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# Investigation of the Optical and Electrical Properties of Copper Telluride and Cadmium Telluride Thin Films Using Electrodeposition Technique

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***Authors' contributions***

*This work was carried out in collaboration between all authors. Author IIL designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors POO, OBU, IBO and PNO managed the analyses of the study. Author PNO managed the literature searches. All authors read and approved the final manuscript.*

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## ABSTRACT

Copper and Cadmium Telluride thin films have been successfully deposited on a glass substrate indium doped Tin oxide (ITO) by electrodeposition technique. The absorbance was measured using M501 UV-visible spectrophotometer in the wavelength range of 300-900 nm. Copper and Cadmium Telluride thin films were investigated at room temperature. The absorbance of cadmium telluride thin films of sample CdTe2 and CdT3 increase with the wavelength while sample CdTe1, CdT4 and CdT5 partially increase as the wavelength increases. The transmittance spectra of the cadmium telluride thin films deposited increases with the wavelength. The absorbance of copper telluride thin films were found to be in the range of 0.152-0.334 for sample CT1, 0.064-0.254 for sample CT2,

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0.065-0.257 for sample CT3, 0.049-0.272 for sample CT4 and 0.009-0.220 for sample CT5. Absorbance of copper telluride films is high in the UV region and in visible and IR regions. The transmission spectrum has a very high transmittance in the VIS-NIR regions of the electromagnetic spectrum. It is also observed that the transmittance of the films is high in visible & infrared regions. The band gap energy of (2.0eV-2.2eV for CT) and (2.2eV-2.5 for CdT) was obtained.

*Keywords: Optical; thin film; indium doped tin oxide (ITO); electrodeposition.*

## 1. INTRODUCTION

Copper Telluride have attracted much interest because of their potential applications in thermoelectric devices and in herterojunction structures [1]. Thin film solar cells using copper telluride (CuTe) absorber layers are one of the primary contenders for large-scale commercialization of photovoltaic. Numerous applications based on CuTe have been deployed worldwide such as in radiation detectors, electro-optical modulators and solar cell fabrication [2]. Cadmium telluride (CdTe) photovoltaic describes a photovoltaic (PV) technology that is based on the use of cadmium telluride, a thin semiconductor layer designed to absorb and convert sunlight into electricity [3] Cadmium telluride PV is the only thin film technology with lower costs than conventional solar cells made of crystalline silicon in multi-kilowatt systems [4-6] CdTe PV is a potential solution to key ecological issues including climate change, energy security, and water scarcity [7] across a range of application scenarios (e.g. commercial rooftop applications or large scale ground mount applications) [8]. On a lifecycle basis, CdTe PV has the smallest carbon footprint, lowest water use and shortest energy payback time of all solar technologies [9-11]. CdTe short energy payback time of less than a year enables for faster carbon reductions without short-term energy deficits. Scalability of CuTe and CdTe technology in the mid-term future; The rare abundance of tellurium of which telluride is the anionic form is comparable to that of platinum in the earth's crust and contributes significantly to the module's cost [12]. CuTe and CdTe photovoltaic is used in some of the world's largest photovoltaic power stations, such as the Topaz Solar Farm. With a share of 5.1% of worldwide PV production, CuTe and CdTe technology accounted for more than half of the thin film market in 2013 [13]. A prominent manufacturer of CuTe and CdTe thin film technology is the company First Solar, based in Tempe, Arizona. Due to its physical properties, CuTe and CdTe is considered a prime candidate for a PV material and has generated great interest in its use. The CuTe and CdTe material is characterized by a direct band gap (2.44 eV and 1.44 eV) with a high absorption coefficient another great advantage of CuTe and CdTe is that it can be deposited by number of techniques including evaporation, sublimation, sputtering and chemical methods [14]. The growth of CuTe and CdTe films by electrodeposition is a simple and low cost process of producing high-quality material for PV device fabrication [15]. Thin film CuTe and CdTe has attracted a great deal of interest for low-cost, high-efficiency photovoltaic energy conversion applications. Among the various techniques that are available for CuTe and CdTe thin film deposition, electrodeposition is a non-vacuum technique and has the advantage of low cost, efficient utilization of raw material, and scalability for high-volume production [16]. At the same time, additional research is still needed to improve upon the process reproducibility and performance levels achieved to date. Among the significant issues are interface carrier recombination and top-layer photon absorption which presently limit the short circuit current, junction recombination which limits the open-circuit voltage, and series-resistance losses which suppress the fill-factor [17].

