm. The spectrophotometer provided the film transmittance measurements.

The transmittance (T) was calculated from the absorbance according to Eqn1

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

The reflectance (R) was obtained from Eqn. 2.

$$A + T + R = 1$$
(.2)

The absorbance coefficients (α) of the films were calculated according to Eqn.3.

$$\alpha = \frac{2.303A}{t}$$
(3)

Where A is absorbance and t is the thickness of the film.

The photon energy (E) was calculated in eV according to Eqn.4

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

The connection between absorbance coefficient (α) and incident photon energy ($h\nu$) according to Taut relation is shown in Eqn.5.

$$\alpha h\nu \quad = A\sqrt{h\nu - E_g}$$
(5)

Result and Discussion.

The absorbance, transmittance, reflectance as plotted against wavelength are presented in Fig 1,2,and 3 respectively. The absorbance spectral showed the film deposited at 70°C absorbed more radiation in the visible region of electromagnetic radiation than the other films coated at 50°C and room temperature. The surface morphological analysis confirmed this because the films were more rough and highly compacted with each other this could be a reason for the high absorbance the result is well agreed with the observation of CZTS thin films were deposited via vapour deposition and the effect of annealing was studied on its solid state properties (Sharmin, Kumar, Al Mamun, & Hossain, 2022).

However, the transmittance of CTS films increase gradually from ultra violet region until it reaches 4.41% at wavelength 519 .0 nm for the film coated at 50ºC in the visible region of electromagnetic radiation, the transmittance is almost constant at this wavelength and continues in the infrared region. The maximum transmittance was at 3.96 % which occurred at 607.0 nm for the films deposited at room temperature, The transmittance of the film grew at 70ºC displayed the least transmittance of 1.1 % at 447.0 nm The reflectance spectral showed that the films reflected little and negligible of the incident photons as shown in the reflectance spectral. The spectral revealed that the maximum reflectance was 2.0 % for the films coated at 50ºC, it reflected 1.5% for the films at room temperature while the films grew at 70ºC was negligible, This shows that the materials can be used as anti reflection in electronics and optoelectronic devices (Shanmugam, Pugazhendhi, Elavarasan, Kasiviswanathan, & Das, 2020).

The band gap of the films was extrapolated from Fig.4a, b.and c for the films deposited at room temperature, 50ºC and 70ºC, respectively. The band gap are 3.10 eV, 3.32 eV and 3.51eV for the films at room temperature, 50ºC and 70ºC, respectively.. The band gap between 1.3 and 1.5eV deviated from the reported band gap reported in the research by Shelke et al.,(2017) the deviation could be attributed to the different in the condition of deposition. This shows that as the deposition temperature increases the band gap increases the factor that caused could be attributed to the reduction in the crystal structures of the films as shown in structural pattern of the films.

