CdTe Thin Films prepared by thermal evaporation on Silicon substrate for photocurrent device Applications

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Abstract:
In this works, CdTe was deposited on glass and Si substrates using thermal evaporation techniques. CdTe has been investigated from the properties (structural, surface morphological, optical and electrical). XRD analyses found the monocrystallite, cubic structure of the CdTe thin film and there is no trace of the other material. UV-Vis measurements indicate that 1.51 eV was found the energy gap of the CdTe thin film. Ag/CdTe/Si/Ag The heterojunction Photodetector has two response peaks located at 450 nm and 900 nm with a maximum sensitivity and detectivity of Ag/CdTe/Si/Ag 0.22 A/W and 3.1x10^12 respectively.

Keywords: Photodetector, CdTe, thin film, solar cell

1-Introduction
Highly sensitive photodetectors used in a wide range of applications, including defense, industries, devices of health, and research of scientific. Fast response, high signal noise ratio, and wide linear dynamic range with a proper spectral response band are important for a high performance Photodetector to meet all of the requirements for various applications. Photodetectors that convert optical input signals into electrical output signals have sparked a lot of interest among various types of optoelectronic devices, particularly in medical imaging and optical communication, and intrachip optical interconnection. Thin films of II-VI semiconductors are currently utilized in many semiconductor instruments and optoelectronic circuits [1,2]. Today, because of the best band gap of 1.51 eV, CdTe is one of key materials of photovoltaic and it has high optical absorption coefficient, CdTe can be used as a good active layer in a Photodetector because of these properties, which enable it to absorption light incident and transport photo-generated charges. CdTe preparing by various techniques such as magnetron sputtering, evaporation of thermal, CBD due to growth under a thermal equilibrium condition, thermal evaporation in vacuum is frequently preferred from a methods used for the preparation of CdTe films and it offers great possibilities to change the deposition conditions to obtain films with a given structure and properties [3, 4]. The properties of CdTe film deposited on glass substrates (structural, optical, and electrical) were investigated in this study, the results were discussed, as well as Photodetector manufacturing discussed.
2-Experimental part

Using a high vacuum coating unit (Edwards type E306A) in a 10-5 Torr vacuum, CdTe films of 800 nm thickness were prepared on a cleaned glass and Si substrate using a thermal evaporation technique. Inside the vacuum chamber, a molybdenum boat used to carry CdTe powder, the distance between source and substrate was around 18 cm, and TF Probe Spectroscopic Reflectometer measured the thickness of the thin film.

![Figure (1) Thermal evaporation technique](image)

3-Result and dissection

1-X-ray diffraction analysis

Figure 1 shows the XRD diffraction patterns of CdTe film. From analysis of XRD noted CdTe have one peak at angle of 23.69° corresponds to (111) plane according to (card n. 00-015-0770), signifying crystallinity and no other diffraction peaks were observed due to impurities or phase, indicating that the as-synthesized CdTe films were pure. Scherrer's formula was used to measure the crystallite size (29) nm. [5].

![Fig. (2) XRD patterns of CdTe thin film.](image)

2-Surface morphological of CdTe

SEM image studied a surface morphology of CdTe thin film. Fig3.shows two different magnifications 1μ and 100nm of a surface morphology. The shape of the particles was sheets and almost spherical. The particle size in range (24.36 to 150.7) nm.
Hall Effect tests are carried out in air at room temperature to determine the form of charge carriers of the semiconductor material, concentration, mobility and conductivity to characterize electrical properties of thin film. CdTe film found p-type with \(6.5 \times 10^{12} \text{cm}^{-3}\), 1.7 \(10^{12} \text{cm}^{-2}/\text{V.s}\) and 1.7 \(10^{-4} (\Omega\cdot\text{cm})^{-1}\) respectively.