## 2. MATERIALS AND METHODS

Copper and cadmium telluride thin films were prepared by electrodeposition technique on the glass substrates indium doped Tin Oxide (ITO). The substrates were cleaned ultrasonically by detergent solution, acetone, and deionised water, respectively, to ensure the complete cleanness. the deposition of copper and cadmium telluride of five electrolyte telluride IV Oxide ($Te0_2$), ($CuS0_2.5H_20$), $Cd^{2+}$, potassium tetraoxosulphate VI ($K_2SO_4$) and tetraoxosulphate VI acid ($H_2SO_4$). The growth of (CuTe and CdTe) films were respect to time of substrate for the deposition. 15 $cm^3$ and 10 $cm^3$ of $Te0_2$ and $Cd^{2+}$ was measured into 100 $cm^3$ beaker using burette. 5 $cm^3$ of $K_2SO_4$ was measured into the same 100 $cm^3$ beaker containing $Te0_2$ and ($CuS0_2.5H_20$) and $Cd^{2+}$ respectively to serve as the inert electrolyte which helps to

**Table 1. Variation of parameters CuTe thin films**

| | Volume of $H_2SO_4$ ($cm^3$) | Volume of $K_2SO_4$ ($cm^3$) | Volume of $Te0_2$ ($cm^3$) | Volume of ($CuS0_2.5H_20$) ($cm^3$) | Voltage (V) | Time (seconds) |
|---|---|---|---|---|---|---|
| CT1 | 2.00 | 2.00 | 15.00 | 10.00 | 2.00 | 60.00 |
| CT2 | 2.00 | 2.00 | 15.00 | 10.00 | 3.00 | 60.00 |
| CT3 | 2.00 | 2.00 | 15.00 | 10.00 | 4.00 | 60.00 |
| CT4 | 2.00 | 2.00 | 15.00 | 10.00 | 5.00 | 60.00 |
| CT5 | 2.00 | 2.00 | 15.00 | 10.00 | 6.00 | 60.00 |

**Table 2. Variation of parameters CdTe thin films**

| Samples | Volume of $H_2SO_4$ ($cm^3$) | Volume of $K_2SO_4$ ($cm^3$) | Volume of $TeO_2$ ($cm^3$) | Volume of $Cd^{2+}$ ($cm^3$) | Voltage (V) | Time (Seconds) |
|---|---|---|---|---|---|---|
| CdT1 | 2.00 | 2.00 | 15.00 | 10.00 | 2.00 | 60.00 |
| CdT2 | 2.00 | 2.00 | 15.00 | 10.00 | 3.00 | 60.00 |
| CdT3 | 2.00 | 2.00 | 15.00 | 10.00 | 4.00 | 60.00 |
| CdT4 | 2.00 | 2.00 | 15.00 | 10.00 | 5.00 | 60.00 |
| CdT5 | 2.00 | 2.00 | 15.00 | 10.00 | 6.00 | 60.00 |

dissociate the copper and cadmium to form the required CuTe and CdTe film on the substrate and the solution was acidified with 5.00 $cm^3$ of dilute $H_2SO_4$ which serves to adjust the pH value. The entire mixture was stirred with the glass rod to achieve uniformity. In each of the reaction baths prepared, a glass substrate and platinum electrode were connected to a DC power supply source and the voltage was maintained at 2-6 V time intervals.

## 3. RESULTS AND DISCUSSION

### 3.1 The Optical Properties of Cadmium Telluride Thin Films

Fig. 1, shows the plot of absorbance as a function of wavelength for CdT1-CdT5 thin films deposited at different voltages at a constant time. From the Fig. 1, it was observed that absorbance of cadmium telluride thin films of sample CdTe2 and CdT3 increase with the wavelength while sample CdTe1, CdT4 and CdT5 partially increase as the wavelength of the deposited material increases which is due to increase in the deposited voltage for sample CdT4 and CdT5 and that of sample CdTe1 is as a result of the concentration of the precursor. The absorbance generally shows high in the UV region and IR regions. The high absorbance in UV region makes the material useful in formation of p-n junction solar cells with other suitable thin film materials for photovoltaic application. These optical properties make cadmium telluride thin films nice glazing material for maintaining cool interior in buildings in warm climate regions while still keeping the rooms well illuminated. To ensure that the thermal radiation from the warm glazing to the interior is inhibited and the thermal energy dissipated in the glazing due to absorption is predominantly transferred to the exterior by enhanced convective heat transfer of the glazing to the exterior as reported in [12-19].