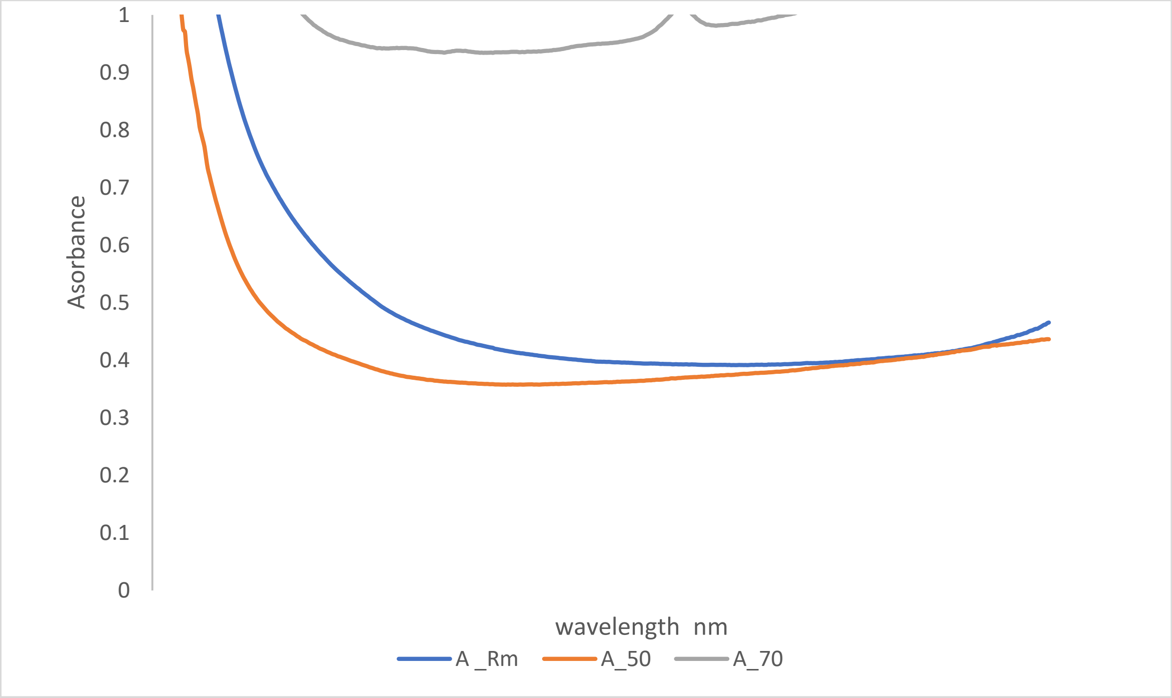

Fig1. The absorbance against wavelength of CTS films at varying deposition temperatures

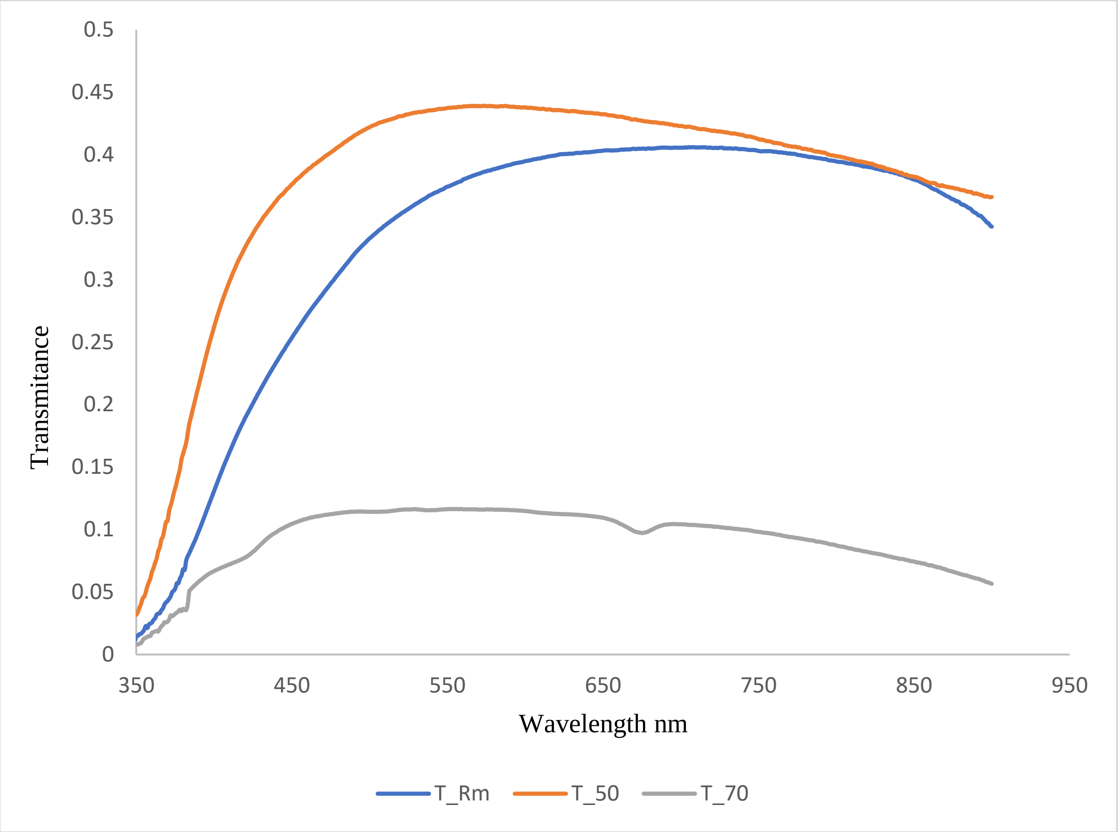

Fig.2: The transmittance against wavelength of CTS films at varying deposition temperatures

