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Optimization physical properties of CdTe /Si solar cell devices fabricated by vacuum evaporation

H. M. Ali[*], M. H. Mustafa
Department of Physics, College of Education for Pure Science / Ibn Al-Haitham, University of Baghdad, Baghdad, Iraq

We investigated at the optical properties, structural makeup, and morphology of thin films of cadmium telluride (CdTe) with a thickness of 150 nm produced by thermal evaporation over glass. The X-ray diffraction study showed that the films had a crystalline composition, a cubic structure, and a preference for grain formation along the (111) crystallographic direction. The outcomes of the inquiry were used to determine these traits. With the use of thin films of CdTe that were doped with Ag at a concentration of 0.5%, the crystallization orientations of pure CdTe (23.58, 39.02, and 46.22) and CdTe:Ag were both determined by X-ray diffraction. orientations (23.72, 39.21, 46.40) For samples that were pure and those that were doped with silver, the optical band gap shrank by (1.52-1.47) eV (400–1100)nm resulting in a drop in the absorption coefficient. An incident power density of (100 mW/cm2) was used to examine the I-V properties of heterojunctions created by light on a variety of clean and doped materials. In accordance with the X-ray diffraction analysis, the films had a cubic structure and dominated grain growth along the (111) crystallographic direction.

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Keywords : optical properties, structural properties and AL/CdTe:Ag /Si/AL Solar cell

1. Introduction

Photovoltaic and photoconductive devices use semiconductors like II-VI, among other things [1, 2]. Over the past 40 years, scholars have paid a lot of attention to heterojunctions (HJs) because they could be used in a wide range of technological applications [3, 4]. Cadmium telluride (CdTe) is remarkable and well-suited for several applications due to its rarity among II–VI compounds and its ability to display both n- and p-type conductivity. This is one of the few II-VI compounds often utilized as a photovoltaic absorber [5]. It processes high absorption coefficients of 10 (>104 cm1) in the visible solar spectrum and has a band gap of 1.5 eV, putting it in the middle of the solar spectrum [6]. The adjustability of this material's band gap in response to different dopant concentrations is one of its advantages [7]. Doped CdTe thin films have drastically changed optical, electrical, and mechanical characteristics. Additionally, it is simple to produce p- and n-type CdTe doping. The first and fifth columns of the periodic table are acceptors, whereas the third and seventh columns are donors. Li, Cu, Ag, N, P, Sb, and As are the most common acceptors, whereas Al, Ga, In, I, and Cl are the most common donors. Depending on where they are placed in the crystalline lattice, [8,9] some elements react differently in CdTe. Optimal doping levels in bulk CdTe are approximately 10^{17} cm3 for holes (As, P, and Li) and 10^{18} cm3 for electrons (Al, I, or In) [10]. Many optoelectronic components, such as infrared and X-ray light detectors, as well as their potential uses in switching and memory systems, utilize CdTe. Cadmium telluride is one of the most promising semiconductor materials for inexpensively

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[*] Corresponding author: hiba.m.a@ihcoedu.uobaghdad.edu.iq

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making thin-film photovoltaic cells with excellent efficiency [11, 12]. The physical qualities of the film rely on the substrate application procedure. CdTe thin films have been fabricated using numerous techniques, including physical vapor deposition [13], pulsed laser deposition [14], RF-sputtering [15], close-spaced sublimation [16], hot wall epitaxy [17], successive ionic layer adsorption and reaction methods [18,19], thermal evaporation [20], and elt. The thermal evaporation technique was employed to manufacture undoped and 0.5% Ag-doped CdTe thin films in this study. Thin coatings on a glass substrate. Studies have examined the impact of doping on the optical characteristics and solar cell performance of CdTe films