Fig. 2, shows the plot of transmittance as a function of wavelength for CdT1-CdT5 thin films deposited at different voltages at a constant time. From Fig. 2, it was observed that the transmittance spectra of the cadmium telluride thin films deposited increases with the wavelength, but both films shows a very high transmittance in the VIS-NIR regions of the electromagnetic spectrum which makes the material a good application in the production of blue and green light emitting device as reported in [13-19].

Fig. 3 shows the plot of reflectance as a function of wavelength. From Fig. 3, it was observed that the films reflect in both region of electromagnetic spectrum UV region and the visible and IR region. The high reflectance of the deposited samples in UV region makes the material useful in formation of p-n junction solar cells with other suitable thin films materials for photovoltaic application.

### 3.2 Optical Properties of Copper Telluride

Fig. 4 shows the plot of optical absorbance spectra as a function of wavelength. From Fig. 4, it was observed that the absorbance of copper telluride thin films were found to be in the range of 0.152-0.334 for sample CT1, 0.064-0.254 for sample CT2, 0.065-0.257 for sample CT3, 0.049-0.272 for sample CT4 and 0.009-0.220 for sample CT5. Absorbance of copper telluride films is high in UV region and in visible and IR regions. The high absorbance in UV region makes the material useful in formation of p-n junction solar cells with other suitable thin film materials for photovoltaic application. These optical properties make copper telluride nice glazing material for maintaining cool interior in buildings in warm climate regions while still keeping the rooms well illuminated. To ensure that the thermal radiation from the warm glazing to the interior is inhibited and the thermal energy dissipated in the glazing due to absorption is predominantly transferred to the exterior by enhanced convective heat transfer of the glazing to the exterior. It was suggested in [14-19] that reflectance in the spectral region should be strengthened while encouraging low thermal emittance.