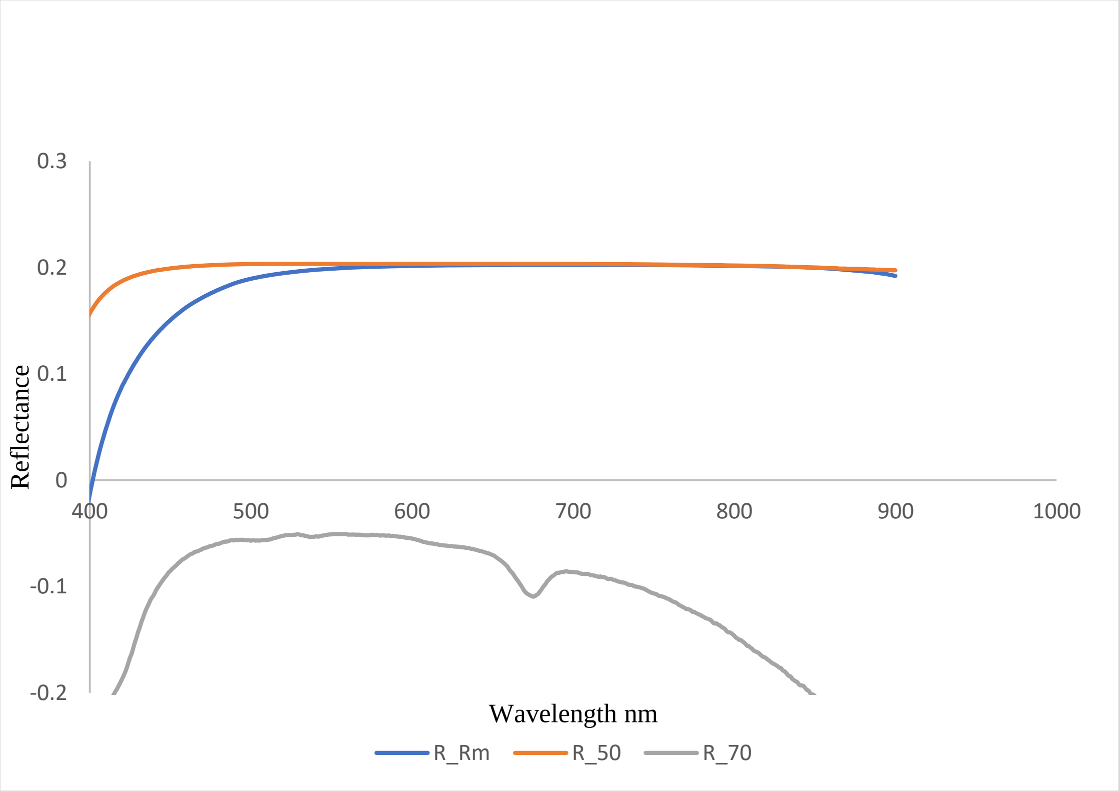

Fig..3: The reflectance against wavelength of CTS films at varying deposition temperatures