4-Optical properties

Using the UV-Visible spectrophotometer, the optical properties of CdTe films were obtained from the transmission (T) spectra of the film deposited on glass. The CdTe transmittance curve in the 500-1100 nm range is shown in Fig.4. The emergence of fringe interference in the spectrum of film transmission. Transmission strongly depends on the structure of the film, which is determined by the methods of preparation, film thickness and conditions of deposition. The transmission was 51%, which is good for optoelectronic devices, particularly for solar cell window layers, as seen from the figure. In addition, a sharp fall at the edge of the band is an indicator of strong CdTe crystallinity in the film; this confirmed further by the XRD review[6]. The wavelength variation of optical absorbance shown in Fig. 4 was examined to find out the essence of the transition involved and the difference in the optical band.

**Fig. (3) SEM image for CdTe**

**Fig. (4) Transmittance and absorbance spectra**
The energy gap could be found from the intercept of $(\alpha \nu) \nu^2$ vs. $\nu \nu$ for direct permitted transitions by Tauc’s relationship [7]. In Fig.5, the $(\alpha \nu) \nu^2$ vs. photon energy plots for CdTe film is present. The optical band gap is 1.51 eV, the wavelength of the excitations wavelength $\sim 821$ nm, this arrangement with [8].

![Graph](image1.png)

**Fig (5) $(\alpha \nu) \nu^2$ versus photon energy plot of CdTe thin film.**

Figure (6) shows that the maximum reflectance value of 0.64 at 800 nm wavelength and refractive index (n) were calculated using the following equation from the reflectance ($R$) results. [9].

$$R + T + A = 1$$
$$n = \frac{1 + \sqrt{R}}{1 - \sqrt{R}}$$

Figure (6) indicates that at 800 nm, the refractive index reaches its maximum value of 2.15. Its value depends on a variety of variables, such as the material type and crystalline structure.

![Graph](image2.png)
5- Spectral responsivity and specific detectivity

Fig7 demonstrates responsivity for CdTe/Si heterojunction as a function of wavelength. The CdTe/Si heterojunction spectral responsivity curve consists of two peaks of response; the first peak is located at 450 nm, whereas the second region is located at 900 nm due to the silicon absorption edge. The highest responsivity is located in a visible area, while the other is located in the NIR region, as seen in the Fig. Partial photons have energy more than the CdTe energy gap ($E_g$ CdTe) and all photons with energy smaller than $E_g$ CdTe could penetrate the thin CdTe under light illumination and arrive at the heterojunction region. Among these photons, Si could only absorb those with energy greater than the crystal Si ($E_g$ Si) band gap and eventually contribute to the photocurrent [10].

Figure (8) depicts the detectivity of CdTe/Si as a function of wavelength from 350 to 950 nm. At 900 nm, the maximum detectivity is approximately $3 \times 10^{12}$ W$^{-1}$ cm$^{-1}$ Hz. 
Fig. 9  Spectral detectivity plots for CdTe/Si as a function of Wavelength.

The light I-V curve of the CdTe /Si (modified CdTe structure with silicon wafer ) shown in Fig.9 (A,B). The resultant I-V curve demonstrates that the output characteristics of the tandem cell confirms higher current at bright (100W/m²) , Voc and FF as compared with the baseline CdTe. The enhancement in efficiency has appeared not only from the increases in Jsc, but also from the Voc as well as FF. From the graph, it is obvious that the CdTe/Si tandem solar cell has better efficiency reach to 7% and the F.F. is found to be 32%.

Fig. 10: I–V characteristics of n-CdTe nanoparticles/p-Si(100) heterojunction,A)in dark ,B) in bright

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Conclusion

the CdTe thin film prepared by thermal evaporation. The optical properties showed that the thin film of the direct band gap CdTe was 1.51 eV. X-ray pattern (XRD) showed that the CdTe was single crystalline with a cubic crystal structure. (SEM) showed that the particle form was sheets and almost spherical. The particle sizes (24.36 to 150.7) nm. The maximum spectral response value of the Ag/CdTe/Si/Ag Photodetector was about 0.22 A/W at (λ) of 900 nm.

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