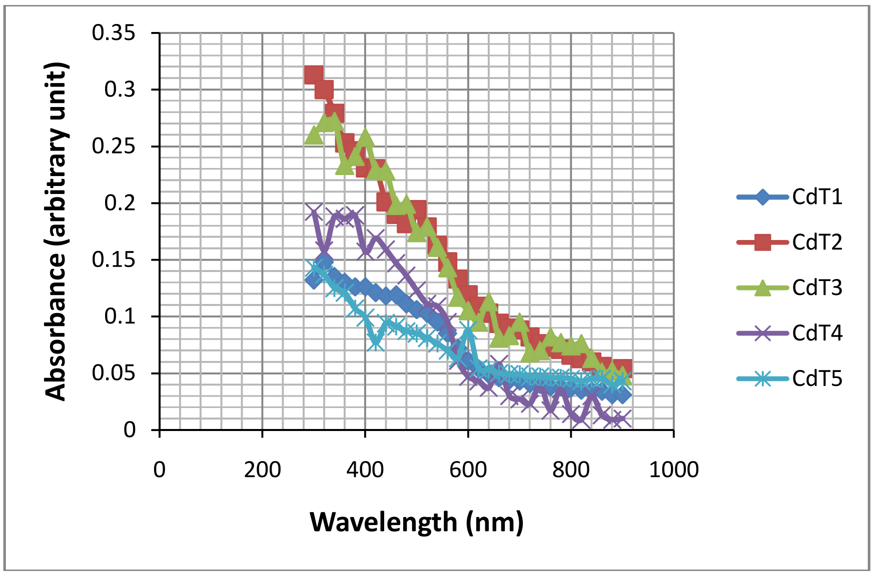


**Fig. 1. Plot of absorbance as a function of wavelength**

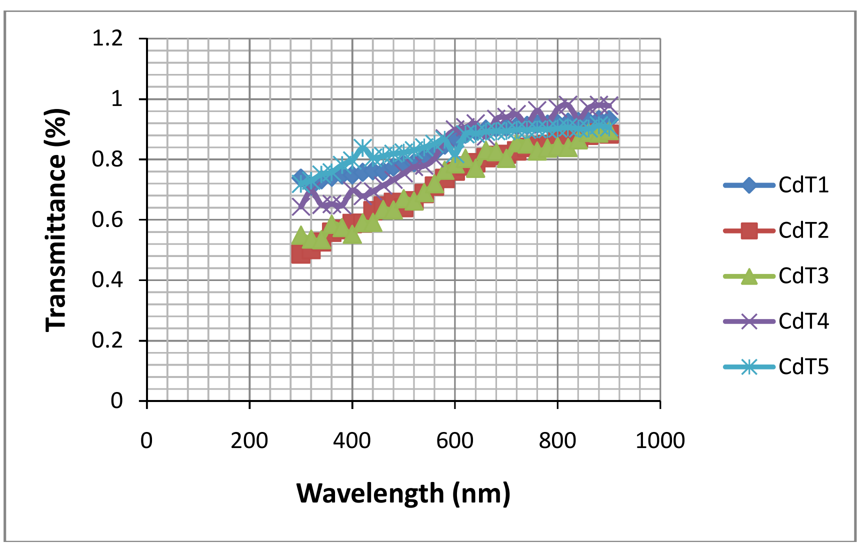


**Fig. 2. Plot of transmittance as a function of wavelength**

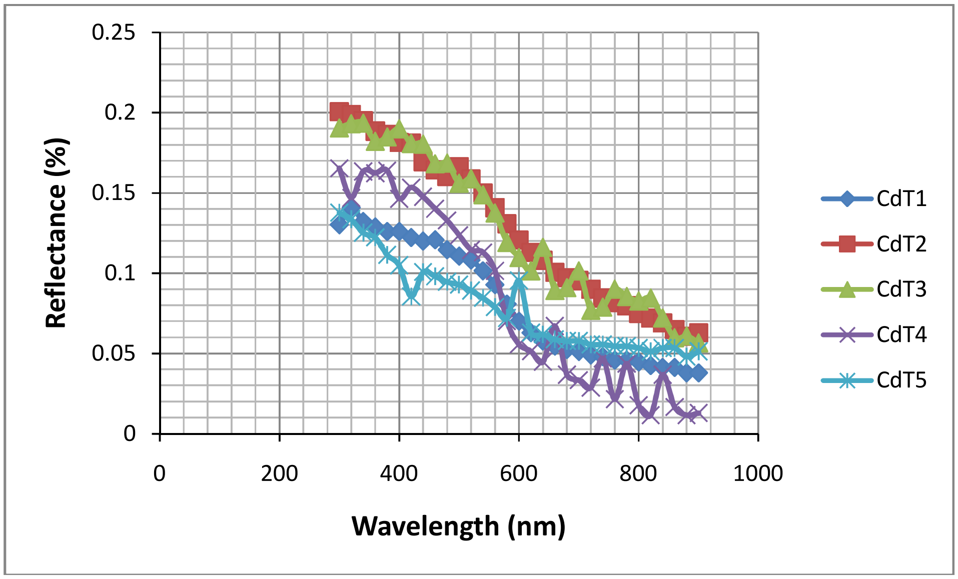


**Fig. 3. Plot of reflectance as a function of wavelength**

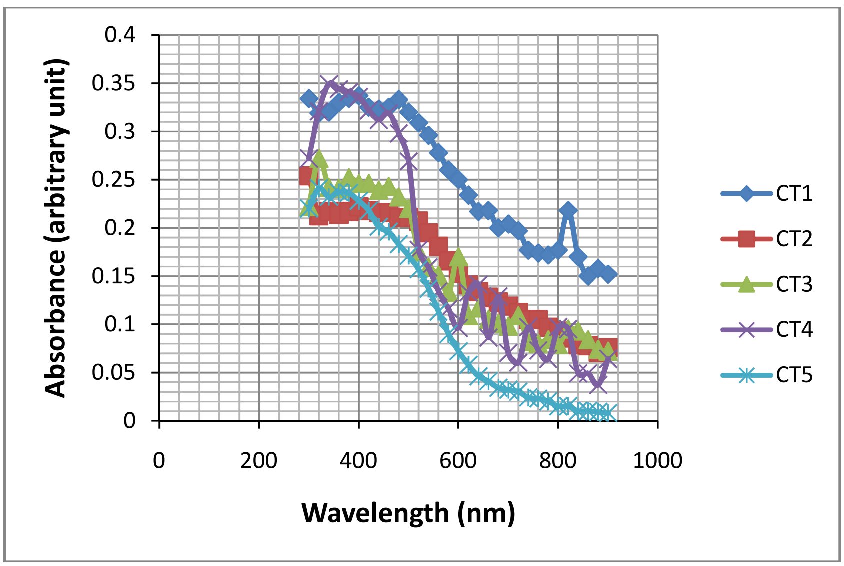


**Fig. 4. Plot of absorbance as a function of wavelength**

Fig. 5 shows the plot of optical transmittance spectra as a function of wavelength. From Fig. 5, it was observed that the transmission spectrum has a very high transmittance in the VIS-NIR regions of the electromagnetic spectrum. It is also observed that the transmittance of the films is high in visible & infrared regions. Copper telluride has peak transmittance in infrared region. The wide transmission revealed in the figure 4 makes the materials useful in manufacturing optical components, windows, mirrors, lenses for high power infra red laser [11,14-19]. The transmittance of sample CT5 increases from UV to the peak value 99% in infrared region and can be as high as 57% in UV region.

Fig. 6 shows the plot of reflectance as a function of wavelength. From figure 6, it was observed that the films reflect much in the UV region of electromagnetic spectrum and the partially fill visible and IR region. The high reflectance of the deposited sample CT5 in UV region makes the material useful in formation of p-n junction solar cells with other suitable thin films materials for photovoltaic application.

