THE INFLUENCE OF THICKNESS ON THE OPTICAL PARAMETERS OF THERMALLY EVAPORATED PURE AND SILVER-DOPED CADMIUM SELENIDE THIN FILMS

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ABSTRACT

Silver doped CdSe thin films has been prepared by thermal evaporation in different proportions (0, 3, 5, and 10) wt.% .Pure cadmium selenide (CdSe) films sediment with different thicknesses (200,218,225,254) nm on glass substrates at room temperature. The results of the measurements through the studying of the optical properties showed that the absorbance of the (CdSe) films increase within the thickness of the film and the distortion ratios for the wavelengths located within the visible region of the electromagnetic spectrum. It also showed that the absorption coefficient of all the prepared films was a value greater than (α >104 cm-1) and that this value increases in general with increasing thickness and distortion ratios, especially at low photonic energies. the results showed as for the value of the optical energy gap, that the films have (CdSe) all direct optical energy gap and its values decrease from (1.76 eV) to (1.73 eV) with increasing thickness. As for the defective films, their value decreases from (1.73 eV) to (1.66 eV) with an increase in the doping percentage.

Key words: Cadmium selenide, Thin films, Thermal evaporation, optical properties.

I. INTRODUCTION

Cadmium selenide CdSe is one of the significant semiconductor metal compounds belonging to group II-VI of the periodic table, the major significance of this compound is due to its electrical and optical properties in the visible range of light, which allowed it to be used in optoelectronic applications [1] and for photovoltaic devices produced such as solar cells [2] and transistors [3], photodetectors [4], lasers [5] and sensors [6]. CdSe film crystallizes in three main forms: hexagonal wurtzite, cubic (sphalerite), and rock salt, but only the hexagonal and cubic structures exist under normal atmospheric pressure. In thin layers, the cubic structure is usually found, while the large bodies have a hexagonal structure. [5] The growth of CdSe films is cubic [7], hexagonal [8], or mixed (polycrystalline) [9]. CdSe is classified as an n-type negative electrical conductor because electrons are the predominant charge carriers in this compound [10]. There are many ways used to prepare CdSe thin films with different deposition techniques, including Dip coating, [11], plasma sputtering [12] spray pyrolysis [13] electrodeposition [14] vacuum evaporation [15], and the method of thermal evaporation in a vacuum was adopted to prepare the films under study. In the present work, pure cadmium selenide films and doped with silver nanoparticles with different ratios were deposited on glass substrates by a thermal evaporation method and then examined by a UV-visible dual-beam spectrometer in the wavelength range 300-1100 nm.

II. MATERIALS AND METHODS

CdSe and silver (99.99% purity Sigma-Aldrich) were mixed at varying doping percentages of silver (0, 3, 5, and 10) wt.%. CdSe thin films have been deposited onto glass substrates using a homemade thermal evaporation system. A vacuum system using the diffusion pump with a base pressure of 1×10^{-5} torr was used for the deposition. In addition, CdSe and CdSe/Ag powders were evaporated from the resistively heated tungsten boat. CdSe films were deposited at room temperature (300) K, with a thickness of (200,218,225,254) nm, and a deposition rate of (1.7±0.1)) nm/sec. The optical properties of the prepared films were determined using UV-Visible 1800 Spectrophotometer (English brand).