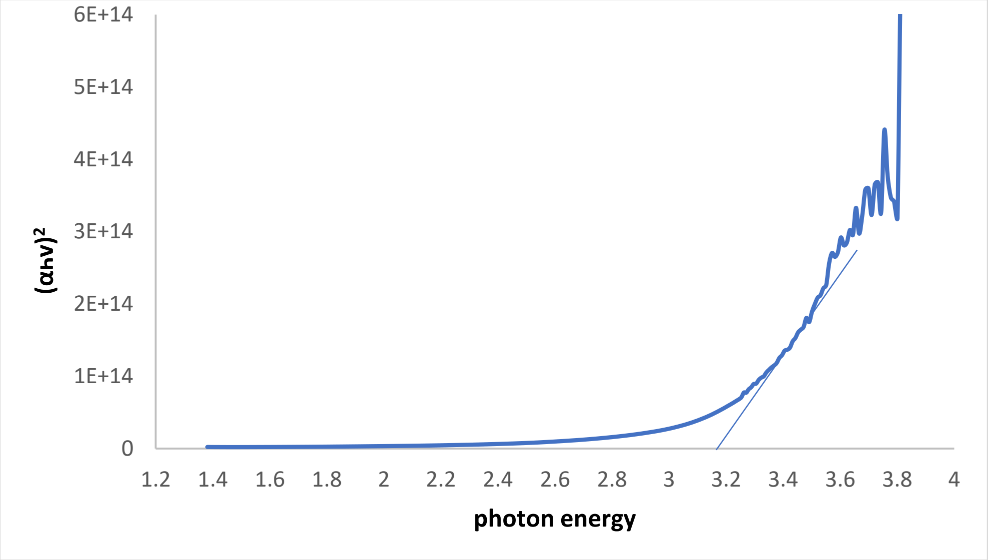

Fig.4a: The energy band gap of film deposited at room temperature

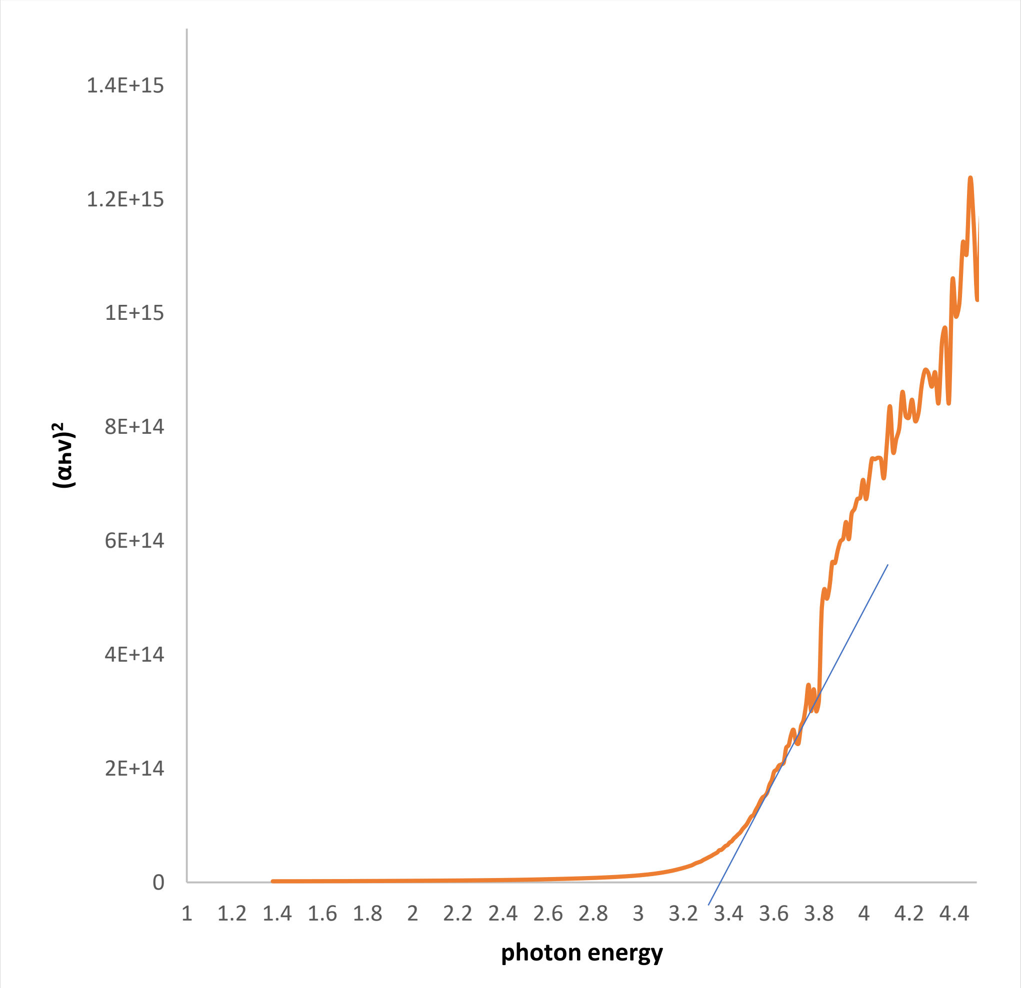

Fig.4b: The energy band gap of film deposited at 50°C

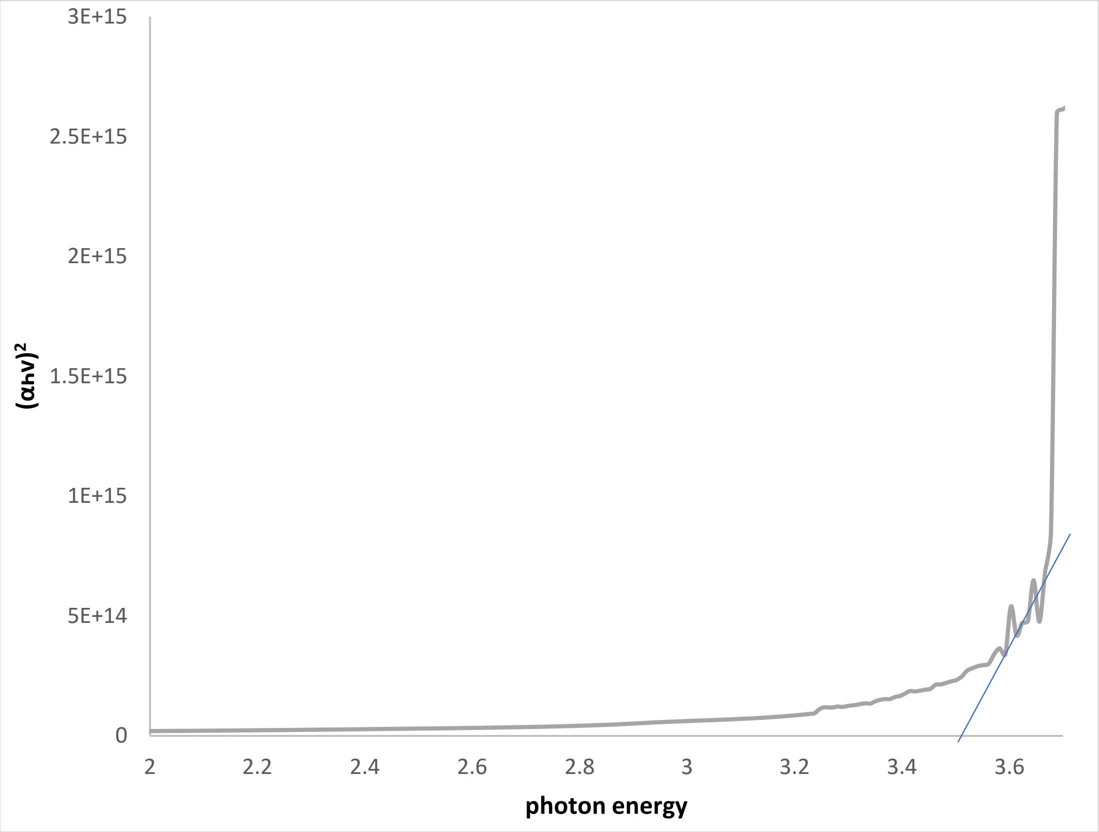

Fig.4c: The energy band gap of film deposited at 70°C

CONCLUSION

The films of copper tin sulphide were successfully coated in soda lime glass via chemical bath deposition procedure and the effect of deposition temperature on optical properties. The transmittance of the films grew at room temperature was the least when compared with the film at 50°C and 70°c. The films exhibited low reflectance in the visible region of electromagnetic spectrum. The band gap of the films increases as the deposition temperature increases. Therefore, the films can be used as buffer layer in the fabrication of thin films solar cell due to its high energy gap.

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