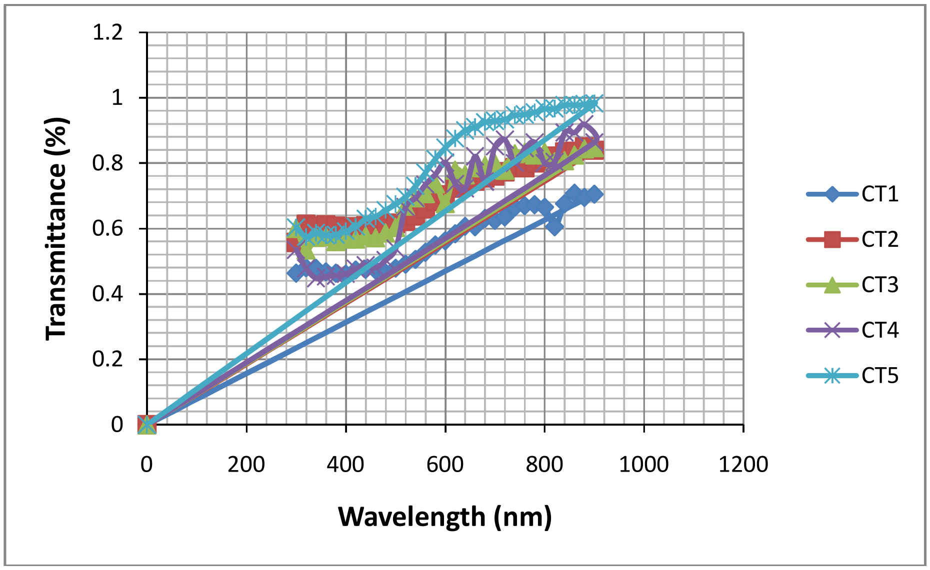


**Fig. 5. Plot of transmittance as a function of wavelength**

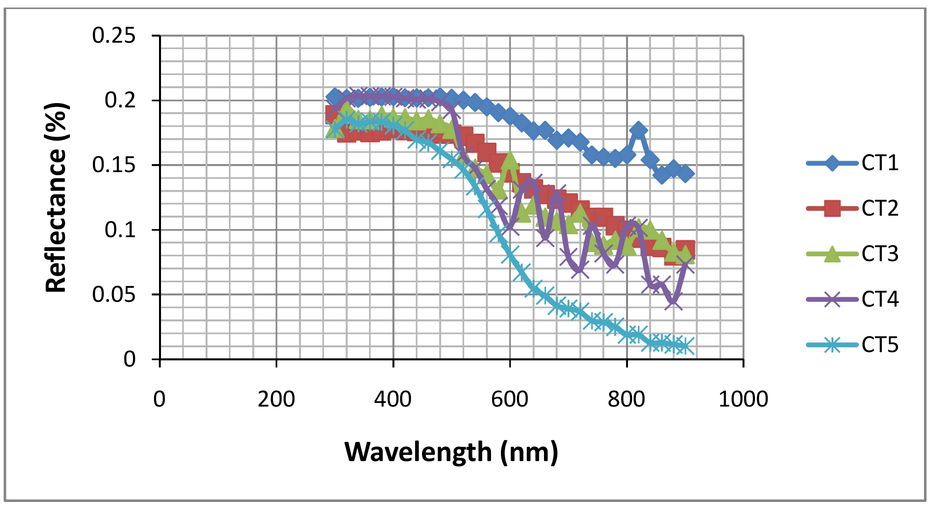


**Fig. 6. Plot of reflectance as a function of wavelength**

The band gap energy and transition types were derived from mathematical processing of the data obtained from the optical absorbance versus photon energy with the following relationships for near edge absorption [6].

$$\alpha = (h\upsilon - E_g)\ n/2 \qquad (1)$$

Where υ is the frequency, h is the Planck's constant, while n carries the value of either 1 or 4. The band gap $E_g$ could be obtained from a straight line plot of $\alpha^2$ as a function of hυ; an extrapolation of the value of $\alpha^2$ to zero will give band gap. If a straight line graph is obtained from n=1, it indicates a direct transition between the states of the semiconductor, whereas the transition is indirect if a straight line graph is obtained from n = 4. The band gap energy of (2.0eV-2.2eV for CT) and (2.2eV-2.5 for CdT) was obtained with an indirect transition shows in figure 7-8 [14-19].

### 3.3 Electrical Properties

Copper and cadmium telluride thin films are known to be a n-type and p-type conductivity. The resistivity of the deposited samples increases from (4.45x $10^6$ - 7.26x $10^6$ $and\ 3.22\text{x}10^6 - 6.15\text{x}10^6 \boldsymbol{\Omega m})^{-1}$ and the thickness increases (189-268 nm and 179-254 nm) The high resistivity for the buffer layers in solar cells helps to improve the conversion efficiency. The resistivity should not be too low due to the inevitable defects in solar cells fabricated during the actual production process. Those defects can cause short circuit, it can drop the open circuit voltage ($V_{oc}$) and fill factor (FF). The buffer layer with high resistivity can effectively overcome those problems caused by defects. As a result, Copper and cadmium telluride thin films values of ($4.45\times 10^6$ and $4.53\times10^6$ $\Omega m)^{-1}$ resistivity is quit suitable for a buffer layer in solar cell and PV panel. [14-19]