III.   RESULTS AND DISCUSSION

(1-3) Absorptance Spectrum

The measurements of absorption spectrometry were made for all the prepared films, through the wavelength range (300-1100) nm. Figure (1) shows the change of the absorbance spectrum as a function of the wavelength of the prepared pure cadmium selenide films with different thicknesses (200,218,225,254) nm. It is noted from the figure is that the behavior of the absorption spectrum for any prepared film is the greatest possible at short wavelengths (high photon energies), and then it decreases when approaching long wavelengths, because the incident waves are photons of varying energies .The figure shows that the absorbance increases in general with the increase in the thickness of the prepared film, and this is due to the increase in the degree of crystallization of the prepared film and then the increase in the particle size, and that the photon falling on the surface of the prepared film will suffer from successive absorption processes by the crystals located inside a single grain, and accordingly, the possibility of its reflection or permeability without being absorbed by the electrons of the compound atoms will be few, especially with the increase in the size of the single grain. Increasing the number of crystals in it with increasing thickness , which leads to its complete absorption and then to an increase in the absorption coefficient. What was previously mentioned agrees with the results of studies [16, 17, 18], in addition to that, it is consistent with the relationship of the thickness of the prepared films to the absorbance, that is, the more the thickness of the prepared membrane increased, the absorbance increased, and this is called Lambert's law in absorption. Figure (2) illustrated the absorption spectrum as a function of the wavelength of (3.5, 10%) silver-doped CdSe films prepared with a thickness of 200 nm. It is noticed from the figure how the added impurities have increased the absorption of the waves with low photonic energies, especially those located at the end of the visible and near infrared region, and this is due to the density of the local levels formed by the impurity atoms in the defective material between the valence and conduction bands, as these levels act as a ladder for the transfer of electrons absorbing photons with energies less than the value of the optical energy gap of the prepared films its absorption. The prepared pure cadmium selenide films with a thickness of (254nm) recorded the greatest absorbance, and this is what corresponded to the lowest permeability obtained for the same value of thickness. With this value of thickness (as well as this percentage of doping) in the manufacture of solar cells as a source of energy in satellites and in the manufacture of modern electronic devices such as the manufacture of photodiodes (a detector of optical signal in the communications system) that operates within the visible region of the electromagnetic spectrum
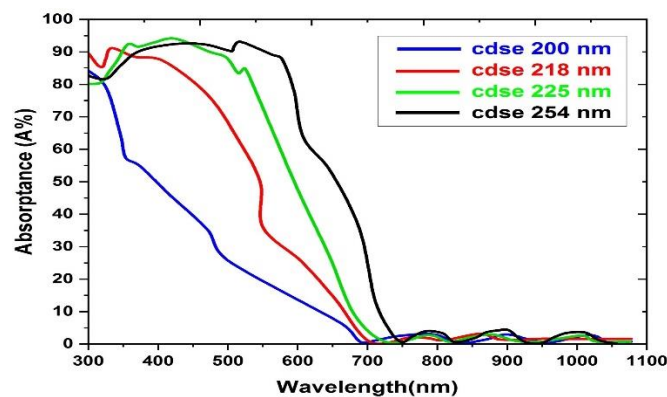

Figure (1) Absorption spectrum as a function of the wavelength of pure (CdSe) films prepared with different thicknesses
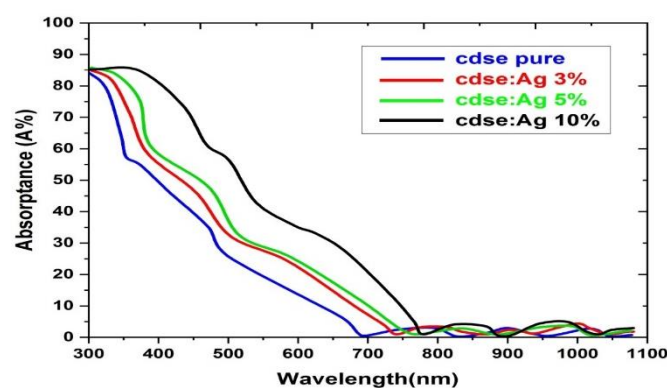

Figure (2) Absorption spectrum as a function of the wavelength of silver-mixed (3, 5, 10%) CdSe films prepared with a