2. Experimental

Thermal evaporation on glass substrates in a high vacuum environment produces CdTe films with a thickness of approximately 150 nm. Also utilized were P-type single-crystal (111) Si wafer substrates. Thermal evaporation was used to create the films on glass substrates (300K) [18]. The thin films were produced by thermal evaporation processes utilizing Edwards-Unit 306 molybdenum boat technology. With a sharp blade, the base holder was removed, and the glass slides were then sliced into 1.5 by 1.5 cm pieces. Using an accessible chemical detergent solution, the pigmented and protein-containing material from the glass slides was removed. Once two values between 20° and 80° were determined using Scherrer's equation and an X-ray diffractometer, the crystalline structure of thin films was used to determine the X-ray diffraction (XRD) technique (SHIMADZU Japan XRD 600). [18]. The transmittance T and absorbance A spectra in the wavelength range (400–1100 nm) of coated materials were measured using a UV/VIS spectrophotometer, and the energy gap was computed using the Tauc equation [17–18]. The combination of atomic force microscopy with a UV-Vis spectrophotometer I-V graph application of the Shockley equation [20] discusses the n-CdTe:Ag/p-Si heterojunction and n-CdTe/p-Si current voltage characteristics. The efficiency of the solar cell was determined [21].

3. Results and discussion

3.1. Structural properties

Figure 1 depicts the XRD analysis of each thin film applied to glass. The ASTM card No. 15.0770 attests to the samples' results being in conformity with established standards, and the graph shows that the samples exhibit an orthorhombic polycrystalline structure with peaks for CdTe and CdTe:Ag (111), (220), (311), and (204) [19] .After doping, the films become more crystalline, which makes the peaks sharper. This shows that the Ag is spread out evenly in the CdTe structure. X-ray diffraction was utilized to examine the structure of these films in detail 2Ɵ from 20° to 80° with 0.05° intervals. The miller index interplanar spacing d (hkl) was estimated using Bragg's rule [20] and Scherer's Formula, which were also utilized to measure the crystalline size of the films (hkl). The values for the (d), (hkl), and average crystallite size are shown in Table 1. These findings are consistent with [5]. The crystallite size may be calculated using Scherrer's formulation (D). [22,23].

$$D = \frac{0.94\,\lambda}{(FWHM)\cos\theta} \tag{1}$$

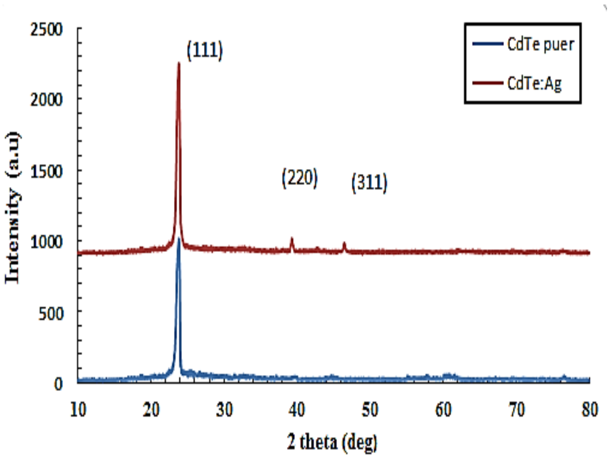

Fig. 1. CdTe and CdTe:Ag thin film XRD pattern.

Table 1. Assignment of X-ray Diffraction CdTe&CdTe: Silver thin films.

Thin films	2theta(°dag)	d(A^0)	crystallite size	DIS (lines.m^{-2})	(hkl)
CdTe	23.58	3.739	36.21	7.622	111
CdTe:Ag	23.72	3.740	38.53	6.734	111
ASTM	23.75	3.742	-	-	111

Figure 2 depicts the CdTe and CdTe:Ag films used in AFM testing (2). Table 2 displays data for the root mean square, average diameter size, and surface roughness. The results showed that grains are tightly packed together to create ridges and dopant. CdTe:Ag films are present on the surface of CdTe. A thin layer increases root mean square and surface roughness as atoms re-spread, migrate, and form crystal grains in low stress orientations. CdTe accelerates grain recrystallization, and the CdTe:Ag ratio grows faster than dopant Ag. The large crystallite size values (62.51–74.23 nm) for these films, as shown in Table 2