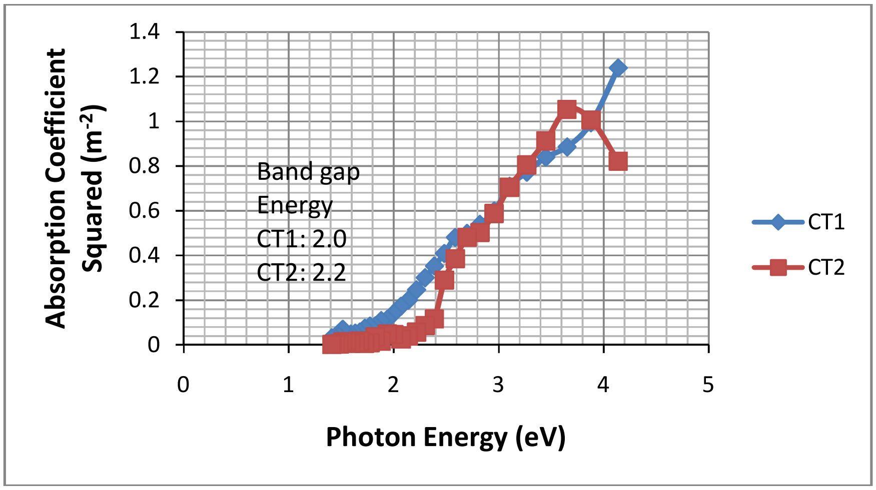


**Fig. 7. The Plot of absorption coefficient square as a function of photo energy**

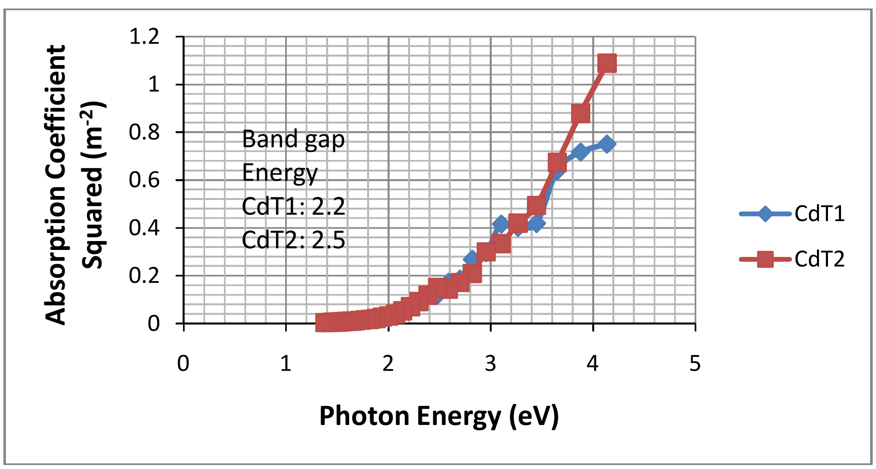


**Fig. 8. The plot of absorption coefficient square as a function of photo energy**

**Table 3. Electrical properties of copper telluride films**

| Samples | Thickness, t $(nm)$ | Resistivity, $\ell$ $(\Omega m)^{-1}$ | Conductivity, $\sigma(\Omega m/cm)^{-1}$ |
|---|---|---|---|
| CT1 | 189 | $4.45\text{x}10^6$ | $2.16\text{x}10^{-6}$ |
| CT2 | 207 | $5.34\text{x}10^6$ | $2.22\text{x}10^{-6}$ |
| CT3 | 224 | $5.84\text{x}10^6$ | $3.11\text{x}10^{-6}$ |
| CT4 | 247 | $6.76\text{x}10^6$ | $3.20\text{x}10^{-6}$ |
| CT5 | 268 | $7.26\text{x}10^6$ | $3.43\text{x}10^{-6}$ |

**Table 4. Electrical properties of cadmium telluride films**

| Samples | Thickness, t $(nm)$ | Resistivity, $\ell$ $(\Omega m)^{-1}$ | Conductivity, σ$(\Omega m/cm)^{-1}$ |
|---|---|---|---|
| CdT1 | 179 | 3.22x$10^6$ | 1.02x$10^{-6}$ |
| CdT2 | 198 | 4.31x$10^6$ | 1.06x$10^{-6}$ |
| CdT3 | 210 | 4.53x$10^6$ | 2.21x$10^{-6}$ |
| CdT4 | 235 | 5.15x$10^6$ | 2.43x$10^{-6}$ |
| CdT5 | 254 | 6.15x$10^6$ | 3.02x$10^{-6}$ |

## 4. CONCLUSION

Copper Telluride thin films have been prepared using electrodeposition technique, the absorbance of cadmium telluride thin films of sample CdTe2 and CdT3 increase as the wavelength of the incident radiation increases while sample CdTe1, CdT4 and CdT5 partially increase as the wavelength of the incident radiation increases. The transmittance spectra of the cadmium telluride thin films deposited increases with the wavelength. the absorbance of copper telluride thin films were found to be in the range of 0.152-0.334 for sample CT1, 0.064-0.254 for sample CT2, 0.065-0.257 for sample CT3, 0.049-0.272 for sample CT4 and 0.009-0.220 for sample CT5. The absorbance of copper telluride films is high in the UV region and in visible and IR regions. The transmission spectrum has a very high transmittance in the VIS-NIR regions of the electromagnetic spectrum. It is also observed that the transmittance of the films is high in visible & infrared regions. The band gap energy of (2.0eV-2.2eV for CT) and (2.2eV-2.5 for CdT) was obtained.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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