thickness of 200 nm

(2-3) Transmittance spectrum

The transmittance spectrum is characterized by the reverse behavior of the absorbance spectrum, as Figure (3) shows the transmittance spectrum as a function of the wavelength (200-700 nm) of the pure cadmium selenide films with thickness (200,218,225,254) nm is constant not exceeding (4%) for all films, which indicates the possibility of manufacturing a detector from the prepared film material that works within the mentioned electromagnetic spectrum range. While the transmittance increases with increasing wavelength in the visible spectrum region (450-770) nm and later the effect of the impurity appears (after the process the distortion) reduces the transmittance of this region. It is also noted from the figure that the transmittance spectrum in the infrared region of longitudinal wavelengths (770-1100) nm is similar to the shape of a sine wave with the appearance of successive peaks and for each thickness, and the reason for this is due to the fluctuation of the bonds between positive cadmium ions and negative selenium ions as a result of infrared energy, because it is insufficient energy (low energy) to break the bond between those ions, which leads to the appearance of those cilia (Fringes). Figure (4) illustrates the spectrum of the waste as a function of the wavelength of the silver-doped cadmium selenide films of (3,5,10%) with a thickness of 200 nm, as it is noticed from the figure how the added impurities worked to reduce the permeability of the films at low-energy waves) The end of the visible and near-infrared region (and that the transmittance spectrum soon begins to decrease gradually with the increase in the percentage of doping, due to the impurity atoms working to form local levels within the forbidden energy gap, i.e. between the valence and conduction bands, which led to an increase in absorption and a decrease in transmittance
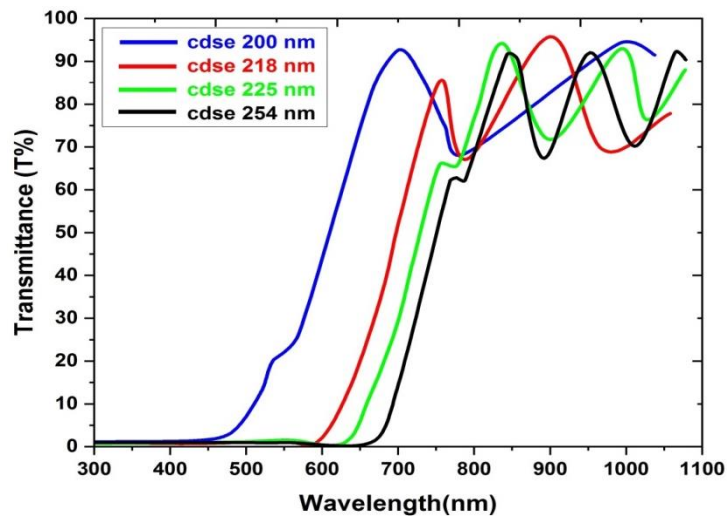

Figure (3) Transmittance spectrum as a function of the wavelength of pure cadmium selenide films of different thicknesses
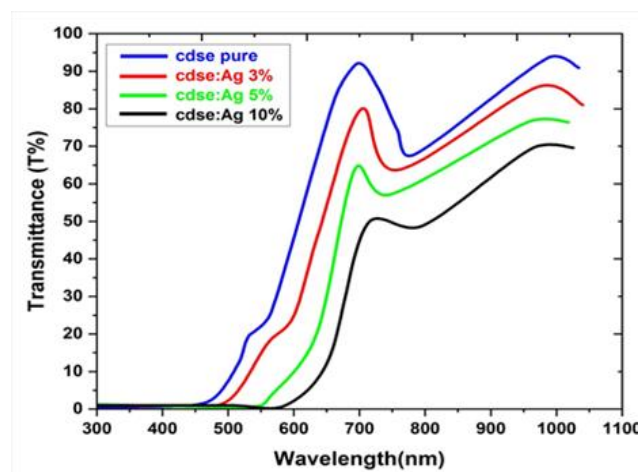

Figure (4) Transmittance spectrum as a function of the wavelength of silver-doped cadmium selenide films of (3, 5, and 10%) with a thickness of 200 nm

(3-3) Reflectance spectrum

The reflectivity spectrum (R) of the prepared pure and doped films was calculated according to the law of energy conservation [19]:

$$A+ R+T=1 \ldots\ldots\ldots (1)$$

Figure (5)shows the reflectivity spectrum as a function of the wavelength of pure (CdSe) films with different thickness. The figure shows that the reflectivity of the films decreases with increasing thickness for the wavelength ranges located within the visible region of the electromagnetic spectrum.