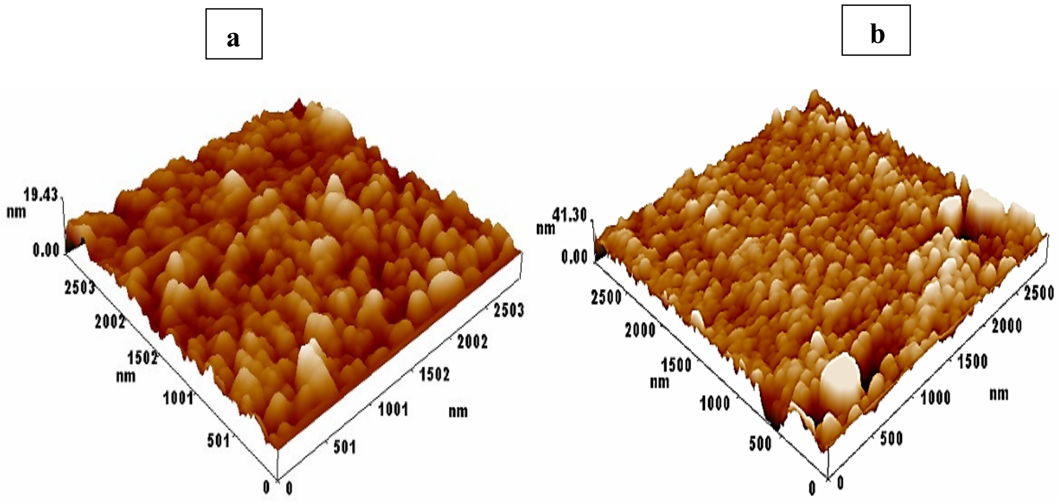

Fig. 2. Thin Films 3D AFM pictures a-CdTe pure,b- CdTe:Ag.

Table 2. Roughness, R MS, Diameter, CdTe, CdTe:Ag.

Thin Film	A.D (nm)	Roughness (Average) (nm)	(RMS) (nm)
CdTe	62.51	4.13	5.63
CdTe: Ag	74.23	8.47	12.5

3.2. Optical properties

Figuer 3 shows the transmittance optical and spectra absorbance of pure CdTe and Ag doped films with ratio of (0.5%) Ag. In the range of wavelengths from 400 nm to 1100 nm , It has been shown that the absorbance goes up as the Ag ratio goes up. This could be because Ag ions in the CdTe lattice help improve crystallinity, and the average size of the crystallites improves crystallinity . Table lists the computed values of the optical constant at the wavelength (wavelenght) of 800 nm (3). This conclusion is consistent with [3,12] In that a reduction in the related reflection causes the values of n to decrease with dopant. For all samples, the transmittance falls as the ratio of Ag rises; this might be a result of greater absorption, which could be related to the deformation of the CdTe induced by Ag ions., transmittance (0.05%–0.09%) reported for the ratio of Ag (0.5%) doped CdTe films.

