ABSTRACT/ The CdTe/CdS solar cell is a device made of different layers, the effect of increasing thickness of CdTe film on the solar cell efficiency was studied. Two thin films CdTe/CdS were prepared using the Ag/CdTe/CdS junction for two different CdTe thickness (200 and 300) nm by a method of high vacuum evaporation. X-ray diffraction tests performed for CdTe, and CdS films, showed that both films are multi-crystallized structures. The measurements of the optical properties showed that the prepared films were highly permeable to wavelengths in the spectral region (600-900) nm. The electrical properties showed that the CdTe films are p-type and the CdS films are n-type. The efficiency of two models was evaluated, the results showed that the efficiencies were 1.29% and 2.12%, respectively, the values of Voc, Isc, Vm, Im, Pm and FF were calculated for the two models, and showed that the high thickness of the CdTe layer increases the cell efficiency values. Keywords: CdTe/CdS solar cell, Multi-Crystallization, Cell Efficiency, High Vacuum Evaporation, Hall Effects.

INTRODUCTION
Thin films have an important role in the applications of solar cells because they have a variety of properties. Solar cells convert sunlight directly into electrical energy known as photovoltaic phenomena [1]. This power is the alternative energy and it is environmentally friend because this direct shift to sunlight means generating electricity without any changes in the state of the environment so the fuel that generates pollution gases such as Co, Co2 and So2 does not resume [2]. The CdTe compound is from the periodic table of semiconductor elements (II-VI) and is a suitable compound for the solar cell industry due to a direct energy gap value of 1.4 eV and has a p-type structure that is highly absorbent to solar radiation. Its density is 5.98 g.cm⁻³, melting point is 1098 °C, and its refractive index is 2.76 [3]. CdS compound is one of the substances that has high permeability to the visible region of
the solar spectrum, therefore was used as a class of influence in solar cell applications [4]. It has a direct energy gap of 2.4 eV with a multi-crystalline structure of type n-type [3] and its density is 4.82 gcm\(^{-3}\) melting point is 1750 °C and its refractive index 2.3 [5]. CdTe/CdS cells are the most suitable films for manufacturing solar cells, for its ease, operation and preparation. At the Parma University of Italy and by the Parma Group, the highest value of CdTe/CdS type of cell was achieved, reaching 16.5% in the university laboratories, which expressed readiness to market it [6]. CdTe/CdS solar cells are the most active cells in renewable power plants and fields, for example, they cover nearly half of the Topaz Solar farm in the US state of Arizona, with a total of about 9 million CdTe/CdS cell is one of the largest power plants in the world, knowing that the cost of generating power from these cells is up to 0.57$ [7]. The aim of this study is to prepare a thin film solar cell CdTe/CdS with different thickness then study their optical and electrical properties.

**MATERIALS AND METHODS**

Two CdTe/CdS films (200, and 300) nm thickness were prepared using the Ag/CdTe/CdS junction by vaporizing a layer of 300 nm silver film on two glass plates with a dimension of (5 x 2) cm, then evaporating the CdTe film layer representing p-type semiconductor on the first model with 300 nm thickness and on the second model with a thickness of 200 nm. In the end, the CdS film layer was vaporized, representing n-type semiconductor on both models with 300 nm thickness. A convection oven type (Binder Heating Chamber) was at 250 °C for annealing the two models, increasing crystalline growth and adhesion between the two films. All films were prepared by high vacuum evaporation. The thickness of the film layer was determined by calculating the mass of the material to be vaporized by using formula (1), that equipped by the system machine.

\[
M = 2\pi R \rho
\]

Where:

- \(M\) mass of material to be vaporized
- \(R\) distance between the fumigation basin and models
- \(\rho\) material density to be vaporized

**RESULTS AND DISCUSSION**

Models prepared for several tests were subjected to experimental measurements, it was necessary to demonstrate that the prepared models are properly prepared according to standards [8]. All the prepared models were subjected to several tests during the experimental measurements, which were:

1. **Optical tests by using (UV-VIS Spectrophotometer) system.**
2. **Electrical tests by using (Hall Effect) measurements.**
3. **Structural tests by using (XRD-X-Ray) diffraction system.**
4. **Finally, the efficiency of the models was tested by using (CT100AAA) cell tester system.**