Figure (6) show the reflectivity spectrum as a function of the wavelength of silver-doped CdSe films with percentages (3,5,10)% with a thickness of 200 nm, where it is clear from the figure that the reflectivity of the doped films decreases with the increase in the percentages of doping at the wavelength within the visible region of the spectrum.
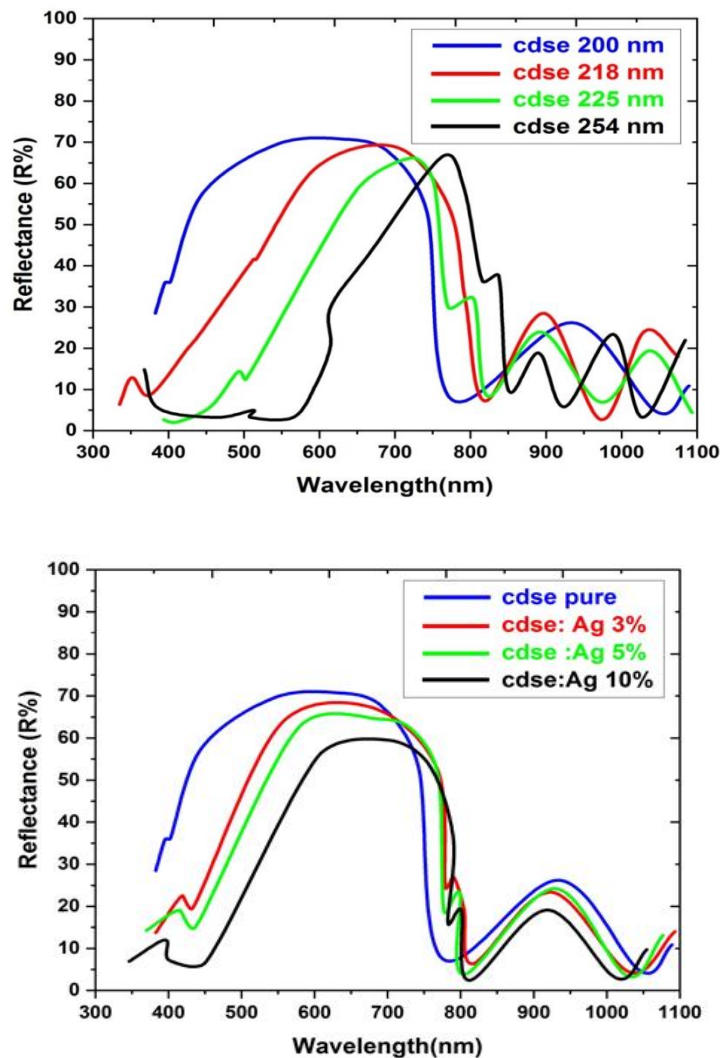

Figure (5) the spectrum represent as a function of the wavelength of pure (CdSe) films

Figure (6) the reflectivity spectrum repraesent as a function of the wavelength of the silver-doped (cdse) films of (3,5,10%) with a thickness of 200 nm

(4-3) Absorption coefficient

It was calculated the absorption coefficient of all prepared films, both pure and mixed with silver, by (3,5,10%) by using trhe equation (2)[20].

$$\alpha = 2.303 \, A/t \ldots\ldots\ldots\ldots (2)$$

Figure (7) shows the change of the absorption coefficient as a function of the energy of the incident photon for the prepared and pure cadmium selenide films of different thicknesses (200, 218, 225, 254) nm, as it is clear from the figure how the absorption coefficient increases with the increase in the energy of the incident photon and for each thickness prepared, As well as the significant increase in the value of the absorption coefficient by increasing the thickness of the film to reach its value greater than $(10^4\, cm^{-1})$ for the energy ranges located in the visible region of the electromagnetic spectrum for films with thickness of 254 nm, while the pure and prepared films with thickness (200 nm) were recorded.) The lowest values obtained for the absorption coefficient and for the same range mentioned above, the reason for this is due to the nature of the relationship between the absorption coefficient and absorbance according to equation (2), in addition to the improvement in the degree of crystallization of the film with increasing thickness, to be consistent with the results of studies [18,21]. The Figure (8), shows the absorption coefficient of silver-doped cadmium selenide films of (3,5,10%) with a thickness of 200 nm. It means that the added impurity atoms, by forming them to local levels, helped to increase the absorption of the material for photons with low energies more after the doping process and thus increase the absorption coefficient according to the relationship (2), and this is consistent with the results of studies [22,23].
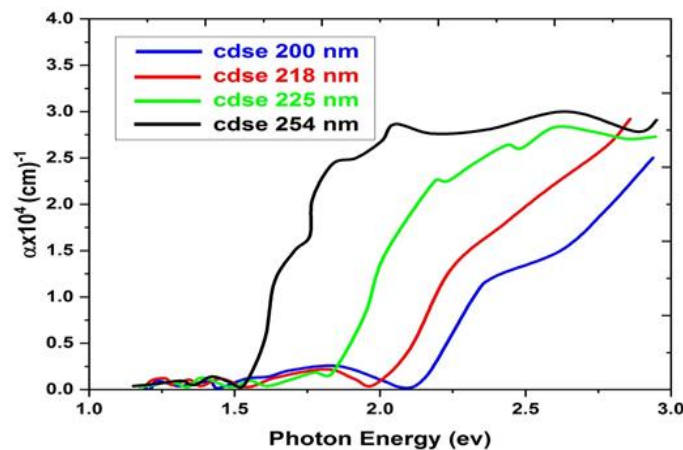