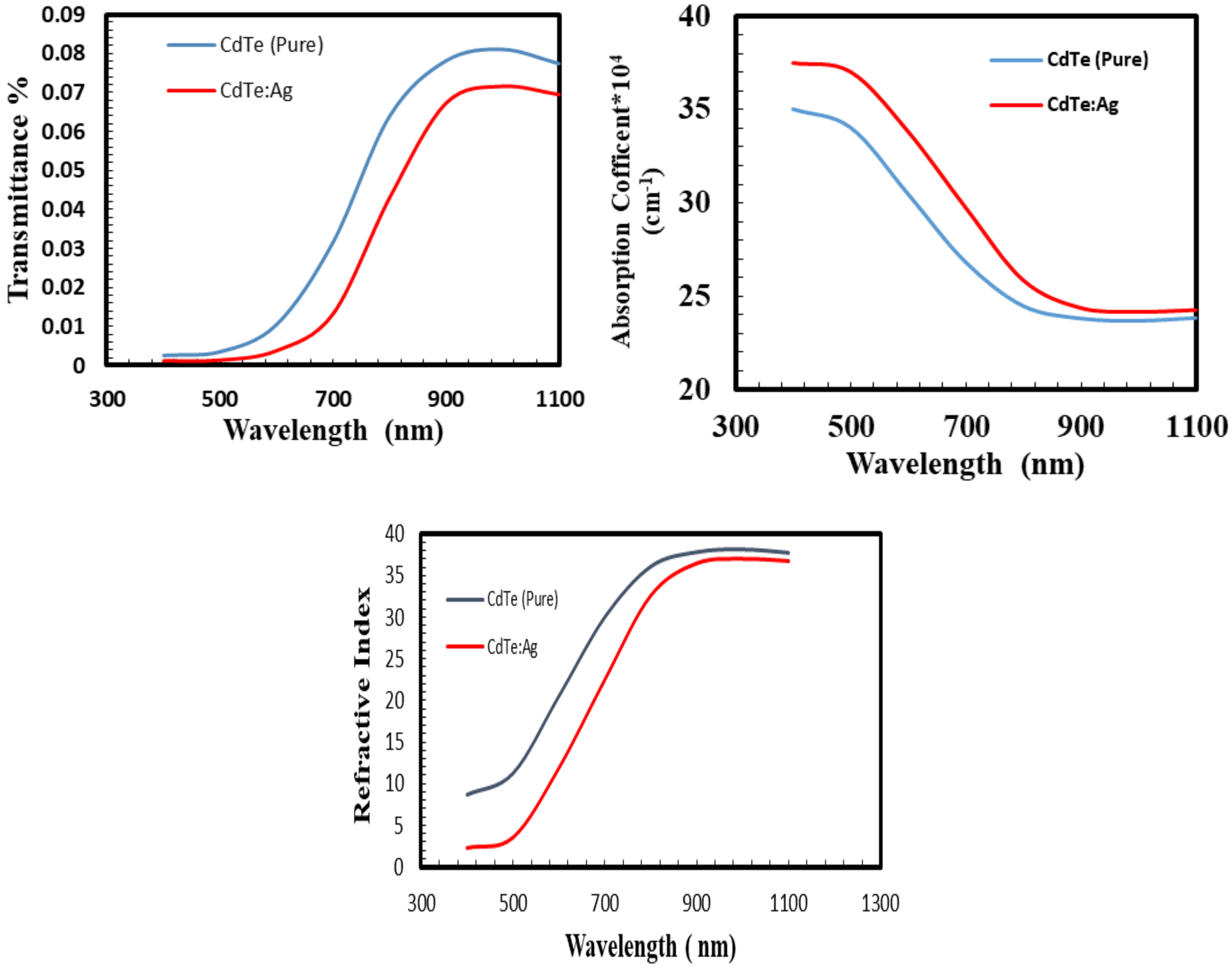

Fig. 3. Refractive index, transmittance, and absorbance of thin films made of CdTe and CdTe: Ag.

The Tauc equation was used to compute the optical energy-gap in the high absorption region[25,26]. CdTe and CdTe:Ag have energy band gaps of 1.52 and 1.47, respectively and this result is very close to the value of the energy gap obtained for pure CdTe films by Fadaam [27]. Table 3 displays Ag ratio in Ag-doped thin films. Because to the higher defect count in films and the observed decreased energy-gap values, the density of localized states in the Eg after doping rises. shifting of the optical energy gap at longer wavelength red has the maximum values during the wavelength range (400-800) nm, and its value is1.47 To comprehend the relationship between surface shape and the rising absorbance, this behavior may be correlated with XRD and AFM data. Due to their high absorbance, samples of CdTe thin films doped with Ag are useful as an optical material for solar cells. [28,30]

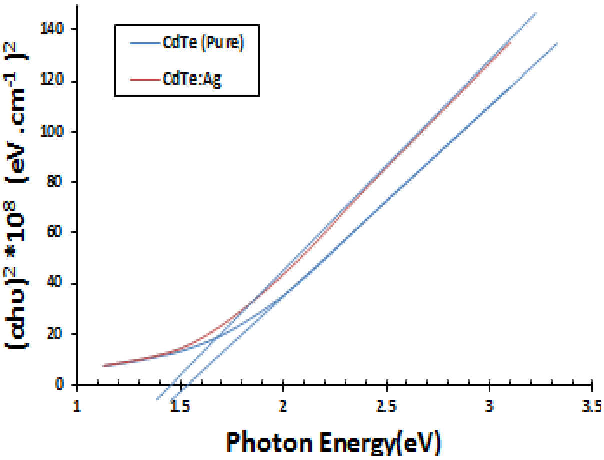

Fig. 4. Optical energy-gap CdTe and CdTe:Ag thin film on glass substrates.