**1. Optical Tests**

The tests of the UV-VIS Spectrophotometer identify the structures of energy bands of the films, which can be used to know the value of the energy gap \(E_g\) for both thin films [9]. If the visual behavior of these films is determined, it is possible to determine which can be used as a good absorption factor for radiation [10] which is important to use in our research. After information obtained from the UV-VIS system, the obtained curves were showed the permeability, reflectivity, absorption and calculation of the energy gaps values of the prepared films as shown in figures (1-8), which revealed the thin film ranges separately. Figure 1 shows the high permeability of the CdTe film as a function of the wave length. Figure 2 shows a little reflectivity of the CdTe film as a function of the wavelength. Figure 3 shows the persistence of absorption of the CdTe film for most of the wavelengths of the photovoltaic radiation. In Figure 4, the energy gap of the CdTe film, as the system calculates its value \(E_g = 1.3eV\), and is close to the value adopted in the literature at \(E_g = 1.4\) eV [9]. For the CdS film, the permeability of the CdS film as a function of the wavelength is presented in figure 5 where the CdS film showed a high permeability. The result was in agreement with that found in the literature [9]. However, the prepared film showed a little reflectivity as a function of the wavelength, which is correspond to the literature [10]. Figure 7 show the persistence of absorption of the CdS film for most of the wavelengths of the photovoltaic radiation. The energy gap of the CdS film is presented in figure 8, as the system calculates its value.
Eg=2.3 eV, and is close to the value \( Eg = 2.4 \) eV that reported in the literature [10].

**Figure 1**: Permeability of the CdTe film as a function of the wave length.

**Figure 2**: Reflectivity of the CdTe film as a function of the wavelength.

**Figure 3**: The persistence of the absorption of the CdTe film.

**Figure 4**: The energy gap of the CdTe film.

**Figure 5**: The permeability of the CdS film.

**Figure 6**: Reflectivity of the CdS film as a function of the wavelength.

**Figure 7**: The persistence of the absorption of the CdS film.
2. Electrical Tests and Hall Effects

Hall Effect tests can identify the type of p-type or n-type of each film, by the concentration and movement of the charge carriers. Figure (9-10) show the electrical properties of the CdTe, CdS Films. Figure 9 shows the bulk concentrations which are positive charge, thus the film type of p-type. The electrical properties of the Cds film are shown in figure 10. It can be seen that the bulk concentrations are negative charge, thus the film type of n-type, these results are compatible with literature [2] and [3].
3. Composition Tests and X-ray Diffraction

XRD systems are used to infer the structural nature of the prepared models [2] [3]. Figures 11 and 12 show the appearance of a number of peaks. It was found that there is a multiple peak which indicates that the prepared films have a good crystallization and a polycrystalline structure that is compatible with the literature [2] [3].

**Figure 11:** Test composition results of CdTe film
4. **Evaluate the Efficiency of the Prepared Cell**

CT100-AAA solar system was used to demonstrate the efficiency of models, by exposing them to the solar simulator according to Iraq solar map with a capacity of 1 sun, i.e., 1000 Wm². The results showed that all efficiency and parameter values such as the fill factor, short circuit current, open circuit voltage, the max voltmeter current, and power. The efficiency values obtained for both models were 1.29% and 2.12% respectively. Figures 13 and 14 show the curve of all electrical parameter values.

![Figure 12: Test composition results of CdS film](image-url)
**Figure 13:** Parameter of the 200 nm prepared cell with efficiency 1.29% 

**Figure 14:** Parameter of the 300 nm prepared cell with efficiency 2.12%
CONCLUSIONS
1. Increasing the thickness of CdTe film led to an increase of solar cell efficiency performance and the value of the fill factor \( ff \), where the increase (100) nm of CdTe thickness led to an increase in the efficiency of performance by 0.83%, besides, to increase in fill factor \( ff \) to be 0.11%.
2. Increasing the thickness of CdTe led to an increase in the values of open – circuit, voltage (\( Voc \)) was increased by (88) mV, and also led to an increase in the amount of short circuit current (\( Isc \)) where was obtain an increase of (7.5) mA.

REFERENCES