Figure (7) Variation of the absorption coefficient as a function of the incident photon energy for the as-prepared pure cadmium selenide films of different thicknesses
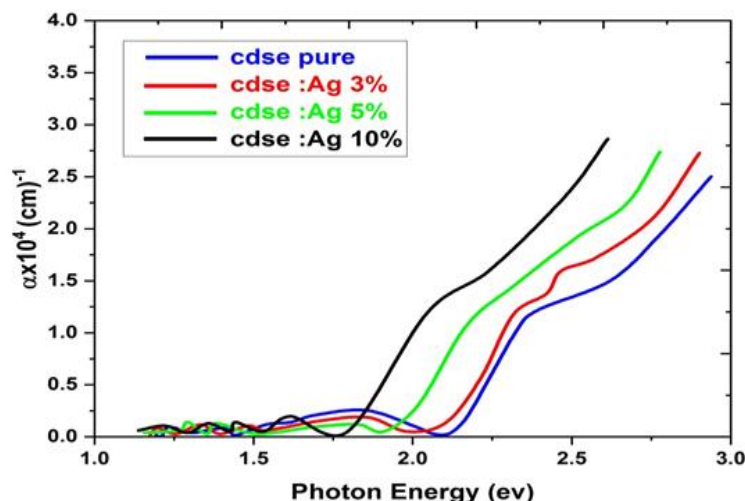

Figure (8) shows the absorption coefficient of silver-doped cadmium selenide films with percentages (3,5,10) with a thickness of 200 nm

(5-3) Optical Energy gap Calculation. (E.g)

The value of the banned optical energy gap is one of the most significant optical values that depend on it in semiconductor physics for the manufacture of many electronic devices such as detectors, solar cells, photodiodes and others. The value of the direct optical energy gap for cadmium selenide films prepared in both its pure and impure forms was calculated using equation (3)[24] after substituting in it for the value of the variable (r) by the amount (2/1) and by drawing the relationship graphically between $(\alpha\, h\upsilon)^2$ and the energy of the projected photon

(hυ), and from the extension of the straight part of the curve to intersect the photon's energy axis at the point [(α hυ) ^{2}= 0] , then he obtained the value of the optical energy gap for direct transmission and for all films. For pure cadmium selenide films with minimum thickness (200 nm) shown in Figure (9), it was found that the value of the energy gap was equal to (1.76eV), and this The value is close to the values reached by previous studies [23,25], it is also noted from the same figure that there is a clear decrease in the value of the energy gap by increasing the thickness of the film so that the gap reaches its lowest value (1.73 eV) at the thickness (254 nm).

$$\alpha\ h\upsilon = B_o(\ h\upsilon - E_g^{opt})^r\ \text{--------------(3)}$$

The reason for this decrease is attributed to the so-called (Quantum size effect), that is, if the particle size is much larger than the Bohr radius and equal to half Anxtrum, then the quantum effect appears and the value of the energy gap will change in inverse proportion to the square of the granular radius based on the Schroedecker equation For any energy level, which led to the appearance of the decrease in the value of the optical energy gap to be consistent with the results of studies [16,17] .