Table 3. For CdTe and CdTe:Ag thin films, E_{gap}^{opt} and absorption coefficient are given. thin film.

λ=500nm		
Sample	**E_{gap}^{opt} (eV)**	**$\alpha \times 10^4$ cm^{-1}**
CdTe	1.52	34.03
CdTe:Ag	1.47	37.02

3.3. Electrical properties

Electrical measurements demonstrated that doping Ag improved the electrical properties of CdTe these films. The n- AL/CdTe:Ag/p-Si/AL solar cell PV's current and voltage density under lighting conditions is shown in Fig. (5), with a voltage range of -0.1 to 0.7mV. Device using a solar cell with Isc of 0.9 mA/cm2 and Voc of 1.23 mV. When the Ag ratio is 0.5%, as shown in Table 4, the efficiency was projected to increase to 1.107% for solar cells. The number of Ag molecules that may be absorbed may rise when the doping ratios in the sample increase due to the sample's growing surface area. While sunlight helps to increase the efficiency of solar cell manufacturing, it can be advantageous to promote quicker electron transit while reducing the likelihood of electron-hole pair recombination [28,31].

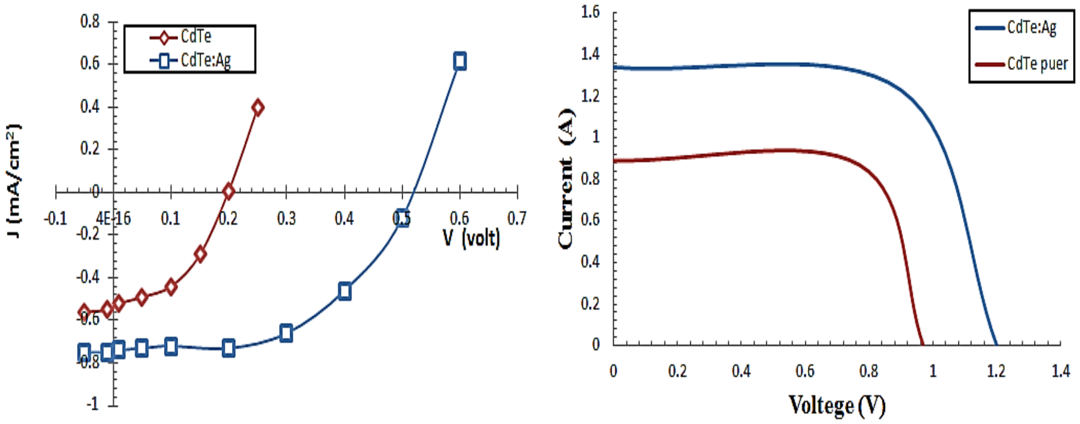

Fig. 5. Current-Voltege characteristic for AL/CdTe:Ag /Si/Al for pure CdTe and CdTe:Ag doped thin film and conversion efficiency Solar cell factors.

Table 4. Factors Solar cell of AL/CdTe:Ag /Si/Al for pure and Ag doped CdTe thin films.

Thin films	**V_{oc} (mV)**	**I_{sc} (mA/cm^2)**	**V_m (mV)**	**I_m (mA/cm^2)**	**F.F%**	**η %**
Pure CdTe	0.9	0.89	0.77	0.87	49.81	0.669
0.5% Ag	1.2	1.34	0.9	1.23	68.84	1.107

4. Conclusion

The thin Ag doped and CdTe sheets were coated using thermal evaporation. The optical, structural and electrical characteristics of cadmium telluride thin films are affected by the amount of Ag doping All of the deposited materials have a cubic structure and are polycrystalline, according to the XRD patterns. With changes in Ag ratios, the grain size grew from 62 to 74 nm. From the optical band-gap 1.52 eV to 1.45 eV,. I-V characteristics for heterojunction (Al/n-CdTe:Ag/p-Si/Al), which has good crystallite size and higher absorption coefficient values, solar cell factors by incident power density value 100 mW/cm^2, maximum efficiency value 1.107%, and fill factor of 68.84%.when dopant the best properties.

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