As for the silver-dotted films with percentages (3,5,10), it is noted from Figure (10) that the added impurity atoms led to a decrease in the value of the optical energy gap of the films and this is due to the density of the donor levels formed by the added impurity atoms near the conduction band, which led to the appearance of a decrease in the value of the energy gap, although it was not significant in its amount, this is due to the fact that some of the added impurity atoms worked to better treat the point defects in the crystal structure of the compound, and that their work was limited to improving the crystal structure And filling the lattice spaces more than its contribution to changing the value of the energy gap by a large amount and this agrees with the results of studies [22, 26].
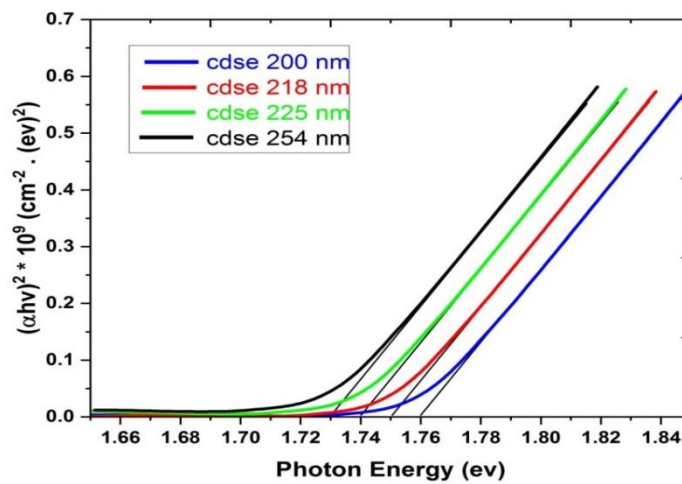

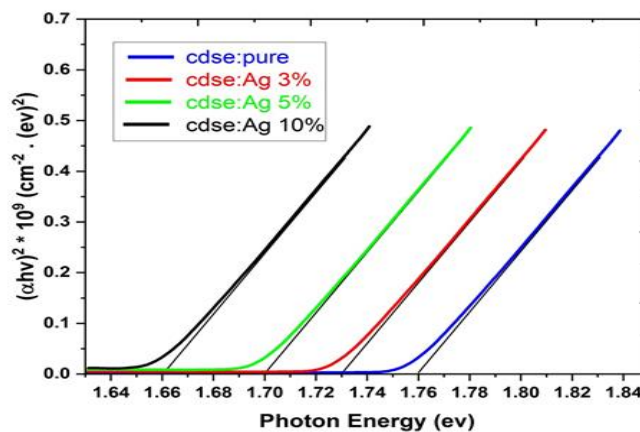Figure (9) The pure cdse optical power gap of different thicknesses

Figure (10) The silver-dotted cdse optical energy gap with a percentage of (3,5,10) and a thickness of 200 nm.

Table (1) shows the optical energy gap values of the pure and prepared cadmium selenide films of different thicknesses, while the table (2) shows the optical energy gap values of silver-doped cadmium selenide films with percentages (3,5,10)% and with a thickness of 200 nm.

Table (1) the optical energy gap values of the prepared and pure cadmium selenide films of different thicknesses.

Thickness(nm)	E_g^{opt} (eV)
200	1.76
218	1.75
225	1.74
254	1.73

Table (2) shows the optical energy gap values of silver-doped cadmium selenide films with a percentage of (3,5,10) and a thickness of 200 nm.

Thickness(200nm)	E_g^{opt} (eV)
Csde	1.76
Csde:Ag 3%	1.73
Cdse:Ag 5%	1.70
Cdse:Ag10%	1.66

IV.   CONCLUSION

It can be employed the films of the pure material to manufacture a detector that works within the ultraviolet range of the electromagnetic spectrum, because the permeability of the prepared films at the mentioned range of the spectrum did not exceed (10%), which qualifies them for use in the manufacture of a detector that works within this range of the spectrum and successfully. The results of the optical tests showed that the increase in thickness or the percentage of doping decreases the transmittance corresponding to an increase in the absorption coefficient, which allows the use of these films in solar cell applications. The results of optical examinations showed that the permeability of pure films is generally not less than (80%) for the ranges of the infrared region and near it, thus making it suitable for fabricating a window for rays operating within this range of the spectrum.

Acknowledgments

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